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WITH THESE I KNOW IT WILL OR IT WILL NOT RAIN: INDIGENOUS INDICATORS OF RAINFALL IN MWANGA DISTRICT, TANZANIA

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ABSTRACT

Weather forecasting is crucial to planning activities which should be undertaken in, and by, various earth systems. Forecasting the characteristics of rainfall, including the start and end of the rainy season, as well as the amount of rainfall to be received in the coming season, is very important in planning for rainfall-related activities and adapting to rainfall-related hazards. Through quantitative and qualitative techniques, this study sought to identify the indigenous indicators used in forecasting rainfall in Mwanga District, Tanzania. Being a semi-arid area and mostly relying on rain-fed agriculture, rainfall forecasting is crucial in planning agricultural activities and adapting to rainfall-related hazards. The identified indicators of the start of rainfall included the sun burning very intensely, the direction of wind, the appearance of clouds in the sky during the dry season, the budding and flowering of some trees, and the behavior of certain animals and birds. Regarding the end of the rainy season, the farmers observed the flowering of some vegetation, the appearance of mushrooms in the land, cold weather, and wind. Besides, the farmers observed wind, the intensity of the sun, high temperatures, as well as the appearance of some butterflies and ants to forecast the amount of rainfall that will be received in the coming season. Although traditional rainfall forecasting is very important, its accuracy has been decreasing due to increasing climate change and variability. Therefore, it is better to use a combination of indicators than relying on one or a few indicators to increase the accuracy of predictions. Further, indigenous knowledge of weather forecasting should be documented to increase the number of people who can use it effectively. It should also be integrated with modern technologies to improve its accuracy.

Keywords: Indigenous rainfall indicators, rainfall forecasting, Mwanga District.

1. INTRODUCTION

Weather forecasting is vital for undertaking various activities on the planet earth. This is due to the fact that weather affects almost all the activities undertaken in various earth's systems. In general, weather and climate affect agriculture, business, transportation, water, building, and tourism, to mention but a few (IPCC, 2007; UNFCCC, 2007; Malekela and Lusiru, 2022). As such, the ability to make accurate and timely weather forecasting is crucial for life supporting systems in general and for socio-economic development in particular.

Weather forecasting can be categorized into two types, namely modern and traditional weather forecasting. Modern weather forecasting is done by analyzing a huge volume of meteorological data collected from across the globe and integrating such data with numerical weather prediction

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models using highly capable computer-based machines (Gissila et al., 2004; Johnston et al., 2004; Rautela and Karki, 2015). While modern weather forecasting uses such very advanced technologies and is effective in making reliable weather forecasting, it relies on data from large geographical areas and meteorological stations, which are mostly located far from many remote and inaccessible areas (Rautela and Karki, 2015).

In contrast, traditional weather forecasting is based on local, indigenous indicators. Such indicators vary from one location to another. They include bio-indicators, celestial bodies, phonological indicators, as well as the characteristics of animals, birds, insects, and various other physical indicators (Chang'a et al., 2010; Okonya and Kroschel, 2013). Local people have done traditional weather forecasting since time immemorial. Such knowledge has been accumulated and used for generations, and has been passed from generation to generation through sayings, folk songs, and folklores (Rautela and Karki, 2015). Thus, local communities have developed a rich knowledge base of weather forecasting.

Despite the weaknesses of traditional weather forecasting with regard to its universal inapplicability, traditional weather forecasting is useful in making decisions on local people's day-to-day activities like farming and travelling (Chang'a et al., 2010; Rautela and Karki, 2015). Further, traditional weather forecasting is simple, as it does not involve using complicated instruments and data, and it is available whenever it is needed. Therefore, it is appropriate for remote and inaccessible areas. Besides, traditional weather forecasting can be integrated with modern weather forecasting to improve the timing of agricultural activities and disaster risk management (Roncoli, (2001). Although traditional weather forecasting is very important, the indicators people use in making the forecasts in various places are not well documented.

This research sought to identify and document the indigenous indicators that the people of Mwanga District in Kilimanjaro Region, Tanzania, use in forecasting rainfall. Located in a semi-arid area of the north-eastern zone of Tanzania, Mwanga District is prone to rainfall-related hazards, particularly drought (Charles et al., 2013). Besides, the people in the district are mostly farmers and pastoralists, who rely on rainfall for production and livelihoods more generally. As such, the ability to forecast rainfall and related disasters is crucial for making informed decisions on various agricultural activities, including appropriate timing for sowing seeds, harvesting, and shifting livestock to suitable locations before an acute shortage of pastures and water occurs. These decisions are crucial for sustained production amidst the current climate variability and for general socio-economic development.

The characteristics of rainfall considered in this study included the nearness of the start and end of the rain season, as well as the amount of rainfall to be received in the forthcoming season. These help farmers make informed decisions on various agricultural activities to undertake and adaptation to rainfall-related disasters. Equally important for farming activities is the ability to forecast the characteristics of rainfall within a few hours or days. Thus, the local indicators used to forecast such characteristics within a few hours or days were also identified.

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2.RESEARCH METHODS

2.1 The Study Area

The study was conducted in Mwanga District, Tanzania. The district is located within 3°25′ and 3°55′ south, and 37°25′ and 37°58′ east. It covers an area of 2,641 square km (URT, 1998). Mwanga District is bordered by Moshi Rural District in the north, the Republic of Kenya in the northeast, Same District in the south, and Simanjiro District of Manyara Region in the west. Agriculture, including crop farming and pastoralism, is the main source of livelihoods in Mwanga District. The farmers in the district are mostly small-holder farmers, and rain-fed farming is the dominant agricultural practice in the district. Although Mwanga depends on agriculture (rain-fed farming in particular) for its livelihoods, the district is located in a semi-arid climatic region with rainfall ranging from 400-600mm per annum. The rainfall received in the district is highly variable (Charles et al., 2013). Thus, the district is prone to extreme climatic events, especially droughts, which frequently affect agricultural activities. As such, the farmers in this district have accumulated knowledge of various indicators of the characteristics of rainfall which have been used to make rainfall forecasting over centuries. This forecasting is important in timing various farming activities and in relation to adaptation to rainfall-related disasters. Thus, the district was considered a suitable area in which to study and document indigenous indicators of rainfall.

2.2 Sampling Procedure

Two wards and two villages (one from each ward) located in the lowland areas in Mwanga District were selected for this study. The wards were selected from the lowland areas, which are the driest areas that are highly affected by weather-related disasters. The selected wards were Lembeni and Mgagao, and the villages were Mangara and Mgagao, respectively. A mixed-research design, which allows for the triangulation of research methods, was adopted. Through this design, the study obtained a wide range of quantitative information and in-depth, qualitative information on the indicators used in forecasting rainfall.

Quantitative sampling was based on the list of all the households given by the relevant Village Executive Officers. The two villages had a total of 1,095 households: 514 in Mangara village and 581 in Mgagao village. 110 households (equivalent to 10% of all the households) were systematically selected and structured interviews were held with them. The number of respondents from each village was determined using proportionate stratified sampling so that a proportional number of respondents could be selected from each village on the basis of the size of its population. Thus, 52 respondents were selected from Mangara village and 58 respondents were selected from Mgagao village.

Besides, this study needed in-depth information from elder respondents (key informants), who were considered knowledgeable about various indicators of rainfall in their areas. Such respondents were purposefully selected and participated in the in-depth interviews. The study had 19 key informants: 11 from Mgagao village and 8 from Lembeni village.

2.3 Data Types and Data Collection Methods

Data for this study included indigenous knowledge of indicators of the beginning and end of the rainy season, as well as the amount of rainfall expected in the coming season. The data were both

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qualitative and quantitative. Qualitative data were collected through in-depth interviews with the key informants. An interview guide was used to ensure consistence of the questions that different interviewees were asked and to allow for the saturation to be reached (the point at which no new ideas are obtained even if other respondents are consulted) (Fusch and Ness, 2015). Quantitative data were collected using a semi-structured questionnaire, which was specially designed for collecting indigenous knowledge and experiences with regard to various indicators used in forecasting rainfall and adaptation to the predicted characteristics of rainfall.

2.4 Data Analysis and Presentation Methods

Qualitative data were analyzed qualitatively. The analysis involved describing and classifying the data, as well as finding connections between various themes (Kitchin and Tate, 2000). Quantitative data were analyzed using descriptive statistics.

3.RESEARCH FINDINGS AND DISCUSSIONS

Since time immemorial, the local communities in the area where this study was conducted have used their indigenous knowledge systems to forecast weather. This is so with regard to rainfall and related hazards, which have greatly been affecting their wellbeing. The respondents mentioned various indigenous indicators they use to predict the characteristics of rainfall for some hours, days, weeks, or a season. This study categorizes the indicators into those indicating rainfall for the forthcoming season (covering a week and longer) and those indicating the characteristics of rainfall within hours to a few days. Besides, the indicators are categorized into those related to vegetation (‘flora indicators’), those related to animals, birds, insects, and ants (‘fauna indicators’), and those related to the sun, moon, stars, clouds, and wind (‘atmospheric indicators’).

3.1 Indicators of Rainfall for the Coming Rainy Season

The findings from the in-depth interviews with the key informants on the indicators used to forecast the beginning and end of the rainy season, as well as the amount of rainfall in the relevant season are presented in Table 1.

Table 1: Indigenous Indicators for Forecasting the Beginning and End of the Rainy Season and the Amount of Rainfall

Rainfall Characteristic	Category of Indicators	Indicator	Observation	Interpretation
Beginning of the rainy season	Atmospheric indicators	Intensity of sunshine	The sun burning very intensely	The rainy season (long or short rainy season) will start within two or three weeks
		Appearance of clouds	Appearance of two little and lighter clouds in the atmosphere	The rainy season will start within a few weeks.

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		Wind patterns	Wind blowing from the east towards the beginning of the long rainy season	The beginning of the long rainy season is still far.
			Wind starts blowing from the south towards the beginning of the long rainy season.	The long rainy season will start within a week or two.
			Occurrences of cyclones during the dry season	The short rainy season is about to start.
		A rainbow	Appearance of a rainbow during the dry season	The rainy season is approaching.
	Flora indicators	The budding and flowering of some trees	Emergence of new leaves and flowers in Kikwata trees (*Senegalia spp.)* and other acacia species	The short rainy season will start within a few weeks.
	Fauna indicators	Rats *(Rattus Rattus)*	Running from the fields to people's houses (because if it rains while they are outside they will be killed)	The rainy season will start in one or a few weeks' time.
		Birds	Appearance of many white birds	The rainy season will start in one or a few weeks' time.
End of the rainy season	Atmospheric indicators	Cold weather	Cold weather conditions during the long rainy season	Approaching the end of the long rainy season
		Winds blowing during the rainy season	Strong winds blowing during the rainy season	The rainy season is coming to an end.
	Flora	Flowering	Appearance of many, big, white flowers in a	The rainy season is coming

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	Indicators		creeping plant locally known as *lisombe or mamondo*	to an end.
		Mushrooms	Flourishing of edible and wild mushrooms	The end of the rainy season is near.
Amount of rainfall in the coming season	Atmospheric indicators	Appearance of the moon	One end of the moon pointing to the study area is tilted upward	Heavy rainfall during the coming rainy season
			One end of the moon pointing to the study area is tilted downward	Little or no rainfall during the coming rainy season
		The morning star	Appearance of the morning star on the eastern side toward the start of the short rainy season	Little or no rainfall during the coming rainy season
			Appearance of the morning star on the western side toward the start of the long rainy season	Little or no rainfall during the coming rainy season
			No morning star is observed	Heavy rainfall during the coming rainy season
		Wind (cyclones)	Frequent cyclones toward the start of the short rainy season	Heavy rainfall is predicted during the short rainy season.
		Early rains	Normally, the area experiences one or two rainy days during the dry seasons. If such rains are heavy	Heavy rains are predicted during the coming rainy season.
		Temperature	High temperature and the sun burning very intensely	Heavy rains are predicted during the coming rainy season.
			Low temperature and	Little rainfall and it may

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			no intensive sunshine	start late.
	Fauna indicators	Butterflies *(rhopalocera)*	Appearance of many white butterflies	A high amount of rainfall is predicted in the coming or the ongoing rainy season.
		Ants	Appearance of many ants	A high amount of rainfall is predicted in the coming or the ongoing rainy season.

As Table 1 shows, the atmospheric indicators of the beginning of the rainy season include the intensity of sunshine, that is, intense sunshine signifies that the rainy season will start soon, and the opposite indicates that the rainy season is yet to start. Experienced farmers also observe the appearance of the moon, stars (particularly the morning star), clouds, wind patterns, and a rainbow to forecast the nearness of the beginning of the rainy season. For instance, winds blowing from the south to the north suggests that the long rainy season is about to start. If the start of the long rainy season is still far, wind continues blowing from the east to the west. The use of wind to forecast the start of the rainy season is also said to be used by other communities. For instance, in their study on indigenous knowledge of seasonal weather forecasting, Okonya and Kroschel (2013) reported that in some areas of Uganda the blowing of wind from the east to the west was used to determine the coming of a dry season.

It is worth noting that the indigenous indicators of weather that are associated with wind, sunshine, the moon, stars, and other major earth features may be used in large spatial areas (Okonya and Kroschel, 2013). Indeed, a number of studies have reported the use of these major earth phenomena in forecasting weather in other places (Chang'a et al 2010; Okonya and Kroschel, 2013; Rautela and Karki, 2015). Other indicators of the start of the rainy season included the budding and flowering of some trees, as well as the appearance and behavior of certain animals (like rats) and birds (Table 1). If there are no such indicators, farmers know that the rainy season is yet to begin.

The end of the rainy season was also signified by various atmospheric and 'flora indicators' in the area where the study was conducted. The presence of cold weather during the long rainy season, for instance, is used by the local people to predict the end of the long rainy season. Normally, it is relatively hot when it rains in the study area. But, as the long rainy season is approaching the end, the area becomes cold, which signifies the end of the rainy season and the beginning of the cold season. Further, if the local people see wind blowing within the rainy season, they conclude that the rainy season is about to end, and that the dry season, which is associated with winds, is about to begin. Regarding the 'flora indicators' of the end of the rainy season, the findings indicated that the flowering of certain creeping plants and the flourishing of mushrooms, both edible and wild, signify that the rainy season is coming to an end.

Another characteristic of rainfall that can be forecasted by the local people using indigenous indicators was the amount of rainfall to be received in the coming rainy season. Among the

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indicators of the amount of rainfall were the appearance of the moon and the morning star (Table 1). Besides, frequent occurrence of cyclones and rain falling in a day or two during the dry season normally indicated that heavy rainfall would be received during the coming rainy season. The absence of these indicators indicated little or the absence of rainfall in the coming rainy season. Besides, high temperature and much sunshine indicate heavy rains in the coming rainy season, but the opposite indicate that there will be little rainfall in the relevant rainy season. Regarding the 'fauna indicators' of the amount of rainfall, the findings indicated that the appearance of many white butterflies and ants indicate heavy rains in the coming or the ongoing season.

3.2 Indicators of the Characteristics of Rainfall within Some Hours to a Few Days

The findings on the indigenous indicators used to forecast the characteristics of rainfall within some hours to a few days in Mwanga are presented in Table 2.

Table 2: Indicators Used to Forecast the Characteristics of Rainfall within Some Hours to a Few Days

Category of Indicators	Indicator	Observation	Interpretation
Atmospheric indicators	Clouds and winds	The presence of clouds and winds at the same time	It may rain within a few days.
		The appearance of clouds and the blowing of wind from all directions	It will rain within a few hours.
	Lightning and thunder	The occurrence of lightning and thunder	It will rain heavily within a few hours.

According to Table 2, it was only the atmospheric indicators that were used to determine the nature of the rainfall expected to come down within some hours or a few days. The findings from the in-depth interviews indicated that, when the local people saw clouds and winds during the rainy season, they concluded that rainfall would come down within a day or a few days. Likewise, when they saw lightning and thunder, they concluded that it would rain within a short time (within hours or a few days). Similarly, Okonya and Kroschel (2013) reported five indicators in this regard, including excess heat, many rain clouds, a red sky in the morning, the appearance of fog in the morning, and body pains for some individuals. Thus, although findings may differ from place to place, they suggest that the indicators used to forecast rainfall within a few hours or days are not as many as those used to forecast the coming rainy season. This means that there may be certain limitations on the forecasting of rainfall characteristics over short temporal scale.

3.3 Indicators of the Nature/Amount of Harvests

The findings on the indicators that the local people use to predict the nature or amount of harvests in a given season are presented in Table 3.

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Table 3: Indicators Used to Predict the Nature or Amount of Harvests

Category of Indicators	Indicator	Observation	Interpretation
Flora indicators	Many fruits	Many fruits in fruit-bearing trees, including mango trees and some wild trees	Poor or no harvests for highly water-intensive crops like maize. Only short-rain requiring and drought-tolerant crops may be harvested.
Fauna indicators	Armyworm caterpillars (*spodoptera frugiperda)*	The appearance of black armyworm caterpillars	There will be good harvests.
		The appearance of green armyworm caterpillars	Poor or no harvests
	Birds	The appearance of white birds which devour black armyworm caterpillars	There will be good harvests.
		The appearance of many and large groups of various species of birds	There will be heavy rains and good harvests.
	Ants	The appearance of many ants carrying some white things eaten as food	Good harvests are expected in the coming or the ongoing season.

As Table 3 shows, the local people used various flora- and fauna-related indicators to forecast the nature of harvests in a given season. It was found that, when the farmers saw many fruits in various trees like mango trees, they concluded that there would be poor harvests with regard to water-intensive crops like maize. In such a season, the farmers were advised to grow short-rain requiring and drought-tolerant crops. The opposite occurred when they observed a few fruits in such trees. In such a situation, the farmers concluded that there would generally be good harvests.

Further, the appearance of black armyworm caterpillars suggested good harvests in a given season, while the appearance of green ones indicated poor or no harvests. It is worth noting that both types of armyworm caterpillars tend to eat and destroy crops. Essentially, the armyworms can eat all the green vegetation present in an area. The findings indicate that, if the farmers saw many black armyworms, they used more pesticides to kill them because they knew it was a good year, unlike when they saw green armyworms. One elder respondent had this to say on this matter during an in-depth interview in Mgagao village, “If we see many black armyworms, we

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use more pesticides than when we see green ones. If the armyworms are green, do not waste your money killing them with pesticides." The other indicators of good harvests that the local people used included the appearance of large groups of birds, especially white birds, and ants coming out of their holes carrying food. Conversely, if these signs are not seen in a particular season, the people conclude that there will be poor harvests and, perhaps, great famine too.

The reliability of rainfall forecasting using indigenous indicators has been affected by climate change, which causes great climatic variations. The responses indicated that people may observe some indicators of good rain, but in reality they receive little or no rainfall at all. Despite the inaccuracy of local rainfall indicators, farmers continue depending on these indicators, and many of them, especially the elderly, still have faith in them.

3.4 Farmers' Adaptation to Various Characteristics of Rainfall

Although the ability to use indigenous indicators to forecast the beginning of the rainy season varied widely among the respondents of this study, one common thing is that at least all the respondents could to some extent forecast the beginning of the rainy season using one or more indicators. Forecasting the beginning of the rainy season was useful in making various decisions on farming activities at the local level, including decisions on proper times of completing the preparation of farms and seed sowing, as well the type of crops to grow. When asked about the strategies they used to adapt to the forecasted late beginning of the rainy season, the respondents gave the responses depicted in Table 4.

Table 4: Farmers' Adaptation to Forecasted Late Beginning of the Rainy Season and the Number of Respondents using Each Strategy

Adaptation Strategy	Number of Respondents	Percentage
Dry-soil planting	103	93.6
Planting early-maturing crops	82	74.5
Planting drought-tolerant crops	37	33.6

As Table 4 shows, there were three particular strategies that the farmers used to adapt to the rainy season that is to start late. They are dry-soil planting, planting early-maturing crops, and drought-tolerant crops. Dry-soil planting involves planting crops in dry soil, before the onset of the rainy season. The farmers use this strategy to make sure that, even if the rainy season is short, they benefit from all the moist days so as to increase the harvests. The findings from the structured interviews agree with the responses from the in-depth interviews, in which the majority of respondents mentioned dry-soil planting as the strategy they commonly used to adapt to the late beginning of the rainy season. "All the farmers in this village practice dry-soil planting," said an elder respondent during an in-depth interview in Mgagao village. Thus, dry-soil planting is a strategy that the majority of farmers use to adapt to the late beginning of the rainy season and short rains. This finding agrees with the finding of Lana et al. (Lana et al., 2017).

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Besides, planting early-maturing and drought-tolerant crops were among the strategies for adapting to the late beginning of the rainy season mentioned by 74.5% and 33.6% of the respondents, respectively. Early-maturing crops included certain maize varieties which were said to mature within less than 75 days, and drought-tolerant crops included cassava and some legumes. The growing of early-maturing and drought-tolerant crops happened when the people predicted that there would be little rainfall in the coming season. Thus, the farmers avoided planting water-intensive crops, but planted drought-tolerant and early-maturing crops instead. However, the findings indicated that, in a few instances where a very acute shortage of rainfall was forecasted, the famers tended to stop farming completely.

4.CONCLUSION

This paper has discussed the indigenous indicators used to forecast rainfall in Mwanga District. The indicators included those related to atmospheric phenomena: sunshine, the moon, stars, wind, and clouds, as well as those related to the characteristics of various plants and animals. The local communities use these indicators to forecast the start and end of the rainy season, the amount of rain to fall in a given season, and the characteristics of rainfall during a few hours or days. Indigenous rainfall forecasting is important for making decisions on various activities to do, especially agricultural activities, as well as to adaptation to rainfall-related hazards like droughts and floods. Nonetheless, the accuracy of the indigenous indicators in rainfall forecasting has been decreasing over time, due to climate change and variability. The farmers find that some of the indicators cannot be used independently of the others. Thus, it is important that they do not rely on only one or a few indicators. Instead, they have to combine several indicators to arrive at more reliable conclusions regarding various characteristics of rainfall. Doing so will reduce the risk of making inaccurate predictions and their impact on planning and adaptation. It is equally important that the indigenous indicators are well documented and integrated with modern weather forecasting techniques to increase their accuracy. This is particularly important now when climate change and variability make it increasingly difficult to successfully forecast the characteristics of weather with much accuracy.

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