No Room for Marginalization: Recognizing the Importance of Local Knowledge For Weather Forecasting in Mbogwe District, Tanzania

Jackson R. Sawe[*]

Abstract

This article documents how smallholder farmers use local knowledge on weather forecasting in Mbogwe District, Tanzania. In particular, it examines farmers' perceptions on weather changes, sources and types of weather information used on weather forecasting, as well as the application of local knowledge on weather forecasting. The article adopted quantitative and qualitative research methodologies. Quantitative data was collected by using household questionnaires and analysed by Statistical Package for the Social Sciences (SPSS) while qualitative data was collected through in-depth interviews and Focused Group Discussions and then analysed by content analysis. Findings indicate that 81% of the respondents reported a decrease in rainfall and 68% increase in temperature, as indicators of changes in weather. It was also found that most farmers (86%) use local knowledge in weather forecasting. Furthermore, it was found that local indicators such as observation of plant and animal behaviour, meteorological bodies and astrological bodies were used by smallholder farmers in weather forecasting. In addition, the use of local knowledge was acknowledged by smallholder farmers as the most reliable and useful source of weather forecasting. Therefore, local forecast knowledge is still a practical source of weather forecasting and it should be promoted instead of being marginalized. The study recommends that collective efforts should be put in place to enhance farmers' use of local knowledge in weather forecasting because local knowledge is site-specific and significantly applicable in local contexts. Moreover, policy and decision makers should recognize and incorporate local knowledge of weather forecasting in various policy issues that deal with climate.

Keywords: *marginalization, local knowledge, weather, weather forecasting, Mbogwe District*

Introduction

Local communities in the world have observed significant changes in weather around the environment in which they live. These changes affect livelihood choices within communities (Nyong et al., 2017). The Fifth Assessment Report of the International Panel on Climate Change (IPCC) shows evidence of a decrease in rainfall and an increase in temperatures across Africa in recent decades. As a result, these changes have affected farming, which is the most climate-sensitive sector, and on which the majority of the people depend as a

[*] Department of Geography, University of Dar es Salaam, Tanzania.

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major source of their livelihoods (IPCC 2018). Changes in weather have caused significant impacts in East Africa. The anticipated impacts of weather changes include an increase in the frequency and severity of events such as droughts, floods and heavy rainstorms, contributing to a decline in crop yields (Shikuku et al., 2017). In East Africa, agriculture—which employs a large proportion of the population—is mainly rain-fed, and highly vulnerable to climate extremes and changes (Oladele, 2017). To reduce farmers' vulnerability to weather changes, it is important to support decision-making processes for smallholder farmers. Moreover, it is crucial to establish reliable climate information services, as well as effective and efficient forecast information dissemination systems (Chang'a et al., 2020).

Proper weather forecasting knowledge and agro-advisories enrich the capacity of smallholder farmers to cope with weather changes make it easier for them to handle weather challenges in crop production (Maren, 2019). In Tanzania, smallholder farmers have been using both local knowledge and modern knowledge systems in weather forecasting in different agro-ecological zones (Sawe et al., 2018). However, there are substantial gaps that exist especially in the provision of user-friendly, location-specific, precise and timely climate and seasonal weather forecast information that addresses the needs of smallholder farmers (Chang'a et al., 2020).

Scientific weather forecasts are often generalized and not downscaled. They are utilized for wider areas, and therefore are less effective for agricultural decisions (Kijazi et al., 2016). Moreover, smallholder farmers have been facing difficulties in accessing forecasts when they need to make farming decisions. Most smallholder farmers, therefore, rely on local knowledge for seasonal weather forecasts, where local-observed indicators and experiences are used to gauge, forecast, and decipher local weather conditions and climate (Shikuku et al., 2017).

Local knowledge is an institutionalized, indigenous, and place-based knowledge rooted in local cultures which has been built upon—and often passed on across—generations through oral history (Osunade, 2016; Orlove et al., 2010). Local knowledge is influenced by observation and experimentation by earlier generations, and provides an inherent connection to one's surroundings and environment (Nyong et al., 2017). Local knowledge on weather forecasting is inbuilt and established in many Tanzanian cultures and communities, following several years of observation (Ziervogel & Opere, 2020). Such knowledge contains different indicators used by various communities and cultures to predict future weather conditions. Smallholder farmers and indigenous experts in Tanzania observe local weather phenomena and behaviours of living organisms such as the appearance and behaviour of animals and plants. Also, they use the direction of wind and types of clouds to forecast local weather conditions such as the onset, cessation, intensity and distribution of rainfall; and the occurrence and magnitude of droughts and flood events (Nyong et al., 2017).

Previous studies in Tanzania indicate that both local and scientific weather forecasts are used for making decisions on crop production, conserving the environment, and dealing with other natural disasters (Chang'a et al., 2020). In rural Tanzania, for example, smallholder farmers have largely relied on local knowledge to forecast the weather through observation and examination of the behaviour of animals, birds, plants and insects (Kijazi et al., 2016; Acharya, 2011). Hence, local knowledge in weather forecasting is fundamental in supporting efforts to improve access to climate services to the majority of smallholder farmers in Tanzania, specifically in areas where meteorological forecasts (and the interpretations therein) are limited.

It has been observed that, despite the importance of local knowledge of weather forecasting, the absence of systematic documentation continues to be a key challenge. Local knowledge is not extensively documented, and is often passed on from one generation to another through oral history. This creates a wide inter-generational gap between local knowledge custodians and the young generation (Maren, 2019). When the old generation who are the main custodians of local knowledge comes to an end, local knowledge also may also disappear (Nyong et al., 2016). Moreover, due to the lack of coordinated research to investigate the reliability, accuracy and/or uncertainty of local knowledge, the use of local knowledge in weather forecasting will remain to be a challenge (Chisadza, 2020).

It is necessary to investigate the lack of local-specific and downscaled weather forecasts, systematic documentation and integration of local knowledge in weather forecasting (Masinde & Bagula, 2018). It is perceived that the loss of local knowledge affects the ability of smallholder farmers in Mbogwe District to survive, especially considering the increasing climate variability and farmers' inability to adjust to climate change. This article documents and presents existing local knowledge in weather forecasting in Tanzania, using Mbogwe District as a case study.

Theoretical and Analytical Framework

Theoretical Framework

This study was guided by the diffusion of innovation model (DOI) developed by Rogers (2003). Rogers defines innovation as any idea, object or practice that is perceived as new by members in a social system. Innovation in this study is perceived in the context of local knowledge in weather forecasting, which has been introduced to farmers to enhance adaptation to climate change and variability. Diffusion is the process by which an innovation is communicated through certain channels among members of a social system over time (Rogers, 2003). The DOI model is a useful framework as it explains attributes such as relative advantage, trialability, observability, knowledge, attitude to change and compatibility. These attributes are all crucial in understanding how farmers use information in adapting to changes in the weather.

The DOI model has had a major influence on the way information is disseminated to end-users, such as farmers. Also, it is essential in creating awareness about innovation adoption factors (Rogers 2003). The channels through which users access information are important in creating knowledge, and in changing peoples' attitudes towards innovations. These channels of communication enhance the flow and exchange of information among users by facilitating farmers' access to, and use of, such information. Therefore, the DOI model was used in this study to determine how local knowledge spreads; and how this knowledge is utilized by smallholder farmers in weather forecasting to enable smooth planning of farming activities and other adaptation measures.

Analytical Framework

Smallholder farmers who live in Mbogwe District have routine interactions with the natural environment, and this gives them an opportunity to observe sensitive changes in the environment that cannot be detected by modern data acquisition techniques. Weather information is traditionally collected by individuals and used for weather forecasting. Bio-physical indicators in the environment such as migration patterns of birds (Osunade et al., 2016), changes in the behaviour of insects, and characteristics of winds and celestial bodies: all provide practical proxies for weather forecasting (Myeya, 2021). Although farmers cannot directly measure weather variables, they can directly observe bio-physical indicators with their senses (Chisadza et al., 2020). The interpretation of these bio-physical variables is therefore used as a proxy for weather changes and variation. (Figure 1).

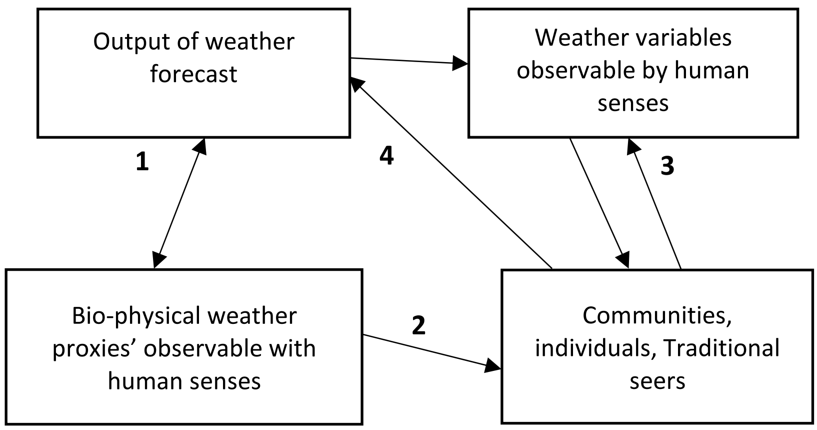

Figure 1: Schematic Presentation of the Production of Weather Forecasting Knowledge for Farmers

Source: Modified from Chisadza et al. (2020)

The first arrow in Figure 1 presents a bi-directional interaction, meaning that sometimes observable bio-physical entities could be results, as well as indicators, of changes that are already happening in weather variables. Therefore, local people either observe weather changes that have taken—or are taking—place, or weather changes that are going to happen in the near future. For instance, the flowering of a certain tree could be due to an increase in humidity that is detectable only by that tree (Churi et al., 2020). For farmers, it can be an indicator of future weather that humans cannot detect by their senses.

The second arrow shows how people observe these bio-physical proxies of weather and collect data, which they then use to make predictions through the path of the third arrow. The third arrow indicates whether a prediction was successful; and also the likelihood of providing effective feedback to the community so that they can refine their knowledge and to provide additional feedback (fourth arrow), on which indicators to follow or use in the future. The production, accumulation and transmission of local weather forecasting knowledge should, therefore, be understood as a dynamic process where farmers not only record observable changes and try to associate them with results or happenings (arrows 2 and 3, respectively), but also get feedback from a continuously changing relationship between observable bio-physical variables and un-observable changes in the weather. This helps them to continuously update and improve their knowledge as farmers (Luseno et al., 2019). Moreover, the output of local knowledge forecasts is used by smallholder farmers to understand the onset and cessation of rainfall, and the scheduling of farming activities: e.g., when to start farm preparation, when to plant, and what types of crops to plant depending on the nature of weather of a specific year. It also helps to determine adaptation measures.

Generally, the reviewed literature, as shown, has not documented clearly how local knowledge is used by smallholder farmers in weather forecasting. This is because it is still viable and practical, especially in rural areas where access to—and utilization of—modern weather forecasts is still a challenge. Therefore, this article attempts to address this knowledge gap by examining how smallholder farmers use local knowledge forecasting for predicting changes in the weather, and for making farming decisions. The article also tries to provide valuable information on the types and sources of weather information, local indicators used in weather forecasting, as well as the reliability of local knowledge on weather forecasts: all for the sake of enhancing smallholder farmers' adaptations.

This article consists of five major sections. Following the introduction of the study in the first section, the second section presents a theoretical literature review and the analytical framework. The third section is a discussion of the research methodology, and the fourth section presents an analysis of the results, as well as a discussion of the findings. The final section consists of a conclusion and recommendations.

Methodology of the Study

Location of the Study Area

This study was conducted in two selected villages in Mbogwe district, Tanzania: Nyakasaluma and Kanegere. Mbongwe District is located at latitude 3°40′0″S and longitude 32°15′0″E (Figure 1). It is bordered by Chato and Geita districts in the north. In the east, it is bordered by Kahama Rural district, in the south by Kahama Urban district, and in the west by Bukombe district.

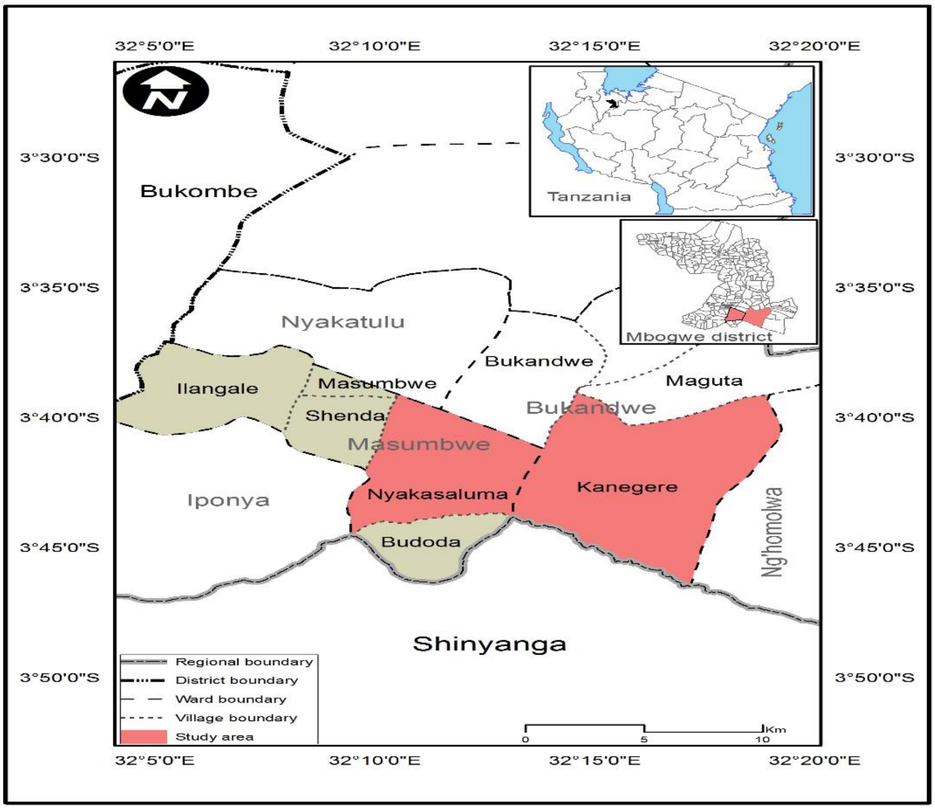

Figure 1: Location of Study Villages in Mbogwe District

Source: Cartographic Unit, Department of Geography, University of Dar es Salaam (2021)

As of 2012, the population of Mbogwe was 193,922. The District was established in 2012, when it was split from Bukombe District and became part of the newly established Geita region. The District has two main rainy seasons: *vuli* (short rain season) from October to December, and *masika* (long rainy season), from February to May. It receives an annual average rainfall of 1400mm to 1600mm. Temperatures of the area range from 28^{0}C to 33^{0}C, with an annual average of 30.5^{0}C (URT, 2020). Therefore, Mbogwe District was purposively selected for this study because it has many households (above 70%) involved in crop production as a major source of livelihood. The majority of its people are smallholder farmers who use traditional knowledge systems in weather prediction (Masinde & Bagula, 2018). Similarly, Nyakasaluma and Kanegere villages were selected because they are inhabited by many smallholder farmers who engage in crop production (about 78%) compared to other villages in the district. Therefore, this District provides a good platform for the study.

Research Design and Approach

This study used a descriptive research design: a design that answers questions on how, what, when and where phenomena occur. Moreover, qualitative and quantitative research methods were also used in the study. These approaches were used to generate qualitative and quantitative information. Furthermore, a mixed research approach was used for triangulation purposes to keep in check weakness of each approach, and to increase the validity and reliability of the data. Generally, this approach was used to generate information about the types and sources of weather information and local indicators used in weather forecasting.

Sample Frame and Sample Size

A sampling frame is a complete list of all units of analysis in a population from which the sample is drawn. In this case, the study was conducted in two villages, namely, Nyakasaluma and Kanegere. The village records showed that the total number of households in Nyakasaluma village was 885, while that of Kanegere village was 777; thus consisting a total of 1662 households that were used the sample frame. From Nyakasaluma village, 50 (equivalent to 5.6%) heads of household were chosen for the study; while from Kanegere village, which had 777 heads of households, a total of 50 (equivalent to 6.4%) respondents were chosen for the study. Finally, from a sample frame of 1662 households, a total of 100 respondents (Table 1) were selected randomly to form the sample. Kothari (2004) suggests that a sample of 5% and above is adequate and recommendable to represent a study population.

Table 1: Number of Respondents Selected from the Study Area

S/N	Village Name	Number of Households	Number of Selected Households		Total	Percentages
			Males	*Females*		
1	Nyakasaluma	885	19	31	50	5.6
2	Kanegere	777	24	26	50	6.4
	Total	**1662**	**43**	**57**	**100**	**6.0**

Source: Field Data, (2021)

Sampling Techniques

Simple random sampling and purposive sampling were used in this study. Simple random sampling was used to select respondents for the quantitative data collected from household surveys. Therefore, this technique was used to enable each respondent to get an equal chance of being selected. Largely, this technique aimed at minimizing bias and increasing validity so that inferences could be drawn from the whole population. To facilitate the operation of this technique, village executive officers from each village provided a list of households. The names of the heads of household were written on pieces of paper, then the papers were shuffled in a box. The selection process was done by randomly picking one piece of paper with one household name from the box. This process was repeated until the required sample size was reached. Moreover, the process was done for all villages under review in the study. The selection process was carried out with the help of village leaders.

Data Collection Methods

This study used primary and secondary data collection methods. The household survey method was used because of the nature of the study. The research approach used sought to generate both quantitative and qualitative information. Therefore, the household survey method was used to collect quantitative data by using questionnaires as a research tool. Both open-ended and closed-ended questions were included in the questionnaires. Moreover, this method was used to gather information from the heads of each household. The information gathered included demographic characteristics of respondents, perceptions on the trend of weather, perceived indicators of weather changes, and local indicators used for weather forecasting. The household survey method was very suitable in this study as most of the information (data) was collected in a short period of time. Moreover, there were no limitations during the process of data collection.

The key informant interview method (with the aid of an interview guide tool) was used to collect qualitative data. This method was used to broaden the understanding on the use of local knowledge on weather forecasting, and also to add more information to the data collected through household interviews. The key informants that were used in this research included the District Agricultural and Extension Officer, village executive officers, two village elders from each village, and a ward agricultural and extension officer. The selection of these key informants was based on their knowledge of the study themes in this research. The key informant interview method was also used to gather detailed information about smallholder farmers' perceptions on the trend of weather, sources of weather information, and how local indicators were used for weather forecasting. The key informants were useful in this study because they were free to express their opinions and perceptions although this method was time-consuming as respondents took a long time to respond to different questions.

In addition, focus group discussions (FGDs) were conducted to generate qualitative data. The FGD method takes advantage of the interaction between small groups of participants who are responding to, and building on, what others in the group said. FGDs act as a source of more detailed qualitative information on social phenomena, of which quantitative data cannot disclose. A checklist tool was used to guide the discussions. A focus group consisted of 10 participants comprising of five men and five women, with consideration on age and experience. The selection of participants was done with the assistance of village leaders. FHGDs took one to two hours depending on the details of the discussion, and they were conducted in Kiswahili. Information obtained was transcribed into English, and then coded by the chief researcher.

As mentioned earlier, FGDs were used to collect data about peoples' perceptions on the trends of weather (rainfall and temperature), and local indicators used in weather forecasting. The advantage of using this method was that most of the information was gathered as participants were free to discuss anything they thought was relevant to the study.

The field observation method was also used in data collection. This method encompasses direct visitation and observation of an area under review. Therefore, onsite field observation was necessary during data collection as it facilitated a deeper understanding of the study area and study themes. The researcher visited community members in the study villages as they went about their daily activities, to observe and record events and practices related to the study. Therefore, through this method the researcher was able to observe how smallholder farmers use local knowledge in weather forecasting. Furthermore, a document review was used to collect secondary data. This involved the review of published and unpublished documents relevant to the study themes. Information about farmers' perceptions on changes in the weather, sources of weather information and local indicators used by smallholder farmers to forecast weather were reviewed. The information collected from document review was important as it helped to verify the information collected through household survey and key informant interviews. Moreover, rainfall and temperature data covering 20 years were obtained from the Tanzania Meteorological Agency (TMA) to assess changes in weather. This data was obtained from the Kahama TMA station. Data from the Kahama TMA station was used due to the lack of such data for Mbogwe district. Kahama Urban District is the immediate neighbour south of Mbogwe district.

Data Analysis and Presentation

Data collected was cleaned, coded, and entered into respective data sheets before it was analysed. The data analysis process mainly involved descriptive statistics. Therefore, quantitative data from household questionnaires was entered into the Statistical Package for the Social Sciences (SPSS) for analysis, while tables and figures were used to present the results. The qualitative data that was collected through in-depth interviews with key informants was analysed using a thematic analysis framework, in which themes were identified and illustrated by using participants' responses and narratives. Qualitative data was used to crosscheck the quantitative information to enhance the reliability of findings and outcomes.

Results and Discussion

Socio-economic Characteristics of Respondents

Results show that of the 100 households visited, the majority of the households were headed by males (67%), while 33% were headed by females. In terms of age, the findings revealed that about 73.7% were 45 and above in terms of age, 15% were aged between 35–44, while 11.3% were between the ages of 25–34. As far as educational levels were concerned, 77% of the household heads had primary education, 6% had secondary education, 3% had post–secondary education and 14% had no formal education. Also, in terms of family size, the findings indicate that about 20% had family sizes of 1–3 members, about 45.5% had family sizes of 4–6 members, about 25.4% had family sizes of 7–9 members, while 10% had family sizes of above ten people.

Furthermore, results indicated that crop farming was the major source of livelihood in the villages under review. This was confirmed by 78% of the respondents. Others sources of livelihoods were livestock keeping (17%), formal employment (2.0%) and those who engaged in businesses (3%). In general, socio-economic characteristics indicate that most of the respondents were over 45 years old and they were therefore appropriate for this study as they had adequate information on how local knowledge was being used in weather prediction in the study area.

Table 1: Socio-economic Characteristics of Respondents

Gender	**Male 67.0% + Female 33.0.% =**				**Total 100%**
Age structure	25-34 years 11.3%	35-44 years 15.0%	45-54years 43.3%%	55 and above 30.4%	100
Education level	None 14.0%	Primary 77.0%	Secondary 6.0%	Post-secondary 3.0%	100
Household size	1-3 20.0%	4–6 4–6	7–9 7–9	10+ 10+	100
Livelihood source	Crop Farming 78.0%	Livestock -keeping 17.0%	Employed 2.0%	Business 3.0%	**100**

Source: Field Data, 2021

Respondents' Perceptions on the Trend of Weather

There is no doubt that the weather does change across the villages under review. Therefore, in the current study, people perceive changes in weather through different indicators as shown in Table 2.

Table 2: Perceived Indicators of Weather Changes

Responses	**Responses**	
	N	**Percent of cases**
Decrease rainfall	81	**81%**
Increase temperature	68	**68%**
Decrease in crop production	59	**59%**
Increase in pests and diseases	40	**40%**
Increase in droughts	37	**37%**
Change in wind	18	**18%**
Total	**303**	**303%**

Note: *Based on multiple responses analysis

Source: Field Data, 2021

These indicators include changes in rainfall whereby about 81% of respondents perceived that rainfall has decreased. A decrease in the amount of rainfall was reported by the majority of respondents because it is the most important source of water for crop production, as well as livestock-keeping. Moreover, about 68% of the respondents reported that temperature had increased. Similarly, temperature was considered a critical environmental factor that directly influences growth and the development of plants and animals. Furthermore, other indicators used to perceive changes in the weather were a decrease in crop production (59%), an increase in crop pests and diseases (40%), an increase in drought incidences (37%) and change in wind direction and speed (18%). The study results imply that respondents were aware of what was happening with regard to changes in the weather in the study area. The findings from the household surveys were supported by FGDs, whereby one participant gave the following account:

> *Over many years we have witnessed changes in the weather through a decrease in rainfall amount, and an increase in temperatures and drought incidences. These are highly disastrous to our lives because they normally disrupt our agricultural activities, and often result in poor crop production* (FGD Participant, Nyakasaluma Village, 2021).

These finding are in line with those of Nzeadibe et al. (2011), in Nigeria, who reported that a decrease in the amount of rainfall is considered a fundamental indicator of weather changes. Moreover, these findings correspond with those of Jing et al. (2015) who did a study in Cameroon and found out that rainfall amount decreased, while temperatures increased. Further, these findings are in line with those of Malekela and Nyomora (2020) who also observed that 87% of farmers in Dar as Salaam region perceived that rainfall decreased, while 80% perceived that temperatures increased. Mwamfupe (2014) also reports that smallholder farmers in Rufiji District consider a decline in crop productivity as an indicator of weather and climate change as influenced by rainfall and temperature amount and distribution. Similar observations were noted by Sawe et al. (2018).

Trends of Rainfall and Temperature

An analysis of the trend of the weather was done using rainfall and temperature data in to find out if farmers' perception corresponded with scientific evidence. The findings from the analysis of TMA data was found to be similar to those reported by smallholder farmers during the household survey (Figure 2). Generally, the results show that there is a decrease in the amount and distribution of rainfall in the study area. A linear trend analysis showed that rainfall had decreased by coefficient of determination (R^2) 0.02263 presented by the equation: $y = -2.5627x + 154.44$.

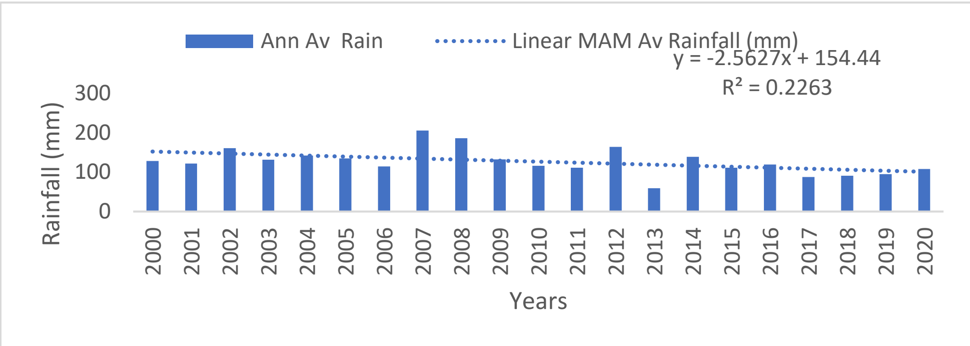

Figure 2: Annual Average Rainfall in Mbogwe District

Source: TMA (2021)

The findings from this study are in line with the findings from Lyimo and Kangalawe (2010) who conducted a study in Shinyanga Rural District and observed that rainfall amount and intensity was decreasing at a non-significant rate of $R^2 = 0.18$, and F probability > 0.47. Even though such trends were not statistically significant, to some extent they were showing a decreasing trend. Similar data was analysed by Sawe et al. (2018) in Manyoni district, and Malekela and Nyomora (2020) in Dar as Salaam region.

Analysis of temperature data was also done using the maximum and minimum annual data. The results from the annual maximum and minimum temperature also tally with results from respondents' perceptions, whereby both indicated an increase in temperature. Annual maximum temperature was increasing at a coefficient determination rate of $R^2 = 0.3117$, as indicated by the equation $y = 0.027 + 30.366$ (Figure (3). The linear trend analysis also indicates that the annual minimum temperature was increasing at a coefficient determination rate of $R^2 = 0.7352$ indicated by equation $y = 0.0622x + 22.047$ (Figure 4).

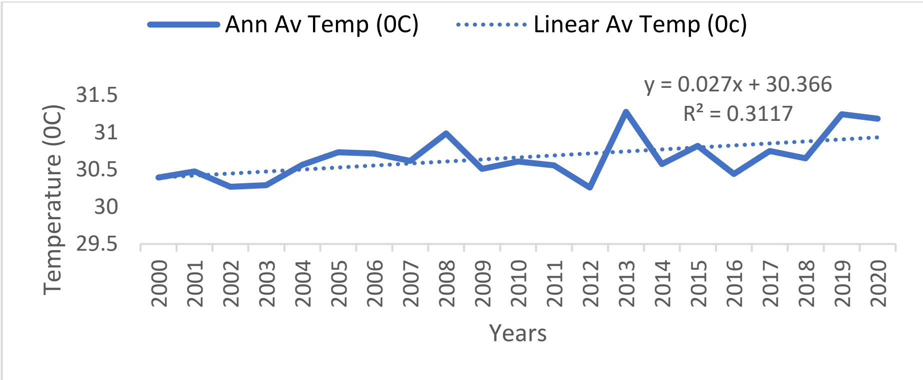

Figure 3: Annual Mean Maximum Temperature in Mbogwe District
Source: Tanzania Meteorological Agency (2021)

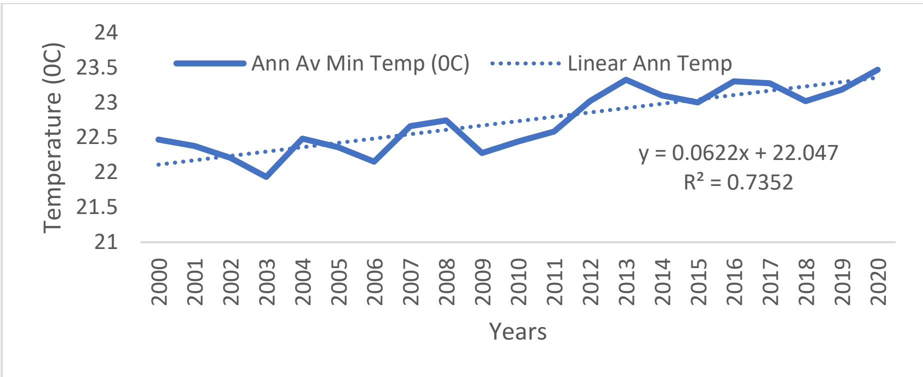

Figure 4: Annual Mean Minimum Temperature in Mbogwe District
Source: Tanzania Meteorological Agency (2021)

These findings conform to the findings by Kijazi et al. (2016) who observed an increase in annual maximum and minimum temperatures in Tanzania. They are also in line with those observed by Mwamfupe (2014) in Rufiji district, where the majority of the people admitted that an increase in temperature was an indicator of changes in the weather in their areas.

Furthermore, it has been reported that the mean global temperature has increased by 0.76^0 C since the 1850s owing to the emission of greenhouse gases (GHGs) provoked by the industrial revolution during the second phase, and has been predicted to rise by $1.8–4.0^0$ C between 1990 and 2100 (IPCC, 2018).

Sources of Information on the Weather

Findings from this study have revealed that smallholder farmers in the villages under review depend on five sources of information to understand weather changes. The general results indicate that farmers' local knowledge was more prevalent as it was reported by 74% of the respondents. This implies that local knowledge is still viable and trusted by the majority of the farming communities in Mbogwe District. The mass media—including the radio and television—was considered another source of information about the weather as reported by 53% of the respondents. Most of the information accessed through the mass media came from the TMA. However, despite being the second source of information, smallholder farmers complained that this information was not accessible at all times since they did not have access to modern communication media channels, and the information was not given on time. Farmers' interaction through meetings was also another source of information on the weather as mentioned by 33% of the respondents (Table 3). Agricultural extension officers (22%) and religious leaders (18%) were also used as sources of such information.

Table 3: Sources of Weather Information

Type of Source	% of Respondents from the Surveyed Villages		Overall total (n=100)
	Nyakasaluma (n=50)	*Kanegere (n=50)*	
Local Knowledge	76% (38)	72% (36)	74% (74)
Mass media	48% (24)	58% (29)	53 % (53)
Farmers interactions	30% (15)	36% (18)	33% (33)
Agricultural officers	20% (10)	24% (12)	22% (22)
Religious leaders	16% (8)	20% (10)	18% (18)

Note: *Based on multiple response analysis
Source: Field data (2021)

The findings from this article match those from Churi et al. (2020) who determined that indigenous knowledge and mass media through radio have remained to be the main sources of information on climate for the majority of rural farmers in Africa. Moreover, Deressa et al. (2019) and Shikuku et al. (2017) found that information on weather and climate change through community interaction is significant in influencing farmers' adaptation choices.

The Use of Local Knowledge on Weather Forecasting

Smallholder farmers in Mbogwe District have been using a combination of plant and animal behaviours, and meteorological and astrological indicators to predict weather conditions. Therefore, in this article, local knowledge indicators for weather forecasting were classified into three main classes: meteorological, astrological, and biological indicators. These local indicators are discussed in the sections that follow.

Observation of Plant and Animal Behaviour

Results from this study show that most of the respondents used plant and animal behaviours as an indicator to predict the weather in their area. This was reported by 86% of respondents who were interviewed. The biological indicator used was plant and animal behaviour. For instance, the flowering of certain trees such as mango and baobab trees was used to forecasting the occurrences and amount of rainfall for the coming season. For example, it is believed that when these trees start to produce flowers, the rainfall season is soon to begin; and when these trees produce many flowers, sufficient rainfall is expected.

It was also reported that when Christmas and baobab trees sprout, it is an indication that the rainy season is approaching; and when *malura* trees sprout and become greener, this is an indication of the ending of the rainy season. Apart from plant behaviour, farmers often use insects, birds and animals to forecast the weather and climate. For instance, the presence of insects such as African army worms (*mapangauhavi)* and coucal birds *(dudumizi)* signifies the beginning of the rainy season, or more precisely, its onset. The appearance of birds locally known as '*nyangeyanje*' was thought to predict rainfall. If the white '*nyangeyanje*' appear, it is an indication that there will be insufficient rainfall in that particular year, while the appearance of the black '*nyangeyanje*' predicts a year with sufficient rainfall. These findings are in line with the findings from a key informant/interviewee, who had the following opinion:

> *In our village normally, we use flowering of plants to predict changes in weather. For example, when the baobab tree produces flowers early in the season, this indicates that the year will have sufficient rainfall. When these flowers survive for long period of time to maturity, this indicates that the year will have scanty rainfall. On the other hand, if the flowers survive for a short period of time, the year will have more rainfall. Indeed, when the* miondo *tree delays to produce flowers, this indicates that rainfall will be insufficient, and when it produces flowers early this indicates sufficient rainfall* (A 79-year-old village elder Interviewee, Nyakasaluma Village, 2021).

The croaking of frogs during the day, and the singing of some birds, were also used by farmers to predict the beginning of the rainfall season. Frogs emerge and croak to cope with the humid air caused by rain. When birds sing out loud, it is an indication of rainfall; while the sighting of an owl in the sky indicates the start of the planting season. When ducks stretch their wings and play in the dust, it is a sign of the onset of rainfall, especially short rains. Similarly, when hens stretch their wings repeatedly, it is a sign of the beginning of short rains. Joshua et al. (2015), in Nigeria, noted that when many birds appear prior to the farming season, it was a sign of sufficient rainfall; and if only a few birds appear prior to farming season, this indicates a shortage of rainfall. Furthermore, Joshua et al. (ibid.) reported that the cries produced by a bird locally known as '*nyenze*' indicate potential sufficient rainfall, while the absence of these cries indicates that there will be insufficient rainfall.

Furthermore, an observation of the movement of some birds was also used to predict the weather. For instance, the findings show that when pigeons move in big groups from west to east in September, or at the beginning of October, this indicates the beginning of a new farming season. When pigeons move from east to west in late March or early April, this indicates the end of a farming season. These observations are in line with those of Deressa et al. (2019), who reported that the movement of birds was an important local indicator used by smallholder farmers in Moshi Rural District to predict the onset and cessation of rainfall. Moreover, the findings are supported by Luseno et al. (2019) who also testify that smallholder farmers in Africa have been observing the migration of animals in to predict the amount and intensity of rainfall. This is very crucial as it dictates farming activities.

Observation of Astrological Bodies

Also, astrological bodies were used by smallholder farmers in weather forecasting. About 40% of the respondents acknowledged to use local knowledge such as observation of the behaviour of the moon, sun and stars. When conducting the household survey, it was claimed that if the moon appeared to be enclosed in a red circle in the beginning of the rainy season, it indicated inadequate rainfall. The results indicate that sufficient rainfall is expected if the moon seems larger than normal. Moreover, if the moon was surrounded by a yellow ring with different colours like those in a rainbow, or if the moon was in a circular shape, these indicate the onset of the long and short rainy seasons. A moon surrounded by heavy clouds is a sign of a good rainfall season. Also, the moon's orientation can be used to predict a drought. A slanted position of the moon crescent is an indicator of a dry season, with less rain expected on the inclined side.

Regarding the sun, data indicated that if the sun shines brighter than usual when most of the sky is covered by dark clouds, there will be sufficient rainfall. This prediction is more precise if insolation is higher during the afternoons, followed by cold nights. Also, when there are very few stars in the sky, this signifies that a heavy rainy season is at hand; however, a collection of many stars in the sky at night is an indication of rainfall cessation. The findings of this study were supported thus by a key informant:

> *For sure the moon and the sun are very important local indicators that are used by most of smallholder farmers in weather forecasting, especially on changes in rainfall amount and temperature. This is done by observing the appearance and characteristics of the moon and the sun. For example, when the moon appears in a rounded shape, this indicates the beginning of the rainy season. Also, when the sun shines less than usual, this signifies the ending of the rainy season. This has been the usual practice for a long time, and I can confidently say that this knowledge has helped us a lot to draw our farming calendar appropriately* (A village elder aged 70 years Interviewee, Kanegere Village).

These findings are supported by Maren et al. (2019) who observed that the majority of the farming communities in East Africa have been observing the characteristics of stars, the moon and the sun for weather prediction. Also, Joshua et al. (2015) suggested that astrological indicators are very useful in weather forecasting as smallholder farmers rely on them to predict the onset and cessation of rainfall. Deressa et al. (2019) also confirm that the sun and the moon have been typically used by smallholder farmers for weather forecasting in developing countries because modern sources of weather forecasting are not well-established.

Observation of Meteorological Indicators

The results indicate that 59% of the respondents admitted to use several meteorological indicators on weather forecasting (Table 4). Temperature levels were used by heads of household to predict the onset and cessation of rainfall. For instance, high temperatures were said to be the best indicators for predicting onset of rainfall. Excessive heat and warming towards the end of the dry season indicate a higher likelihood of above-normal rainfall, while high temperatures during the night indicate a likelihood of rainfall the next day. Moreover, the rise in temperature at the end of July to August shows that the rainfall season is at hand. However, if the temperature takes longer to rise, (September to November), it is an indication that the rainfall season will delay and that the rain will fall in small amounts. The same results were found by Maren et al. (2019) who did a study across the East African countries of Tanzania, Kenya and Uganda.

Table 4: Local Indicators Used in Weather Forecasting

Type of the Source	**% of Respondents from the Study Villages**		**Overall Total (n=100)**
	Nyakasaluma (n=50)	***Kanegere (n=50)***	
Plant and animal behaviour	92% (46)	80% (40)	86% (86)
Astrological bodies	42% (21)	38% (19)	40% (40)
Meteorological indicators	56% (28)	62% (31)	59% (59)

Source: Field data, (2021)

Findings also suggest that strong and spin winds indicate an imminent onset of rainfall. However, repeated lightning in the evening during the dry season indicates an onset of the short rainy season, locally known as *vuli*. A rainbow is similarly used for forecasting weather. Findings show that when there is a rainbow during a downpour, rainfall will soon come to an end. If a rainbow occurs many times during a rainy season, it indicates a shortage of rainfall. In addition, the absence of rainbows throughout the rainy period is a strong indicator of a good rainy season. The formation of thick clouds indicate heavy rainfall for the preparation of farms; while strong winds—especially from September to October—indicate the onset of the rainy season. These findings relate to those of a study by Chang'a et al. (2020) in Mbarali District, Tanzania, who reported that winds and rainbows were used by smallholder farmers on weather forecasting since they are easily notable and usually available. Luseno et al. (2019) also commented that the intensity of wind significantly determines cloud formation as well as the amount of rainfall that is likely to occur in a particular season.

Reliability and Use of Weather Forecast Information

The findings in Table 5 illustrate the perceived reliability of local knowledge on weather forecasts compared to scientific forecasts. The majority of the respondents (69%) believed that local knowledge on weather forecasts is reliable, while 35% of the respondents were of the opinion that scientific forecasting was more reliable. Less than a quarter (21%) of the respondents said that local knowledge was somehow reliable, whereas 30% thought otherwise. A minority of the smallholder farmers (10%) perceived local knowledge as unreliable. In 2020, for example, a comparison of the seasonal March-April-May (MAM) forecasts from local forecasts and the TMA in Mbogwe District showed that both approaches predicted a normal rainfall season. The local knowledge forecasts were, however, more reliable in the long-rain (MAM) season, compared to the short-rain season (October-November-December).

Table 5: Reliability of Local and Scientific Weather Forecast Information

Type of the Source	% of Responses		Overall total (n=100)
	Local Knowledge	Scientific Knowledge	
Reliable	69%	35%	52%
Somehow reliable	21%	30%	30%
Not reliable	10%	35%	27.5%

Source: Field data, (2020)

In addition, findings from FGDs indicated that the majority of the smallholder farmers were aware of local weather forecasts as they had been using them for planning their agricultural activities. Moreover, interviews with village executive officers in Nyakasaluma and Kanegere villages disclosed that a local-knowledge-forecasting group was formed in each village. After every four months, these groups meet with experts from the TMA to compare local knowledge forecasts with seasonal outlook forecasts from the TMA. The forecasts were then incorporated and packed for dissemination to smallholder farmers in Mbogwe District.

These results are consistent with those of Luseno et al. (2019), who found that farmers in Southern Ethiopia and Northern Kenya expressed considerable confidence in local knowledge forecasts with regard to onset and cessation of rainfall in their areas. Likewise, a study in Southern Malawi by Joshua et al. (2015) found that local knowledge forecasts were perceived to be more accurate than scientific forecasts, and smallholder farmers relied on local knowledge to make decisions on land preparation, crop selection, planting, weeding, harvesting, storage, and processing of food.

Conclusion and Recommendations

This study found out that smallholder farmers in Mbogwe District have been using local knowledge on weather forecasting by observing both plant and animal behaviour, meteorological indicators as well as astrological bodies. Furthermore, it has revealed that local knowledge forecasting is a very reliable source of climate and weather information used by smallholder farmers. Moreover, local knowledge plays a key role in supporting smallholder farmers' agricultural decisions, especially in the absence of downscaled location-specific forecasts. Thus the article recommends that local forecasting should be promoted rather than marginalized since the majority of smallholder farmers—especially in rural areas—significantly continue to rely on it for agricultural planning. Moreover, there is a need to integrate local forecasting and scientific forecasting to improve the accuracy, validity and reliability of weather forecasts. Furthermore, policy- and decision- makers should recognize the position of local knowledge in weather forecasting, and take it into consideration during policy review and formulation.

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