Smallholder Farmers Awareness and Perceptions of Climate Change in Moshi Rural District, Tanzania

Mushy, R. B.

The Open University of Tanzania
Email: reguli.mushy@out.ac.tz

Abstract

Farmers' perception of climate change is a pre-requisite for undertaking adaptation actions. However little is known on how smallholder farmers in different agro ecological zones of Tanzania perceive climate change. This study examined the perception of climate change among smallholder farmers in different agro ecological zones of Moshi Rural district, Tanzania. Primary data were obtained from 359 household heads and 35 key informants. Data collection methods for this study were questionnaire survey, in-depth interviews, focus group discussions and observation. Questionnaires were administered to 359 household heads while in-depth interviews were administered to key informants. Historical data for rainfall and temperature were obtained from Tanzania Meteorological Agency. Analysis involved descriptive statistics for quantitative data and content analysis for qualitative data. Findings from this study revealed that majority (98.3%) of farming households were aware of climate change in terms of increasing temperature and reduced rainfall. Furthermore, 92.5 % of respondents perceived that temperatures have increased, while 74.9 % perceived that rainfall has decreased. However, these perceptions differed between the different agro ecological zones. Most farmers perceived that amounts and duration of rainfall had decreased. Rainfall has been more unpredictable, unevenly distributed, as well as starts late and ends early. Farmers perceived that the wet season is getting shorter because they perceived that currently, the wet season starts late. The study has indicated that majority of farmers are aware of climate change, but failed to understand the nature and extent of its impacts due to limited access to up-dated climate related information. Therefore, provision of timely, relevant

and user-friendly climate information should strategically reach smallholder farmers.

Introduction

Climate change is one of the most significant global challenges in the twenty first century. The average global surface temperature has warmed up 0.8 degree Celsius (°C) in the past century and 0.6°C in the past three decades largely because of human activities (Adger *et al*., 2007; Boko *et al.,* 2007; IPCC, 2014). The Intergovernmental Panel on Climate Change (IPCC) has projected that if the greenhouse gas emissions continue to raise, the mean global temperatures will increase between 1.4 and 5.8°C by the year 2100. Such an increase will cause significant impacts on humans and ecosystems (IPCC, 2007).

Farmers' perception that climate change is happening is a basis for undertaking adaptation strategies. Perception to climate change depends on what people can see and feel about climate including temperature and rainfall together with their direct impacts on livelihood activities particularly farming (Bele *et al*., 2014). According to Maddison (2007), farmers who notice and are aware of climate change and its impacts are more likely to undertake adaptation measures that help them reduce losses or take advantage of opportunities associated with these changes than those who are not aware of it. Knowledge and awareness on changing climate variables such as precipitation and temperature regimes helps farmers decide whether or not to undertake adaptation strategies.

The impacts of climate change are more significant in the least developed countries (LDCs) than in developed countries, particularly in Sub-Saharan Africa (SSA) where rain-fed agriculture is the mainstay of more than 80 percent of its population (Agrawala *et al.,* 2003; Lema and Majule, 2009; Mertz *et al*., 2009; Yanda and Mubaya, 2011). Furthermore, the impacts of climate change are the most pronounced among poor and marginal populations whose livelihoods are primarily dependent on natural resources base

(Rodima-Taylor *et al*., 2012). Tanzania like other developing countries is experiencing climate change and its impacts which are manifested in increasing weather extremes, changes in rainfall patterns and increasing droughts and floods (Yanda and Mubaya, 2011). The increasing intensity of droughts, floods and changes to growing seasons have significant effects on agricultural productivity, water supply, food security and, in turn, human welfare and poverty levels (Majule *et al*., 2004; Yanda *et al*., 2006). In Tanzania, the glacial retreat observed on Mount Kilimanjaro, is arguably, the most iconic indication of climate change where over the 20th century the spatial extent of ice cap has decreased by 80 percent (URT, 2007; Agrawala *et al*., 2003). With the current rate of warming, it is projected that the glacier may disappear entirely by 2020 (URT, 2007; Agrawala *et al*., 2003).

This will have considerable implications for the local ecosystems on the mountain slopes, which provide critical water services and support livelihoods for over a million local inhabitants on the slopes of the mountain, and the whole of Pangani river basin (Agrawala *et al*., 2003; Meena and O'Keefe, 2008). Given the fact that the majority of people in Moshi Rural District are smallholder farmers who depend largely on rain-fed agriculture, climate change will adversely affect their agricultural production and their means for subsistence. Another indicator of climate change observed and reported in Tanzania is the incidences of highland malaria in areas that were free from mosquitoes and malaria (Yanda *et al*., 2006; Mboera *et al*., 2010; Kangalawe, 2009). With the increase in temperature, incidences of malaria have been reported in highland areas such as Kilimanjaro region (where the study area is located) and Mbeya region (Mboera *et al*., 2010). Kangalawe (2009) reported a clear association between temperature trends and malaria incidences. Furthermore, expansion of different crop pests and diseases into cold and highland areas has been on an increase due to climate change (IPCC, 2014). Different scholars have studied the perceptions of climate change among farmers in different parts of the world. These include studies by Bele *et al*. (2014); Nhemachena and Hassan (2007); Gbetibouo (2009);

Hassan and Nhemachena (2008); Nyanga *et al*. (2011); Deressa *et al*. (2011); Fosu-Mensah *et al*. (2012); Okonya *et al*. (2013); Bushesha (2014); Komba and Muchapondwa (2012) and Slegers (2008). However none of these studies focused on perceptions of climate change among smallholder farmers along the different agro-ecological zones. This study therefore examined how smallholder farmers in Moshi Rural district perceived climate change along the different agro-ecological zones.

Methodology

The study was conducted in Moshi Rural District, Kilimanjaro Region, North Eastern Tanzania, covering the southern slopes of Mount Kilimanjaro. The district is located, between latitude 3º10'S and 3º48'S; and longitude 37º15'E and 37º36'E. It covers an area of 1529 kilometre squares (km^2) and administratively it is divided into four divisions, 31 wards and 165 villages (URT, 2013). A cross-sectional research design was used in this study. A combination of multi-stage random sampling, stratified and purposive sampling procedures were used to select the sample. The sampling frame for this study comprised of 3,548 household heads drawn from six villages, where two villages from the three agro-ecological zones, namely, highland, midland and lowlands were included. The sampling unit was household heads. Household heads were selected because in most cases, they are decision makers at household level. Therefore, they were thought to be more knowledgeable case under study. Random sampling procedure was used to get the sample of 359 heads of households from the six selected villages. To get the sample size above, the formula proposed by Israel (1992:3) at 95 percent confidence level and P = 0.5 was applied as illustrated below:

$$n = \frac{N}{1 + N(e)^2}$$

Where; n = sample size
N = population size for households in the sampled villages
e = the level of precision

Apart from household heads, the study also involved 35 key informants, purposively selected, depending on their administrative position at village, ward, district levels and/or their experiences on climate change as well as the study area. Face to face administered questionnaire interviews with household heads, in-depth interviews with key informants, focus group discussions, observation as well as documentary review were employed. Climate data particularly temperature and rainfall were collected from Tanzania Meteorological Agency (TMA), covering two meteorological stations, namely, Moshi Airport station and Lyamungo station. Available data from the two stations was for the period of 51 years from 1961 to 2011. Quantitative data were analysed using statistical package for social sciences (IBM-SPSS version 20) computer software whereas qualitative data was analysed using content analysis.

Results and Discussions

Smallholder Farmers' Awareness on Climate Change

Local people as well as their communities are knowledgeable of their environment and hence, experiences. Local people's perceptions of climate are related to climate parameters or elements, which directly influence their livelihood activities especially farming. Elements are rainfall, drought or dry spells, temperature and floods. Such parameters were reported to have changed significantly from what used to be in the past. For example, during the 1970s and 1980s, rainfall amounts were high and more predictable than years after 2000. Smallholder farmers in Moshi Rural district are aware of climate change through their farming experiences. Through their daily farming activities, farmers have noticed changes in rainfall and temperature patterns in their local environment, and hence they are aware of climate changes. Results from the field survey indicated that 98.3 percent of households from the study area were aware of climate change and changing climate variables or indicators taking place in their respective villages (Table 1). There was a slight variation between villages on awareness of climate change. In Mawala and Mruwia villages, all respondents reported to be aware of climate change, while in Materuni village, awareness level among respondents was 95 percent (Table 1).

Table 1: Smallholder farmers' perceptions of different indicators of climate change

	Mawala (n = 38)	Kisange sangeni (n = 64)	Kirima Kati (n=103)	Kirima Juu (n=76)	Mruwia (n=35)	Materuni (n=43)	Study area (n=359)
Awareness on changing climate variables or indicators							
Yes	100.0	98.4	99.0	97.4	100.0	95.3	98.3
No	0.0	1.6	1.0	2.6	0.0	4.7	1.7
Perception on Rainfall amount							
Increasing	0.0	0.0	0.0	0.0	2.9	4.7	0.8
Decreasing	89.5	87.5	76.7	60.5	85.7	55.8	74.9
Fluctuating	10.5	12.5	7.8	18.4	11.4	25.5	13.7
No change	0.0	0.0	15.5	21.1	0.0	14.0	10.6
Perception on Temperature							
Increasing	94.7	98.4	95.1	89.5	85.7	86.1	92.5
Fluctuating	5.3	1.6	4.9	2.6	5.7	2.3	1.9
No change	0.0	0.0	0.0	7.9	8.6	11.6	5.6
Perception on Drought/ Dry spell							
Increasing	86.8	90.6	74.8	61.8	45.7	27.9	67.7
Fluctuating	13.2	7.8	7.8	14.5	34.3	44.2	16.7
No change	0.0	1.6	17.4	23.7	20.0	27.9	15.6
Perception on Rainfall variability							
Increasing	78.9	84.4	41.7	43.4	57.1	30.2	53.8
Fluctuating	18.4	9.4	14.6	17.1	34.3	27.9	18.1
No change	2.7	6.2	43.7	39.5	8.6	41.9	28.1
Perception on Floods							
Increasing	13.2	40.6	0.0	0.0	2.9	0.0	8.9
Fluctuating	10.5	12.5	0.0	0.0	0.0	0.0	3.4
No change	76.3	46.9	100	100	97.1	100.0	87.7
Late onset and early cessation of rainfall							
Increasing	42.2	57.8	47.6	38.2	45.7	37.2	45.4
Decreasing	0.0	0.0	0.0	0.0	2.9	2.3	0.6
Fluctuating	28.9	20.3	13.6	21.1	34.3	25.6	21.4
No change	28.9	21.9	38.8	40.8	17.1	34.9	32.6

Source: Field Survey (2013)

These findings are similar to other studies conducted in other areas such as the semi-arid central Tanzania (Slegers, 2008; Mongi *et al*., 2010; Lema and Majule, 2009; Swai *et al*., 2012), Rufiji basin (Ndesanjo *et al*., 2012), the Sahel (Mertz *et al*., 2009), Nile Basin in Ethiopia (Deressa *et al*., 2008, Deressa *et al*., 2011), Zambia (Nyanga *et al*., 2011) and Southern Africa (Nhemachena and Hassan, 2007), to mention a few. The studies showed that smallholder farmers are aware of climate change through their daily activities. In the study villages, it was revealed that awareness of climate change was not influenced by location, socio-economic status and household characteristics.

Smallholder Farmers' Perception of changes in Rainfall Patterns

The results from household survey indicated that the 74.9 percent of households perceived that rainfall has been decreasing over the past two decades, while 13.6 percent reported that rainfall has been fluctuating (Table 1). When comparing data by villages, it was revealed that Mawala and Kisangesangeni villagers are more concerned with decreasing trends of rainfall as reported by 89.5 percent and 87.5 percent of respondents, respectively. In Materuni village about a quarter (25.6%) of respondents reported that rainfall has been more variable than it used to be in the past years. In Kirima Juu and Kirima Kati villages, farmers reported to have seen no changes in rainfall over the past thirty years as reported by 21.1 percent and 15.5 percent of respondents, respectively (Table 1). The variation in perceptions was due to altitudinal influence, where the lowland areas experience less rains compared to the highlands which receive more rainfall over a long period time.

Respondents who perceived changes in rainfall stated that the amounts and duration had decreased and that rainfall has been more unpredictable as well as unevenly distributed particularly over the past 20 years. It was further revealed during the interviews with key informants that over the past decade, there has been a decline in rainfall amounts especially in the lowlands where for about three consecutive years, they experienced droughts due to inadequate rainfall. Farmers' perceptions tally with historical data. Analysis of historical (meteorological) data for Lyamungo and Moshi Airport stations from 1961 to 2011 generally shows a slight decline in trends of total annual rainfall. Using simple regression model, the analysis showed a slight decreasing trend in the pattern of annual rainfall. The decline was more noticeable in Lyamungo station where it shows a decline trend of $R^2 = 0.0312$, $p < 0.1827$ ($y = -3.9695x + 1610$) (Figure 1), while in Moshi airport, the trend was $R^2 = 0.0088$, $p < 0.5130$ ($y = -1.6312x + 905.08$) (Figure 2). Similar results were also reported by Lyimo and Kangalawe (2010) who observed that in Shinyanga rural district, rainfall was decreasing though at a non significant rate of $R^2 = 0.18$, F probability > 0.47. Although these trends are not statistically significant, they still show a declining trend of rainfall in the study area. Despite the fact that the total annual rainfall is not generally deficient, the yearly distribution of rainfall on the southern slopes of Mountain Kilimanjaro (Moshi Rural district) is highly variable, thereby posing a major threat to the heavily rain-dependent subsistent agricultural system (Mulangu and Krybill, 2013).

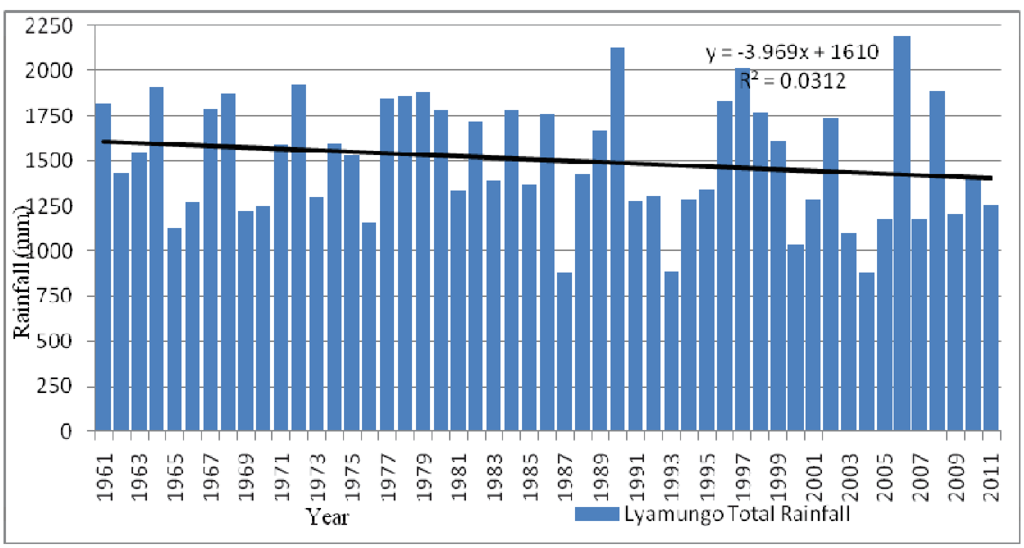

Figure 1: Total annual rainfall (in mm) for Lyamungo station

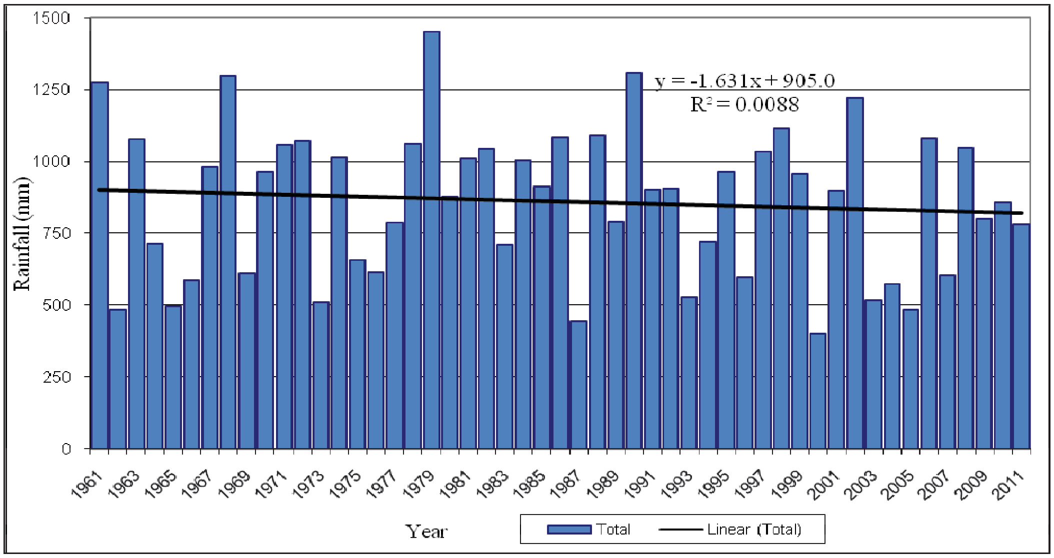

Figure 2: Total annual rainfall (in mm) for Moshi Airport station

Focus group discussions and interviews with key informants revealed that over the past two decades, rains have been highly unpredictable, unreliable and unevenly distributed compared to past years. Furthermore, rainfall distribution varies considerably from one agro ecological zone to another. For example, over the period of 13 years from the year 2000, eight years have experienced droughts while five years have experienced floods particularly in the lowlands.

Discussion with key informants in the highland zone revealed that despite the fact that there has been reduction in rainfall amounts in Materuni and Mruwia villages, it still rains and can still support crops grown there. What was noticed was more of rainfall variability nature rather than decreasing trends. It was learnt that farmers could experience a few years of decreased rainfall amounts then followed by years of adequate and even more than adequate amounts of rainfall. In the lowland zone (Mawala and Kisangesangeni villages), focus group discussions revealed that over years, the amounts of rainfall have been declining to the extent that smallholder farmers did not harvest their crops due to recurrent droughts. The analysis of rainfall data further revealed that from the year 2000, the years with rainfall below average have increased compared to past years. For example, over the past 12 years from 2000 to 2011, data revealed that nine years in the highland zone and seven years in the lowland zone had rainfall below average (Figure 3).

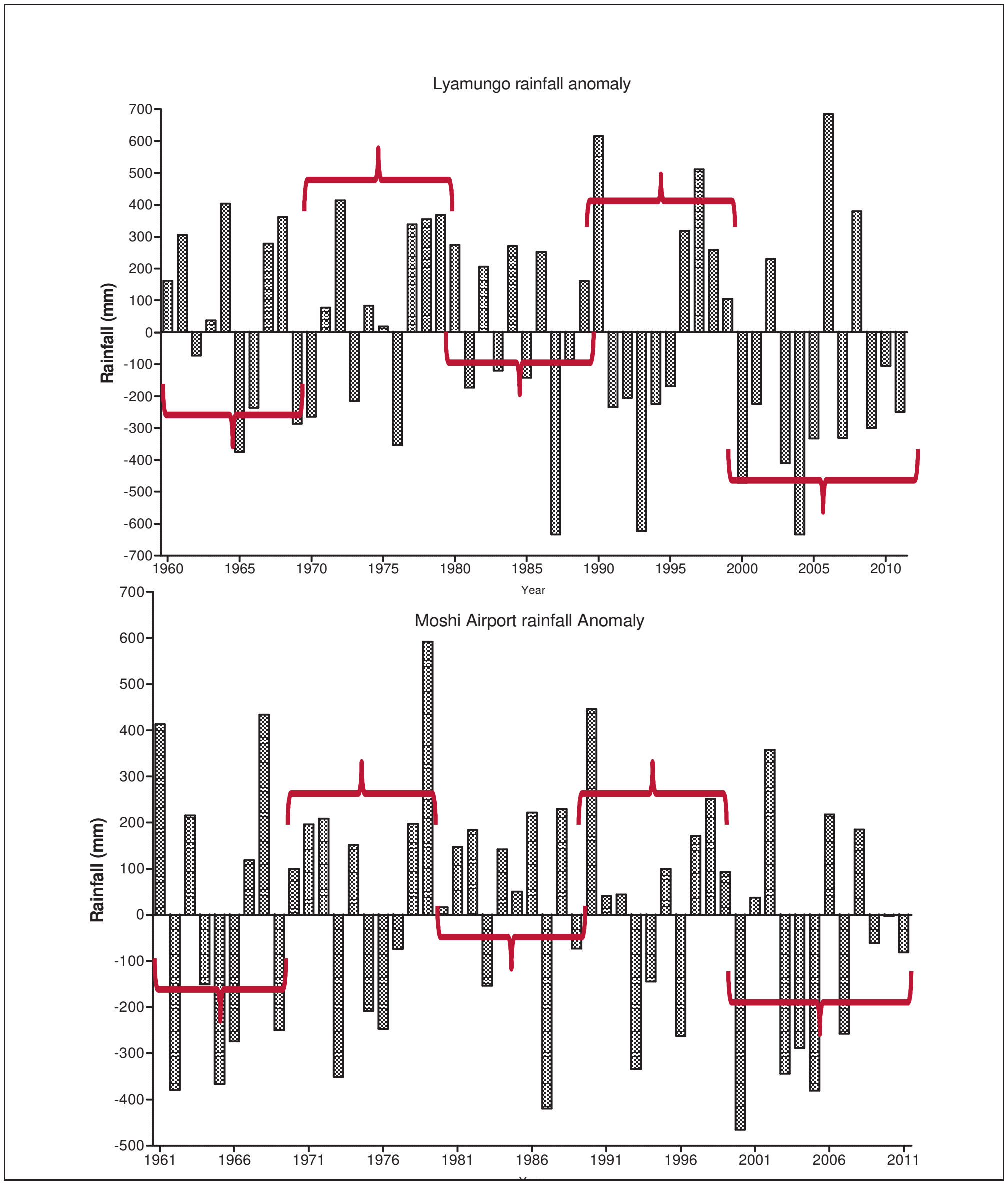

Figure 3: Rainfall anomaly for Moshi Airport and Lyamungo Stations

From Figure 3 it is implied that the frequencies of drought (agricultural drought) and dry spells in the study area are on the increase. Meena and O'Keefe (2007) had similar observations that the frequency of droughts increased tremendously over the past decade, coupled up with famine in Kilimanjaro region. The observed rainfall anomaly in Figure 3 is in line with *El Niño* and *La Niña* years, which are associated with ENSO (Table 2). According to NOAA (2011), strong *La Niña* years are associated with decreased rainfall amounts below normal, while during *El Niño* phase, higher rainfall amounts above normal were received.

Table 2: *El Niño* and *La Niña* years

	Years
Strong *El Niño*	1982/83, 1991/92, 1997/98
Moderate *El Niño*	1986/87, 1987/88, 1992/93, 1994/95, 2002/03, 2004/05, 2006/07
Strong *La Niña*	1988/89, 1999/2000
Moderate *La Niña*	1983/84, 1985/86, 1995/96, 1998/99, 2000/01, 2005/06, 2007/08

Source: NOAA (2011)

Swai *et al*. (2012) noted that rainfall has been more erratic, more unpredictable and continues to decrease in amount in Bahi and Kondoa districts, Tanzania. In the Southern African region, Nhemachena and Hassan (2007) reported that majority of farmers perceived that there was decline in precipitation and that the region was getting drier and there were pronounced changes in timing of rains. Although some literature sources show that East Africa is generally expected to get wetter with climate change, findings in this chapter contradict this generalization. Studies undertaken in Tanzania indicate that areas with bimodal rainfall pattern including northeastern Tanzania (where Moshi rural district is located) will experience increased rainfall amounts (URT, 2003, 2007). However, findings presented in this paper contradict this generalization, where rainfall has shown declining trend.

Smallholder Farmers' Perception of onset and cessation of Rainfall Season

Smallholder farmers in Moshi Rural district also reported changes in onset and cessation of rainy season over the past decades. Thus, 45.4 percent of respondents reported that rainfall started late and ended early in the past two decades compared to what they used to experience since time immemorial. Then 32.6 percent of respondents reported that onset and cessation of rains have not changed (Table 1). One respondent had this to say:

> BOX 1
>
> "When we were still young, there were clear cut differences in the rainy seasons, but nowadays, things have changed. Rains are no longer predictable – we could prepare our fields but stay for weeks or months before it rains. Even when it rains, it rains just for a short period then it stops" (Key Informant (94), Kirima Kati village).

Village analysis revealed that 57.7 percent of respondents in Kisangesangeni village felt that late onset and early cessation of rainfall trends have been on an increase. In Kirima Kati and Kirima Juu villages, farmers were of the opinion that onset and cessation of rainfall have not changed as reported by 38.8 percent and 40.8 percent of respondents respectively (Table 1). The trends of late onset and early cessation of rainfall were reported also in Meatu and Iramba districts. Synnevag *et al*. (2015) reported that farmers in Meatu and Iramba districts noted change in onset of rainfall from September/October to November/December, and cessation of rainfall from May/June to April/May. Hence, such patterns shortened the growing season by approximately two months (*ibid*.). Farmers also reported an increase in duration of dry season compared to the situation in the 1970s.

Smallholder Farmers' Perception of Droughts

Majority of respondents (67.7%) in the study area reported an increase in the frequency and intensity of drought. However, drought frequency differed between the highland and the lowland villages. For example, whereas the majority of respondents from Kisangesangeni and Mawala villages (90.6% and 86.6% respectively) reported increase in the frequency of droughts, in Materuni and Mruwia villages it was reported by only 27.9% and 45.7% respectively. In the highlands, apart from decrease in intensity and duration of rainfall, a common indicator for extended dry spell is the decrease in water sources particularly springs/wetlands and disappearance as well as reduction in river flow. Consequently, most traditional irrigation canals have dried up. In the lowlands, rainfall reduction has been clearly marked. During in-depth interviews, one respondent had this to say:

BOX 2

"Previously, there were plenty of rains, which used to rain consistently but nowadays there is a lot of variability and inconsistency during the rainy season. Temperatures have also increased tremendously especially in recent years. The cold season has also been reduced a lot and we do not have as cold period as we used to have when I was a youth, where one would wear cold clothes throughout the day and use three blankets during the night times to get warm" (Respondent (68), Materuni village).

Similar results were observed by Habiba *et al*. (2012) who found that majority of respondents (92% of owner-cum-tenant farmers) in northwestern Bangladesh reported that drought conditions occurred more frequently in their areas than they used to be in the past 30 years. Farmers in northwestern Bangladesh mentioned that nowadays drought occurs once in every year compared to previous decades (*ibid*.).

Smallholder Farmers' Perception of Changes in Temperature

Results from household survey indicated that 92.5 percent of respondents perceived that there has been an increase in trends of temperature in recent years, and only 5.6 percent reported to have not felt any change in temperature trends, while 1.9 percent reported that temperatures have been fluctuating over time. Increasing temperature was reported more in the lowland villages than highland villages by 98.4 percent, 94.7 percent and 95.1 percent for Kisangesangeni, Mawala and Kirima Kati villages, respectively. Respondents who did not feel changes in temperature were from the highland villages as reported by 11.6 percent and 8.6 percent of respondents from Materuni and Mruwia villages, respectively (Table 1). Smallholder farmers perceptions of temperature are in-line with meteorological data obtained from TMA.

In Moshi rural district, temperature varies greatly between lowland and highland zones mainly due to altitudinal influence. The analysis of historical data from TMA showed a statistically significant increase in maximum and minimum temperature (at 0.05, with p value = 0.0001) in both Lyamungo and Moshi Airport stations. The minimum temperature showed a higher increase compared to maximum temperature. For the period of 51 years from 1961 to 2011, maximum temperature in Lyamungo station increased at about 1.4^{o}C, while the minimum temperature increased by 1.7^{o}C (Figures 4 and 5). On the other hand, over the same period, the maximum temperature records from Moshi airport station increased at about 1.0^{o}C, while the minimum temperature increased by 1.3^{o}C (Figures 6 and 7).

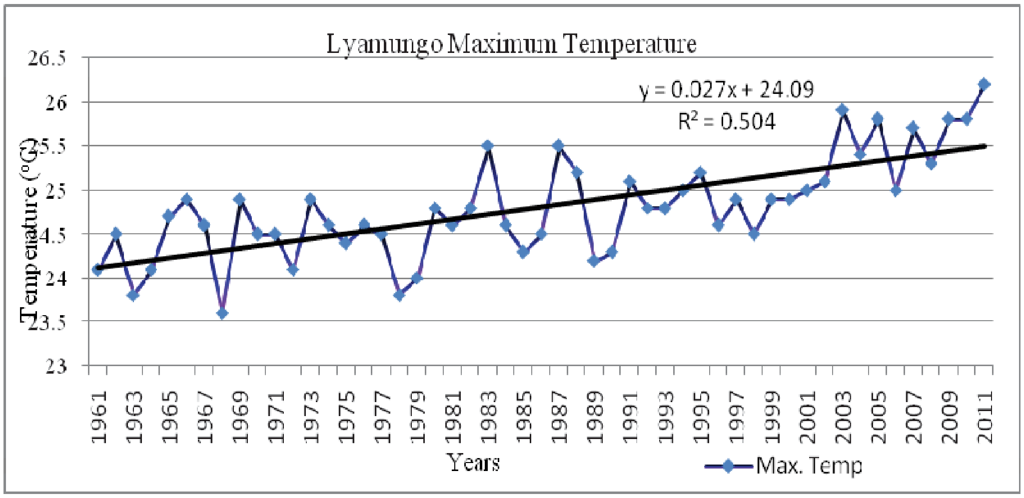

Figure 4: Lyamungo Maximum Temperature

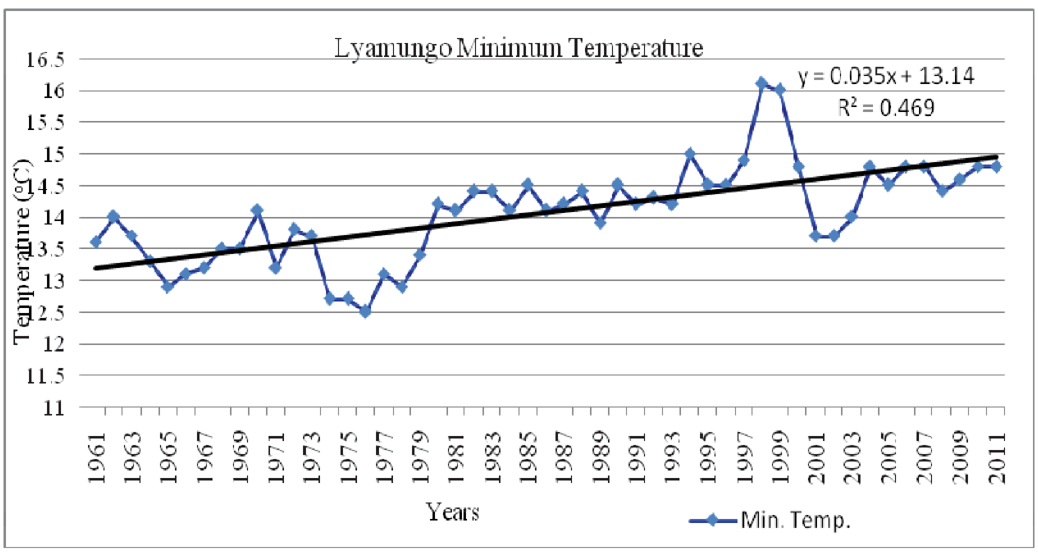

Figure 5: Lyamungo Minimum Temperature

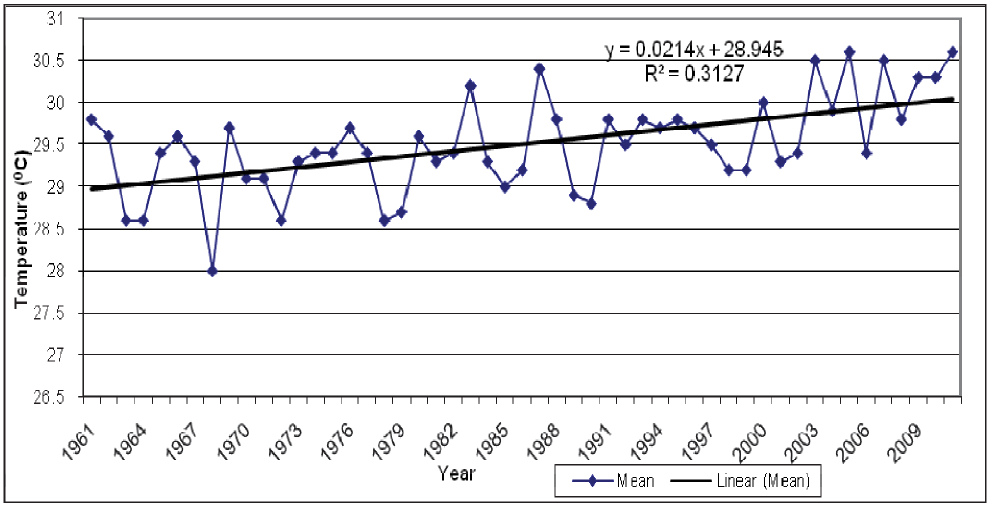

Figure 6: Moshi Maximum Temperature

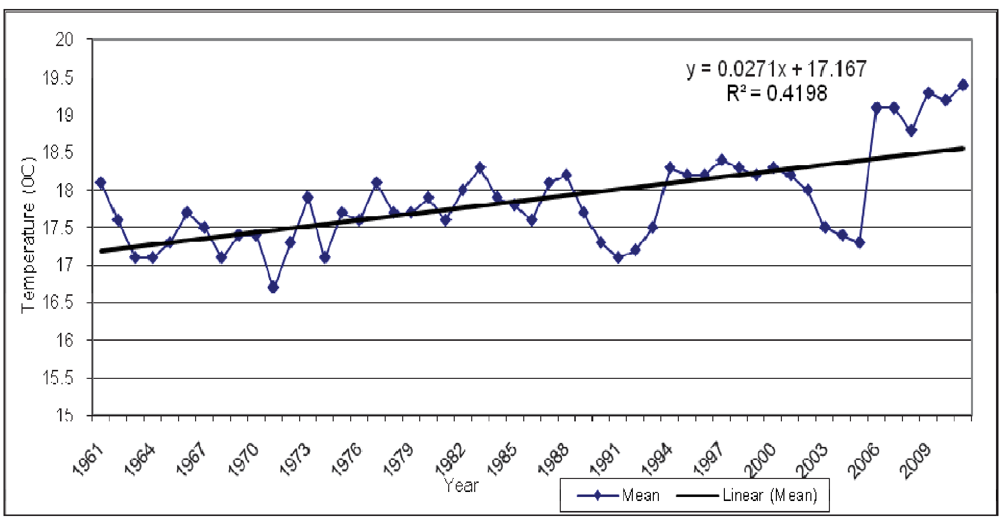

Figure 7: Moshi Minimum Temperature

Furthermore, temperature data analysis at Moshi Airport station showed a higher increase in minimum temperature than maximum temperature. This is evidenced by 42 percent (R^2 = 0.4198) of the observed variance for minimum temperature compared to 31 percent (R^2 = 0.3127) variance of maximum temperature. However, at

Lyamungo station temperature analysis showed a slight higher percentage (50.4%) of the maximum temperature (R^2 = 0.504) than 47 percent of minimum temperature (R^2 = 0.469) from 1961 to 2011. Generally, from the meteorological data analysis, it is evident that the minimum temperatures increased at a higher rate than maximum temperatures. Smallholder farmers also perceived an increase in duration of hot days, indicating that generally temperatures were on the increase. During discussions with key informants, it was pointed out that duration of cold season had decreased tremendously while extending the hot days and dry spells. In-depth interviews with key informants from all three agro-ecological zones revealed that the season that used to be cool or cold has been shrinking and the extent of the coldness in the season was reduced to a greater extent. In due regard, it can be seen that there has been an increase in both minimum and maximum temperatures as evidenced from historical data.

The National Bureau of Statistics (2014) report shows that the highest mean maximum air temperature in Tanzania in the year 2012 was 35.2^{o}C observed at Kilimanjaro station (Moshi airport station). That was followed by Dar es Salaam and Coast station with 33.2^{o}C and Morogoro station with 33.1^{o}C (NBS, 2014). It implies that Moshi district generally was hotter than any other places in Tanzania, and that situation affects not only human systems but also natural systems. Several scholarly studies including Nhemachena and Hassan (2007), Mertz *et al*. (2009), Lema and Majule (2009) and Deressa *et al*. (2011) revealed similar trends in temperature increase. Lema and Majule (2009), for example, reported that in Manyoni district, there has been an increase in temperatures over the past 10 years especially between September and December. Similar trends were observed by Mertz *et al*. (2009) in the West African Sahel region, Deressa *et al*. (2011) in the Nile basin of Ethiopia as well as Nhemachena and Hassan (2007) in southern African region.

Conclusions and Recommendations

Results from this study imply that smallholder farmers in Moshi Rural district were aware of climate change. They noted decreased rainfall amounts, increased temperature and late onset as well as early cessation of rainfall in their area over the past 40 years. Droughts and increased dry spells were also noted in the study area but more specifically in the lowland villages. Such perceptions are in line with empirical evidence from other scientists that showed or predicted an increase in temperature, droughts and decreased rainfall amounts in some parts of Tanzania and Africa, in general.

Rainfall data from Lyamungo and Moshi airport stations have shown inter annual variations with clear evidence of several years of rainfall above and below long-term average. Although the annual total rainfall showed a declining trend of rainfall at a non-significant level, such data cannot be used to make a clear case for or against climate change. The data showed years with extreme high and low rainfall amounts both monthly, seasonally and annually. It was indicated that generally, MAM is the wettest season in the year and it is the main growing season particularly for smallholder farmers who depend on rain-fed farming.

Furthermore, temperatures have clearly shown an increasing trend at both stations where minimum temperatures were higher than maximum temperatures for both stations from 1962 to 2011. At Lyamungo station, maximum temperatures increased by 1.3^{o}C, while the minimum temperature increased by 1.7^{o}C. Moshi airport station recorded maximum temperature increase of about 1.0^{o}C, while the minimum temperature increased by 1.3^{o}C. The study indicated that majority of farmers are aware of climate change. However, they failed to understand the nature and extent of its impacts due to limited access to up-dated climate related information. Therefore, provision of timely, relevant and user-friendly climate information should strategically reach smallholder farmers. Provision of weather and climate related information to farmers would enable them to make well-informed decisions regarding adaptation to climate change. The provision of climate information should be done by the TMA in collaboration with the district agricultural officer and extension officers at all levels.

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