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Towards establishing an effective data management system in Tanzania: A comparative analysis of scientific climate data and farmers' perception of climate change and variability

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Abstract

This paper examines and compares farmers' perceptions of climate change with climate data from the Tanzania Meteorological Agency from 2002 to 2011. Data was collected from Singida and Dodoma regions in Tanzania using both qualitative and quantitative methods. Focus group discussions and semi-structured interviews were used to collect qualitative data. Quantitative data were derived from climatic records and semi-structured interviews. Key survey findings indicate that farmers perceived increased temperatures and unpredictable rainfall patterns. Findings based on weather data also confirmed erratic rainfall patterns and increased temperature and showed corroboration between farmers' perceptions and scientific evidence from climate data. To promote accuracy and reliability of climate data in decision-making, the study recommends the use of mobile phone devices and cloud computing technology to foster timely collection of weather data and proper record-keeping. It suggests that a clear policy framework should be formulated to guide controlling and managing of weather data records from initial production to their final deposition centre.

Key words: Agriculture sector; climate change adaptation; climate data; climate change perception; meteorological data management.

Introduction

Climate change has affected traditional farming systems in a majority of sub-Saharan African countries (Boko, Niang, Nyong, Vogel, Githeko and Medany, 2007). Climate change has also affected farming seasons, type of crops grown, agricultural technology, rainfall onset and pattern and food security. Tanzania like many countries in sub-Saharan Africa has been adversely affected by climate change. Many parts of the country have experienced recurring floods and droughts which have had an adverse impact on the economy (Chang'a, Kijazi, Luhunga and N'gongolo, 2017).

The agriculture sector in Tanzania employs the majority of manpower and contributes significantly to the national economy. Tanzania's agricultural economy largely depends on rain-fed farming, hence making understanding the trends and patterns of climatic extremes becomes inevitable (Chang'a, *et al.,* 2017). In this regard, the climate change impact on this sector extensively affects the country's economy and agricultural production systems.

Climate change indicators include rainfall, temperature and wind intensity. It is characterised by erratic rainfall, changes in rainfall onset, prolonged drought, increased temperatures and wind intensity. It is also measured by increased plant and animal diseases, pests, food insecurity, human diseases, changes in ecology and biodiversity and water scarcity (Elia, Mutula and Stilwell, 2014). The United Nations Framework on Climate Change (UNFCC), Intergovernmental Panel on Climate Change (IPCC), World Meteorological Organisation and the Tanzania Meteorological Agency (TMA) are some of the institutions which generate and disseminate climate data and information featuring spatial and temporal rainfall and temperature trends. These institutions support government efforts to cope and adapt to climate change by providing technical assistance in data production, processing and management of weather forecasting.

The climate data these institutions collect and record from the organisations is crucial in ascertaining climate changes. Moreover, reliable climate data is crucial in depicting trends in rainfall and temperature for a comparative analysis of historical climate data and farmers' perceptions on climate change. The synergy between recorded meteorological scientific weather dataand farmers' perceptions can account for and inform the weather and climate change realism. Mason, Kruczkiewicz and Ceccato (2015) revealed that, even though climate data is in high demand by practitioners yet it is not readily available and accessible. This makes it difficult for researchers to embark on comparative research on climate trends. Local people who have lived in an area for an extended period are viable sources of climate change historical data on past and current climate trends. To integrate climate risks, make clear decisions and foster sustainable development, there is a need to integrate and compare quality climate data to understand local and national climate change trends.

Whereas data refers to raw facts or figures, represented in a formalised manner, records signify recorded evidence of a complete activity, which has content, context, structure and which can initiate action (Shepherd and Yeo, 2003). Thus proper climate data captured, recorded and shared from district to regional meteorological stations can promote farmers' understanding and change in attitude and providing evidence for scientists to make timely and effective comparisons regarding the climate over time. Reliable climate data from lower scale levels such as district levels is essential in providing regional and national aggregated climate data which policy-makers and farmers can use to enhance the climate decision

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support system and in the process contribute to judicious decision-making to achieve sustainable development. Climate data is an important tool which fosters joint efforts between scientists, decision-makers and farmers towards identification of local adaptation options and in establishing proper mitigation measures. To facilitate timely and convenient use of climate data and decision-making, the data from district, regional and the central meteorological stations ought to be timely and properly collected, transferred, shared and preserved.

Despite improved efforts to manage climate data and to provide real time climate data and information to users, many farmers, extension officers and policy-makers in many developing countries such as Ethiopia (Meze-Hausken, 2004) and Tanzania still experience challenges in accessing scientific climate data collected over time and recorded in meteorological stations in a timely manner. Climate data collected over time reflects climatic changes, proper collection and timely access to such climate data becomes prudent in improving the accuracy of information produced to support informed decisions on adaptation towards promoting sustainable development. Kemausuor, Dwamena, Bart-Plange and Kyei-Baffour (2011) contend that inadequate knowledge on climate changes in developing countries affects sustainable agriculture. Access to reliable and timely climate data is crucial in improving farmers' perceptions of and knowledge on climate change that could favour the adoption of adaptation strategies.

This study investigated farmers' attitudes to and perception of rainfall and temperature changes relative to climate data from the TMA in the study areas from 2002-2011. The study was conducted at Maluga and Chibelela villages in Singida and Dodoma regions of Tanzania, respectively. These villages are semi-arid; hence decreased rainfall could significantly affect farmers' livelihoods and exacerbate poverty. The study also proposes for an effective Tanzania Meteorological Agency system and framework to manage climate data.

Literature Review

Several studies have been conducted to compare farmers' perception of climate change and the climate data from national meteorological agencies. The studies include those by Amadou, Villamor, Attua and Traore (2015) and Kemausuor, Dwamena, Bart-Plange and Kyei-Baffour (2011) in Ghana; Ogalleh, Vogl, Eitzinger and Huaser (2012) in Kenya; Elum, Modise and Marr (2017) in South Africa; Tamiru, Tesfaye and Mamo (2014) in Ethiopia, Chang'a *et al*. (2017) and Mkonda, He and Festin (2018) in Tanzania. Comparing farmers' perception with scientific climate data has the potential to reduce farmers' vulnerability, increase temporal and spatial variability and enhance the adaptive capacity of communities (Tamiru, Tesfaye and Mamo 2014). It provides evidence and becomes a crucial impetus towards shaping climate change discourses and in setting and building the climate change agenda. Climate data, therefore, is crucial in promoting sustainable development goals (SDGs). In fact, farmers' access to reliable and timely data can catalyse the realisation of sustainable development goals two, six, thirteen and fifteen by promoting food security and reducing hunger (SDG 2); enhancing sustainable use and management of water (SDG 6); combating desertification and land degradation and sustainable management of forests (SDG 15); and collectively enhance the adaptation to climate change (13).

Methodology

Study Area

The study was conducted at Chibelela and Maluga villages in central semi-arid regions of Dodoma and Singida regions respectively in Tanzania (Figure 1). The regions receive bimodal rainfall with an annual average of less than 800mmand annual mean minimum and maximum temperature between 16 and 30 degrees centigrade (Chang'a, Yanda and Ngana 2010**)**. The first rainy season is from December to January and the second (main rainy season) from March to May.

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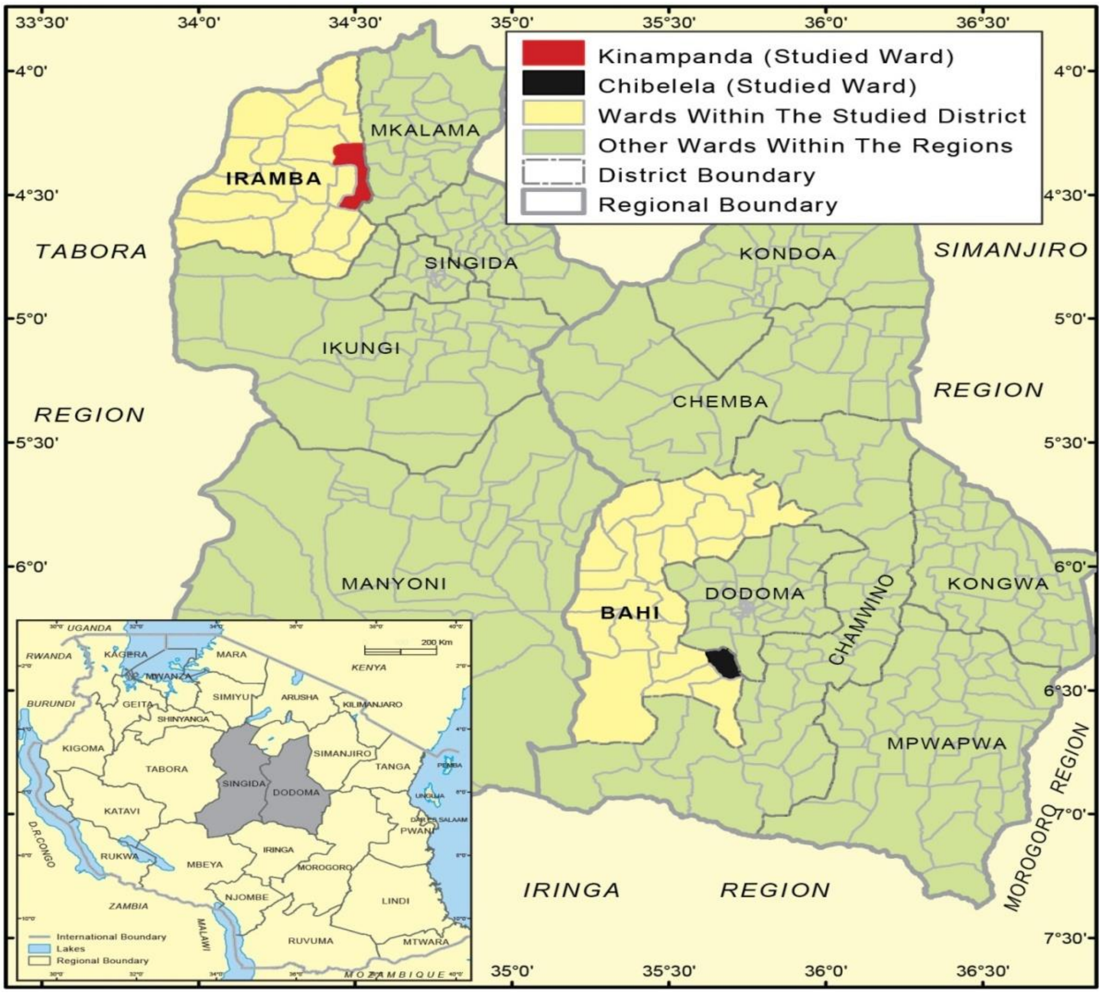

Figure 1: Geographical location of the study area.

The farming system in the study areas is dominated by crop production. Major crops grown at Chibelela village are sorghum, maize, sunflower, groundnuts, grapes, sesame, finger millet, cowpeas, groundnuts and rice. Major crops cultivated at Maluga village are sorghum, maize, sunflowers, groundnuts and beans.

Chibelela village farmers grow sunflower, sesame and grapes as cash crops, and sorghum, maize, rice and groundnuts as both food and cash crops. Maluga village farmers grow sunflower for cash and sorghum and maize mainly as both food and cash crops. Many farmers who engage in farming also keep livestock which include cattle, sheep, goats, pigs, donkeys and chickens.

Data Collection

This study applied both quantitative and qualitative research approaches in data collection. Semi-structured interviews and Focus Group Discussions (FGDs) were the survey tools applied to collect quantitative and qualitative data on climate change from respondents. Data was collected on farmer perceptions on changes perceived in climate patterns and impacts. The study population comprised farmers drawn from Maluga and Chibelela villages in Singida and Dodoma regions.

The study further analysed long-term rainfall and temperature data in the study areas from two Tanzania Meteorological Agency stations using Microsoft Office Excel 2007. Data was collected for the decade of 2002–2011. The software helped to generate rainfall and temperature patterns and trends in a graphical form. The study then compared farmers' perceptions of climate change with analysed meteorological recorded data.

Sampling technique and data analysis

The estimated population of farmers at Chibelela is 1,704 and at Maluga village is 1,451 (Village Government 2011a; Village Government 2011b). Israel formula was used to estimate the proportion of sample size (1992) at 90 percent confidence level. A sample of 94 farmers was derived from Maluga and 95 from Chibelela. In each village, half of the sample of farmers were conveniently and purposively selected and interviewed. Of the 47 farmers selected at Maluga village, eight did not complete the interviews (83% response rate) whereas all the respondents at Chibelela were interviewed. Thus, 36 farmers were drawn from Maluga village and 48 from Chibelela village. The sample size in this study was deemed sufficient to provide adequate data and provide a basis for generalisation as it is above the figure of 30 recommended by Stephen and Hombay (1997).

Quantitative data were derived from climatic records and semi-structured interviews. Qualitative data were derived from focus group discussions and interviews. Two FGDs of eight (8) participants were used to collect qualitative information. FGD participants comprised village elderly people (aged 50 years) and influential villagers who were purposively selected as could recall and explain weather changes and farming practices applied from 2002 to 2011. The extension officers, village leaders and researcher were involved in selecting the farmers.

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Qualitative data from the interviews and FGDs were analysed qualitatively. Content analysis was used to establish patterns and issues related to villagers' perceptions of weather changes in relation to farming. On the other hand, quantitative data from semi-structured interviews were entered into the computer, edited and coded using a Statistical Package for Social Science (SPSS) version 20, with Microsoft Excel Sheet 2007 being used to calculate the mean rainfall and temperature data from the TMA to derive the graphs, Pie-charts and bar-charts which were used to present data on the variables under study.

Results and Discussion

Farmers' Attitudes and Perceptions of Rainfall and Temperature

Farmers' attitudes and perceptions constitute a critical component in understanding climate change issues and designing appropriate adaptation strategies. Farmers were requested to share their perceptions on the frequency and experience of drought and rainfall patterns when comparing the prevailing environment and that of the previous decade. Findings from semi-structured interviews showed that most of the farmers have observed frequent droughts, erratic rainfall patterns and a temperature increases. Most (82 or 97.6%) respondents perceive an increase in erratic rainfall patterns whereas only two (2.4%) respondents indicated that they had not witnessed any significant changes in rainfall patterns in the last decade at both Chibelela and Maluga villages.

Similar findings on decreased rainfall and increased erratic rainfall pattern were noted during the FGD and interviews. The results showed that in the last decade some farmers confirmed to have observed a significant decrease in the amount of rainfall and its unreliability because of its erratic onset. Farmers pointed out that of late rainfall patterns have changed and that rainfall starts much earlier and at times later than usual. The findings show that, in the past, the onset rainfall used to be specific and lasted for longer periods than the present patterns. A farmer at Chibelela village said, "Rainfall has been so unpredictable, erratic and with reduced intensity… In the past, rainfall used to begin between 15and 20 December and did not stop till the mid of June the following year. Nonetheless, the situation these days has changed the rain ends in February or March".

A similar observation on rainfall date changes was noted at Maluga village and one farmer commented: "In the past rainfall would start on 15 November and end in May the next year. However, current trends show that rainfall may end in March or early April in the subsequent year unlike in the past". He added: "These days, the rainy season has been shorter, more unpredictable and dry spells have increased". What remains critical is farmers' access to timely and relevant information required to make informed decisions pertaining to climate change and adaptation. Information ought to flow through reliable channels to enable quick acceptance, diffusion and use by farmers.

With regard to the respondents' perceptions of the perceived increase in temperature in the last decade, the study findings from semi-structured interviews indicate that most (69 or 82%) of the farmers perceived an increase in temperature whereas a minority (15 or 18%) did not perceive any increase in temperature. One farmer commented, "These days the temperature and wind have increased compared to the last decade". On other hand, one farmer quipped, "I think the temperature has not changed, it is just the same…"

These results indicate according to farmers' perceptions, rainfall and temperature patterns have changed. The findings are consistent with earlier studies by Slegers (2008), Gwimbi (2009) and Mengistu (2011) who found that farmers in Tanzania, Zimbabwe and Ethiopia, respectively, similarly perceive an increase in droughts, reduced and erratic rainfall coupled with an increase in temperature in the last decade. The current findings are also similar to those of Ogalleh, *et al.* (2012). Their study observed an increase in drought and temperature and a decrease in rainfall in the last four decades. On the other hand, they differ with those of Amadou *et al*. (2015) who found that in Ghana farmers perceived a decrease in rainfall and an increase in temperatures.

Farmers' Perception of Changing Farming Practices

Changes in weather patterns and climate have prompted farmers to change their farming practices. As a result, they have resorted to new drought-resistant and high yield seed varieties in addition to applying chemical fertilisers to ensure adequate harvests. Through the FGDs farmers stated that in the past, they used to practise traditional cultivation by throwing seeds onto the soil in a small area, which would result in harvesting large quantities. The scenario is different nowadays as farmers need to apply new scientific methods to ensure good yields. Supporting this finding, a statement from a Chibelela village farmer represented the popular view offarmers in the study area: "Nowadays, if a farmer fails to apply fertiliser, pesticides and deep soil water preserving methods when cultivating, he/she is most likely going to have poor harvest".

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Despite farmers' perceived changes in soil fertility, the study findings revealed that some farmers have developed negative attitudes towards some seed varieties and industrial fertiliser. The findings also revealed that most of the farmers have a negative perception of the newly-introduced improved sorghum varieties dubbed 'white' sorghum. They claim white sorghum is tasteless compared to the indigenous sorghum variety 'Lugugu' which is s less attacked by diseases, insects and birds, compared to the indigenous varieties. Farmers also reported that industrial fertilisererodes soil fertility. These findings confirm those by Rogers (2003:221), who observed that attitude and relative advantage influences the use of innovations. To overcome these barriers, farmers need reliable and scientifically tested information to make them realise how unfounded their beliefs have been. As the beliefs are culturally and deeply embedded, the use of interpersonal sources such as social networks is inevitable (Rogers, 2003).

Farmers were also of the opinion that recent changes in weather and climate have led to an increase harmful insects such as the larger grain borer, and spread of diseases in the villages. The insects destroy grain and maize and peas seed. In this regard, a farmer from Maluga village commented: "Recently, farmers have observed an increase in the number of insects which do not only destroy grains in the field, but also destroy cultivated cropsin the field". Another farmer said, "These days there is also an increase in human diseases such as malaria and vector insects such as mosquitoes compared to the last decade". These findings concur with those of Lema and Majule (2009), who observed unpredictable rainfall, high pests and diseases presence and low soil fertility in semi-arid areas of Tanzania.

Having solicited views from farmers on weather and climate changes, their perceptions were compared with rainfall and temperature data analysed from the Tanzania Meteorological Agency (TMA). These two climate variables are mostly used to explain and predict climate change. The aim was to observe and ascertain similarities or differences between the localised respondents' perceptions of rainfall patterns and temperature changes in the last ten years. This comparison can contribute to understanding of the link and synergy between scientific weather data and farmers' local perceptions of climate change and variability. The subsequent sections present and discuss TMA weather findings of Chibelela and Maluga villagers.

Rainfall and Temperature Weather Data from TMA: Chibelela Village

Mean annual rainfall and temperature data for 2002-2011 were analysed and used to plot graphs to depict trends in rainfall and temperature in Chibelela village (Figures 2 and 3). The study findings show that there has been a decrease in rainfall and an increase in temperature for the last decade in Chibelela village in Dodoma region.

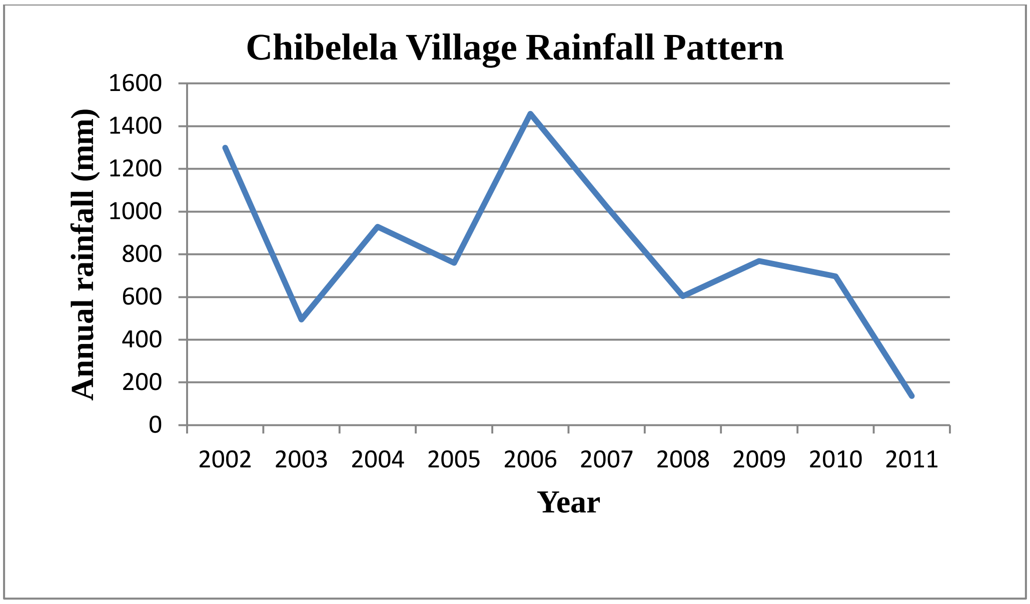

Figure 2: A Graphical Representation of mean Annual Rainfall trends for 2002–2011 at Chibelela village (Source: TMA 2012 rainfall data)

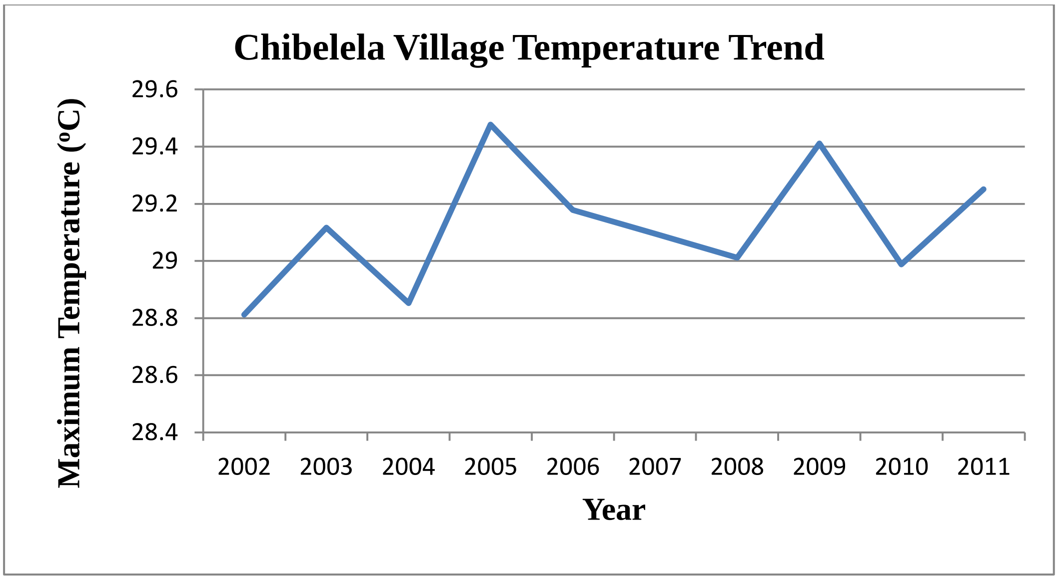

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Figure 3: A Graphical Representation of Temperature Trends for 2002–2011 at Chibelela village (Source: TMA 2012 temperature data)

Rainfall and Temperature Data from TMA: Maluga Village

Mean annual rainfall and temperature data for 2002-2011 were further analysed and used to plot graphs to depict trends in rainfall and temperature in Maluga village, Singida region. The resultant graphs are presented as figures 4 and 5.

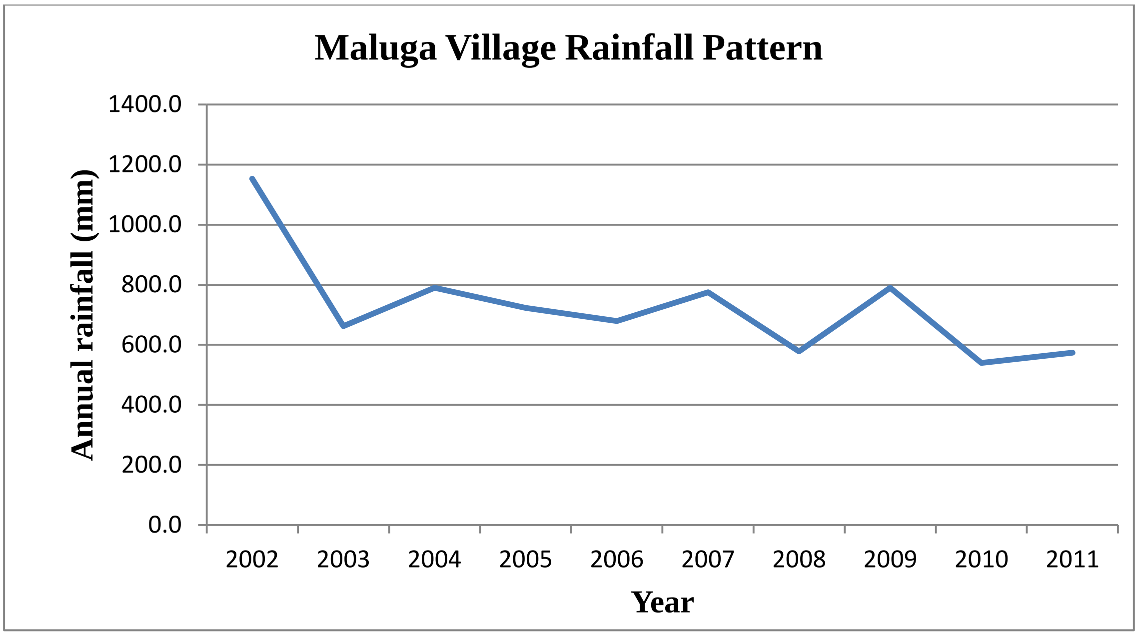

Figure 4: A Graphical Representation of Annual Rainfall Patterns for the period of 2002–2011 at Maluga village (Source: TMA 2012 rainfall data)

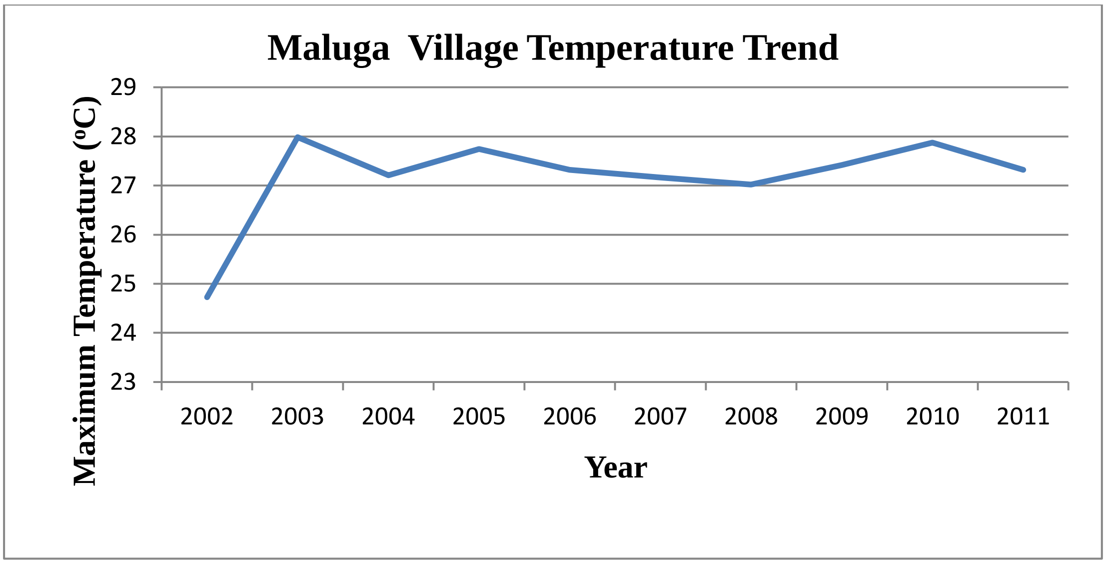

Figure 5: A Graphical Representation of Temperature Trends for 2002–2011 at Maluga village (Source: TMA 2012 temperature data)

These findings from TMA show that there is a decrease in rainfall and an increase in temperature for both villages. The results confirm the perceptions and fears of farmers regarding the increase in temperature and decrease in rainfall in the last 10 years. The research findings from the two villages are in line with those for the central semi-arid areas in Tanzania that Slegers (2008), Lema and Majule (2009) and Lyimo and Kangalawe (2010) established. These researches in semi-arid central Tanzania had established that farmers perceived an increase in the prevalence of droughts and rainfall variability in the past two decades, contending that droughts had actually increased and continued to recur. Similar findings were noted in Zimbabwe by Mutekwa (2009), who found that farmers perceived a high frequency and severity of drought, changes in the timing and pattern of seasons, excessive precipitation and the drying up of dams, rivers and wells. Gwimbi (2009) and Mengistu (2011) also found that farmers in Zimbabwe and Ethiopia, respectively, had perceived an increase in droughts, a reduction in rainfall, which had incidentally also become erratic, in addition to an increase in temperatures in recent years.

Farmers' attitudes and perceptions can influence how they respond to changes in the weather and climate, thus confirming their primacy in the mitigation and adaptation to climate change. Newly-introduced programmes on climatic change adaption can also be adapted effectively once people have positive attitudes. This argument finds ready support from Moser and Ekstrom (2010), who explained that attitudinal and behavioural changes are crucial in collaboration, changing peoples' ways of thinking and determining a paradigm shift in resource distribution. Moreover, attitude change is vital in institutional settings as it facilitates the engendering of effective use of natural resources (ibid.). Attitude change can be extremely hard to achieve, however. Rogers (2003) also indicated that the attitude to and resultant decisions regarding an innovation, to a great, extent can be traced to the characteristics of the innovation by potential users.

Climate Data Management System

This study contends that, since the geographical locations of regions in Tanzania are different and dispersed, there should be efficient and effective means fortimely collecting, sharing and managing weather and climate scientific data from meteorological stations at district levels to

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the central meteorological data centre to minimise chances of data loss. Such a situation would allow farmers to scientifically ascertain changes in weather and climate over the years. The availability of timely recorded and reliable weather data can provide evidence, which scientists and other key decision-makers need either to support or reject farmers' perception of climate change they observe within a specified locale. The scientific climate data that has been systematically collected, documented and preserved from MET stations is crucial to farmers and policy-makers in making informed decisions regarding weather and climate changes.

Thus far climate change is generally perceived by many as not an immediate but distant problem (Orindi and Murray, 2005). As such, farmers' level of awareness, understanding and adoption of innovations can be promoted by providing them with evidence-based climate information products and services on the trends and patterns of rainfall and temperatures. The reliability and authenticity of weather forecasts data and information to be used to project climate variability and change in a country depends on the accuracy of data which is recorded daily and throughout the year. However, climatic parameters such as rainfall, temperature and wind pattern in rural areas can be effectively tracked and used to plan for adaptation programmes if there is proper and timely recording of climate data from meteorological stations. Despite the improved means for collecting, sharing and storing weather data due tot of advancements in technology (Mason, Kruczkiewicz and Ceccato, 2015), meteorological stations in most rural regions of Tanzania still use improper methods to collect and transfer climate data from village/district weather stations to the Tanzania Meteorological Agency Centre. In fact, the conventional means of information collection and preservation is slow, unreliable, cumbersome and difficult to access.

Nonetheless, with the advancement and internet consolidation and mobile phone usage in Tanzania, the country could embark on a new direction in improving climate data management, access and use. Currently, the Internet and mobile phone users have reached 19.8 and 40 million subscribers in the country (Media Council of Tanzania, 2017). The progress in technology infrastructure in rural areas and increased usage of online devices is an important milestone in fostering quick and reliable means of transferring weather data from meteorological stations to the Tanzania Meteorological data centre. Instead of meteorologists recording weather data from meteorological stations and manually storing the data in print format at a meteorological station, mobile phones with Internet access and cloud

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computing could be used to capture and manage data from meteorological stations at regional levels across the country. This conception is diametrically presented in Figure 6:

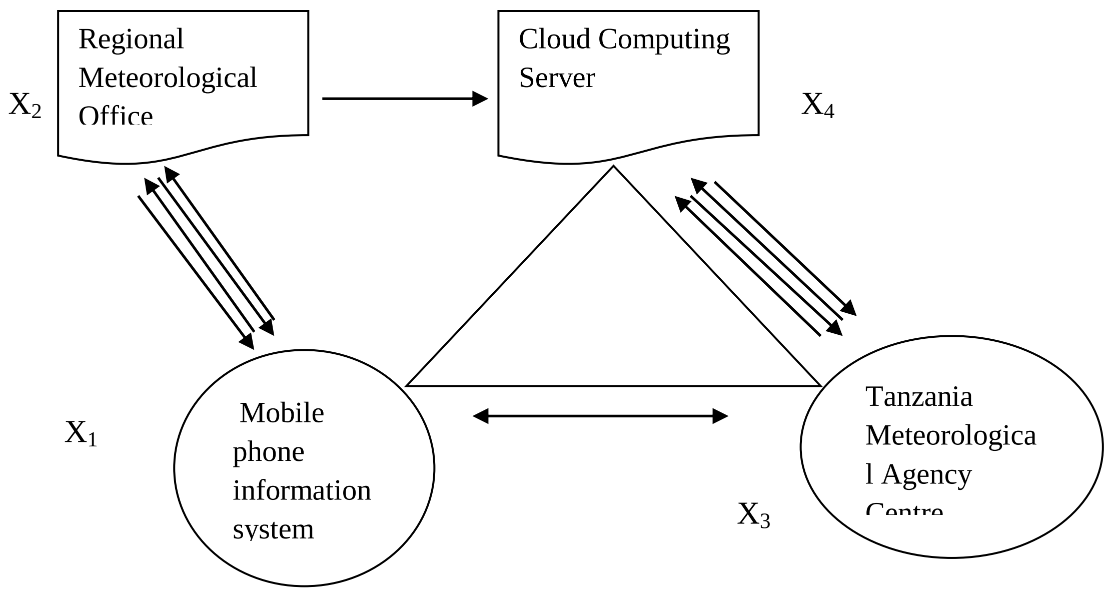

Figure 6: Climate Data Management System

Key Data Processing Activities

X_1: Capturing and Processing

X_2: Organising, Processing, Storing, Transfer to Cloud Server (Internet based)

X_3: Data communication, transfer and backup

X_4: Data shared and access through Cloud Server

Cloud computing provides quick and reliable means for storing and preserving data through virtual servers. To enhance timely and reliable climate data in rural areas, data collected from a specific weather station is captured and processed by networked mobile phones. The raw data collected is then transferred from the meteorological weather station to the regional meteorological station and as backup to the TMA centre. The data received at regional meteorological office is then organised, processed, stored and transferred to cloud servers.

Data collected and processed from all regional meteorological stations is then conveniently and timely accessed by the TMA. This process facilitates climate data transfer and communication from the meteorological stations in addition to promoting timely and convenient access and use of data generated from meteorological stations. Moreover, it enhances the production of quality and reliable data as it reduces chances of omission or errors in the data capturing and processing process. Quality data managed by the TMA is crucial in predicting climate change and decision-making. Access to accurate and timely weather data is crucial for decision makers in mitigating and adapting to climate change. The system also serves as backup in case of the occurrence of natural disasters in any data processing process.

The proposed climate data management system and architecture is essential in ascertaining the extent and scale of changes in weather and climate at the lower regional scale and across the country. In a bid to promote adaptation to climate change, scientists need to have reliable climate data which has been carefully collected, documented and preserved to facilitate informed decision-making. In this regard, climate data serves as a tool for tracing and comparing climate changes of a particular area. Proper climate data management from lower levels such as the village, district and regional levels is crucial in providing clear empirical evidence to decision-makers on climate changes from lower to higher global scales. On the whole, the availability and provision of timely and quality information from meteorological stations has the potential of providing reliable climate information, which can positively influence farmers' perception of climate change and attendant adaptation. The information can also reduce farmers' uncertainty and anomalous state of knowledge and promote diffusion and adoption of innovations for sustainable agriculture (Rogers, 2003; Kemausuor*et al*., 2011).

On the basis of the research findings, the study recommends that adequate funding should be set aside for investing in technology and equipment across the country. Information and Communication Technology (ICT) tools such as mobile phones and cloud computing should also be adapted for use in meteorological stations and TMA centres for timely and proper management of the weather and climate records. The study further suggests regular software updates and proper training of meteorologists' to foster proper collection and management of weather data records in the country. This study further recommends that a policy framework should be designed to guide collection and management of electronic weather data records in weather station and archiving centres.

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