The Role of Indigenous Weather Forecast in Enhancing Agricultural Production in Tanzania

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ABSTRACT

Tanzania as most Sub-Sahara countries depend mostly on rain-fed agriculture, which makes it vulnerable to the erratic patterns and variability of rainfall. A study was conducted in Burunga and Mbalibali villages in Serengeti district, Tanzania to determine the role of indigenous knowledge systems (IKS) in understanding and disseminating information on rainfall patterns and variability for crop productivity improvements. The paper aimed to understand the process of Drawing on findings of interviews and focus group discussions the paper suggests that agricultural activities are practised based on indigenous knowledge – informed by indicators developed over time and space – to understand the onset and end of rainfall. The indicators for predicting onset, end, and the amount of rainfall are mainly based on the observations of the changing characteristics of the surrounding environment on the atmosphere (wind systems, stars, moon); on the land surface (flora and fauna); and natural systems. These indicators are owned mainly by IKS holders who are mainly elders. Elders then transmit this knowledge to youngsters through either word of mouth or best practices or experiences when conducting socio-cultural and economic activities. The knowledge is then employed for planning and production of agriculture; and processing and storage of agricultural harvests. These findings form the basis for concrete recommendations to the governments in Africa to formulate policies and enact laws to backup indigenous based technologies for sustainable development.

Introduction

In Tanzania, as in most Sub-Sahara Africa, agricultural sector forms the backbone of her economies, supporting over 70 percent of the population and provides sources of livelihoods and employment to the majority of the population in the country, which is mainly rural based (World Bank, 1997); URT, 2011). Agriculture constitutes about 60 percent of foreign earnings and employs over 80 percent of the population (URT, 2011). Agricultural production and development remain therefore to be an important driving force towards achieving food security and hence reducing poverty in the Sub-Sahara region (Kibassa, 2013).

In Tanzania, rain-fed agriculture has, for many years, been the traditional ways of farming. This type of farming relies very much on the availability and reliability of rainfall over time and space. To be able to prepare for their agricultural production, peasant communities require correct and reliable information on when rainfall is expected to begin and end in their specific localities (Ingram et al, 2002; Luseno et al, 2003). Thus, receiving correct information on rainfall patterns and variability and applying them are necessary to the peasant communities in predicting the future productivity of their economic activities, such as crop and livestock husbandry. While both modern and indigenous science technologies of rainfall forecasting are available, the decision on which technology that individuals and communities should use depend very much on the accessibility to the technology and the ability to analyze, interpret and use the forecast information available (Karki and Bauer, 2004; Rogers, 2003; Sarker et. al, 2008). However, it is well documented that in many countries, south of the Sahara, modern science based technologies are unreliable with limited accessibility (Jackson, 1989; Luseno et al, 2003; Mwiturubani, 2005). Peasant communities therefore tend to rely on indigenous based technologies,

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which are developed from over long history of interaction with the surrounding environment and in most cases are embedded with their cultures.

However, depending on the socio-cultural organizations of some societies, some members of the community may either not benefit from the available systems of acquiring knowledge on climate change or may resist to acquire that knowledge altogether (Mwiturubani, 2009). This paper examines the role of indigenous knowledge systems (IKS) in understanding rainfall patterns and variability and how that knowledge is employed in enhancing agricultural production for food security in Tanzania.

Knowledge on rainfall variability and its effects on crop production

Crop production and livestock keeping are the prominent human activities in many parts of the developing countries, particularly in the Sub-Saharan Africa. These economic activities are practised both for subsistence and commercial purposes, and are dynamic in response to climatic and ecological changes, population growth and economic development. In Peasant communities, such as those found in Burunga and Mbalibali villages, knowledge on rainfall patterns and variability is much important for their production system (Deressa et al 2010). This is mainly because they rely mostly on weather-dependent agricultural production. Knowledge on rainfall patterns and variability and particularly when it is expected to begin or end is actually necessary to the peasant communities for them to be able to predict the future productivity of crops and livestock husbandry. Although, one cannot be certain of what to expect in the next season (Hammer et al, 2002), peasants' decisions on what to produce, where and when depend very much on the knowledge of the expected future climatic conditions. Equally important is the decisions of how much harvests should be stored, which depend on the knowledge of when the next harvests is expected.

Furthermore, livelihoods of the peasant communities are largely dependent on surrounding natural resources, such as water, soils, forests and pastures. They therefore constantly interact and adapt themselves to their environment in order to make living. The environment and weather patterns in which local people depend on is dynamic, changing both over time and space. Through this constant interaction with the dynamic surrounding environment local people may study it carefully and systematically through observations, best practices and experiences and come up with indicators for climate change prediction (Vijiak et al, 2005). The holders of these indicators are therefore able to either forecast (Luseno et al 2003) or provide forecast information (Fairhead and Scoones, 2005) on rainfall patterns and variability to their fellow members of the community. Different socio-economic activities, however, may require different forecast information at different times and space. For instance, livestock keepers may only need to know when rainfall is expected to begin in the water catchment areas, such that, due to run-off, water levels in the rivers which originate from the water catchment areas increases. This is different from a crop cultivator who need forecast information to indicate onset and end of rainfall in order to start land preparations for crop production. This paper concentrates itself on IKS based rainfall forecast information, which enables peasant communities to design strategies to adapt to rainfall variability in their crop production systems.

However, local people are not completely isolated from external world. They utilise forecasts of rainfall patterns and variability from modern science sources, such as meteorological agencies for their socio-economic development. Depending on the socio-cultural and economic status of the society, such as level of formal education and access to the media, modern science based rainfall forecasting information may or may not be important to local people in different location over time period in understanding rainfall variability (Luseno et al, 2003; Makwara, 2013). Issues related to institutional arrangements both formal and informal, education levels and gender play an important role in accessing and controlling rainfall forecasts information based on modern sciences. For instance, while local people may need information specifically on rainfall amount, duration and distribution over time and space in their locality, modern science based information covers mainly a large area and hence become difficult for local peasants to understand and internalize in their production systems. Despite the fact that peasant communities may have strong interest to receiving rainfall forecasts information based on modern science, the information may be rendered not reliable due to either inadequate meteorological stations hence no rainfall data available (Jackson, 1989) or inability of local people to access and understand the information. They remain with what they describe as reliable and effective sources of information on rainfall patterns and variability, which are the IKS holders and practitioners.

Methods and Materials

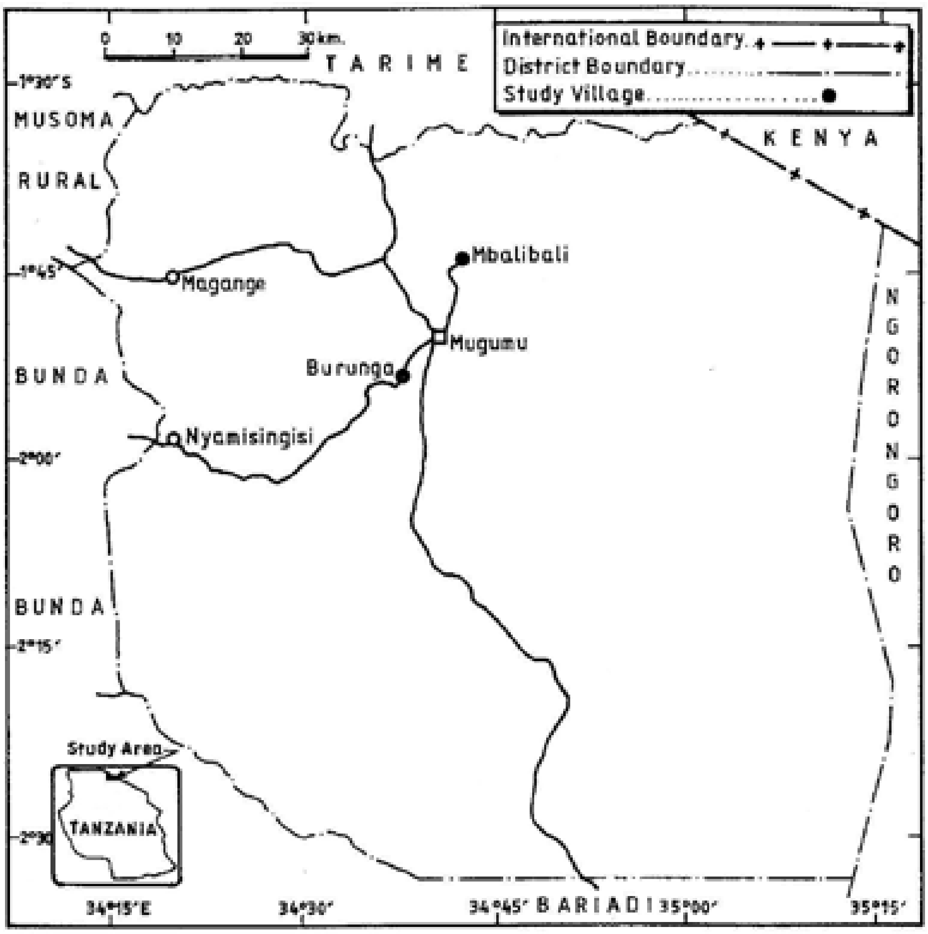
Data for the analysis in this paper are from a study that was conducted in Burunga and Mbalibali villages in Serengeti district, Tanzania (Figure 1). The main purpose for the research was two folds; first to understand and examine IK technologies that local people employ in understanding rainfall changes and variability. Second to understand the applicability of IK technologies in developing agricultural adaptation strategies to rainfall change and variability hence improve agricultural production.

Burunga village is located close to the urban locality about 3.5 km from Mugumu town while Mbalibali village is located in a purely rural locality about 19 km from Mugumu town. Being headquarter of Serengeti district, Mugumu is the main urban centre in the district. This purposeful selection of the two villages was done to gauge any influences of urban on receiving and applying indigenous knowledge systems. People in both villages are agro-pastoralists. Ikoma, Nata and Kurya are the major ethnic groups in Burunga village while Kurya is the main ethnic group in Mbalibali village.

The main methods employed in data generation include in-depth interviews to IK holders, semi-structured interviews and focus group discussions to the local people and agricultural extension officers. A total of 12 IK holders, 120 local people (respondents) and 2 agricultural extension officers participated in the research.

IKS holders and selected respondents were asked to rank key indicators for rainfall forecast based on indigenous knowledge with 01 indicating the most effective indicator while 5 indicating the least effective one. A total of 12 IKS holders and 40 elders participated in the ranking exercises. Similarly, selected elders and IKS holders were asked to rank the indigenous agricultural coping strategies to rainfall variability as practiced in their villages.

Figure 1: Map of the study area



Results

Sample characteristics

The characteristics of respondents and other participants in the research appear in Figure 2 and Table 1. In general there were 12 IK holders, 44 elders (60+ years old), 54 adults (35 – 60 years old) and 22 youth/young adults (15 – 34 years old). All IK holders were over 50 years of age. The gender distribution of the respondents is provided in Table 1. For the IK holders and elders there were more male respondents than female, which indicate that men, due to gender division of labour, which make them interact most with the surrounding environment, are the major holders of IKS. On the other hand, for adults there were more women because they dominate crop production activities while men are engaged in non-farm activities hence being so mobile.

In the study villages, age seems to determine the level of formal education one has attained (Table 2). Over 80 percent of IK holders and 50 percent of elders in the sample had not attained any formal education while all adults and youth had attained primary education and above. According to the culture of the people in the study area, which follow patriarch systems, male elders are the decision-makers both at the family and community levels. The non formal level of education indicates therefore that local people have no ability to access and understand modern sciences and hence utilise their indigenous knowledge in performing their day to day socio-economic activities.

When respondents asked to rank the main economic activities, the findings revealed that crop production and livestock husbandry are the overriding economic activities with 43 and 28 percent respectively (Figure 3). Other potentially important activities are petty business (10 percent), charcoal making (8 percent), fishing (8 percent) and teaching (3 percent). Most of these economic activities, with exception of petty business and teaching, depend on the environment and climatic conditions.

Crop production (over 99 percent) are rain-fed and the major food crops grown are maize, cassava, sweet potatoes, finger millet, sorghum, paddy, beans and vegetables. Cotton, coffee, tobacco, sunflower and groundnuts are grown as cash crops. The major types of livestock include cattle, goats, sheep and donkey. Livestock are kept for different purposes such as milk, meat, dowry, ox-plough and prestige.

Figure 2: Percentage distribution of categories of respondents

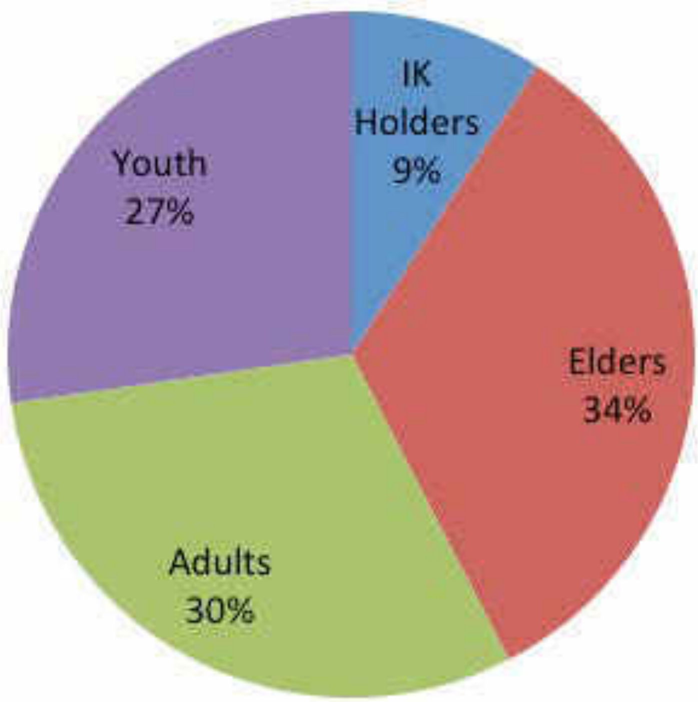


Figure 3: Percentage distribution of the main economic activities

Table 1: Gender Distribution of Respondents (N = 132)

Location	IK holders (N=12)		Elders (N=44)		adults (N=54)		youth (N=22)	
	Male	Female	Male	Female	Male	Female	Male	female
Burunga	25%	8.3%	22.7%	11.4%	22.2%	26%	36.4%	22.7%
Mbalibali	41.7%	25%	47.7%	18.2%	14.8%	37%	22.7%	18.2%

Table 2: Education Distribution of Respondents by Gender (N = 132)

Education	IK holders (N=12)		Elders (N=44)		adults (N=54)		youth (N=22)	
	Male	Female	Male	Female	Male	Female	Male	female
No Formal	50%	33.3%	29.5%	20.5%	-	-	-	-
Primary	16.7%	-	20.5%	9%	26%	55.5%	22.7%	27.3%
Secondary	-	-	20.5%	-	11.1%	3.7%	13.6%	22.7%
Tertiary	-	-	-	-	3.7%	-	9.1%	4.6%

IKS development, learning and transmission

IK holders and elders indicated that when they look at a plant or animal, when they listen to the songs of birds and animals, when they look at the movements of macro organisms, or when they look at wind systems there are more than just looking or listening. There is certain information being communicated to them. In fact biodiversity (flora, fauna and organisms) and components of astronomy science such as stars and the moon have the language, which if one understands it clearly, will be able to explain and predict the hydrological conditions in the next days, moths or even years. It is argued therefore that biodiversity (flora, fauna and micro-organisms) and astronomy science (stars, the moon) are the key components to the development of IKS in the study area. This indicates that IKS is leant through practices and word of mouth from one person here referred to as IK holder to another. Given the gender division of labour in practicing socio-cultural and economic activities, learning of IKS is also gendered. Male respondents indicated that they learn IKS either through experiences and practices or from their male elders. On the other hand, female respondents revealed that they learn IKS either through experiences and practices or from their female elders. The holders of IKS revealed that IKS based technology is dynamic and that it changes with the changing environment. For instance, an indicator for rainfall forecasting which used to be effective may be tested and found to be ineffective, hence discarded from the list.

IKS on rainfall prediction

IKS on rainfall prediction that local people develop are embedded and containing the culture and belief systems, production systems and interactions with the surrounding environment. Local people study, over considerable long time, the changing characteristics of flora, fauna, organisms and the atmosphere in relation to rainfall changes and variability and come up with a series of indicators that describe rainfall variability over time and space. The indicators for forecasting rainfall onset and end enable local people to either prepare for the expected adverse hydrological conditions or take advantage of the expected favorable hydrological conditions in their socio-economic activities. These indicators have been developed based on practices and experiences gained while interacting with the environment particularly when practising their economic activities over considerable long period of time. The main sources of information about indicators of rainfall forecasting, which seem to be determined by include elders (33.3%); own observation of the indicators while conducting different socio-economic activities (20.5%) and both elders and own observation (46.2%) (Table 3). The ways people practice their economic activities therefore determine the type(s) of IK developed and employed in a specific geographical location over time.

Table 3: Sources of Information about indicators of rainfall forecasting by age group

Source of information	**Age group**						**Total**
	15 – 24 (N = 10)	**25 – 34 (N = 12)**	**35 – 44 (N = 20)**	**45 – 54 (N = 20)**	**55 – 64 (N = 20)**	**65+ (N = 50)**	**N= 132**
Elders	100	100	50	40	20	-	33.3
Own observation	-	-	20	10	35	28	20.5
Both elders and Own observations	-	-	30	50	45	72	46.2

The main indicators, which have been developed and employed for rainfall forecasts in Serengeti district, are in seven major categories, namely vegetation characteristics, elements of weather, wild animal behaviors, insects behaviors, astronomy science, water bodies characteristics, and birds behaviors. These indicators are used both to predict the beginning and end of rainfall, but with different signs (Table 4). It is important to note however that one indicator and its associated signs may not be sufficient to forecast the onset and/or end of rainfall, instead local people use a combination of indicators and their associated signs to reach a decision about the expected hydrological conditions in their area.

Table 4: Indigenous knowledge on rainfall forecasts

Category	Indicator	Sign	Meaning/explanations
Vegetation characteristics	Reed grass species	Presence/absence	Presence of reed indicates consistent increase of rainfall over a specific season while absence signifies consistent decrease of rainfall over specific season.
	Cactus plant species	Presence/absence	Presence of cactus indicates consistent decrease of rainfall over long period while absence signifies consistent increase of rainfall over long period of time.
Elements of weather	Wind systems	Blowing direction	When winds blow from west to east it signifies beginning of rainfall season, while from east to west indicates end of rainfall season.
	Whirling winds	Direction of movements	Movement from west to east indicates rainfall onset, while from east to west indicates end of rainfall season.
	Temperature	Increase/decrease	Consistent increase of temperature during the night signifies rainfall onset while consistent cold temperature during the night signifies end of rainfall season.
	Moisture	Increase/decrease	Increase of moisture on the top soil is an indication of the beginning of rainfall.
	Mists	Time of occurrences and where.	When mists occur early in the morning in the lowland and flatland indicates either onset or end of rainfall season
	Dew	Increase/decrease	Increase of dew in the morning is an indication of rainfall onset while decrease indicates end of rainfall season.
	Clouds	Height, direction of formation	Low clouds and which form in the east direction indicates onset of rainfall.
Wild animal behaviours	Hyena, wild dogs	crying	When crying early in the morning is a sign of rainfall onset; when crying in the evening is a sign of ending rainfall season.
	Wildebeest	Specific route/ direction of migration	Movements to the east indicates rainfall onset while movements to the west indicates consistent dry season.
	Crocodile, Hippos	Movement from one water source/ point to the next	Movements indicate decrease or increase of rainfall amount.
Insects behaviours	Red ants	Increase/decrease movements	Frequent movements of red ants indicate rainfall onset
	White ants	Build anthills	Starting building anthills is a sign of rainfall onset.
	Termites	Presence	Presence of termites in the evening during rain season indicates end of rainfall.

Astronomy science	Stars	Groupings	When stars group towards the west is a sign of rainfall onset while when grouping is towards the east indicates end of rainfall season.
	Crescent moon	Mist sign on the crescent	Mists sign on the crescent at the beginning of the year indicates sufficient rainfall throughout the year, while mists sign in any other time of the year indicates rainfall onset
	Lightning	Direction and time of lightning	Lightning early in the morning and late in the evening from the west indicates rainfall onset while from the east indicates end of rainfall season
Birds behaviours	Swallows	Direction of movements	Movement from west to east indicates rainfall onset while from east to west indicates end of rainfall season.
	Owl, Pigeon	Time of singing	When singing frequently early in the morning and late in the evening rainfall is expected to begin
Water bodies characteristics	Water levels in natural wells	Increase/decrease water levels	When water levels increase, which is observed early in the morning, rainfall is expected to begin

Vegetation

The findings revealed that the growth of a reed grass species (*Typha capensis*) locally known as *Ilinyaga* indicates high rainfall and hence high moisture contents in the soils. This is because germination and growth of *Illinyaga* species requires high moisture content in the soils. Thus, the presence or absence of *Illinyaga* indicates variability of rainfall. It was noted that *Illinyaga* occurs in a specific landscape, that is, it occurs in the lowland and flatland and never in the landscape with steep slopes. This is probably due to high run-off of rainwater where there is steep slope.

Similarly, presence or absence of cactus plant species (*Opunita ficus*) locally known as *Ngoto* indicates low or high rainfall respectively. Thus, the growth of this type of plant species indicates persistent low rainfall over considerably long periods of time, mainly over ten years. On the other hand, when this type of tree species disappears indicates persistent high rainfall over considerably long period, for over ten years.

Clouds

Cloud is an aggregation, or grouping, of moisture droplets that are suspended in air and are great enough in volume and density to be visible to the human eye (Christopherson, 1994). Clouds are classified by altitude and by shape resulting into three forms namely cumulus, altostratus and cirrus clouds which are low, middle and high clouds respectively. Low clouds are found up to 2000m from the earth's surface, middle clouds between 2000m and 6000m and high clouds between 6000m and 13000m. For the local people there are only two types of clouds namely low surface clouds locally known as *amasaro gahanse*, and high clouds locally known as *amasaro gaigoro*. There are also two forms of clouds namely heavy black clouds locally known as *amasaro amamwamu* and light white clouds locally known as *amasaro amalabhu*.

It was noted that when black low-surface clouds are observed is an indication of heavy rainfall while white clouds indicates no or little rainfall. These types of clouds are normally formed in the east direction based on four compass direction systems. On the other hand, high clouds indicate end of rainfall season or dry season.

Wind systems

Local people in Serengeti district use wind characteristics as indicators for rainfall forecasts. The observation of wind characteristics, particularly the direction in which the wind blows to and from, based on four compass directions, gives an indication of whether one should expect or not expect rainfall or whether rainfall will continue to rain or will end. The west-east winds usually accompanied with swallows indicate that rainfall is expected to rain in the next one to three weeks. It should however be noted that Lake Victoria is located in the west of Serengeti district hence though majority of the respondents do not relate winds with the characteristics of the lake, it seems these winds carry moist from the lake and hence cause rainfall in the inland. On the other hand, the east-west winds, during the rainy season, indicate that rain season is expected to end in the next one to two weeks. Similarly, the east-west winds, during the dry season, mean that one should not expect rainfall in the near future.

Whirling winds

The whirling wind is the wind blowing in a cyclonal, rotary or twisting movement from a high to a low-pressure area and causes the formation of rain clouds (Nentjes, 1999). The movements of the whirling winds normally follow the direction in which winds blow, but they are common mainly between 10.00am to 4.00pm in a day. When the whirling winds blow from west to east, rainfall is expected in the next two to three weeks. On the other hand, when the direction of the whirling winds is from east to west, it indicates that the rainfall season is not expected in the coming few weeks or months.

Temperature

Local people use temperature, which occurs during the night to forecast rainfall. It was noted that when there is increase of temperature during the night is the sign that rainfall is expected within the next few weeks while decrease of temperature, a state referred to as cold conditions, indicates end of rainfall season. The decrease of temperature is also a sign of expected prolonged dry season over a particular geographical location.

Dew

Minute water droplets formed on the grasses and tree leaves during the morning are referred to as dew known locally as *Urumi*. Dew is associated with temperature and pressure where by the air cools to the saturation point under constant pressure hence form water droplets. Local people indicated that when there is prolonged dry season and eventually dew is formed on grasses and tree leaves during the morning, rainfall is normally expected to begin in the next three to ten days. On the other hand, when dew decreases during the rain season and regardless of whether it rains in the previous day or not, rainfall is expected to end within the next one week.

Mists

Mist is the diurnal element of weather occurring mainly in the plateau and mountains during the morning. The occurrence of mists, locally known as *endumbe,* on the plateau and hills in the morning during the dry season indicates that rainfall is expected to begin within two to three weeks. On the other hand, when mists occur in the lowlands and flat lands in the morning during the rainy season indicates that rainfall is expected to end within the next two weeks.

Moisture

Moisture is the relative humidity held in the air and depends on temperature and barometric pressure. The increase of moisture content on dry soils is a sign that the air has started to reach the saturation point and hence start to form minute water droplets. In the study area moisture content is only employed to forecast the onset of rainfall. The availability of moisture on the dry soils and stones in the morning during the extended dry season indicates that rainfall is expected to begin within the next three weeks.

Stars

Observation and explanation of the characteristics of the stars is the astronomy science, which deals with the study of the events occurring beyond the earth's surface and its atmosphere. It was noted that when stars form groups over the sky towards the west direction based on the four compass directions, the onset of rainfall is expected within the next two weeks. The observation of the characteristics of stars is mainly done during the mid-night.

The crescent moon

Observation of the characteristics of the moon at its two main stages, that is, young – increasing moon; and old – decreasing moon gives some indications of expected weather conditions. It was noted that when the mist sign is observed on the crescent moon (increasing moon) showing up from the west direction during the evening indicates that before it becomes full moon rainfall is expected to begin, normally within two weeks. Similarly, the mist sign on the crescent moon (decreasing moon) showing up from the east direction early in the morning indicates that before the next young moon (increasing moon) rainfall is expected to begin. On the other hand, when the crescent moon both increasing and decreasing is clear with-out any sign of mists, rainfall is not expected to begin in the next few months. For the *Kurya* people the moon is a big star, hence the observation of the characteristics of the crescent moon is mainly done during the late evening and after mid-night.

Similarly, the characteristics of the crescent moon at the beginning of the year are used to determine the nature of the coming year. When the crescent moon (both decreasing and increasing) of the first month (based on IKS, table 4) of the year has more mists is the indication that the year that begins will have much rainfall. On the other hand, when the crescent moon (both decreasing and increasing) of the first month of the year is clear is the indication that drought will dominate the year that begins. IK holders make this observation and they thereafter announce the expected nature of the year to the local people. As one respondent in Mbalibali village revealed local people are always made aware at the beginning of the year about the expected hydrological conditions such as floods and droughts, social conditions such as wars, and economic conditions such as hunger (shortage of food) of the year that have just started. He said:

"Most of the time we know what is going to happen in the year. IK holders normally inform us at the beginning of the year, based on their dreams, whether drought, floods, good harvests, hunger or wars shall occur or not. We therefore prepare ourselves".

Further interview with IK holders revealed that they normally study the characteristics of the crescent moon to understand the expected conditions of the year rather than dreams. However, they keep their secret and inform local people that they have got the information through dreams. This to some extent increases trust of the local people to the information given.

Lightning

Lightning is a brilliant electric spark discharge in the atmosphere, occurring within a thundercloud, between clouds, or between a cloud and the ground (Brosnahan, 2002). Thus, lightning indicates that there are clouds in the atmosphere though may not be seen in some places on the earth's surface where the lightning is visible. Local people use lightning as an indicator for forecasting the onset and end of rainfall season. Rainfall onset or end is only differentiated by the direction from which lightning occurs based on the four compass directions. When lightning occurs early in the morning and late in the evening from the western direction, rainfall is expected to begin within the next two weeks. On the other hand, when lightning occurs from the eastern direction early in the morning and late in the evening, rainfall is either expected to end within the next two weeks or if it is a dry season, rainfall is not expected in the next few weeks. Lightning is mainly observed early in the morning when the first cock crows. The tool is more effective when there has been long dry season of more than four months consecutively.

Insect behaviours

The changing behaviours of the red and white ants over time in a year reflect the time for onset or end of rainfall. When rainfall is about to begin, red ants start to shift from one place to another looking for a safe place to stay where they won't be affected by rainwater. When red ants increase movements the onset of rainfall is expected in the next one to two weeks. Similarly, the building and maintaining anthills by white ants give a signal of when the onset of rainfall is expected. During the dry season, anthills become dry and hard without or with little moisture, but, when it is about to rain the moisture tend to increase on anthills and ants start to increase the size of the anthills.

With respect to the end of rainfall, termite behaviours inform local people about the end of rainfall. Once termites are seen during the evening, rainfall season is expected to end within the next three days. Exception cases may occur however and rainfall continues after termites have occurred when winds continue to blow from west to east.

Birds' behaviours

The main birds' characteristics, which are used for rainfall forecasting, in the study area include seasonal movement and singing. Normally, the movements of the birds follow the direction of winds. It was indicated that when swallows move in groups from west to east, rainfall is expected to begin within the next two weeks. On the other hand, the movement of swallows from east to west indicates that rainfall is about to end within the next two weeks. Similarly, the movement of swallows from east to west during the dry season indicates that rainfall is not expected in the next few weeks or months. Again, when some birds, such as owl and pigeon, sing frequently, especially during the evening and early the morning rainfall is expected to begin within the next two weeks.

Wild animal behaviours

Some wild animals, such as Hyenas and Wild Dogs have specific behaviours, which are related to the expected weather conditions. When Hyenas and wild Dogs cry frequently early in the morning is a signal that rainfall is expected to rain within the next one week. On the other hand, when wild Dogs and Hyenas cry frequently late in the evening during the rain season is the signal that rainfall is expected to end within the next one week.

Similarly, Local people have been observing the migration patterns of wildebeests over many years and relate them with rainfall patterns in their areas. The movements of wildebeest from east to west indicate that there will be persistent drought for several next months while the west-east movement is a sign that rainfall is about to begin within two weeks.

Similarly, local people have observed over time behaviours of some big reptiles and mammals, which live in water bodies, to develop indicators of water variability over time and space as a result of rainfall variability. When crocodile and hippopotamus move from one water source to another and vice versa or disappear completely is an indication of changes of water levels, which is a function of either increase or decrease of rainfall.

Table 5: Ranking of the effectiveness of the indicators in rainfall forecasting

Tools for rainfall forecasting	Ranking	Percentage
Astronomy science (lightning, crescent moon, stars)	1	85
Elements of weather (wind systems, whirling winds, temperature, mists, dew, moisture, clouds)	2	72
Insects behaviors (red ants, white ants, termites)	3.5	70
Wild animal behaviors (hippos, crocodile, wildebeest)	3.5	70
Birds behaviors (swallows, owls, pigeon)	5	64
Vegetation characteristics (reed grass, cactus)	6	60
Water characteristics (water levels in natural wells)	7	54

Local months and the agricultural calendar

Based on the Indigenous knowledge on rainfall variability, as explained above, local people are able to develop an agricultural calendar. The calendar is based on the local months with each month constituting specific activities based on rainfall amount. Rainfall is described as high, moderate or low, and depends on the level and extent that rainwater wet the soils and the resulting run-off understood mainly as flood. Different activities particularly on crop and livestock husbandry depend very much on the knowledge of wet and dry seasons and their variations over time and space (Table 4).

Table 4: Local name of the months, meaning and agricultural activities undertaken in each month

Local name of the month	Meaning/agricultural activities undertaken
Kinyariri	Low rainfall; late weeding of crops, which were planted during the short season. Preparation of farms for long season planting
Itabararia	A month with little rainfall, which is between January and February. Harvesting crops, which were planted during short season. Preparation and planting (seeding) month for long season
Ketaturi/Kinyatuti/Matui	A month mainly for weeding crops; There is little or no rainfall at all
Kimwamu	A month in which heavy clouds cover the sky accompanied by heavy rainfall and thunderstorms almost every day. It rains every place. Overflow of rivers. Natural springs increase even on the flat lands
Kerabu	A month in which light clouds cover the sky and it rains in few places
Iheta	Paths are made within the crop farms to make easy for chasing away birds, which destroy crops. Crops are almost ready to harvest. Little or no rainfall at all
Mabeho	A month which is too cold (winter) indicating the end of rain season. A month, in which people start harvesting crops. Livestock graze on the harvested plots

Nyansahi	A month after harvest with no rainfall. Weddings are common during this month. Women carry sorghum, maize and millet flours when visiting relatives
Kuryaemasariro	People have utilised their harvests during Nyansahi month and some people have not remained with enough food, which make them cry for utilising all the food for weddings and other luxuries. Preparations of farms for short season begin. Rainfall begin
Egaratiga	Preparations of farms continue including putting demarcation to indicate the boundaries between farms to avoid conflicts in using the land
Tirya ya Mbele	Planting of cereal crops for short season
Tirya ya Nyuma	Planting and early weeding for short season

Indigenous agricultural adaptation strategies to rainfall changes

Based on the indigenous knowledge on rainfall patterns and variability local people come up with agricultural adaptation strategies, which maximize the use of available rainfall hence sufficient food supply to the community. The indigenous agricultural strategies as used in Burunga and Mbalibali villages include selecting the type of landscape (land surface units) where crops are grown, when crops should be grown (cultivation seasons), techniques employed during cultivation, type of crops to be grown such as drought-tolerant crops, processing and storing food after harvests, and dry-up and store vegetables to be used during dry season. Thus, what, where, when and how to cultivate crops depend on among other factors the knowledge of the amount of rainfall in a specific time period (season) and the capacity of different landscapes to hold water. Indigenous knowledge on whether rainfall will be in-time or late enables local people to adjust planting dates, maximize the use of rainfall, and to strategise on the use of the available food.

Selection of the land units

When insufficiency rainfall is expected over long period of time, local people cultivate in the lowlands with relatively high moisture. Furthermore, when relatively low rainfall over long period of time say over five years is expected, food crops, which are commonly grown in the uplands (those requiring low moisture), can be grown in the lowlands and when there is relatively high rainfall food crops, which are commonly grown on lowlands (those requiring high moisture) can be grown on uplands. This strategy ensures sustainability of food sufficiency at the household levels throughout the year.

Planting crops on ridges

Planting and growing crops on constructed ridges, locally known as *emegoka,* is an agricultural strategy for both low and high rainfall seasons. When low rainfall is expected ridges are used in order to tap surface run-off when it rains and hence maximize moisture for plant growth. Similarly, during heavy rainfall, ridges reduce surface run-off and therefore minimise its impacts on the land, such as soil erosion.

Planting drought resistant crops

Drought-tolerant crops such as cassava and sweet-potatoes are normally grown when peasants expect to have less rainfall in the year. It was indicated that cassava was not a food crop in Serengeti district prior to the 1970s. In the 1970s there was a persistent dry seasons which reduced soil moisture most of the months in the year, hence caused food insecurity in the region. As a strategy to minimize the impacts of droughts and hence food shortage, cassava, which is a drought-tolerant crop, was introduced. The introduction of cassava as food crop, according to the interviewees, was based on the knowledge local people had on the plant and had been tested to know that the plant was not poisonous.

Supplementary season

It was indicated that in the study villages, cultivators used to have single cultivation season in a year, that is, long season because of the availability and reliability of rainfall, which enabled households to have enough harvests sufficient for the whole year. The decrease of rainfall necessitated the introduction of second cultivation season, that is, short season locally known as *omobho*, to supplement food deficits due to unreliable rainfall. Although other factors, such as population increase at the household level and commercialization of agriculture, may have caused the shift from one cultivation season to having two cultivation seasons in the year, it was revealed that the cultivation during the short rain season is a result of decrease of rainfall that reduced harvests to a great extent.

Use of wild fruits

Local people have also been using indigenous wild fruits to supplement food deficit caused by hydrological extremes such as drought. Local people through interaction with the surrounding environment over long time, identifies some indigenous trees whose fruits are suitable for human consumption. Examples of these trees are those locally known as *emeseka*, which produces *ichinseka fruits* and *emeko* (a type of fig tree), which produces *obhoko fruits*. To conserve some of these trees and hence avoid travelling long distance to get these fruits when they need them, some households opt to domesticate them (Figure 3). It was important to note that some of these indigenous fruit trees are tolerant to droughts and that their fruits ripe during the dry season.

Figure 3: An example of wild fruits *(ichinseka), which is domesticated.*

Use of indigenous vegetables

When low or no rainfall is expected in a year, some leafy indigenous vegetables are preserved for use during the dry season. The leaves are simply stripped from the stem and dried up in the sun. The common vegetables, which dried up and preserved for use during the dry season are locally known as *ilitiambwi*. This strategy is intended to reduce expenditure on vegetables during the dry season when vegetables become a scarce commodity.

Indigenous post harvest strategies

Post harvest strategies may include drying up of root crops such as cassava (Figure 4) and for cereal and legume grains they include pre-drying in the field, threshing, drying, and storage. Stored food has to be added some indigenous preservatives, which are made out of specific tree leaves, to avoid rotting and avoid or reduce attack from insects and pestcides. Women are mainly responsible for food processing and storage. There are different storage facilities but the common one is the use of granaries locally known as *amaghala* (Figure 5).

Figure 4: Cassava dry up by the sun before stored in a granary

Figure 5: Grains and legume food storage facility (Granary) (*amaghala*)

Discussion

The findings from this study revealed that local people possess tools and associated indicators, which are employed in understanding rainfall variability. These tools and associated indicators are mostly based on what is observable (Vijiak et. al, 2005), developed and experimented over long history of interactions with the surrounding environment. The tools and indicators on rainfall changes and variations are mainly based on the observations of the changing characteristics of the surrounding environment both on the atmosphere, such as wind systems, on the land surface – flora and fauna and other natural systems, such as natural springs. As indicated earlier, one tool and its indicator(s) may or may not be sufficient in the prediction of rainfall onset and/or end. Thus, in most cases local people use a combination of tools and their indicators to forecast rainfall onset and end in order to either prepare for the expected adverse hydrological conditions or take advantage of the expected favourable hydrological conditions in their socio-economic activities. Local people base their crop husbandry decisions on the knowledge of rainfall variability developed from years of observations, and experiences.

The effective use of rainfall forecasts requires that the right audience receives and correctly interprets the forecast information at the right time in a particular location (Hammer et al, 2002). For rainfall changes and variations information to have value should reach local people at the grass root who utilise the information in making decisions affecting their livelihood strategies such as what, where and when to produce certain type of crops. The livelihood strategies, which are commonly used in the study area in response to changes and variations of rainfall include selecting the type of crops to be grown and the landscape (land surface units) where crops are grown. Others are such as when the crops should be grown (cultivation seasons) and techniques employed during cultivation. Drought-tolerant crops such as cassava have been for instance grown when peasants expect to have less rainfall in the year. Similarly, local peasants cultivate in the lowlands when they expect less rainfall in order to utilise the soil moisture content as they believe that lowlands have the ability to keep moisture for long time even during the dry seasons. Ali (2003) observes similar livelihood strategy in South-western Bangladesh that local people have been cultivating on the flood plain during persistent droughts.

The findings from this study reveal that local people in the study area as elsewhere in Africa (Deressa et. al, 2010); Kibassa, 2013) adopt and modify livelihood strategies as a response to the rainfall variability both over time and space. To adopt a specific strategy, local people need to have the knowledge of the past, current and expected rainfall in their area. This study therefore illustrates that rural livelihood strategies in coping with rainfall variations that local people develop are diverse. Thus in the study area decisions on where, when and how to practise crop husbandry depend on indigenous knowledge on rainfall patterns and variability hence increase crop production and reduce to greater extent food insecurity.

Conclusion and recommendations

This study has demonstrated that local people in the study area have developed tools based on practical experiences gained over time for monitoring weather conditions to enable them improve crop production. The tools employ the knowledge that local people have gained about vegetation, wild animal behaviours, insects behaviours, water levels, elements of weather and astronomy science. The tools are generally effective and most local people depend on them. It is concluded therefore that local people in the study area poses tools and associated indicators, which are effective in understanding rainfall variability hence design production systems based on that knowledge. The tools and associated indicators employed are specific and detailed describing when certain hydrological conditions, such as rainfall and droughts, are expected and therefore prepare themselves.

To bring significant improvement in the agricultural production systems in the study area, it is recommended that policy makers and planners take time to learn, understand and take into account knowledge systems and adaptive management practices of the local people which are deeply embedded in their values, beliefs and assumptions. Furthermore, to have sustainable food production sector specific policies that relate to agriculture need to include some components of indigenous knowledge that are used in rainfall forecasting and in agricultural production systems.

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