Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.4, No.16, 2014


# Rain-Fed Farming System at a Crossroads in Semi-Arid Areas of Tanzania: What Roles do Climate Variability and Change Play?

Samwel J. Kabote [1*] Delphina P. Mamiro[2] Gry Synnevåg[3] Justin K. Urassa[1] Amon Z. Mattee[4]
Emanuel E. Chingonikaya[1] Jonathan S. Mbwambo[1] Carolyne I. Nombo[1] Leah M. Masolwa[5]
1.Development Studies Institute, Sokoine University of Agriculture, P.O. Box 3024, Morogoro, Tanzania
2. Department of Crop Science and Production, Sokoine University of Agriculture, P.O. Box 3005, Morogoro
3.Department of International Environment and Development, Norwegian University of Life Sciences, Noragric 1432 Ås, Norway
4.Department of Agricultural Extension, Sokoine University of Agriculture, P. O. Box 3002, Morogoro Tanzania
5.Tumbi Agricultural Research Institute, P. O. Box 306, Tumbi, Tabora Tanzania
* Corresponding author: samwel.kabote@yahoo.com

**Abstract**
Positive changes, like adopting drought resistant crop varieties, in the rain-fed farming system (RFFS) in response to climate variability and change enhance system's ability to support people's living as opposed to negative changes, like lack of pastures, which put the system at risk of failure in supporting the living. Using participatory rural appraisal (PRA) and household survey, this paper examined the roles of climate variability and change in triggering changes in RFFS. Specifically, the paper: (i) assessed dominant crop and livestock farming system; (ii) assessed the change element of crop and livestock production systems; and (iii) examined factors for the changes in RFFS. A random sample of 388 households was used. Qualitative data analysis was done through content analysis. Binary logistic regression was used to assess factors that explain changes on RFFS. The results showed that dominant crops were different in each village. Secondly, some changes in crop varieties and in livestock grazing arrangements were noted in response to climate variability and change. Unlike the hypothesis ($P>0.05$), the results demonstrated that warming ($ß = -10.61$, Wald = 36.26, $P \leq 0.001$) showed highest significant impact on likelihood of adopting new crop varieties relative to other factors. Similarly, drought ($ß = 2.16$, Wald = 6.82, $P \leq 0.009$) showed highest impact on the likelihood of changing a grazing place. Yet, the changes were constrained by factors like natural resources protective policies, failure of crop varieties to withstand warming and drought, and poor land use management. Therefore, the RFFS was at a crossroads with implications on system sustainability and livelihoods. The government and private interventions should support farmers and agro-pastoralists to manage risks related to the changes in RFFS in response to climate variability and change.
**Keywords**: Climate change, agro-pastoralism, livelihoods, semi-arid, Tanzania

## 1. Introduction

Climate change, as a concept is defined in almost every academic work that addresses concerns of climate variability and change (O'Brien *et al.,* 2006; IPCC, 2007; FAO, 2008). The most cited definition of climate change is that of the IPCC (2007), which defines climate change as a long-term change in statistics of rainfall, temperature and extreme weather episodes. Climate variability on the other hand, is defined as temporal and/or spatial variations of the mean state and other weather statistics of the climate beyond individual weather events (IPCC, 2007). These phenomena have potential impacts on sectors including water, food and nutrition, agriculture, human health, ecosystem, and infrastructure (IPCC, 2014). The impacts are differentiated by geographical location, gender and wealth status. Women are more affected because of asymmetrical gender relations (Nombo *et al.,* 2013). On the other hand, semi-arid agro-ecological zones are more vulnerable mainly due to unfavourable climatic environment and over dependency on the agricultural sector and natural resources, which are sensitive to climate variability and change (Senkondo *et al.,* 2004; Sarr, 2012; Milan and Ho, 2014).

Rainfall is more variable in semi-arid areas[1] (UDSM, 1999; Huang *et al.,* 2012). Literature defines semi-arid areas based on its climate especially rainfall. However, based on range of rainfall the definition is not consistent. As such, some scholars do not differentiate semi-arid from arid areas (Huang *et al.,* 2012; Sarr, 2012). Thus, this study takes the range of rainfall in semi-arid areas to be between 400 mm and 900 mm per year. Semi-arid areas are also characterized by drought, inadequate soil moisture, soil infertility, higher day time temperature and higher evaporation that exceed precipitation (Senkondo *et al.,* 2004; Vette, 2009; Mongi *et al.,* 2010).

[1] Some scholars have defined these areas as ones having a mean annual rainfall of as low as between 200 and 600 mm (Huang *et al.,* 2012; Sarr, 2012). Others give a range between 500 and 800 mm per year (URT, 2007; Mongi *et al*., 2010); while some report mean annual rainfalls, which range between 600 and 800 mm (UDSM, 1999).

 

Agriculture and pastoralism are major farming systems in semi-arid areas. Farming system[2] has been defined (composed of sub-systems) as a broader and complex relationship of farm enterprises (FAO, 2008; Dixon *et al.,* 2001; Behera and Sharma, 2007). The concept is taken in this paper to mean a set of inter-related, interacting and interdependent elements acting together to support livelihoods and is capable of reacting as a whole to climatic and non-climatic factors. The paper also takes a system that entirely depends on rainfall as a rain-fed farming system (RFFS). Its components that basically interact together and, which are managed by farming households include crops, animals, soils, labour, capital, land, power and technologies used (Dixon *et al.,* 2001; Behera and Sharma, 2007).

The impact of climate variability and change on RFFS is overarching in Africa and Tanzania in particular (IPCC, 2007; Sarr, 2012). In addition, the phenomena interact with non-climatic factors like economic (market, input, and credit), political factors (institutions), social and cultural (tenure, taboos, local beliefs, marital institutions, religion and food preference), household priorities (food and income), biological (pests and diseases) and resource factors (land, knowledge and labour) (Behera and Sharma, 2007) in affecting the RFFS. Maddison (2006) also assert that social economic characteristics of the household like household size, age of the household head, respondents' sex, occupation and education level of the household head influence changes on RFFS. This paper conceptualizes changes in RFFS in response to climate variability and change that can improve crop production and livestock keeping as positive changes while those changes, which threaten RFFS, are taken as negative changes.

Studies on the impact of climate variability and change are numerous in Sub-Saharan Africa (SSA) and more specifically in Tanzania, but most of them focus either in livestock (Galvin *et al.,* 2001) or in agriculture (Paavola, 2008; Mongi *et al*., 2010; Lema and Majule, 2009; Swai *et al.,* 2012; Juana *et al.,* 2013; Legesse *et al.,* 2013). On the other hand, studies which focus on changes in both agriculture and livestock, like Meena *et al*. (2008) and Mbilinyi, *et al.* (2013), in response to climate variability and change are limited in the country. This means that most of the existing studies divide RFFS into single components with an idea that results from the components can be added to one another (Darnhofer *et al.,* 2008). This approach tends to overlook important things including factors that affect the entire RFFS and, therefore, can hardly help to understand system changes and how to deal with them comprehensively. While information on the change process of RFFS in response to climate variability and change is scarce; crop failure, scarcity of water and pasture are on the increase (Lema and Majule, 2009).

Using system thinking approach, which views a farm as one system, and that change in one part affects other system organization (Darnhofer *et al.,* 2010); this paper examined the role of climate variability and change in triggering changes in RFFS in semi-arid areas. The paper takes a broader view of climate variability and change by considering different manifestations of the phenomena based on farmers' perceptions and empirical literature (Maddison, 2006). Thus, the paper contributes knowledge on the changes in RFFS in response to climate variability and change. Specifically, the paper: (i) assessed dominant crop and livestock farming system; (ii) assessed changes in crop and livestock production systems; and (iii) examined major predictors of the changes in RFFS. The results from this study are important in choosing policy interventions in crop and livestock production systems to manage risks of climate variability and change. The results can also help smallholder farmers be able to address risks associated with climate variability and change. The next sections describe the study areas, methodology and discuss the results. Finally, the paper winds up by presenting conclusions and recommendations.

## 2. The study area

This study was conducted in Meatu District found in Simiyu Region and in Iramba District found in Singida Region. As described by Kabote *et al*. (2013), Meatu District lies between latitudes $3^o$ and $4^o$ South and longitudes $34^o$ and $35^o$ East, and its altitude ranges between 1000 and 1500 m.a.s.l. The district's vegetation is characterized by shrubs and thorny trees scattered or clustered in some areas. Most parts in the southern zone of the district have bare soils especially during dry seasons compared to the northern zone. On the other hand, Iramba District lies between $4^0$ to $4^0.3^,$ latitudes South and $34^0$ to $35^0$ longitudes East. Vegetation is mainly natural including Miombo woodlands, acacia woodlands and grasslands. More trees are found on hills compared to flat terrains in the low lands.

The mean annual rainfall in Meatu District ranges between 400 and 900 mm in the southern and northern agro-ecological zones of the district, respectively and rainfall regime is unimodal. Iramba District on the other hand, receives a mean annual rainfall of between 500 and 850 mm. Surface temperature in the district ranges between 150C in July and 300C in October (Iramba District Council, 2009). Excluding district headquarters at Kiomboi in Iramba and Mwanhuzi in Meatu, the other areas are rural, dominated by smallholder farmers and agro-pastoralists. The districts were selected because: (i) crop failure has increasingly become

[2] See Behera and Sharma (2007) for more definitions of farming systems and its classification

common each year. This necessitates the district authorities to provide food aid for the people to address hunger problem. (ii) The districts are contiguous. This was important to assess variations in rainfall and temperature between adjacent districts lying entirely in semi-arid areas dominated by different ethnic groups. (iii) Livelihoods in both districts depend on crop production and agro-pastoralism. However, dependence on rainfall exceeds 95% (NBS, 2009). The study involved three villages including Kidaru in Iramba District, Singida Region; and Mwashata and Mwamanimba in Meatu District, Simiyu Region (Fig. 1). These villages lie entirely in semi-arid agro-ecological zone in which rainfall is already uncertain even without climate variability and change (Kabote et al., 2013). The criteria for village selection were based on the history of frequency of drought, crop failure, hunger and history of receiving food aid, which have increasingly become common in the past ten years. This information was provided by the district agricultural officers.

## 3. Methodology

### 3.1 Research design

The study adopted a cross-sectional design in order to examine the current situation (Mann, 2003). Data collection and analysis took place in two stages. Participatory rural appraisal (PRA), mainly focus group discussions (FGDs), preceded, household survey. Thus, the first stage informed the second stage (Bryman, 2006). The results from the two stages were integrated so as to expand the scope and improve quality of the results (Sandelowski, 2000). This approach is known as exploratory sequential research design (Gilbert, 2010). The study used a household as a unit of analysis during the survey because of its responsibility in decision making on resource use (Darnhofer *et al.,* 2010). Respondents were visited at home, and either the household head or spouse was interviewed depending on availability. Table 1 shows proportions of males and females interviewed during a household survey. It was important to involve men and women in order to capture men's and women's views.

### 3.2 participatory rural appraisal

Participatory rural appraisal (PRA), mainly focus group discussions (FGDs), involved household heads and spouses, farmers and agro-pastoralists. This aimed at enabling participants to take part in the analysis of the issues under study (Chambers, 1994). The study involved a total of seven FGDs, encompassing 63 participants. The plan was to have 6-12 members per FGD (Masadeh, 2012) for effective participation and good quality of data, but participants ranged from six to 14 because some members came without being invited. There were separate groups for men and women to capture views from each group because, traditionally, women in the Sukuma[3] community do not speak freely in the presence of men participants. The study learned in Kidaru that women could also not speak freely. This also justified a need to have separate men and women groups. Discussions were tape recorded. Agriculture and livestock extension officers were consulted only for clarification of some technical issues. Characteristics of FGDs participants are presented in Table 2.

### 3.3 Household survey

A structured questionnaire was administered to 388 randomly selected respondents drawn using systematic random sampling techniques. The social economic characteristics of respondents are presented in Table 3.Ten respondents at Mwakasumbi village participated during pre-testing of the questionnaire to ensure validity and reliability. Sampling frames were prepared for each village by listing names of all household heads. The listing did not follow any specific arrangement in order to minimize bias during sampling (Kothari, 2004). A random sample from each village was selected from the list of names after a certain sampling interval that was obtained by dividing the total number of households in the village by the predetermined sample size in that village. Simple random sampling was applied to select the first respondent whereby each name in the first interval was written on a piece of paper and then put together in a basket from which one paper piece was picked. The name on the piece of paper that was picked from the basket earmarked the beginning of the systematic sampling. In order to minimize sampling error and improve quality of research results, a sample should be neither too small nor too big (Bartlett *et al.,* 2001). Interviews to fill the questionnaires were done at respondents' homes after prior information. The questions asked were closed ended to capture climate and non-climatic factors which explained adoption of improved crop varieties and changes in grazing arrangements. The sample size was determined using the formula as presented by Kothari (2004).

$$n = \frac{z^2 * p * q}{e^2} \quad \text{.......Equation (i)}$$

[3] Ethnic group that dominates in Shinyanga, Mwanza, Geita,Tabora and Simiyu Regions including Meatu District

Where:
z = the value of the standard variate at a given confidence level usually 1.96 at 95% confidence level; n = sample size; p = sample proportion, for maximum n, p = 0.5; q = 1-p that is: 1-0.5 = 0.5; and e = precision or margin of error which is normally 0.05 (5%) at 95% confidence level. Substituting the values we get n = 391. However, the sample size used was 388 because, 3 copies of questionnaires were not filled properly and therefore were discarded. Based on the total number of households, which was, during data collection 444 in Kidaru; 462 in Mwashata and 315 Mwamanimba villages respectively, making a total of 1201 households, the following formula was used to estimate the sample in each village.

ni = n*pi........................................................................................Equation (ii)

Where: pi = proportion of households in a village; and n = total number of households and $n_i$ = selected sample per village. The proportion (pi) of households in each village was calculated by taking number of households in a village divided by total number of households in the three villages which was 1201. By substituting the values in equation (ii) we get the following number of selected households in each village as presented in Table 4.

**3.4 Data analysis**
The analysis of qualitative data involved transcriptions of tape recorded information into text before being organized into specific themes based on the objectives of the study. Quantitative data were analyzed using the Statistical Package for Social Sciences (SPSS). Based on size of land and ownership of livestock especially cattle, ability to hire labour, and also based on the households' food security, Nombo *et al.* (2013) classified households in the study area into the rich, the poor and the not so poor. Therefore, the current study used this classification to quantify the magnitude of some variables. A binary logistic regression as explained by Chan (2004) and Peng *et al.* (2002) was used to test the hypothesis that climate and non-climatic factors have the same impact ($P \geq 0.05$) on adopting improved crop varieties and also on changing grazing arrangements including where to graze the livestock.

Interpretation of the output from the model focused on β-coefficients for measuring the directions of the impact (positive or negative) of predictor variables; Wald statistics for measuring the magnitudes of the impact; p-values for testing significance of the impact, and odds ratios (EXP(B) values) for predicting the number of times various predictor variables have chances relative to one another regarding adoption of improved varieties and change of grazing areas. The binary logistic regression model used is shown in equation (iii).
$\text{Log}\,[Pi/1\text{-}Pi] = \beta_0 + \beta_1X_1 + \beta_2X_2 + ... + \beta_{13}X_{13}$…………………………Equation (iii)
Where:

Log [Pi/1-Pi] = Natural logarithm of the odds for adopting improved varieties or change on grazing place; $\beta_0$ = Constant; $\beta_1$ to $\beta_{13}$ = Logistic regression coefficients of the predictor variables, $X_1$ = insufficient rainfall, $X_2$ = increased warming, $X_3$ = increased drought, $X_4$ = rainfall unpredictability, $X_5$ = early cessation, $X_6$ = extension services, $X_7$ = market, $X_8$ = respondents' sex, $X_9$ = food preference, $X_{10}$ = respondents' age, $X_{11}$ = respondents' years of schooling, $X_{12}$ = household size and $X_{13}$ = occupation. For change on grazing places, predictor variables were: $X_1$ = insufficient rainfall, $X_2$ = increased drought, $X_3$ = agriculture expansion, $X_4$ = government policies, $X_5$ = respondents' sex $X_6$ = respondents' age, $X_7$ = years of schooling and $X_8$ = household size. The variables entered in the model were derived from farmers' perceptions (Appendix 13). Only maize and sorghum were involved in this analysis because FGDs reported change in varieties for these crops for the past 30 years. Both dummy and continuous predictor variables were used while the two dependent variables were binary (Table 5).

**4. Results and discussion**
**4.1 Farming systems and climate variability and change**
The qualitative results collected during FGDs showed that the dominant crops differed by villages. Sorghum was grown mainly at Mwamanimba, bulrush millet at Kidaru and maize at Mwashata and Mwamanimba. These results were in line with quantitative results presented in Table 6. The association between types of crops grown per village was significant ($p \leq 0.01$). According to Healey (2005), the Phi-values[4] greater than 0.3, which are shown in Table 6, indicate strong association. This difference was mainly due to differences in the amount of rainfall received in the villages. This is supported by the moisture requirements for each crop presented in Table 7.
The northern part of Meatu where Mwashata is located, receives up to 900 mm of annual rainfall relative to Kidaru and Mwamanimba, which on average receive annual rainfall of 550 mm and 400 mm respectively

[4] The Phi-values between 0.00 and 0.1 would suggest weak association, whereas the Phi-values between 0.11 and 0.30 would mean moderate association (Healey, 2005).

(Iramba District Council, 2009; Meatu District Council, 2009). For the period between 1994 and 2011, a seasonal rainfall in Meatu and Iramba for a six-month period from November to April ranged between 669.6 mm and 777.4 mm respectively (Kabote *et al.,* 2013). Based on the moisture requirements reported by TARO (1987a-e), such seasonal rainfall favoured sorghum in Mwamanimba, maize in Mwashata, bulrush millet and sunflower in Kidaru and Mwamanimba. Other climatic factors that affected crop production as reported during FGDs are presented in Table 8. The month when rainfall started and when it ended and the changes since the 1970s were quantified during household survey and presented in Table 9 and 10.

As reported in Table 8, the major four threatening manifestation of climate variability and change were drought, rainfall unpredictability, late onset and early cessation of rainfall. The changes in onset of rainfall were mainly from September to November in the 1970s to November or December in the 2013. End of rainfall had also changed mainly from May or June in the 1970s to March or April in the 2013. This is supported by Kabote *et al.* (2013) who implicated decreasing meteorological rainfall trend in April with early cessation of rainfall in Meatu and Iramba. These changes in rainfall patterns had affected the whole cropping system as reported by the male FGD at Mwamanimba:

> "...In the 1970s, we planted sorghum in September or October and harvested in July...we planted maize from December to February and harvesting period for maize began in April...today we are not sure on which date we can start planting sorghum or maize because the rainfall onset had become more variable..." (Mwamanimba, 25th January 2013).

That quotation justified that changes in RFFS were inevitable to minimize crop failure due to changes in rainfall patterns. In addition, FGDs reported that crop insect pests, diseases and the February dry spell[5], did not affect maize yields when planted during February in the 1970s. In addition, the dry spell had extended back to January thus interrupting the crop growing period. Mongi *et al.* (2010) also reported similar results. In addition, uncertainties in the cropping calendar due to climate variability and change is also reported by Darnhofer *et al.* (2010). The results also showed that agro-pastoralism was widely practised (Table 11). This was not surprising because agro-pastoralism is common in semi-arid areas where climatic conditions do not favour crop production (Vetter, 2009). The p-values in Table 11 show that there was significant association between livestock keeping, except for keeping donkeys, and wealth status. Similar results were reported by Nombo *et al.* (2013). The association showed that the majority of the rich kept livestock compared to the poor and the not so poor households. Using the Phi-values shown in the last column in Table 11, it can be deduced that the association between livestock keeping and wealth status was moderate because the Phi-values ranged from 0.11 to 0.29 (Healey, 2005).

### 4.2 Changes in crop and livestock production systems

The results from (FGD) showed that sunflower was adopted between 2008 and 2010 as a cash crop in Mwashata and Mwamanimba, and in the 1990s in Kidaru village. This crop had replaced cotton in Kidaru because, as reported in the previous section in this paper, the village received less amount of rainfall, which was appropriate for sunflower (600 mm to 1000 mm), but not for cotton that needs 850 mm to1100 mm of rainfall per year (TARO, 1987e; 1987d; Chapagain *et al.,* 2006). Climatic conditions, in addition to price failure for cotton following adoption of the free market policies established in the 1980s and 1990s, accelerated adoption of sunflower. Changes in crop production are summarized as follows:

> "...It is possible to experience crop failure every year due to drought and rainfall unpredictability...rainfall may start earlier, but it can also end earlier in April compared to the situation in the 1970s when it used to end in May or in early June..." (Male FGD, Mwashata, 22nd January 2013).

The quotation implies that the changes in rainfall patterns had occurred, which were affecting crop production. This was also mentioned in the women FGD in Mwashata. At Mwamanimba, FGDs reported that drought occurred consecutively since 2003. At Kidaru, on the other hand, FGDs reported that drought occurred eight times while at Mwashata it was reported that drought occurred seven times over the same period. This stimulated adoption of drought resistant crops like bulrush millet – positive changes – particularly since the 1980s. This crop had disappeared in Mwashata and Mwamanimba because it is less preferred by the Sukuma relative to the Nyiramba, and also due to bird infestation (Nombo *et al.,* 2013).

[5] A dry spell is a sequence of at least 15 consecutive dry days with less than a threshold value of rainfall, greater or equal to 1.0 mm per day. This period normally occurs at a certain time during the rainy season. Such a period can sometimes be abnormally long, but it is shorter and not as severe as drought (Mathugama and Peiris, 2011).

The household survey data presented in Table 12 explicitly showed that 66% of the rich households adopted improved maize varieties. This can also be interpreted that the poor and the not so poor were more at risk of being affected by climate variability due to inability to adopt improved seed varieties. However, there was no significant association between adoption of maize varieties and wealth status at 5% (Table 12). The same Table also shows that 64% of the rich and 53% of the not so poor did not adopt improved varieties of sorghum. This implies that majority including the poor and not so poor, were unable or unwilling to adopt improved varieties of sorghum. There was also no significant association between adoption of improved varieties of sorghum and wealth status at 5% (Table 12). Notably, FGDs reported that even improved varieties of sorghum were not able to withstand drought. This was a negative change that suggests a need for different crop varieties. Discussions during FGDs also showed that some households had adopted improved varieties of maize and sorghum (Table 13) as a response to climate variability and change, especially drought. Sources of improved varieties were mentioned to include District Agricultural and Livestock Departments and private agro-dealers[6] in Bariadi, Mwanhuzi and Kiomboi. In many cases, harvests in one year were used as seeds in the next year implying that supporting smallholder farmers in terms of improved varieties is essential to manage risks of climate variability and change.

Qualitative results also revealed that livestock deaths had increased relative to the situation in the 1970s. This was due to anthrax and rift valley fever. Insufficient knowledge on disease control among agro-pastoralists exacerbated livestock deaths leading to decrease in the number of livestock. In addition, seasonal movements of agro-pastoralists usually led by adult men, leaving behind women, girls and elders, to other regions, within the country, like Rukwa, Tabora, Kigoma, and Morogoro Regions in search for pasture and water contributed to the decrease in number of livestock as well. Similar results in increased mobility were also reported by Afifi *et al*. (2014) in northern Tanzania. This implies that mobility of agro-pastoralists in response to drought is a common phenomenon in the country.

In addition, drought had increased distance, duration and frequency of movements of agro-pastoralists. For instance, duration to stay away with the livestock searching for water and pasture had increased from two months in the 1970s to six months or more by 2013. Similar results are also reported by Mongi *et al.* (2010). Consequently, small herds, ox-plough and weak livestock could only be found in the villages throughout the year. Mobility also involved bigger herds of goats and sheep (500 and more), which was not the case in the 1970s.

In addition to seasonal movements, qualitative results showed that agro-pastoralists adopted practises like purchase of grazing areas, grazing in own household plots, grazing in conserved areas at Mwashata and Mwamanimba in Meatu, and grazing up the hills in the conserved forest along the Great East African rift valley at Kidaru. Communal conservation of pasture areas locally known as Ngitiri had disappeared in Meatu due to increased demand for land caused by agriculture expansion responding to climate variability and change. Qualitative results also showed that, at Kidaru, natural resource conservation policies allowed grazing up the hills, but not agriculture activities to avoid deforestation and environmental degradation in general. On the other hand, the game reserve policies prohibited grazing activities in the game reserve in Meatu. Thus, conflicts and killings were reported between agro-pastoralists and conservation authorities at Mwamanimba and Mwashata villages. Yet, the game reserve had increasingly become potential for grazing livestock as a consequence of drought and agriculture expansion since the 1970s. To stress this, one of the male FGD participants at Mwamanimba summarized his views by saying:

> "…grazing livestock in the Maswa Game Reserve is part of life…this will stay forever unless pasture and water scarcity problems are addressed…"

That quotation can be interpreted that stopping grazing activities in conserved areas in Meatu was difficult. This suggests strengthening of institutions and interventions that govern use of pasture and water in conserved areas. Prolonged drought had also prompted agro-pastoralists to dig water holes in lowlands and along the rivers in search of water for the livestock and also for domestic use since the 1980s. Interestingly, FGDs reported that depths for the water holes increased over time definitely due to increased drought. Mattee and Shem (2006) and Mati *et al*. (2005) also reported presence of water holes for livestock in semi-arid northern Tanzania and in Kenya. The results of this paper also showed that rivers had increasingly become seasonal; making water scarcity a serious problem even during wet seasons.

[6] Retail distributors of agricultural inputs such as seeds, tools, pesticides and fertilizers

 

## 4.3 Changes in interaction between crop and livestock production systems

As reported in the previous section in this paper, seasonal movements of livestock occurred in response to factors like drought, population increase and agriculture expansion. Movement of livestock occurred between January and July in Kidaru and Mwashata mainly to address lack of agricultural land exacerbated by increased human population and agricultural expansion. This was justified by a male FGD at Mwamanimba as follows:

> "...Unlike in the 1970s, when we grazed our livestock within or nearby our village...we are now moving our livestock seasonally to give way for agricultural activities...in the 1970s, we grazed anywhere without any problem, but now we are sometimes purchasing places for grazing..." (Male FGD, Mwamanimba, 26$^{th}$ January 2013).

That quotation implies that crop production interacted with seasonal movement of the livestock because of dwindling grazing places. It was difficult to separate agricultural expansion and manifestations of climate variability and change that triggered the interactions. Livestock were taken off to open a window for crop production. During the dry season (July to December), livestock were taken back in the study area. At that period, crop residues provided feeds for the livestock, but only from the own household farm.

At Mwamanimba, on the other hand, livestock were moved from the villages during dry seasons when pasture and water were scarce. Moving back to the villages was during growing seasons in which livestock had to feed mainly in the own household farm. Unlike at Mwashata and Kidaru, the driving factor for seasonal movements of livestock at Mwamanimba was mainly lack of pasture as a direct consequence of drought. Since the 2000s, seasonal movements had become more complicated. This practise reduced household labour force from men and boys who were involved in the mobility. Similar results are reported by Rademacher-Schulz *et al*. (2014) in northern Ghana. This can negatively affect food production contributing to poor nutrition for women, elders and children who did not participate in the mobility. Poor nutrition for women has implications on child nutrition and health. However, seasonal migration to urban areas, which does not involve livestock movements, supports livelihoods in Peru (Milan and Ho, 2014).

Although FGDs supported by Rademacher-Schulz *et al*. (2014) reported decrease in herds of livestock due to deaths caused by diseases, observation revealed that the herds were still bigger with some households owning more than one thousand cattle. This, in addition to drought and poor land use management system; whereby there was no land allocated for different use like agriculture, grazing and human settlement, put crop and livestock production at a crossroads. Therefore, men and boys in agro-pastoralist households were temporally or sometimes permanently separated from their families, in a way to searching water and pasture. Unlike in the 1970s when livestock grazed anywhere within a village, the situation had changed due to dwindling of grazing areas. Crop residues after harvesting period had increasingly become an important source of livestock feeds. As such, interactions between crop and livestock keeping seemed to be important for supporting livelihoods in the study area. In addition, seasonal movements affected both men and women, but women appeared to be more affected. The FGDs at Kidaru justified by reporting that:

> "...men and women are affected by seasonal movements of husbands and boys who take the livestock up the hills…last year (2012) two boys were injured...women, children and the aged left at home, can live in hardship especially during food shortage periods..." (Mixed men and women FGDs, Kidaru, 31$^{st}$ May, 2013).

In addition, as men and boys stay longer away from their families, gender relations in the long-run are subject to change due to change in gender roles. Women in absence of the husbands are likely to perform men's roles (Nombo *et al.,* 2013). This can disadvantage women because they are already overburdened by domestic chores due to unequal gender relations (IPCC, 2014). Nevertheless, perhaps because of ignoring gender dimension in their studies, some scholars have concluded that seasonal movement of livestock in semi-arid areas is critical for optimal utilization of pastures (Mattee and Shem; 2006; Rota, 2009). On the other hand, for many years, Tanzania's national policies have been pushing for sedentarization with argument that such movements pose serious environmental degradation and desertification.

## 4.4 Major predictors of the changes in the RFFS

The previous section in this paper demonstrated that both climate and non-climate factors contributed to changes in the rain-fed farming system (RFFS) particularly adopting improved crop varieties and practising new grazing places. Using binary logistic regression model, it was essential to determine which one between climate and non-climatic factors played a great role on triggering the changes. The dependent variables were adoption of new crop varieties and changing a grazing place (Table 16). The Hosmer and Lemeshow test showed that the model fitted well the data ($P > 0.05$) (Table 14 and 15).

The results in Table 16 showed that adopting new crop varieties was prominent at Mwashata followed by Mwamanimba. Notably, as reported during FGDs, adoption of new crop varieties was higher in maize and sorghum relative to other crops in the study areas. On the other hand, changing a grazing place was prominent at Mwanimanimba relative to other villages (Table 16) because of lack of pastures aggravated by drought. Descriptive statistics for independent variables entered in the model are presented in Table 17.

The empirical results showed that, out of 13 variables entered in the binary logistic regression model, increased warming showed highest significant contribution to the likelihood of adopting improved crop varieties (maize and sorghum) at 0.1% followed by early cessation, which was significant at 0.2%. Other variables which showed significant contribution include increased drought, which was significant at 0.5% and insufficient rainfall, which was significant at 0.7%. Food preference and respondents' sex were significant at 2%. The rest variables were not significant at 5% level of significance (Table 18), though had some influence as reported in the previous sections in this paper and also as demonstrated by Maddison (2006).

The positive sign on ß-coefficients implies that such variables increased respondents' likelihood to adopt new crop varieties as opposed to the negative sign. Using Wald statistic values, Table 18 shows that warming had highest impact (ß = -10.61, Wald = 36.26, $P \leq 0.001$) on the likelihood of adopting improved crop varieties relative to other factors including non-climatic factors. The odds ratio for warming was 0.000 suggesting that for every unit increase in surface temperature there would be no change on the respondents' likelihood to adopt new improved varieties. Arguably, warming overlapped with variables like drought and early cessation of rainfall such that it was difficult to disentangle them. This posed serious challenges to smallholder farming as an enterprise. Using meteorological data, Kabote *et al.* (2013) also reported similar results. Serious rainfall variability that negatively affects farming activities has also been reported in various places over the global (IPCC, 2014), like India (Murali and Afifi, 2014) and Ghana (Rademacher-Schulz *et al.,* 2014).

Quantitative results in Table 19 showed that, out of 8 variables entered in the model, increased drought was significant at 0.9% while agricultural expansion and insufficient rainfall were significant at 1%. Using Wald statistic values, the results also showed that drought had the highest impact (ß = 2.16, Wald = 6.82, $P \leq 0.009$) on the likelihood of adopting new grazing places, far away as opposed to the 1970s, when agro-pastoralists grazed the livestock anywhere within or nearby the village of domicile. The results also showed that the odds ratio for drought was 8.70. This can be interpreted that drought had over eight times likelihood of causing changes in grazing places relative to other variables. The rest variables were not significant at 5% level of significance. The demand for agricultural land was high due to increased population. Nonetheless, it was difficult to disentangle agriculture expansion, drought and insufficient rainfall because farmers expanded their farm size in response to climate variability and change (Table 19). Nombo *et al.* (2013) also reported that smallholder farmers had to expand their farm size to minimize the impact of climate variability and change in Meatu and Iramba.

Arguably, pastures had decreased because of dwindling grazing places as a consequence of climate variability and change. This required smallholder farmers and agro-pastoralists to change their grazing arrangements and therefore the distance to move with the livestock seeking for pastures increased, which in turn reduced time required by agro-pastoralists to engage in crop production. This had definitely caused food insecurity. Rademacher-Schulz *et al.* (2014) also reported that increased mobility among smallholder farmers caused food insecurity in Ghana. In addition, adopting new crop varieties and grazing arrangements to cushion the impact of climate variability and change was unavoidable for sustainable rain-fed farming system (RFFS). However, existing crop varieties failed to withstand warming and drought, which intertwined with agriculture expansion. Also, conservation policies particularly in Meatu, reported in this paper put the system, especially livestock keeping, at a crossroads such that the policies were protective on use of pastures in conserved areas.

## 5. Conclusions and recommendations

Based on the results and discussion of this paper, the following conclusions are made: firstly, unlike the hypothesis ($P > 0.05$), manifestations of climate variability and change showed significant impact on adopting crop varieties and changing grazing places relative to non-climatic factors. Warming, drought and agriculture expansion showed the highest impact on adopting improved crop varieties and on changing grazing places compared to non-climatic factors. Nevertheless, the changes on improved crop varieties and new grazing arrangements were constrained by issues like protective natural resource conservation policies and inability of existing improved crop varieties to withstand climatic changes. Secondly, climate variability and change had increased the need for crop-livestock interactions, but poor land use management constrained these interactions, meaning that climate variability and change had negative outcomes on the RFFS. The changes in RFFS could clearly be understood through system thinking approach, which takes on board climatic and non-climatic factors. Therefore, the RFFS was at a crossroads.

Based on the conclusions, the following recommendations are made: first, interventions promoted by the government and Non-governmental Organizations (NGOs) on crop and livestock production should focus on researching more drought and disease resistant crop varieties, especially sorghum, bulrush millet and sunflower, which can withstand climate variability and change. This is important because existing crop varieties had failed to withstand climatic changes. Secondly, other interventions should focus on creating awareness and education among agro-pastoralists on the importance of minimizing the herds to a manageable and productive size while improving pasture management to address scarcity of water and dwindling of grazing areas. Thirdly, other interventions need to focus on harmonizing the use of pasture and land among agro-pastoralists and resource conservation policies. This is important in order to address conflicts on resource use that had already happened. Fourthly, because of drought especially since the 2000s, there is a need for interventions to focus on construction of water reservoirs and irrigation structures, so that smallholder farmers can switch from RFFS to an irrigated farming system. This can practically be done by collecting water from seasonal rivers, which are available in the study area, and store it for irrigation purposes. Switching to irrigated farming should be accompanied by creating awareness on use of good agronomic practices and sustainable land use planning to address land use related conflicts. Finally, the paper recommends further studies on changes in gender relations, nutrition and health, farmer's risks and marriage dynamics associated with climate variability and change. Further studies should also focus on impacts of climate variability and change between male and female headed households.

## References

Afifi, T., Liwenga, E and Kwezi, L. (2014). Rainfall induced crop failure, food security and out-migration in Same-Kilimanjaro, Tanzania. *Climate and Development* 6(1): 53-60.

Bartlett, J.E., Kotrlik, J.W and Higgins, C.C. (2001). Organizational research: determining appropriate sample size in survey research. *Information Technology, Learning, and Performance Journal* 19(1): 43-50.

Behera, U.K and Sharma, A.R. (2007). Modern Concepts of Agriculture. India Agricultural Research Institute. 37pp.

Bryman, A. (2006). Integrating quantitative and qualitative research: how is it done? *Qualitative Research* 6(1): 97-113.

Chambers, R. (1994). Participatory rural appraisal: challenges, potentials and paradigm. *World Development* 22(10): 1437-1454.

Chan, Y.H. (2004). Logistic regression analysis. *Singapore Medical Journal* 45 (1): 149-153.

Chapagain, A.K., Hoekstra, A.Y., Savenije H.H.G., Gautam, R. (2006). The water footprint of cotton consumption: an assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries. *Ecological Economics* 60:186-203.

Darnhofer, I., Bellon, S., Dedieu, B and Milestad, R. (2008). Adaptive Farming Systems: A Position Paper. Presented at the 8th European IFSA Symposium Held on 6-10 July 2008, Clermont Ferrand, France. 13pp.

Darnhofer, I., Bellon, S., Dedieu, B and Milestad, R. (2010). Adaptiveness to enhance the sustainability of farming systems: a review. *Agronomy for Sustainable Development* 30: 545-555.

Dixon, J., Gulliver, A and Gibbon, D. (2001). Farming Systems and Poverty: Improving Farmers' Livelihoods in a Changing World. FAO and WB. 41pp.

Food and Agriculture Organization (FAO). (2008). Climate Change and Food Security: A Framework Document. 93pp.

Galvin, K.A., Boone, R.B., Smith, N.M and Lynn, S.J. (2001). Impacts of climate variability on East African pastoralists: linking social science and remote sensing. *Climate Research* 19: 161-172.

Gilbert, G.L. (2010). A Sequential Exploratory Mixed Methods Evaluation of Graduate Training and Development in the Construction Industry. PhD Thesis, RMIT University. 248pp.

Healey, J.F. (2005). Statistics: *A Tool for Social Research*, 7th Edition, Thomson Wadsworth. United Kingdom. 556pp.

Huang, J., Guan, X and Ji, F. (2012). Enhanced cold-season warming in semi-arid regions. *Atmospheric Chemistry and Physics* 12: 4627-4653.

Intergovernmental Panel on Climate Change (IPCC). (2007). Summary for Policy Makers. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* (Edited by Parry, M.L., Canziani, O.F., Palutikof, J.P., Van der Linden, P.J and Hanson, C.E.), Cambridge University Press, Cambridge. pp. 7-22.

Intergovernmental Panel on Climate Change (IPCC). (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field C, Barros V, Mach K, Mastrandrea M (eds)]. Cambridge University Press, Cambridge.

Iramba District Council. (2009). Iramba District Socio-Economic Profile. Iramba District Council; Kiomboi. 10pp.

Juana, J.S., kahaka, Z and Okurut, F.N. (2013). Farmers' perceptions to climate change in Sub-Saharan Africa: a synthesis of empirical studies and implications for public policy in African agriculture. *Journal of Agricultural Science* 5(4): 121-135.

Kabote, S.J., Mamiro, D., Synnevåg, G., Urassa, J.K., Mattee, A.Z., Mbwambo, J.S., Nombo, C.I., Masolwa, L.W and Chingonikaya, E.E. (2013). Inter-annual anomaly and seasonal variability of rainfall and temperature in selected semi-arid areas of Tanzania. *Journal of Continuing Education and Extension* 4(2): 295-317.

Kaliba A.R.M., Verkuijl. H., Mwangi. W., Byamungu. D.A., Anandajayasekeram P., Moshi. A.J. (1998). *Adoption of Maize Production Technologies in Western Tanzania. International Maize and Wheat Improvement Center (CIMMYT)*. United Republic of Tanzania, Dar es Salaam.

Kothari, C.R. (2004). *Research Methodology Methods and Techniques*, Revised 2nd Edition. New Age International Publishers, New Delhi. 401pp.

Legesse, B., Ayele, Y and Bewket, W (2013). Smallholder farmers' perceptions and adaptations to climate variability and climate change in Doba District, West Hararghe, Ethiopia. *Asian Journal of Empirical Research* 3(3): 251-265.

Lema, M.A and Majule, A.E. (2009). Impacts of climate change, variability and adaptation strategies on agriculture in semi arid areas of Tanzania: the case of Manyoni District in Singida Region, Tanzania. *African Journal of Environmental Science and Technology* 3(8): 206-218.

Maddison, D. (2006). The Perception of and Adaptation to Climate Change in Africa. CEEPA Discussion Paper No. 10. Centre for Environmental Economics and Policy in Africa. 47pp.

Mann, C.J. (2003). Observational research methods. research design II: cohort, cross sectional, and case studies. *Emergency Medical Journal* 20: 54-60.

Masadeh, M.A. (2012). Focus group: reviews and practices. *International Journal of Applied Science and Technology* 2(10): 63-68.

Mathugama, S.C and Peiris, T.S.G. (2011). Critical evaluation of dry spell research. *International Journal of Basic and Applied Sciences* 11(6): 153-160.

Mati, B.M., Muchiri, J.M., Njenga, K., Penning de Vries, F., Merrey, D.J. (2005). *Assessing water availability under pastoral livestock systems in drought-prone Isiolo District, Kenya.* Working Paper 106. International Water Management Institute (IWMI), Colombo.

Mattee, A.Z and Shem, M. (2006). *Ambivalence and Contradictions: A Review of Policy Environment in Tanzania in Relation to Pastoralism*. Issue Paper No. 140. International Institute for Environment and Development, London. 140 pp.

Mbilinyi, A., Ole Saibul, G and Kazi, V. (2013). Impact of Climate Change to Small Scale Farmers: Voices of Farmers in Village Communities in Tanzania. Economic and Social Research Foundation, Dar es Salaam. 36pp.

Meatu District Council. (2009). Meatu District Socio-Economic Profile. Meatu District Council; Mwanhuzi. 89pp.

Meena, H.E., Lugenja, M.S., Ntikha, O.A and Hermes, M. (2008). Analyses of Technological and Policy Options for Adaptation to Consequences of Climate Change in Tanzania: The Case of Crops and Livestock. CEEST Foundation for Energy, Environment and Development. 31pp.

Milan, A and Ho, R. (2014). Livelihood and migration patterns at different altitudes in the central highlands of Peru. *Climate and Development* 6(1): 69-76.

Mongi, H., Majule, A.E and Lyimo, J.G. (2010). Vulnerability and adaptation of rain fed agriculture to climate change and variability in semi-arid Tanzania. *African Journal of Environmental Sciences and Technology* 4(6): 371-381.

Murali, J and Afifi, T. (2014). Rainfall variability, food security and human mobility in the Janjgir-Champa district of Chhattisgarh state, India. *Climate and Development* 6(1): 28-37.

National Bureau of Statistics (NBS). (2009). *Household Budget Survey 2007*. National Bureau of Statistics, Dar es Salaam.

Nombo, C.I., Urassa, J.K., Mbwambo, J.S., Mattee, A.Z., Mamiro, D.P., Kabote, S.J., Matata, L and Synnevåg, G. (2013). A gendered analysis of climate change impacts and adaptations in semi-arid area farming systems of Tanzania. *Journal of Continuing Education and Extension* 4(1): 212-227.

O'Brien, G., O'Keefe, P., Rose, J. and Wisner, B. (2006). Climate change and disaster management. *Disasters* 30(1): 64-80.

Paavola, J. (2008). Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. *Environmental Science and Policy* 11: 642-654.

Peng, C.J., Lee, K.L and Ingersoll, G.M. (2002). An introduction to logistic regression analysis and reporting. *The Journal of Educational Research* 96 (1): 1-14.

Rademacher-Schulz, C., Schrave, B and Mahama, E.S. (2014). Time matters: shifting seasonal migration in Northern Ghana in response to rainfall variability and food security. *Climate and Development* 6(1): 46-52.

Rota, A. (2009). *Livestock and Pastoralism*. International Fund for Agricultural Development, Rome. 8pp.

Saadan, H.M., Mgonja, M.A and Obilana, A.B. (2000). *Performance of the Sorghum Variety Macia in Multiple Environment in Tanzania*. Sorghum and Millet Improvement Net Work. 10pp.

Sandelowski, M. (2000). Focus on research methods combining qualitative and quantitative sampling, data collection, and analysis techniques in mixed-method studies. *Research in Nursing and Health* 23: 246-255.

Sarr, B (2012). Present and Future Climate Change in the Semi-arid Region of West Africa: A Crucial Input for Practical Adaptation in Agriculture. Atmospheric Science Letters, wileyonlinelibrary.com Accessed on 8/7/2013.

Senkondo, E.M.M., Msangi, K., Xavery, P., Lazaro, E.A and Hatibu, N. (2004). Profitability of rainwater harvesting for agricultural production in selected semi-arid areas of Tanzania. *Journal of Applied Irrigation Science* 39(1): 65-81.

Swai, O.W., Mbwambo, J.S and Magayane, F.T. (2012). Gender and adaptation practices to the effects of climate change in Bahi and Kondoa Districts, Dodoma Region, Tanzania. *Journal of Sustainable Development* 5(12): 65-77.

Tanzania Agricultural Research Organization. (TARO). (1987a). Recommendations for Maize Production in Tanzania. TARO, Dar-es-Salaam. 24pp.

Tanzania Agricultural Research Organization. (TARO). (1987b). Recommendations for Sweet Potatoes Production in Tanzania. TARO, Dar-es-Salaam. 26pp.

Tanzania Agricultural Research Organization. (TARO). (1987c). Recommendations for Bulrush millet Production in Tanzania. TARO, Dar-es-Salaam. 22pp.

Tanzania Agricultural Research Organization (TARO). (1987d). Recommendations for Cotton Production in Tanzania. TARO, Dar-es-Salaam. 31pp.

Tanzania Agricultural Research Organization. (TARO). (1987e). Recommendations for Sunflower Production in Tanzania. TARO, Dar-es-Salaam. 21pp.

Tanzania Agricultural Research Organization. (TARO). (1987f). Recommendations for Green gram Production in Tanzania. TARO, Dar-es-Salaam. 20pp.

University of Dar es Salaam. (UDSM). (1999). *Rethinking Natural Resources Degradation in Semi-Arid Sub-Saharan Africa: The Case of Semi-arid Tanzania*. University of Dar es Salaam, Dar es Salaam. 58pp.

Vette, S. (2009). Drought, change and resilience in South Africa's arid and semi-arid rangelands. *South African Journal of Science* 105: 29-33.

Table 1: Percentage of respondents involved by respondents' sex

| Respondent's sex | Kidaru (n=142) | Mwamanimba (n=101) | Mwashata (n=145) | Total (N=388) |
|---|---|---|---|---|
| Female | 42 | 30 | 43 | 39 |
| Male | 58 | 70 | 57 | 61 |

*Table 2: Characteristics of FGDs participants*

| Village name | Number of FGDs conducted | Number of male participants | Number of female participants | Mean age (years) | Minimum age (years) | Maximum age (years) |
|---|---|---|---|---|---|---|
| Kidaru | 3 | 6 | 9 | 44 | 25 | 60 |
| Mwashata | 2 | 10 | 14 | 42 | 29 | 63 |
| Mwamanimba | 2 | 13 | 11 | 49 | 31 | 68 |
| **Total** | **7** | **29** | **34** | **NA** | **NA** | **NA** |

Note: FGDs = Focus Group Discussions; NA = Not Applicable

Table 3: Some descriptive statistics of respondents' characteristics

| Variable | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|
| Age | 18 | 100 | 46 | 14.3 |
| Years of schooling | 0.0 | 14 | 5 | 3.3 |
| Number of household members | 1 | 15 | 7 | 5.3 |
| Household farm size owned (Acres) | 0.0 | 40 | 6 | 7.4 |

*Table 4: Number of households involved in the survey*

| Village name | Total number of households | Selected households | Selected households (%) | Women involved (%) |
|---|---|---|---|---|
| Kidaru | 444 | 142 | 32 | 42 |
| Mwashata | 462 | 145 | 31 | 30 |
| Mwamanimba | 315 | 101 | 32 | 43 |
| **Total** | **1201** | **388** | **32** | **39** |

*Table 6: Percentage responses on dominant crops grown during 2012/13 (n=388)*

| Type of crop | Variable | Kidaru (n=142) | Mwamanimba (n=101) | Mwashata (n=145) | Chi-square | P-Value | Phi-Value |
|---|---|---|---|---|---|---|---|
| Maize | Grown | 37 | 85 | 96 | 135.934 | 0.000 | 0.592 |
| | Not grown | 63 | 15 | 4 | | | |
| Sorghum | Grown | 38 | 65 | 9 | 85.400 | 0.000 | 0.469 |
| | Not grown | 62 | 35 | 91 | | | |
| Sweet potatoes | Grown | 16 | 78 | 72 | 123.430 | 0.000 | 0.564 |
| | Not grown | 84 | 22 | 28 | | | |
| Bulrush millet | Grown | 74 | 4 | 3 | 214.359 | 0.000 | 0.743 |
| | Not grown | 26 | 96 | 97 | | | |
| Cotton | Grown | 4 | 93 | 69 | 218.394 | 0.000 | 0.750 |
| | Not grown | 96 | 7 | 31 | | | |
| Sunflower | Grown | 65 | 19 | 35 | 56.081 | 0.000 | 0.380 |
| | Not grown | 35 | 81 | 65 | | | |

 

***Table 7: Crops and water requirements***

| Common name | Scientific name | Rainfall requirements (mm) |
|---|---|---|
| Maize | *Zea mays (* L.) | 500-2000 |
| Sorghum | *Sorghum bicolor* (L) Moench | 250-1200 |
| Paddy rice | *Oryza sativa* (L.) | 1200- 1800 |
| Sweet potatoes | *Ipomoea batatas* (L.) Lam | 500-1600 |
| Bulrush millet | *Pennisetum glaucum* (L.) R. Br | 275-1500 |
| Cotton | *Gossypium hirsutum* (L.) | 850-1100 |
| Sunflower | *Helianthus annuus* (L.) | 600-1000 |
| Green gram | *Vigna radiata* (L.) | 600-800 |

**Sources**: Tanzania Agricultural Research Organization (TARO), 1987a; 1987b; 1987c; 1987d; 1987e; 1987f; Kaliba *et al.,* 1998; Saadan *et al.,* 2000; Chapagain *et al.,* 2006)

Table 5: Definitions of variables used in the binary logistic regression model

| Variable | Definition | Level of measurement |
|---|---|---|
| Adopting new crops or crop varieties | Smallholder farmers using new emerging crops or crop varieties | Nominal<br>Yes = 1, No = 0 |
| Changes in grazing place | Moving away from the village of domicile in search for pasture | Nominal<br>Yes = 1, No = 0 |
| Insufficient rainfall | Amount of rainfall received not enough for the crops to attain maturity or for the livestock to have enough pasture and water | Nominal<br>Yes = 1, No = 0 |
| Increased warming | Day time temperature increase | Nominal<br>Yes = 1, No = 0 |
| Increased drought | Long period of no rain within a crop growing period than it is expected | Nominal<br>Yes = 1, No = 0 |
| Rainfall unpredictability | Inability to predict whether it can rain when it is expected to rain | Nominal<br>Yes = 1, No = 0 |
| Early cessation of rainfall | A month in which the rain starts | Nominal<br>Yes = 1, No = 0 |
| Extension services | Knowledge or information obtained by smallholder farmers from agriculture extension officers | Nominal<br>Yes = 1, No = 0 |
| Market access | Ability to purchase improved crop varieties or ability to engage in marketing process to sell the crop produce | Nominal<br>Yes = 1, No = 0 |
| Respondents' sex | Sex of the respondents | Male = 1, Female = 0 |
| Food preference | Most preferred food in relation to type of a crop | Nominal<br>Yes = 1, No = 0 |
| Respondents' age | Age of the respondent | Ratio<br>(Years) |
| Years of schooling | Number of years the respondent spent in the school | Ratio<br>(Years) |
| Household size | Number of people living under one household head | Interval<br>(Number of people) |
| Occupation | Being crop producer only or agro-pastoralist | Crop producer only = 1, agro-pastoralist = 0 |
| Agriculture expansion | Expanding size of cultivated land | Nominal<br>Yes = 1, No = 0 |
| Government policy | Protective government policy to producing a certain crop or a crop variety | Nominal<br>Yes = 1, No = 0 |
| Gender relations | Social, cultural and power relations existing between men and women in society | Division of labour, division of power and social-cultural norms |

 

Table 8: Pair-wise ranking results on threatening climatic indicators

| Variable | Kidaru village | | | | Mwashata village | | | | Mwamanimba village | | | | Overall score | Overall rank based on overall scores |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | Female | | Male | | Female | | Male | | Female | | | |
| | Total score | Rank | Total score | Rank | Total score | Rank | Total score | Rank | Total score | Rank | Total score | Rank | | |
| Insufficient rainfall | 4 | 2 | 5 | 1 | 2 | 6 | 3 | 6 | 2 | 7 | 4 | 5 | 20 | 6 |
| Unpredictable rainfall | 4 | 2 | 4 | 2 | 7 | 2 | 6 | 4 | 5 | 4 | 5 | 4 | 31 | 2 |
| Uneven rainfall distribution | 2 | 5 | 2 | 5 | 4 | 3 | 2 | 7 | 4 | 5 | 3 | 6 | 17 | 7 |
| Drought | 3 | 2 | 3 | 4 | 9 | 1 | 7 | 2 | 3 | 6 | 6 | 3 | 37 | 1 |
| Late onset | 2 | 5 | 4 | 2 | 2 | 6 | 4 | 5 | 8 | 1 | 7 | 2 | 27 | 4 |
| Earlier cessation | 1 | 7 | 2 | 5 | 4 | 3 | 7 | 2 | 7 | 2 | 8 | 1 | 29 | 3 |
| Strong wind | 5 | 1 | 1 | 7 | 1 | 7 | 9 | 1 | 6 | 3 | 0 | 7 | 22 | 5 |

Table 9: Percentage responses on changes in onset of rainfall since the 1970s

| Month/period | Onset of rainfall in the 1970s | | | Onset of rainfall in 2013 | | |
|---|---|---|---|---|---|---|
| | Kidaru (n=142) | Mwamanimba (n=101) | Mwashata (n=145) | Kidaru (n=142) | Mwamanimba (n=101) | Mwashata (n=145) |
| September | 6 | 6 | 32 | 0 | 6 | 2 |
| October | 16 | 41 | 38 | 4 | 4 | 8 |
| November | 45 | 29 | 12 | 31 | 15 | 38 |
| December | 18 | 9 | 3 | 51 | 30 | 27 |
| October/November | 6 | 6 | 5 | 5 | 16 | 8 |
| November/December | 7 | 8 | 10 | 2 | 2 | 10 |
| January | 2 | 1 | 0 | 7 | 27 | 7 |

Table 10: Percentage responses on changes in cessation of rainfall since the 1970s

| Month/period | Cessation of rainfall in the 1970s | | | Cessation of rainfall in 2013 | | |
|---|---|---|---|---|---|---|
| | Kidaru (n=142) | Mwamanimba (n=101) | Mwashata (n=145) | Kidaru (n=142) | Mwamanimba (n=101) | Mwashata (n=145) |
| March | 0 | 0 | 0 | 18 | 39 | 32 |
| April | 16 | 14 | 7 | 56 | 53 | 55 |
| May | 51 | 57 | 65 | 16 | 3 | 5 |
| June | 25 | 9 | 17 | 7 | 1 | 3 |
| March/April | 2 | 1 | 1 | 1 | 4 | 5 |
| April/May | 4 | 6 | 4 | 1 | 0 | 0 |
| May/June | 2 | 13 | 6 | 1 | 0 | 0 |

***Table 11: Percentage responses on dominant livestock (n = 388)***

| Livestock | Variable | Wealth status | | | Chi-square | P-Value | Phi-Value |
|---|---|---|---|---|---|---|---|
| | | Poor (n=192) | Not so poor (n=152) | Rich (n=44) | | | |
| Cattle | Keep | 42 | 71 | 68 | 32.661 | 0.000 | 0.290 |
| | Do not keep | 58 | 29 | 32 | | | |
| Goat | Keep | 37 | 54 | 61 | 15.074 | 0.001 | 0.197 |
| | Do not keep | 63 | 46 | 39 | | | |
| Sheep | Keep | 23 | 33 | 57 | 19.124 | 0.000 | 0.222 |
| | Do not keep | 77 | 67 | 43 | | | |
| Donkey | Keep | 6 | 8 | 16 | 5.209 | 0.074 | 0.116 |
| | Do not keep | 94 | 92 | 84 | | | |
| Pigs | Keep | 8 | 15 | 25 | 9.783 | 0.008 | 0.159 |
| | Do not keep | 92 | 85 | 75 | | | |
| Poultry | Keep | 49 | 64 | 66 | 8.734 | 0.013 | 0.150 |
| | Do not keep | 51 | 36 | 34 | | | |

***Table 12: Percentage responses on adoption of improved varieties (n=388)***

| Type of crop | Variable | Wealth status Poor (n=192) | Not so poor (n=152) | Rich (n=44) | Chi-square | P-Value | Cramer's V - value |
|---|---|---|---|---|---|---|---|
| Maize | Adopted | 46 | 49 | 66 | 8.637 | 0.071 | 0.105 |
| | Not adopted | 24 | 24 | 25 | | | |
| | Neutral | 30 | 27 | 9 | | | |
| Sorghum | Adopted | 24 | 20 | 27 | 9.374 | 0.052 | 0.110 |
| | Not adopted | 46 | 53 | 64 | | | |
| | Neutral | 30 | 27 | 9 | | | |

Note: Neutral means, improved varieties were occasionally used

**Table 13: Adoption of improved crop varieties**

| Type of crop variety | Kidaru village: Existing situation | Kidaru village: Situation in the 1980s | Mwashata village: Existing situation | Mwashata village: Situation in the 1980s | Mwamanimba village: Existing situation | Mwamanimba village: Situation in the 1980s |
|---|---|---|---|---|---|---|
| Maize | Varieties include *Kagiri* (short), Kilima (medium), Dekalb (DK) (short), *Pundamilia* (medium) and *Tembo* (long) | Long-term varieties include hybrid (H 614) and Ukiriguru composite (UCA) | Varieties include *Katumbili* (short), *Pundamilia* (medium), and *Simba* (medium). These take 2 to 3 months to attain maturity | Long-term variety mainly *gembe,* which took about 4 months to attain maturity. | Varieties include *katumaini and, kagri (short) and katumbili (medium).* These take 2 to 3 months to attain maturity | Local variety mainly *gembe,* which took about 4 months to attain maturity |
| Sorghum | Varieties include *mkombitunna* in Nyiramba language (goose like against bird attack) | Long-term varieties including *korongo, tembe, kakera* and *kalolo* | Short-term varieties including *malawi, ng'hulya and ngudungu* | Long-term variety mainly *ng'holongo* which took about 6 to 7 months to attain maturity | Short-term varieties including *serena, miningamhera, and pato* | Long-term variety mainly *ng'holongo* that took about 6 to 7 months to attain maturity |

Table 14: Model fit for adopting improved varieties

| **A: Omnibus tests of model coefficients** | | | |
|---|---|---|---|
| | $X^2$-square | Degree of freedom | p-value |
| Step | 427.448 | 13 | 0.000 |
| Block | 427.448 | 13 | 0.000 |
| Model | 427.448 | 13 | 0.000 |
| **B: Model summary** | | | |
| Step | -2 Log likelihood | Cox & Snell R Square | Nagelkerke R Square |
| 1 | 92.973 | 0.668 | 0.904 |
| **C: Hosmer and Lemeshow test** | | | |
| Step | $X^2$-square | Degree of freedom | p-value |
| 1 | 4.476 | 8 | 0.812 |

Table 15: Model fit for changing grazing areas

| **A: Omnibus tests of model coefficients** | | | |
|---|---|---|---|
| | $X^2$-square | Degree of freedom | p-value |
| Step | 38.252 | 9 | 0.000 |
| Block | 38.252 | 9 | 0.000 |
| Model | 38.252 | 9 | 0.000 |
| **B: Model summary** | | | |
| Step | -2 Log likelihood | Cox & Snell R Square | Nagelkerke R Square |
| 1 | 66.650 | 0.384 | 0.522 |
| **C: Hosmer and Lemeshow test** | | | |
| Step | $X^2$-square | Degree of freedom | p-value |
| 1 | 14.710 | 8 | 0.065 |

 

*Table 16: Percentage responses on adopting new crop varieties and changing a grazing place*

| Variable | Kidaru (n = 142) | Mwamanimba (n = 101) | Mwashata (n = 145) |
|---|---|---|---|
| **(a) Adopting new crop varieties (N = 388)** | | | |
| Adopted | 39 | 69 | 76 |
| Did not adopt | 61 | 31 | 24 |
| **(b) Changing a grazing place (N = 181)** | | | |
| Changed | 52 | 76 | 69 |
| Did not change | 48 | 24 | 31 |

*Table 17: Independent variables entered in the model for adopting new crop varieties and changing a grazing place*

**(a) Adopting new crop varieties (N = 388)**

| Variable | Caused adoption (%) | Did not cause adoption (%) |
|---|---|---|
| Insufficient rainfall | 62 | 38 |
| Increased warming | 69 | 31 |
| Increased drought | 68 | 32 |
| Rainfall unpredictability | 58 | 42 |
| Early cessation of rainfall | 62 | 38 |
| Extension services | 32 | 68 |
| Market access | 5 | 95 |
| Food preference | 57 | 43 |
| Occupation | 13 | 87 |

**(b) Changing a grazing place (N = 181)**

| Variable | Caused changes (%) | Did not cause changes (%) |
|---|---|---|
| Insufficient rainfall | 74 | 26 |
| Increased drought | 78 | 22 |
| Agriculture expansion | 79 | 21 |
| Government policy | 3 | 97 |

Note: The sample size for changing a grazing place is for the households that kept cattle

*Table 18: Rsults of the logistic regression on the likelihood of farm households adopting new crop varieties (n=388)*

| Variables entered in the model | ß | S.E | Wald | p-value | Odds ratio |
|---|---|---|---|---|---|
| Insufficient rainfall | 1.61 | 0.59 | 7.26 | 0.007 | 5.00 |
| Increased warming | -10.61 | 1.76 | 36.26 | 0.000 | 0.00 |
| Increased droughts | 3.35 | 1.17 | 8.06 | 0.005 | 28.38 |
| Rainfall unpredictability | 2.16 | 1.19 | 3.29 | 0.070 | 8.72 |
| Early cessation | 2.50 | 0.81 | 9.45 | 0.002 | 12.25 |
| Extension services | 2.93 | 1.58 | 0.01 | 0.993 | 2.48 |
| Market | 7.25 | 3.93 | 3.39 | 0.065 | 1.40 |
| Respondents' sex | 1.55 | 0.70 | 4.90 | 0.027 | 4.74 |
| Food preference | 2.53 | 1.10 | 5.28 | 0.021 | 12.64 |
| Respondents' age | 0.01 | 0.02 | 0.48 | 0.484 | 1.01 |
| Years of schooling | -1.12 | 0.12 | 1.07 | 0.300 | 0.88 |
| Household size | -0.03 | 0.10 | 0.08 | 0.765 | 0.97 |
| Occupation | 1.36 | 0.72 | 3.49 | 0.062 | 3.90 |
| Constant | -3.05 | 1.53 | 3.98 | 0.046 | 0.04 |

***Table 19: Results of the logistic regression on the likelihood of changing grazing system (n=181a)***

| Variables entered in the model | ß | S.E | Wald | p-value | Odds ratio |
|---|---|---|---|---|---|
| Insufficient rainfall | 1.69 | 0.70 | 5.82 | 0.016 | 5.44 |
| Increased drought | 2.16 | 0.83 | 6.82 | 0.009 | 8.70 |
| Agriculture expansion | 2.43 | 0.98 | 6.18 | 0.013 | 11.32 |
| Government policy | 1.65 | 1.41 | 1.37 | 0.242 | 5.21 |
| Respondents' sex | -0.91 | 0.73 | 1.56 | 0.214 | 0.40 |
| Respondents' age | -0.01 | 0.02 | 0.14 | 0.710 | 0.99 |
| Years of schooling | 0.08 | 0.09 | 0.71 | 0.399 | 1.08 |
| Household size | 0.01 | 0.04 | 0.12 | 0.730 | 1.01 |
| Constant | -1.46 | 1.31 | 1.24 | 0.266 | 0.23 |

[a]Sample size (n) involves only households who kept cattle

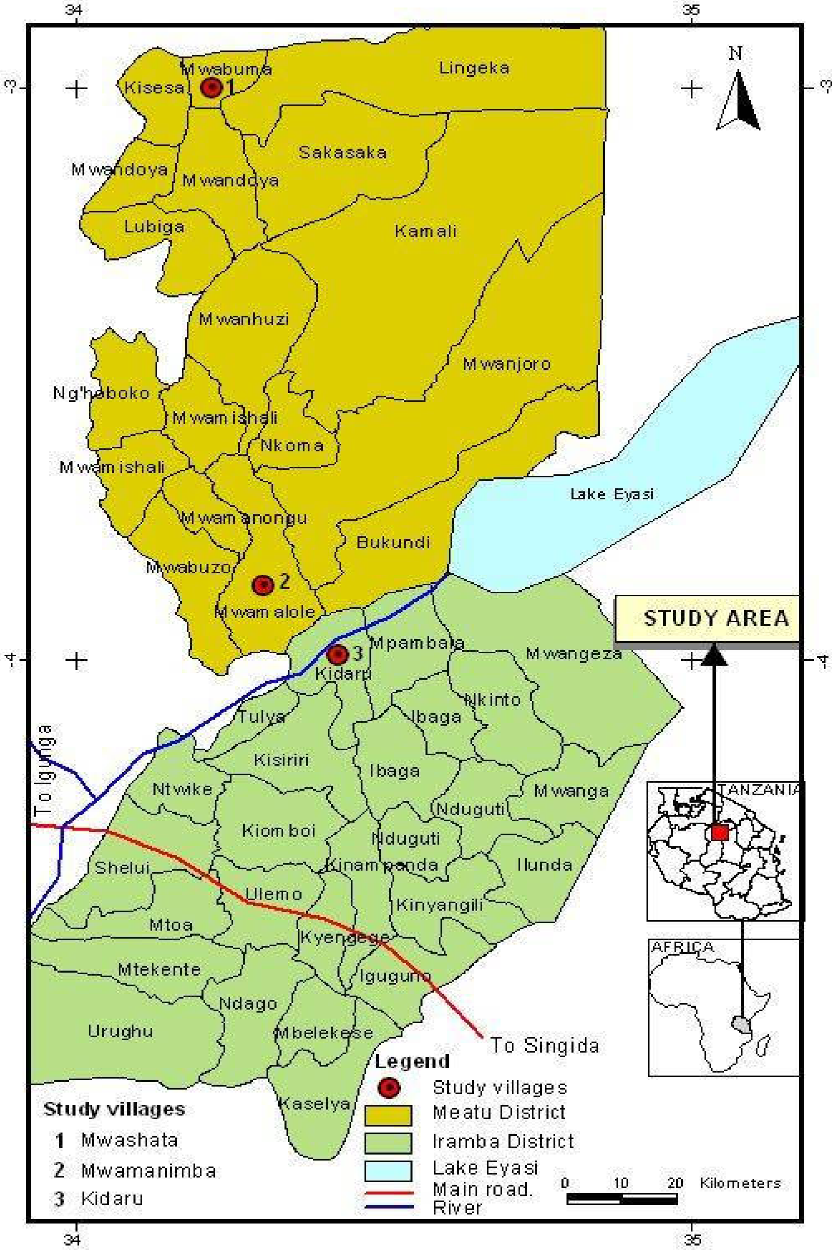


**Figure 1: Map of Tanzania showing study villages**