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Perceptions of Smallholder Rice Farmers on Traditional and Conventional Weather Forecasting in Zanzibar, Tanzania

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Abstract

This paper assesses the perceptions of the smallholder rice farmers in Zanzibar on the use of conventional and indigenous knowledge (IK) for seasonal weather forecasting and farming decisions. It draws data from a study that was conducted in two rice fields in Central district, Unguja, and four rice fields in Micheweni district, Pemba. The paper mainly employs qualitative data from focus group discussions and interviews. The results reveal that farmers, particularly from rain-fed rice fields, have limited access to conventional seasonal weather forecasts, and thus rely on the knowledge of traditional weather forecasting. This is ascribed to their negative perceptions on conventional seasonal weather forecasts, limited access to extension services, and limited access to media, such as television and radio that provide weather information, which is attributed to low rural electrification and poverty. The results also showed that smallholder rice farmers in the islands use their own indigenous knowledge to forecast weather and utilise it for the preparation of fields, planting and harvesting of rice. The study highlights that, recent fluctuations in rice production is attributable to the variability of rainfall, rainfall seasons, and incidences of extreme floods. This illustrate the challenges of both conventional and traditional weather forecasting systems, and underscore the need and importance of integrating traditional and conventional weather forecasting to increase access to conventional weather forecasting to boost resilience to the impacts of current and future climate changes.

Keywords: *weather forecast, perceptions, indigenous knowledge, rice farmers, Zanzibar*

1. Introduction

Indigenous knowledge (IK) is defined as institutionalized local place-based knowledge that is embedded in local cultures and passed on across generations through oral history (Osunade, 1994). IK is sometimes regarded as traditional ecological knowledge (Berkes, 2009). Historically -- and to date -- local communities in different parts of the world have continued to rely on IK in conserving the environment and managing risks that are associated with

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natural disasters (Kijazi et al., 2012; Chang'a et al., 2010). Communities, particularly those living in drought and flood-prone areas, have generated a vast body of indigenous knowledge on disaster prevention and mitigation through early warning and preparedness (Roncoli et al., 2002; Anandaraja et al., 2008). This is the case in the United Republic of Tanzania, and Zanzibar in particular, where indigenous knowledge is used in rainfall forecasting for rice-farming in deciding when, where and what to plant. Scientists and rice farmers used different methods to predict a likely behaviour of weather in the planting season (Chang'a et al., 2010). Studies show that crop management strategies—such as planting time, weeding, fertilization, and application of pesticides—are shaped by predictive weather information, particularly rainfall-related forecasts (Moeletsi et al., 2013; Roudier et al., 2014; Jiri et al., 2016). Over centuries, farmers in Tanzania Mainland and Zanzibar have largely relied on IK to predict weather through observation and monitoring the behaviour of animals, birds, plants and insects (Kihupi et al., 2002; Mhita, 2006; Kangalawe et al., 2011; Kangalawe & Lyimo, 2013). The bundle of knowledge in IK range from the constellation of stars, animal behaviour, cloud cover and its type, blossoming of certain indigenous trees, appearance and disappearance of reptiles, to migration of bird species, and many others. Early warning systems are very important tools that provide scientific information needed for the adaptation to weather-related risks and disasters. Globally, early warning systems provided by meteorological organisations are used by farmers to plan for crop seasons and any anticipated changes of weather phenomena and hazards.

Evidence from various parts of Africa suggests that the perceived accuracy of traditional seasonal forecasts remains an important factor in the adoption of seasonal weather forecasts among smallholder farmers (Mbewe et al., 2019; Elia et al., 2014; Makame, 2013). A study by Elia et al. (2014) in semi-arid central Tanzania shows that farmers have continuously relied on traditional methods to predict weather patterns and make the necessary farming adjustments, instead of depending on conventional seasonal weather forecasts, which are perceived as unreliable and untimely. According to this study, uncertainty about seasonal weather forecasts is one of the most critical factors that forces farmers to continue using IK. In Africa, for instance, language barriers, legitimacy, trust relationship between climate forecasters-messengers and communities, credibility, scale, cognitive capacity, procedural and institutional barriers, and low local capacity to act on forecasts have been cited as the constraints in the accessibility and utilization of weather forecasts amongst the smallholder farmers (Tall, 2010; Patt & Gwata, 2002).

Studies show that legitimacy—in which forecasting is perceived as interfering with the local knowledge system—limits the adoption of seasonal forecasts

within the social systems (Elia et al., 2014; Patt & Gwata, 2002). Accessibility and loss of trust caused by either previous inaccuracy of seasonal forecasts, or the inability of the information to help farmers take certain decisions to adapt with climate variability, are also viewed as limiting factors for the adoption of seasonal weather forecasts in Africa (Patt & Gwata, 2002; Millner & Washington, 2001; Kalanda-Joshua et al., 2011). For example, Patt and Gwata (2002) narrated a story in Brazil where smallholder farmers decided not to follow seasonal weather forecasts after the 1997–1998 El Niño in Brazil, when events did not occur exactly as predicted. It is generally argued that scientific weather forecasts are often not downscaled: they are provided for wider areas and often too generalized, making them less effective for farm-level decisions (Randely et al., 2019). According to Randely (ibid.), smallholder farmers in Lushoto, Tanzania, believed that indigenous weather forecasts era more reliable and effective compared with scientific/ conventional weather forecasts as they help them in their local context. These views are consistent with the findings of other studies (Chang'a et al., 2010; Soropa et al., 2015; Jiri et al., 2016).

It is this dichotomy that necessitates the need for the integration of conventional seasonal weather forecasts and IK in making weather predictions. For example, in Malawi, a study by Kalanda-Joshua et al. (2011) underscored the fact that conventional weather predictions were not used, and thus not useful as they failed to incorporate traditional knowledge systems. Moreover, evidences of the integration of IK and conventional weather forecasts have been observed in many parts of Africa (Patt & Gwata, 2002; Chang'a et al., 2010; Radeny et al. 2019). For instance, a study by Radeny et al. (2019) in Ethiopia, Tanzania and Uganda revealed that farmers and pastoralists use a combination of meteorological, biological, and astrological indicators to forecast local weather conditions. Similarly, a study by Chang'a et al. (2010) reported that in the 2009/2010 rainfall season, both indigenous knowledge specialists and the Tanzania Meteorological Authority (TMA) had similar predictions on the seasonal rainfall, with both predicting that the season would be characterized by normal to above normal rainfall. The result highlights the need for integrating indigenous and scientific knowledge in seasonal weather forecasts to ascertain the level of accuracy and acceptability of the predictions.

Studies in Africa have revealed that IK weather forecasting indicators are based on a wide range of phenomena, ranging from atmospheric conditions, biotic (plant phenology and animal) behaviour, to meteorological and astronomic features (Elia et al., 2014; Mbewe et al., 2019; Radeny et al., 2019). Indicators of early or late onset of rains have been used to tell the nature of that particular rainy season. Similar indicators have also been observed in

many parts of Africa (see Chang'a et al., 2010; Kijazi et al., 2012; Elia et al., 2014; Mbewe et al., 2019; Radeny et al., 2019). In-spite of a multiple number of studies on traditional weather predictions, the knowledge and awareness gaps on a comprehensive mapping of communities' perceptions on both conventional and indigenous forecasting systems still exist. These gaps are obvious in Zanzibar where such studies are scarce. In Africa, rice-farming is mainly under rain-fed systems, which are largely influenced and controlled by the climate. This paper, therefore, examines the perceptions of smallholder rice farmers on both traditional and conventional weather forecasts, and assesses the use of traditional weather forecasting in small-scale rice-farming in Zanzibar.

2. Methods

2.1 Description of the Study Areas

The data for this paper were collected from a study that was conducted in Micheweni district, Pemba; and Central district, in Unguja (Figures 1 and 2). Specifically, two (2) rice fields (Cheju-irrigation and Mayungi-rain-fed) were selected in the Central district of Unguja; and four (4) rice fields (Kinyakuzi-irrigation, Koowe, Chwaka and Ukele-rain-fed) were selected in Micheweni district. Thus, both irrigated and rain-fed rice fields were selected for this study. The Micheweni district ranks as the poorest district in Zanzibar, with a high percentage of illiteracy. It is estimated that more than 50% of the population lives below the poverty line. Most households are women-headed since men spend most of their time in fishing camps outside Pemba. The selection of the district was also based on the high incidences of exposure to the impacts of climate change and variability, such as drought, seawater inundation, and unreliability of rainfall. On the other hand, the selection of Central district in Unguja was based on incidences of rainwater floods and droughts. The selection of these study sites was also based on the farming systems (irrigation or rain-fed), and exposure to variability in rainfall and coastal flooding.

The climate of Zanzibar is characterised by tropical and humid weather conditions, with four main seasons in a year: summer, known locally as *kiangazi* (January–February); the long rainy season, locally known as *masika* (March–May); winter, known as *mchoo* in Pemba and *pupwe* in Unguja (June–August/September), and a short rainy season (*vuli)* (October–December). Although rainfall is experienced during all the four seasons, the highest rainfall—ranging between 1000–1300mm—occurs during the long and short rainy seasons; while very low rainfall occurs during the winter and summer seasons. The annual average rainfall is up to 2000mm per annum (Walsh, 2009). With regard to temperatures, Zanzibar experiences monthly maximum temperatures of 28–32ºC; and monthly minimum temperatures of 18–22ºC (Owen, 1993).

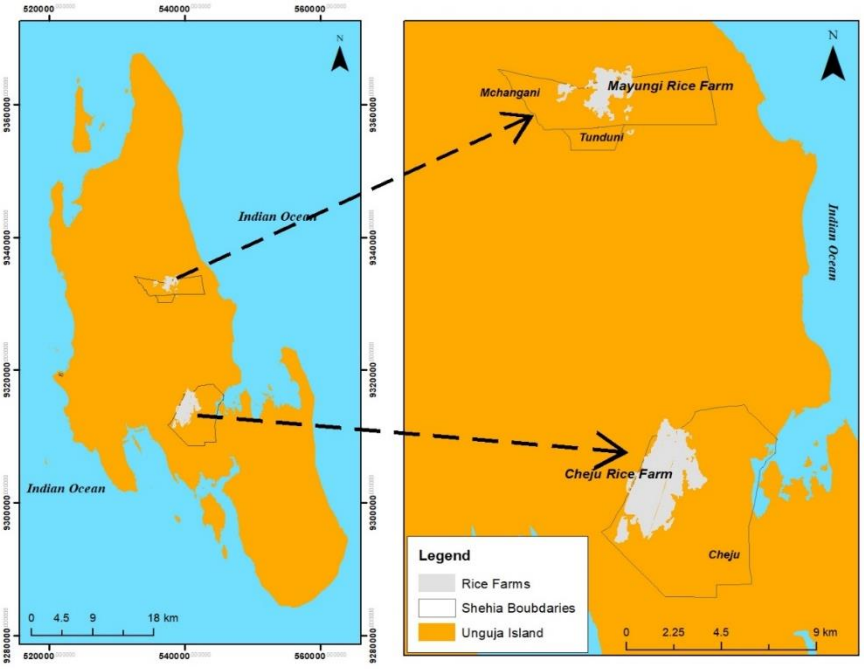

Figure 1: The Location of the Study Areas in Unguja Islands

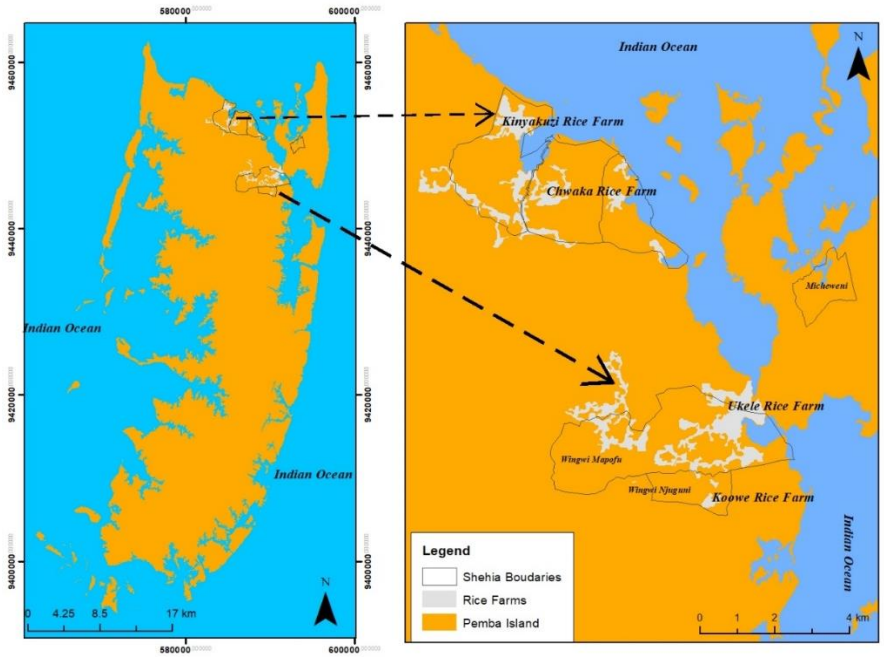

Figure 2: The Location of the Study Areas in Pemba Island

2.2 Methods of Data Collection

Both primary and secondary data were collected and analysed to provide insights into the key objectives of the study. Quantitative data were mainly collected using focus group discussions (FGDs) and interviews. The selection of these methods was based on the fact that they help in gaining an in-depth understanding of social issues, perceptions and experiences on weather behaviour and characteristics. Six (6) FGDs were conducted; one in each study site. Each FGD involved 6 elderly participants who were selected purposively on the basis of their age and knowledge on traditional weather forecasting. Heterogeneity and gender of the participants were also considered when selecting the participants for inclusion in the FGDs. A total of 12 elderly smallholder rice farmers (i.e., 2 from each site)—out of those who participated in the FGDs—were selected for detailed interviews. These farmers were selected based on their deep knowledge of the traditional methods used to forecast weather in their areas. The interview results were used to triangulate the information obtained from the FGDs, and were arranged based on the themes of the knowledge used for weather forecasts.

3. Results and Discussion

3.1 Traditional Methods for Predicting Weather in the Study Areas

Rainfall and temperature variability over the last two decades have had a significant impact on the production of rice and other agriculture produce in Zanzibar (Makame, 2013). The results of this study indicate that smallholder rice farmers rarely use conventional seasonal weather forecasts due to a limited access to this information attributed to low access to extension services by a majority of the farmers; low access to media services such as TV and radio contributed by poor rural electrification and poverty; and a negative perception of conventional weather forecasts. This is exemplified by an observation from an interview with a smallholder rice farmer from Mayungi, who stated:

> *"The Swahili culture has its own way of predicting weather that was inherited from our ancestors. For example, we plan the date of planting and harvesting based on the traditional new year (*mwaka kogwa *in Kiswahili). We normally do not use this normal year calendar of January to December, but we have our own way of counting it using a traditional-year calculation. This new year is celebrated regularly in Makunduchi village, South district, Zanzibar."*

In Zanzibar, seasonal weather forecast is normally received by the Ministry of Agriculture from the Tanzania Meteorological Authority (TMA). The information is then translated with regards to rice-farming and communicated to extension officers, who then disseminates it to farmers on the ground. However, interviews with farmers show that accessibility to extension services is considerably limited across the study sites. For instance, in rain-fed rice areas, where this service is highly needed, most of the time it is not accessible;

and where it accessible, it is sometimes not reliable. This has forced farmers to rely on their capacity to forecast rainfall using their traditional knowledge instead of conventional weather forecasts. For example, the delay in the preparation of rice farms in the 2019–2020 season, due to abnormal high rainfall, was attributed to the lack of access to conventional weather forecasts and limited capacity of the traditional weather forecast to predict the extremes. The perceived low value of conventional seasonal weather forecasts amongst rice farmers is alarming as rice-farming is very sensitive to climatic factors; and thus it would be expected that farmers would use such forecasts especially given the current abnormal variabilities of rainfall and temperatures, conditions that render rice-farming in the study areas highly vulnerable. The following sub-sections identify and explain the various ways through which farmers forecast weather for rice-farming across the study sites.

3.1.1 Biotic Indicators Used by Farmers to Forecast Seasonal Weather

1. Use of Plants

Various plant species were mentioned to be handy in weather predictions in a variety of ways (Risiro et al*.,* 2012). As highlighted by Elia et al. (2014), rice farmers use plant phenology such as flowering and fruit-bearing, as well as sprouting of tree leaves to predict weather. Table 1 provides a summary of plant indicators that rice farmers use to predict weather and climate, and inform decision-making on farming activities. Farmer mentioned that when specific trees—such as the smelly-berry finger leaf *(Vitex doniana*), locally known as *mfuu*; jamun fruit/black plum (*Syzygium cuminii / syzygium jambolanum),* locally known as *mzambarau;* and the turmeric plant *(Curcuma longa),* locally known as *manjano*—produce fruits, they are indicating the onset of the long rainy season (*masika).* A high yield of these plants also indicates a good forthcoming planting season, with good rains. The production fruits of the above-mentioned plants often starts in February; corresponding with the cessation of the *summer* season. Usually, the ripening of the fruits occurs in April/May, which correspond with the peak of the long rainy season. Other indicator plants include the common nettle plant (*Urtica dioica),* locally known as *upupu,* which starts the flowering of tiny hairs from February to April, signifying the onset of the long rainy season. Equally, when the tiny hairs start to distribute, it signifies the end of the rainy season, and the commencement of the winter season.

The flowering of the polynesian arrow root plant *(Tacca leontopetaloides*), locally known as *uwanga; the* flowering of a plant locally known as *mwalimu na wanafunzi wake (English name unidentified);* and the flowering of the nutgrass weed (*Mariscus dubius / Cyperus rotundus,* locally known as *mnjaanjaa,* signifies an imminent onset of the long rainy season. Also, the flowering and generation of new leaves of baobab trees (*Adansonia digitata*), locally known as *mbuyu,* indicate an imminent onset of rainfall and prospects of having long rains.

Table 1: Some of the Common Plants Often Used as Biotic Indicators

Local/ Swahili Name	English Name	Scientific Name	The sign used to relate on:	Decision of farmers on farming activities based on prediction
Mfuu (fuu fruit)	Smelly-berry fingerleaf	*Vitex doniana*	Production of fruits indicate onset of long rainy season (*masika*), and the ripening of fruits indicates the peak of *masika* (April/May). Abundance of the fruits indicate a good rainy season	Ensure that when rain comes, rice crops are already planted and developing Farmer prepare to
*Mzambarau (*zambarau fruit*)*	Jamun fruit/black plum	*Syzygium cuminii / syzygium jambolanum*	The production of fruits is a sign of the onset of long rainy season. The ripening of fruits indicates the cessation of the rainy season	sow rice weeds and transplant rice. For irrigation farmer
Mnjaanjaa / mndago / ndago mto	Nutgrass weed	*Mariscus dubius / Cyperus rotundus*	Flowering of the plant (Feb. to April) indicates an imminent onset of long rainy season	and farmer affected with floods, who prepare to reconstruct earth
Manjano	Turmeric plant	*Curcuma longa*	When the plants start to produce turmeric, it indicates an imminent onset of a long rainy season	canals and streams to remove water out of the field
Upupu	Common Nettle plant	*Urtica dioica*	Significant flowering to the development of tiny hairs from Feb. to April is a sign of long rainy season If the tiny hairs start to distribute, it indicates the last of long grain season to start winter	Farmer prepared for harvesting process, drying, storing and milling of rice
Uwanga jike	Polynesian arrowroot	*Tacca leontope-taloides*	Significant flowering from March to April indicates imminent onset of long rains	
Mwalim na wanafunzi wake	English name could not be found		Flowering yellow flower on the end of Feb. to April indicates a long rainy season	
Mbuyu	Baobab tree	~~(~~*Adansonia digitata*~~)~~	The flowering and generation of new leaves indicate the onset of rains and prospects of long rains	
Msufi	Silk cotton tree	*Ceiba pentandra*	When the fruits of the cotton fibers that rain from the tree start to ripen it indicates the imminent onset of summer. Usually, the flowering ripens in Dec.	Preparation of the land for farming, and transplanting.

Upundi	English name could not be found	*Heteropogon Contortus*	Flowering of the plant (grasses) during Dec. to Feb. indicate the onset of summer	Maintaining of soil fertility and pest management
Pilipili doria	English name could not be found	*Sorindeia madagasca-riensis*	The flower starts at short rainy season but when the fruits ripen it indicates summer onset	especially caused by dry weather
Muembe mkwaju	Mango tree	*Mangifera indica*	The dense flowering of mango fruits indicates drought in upcoming season, while the poor fruit of mango indicate good harvesting year	For rain-fed farmer preserve food and plant drought resistance crops
Kiazi kikuu	Purple yam, tube, or greater yam	*Dioscorea alata / Trichilia emetic.*	When leaves sprouts indicate rain onset. The germination of greater yam signifies onset of the winter condition	Prepare for ripening stage of the rice

Source: Field Survey, 2018

The results above are similar to those of the studies by Kalanda-Joshua et al. (2011), Risiro et al. (2012) and Kijazi et al. (2012). These studies show that when trees start growing new leaves, it means rains are near; early sprouting of new leaves means rains will come early that particular year; and late foliaging indicates late onset of rainfall, which usually translate to a bad rainfall season that is short. The results from FGDs revealed that farmers used these indicators to prepare for the planting of rice. The ripening of the silk cotton tree (*Ceiba pentandra)* in December is linked with the onset of the summer season. When the *Sorindeia madagascariensis* plant, locally known as *mpilipili doria*—whose flowers and fruits often appear during the short rainy season (*vuli)*—starts bearing fruits, farmers usually interpret this as an indicator for the onset of the summer season. Another plant used as an indicator of weather change include black speargrass (*Heteropogon contortus),* locally known as *upundi.* When the plant starts flowering, it signifies the onset of the summer season. For the purple yam, tube or greater yam (*Dioscorea alata*), their germination indicate the onset of the winter season. Another plant used by farmers to predict weather is the mango tree (*Mangifera indica*), locally known as *mwembe*. A heavy flowering of mango trees indicates a potential drought season and food scarcity. These results are similar to those of Kalanda-Joshua et al. (2011), Risiro et al. (2012), and Kijazi et al. (2012).

3.1.2 Use of Animals, Birds and Insects

Apart from plants, animals are also used as biotic indicators (Risiro et al*.,* 2012; Muyambo et al*.,* 2017; Radeny et al*.,* 2019; Ubisi et al*.,* 2019). Acharya (2011) argued that the behaviour of animals can reliably be used to predict the onset of the rainy season, upcoming rain, and the occurrence of extreme events such as floods as they alter their behaviours to suit upcoming natural dangers.

According to Alvera (2013), animals have the ability to detect heavy rains, storms, droughts or thunderstorms by using frequencies of sound waves and changes of atmospheric/ barometric pressure. Also, they have the capability to detect and react to ultrasound or micro tumbler that human beings cannot detect (Acharya, 2011). Similarly, the behaviour, appearance, and movement of some birds are frequently used to predict seasonal weather (Radeny, 2019). Some physiological phenomena in animals can be linked with meteorological weather conditions, and hence enable one to predict a weather condition. A study by UNEP (2008) in the Southern Africa reported that the singing, nesting and chirping of certain birds appear to be a useful indicator for the onset of rains, while the appearance and movement of some birds are frequently used to predict seasonal weather (Radeny, 2019).

1. Birds

The sound of sea eagle *(Haliaeetus spp),* locally known as *furukombe,* is used as a biotic indicator for seasonal weather forecasts. When the sea eagle sings at a very high distance in the sky, it indicates an imminent onset of summer; while if it sings at a low altitude it often signifies the middle of summer, which occurs from January to February. The appearance of this bird at a close distance signifies the peak of the summer season, locally known as *kiangazi kandanda.* The special sound of velvet mantled birds (*Drongo dicrurus modestus),* locally known as *mramba mahmeli*; and the sound of the yellow-rumped tinkerbird (*Pogoniulus bilineatus*), locally known as *kitororo maringo:* all indicate an imminent onset of the summer season. The appearance of a schools of birds, locally known as *chokozi;* green wood hoopoe/violet wood hoopoe birds *(Phoeniculus purpureus),* locally known *as goregore;* pied-crow/ white napped raven (*Corvus albus*/*Convus albicollis*), locally known as *kunguru mabaka*/*kungura wa Pemba:* all of which take place from January to the end of February, signify the onset of summer. During the interviews with local rice farmers, it was revealed that all these schools of birds are migratory species of birds that migrate to Unguja from Pemba Island during the summer season (Table 2).

Risiro et al. (2012) have made similar observations: that the arrival of migratory birds indicates the approach of the summer season. The unique sound of owl birds (*Strigiformes*), locally known as *bundi,* indicates an imminent onset of rainfall either in the same day, or within the same week. Results from the FGDs revealed that the sound of an owl was associated with a good planting season; but it also indicate the death of a person. These results are similar with Rodeny (2019) who stated that farmers in East Africa use the sound of owl to predict a good planning season. Also, the appearance of the white-barred peculate (*picumninae),* locally known as *magonota,* indicates an imminent onset of rainfall, and a good rainy season; while the appearance of the sun bird (*Nectariniidae),* locally known as *chozi,* in mid-February signifies an imminent onset of a long rainy season with good rains. Rice farmers use such predictions to plan for the beginning of the rice season (see Table 2).

Table 2: Knowledge of Local Indicators Based on Birds

Local/ Swahili name	English Name	Scientific Name	The sign used to relate on:	Decision of farmers on farming activities based on prediction
Furukombe	Sea eagle	*Haliaeetus*	The sound of sea eagle and flying of the bird at high altitude in the sky indicates an imminent the onset of summer. But in the flying of the Bird at low altitude or settling of the bird on the trees signifies the middle of summer (*kiangazi kandanda*) Jan. to Feb.	Farmer make preparation of land, fertilizing, planting, weeding, spraying, etc. Prepare drought resistance seed and short seed varieties
Mramba mahameli	Velvet – Mantled Drongo	*Dicrurus modestus*	The unique sound from the grey colour bird indicate the onset of summer	Prepare soil and water management etc.
Chokozi	English name not identified	Scientific name not identified	The flying of large schools of *choko*zi birds from one area to another indicates the onset of summer	Water harvesting, plot bunds and irrigation
Kitororo maringo	Yellow – rumped tinkerbird	*Pogoniulus bilineatus*	The sound of the bird indicates summer season mostly in Jan. to Feb.	Plant other crops which resist drought like cassava
Goregore	Green wood hoopoe/ Violet wood hoopoe	*Phoeniculus purpureus* / *Phoeniculus purpureus*	The sound of birds indicates an imminent the onset of summer. Usually travel in groups from Jan. to the end of Feb.	Prepare for pest and diseases management for burning, spraying chemicals,, and use of other organic pesticides like ash
Kunguru mabaka / *kunguru wa Pemba*	Pied-crow/ White napped raven	*Corvus albus* / *Convus albicollis*	These bird species migrate to Unguja during summer, often from Jan. to Feb. Appearance of the schools of bird signify the onset of summer.	
Bata viziwa	English name not identified	Scientific name not identified	The appearance of these birds indicates long rainy season onset	Ensure that when rain comes the rice crop and other crops are already planted and developing
Bundi	Owl	Strigiformes	The sound of owls signifies an imminent rainfall (within a week) and good rainy season	Prepare for weeding and spraying
Chozi	Sun bird	Nectariniidae	The sound of the birds signifies an imminent onset of the long rainy season (*masika*	Prepare for harvesting process.
Magonota / *vigongota*	White – barred peculate	Picumninae	Appearance of birds indicates an imminent rain onset	Plan for farm activities according to rain expected

Source: Field Survey, 2018

2. Insects

The respondents discussed on insects that are commonly used as bio-indicators for seasonal weather forecasts, and how the indicators are used by farmers to make decision on rice-farming. Table 3 presents a list of the most common insect's bio-indicators. The FGDs revealed that the appearance of an army or a colony of red ants (*Dorylus*), locally known as *siafu,* which travel together in defined paths carrying food, and move towards people's homes, signifies an imminent onset of the rainy season (within a few days). Also, the appearance of many termites (*Isoptera/Ancistrotermes sp.*), locally known as *mchwa,* indicates an imminent approach of the rainy season; while the appearance of flying termites that discard their wings while flying would signify an imminent onset of rainfall and good rains during the coming season. These finding differs with those of Elia et al. (2014), who claimed that termites (*Ancistrotermes sp.)* are not used in rainfall prediction; and that their appearance in large numbers after a rainfall season is taken to signify famine as they destroy the already-cultivated crops.

Table 3: Knowledge on Local Indicators Based on Insects

Local/ Swahili Name	English Name	Scientific Name	The sign used to relate on:	Farmer's decision based on prediction
Siafu	Red ants/Driver ants/ safari ants	*Dorylus spp*	The large group of army ants that move together in a line with food toward their hole signifies the imminent rain onset either for season or within few days	Prepare for growing season with good rains Plan the methods of control pests and diseases caused by wet condition
Mchwa	Termites	*Isoptera / (Ancistrotermes sp.)*	The species that remove their wings while flying, signifies good rains in the coming rainy season and the imminent appearance of rainfall.	Farmer plans the methods for controlling weeds of rice, either use herbicides for rain - fed or use hand weeding.
Madunga mvua	English name not found	Scientific name not found	Appearance of this insect is a sign of good rain during the rainy season, the insects look like grasshopper which fly during the noon and while flying they lose (shade) their wings.	For flood prone area and irrigation area prepare and rehabilitation of the canals and stream.
Mbukachi	English name not found	Scientific name not found	Small insects which come out of the soil to the surface, like most to play in coconut indicates good rain	Farmer planting the seed that require plaint of water (flood resistance seed)

Vimeta-meta	Fireflies	*Lampyridae*	Appearance of fireflies in groups is a sign of rain either within a week or onset of high rainy season	
Nyuki	Bee	Different varieties	The group of bees predict imminent summer onset when they migrate from South to North follow the direction of wind.	Farmer prepare for soil and water management e.g. Plot bunds. rain water harvesting for conserving water
			If the group of bee travel from North to south indicates onset of rainy season	Preparation of soil and planting materials- e.g. ploughing
Panzi kijani	Green grass grasshoppers	*(Hesperotettix sp.)*	The group of green grass grasshoppers indicate imminence of rain and good harvest season	Preserve food used during rainy season
Majongoo	Millipedes	Different species	The appearance of millipedes indicates imminent rain on set and good rainy season	Prepare for harvesting and storage
Viwavi Jeshi	Army worms	*Spodoptera exempta)*	The group of army warms indicate imminent rain on set and good rainy season	

Source: Field Survey, 2018

The results further revealed that the appearance of insects locally known as *madunga mvua* (English name not found), implied reliable rains during the rainy season; while the appearance of small insects, locally known as *mbukachi* (English name not found), which come out of the soil to the surface, and often settle in coconut shells, implies an imminent onset of rains and good rains during the coming season. It was also revealed that the appearance of a large group of fireflies (*Lampyridae),* locally known as *vimetameta,* was a sign of imminent rains within a week, or an onset of a high rainy season. On the other hand, the appearance of a school of bees that migrate from South to North, following the direction of the wind, would predict an imminent summer onset and dry spells during the summer season. The results from the FGDs revealed that the appearance of millipedes (various species), locally known as *majongoo,* army worms (*Spodoptera exempta*) and varieties of butterflies (local known as *vipepeo*), and in large numbers (swarm of butterflies), is a sign of the onset of rains; while the appearance of a group of green grass grasshoppers indicate a good harvest year. The finding is similar with those of the studies by Elia et al. (2014) and Risiro et al. (2012).

3. Livestock and Humans as Indicators for Weather Forecast

The study also inquired from the respondents on weather forecast indicators from livestock and human beings, and how they used these to forecast weather and assist in making decisions in rice-farming and adaptation to the impacts of climate change and variability (Table 4). During the FGDs, it was revealed that cattle of different types occasionally perform frisky jumping (locally known as *uhongoo*), which signifies an imminent onset of a rainy season (mostly within a week). Alternatively, if the cattle, goat and sheep flap their ears repeatedly during the dry season, this is an indication that there is an imminent onset of the rainy season, and prospects of a good rainy season. Furthermore, the appearance of ducks (*Anas platyrhynchos domesticus*) playing in dusts and stretching their wings would imply an onset of the short rainy season.

Table 4: Knowledge of Weather Indicator Based on Animals and Human Alignment or Behaviour

Local/ Swahili Name	English Name	Scientific Name	The sign used to relate on:
Ngombe kucheza uhongoo	Cattle	Different varieties	When the cattle became frisky by jumping signifies the sense on rain that are near within a week (upcoming rain)
Bata	Ducks	Different varieties	When ducks playing in dusts and stretching their wings is a sign of the imminent onset of the short rain.
Vyura	Frogs	Different varieties	When frogs make high pitch sounds indicates imminent onset of the rainy season, the higher the sound pitch the heaver would be the upcoming rains
Binadamu	Human alignment	Any human being common for elders	Shaking of one part of head, severeness of breathing problem for asthma patients, severe chest pains extending to the legs (kichomi) are sign of upcoming heavy rains

Source: Field Survey, 2018

Apart from livestock, it was also revealed that some human body feelings could be closely associated with upcoming weather conditions. For instance, the shaking of one part of a human head, severeness of the breathing problem for asthma patients, pains extending to the legs—locally known as *kichomi*—are signs used to predict for an upcoming heavy rains during the short rainy season. Similar results were also reported in other parts of Africa. For example, a study by Risiro et al. (2012) showed that human ailments such as asthma and backache were used as weather predictors: that when patients suffer most from these ailments, it indicates that windy, cold conditions, high humidity and rains are likely to be experienced within a short period of time (Risiro et al. 2012; Chengula & Nyambo, 2016).

4. Astronomic and Meteorological Indicators of Weather Forecast

Farmers use traditional meteorological indicators to make critical decisions regarding planting, preparation of storage facilities, post-harvest handlings, as well as exploring market opportunities for their harvests (Radeny et al., 2019). Rice farmers in the study area use specific meteorological indicators to discern the onset of a rainfall season (Table 5). Among the most common traditional meteorological indicators are: thunderstorms, lightning, clear skies and night temperature. If thunderstorms start first without rain during the rainy season, this would imply an upcoming light rain. Alternatively, if there is lightning from the East side, locally known as *urejua,* that would imply no rains in the coming day; while if the lightning starts from the west (*uchejua*), that would indicate an imminent rain coming during the day or the next day. Furthermore, if lightning and thunderstorms come from the south, it signifies an imminent heavy rainfall within a week (short rain). Additionally, abnormally high temperatures during the night would indicate an upcoming heavy rain during the same day or next day. This indicator is very common in the study area.

Table 5: Knowledge of Weather Indicators Based on Thunderstorms and Lightening

Sign	Description in Relation to Rainfall	Action of Rice Farmers
Thunderstorms without rains during rainy season	Indicates low rain in the coming rainy season	Prepare to grow drought resistant crops.
lightning	If the lightening starts from the east (*urejua*) that would be a sign of no rain in the coming day; but if it starts from the west (*uchejua*), this would indicate that there is an imminent rain	Prepare and plan for rains to come for different farming activities. Prepare and plan for the excess rain and its impacts.
Lightning and thunderstone	If lightning and thunderstones come from the south, it indicates high rainfall within a week	

Source: Field Survey, 2018

Farmers were also reported to use the manner in which winds blow, or a rainfall pattern, to forecast weather behaviours. The occurrence of strong winds during a sunny day and high temperature conditions would indicate low rainfalls in the coming rainy season (Table 6). The FGDs also revealed that farmers predict drought conditions or low rains during the coming long rainy season if the rains during the short rainy season (*vuli*) run for a brief period. Furthermore, if the northerly winds (locally known as *pepo za kaskazi),* that blow from north to south, blow at exceptionally high speeds for long periods, this would indicate an upcoming drought or dry spells in the coming season. If such similar conditions occur for the southern winds (locally known as *pepo za kusi*) that blow from south

to north, this would indicates an onset of winter season and an upcoming severe cold winter. A high frequency of the occurrence of wind swirls from April to July would predict the onset of a long rainy season that is accompanied with both human and animal diseases. It was reported that farmers believed that the occurrence of wind swirls relate to the power of devils that bring diseases to livestock. Finally, it was informed that high temperatures at night in the months of September to December was a sign of good rains, while low temperatures at night indicates a late onset of rains.

Table 6: Knowledge of Weather Pattern and Dynamics Indicators

Signs	Time of Occurrence	Description in Relation to Rainfall
Blowing of wind, sunny and high temperature		Indicates low rain in the coming rainy season
If the rainy in short rainy season (*vuli*) will raining in short time) and then no more rain	Sept.–Nov.	Indicates low rain and dry spells in the coming long rainy season (masika)
Prolonged of north-east Monsoon wind local known as *(pepo za kaskazi*	Mid-Dec.–Jan.	Signifies dry spells or drought in summer season
Prolonged of easterly wind/ morning wind locally known as *matlai*	March–April	Indicates heavy rainfall during the long rainy season (spring) local known as *(masika/ mvua za mwaka)*
Strong winds of south monsoon wind local known as *kusi*	May–Oct.	Indicates that the upcoming winter season will be very strong *(kipupwe)*
The prolonged of the strong wind of westerly wind *(mmande)*	Nov.–Dec.	Signifies high rainfall during the short rainy season Autumn, locally known as (*vuli/mchoo)*
Wind swirl	Apr.–July	High frequency of occurrence of wind swirls indicates high likelihood of occurrences of diseases both for human and animals
Atmospheric temperature	Sept.–Dec.	High temperature at night is a sign of good rainy season and long plantation season while low temperature at night indicate no rain and late plantation season

Source: Field Survey, 2018

With regards to stars and clouds, the results show that that farmers in the study area use visible stars for planning the whole process of growing rice from planting to harvesting (Table 7). If a group of stars—locally known as *nyota za kilimia (*English name not found)—that move together from east to west,

appear in February, this is an indicator of heavy rains during the long rainy season (*masika*), and also it predicts a good rainy season. The study finding is corroborated with the study by Elia et al. (2014), which found that farmers of Malunge village, in Tanzania, used a group of stars (known as *nimila*) to predict rainfall and a good season. The FGD results also revealed that dark grey-coloured clouds (*Nimbostratus clouds)* indicate an imminent onset of rains that could start in a few hours, last for several days, and very likely lead to floods. These results concur with Risiro et al. (2012) and Zuma-Netshiukhwi et al. (2013): that cumulonimbus clouds (*mawingu pamba*) indicate severe weather conditions of heavy rains and thunderstorms within a short period. Another indicator used is the rainbow: if half-seen in the sky in the absence of winds, this would indicate an imminent rain within 24 hours.

Table 7: Knowledge of Weather Indicators Based on the Stars and Clouds

Swahili Name	**English name**	**Prediction**
Nyota za kilimia	Not found	The stars move from east to west, the star indicate time for planting and the farmer used the stars as common indicator, which guide rice-farming time from planting to harvesting. Usually appear from February to March/May. If the star delays its appearance within a set timeframe, a bad season with less rainfall, is predicted
Wingu jeusi	Nimbostratus Clouds	Dark grey coloured clouds indicates the imminent coming of the rains that could start in few hours, and could last for several days and very likely leading to floods
Mawingu Pamba	Cumulonimbus clouds	Indicates severe weather conditions of heavy rains and thunderstorms within a short period.
Kipigi	Rainbow	If half seen in the sky, in the absence of winds, this would indicate an imminent rain within 24 hours

Source: Field Survey, 2018

5. Weather Forecast Based on Local Ceremonies

For decades, farmers in the study areas had been planning their agriculture calendars based an annual local ceremony called *mwaka kogwa*, which takes place at Makunduchi, Zanzibar, every year. Traditional rain predictions and local agriculture experts used to count each hour from sunrise to sunset, of the same day of *mwaka kogwa* ceremony, to predict the weather for the whole year. They normally record the weather conditions for each hour from early morning to the evening in this day of the ceremony, and these hourly recorded conditions assist them to predict the weather of each month ahead until the next ceremony of *mwaka kogwa*. During the present study, it was revealed that most of the respondents, especially rain-fed agricultural farmers from both Unguja and Pemba, believed on this prediction; and follow the calendar linked with *mwaka kogwa* to plan their farming activities.

Conclusion

This study has revealed that despite the threat posed by increasing climate variability and unprecedented impacts of climate change to agriculture and all socio-economic sectors, smallholder rice farmers are still having challenges in accessing and utilizing conventional seasonal weather forecasts by the TMA. The accessibility and utilization of conventional seasonal climate forecasts is important for farm-level decision-making, and is an integral part of climate change adaptation, particularly with increasing accuracy of seasonal forecasts. The adoption and utilization of this information can help farmers adjust and build resilience to predicted risks of weather variability. The study, however, has shown that local people have their own way of predicting weather, which is directly linked with rice-farming processes. The results revealed that smallholder farmers used various local indicators that alert them about weather conditions, which help them make decisions on what actions to take in the field with regards to predicted weather conditions. The fact that some studies have found similarities between traditional weather forecasts and conventional weather forecasts, and given the importance of this to rice farmers, means that an attempt should be made to explore the possibility and modality of integrating tradition and conventional weather forecasting systems to enhance the accuracy, uptake and utilization of weather forecasts.

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