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Research Article

The significance of indigenous weather forecast knowledge and practices under weather variability and climate change: a case study of smallholder farmers on the slopes of Mount Kilimanjaro

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This paper discusses the implication of indigenous knowledge-based weather forecasts (IK-BFs) as a tool for reducing risks associated with weather variability and climate change among smallholder farmers on the south eastern slopes of Mount Kilimanjaro in Moshi Rural District of Tanzania. Participatory research approaches and household surveys were used to identify and document past and existing IK-BF practices. Local communities in the study transect use traditional experiences and knowledge to predict impending weather conditions by observing a combination of locally available indicators: plant phenology (40.80%), bird behaviour (21.33%), atmospheric changes (10.40%), insects' behaviour (7.20%), environmental changes on Kilimanjaro, Pare and Ugweno mountains (4.80%), astronomical indicators (4.8%), animal behaviour (4.00%), water related indicators (3.73%) and traditional calendars (2.93%). The study established that 60% of farmers use and trust IK-BFs over modern science-based forecasts (SCFs). Although about 86.3% of respondents observed some correlation between IK-BFs and SCFs, and 93.6% supported integration of the two sets of information, the nature and extent of their correlation is not yet established. We none the less recommend that IK-BFs be taken into relevant national policies and development frameworks to facilitate agro-ecological conservation for use and delivery of effective weather and climate services to farming communities.

Key words: Indigenous knowledge, weather forecast, smallholder farmers, climate change and variability

INTRODUCTION

The ability of small scale farmers to accurately forecast and use impending weather information is imperative for ensuring the sustainability of livelihoods under increasingly variable weather, and a changing climate. The unpredictability and uncertainties associated with conventional weather forecasts is making it difficult for rain-dependent farmers to adapt, and is increasing the salience of timely local information thus exacerbating instability of food security in many parts of East Africa (East African Community, 2011). It has been suggested that agricultural production in Africa would be more resilient to the impacts climate variability and change partly if official recognition were to be given to local knowledge (Wangui *et al.,* 2012). Others question the usefulness of past experience, whether encoded in official trend data or local knowledge, in so far as climate change is varying the range and rate of change in numerous weather and biological parameters in unpredictable ways.

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Climate change and variability thus poses a great challenge not only to meteorologists in their efforts to improve the accuracy and reliability of weather forecasts, but also to farmers who desperately depend on such information. Agro-meteorological information can be obtained from both seasonal climate/weather forecasts (SCFs) and indigenous knowledge-based seasonal forecasts (IK-BFs) (Chagonda *et al.,* 2010). Highly specialized national meteorological and hydrological institutions generate weather and climate-related products under guidelines set by the World Meteorological Organization (Kijazi *et al.,* 2012). However, these conventional seasonal weather forecasts are not widely used in agricultural practice because they are perceived by farmers to be insufficiently area specific, unreliable, poorly packaged and untimely disseminated (Boko *et al*., 2007). In contrast, indigenous knowledge-based weather forecasts are produced locally by people who live in an area and typically are based on multi-indicator observations and years of individual and collective experience (Chang'a, 2012). For a very long time, people in rural areas have observed the behaviour of plants, animals and insects, the condition of physical features such as mountains, and atmospheric states to predict impending weather patterns (Risiro *et al.,* 2012). However useful in the past these might have been, the increasing variability in the timing and intensity of temperature and rainfall, suggests that new measures might be needed. Moreover, the advent of conventional weather forecasts has resulted in less use and promotion of IKFs within farming communities (Chang'a *et al., 2010a)*.

There is an increasing consciousness that indigenous knowledge determines decision making in many human activities, including agriculture, forestry, health care, and resource management (African Technology Policy Studies [ATPS], 2013). A number of studies indicate that in some parts of Africa contemporary and indigenous weather forecast information continues to guide farm level decision making (Lucio, 1999, Risiro *et, al*., 2012; Chang'a, *et, al.,* 2010 b; Chang'a, 2012). In Tanzania, rural communities in the central semi-arid regions and southern highlands are known to use indigenous knowledge to cope with weather –related hazards such as drought and floods (Chang'a, *et al.,* 2010b). However, indigenous knowledge-based weather forecasts are facing a number of new challenges. First, the relevant bodies of knowledge, and how they are generated and transmitted over time, are not well identified and documented. Secondly, the custodial traditions and cultures are dying out and younger generations are reluctant to invest in developing the skills needed. Many of the biological indicators used for prediction are disappearing because of changes in farming and resource use practices, land clearing, and increasing weather variability (Mapara, 2009; Mahoo, *et al.,* 2015). The validity and reliability of IK-BFs, and how they might be used to complement conventional weather forecasts has been little studied. However, there is a need first to document and explore the significance of IK-BFs to small scale farmers, and the understanding involved: these issues form the main focus of this study.

METHODOLOGY

Description of the study area

The study was conducted in single geographical area categorised into different toposequence (altitudinal gradients) zones. This enabled comparisons of indicators associated with a range of ecological and climatic parameters but the study did not attempt to compare or correlate traditional observations and weather forecasts and scientific observations and forecasts. It was carried out in Moshi rural district on the slopes of Mount Kilimanjaro (Figure 1) between March and August 2014. It covered an altitudinal transect of about 21 kilometres long and 3 kilometres wide from Kisangesangeni village Miwaleni Springs (700-900 m.a.s.l.) on the lowest part to Maruwa-Nduoni (1900-2100m.a.s.l.) Kirua Vunjo on the highest location. The area was divided into four altitudinal zones: lower zone (700-900m.a.s.l.), mid lower zone (900-1500 m.a.s.l.), mid upper zone (1500-1900 m.a.s.l.) and upper zone (1900-2100 m.a.s.l.) based on temperature and humidity. Segmenting this study area into altitudinal zones was useful for comparison analysis of agro-climatic parameters based on the biophysical characteristics of each zone. To be able to collect large and representative information of the study area, eleven (11) villages were randomly chosen for primary data collection. These villages included Nduoni and Kwamare in the upper zone; Iwa, Kopachi and Sumi in the mid upper zone; and Kisangani, Mafurwanjeni and Uparo in the mid lower zone; Yamakaa, Uchira and Kisangesangeni in the lower zone (Figure 2).

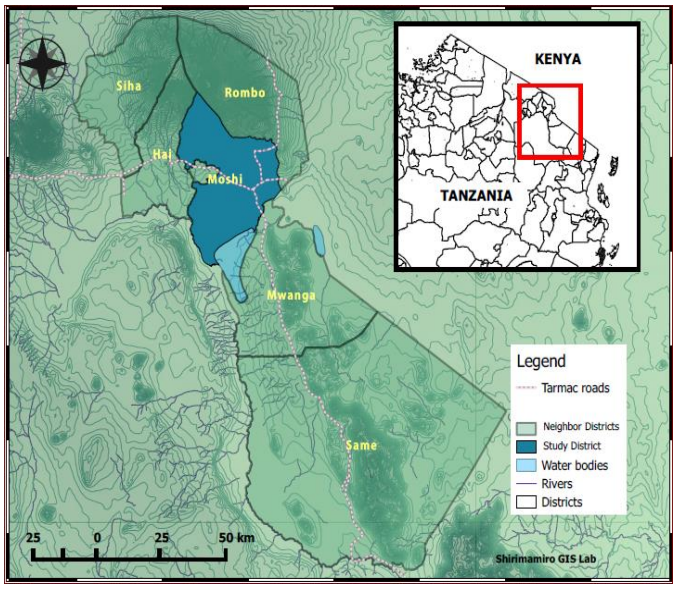


Figure 1. Tanzania showing Kilimanjaro region and Moshi rural district
Source: Shirimamiro GIS lab (2015)

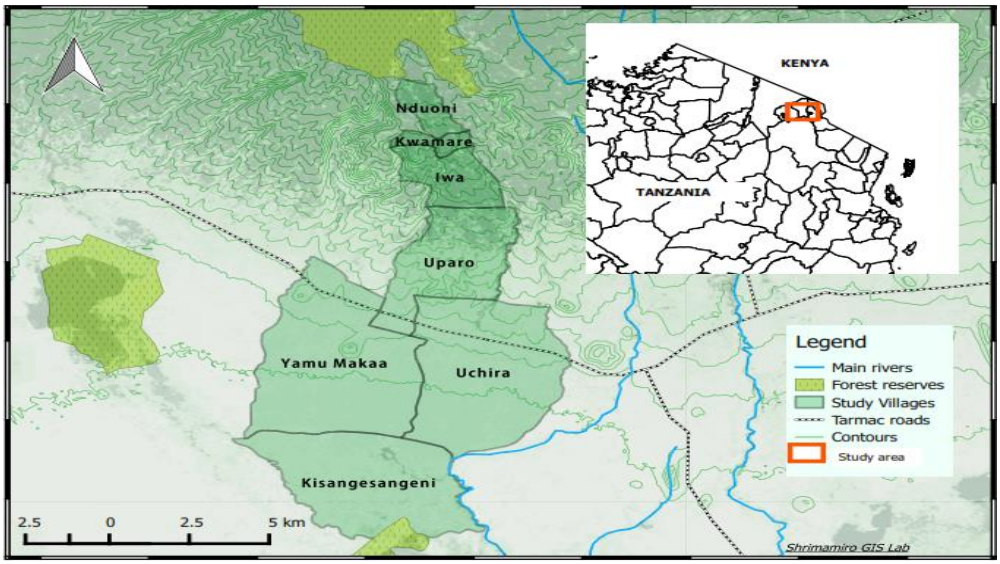


Figure 2. Study transect and sample villages
Source: Shirimamiro GIS lab, (2015).

Data collection

A mix of participatory research appraisals (PRAs) was applied, (mainly key informant interviews (KII), focused group discussions (FDGs) and household surveys (HHS) in order to explore the perceptions of local communities of the application and reliability of conventional weather forecasts and the pathways by which these were communicated to farmers. The challenges embedded in the packaging and dissemination of seasonal weather forecasts to farming communities were assessed, using key informant interviews and household surveys. The PRAs included open questions and semi structured questions that allowed open and flexible dialogue between researcher and respondents. Adopting similar approaches of Leech (2005), Mason and Mark (2010), 8 percent (about 20 households) of the total households in each village were included in the household survey. In total, 375 randomly selected households from all eleven villages were included in the study.

In addition to the household survey, a purposive sampling procedure was used for administering key informant interviews and the FGDs. A total of 23 FGDs, based on flexible open questions and semi structured questions were conducted throughout the study transect. Twelve of the FGDs were homogenous with respect to gender, involving 4 FGDs in one village in each zone: Nduoni in the upper zone; Iwa in the mid-zone and Kisangesangeni in the lower zone. Eleven FGDs with diverse participants based on gender, age, and experience were held, one each in the remaining villages. During each of the FGDs, Venn diagrams drawn by the researchers, showing the ways that information flows from forecasters to users, were used to help farmers identify more suitable options for weather forecast communication pathways according to the conditions of their localities and preferences.

Data analysis

Primary analysis was conducted with farmers. Forecast communication diagrams were used during the interviews and FGDs to identify the impact of each source of weather and climate information on communication pathways, from forecasters to users. In order to analyse and compare existing communication pathways, the production of official weather forecasts, and the study findings, a documentary review was conducted and analysed by means of content analysis. A thematic and content analysis was also applied to all the interview and FGD data, and the Statistical Package for Social Sciences (SPSS) version 21 and Microsoft Excel software, were used to make a descriptive statistical analysis of the household survey data.

RESULTS AND DISCUSSION

Indigenous knowledge-based weather forecast (IK-BFs) practices

The study found that local communities have their own indigenous knowledge-based weather forecasting practices based on locally available environmental, biological, astronomical as well as mythical indicators (Tables 1-5). The indicators are used in different combinations depending on a community's location along the altitudinal gradient.

i. **Plant phenological changes (Table 1).** 41% of respondents reported phenological changes of specific indigenous plants and trees such as: fruiting of Mzambarau *(Syzygiumguineense (*Willd*)* DC; flowering of Msangafue (*Amorphophallus Abyssinicus* (A.Rich N.E.Br)); Mgongachuma (*Acacia drepanolobinm* Sjőstedt), and Mfurufuru *(Myrica Msalicisfolia)* in



Mzambarau *(Syzygiumguineense* **(**Willd) DC**.** Common at the lower zone.



Migomba pori (*Vangueria infausta* Burch).



Msangafue **(***Amorphophallus abyssinicus* (A.Rich N.E.Br))



Mringaringa ***(Cordia Africana*** Lam***).***

Plate 1. Plant indicators



A. Heavy dark clouds, spotted East of Miwaleni indicating possible onset of rains



B. Mkoryi (Rain-bow) spotted east of Uchira village indicating possible stoppage of rains

Plate 2. Atmospheric indicators

January and shading of leaves of Ndichio (*Dioscorea asterius*) trees in November, December and January. Local communities associate these changes with the onset of *Masika* (long) rains during March-May. When similar changes appear in August and September, according to respondents, they are used as an indication of the onset of the *Vuli* (short) rains in October-December. Sprouting of Migomba Pori **(***Vangueria infausta* Burch species) in January would indicate the onset of the *Masika* rain within a month or so.

ii. **Bird behaviour (Table 2):** the behaviour of certain birds was reported by 21. 0% of respondents. The singing of *Ndekrefa* (rain bird), the Malachite

Table 1: Plant indicators used in weather forecasting along the altitudinal gradients and application

Name of indicator Plant(Local/Swahili name)	English name	Scientific name	Zone where found	Description and Traits observed for weather prediction	Reliability[1]
Mringaringa (Chagga)		*Cordia africana* Lam.	Upper and mid zones	A tree that grows very big common in the upper and mid zones. Used for timber production and provision of shade for coffee and banana in the Chagga home garden farming system. A significant flowering (yellowish) of this tree in December to January indicates rain onset within less than a month's time. Rains associated with flowering of this tree is called "*Uringaringa rains*"	Very Reliable
Msangafue (Chagga*)*		*Amorphophallus abyssinicus* (A.Rich N.E.Br)	Upper and mid zones	It is a flowering plant which usually appears once per year. Mostly known among elders than youth. It is found under shades of big trees and banana in the upper and middle zones. It gives red flowers in January indicating onset of Masika rainfall.	Very reliable
Mfuruanje (Chagga)		*Albizia-gummifera*	Upper and mid zones	A big tree that shade leaves and gives white flowers in November to December indicating onset of rains in a month to come. In August and September, Mfuruanje trees are infested by spittlebugs which indicate onset of vuli rains. This rain is also called "*Nyamvia" meaning* associated with Mvia (spittlebugs). This indicator is mainly used to remind local people in the upper and mid zones of banana planting time.	Very reliable.
Ndaraho		*Deinbollia Kilimandscharia.Taub*	Upper and mid zones	A shrub whose leaves are used as fodder for livestock in the upper and mid zones and the fruits are edible. When fruits appear, it indicates onset of rains within some two to three weeks.	Normal
Nginda (Chagga), Migomba (Kiswahili**)**	Banana plant	*Musa m.esculentum*	Upper and mid zones	Bending of banana nipple *"Kiringitia"* [2]before the banana bunch. When this last banana leaf bends downward, it indicates onset of rain. Also when a new banana bud emerges with white fluid leaking out of it would indicate onset of rains within a month's time.	Reliable
Ndichio		*Dioscorea asterius*	Mid zone	A big tree along mid highlands. This tree shade leaves in January indicating onset of rains.	Normal
Msesewe[3]		*Rovalisia Caffa*	Upper and mid zone	It is a common tree in upper zone. It shades leaves and flowers in January indicating onset of masika rains. The bark has medicinal uses; and also used in traditional brewing of mbege, the local beer.	Reliable
Mriri		*Erythrina abysinica*	Upper and mid lower zones	It is found in many parts in Northern Tanzania. It gives red flowers in January and February indicating onset of masika rains.	Reliable
Mfurufuru		*Myrica Msalicisfolia*	Upper zone	Shade leaves and flowers in December and January respectively indicating onset of masika rains.	Reliable

[1] Reliability of these indicators is based on respondent's perception and experiences. scientific measurements not established

[2] The last banana leaf before the banana bunch. NB. It is not common to every banana species, only experienced elders have the knowledge of this indicator.

[3] The flowering of this tree is associated with St. Bernadette's festival according to the Roman Catholic Church calendar. For this reason, just like for a Charismas tree, it is known as *"Mbernadeta"* meaning Bernadeta tree.

Table 1. Cont.

Parachichi	Avocado trees	*Persea americana*	Upper, mid and lower zone	Flowering of these trees would indicate onset of vuli rains. However over bearing is interpreted as bad harvest year. If few fruits are formed, it predicts a good rain season with good harvest.	Reliable
Miembe	Mango trees	*Mangifera indica*	Mid and lower zones	Significant flowering of mango trees indicate a potential drought season. But poor fruiting of mango tree indicates good year i.e. a year with plenty of rains and good harvest.	Reliable
Mratune(Chagga),Kisapa(Pare)/Kiluma/Kamba)	Aloe	*Aloe Vera*	Mid and lower zones	Flowering and significant leaf thickening of these plants in January is indicatives of onset of rains	Reliable
Kia (kichagga) Kiazi kikuu(Kiswahili)	Yams	*Trichilia emetic.*Vahl	Upper and mid upper lower zones	When their leaves sprout, is indicative of rain onset.	Reliable
Dingoro (Kichagga)		*Ximenia americana L.Var.caffra (sond) Engl.*	Mid lower zones	Flowering of this is indicative of rain onset. It is also used for traditional medicines especially by the Masai.	Reliable
Kikwata (Pare)	Kikwata	*Acacia mellifera* (Vahl) Benth	Mid lower and lower zones	Flowering and shading of leaves indicates onset of rains	Reliable
Mng'ong'o[4] (Pare)		*Sclerocarya birrea*(A.Rich) Hochst	Mid Lower zone	When it produces fruits in January and February is indicative of the onset of masika rains.	Reliable
Mughaa (Pare)	Mgunga chuma	*Acacia drepanolobinm* Sjőstedt	Lower zone	If it produces white flowers in December and January which is indicative of rain onset.	Reliable
Zambarau (Kiswahili)	Zambarau	*Syzygium guineense* (Willd)DC	Lower zone	When fruits are produced, it indicates onset of rains. The fruits remind farmers about planting dates for maize crops.	Reliable

Table 2. List of indicator birds used in weather forecasting along the altitudinal gradients and application

Name of indicator	**English name**	**Scientific name**	**Zone**	**Description of indicator as used in predicting weather**	**Reliability**
Ndekrefa (Kichagga)	Malachite Sunbird		Upper and mid zones	It is famous in the highlands and mid zones for its song call that resembles the Chagga name *Ndekrefa*. When this bird sings in January and February or in the middle of a prolonged drought, is indicative of rainfall onset.	Reliable
Saranga (Kipare)	Tropical boubou		All zones	When it appears flying over water bodies like military jets is indicative of immediate rain down–pour.	Reliable
Dudumizi(Kiswahili)	White-browed_Coucal	*Centropus superciliosus*	Mid and lower zone	The singing of this bird early in the morning would indicate onset of rains.	Reliable
Motutu (Kichagga)	-	-	All zones	Black, bigger than a pigeon in size, and flies over short distances, moves in groups of four or so. Their appearance is indicative of onset of rainfall.	Reliable
Leleki/Mchekuakaa (Kipare)	-	-	Mid lower zone	Its frequent song call in the morning and evening is indicative of rain onset.	Reliable
Mpalangala(Kipare)	Red winged Starling	*Onychognathus morio*	All zones	Its frequent singing when it is cloudy would indicate onset of rains.	Reliable

[4] This tree is used for traditional medicines. And because of this, this tree has disappeared and can hardly be found in the lower zones

	
Safari ants/red ants (*Siafu* in Swahili)	Closed holes by flying termites *(Kumbikumbi in swahili*) indicating onset of heavy rainfall

Plate 3. Indicators insects



Plate 4. Abundance of snow coverage on Kibo (left) and Mawenzi (right) peaks of Mt. Kilimanjaro, Source: Photo by Brigitte Nyambo.

Sunbird*, Dudumizi, the* white-browed coucal and *Motutu or Mpalangala,* and the red-winged starling after a prolonged drought would indicate the imminent onset of rains and a good rainy season.

iii. **Atmospheric changes (Table 3):** these were reported by 10.00% of respondents. Observations include temperature intensification; thunder and lightning (*mbawa or nyimbulimbuli*); sighting heavy dark clouds over the eastern side of *Pare and Ugweno mountains;* the blowing of wind from east to west in the lower and mid lower zones, and north east to south west in the upper and mid upper zones in January and vice versa in early February, as indicative of the impending rainy season in late February or early March. The appearance of a rain bow (*mkoryi*) is taken to indicate a temporary rainfall stoppage or to mark the gradual end of a rainy season.

iv. **Astronomical changes (Table 3):** these were reported by 5 % of respondents. The appearance of the moon in a crescent shape; and solar eclipse are also used to predict an impending rainy season.

v. **Insect behaviour (Table 4):** the behaviour of specific insects was reported by 7.00 % of the respondents. The presence of various types *of insects such as spittle bug*s (*Machaerotidae* spp) on trees, the movement of *safari ants* (*Shifameso)* (*Dorylus wilverthi),* the occurrence of large numbers of big black ants (*Nondo*) that prey on brown ants and white termites (*Msora or Mkokye*) (*Pogonomyrmex* spp.), emerging from their nests to forage (spreading over on the surface looking for food and shelter) are indicative of impending rains.

vi. **Amount of cloud cover on Mount Kilimanjaro:** Environmental changes on Kibo and Mawenzi peaks of Kilimanjaro Mountain, Pare and Ugweno mountains were reported by 5.00% of respondents. The appearance of a relatively large amount of snow cover on the Kibo and Mawenzi peaks of Mt. Kilimanjaro [plate 4] according to FGDs with elders is a good indicator of an abundance of rainfall and a correspondingly good agricultural year. Sighting natural fires on Ugweno and the Pare Mountains in January and February would indicate the onset of a

Table 3. Atmospheric and astronomical indicators used in weather forecasting and application

Local name of indicator	*English Name*	*Zone*	*Description of indicator as used in weather prediction*	*Reliability*
Temperature increasing	-	All four zones	Increasing surface temperature would indicate onset of rainfall.	Reliable
Mawingu (Kiswahili) Mapichi (Kichagga)	Clouds	All four zones	Spotting of heavy dark/whitish clouds in the eastern part would indicate onset of rains	Reliable
Mkoryi (Kichagga); Upinde (Kiswahili)	Rain-bow	All four zones	Appearance of rainbow indicates that rainfall would temporarily or permanently stop.	Reliable
Makururuma (Kichagga); Radi (Kiswahili) and Mbawa (Kichagga); or Nyimbulimbuli (Kiswahili)	Thunder and lighting	All four zones	The thunder and lightning in February and early March is indicative of eminent rains.	Reliable.
Mbalamwezi/mwezi (Kiswahili)	The moon	All four zones	When it is full indicates no rain. When it is half and its horns points up, indicates shortage or no rains. But when it is half and the horns points east or west, indicates onset of rains.	Reliable
Kupatwa kwa jua (Kiswahili)	solar eclipse	Upper zone	The appearance of solar eclipse is indicative of rain onset.	Reliable in combination with other indicators.

Table 4. List of insect indicators used in weather forecasting along the altitudinal gradients and application

Local name	**English name**	**Scientific name**	**Zone where it found**	**Description of the indicators as used in predicting weather**	**Reliability**
Siafu(Kiswahili) Shivameso(Kichagga)	Safari ants	*Dorylus* spp	All zones	Vigorous foraging by safari ants is associated with the onset rain. However, in the process these insects also invade households for shelter. Safari ants were reported during KII with elders as a nuisance to human and livestock (cows, goats, chicken) because they usually invade houses and livestock shelters before the onset of rains.	Reliable
Mvia (Kichagga)	Spittlebugs	*Machaerotidae* spp.	Upper and mid zones	Spittle foam (locally known as saliva) common in August and September would indicate onset of vuli rains. The foam shields the spittlebug nymphs from predators, insulates them from temperature extremes; and prevents them from dehydrating.	Reliable
Msora (Kichagga) /Mchwa (Kiswahili)	Termites		All zones	Termites of different species foraging around homesteads on different materials such as wood, clothes, grasses etc. is used as an indicator for the onset of rains within hours.	Reliable.
Nondo (Kichagga)	Black moisture ants	-	Upper and mid zones	Moisture ants get their name from their habit of nesting in high-moisture areas in the highlands. When they appear moving around rotten moisture litter and leaves would indicate and immediate onset of rains. They also prey on other ants such as the brown ants.	Reliable

Table 4. Cont.

Mambo (Kichagga), Majimoto(Kiswahili)	Fire ants		Upper and mid zones	These nests on trees and may be very aggressive when disturbed. Their appearance in large numbers moving down and up trees would indicate onset of rains.	Reliable
Ngumbi (Kichagga); Kumbikumbi(Kiswahili)	Flying termite		all zones	These flying termites move out of their underground nests or mounds after rains. When it is dry and about to rain, the ants would seal the entrances to the mounds to prevent rain water from entering inside. When communities observe this, they know it would rain soon.	Reliable
Mayenje (Kichagga); Mende /kombamwiko (Kiswahili)	Cockroaches	*Blattaria* spp.	All zones	They are commonly found near waste deposits or in the kitchen, where food is present. Moving into homes for food and shelter avoiding wet conditions would indicate onset of rains.	Reliable
Nyonge (Kichagga) Viwavijeshi (Kiswahili)	Army worms	*Spodoptera exempta*	All zones	Appearance of armyworms during the month of February and early March signifies abundant rainfall in the upcoming season and a successful agricultural year.	Reliable

Table 2. Animal behaviour indicators and human disorder used in weather forecast and application

Name of indicator	**English name**	**Scientific name**	**Zone**	**Description of indicator as used in predicting weather**	**Reliability**
Kaa (Kiswahili), Ngala (Kichagga)	*Crabs*	*Brachyura spp*	Upper, and mid upper zone.	The migration of crabs from streams and rivers to upper grounds would indicate possible flooding or subsequent heavy rainfall.	Reliable in combination with other indicators
Vyura	*Frogs*	*Anura spp*	All four zones	Croaking frogs in the morning and evening around water bodies signifies onset of rains	Reliable
Ngaagha(Kichagga), Komba (Kiswahili)	*Lemurs*	*Lemuriformes*	Upper zone	The sighting of lemurs around homesteads in upper and mid zones signifies rainfall onset.	Reliable in combination with other indicators
Beberu (Kiswahili), Kyoro (Kichagga)	*He goats*	*Capra aegagrus hircus*	Upper and lower zones	When billy goats produces mating sounds during the night and early morning would indicate onset of rains.	Reliable
Mbwa (Kiswahili), Kite (Kichagga)	Dogs	*Canis lupus familiaris*	Upper zones	When dogs mate and barks a lot during the night is indicative of rain onset.	Reliable
Homa ya mwili	General Illness	-	All four zones	When elders feel general sickness and aching of joints or the back it indicates onset of rains. This also happens when rainfall season is about to cease.	Reliable
Jasho jingi	Sweating profusely	-	All four zones	unusual human body sweating especially during the night is indicative of imminent rainfall season	Reliable

good rainfall and would translate into a good agricultural season.

vii. **Animal behaviour (Table 5):** this was reported by 4.00% of respondents**.** The migration of crabs from streams to higher ground; the continuous croaking of frogs (*vyura*); billy goats and dogs making noises during the night and the sighting of the bush baby (*Galago senegalensis*) could all indicate impending rainfall.

viii. Water bodies**:** Water-related indicators were reported by 4% of the respondents. An increase in the volume of water in streams during dry seasons, especially in December and January, would indicate the onset of rains. A profusion of organisms living in water such as crabs, frogs, snails (*anelidi*) whirligig beetles (water boatman) (swimming on the water's surface, with the upper half of their bodies above the surface), also is indicative of imminent rainfall season.

ix. **Religious and traditional calendars of events:** The Roman Catholic Church festival calendar was reported by 3.00% of respondents. The Christmas celebration on 25th December each year reminds farmers that the end of *vuli* rains is imminent and the dry season is beginning. St. Bernadeta's festival in February reminds communities of planting time; the beginning of *Kwaresma* (Easter fasting) and (Ash Wednesday) around late February or early March are reminders that heavy rains can be expected throughout the Holy week to the first week after Easter day.

x. **Myths and rainmakers:** Myths and rain-making ceremonies and rituals are also used. FGDs and KII participants from across the altitudinal gradients consistently confirmed the existence of rain-makers and mythical beliefs regarding rainfall. The last rain-making ceremony in the area was performed on 4th April 2014.

The study recorded that the type of indicators favoured varies along the altitudinal gradients, and correlated with agro-climatic parameters. The best indicators at the upper zone are held to be a combination of plant phenological changes (of Mringaringa, Msangafue, Mriri (*Erythrina Abysinica),* Mfuruanje and Mfurufuru); the behaviour of specific birds (Ndekrefa and Dudumizi); and the movement of insects (safari ants, black ants, flying termites and mvia (for *vuli* rains). On the other hand, Mgungachuma, Mzambarau, Dudumizi are more commonly used in the lower zones.

The study also found that IFK varies across population groups based on sex and age of the respondents. Men were found to be more knowledgeable than women, and elders (especially male) were found to be more knowledgeable about IK-BFs than younger people and females.

Furthermore, 56.27% of respondents stated that there are no formal communication pathways for IK-BFs. 41.07% of respondents reported that IK-BF information is communicated during informal meetings with the elders. As a result, the information spreads slowly to non IK-BF experts; limiting its wider application despite the fact that it is regarded as a reliable and trustworthy form of weather forecasting. Key informants emphasised that IK-BF is under threat because the generation of elders who currently are the custodians of the knowledge are dying out, a considerable number of indicators are disappearing, and rivers whose volume fluctuations formerly were used to predict upcoming rain onset have dried out. Both the FDGs and KIIs confirmed that some biological indicators such as the Ndekrefa bird and butterflies have disappeared and/or have become rare. They stressed the need for deliberate effort to conserve and promote such indicators for future use in local weather tracking and response. This in turn would require strong policy support. Additional useful measures surfaced in this study: the provision of comprehensive education on IK-BF in schools and among community members, especially the youth was emphasized by communities.

SCFs and IKFs potential for integration

Other studies conducted on indigenous-based weather forecasting in Africa (Mapara, 2009; Risiro, 2012; Chang'a *et al.*, 2010a and Makwara, 2013) conclude that both modern and traditional methods have some strengths and weaknesses, and should be used in a complementary fashion to produce more comprehensive information on weather forecasts for community-based end users. We now discuss this suggestion in more detail.

The Tanzania major rainfall maxima, as well as the historically uni-modal rainfall patterns in the south and the bimodal patterns in the north, are closely related to the general air circulation over eastern Africa and adjacent areas (Zorita and Tilya, 2002; Kijazi *et al.,* 2012). The main rainfall forcing factors are the intercontinental convergence zone (ITCZ), monsoon winds, the El Niño Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD), the Congo air masses (Westerlies), tropical cyclones and meso-scale features. These are all used by the Tanzania Meteorological Agency (TMA) to predict SCFs. They are also used in a derivative fashion by local communities in the study area to predict impending weather conditions (Chang'a *et al.,* 2012). The results from this study's household survey show that about 86.3% of respondents perceived a correlation between SCFs and IK-BFs. Respondents stated that they could observe periodic changes in wind direction and the relative speed of winds in the month of February, indicating the onset of rains in early March. This correlates to what TMA refers to as the squalls of the trade winds near the equator, taken as indicative of rain onset over the same period (March). In 2013, for example, when the last observed rainfall season for the period March- May rainfall 2013 was analysed by the TMA, 43.7% of the respondents in our study stated that they had observed a good correlation between the IK-BFs and TMA information; 48.5% had perceived a normal correlation while only 7.9% observed no correlation (Figure 3). From our interviews with TMA scientists it is evident that plants, animals, insects and the local movements of wind and pressure indeed are

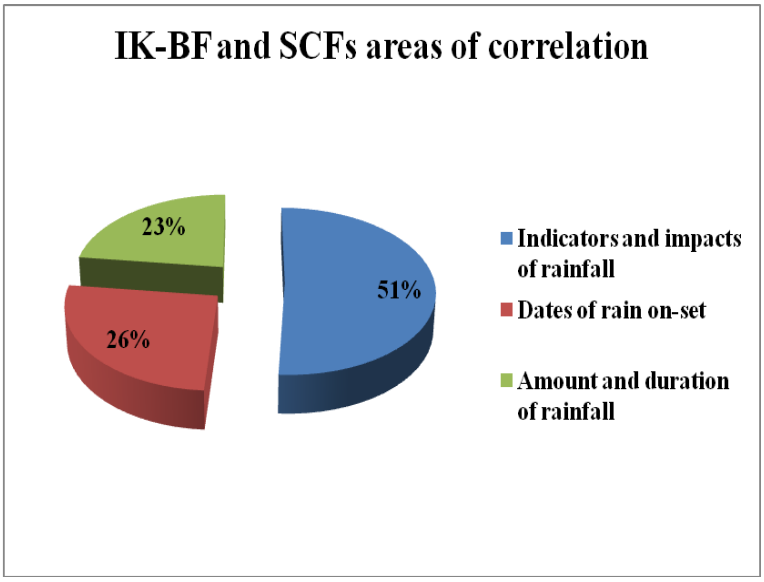


Figure 3. Examples of IK-BF and SCF correlations

sensitive to alterations in climatic and weather parameters (Lutgens and Tarbuck, 2010); although the causal factors behind these scientifically-established facts remain little understood by local communities they are exploited in traditional weather forecasting. For instance, we have reported in this paper that the upper zone dwellers relate coverage of snow on Mount Kilimanjaro with the onset of rainfall in the area; condensation of moist air takes place at 2500 to 3000 m.a.s.l. (Zorita and Tilya, 2002). One of the factors contributing to seasonal rainfall over the eastern and southern plains of Mt Kilimanjaro include moisture influence from the Indian ocean, Indian Ocean Dipole (IOD) and the monsoon winds which forces moist air from Indian ocean up the Mountain (Chang'a *et al.,* 2012), resulting in relief rainfall. On reaching the height of about 2500 m.a.s.l. and above, the moist air strongly condenses to form what is observed by local people in the area as snow and clouds on Kibo and Mawenzi peaks and used in weather forecasting.

However, it was observed during FGDs with elders across the study transect that indigenous weather forecasting knowledge and use are constrained by a number of factors: lack of documentation which means that the information is individually owned in peoples' minds and shared only through oral traditions, and without recording the reference events and patterns; the information flow pathways are slow and do not reach all community members on time; some of the reliable biological indicators used in IK-BFs have disappeared or are on the point of extinction.

At the same time, according to TMA informants, the SCF's system of information production and dissemination is flawed. Integrating the two sets of observation and knowledge to optimise the production and distribution of more reliable, timely and localised weather forecasts was supported by 93.6% of respondents. Only 3.7% disapproved while 2.7% remained ambivalent. Participants in the FGDs further insisted that integrating the two knowledge systems not only could improve weather forecast accuracy and uptake by users, but also could open pathways towards restoration and preservation of IK-BF capacity in the communities.

Use of weather forecasts in farm level decision making

To understand respondents' demand for weather information for use in farm level decision-making, respondents to the household survey were asked how they timed planting dates for maize, the main cereal crop. Additional questions were asked to probe the criteria used to decide when to prepare land, sow seeds, harvest, and plan other non-farm activities. Cross tabulation analysis of the results showed that 74% of the respondents practiced dry planting (sowing seeds before the onset of the first rainfall), while only 26 % sow after the first rainfall. In both cases their decision (in order of importance) is informed by indigenous-based weather forecasts, TMA weather forecasts and agricultural advisories from area extensions officers (Figure 4). The reasons for farmers' preferring traditional weather forecasts rather than the TMA's weather forecasts issued are presented in the subsequent section of the paper.

[Insert Figure 4 here]

The FGD sessions elucidated that this preference is related to weather variability, as summarized in Table 6. Analysis of the FGD and KII information, across all survey zones, highlights that weather and climate information is considered essential for effective on-farm decision making. The analysis also revealed that men and women use such information differently in some respects (Table 7). For instance, our analysis showed that women are the most in need of, and play a central role in applying, weather information for ensuring food security at the household level, also reported elsewhere (Muthoni and Wangui 2013).

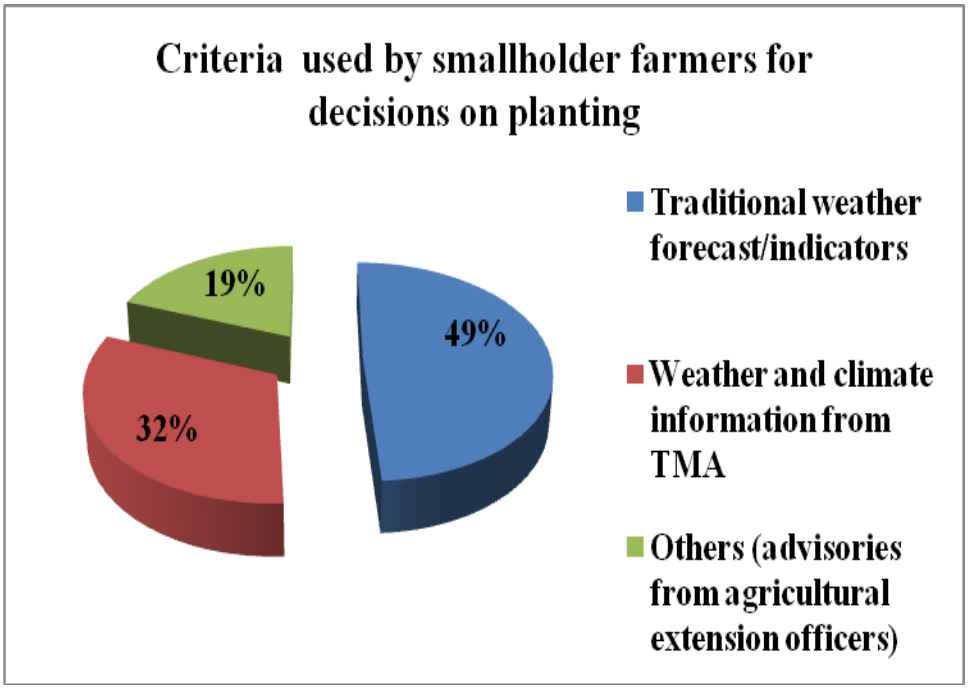


Figure 4. Criteria used by farmers for decisions on planting dates

Table 3. Reasons for planting before or after the first rain

Planting before the first rains	Planting after the first rains
1. Since rains are not reliable and unpredictable such that the amount and duration of rains are not clear, planting early ensures effective use of the first rains mainly for seed germination, which may be able to withstand dry conditions longer.	Since the rains are not reliable, to be sure that rains are enough and available throughout the crops life time, it is always better to wait for the long lasting rains
2. It is always easy to work on dry soil than wet soils especially when one has a large plot, uses hand hoe and human labour.	The risk of losses in case a rain stops suddenly is higher than work tediousness in the farm. Costs of seeds and fertilizers can be saved.
3. If rains come in low amounts and intermittently, planted seeds in wet soil may rot and hence incurring more costs for re-planting.	If first rains come in very low amounts and meet seeds already in the soil, there is high possibility for seedlings to dry and eventually die before the heavy rains sets on.
4. Costs of hired labour remain low if soil is dry. Less time is used e.g. One person can spend two or three days to plant an acre in dry soils compared to a week when the soil is wet.	Not Applicable

CONCLUSIONS AND RECOMMENDATIONS

Indigenous knowledge of weather trends and patterns is still intact in communities living along the altitudinal gradients of the south eastern slopes of Mount Kilimanjaro. Local people have relied upon this knowledge to plan and manage agricultural production and food security at community and household level for a long time. More in-depth studies of the scientific validity and accuracy of IK-BFs should be carried out in order to establish a more comprehensive knowledge and database that could be used to develop weather forecasting systems robust enough to be useful under climate change. Urgent action in this respect is needed because the IK-BF is threatened by both anthropogenic activities and climate change. In addition to further research, public and in-school education to create more awareness of the significance and role of IK-BFs in sustaining rural livelihoods is thus recommended, as well as stronger policy support for evolving weather forecasting capabilities that draw on both scientific and traditional knowledge and observations.

Table 4. Use of weather forecast/climate information by men and women

S/N	Use	Men	Women
1	Farm preparation timing	✓	✓
2	Timing of planting dates	✓	✓
3	Choice of seeds to plant e.g. short term seeds or long-term seeds.	✓	✓
4	Choice of crops to plant e.g. drought resistant crops and varieties (such as millet, sorghum etc), long term or short-term crops.	✓	✓
5	Determining and budgeting costs of production (e.g. costs of wage laborers at farm, costs of tilling/cultivation-by tractor (when wet after first rains) or hand hoe (when dry before first rains) against other household expenses/needs (House construction, school fees,)	✓	X
6	Choice of place (upstream farms or downstream farms) depending on the recommended seeds, crops and forecasted rain conditions.	✓	✓
7	Planning alternative household income sources e.g. investing more in crop production if it is a good rainy season or investing on other non-farm activities if it is a bad rainy season.	✓	X
8	Food budgeting and control to suit foreseen harvest conditions against available food stocks e.g. switching to two meals a day if harvests are poor, directing resources to buying food, and looking for additional food sources (those that are normally not staple when food is abundant).	X	✓
9	Planning post harvest food storage, management and use	✓	✓
10	Planning disaster risk reduction and preparedness to post disaster adaptation e.g. dealing with floods that destroys crops on farms, properties and houses at the low zone, but also planning alternative livelihoods after droughts(along all altitudinal zones)	✓	X

Legend
✓ Applicable for the particular gender
X. Not applicable for the particular gender

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