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# Smallholder Farmers' Local Knowledge in Adaptation to Climate Variability: Experience from Ludewa District, Tanzania

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**Abstract**

Smallholder farmers constitute a significant proportion of the world's population that is vulnerable to climate variability. This is because they derive their livelihoods from agriculture, which heavily relies on rainfall as a source of moisture for crops production. Therefore, smallholder farmers are exposed to changes in rainfall patterns, temperature variation and extreme events such as floods and drought that could lead to disasters. Hence adaptation strategies are fundamental to reduce the impacts of climate variability. However, in order to plan for adaptation, the emphasis has been on formal knowledge systems that in most cases are not accessible to and affordable by most of the smallholder farmers. Generally, farmers have their local knowledge that they use to adapt to climate variability. This article uncovers the role of smallholder farmers' local knowledge in adaptation to climate variability. The study was conducted in Ludewa district in the Njombe region. Methods used in data collection were semi-structured interviews, key informant interviews and FGDs. A total of 355 respondents were randomly selected for a structured interview. The collected data were analysed using IBM Statistical Product and Service Solution, and content analysis. To reduce vulnerability to climate variability, smallholder farmers use local knowledge such as weather forecasts, valley bottom cultivation, diversification of crops, early preparation of farms, and use of drought-tolerant crops and diversification of economic activities and soil moisture conservation methods such as mulching. The article concludes that neither local knowledge nor formal knowledge is sufficient by its own right for sustainable adaptation. Therefore, taking action to strengthen conditions for continued use of local knowledge is essential as well as investigating the best way to integrate with formal adaptation knowledge.

## 1. Introduction

Agricultural production is directly affected by climate variability and is one of the most vulnerable sectors (IPCC, 2014; Altieri, Nicholls & Henao 2015). This is mainly due to agricultural production being inherently sensitive to climatic conditions. Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events (IPCC, 2014). Variability may be due to natural internal processes within the climate system or to variations in natural or anthropogenic external forces. According to IPCC (2014), the impacts of climate variability are more pronounced in developing countries where agriculture is rain-fed, and the countries have low capacity to adapt. Smallholder farmers are affected by intra and inter-seasonal climate variability, recurrent floods and droughts that have an implication on crop yield and food security (Altieri *et al*., 2015; Audefroy & Sanchez 2017). Therefore, adaptation strategies are fundamental if farmers are to minimise the effect of climate variability. There are numerous definitions of the term adaptation, depending on the approach that one focuses. With regard to this paper, Smit, Burtonn & Street, (1999) definition is adopted. Adaptation refers to adjustment to improve the viability of economic and social activities to reduce vulnerability to current climate variability, extreme events and long term climate change. Adaptation opens an avenue for people to make use of opportunities and minimise the resultant vulnerability from climate variability. Generally, climate variability makes it difficult for a country such as Tanzania to achieve the Sustainable Development Goal No 13 that calls for an urgent action to combat climate change and its impacts and her 2025 vision. Thus, it is important to have clear strategies to reduce vulnerability and enhance farmers' resilience to the impacts of climate variability.

Approaches to adapt to climate variability and change in agriculture have been dealt with by different authors. Wall, Smit & Wandel (2007) have explained three approaches to climate variability and change adaptation in agriculture. These include the impact-based approach, context-based approach and process-based approach (bottom-up approach). Fussel (2007) has given a detailed explanation of two approaches: a hazard-based approach and vulnerability-based approach. Both impacts based approach and hazard-based approach, focus on climatic effects of the future climate change. They are based on modelling, forecasting and formal risk management with limited consideration of non-climatic factors and current climate variability. This paper is based on a vulnerability approach, which emphasises on the integrated way of assessing the adaptation to climate variability and change. It recognises the role of local practitioners as their experience and knowledge provides a starting point for effective adaptation plans (Fussel, 2007). The approaches consider stakeholder experiences' and knowledge of managing climate risks by linking adaptation directly to their activities in a specific context. The use of the vulnerability approach is based on the fact that it considers the complex realities farmers face in their context. It considers the adaptive capacity of individuals or social group to respond to stress they face in the process of earning their livelihoods (Blaikie, Canon & Davis, 1994)

Farmers have historically been adapting to climate variability (Nyong, Adesina & Elasha 2007; Mugambiwa, 2018) as they interact daily with environmental resources. So, they have a range of local adaptation strategies such as crop diversification, mulching, agroforestry, traditional irrigation, the timing of farm operation, using alternative fallow and tillage and diversification of income sources (Smit & Skinner, 2002; Below, Artner, & Sieber 2010; Mugambiwa, 2018). Farmers' knowledge has been named differently. Common terms used include indigenous knowledge, traditional knowledge, traditional ecological knowledge, local knowledge, farmers' knowledge, folk knowledge and indigenous science. Although each term may have different connotations, they often share adequate meaning to be utilised interchangeably (Nakashima, Jennifer, Rubis, & Krupnik, 2018). The operational definition of local knowledge for this article is adapted from Berkes (2012) that says it is the cumulative body of knowledge, practices and beliefs evolving by adaptive process and handed down through by cultural transmission about the relationship of living beings with one another and their environment.

Local knowledge has been observed to be a powerful tool for managing complex issues such as climate variability (Grenier, 1998; Nyong *et al*. and Audefroy *et al*., 2017). However, since the colonial period, traditional knowledge was ignored and depicted as primitive (Grenier, 1998; & Hosen, Nakamura & Hamzah, 2020). Nonetheless, recently there has been an increased interest in the role and importance of local knowledge by policymakers and scientists both at the national and international levels (URT, 2012; IPCC, 2014; Nakashima *et al*., 2018). Yet little effort has been made to understand the role and efficacy of local knowledge. Much emphasis is still placed on formal knowledge systems which in most cases are not accessible and affordable to most farmers (Hosen *et al*., 2020). Accessibility to formal knowledge in some area is hindered by poor infrastructure, and whenever that knowledge is accessible, then high cost becomes a limit.

Generally, the value of local communities knowledge started to be acknowledged since the Earth Summit in Rio de Janerio in 1992 (United Nations Conference on the Environment and Development. Agenda 21 declared the right of indigenous knowledge to be conserved and the right of local communities to be involved in any plan attaching their interests in relation to environmental conservation. In addition article 8 (j) of the convention of Biological Diversity has contributed to the requirement of signatories to respect, preserve and maintain knowledge innovation and practice of local communities (Nakashima & Roue, 2002). Since then, local knowledge has gained recognition from both scientists and policymakers. Parallel to climate, the value of local knowledge has been acknowledged by different studies such as IPCC (2014); Nakashima, Galloway, Thulstrup, Ramos, Castillo & Rubis (2012); Audefroy *et al.*, (2017) Nakashima *et al.*, (2018) and Hosen *et al.*, (2020).

Local knowledge is a base of local-level decision making in different aspects such as natural resources management, agriculture, education and health care (Nakashima *et al.*, 2012 & Hosen *et al.*, 2020). It has a value to scientists and planners who are motivated to improve rural communities' condition. Local knowledge is a valuable resource that gives humankind a means on how to interact with the changes in their environment (Grenier, 1998). They are culturally appropriate, locally available, inexpensive and effective. Therefore, paying attention to local knowledge creates mutual respect and builds a partnership for designing a plan that is appropriate for solving the climate-related problem (Grenier, 1998; Nakashima *et al.*, 2018; Hosen *et al.*, 2020). Development efforts that disregard the local knowledge system are less likely to achieve intended goals (Grenier, 1998, Nakashima *et al.*, 2018).

According to Berkes, (2012) & Nakashima *et al.* (2018), local people have been adapting to changing environment by drawing on their local knowledge. With unprecedented changes, their knowledge becomes inadequate to adapt. This implies the need to integrate with another source of knowledge to increase farmers' adaptive capacity (Nakashima *et al.* 2018). Integration of local knowledge with experts' knowledge is an important prerequisite for facilitating effective adaptation (Swiderska, Reid, Song, Mutta, Ongugo, Pakia, Oros & Barriga, 2018). However, the integration of these knowledge systems needs detailed research to understand local know-how. Therefore, this article bridges the gap by contributing to the understanding of smallholder farmers' knowledge in adaptation to changing climate in Ludewa district in Southern Tanzania.

## 2. Methodology

### 2.1 Description of the Study Area

The study was conducted in Ludewa District in Southern Highland of Tanzania. Ludewa district is among the four districts of Njombe region. Ludewa is located approximately 34$^{0}$10′E - 35$^{0}$21′E and 09$^{0}$30′S – 10$^{0}$36′S in the Njombe region, in South-West Tanzania along Lake Nyasa, which is in East Africa Rift Valley System (Haulle, 2007). It lies between 500m and 2800m above sea level. The ethnic groups in this district are mainly Pangwa, Manda and Kisi.

Ludewa district is characterised by tropical climate regulated by altitude (IRA, 2007). The area has a single rain season from November to May, and it is dry during the rest of the period. It is divided into three agro-ecological zones; which are the highlands zone; the Midlands zone and the Lowland zone (IRA, 2007). These zones are differentiated by altitude, rainfall, temperature and soil. Annual rainfall ranges between 900mm to 1600mm. Whereby the highlands receive annual rainfall that range between 1000mm-1600mm; midlands annual average rainfall is 1200mm while the lowlands the annual average rainfall is 900mm. Due to rainfall and temperature variations, there is some difference in crops grown and animals kept from one agro-ecological zone to another though some crops and animals are found in all zones.

### 2.2 Research design and sampling

The study employed both quantitative and qualitative methods. Varieties of methods were used to obtain information, and various stakeholders were involved. The qualitative approach focused on collecting information about farmer's knowledge and perceptions on adaptation to climate variability. Under the quantitative, questionnaire and secondary sources were used to acquire data. Triangulation enabled the study to validate data and ensure the reliability and quality of the study.

The study employed three sampling techniques; namely, stratified, simple random and purposive sampling. Stratified and purposive sampling was used to select wards and villages to ensure that each agro-ecological was represented. The villages selected were as follow Madope and Shaurimoyo (Highlands), Ludewa Rural, Madunda and Luana (midlands) and Nkomang'ombe, Mbongo and Ilela (lowlands). The total households for the sampled villages were 4,190 (Ludewa District Council Office, 2011). To get the sample size for the study, the number of the household (4190) was entered in the sample size calculation table developed by The Research Advisors (2006). Then the desired confidence level of 95.0% and a margin error of 0.05 was set, which gave a sample size of 355 households. The sample size was about 8.5% of the total household of the selected villages. Boyd (2002) states that the sample size should be at least 5% of the target population. Probability proportional to size was used to get the proportion sample size for each village (Table 1). To obtain heads of households for the study, the simple random method was employed. The sampled list of households in the eight villages was obtained with the help of ward executive officer and villages' chairperson.

| **Table 1: A sample size of households from selected villagesAgro-ecological zone** | **Wards** | **Villages** | **No. of Households** | **Sample size** |
|---|---|---|---:|---:|
| Low lands | Nkomang'ombe | Nkomang'ombe | 565 | 48 |
| | Manda | Mbongo | 518 | 44 |
| | Ruhuhu | Ilela | 266 | 22 |
| Midlands | Ludewa | Ludewa Rural | 852 | 72 |
| | Mawengi | Madunda | 364 | 31 |
| | Luana | Luana | 598 | 51 |
| Highlands | Madope | Madope | 415 | 35 |
| | Lugarawa | Shaurimoyo | 612 | 52 |
| | | **Total** | **4190** | **355** |

Purposive sampling was used to obtain elders and officials for an in-depth interview. These included two farmers (male and female) with long experience in farming (with age above 50 years), in each village that made 16 elders; four district officials - one agricultural officer, one water resources officer, one natural resources officer, and one health officer. Moreover, purposive sampling was also used to obtain experienced farmers in farming at least for more than ten years for FGD and those who were voluntary ready to participate. One FGD was done in each village that involved six farmers by ensuring that both females and males were included.

### 2.3 Methods of data collection and analysis

The methods of data collection included a semi-structured interview, key informant interviews, focus group discussion (FGD) and documentary review. The data collected through the questionnaire and were later coded and cleaned. The coded and cleaned data were analysed by using IBM Statistical Product and Service Solution version 20. Descriptive statistics were used in the analysis, such as frequencies and percentages of household responses on different issues. Times series data on rainfall, the temperature was analysed to establish trend using Microsoft excel. Qualitative data from FGD, in-depth interviews were analysed by using content analysis method. This involved extracting information from narratives to obtain categories of emerging themes. Through these methods, it was possible to uncover knowledge techniques used by the smallholder farmers in adapting to climate variability.

## 3. Results and Discussion

### 3.1 Smallholder Farmers' Knowledge on Temperature and Rainfall Patterns

Temperature and rainfall determine when to prepare farms, which crops to grow, when to plant and when to harvest. Change in rainfall and temperature patterns affect crop production as well as hydrological system (IPCC, 2014). All these in one way or another have an impact on crop production. Most of the respondents' major activity was crop production (81.5%). The rest were livestock keepers (11.5%); wage employment (0.7%); fishing (0.4%); and petty businesses (5.8%). Therefore, crop production formed a major source of income. The major crops produced were cassava

(*Manihot esculenta)* in lowlands, maise *(Zea mays)*, Irish potatoes and beans in midlands and highlands.

Different factors were revealed to affect crop production in the study area. Lack of farm inputs and their high cost were the major factors that caused the decrease in crop production (54%). The decrease of/and unpredictable rainfall was the second factor whereby 26.2% of the respondents mentioned it. Other factors included lack of capital (5%), lack of market and poor infrastructure (4.8%), pests and diseases (4.7%), lack of education (2.8%), loss of soil fertility (0.9%), and uncontrolled grazing (0.4%). During the in-depth interview with the agricultural officer, it was shown that the crop production was very low due to drought and floods lowland zone; namely, Masasi and Mwambao divisions. Therefore, not only climate variability affects production but also non-climatic factors. During the study, there were no secondary data on temperature measurement in Ludewa district. From primary data, it was noted that there was an increase in temperature. Heads of households' response on the trend of temperature from 1980 to 2010 were as follow: 72% said that there was a temperature increase; 8.7% said there was temperature decrease; 14.6% said there was no change of temperature; 3.4% said that they did not know and 1.1% said there was temperature fluctuation. Farmers through FGD revealed that an increase of average temperature expands the range of pests and diseases to survive which attack animals, plants as well as a human being. This is supported by Altieri *et al.*, (2015) that temperature is an important driver of reproduction and survival of pests. In the study rice blast was reported to attack paddy and armyworms attacked maize Also, an increase of average temperature increases evapotranspiration which results in the reduction of soil moisture hence loss of arable land and low crop production.

With regard to rainfall, only data that represent highland zones were collected at Lusitu station. Figure 1 shows the average monthly rainfall trends from 1980 to 2010, while Figure 2 shows total rainfall per year from 1980 to 2010. The data show a variation of rainfall from year to year. A great variation of less rainfall was recorded from 1996 onwards. The generalised trend for both total annual rainfall and annual average monthly rainfall indicates a slight decrease in rainfall over the years. $R^2$ for average monthly rainfall was 0.389, which is equivalent to 38.9% and $R^2$ for total rainfall change was 0.4464 (44.6%).

Secondary data were supported by primary data that rainfall was decreasing as years go; whereby 96% of the respondents said there was a decrease of rainfall; 1.1% said rainfall was increasing; 2.2% said there were no changes, and 1.1% admitted that they did not know. An in-depth interview with agricultural officer revealed that in the past rainfall normally started in November but nowadays it may start in December or January and ended in May or June, but currently it normally ends in March or April.

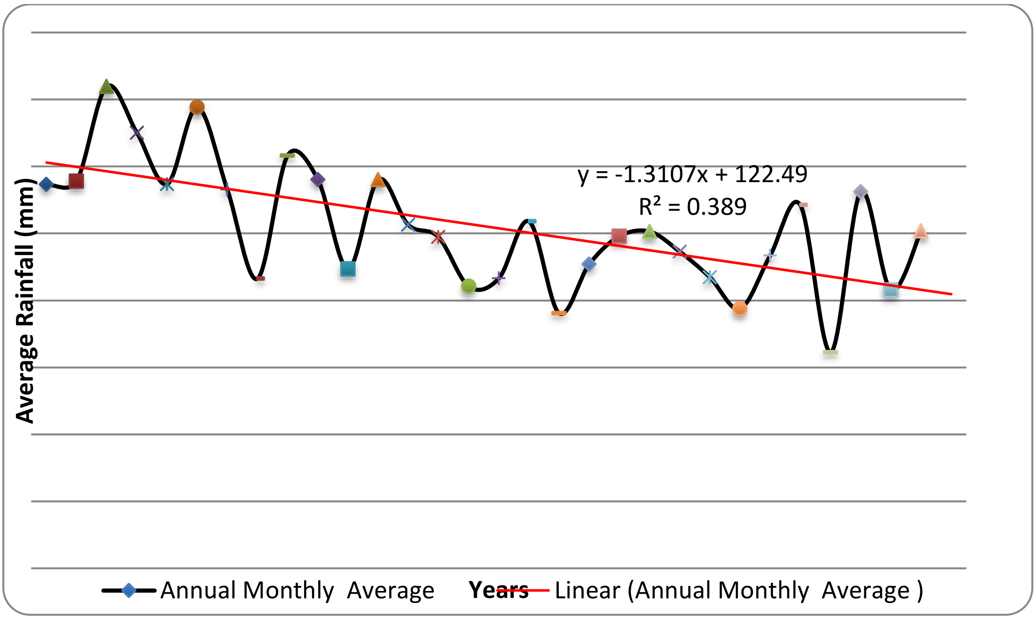

**Figure 1. Average annual rainfalls at Lusitu from 1980 to 2010**
**Source: Tanzania Meteorological Agency (2013)**

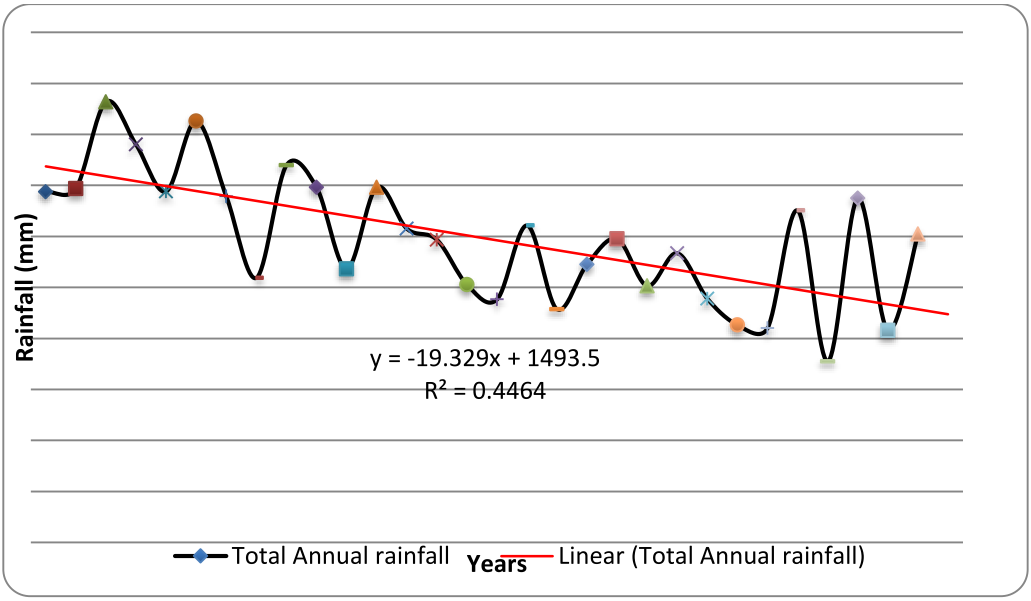

**Figure 2. Total Annual rainfalls at Lusitu from 1980 to 2010**
**Source: Tanzania Meteorological Agency (2013)**

Furthermore, extreme climate-related events were reported to have occurred in the study area. Food shortage was mentioned by 44.1%; followed by drought revealed by 18.6%; and floods reported by 17.3%, while extreme cold was mentioned by 4.3% as well as extreme wind said by 3.6% mainly in the lowland. Secondary data from district disaster file showed the existence of extreme events as depicted in Table 2. The reported disaster included heavy rainfall, floods, strong winds, hail rainfall, thunderstorm, army warm and drought. Most of them were associated with food shortage.

**Table 2 Climate disasters Profile from 1992-2013**

| **Type of disaster** | **Frequency** | **Percent** |
|---|---|---|
| Heavy rainfall with strong wind | 16 | 41.0 |
| Flood | 10 | 25.6 |
| Hail rainfall | 3 | 7.7 |
| Strong wind | 3 | 7.7 |
| Drought | 3 | 7.7 |
| Thunderstorms | 2 | 5.1 |
| Armyworms | 2 | 5.1 |

**Source:** Compiled from Ludewa District Disaster file (2013)

Respondents associated climate variability and change with different causes. The dominant cause was the loss of vegetation, particularly forests (50% of respondents). Other causes included environmental degradation (20% of respondents) such as fire burning, overgrazing, and farming in water sources, negligence of customs and traditions; lack of education, increase of industries, Lake Nyasa disturbance and population increase. Through FGD almost in all study villages depletion of natural vegetation was mainly contributed by farming activities, timber production, brick burning and charcoal making and firewood collection. Box 1 & 2 shows a quote from in-depth interview and FGD that indicates forest depletion due to anthropogenic activities.

**Box 1 Forest depletion due to human activities**

*"There were many forests in the past, but, now they are being depleted due to anthropogenic activities such as firewood collection, building activities, making boats, expansion of farms. People cut trees, but they do not plant. This situation disturbs the rain patterns as well as the availability of water in sources such as springs and rivers".*
**Source: An interview with 85 years old man in Ilela Village (2013)**

**Box 2 Knowledge on the relationship between forests and changes of climate**

*"Before 1990 climate condition was good because the population of people was low so forest depletion was also low. Forests were bringing good climate including rain. Now the population of people has increased, and the demand for building materials, agricultural land, firewood, water has also increased. For example, people want to build modern houses they need burned bricks whereby natural forests are sources of firewood, but trees are cut without replanting. This has caused an increase in an area without trees. For example, in this area where we are, there was a forest, but now there are no trees, people travel far away to get firewood for cooking and burning bricks. Depletion of the forest has decreased humidity responsible for rain formation".*
**Source:** Male of 66 years in Ludewa village (2013)

One of the farming practices reported to contribute to loss of vegetation was called *matema* (trees are cut down and burned to make the soil fertile). It was said that every year a virgin land was cleared for *matema*. It was also observed that the major source of power for different activity was biomass. The 99% (353) of respondents used firewood for cooking, and 1% used charcoal. Farmers' knowledge concurred with IPCC (2014) that other than natural influence human influence is contributing to current climate variability. According to Cunningham (2001), loss of forests contributes 14% of global greenhouse gases emission. IPCC (2014) and URT (2008) have pointed out that developing countries contribute 17% of emission from deforestation and Africa contributes only 3% of the global greenhouse emission.

### 3.2 Smallholder farmers' Knowledge on the weather forecast

Access to weather forecasting information plays a great role to improve the adaptive capacity of farmers. However, this depends on the nature of the information provided and ways of providing information. In the study area, about 66% of respondents had access to weather forecast information; 33.6% had no access to information, and 0.3% did not know. The information they got was about rainfall, temperature and wind. However, farmers did not use such information on making a decision about farming activities because they were not focused on their local environment. So they ended up using their local experience in making a decision on farming activities (Table.3). The local methods used were based on a certain type of trees, birds, water bodies, insects and climatic elements.

Some of the trees mentioned were mango trees (Manginifera indica), *mitewele* (Brachystegia bohemii) and *miyombo* (Brachystegia spiciformis). When Mango trees produce many fruits that is an indication of little rainfall in that year and when they produce fewer fruits, this is an indication of much rainfall. When new leaves of *mitewele and miyombo* trees become dark green that signifies that rain is near to start, farmers start to prepare their farms. Birds' squawk such as of *njalikoko* (Cuculus solitarius) 'njalikoko njalikoko', *dudumizi* (Contropus ssp) 'dudududududu' *and nyamnembwe* (Metro's hirundineous) 'chichichichi' are used by farmers as a sign to indicate rain is near to start. Farmers also use water bodies such as streams, spring, and wetland to show whether rain is near to fall by looking at water levels. There is a difference in water bodies' behaviour depending on the season. When rain is near to start water level tends to rise. Therefore, farmers are kin to observe the dynamics of water bodies to detect when rainfall is to start. Furthermore, insects like *viyinji*, butterfly and armyworm are the sign used by farmers: when *viyinji* start to tweet 'n*jinjinjinjinji*' is an indicator that the rains are near to start; the movement of butterflies from west to east is used as a sign to indicate rain is near to start and appearance of armyworm is an indicator of abundant rainfall in a particular year. Temperature and winds are important indicators used by farmers in forecasting. In terms of temperature, farmers observe its tendency in a particular year if it is high, then the rain would start early, and if it is low, the rain will delay. Also, farmers observe the direction of the wind. When wind moves from South West to North East it indicates rain is near. These were the precursors which indicate the coming of the rain season, so farmers prepared their farms. Similar findings have been she was reported by Chang'a, Yanda & Ngana (2010) in Kilolo and Rungwe District. The only difference is the type of plants and animals that are used by farmers to predict rainfall patterns.

**Table 3. Local knowledge used by farmers to foretell rainfall onset and intensity**

| **Indicator name** | **Onset /mount/duration** | **Local indicator** |
|---|---|---|
| Mangoes (Manginifera indica) | When they produce more flowers/fruits they indicate less rainfall in that year, and when they produce fewer fruits they indicate more rainfall | Fruits production |
| *Mitewele* (Brachystegia bohemii) *and miyombo* (Brachystegia spiciformis) | When new leaves become dark green they indicate rain is near to start. | The colour of the leave |
| Dudumizi bird (Contropus ssp) | When heard singing 'dudududududu' early in the morning that indicates rainfall is near to start. | Bird's sound |
| *Nyamnembwe* bird (Metro's hirundineous) | When appear and heard singing 'chichichichi' that indicates rain is about to fall. | Bird's sound |
| *Njalikoko* bird (Cuculus solitarius) | When heard singing 'njalikoko njalikoko' that indicates rain is about to fall. | Bird's sound |

| **Indicator name** | **Onset /mount/duration** | **Local indicator** |
|---|---|---|
| Water bodies: streams river, wetland, springs | When the water level rises, that indicates rain is about to fall. | Water level |
| Butterflies (insects) | When they move from west to east, they indicate rain is about to start. | Direction and movement of insects |
| Armyworm (Spodoptera exempta) | When they appear that indicates abundant rainfall in that year | Appearance |
| Temperature | The high temperature in October and November indicates that rain will come early and low temperature in the same months indicate that rain will delay. | Temperature |
| Wind | Movement from South East to North West indicates rain is near. | Wind direction |

Farmers, through FGD, revealed that in the past, it was easy to understand when the rain seasons was to start by using the above local methods. However, although those signs are still being used, sometimes they fail to give the correct prediction, and they had no alternative because modern ways are not of their localities. A similar observation has been reported in the literature such as Roncoli, Ingram & Kirshen (2002). According to Roncoli *et al*. (2002), farmers had to mix local strategies with extension advice to adapt to the impact of climate variability. In this study, though some were aware of modern weather forecasting they did not use them because the information provided was based on a regional scale, so were not practical to their local context. Generally, farmers are interested in rainfall season onset and cut off, distribution and intensity because of their direct influence on crop production. Hence local signs could be more important if they could be integrated with formal weather forecasting.

## 3.3 Farmers Local Knowledge on Adaptation to Changing Rainfall Patterns

Other than using local weather forecasting knowledge smallholder farmers have different adaptation strategies to the changing rainfall patterns. The responses from the heads of households showed that farmers were using different adaptation strategies to climate variability. Adaptation strategies include valley bottom cultivation reported by 38.9% of respondents; diversification (7.3%); growing early maturing crops and drought-resistant crops (4.4%); early preparation of farms (2.5%); conducting petty trade (0.3%); involvement in forestry management and tree planting (9.8%); avoiding cultivation near water sources (1.2%), and custom practice (praying to their God) (0.9%). Valley bottom (*vinyungu*) cultivation was the main strategy in adapting to rainfall variability. However, it was practised mainly in the midlands and highlands. During the FGD with farmers in Madunda village, it was revealed that valley bottom cultivation *(vinyungu)* is practised during the dry season and it was done as a strategy to increase food production. This helped farmers to offset food shortages that normally occur between December and February while at the same time providing seeds for the next planting season. It was said by one male farmer in FGD that irrigation could be the most appropriate strategy to tackle rainfall variability and increase income, but low technology hindered sustainability. This was because they normally used buckets to irrigate their crops or they depend on natural soil moisture hence low productivity. However, few farmers reported using pumps and sprinklers to irrigate their small farms. *Moneymaker pumps* were used to irrigate vegetables and tree seed nurseries. Farmers in Madope village used sprinklers to irrigate Irish potatoes. This was used in gentle slopes where water flows easily. The source of water was small rivers, streams and springs. However, there were challenges like cost of buying pipes and poor infrastructure to transport crops to the market. This implies that the blending of local and modern knowledge is one way to increase the effectiveness of adaptation.

Table 4 indicates irrigation status in Ludewa district whereby the estimated potential area for irrigation is 4090 hectares (ha) while the area under irrigation was 252ha (6.2%) mainly traditional. About 3838 (93.8%) ha were yet to be developed. If developed could help farmers to increase their income in case of rainfall shortfall, particularly in lowland agro-ecological zone where drought was the main problem due to its semi-arid condition.

**Table 4. Irrigation status in Ludewa district by 2011/2012**

| **Ward** | **Potential (Ha)** | **Ha Under Irrigation** | **Crops irrigated** | **Ha not developed** |
|---|---|---|---|---|
| Ibumi | 2700 | 60 (local) | Paddy, maize and vegetables | 2640 |
| Mlangali | 140 | 32 (Mkiu) | Vegetable, Irish potatoes and fruits | 108 |
| Manda | 800 | 80 (Local) | Maize, paddy and vegetables | 720 |
| Luilo | 450 | 80 (Lifua) | Paddy | 370 |
| **Total** | **4,090** | **252 (6.2%)** | | **3838 (93.8)** |

**Source:** Compiled from Ludewa District Profile (2014)

Low development irrigation status is a nationwide problem. According to the National Agricultural Policy (2013), irrigation potential in Tanzania is 29.4 million hectares. However, only 1.5% of the potential irrigation area is developed. A farming household that uses irrigation is less than 5 per cent. Underdevelopment of irrigation potentials in Tanzania is by both private and government institutions. National Strategy for Growth and Reduction of Poverty (NSGRP) (2010) has set a goal to increase irrigation. However, achievements depend on the willingness and commitment of the government to support farmers to establish irrigation infrastructures. Lack of irrigation facilities due to poverty undermine farmers' efforts to adapt to rainfall variability (National Agricultural Policy, 2013). Therefore, both private and government institutions need to support farmers financially to develop irrigation scheme and provide skills on how to use water efficiently.

Early preparation of farms was reported to be appropriate for first rainfall timing. It enabled farmers to plant seed crops at the onset of rains. It was revealed during in-depth interviews that farmers believe that if you plant during the first rains, the possibility of crops to grow well was greater than if planting /sowing was delayed. However, in the lowland, it was revealed that sometime even if you planted early crops could still not grow well because in most cases these days in February rainfall tends to stop for a long time leading to the withering of crops.

Farmers also grow different types of crops that are drought tolerant and early maturing. Cassava is the dominant crop in the lowlands due to the semi-arid condition. A similar result was found by Nyong *et al*., (2007), whose study done in the Sahel argues that farmers for a long time have survived by growing early-maturing and drought-tolerant crops. Although the cassavas produced in the study areas were tolerant to drought, they took a long time to mature almost a year. This implies that there is a need for farmers to be exposed to new species with high production and that matures early. Farmers grow more than one crop either within the same farm or in different farms depending on the type of crops (diversification). For example, in the lowland, other crops grown were maize, paddy, groundnuts, sweet potatoes, vegetables and fruits. In the midlands, they grew maize and beans as the major crops. Other crops include vegetables, fruits, round potatoes, sweet potatoes, sunflower, coffee, wheat and peas. While in the highland zone farmers grew maize, round potatoes, and beans, as major crops. Other crops include wheat, peas, fruits and tea. These adaptation strategies are also reported by other researchers such as; Thomas, Twyman, Osbahr & Hewitson (2007) in South Africa and Kitinya, Onwonga, Onyango, Mbuvi & Kironchi (2012) in Makueni-Kenya; Hosen *et al*., (2020) in Northwest Borneo Island.

To address the problem of floods, farmers mentioned that they cultivated their farms far away from river banks; practised migration farming; and making water channels as well as using boats to harvest maize and government aids as adaptation strategies. Rainwater harvesting is one of the potential adaptations to climate variability in the world. However, in the study area, rainwater harvesting for farming was not practised contrary to Kitinya *et al*., (2012) who found farmers harvesting rainfall as an adaptation strategy in Makueni, Kenya. Despite the fact that the National Climate Change Adaptation Strategy (2012) and National Agricultural Policy (2013) emphasize the development of rainwater harvesting techniques; however, little has been done to create awareness and build capacity for farmers.

## 3.4 Changes in crops grown.

Study findings show that many farmers did not change crop varieties grown; whereby 71.3% of smallholder farmers used crop seeds obtained from their harvesting. Through the FGD, it was revealed that farmers preferred to use seeds from their harvest because they were the main available source in their environment. It was revealed that although improved seeds (quality declared seeds – QDS) have a good harvest, it was very expensive to manage them than local seeds. Farmers had their own ways of selecting and storing seeds such as maize. Through FGD it was revealed that they normally select well-grown crops for seed. After selecting they stored them in such a way, no pests could affect by using kerosene oil or smoke. It is expected that due to climate variability farmers could have opted for improved seed varieties, but, it was not so. Also, it was revealed that the taste of improved maize was not good, and they easily decay in case of prolonged rain. Therefore, the majority who grew improved seeds was for selling and not for their own food. So both local and improved seeds have advantages and disadvantages. Box. 3 is a quotation from one of the elders involved in FGD.

**Box 3. Use of improved and local seed in adapting to climate variability**

> *We use improved maize seeds, but we have not abandoned local seeds. Local seeds are for our own household food, and improved maize is for sell. This is because local seeds taste good than improved seeds. Also, local seeds' harvest is little per acre but is heavy compared to improved seeds which have many harvests per acre but very light. On the other hand, in case of prolonged rain improved maize decay efficiently than local maize. This is because local maize when mature turndown and they are closed well in such a way water cannot penetrate inside while modern maize does not turn down when matured, and they are not closed well-allowing water to inter inside, thus easily getting decayed with the prolonged rainy season.* **Source: 73-year-old male in Ludewa village (2013)**

Therefore, in some cases, farmers are reluctant to change; they prefer local seeds than improved seeds. Nakashima *et al*. (2012) argued that local varieties have advantages of being cheap and easily accessible because they come from farmers own saved seeds and modern varieties are to be bought, depending on the market availability and require costly inputs. Local ways were dominant because of inaccessibility of improved seeds, and when accessible, the prices were not affordable by most of the farmers. Swiderska *et al*. (2018) recommend the need to support local seed production initiatives.

Improved seeds are unlikely to provide successful adaptation because of management required and low market and consumption. These imply that the improvement of adaptation strategies should be within farmers' socio-economic and environmental context, considering multiple factors that influence production (Hosen *et al.*, 2020).

### 3.5 Local Knowledge on Conservational Agriculture

Conservational agriculture refers to the ways of farming that farmers use to achieve sustained production while conserving the environment. Farmers in the study area practised different farming systems depending on the nature of their environment. Different methods were used to conserve soil fertility in the study area. These include the use of organic manure, land fallowing, and crop rotation, use of inorganic fertilizer and burning of plant residues. Organic manure helps to maintain soil fertility as well as to store soil moisture important for the growth of crops. Organic manure was mainly used in the garden and small farm because in most cases cattle were kept in an outdoor grazing system. This made it difficult to collect manure. Also, not all farmers had cattle. So they were only able to collect manure from pigs, poultry, goats and guinea pig *(simbilisi)*. In the lowlands, even manure from the pig was difficult to collect because they were left out like cattle. Scherr, Shames & Friedman (2012) have shown that soil organic matter is critical for increasing agricultural resilience to climate variability. It improves adaptive capacity by increasing soil water holding capacity and soil fertility while at the same time sequestering carbon. This was also found by Kitinya *et al.*, (2012) in Makueni County, Kenya that use of manure increases productivity, helps to respond better to unpredictable weather and increases income.

Farmers also used land furrowing as a means of maintaining soil fertility. Other than conserving soil fertility this strategy increases carbon sink because it allows the forest to regenerate; however, population increase was reducing its sustainability. FAO (2014) has shown that high population growth increases pressure on agricultural production and natural resource hence increasing the challenge of poverty reduction. One or two years of leaving the farms to regenerate were shorter, and the majority do not practice it due to shortage of land. Generally, the use of fertilizers to improve soil fertility was minimal, thus adding to low production. It was revealed during

FGD that inaccessibility and high prices of fertilizer made farmers follow fertile land near water sources and practice slash and burn hence degrading the environment. Therefore, not all local practices were beneficial to sustainable agriculture (Briggs & Sharp, 2004).

About 76% of the respondents reported doing nothing in conserving soil moisture. The remaining percent conserved plant species that stores moisture; they made water channels and terraces used to irrigation; they practised mulching and used organic manure. Mulching and organic manure were the common ways of conserving soil moisture but were mainly used in the vegetable garden, except in Madunda where they were used in coffee production and Madope where it was used to prevent tea and vegetables from drying from frost. In preventing frost from drying crops, grasses were put on top of the crop while in conserving moisture grasses were laid on the soil surface. Other than conserving soil moisture mulching was also said to improve soil fertility and moderate temperature. Vegetation that conserves soil moisture included *Mivengi (syzygium cordatum), Midobole (Hagenia abyssinica), Mavangalala* (*Musa sp/Ensete ventricosum)* and *Mahimbi (Colcasia esculenta*). These have a double impact: for example, *Mivengi* apart from preserving water they also provide edible fruits while *Midobole* provided timber and *Mahimbi* (yams) provided food. According to Banning, Corsi &Vargas (2013), minimum tillage or none tillage can be combined with soil cover to prevent soil erosion and maintain soil moisture. Covering ground surface improves soil surface condition, organic content and porosity. In turn these influence infiltration, water storage hence water availability for plant growth.

## Conclusion

This article has analyzed various local knowledge that helps smallholder farmers to adapt to climate variability in Ludewa district. They include use of local weather forecasts, valley bottom cultivation, diversification of crops and use of drought-tolerant crop varieties. From the study findings, it is concluded that smallholder farmers evolve local knowledge used to adapt to climate variability at the local level. The knowledge they possess is a base for decision making in their farming activities as well as in natural resources conservation and management. Although smallholder farmers practise these local adaptation strategies, their success is overwhelmed by increasing changes of climate and non-climatic factors. Therefore, taking action to strengthen conditions for continued use of local knowledge is essential. This is because adaptations to climate variability are context-specific. So to improve adaptation strategies, holistic understanding of the factors that fuels vulnerability to climate variability is crucial so as they are considered when planning for farming activities. Also, it is important to understand how local adaptation can be merged with formal adaptation because neither local knowledge nor formal knowledge is sufficient by its own right for sustainable adaptation.

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