Perceived and measured climate variability and change in semi-arid environments in Tanzania: experiences from Iramba and Meatu Districts

Samwel J. Kabote*

Development Studies Institute,
Sokoine University of Agriculture,
P.O. Box 3024, Morogoro, Tanzania
Email: samwel.kabote@yahoo.com
*Corresponding author

Delphina P. Mamiro

Department of Crop Science and Production,
Sokoine University of Agriculture,
P.O. Box 3005, Morogoro, Tanzania
Email: mamirodelphi@gmail.com

Gry Synnevåg

Department of International Environment and Development Studies,
Norwegian University of Life Sciences,
Noragric 1432 Ås, Norway
Email: gry.synnevag@umb.no

Justin K. Urassa

Development Studies Institute,
Sokoine University of Agriculture,
P.O. Box 3024, Morogoro, Tanzania
Email: jksurassa@yahoo.co.uk

Amon Z. Mattee

Department of Agricultural Extension,
Sokoine University of Agriculture,
P.O. Box 3002, Morogoro, Tanzania
Email: azmattee2009@yahoo.com

Jonathan S. Mbwambo, Carolyne I. Nombo and Emanuel E. Chingonikaya

Development Studies Institute,
Sokoine University of Agriculture,
P.O. Box 3024, Morogoro, Tanzania
Email: jonahtz@yahoo.com
Email: cnombo@yahoo.com
Email: emanuel.chingonikaya@yahoo.com

Leah Masolwa

Tumbi Agricultural Research Institute,
P.O. Box 306, Tumbi, Tabora, Tanzania
Email: leahmasolwa@yahoo.co.uk

Abstract: This paper combines farmers' perceptions of climate variability and change and meteorological data trends to generate empirical evidence to broaden an understanding of the phenomena. The results show an agreement on changing rainfall patterns. Bad years described by drought frequencies, temperature, and dry spell have increased since the 1970s. Crop growing period has decreased by one month in Meatu and by more than a month in Iramba. As hypothesised, the Mann-Whitney U test shows similar men and women's perceptions at 5% level of significance (P value = 0.701). Similarly, the Kruskal-Wallis H test indicates that the poor, not so poor and the rich have the same perceptions (P value = 0.281). These results have implications on crop and livestock production systems and on livelihoods more generally. We conclude that climate variability and change manifestations overlap, making it a complex phenomena perceived equally by men, women, the poor and non-poor. This is understood holistically by combining farmers' perceptions and meteorological data trends to inform adaptation strategies related decision making.

Keywords: farmers' perceptions; meteorological data; climate variability; agro-pastoralism.

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Biographical notes: Samwel J. Kabote holds a PhD in Rural Development. His PhD research topic was 'impact of climate variability and change on rain-fed farming system in semi-arid environments in Tanzania'. He also holds BSc in Environmental Sciences and Management and MA in Development Studies. Currently, he is a member in a gender and climate change project implemented by Sokoine University of Agriculture (SUA) and also a Lecturer at SUA in the institute of development studies.

Delphina P. Mamiro is an Associate Professor in the Department of Crop Science at SUA. She has published several journal articles, books and book chapters in areas of tropical legumes, climate change and farming systems, adoption of new innovative agricultural technologies, mushrooms, vegetable crops and improved crop varieties.

Gry Synnevåg is an Associate Professor in Department for International Environment and Development Studies (Noragric), UMB. She is a Senior Researcher in the department. She has published several journal articles, books and book chapters in rural development, agriculture, food- and livelihood security, sustainable use and management of natural resources in a climate change perspective, institutional and community development, mainly in the semi arid, food insecure and conflict affected areas of Africa and Asia.

Justin K. Urassa holds a PhD in Development Studies and an MSc in Social Research Methods from the University of Sussex, Post-graduate Diploma in Poverty Analysis for Socioeconomic Security and Development from the Institute of Social Studies-The Hague, in collaboration with the Economic and Social Research Foundation (ESRF) and Research on Poverty Alleviation (REPOA), Tanzania. He has published several journal articles, books and book chapters in areas of development studies, agriculture and climate change. Currently, he is a Senior Lecturer at SUA.

Amon Z. Mattee is an Associate Professor in Department of Agricultural Education and Extension with close to 40 years tenure at SUA. He brings a wealth of experience and insights into iAGRI. He works closely with the Project Directors and the SUA staff to move forward the capacity building component, including the leadership development as well as the private sector linkages initiatives. His main area of teaching and research is agricultural extension and rural development.

Jonathan S. Mbwambo holds a PhD in Rural Development from SUA. He worked as a Deputy Director and as a Director in the Institute of Development Studies at SUA. He has published several journal articles and book chapters in areas of biodiversity, food security, climate change to name a few. Currently, he is working with the ministry of education and vocational training at a capacity of deputy director.

Carolyne I. Nombo is an Associate Professor in Rural Development specialised in Gender at Development Studies Institute, Sokoine University of Agriculture, Tanzania. She has published 17 papers in refereed journals and a contributor of four book chapters in areas of gender, rural livelihood and development, HIV/AIDS, community organisations and local institutions.

Emanuel E. Chingonikaya is a Senior Lecturer in the Institute of Development Studies at SUA. He has published more than 30 journal articles and book chapters in areas of community-based forest management, development studies, food security, climate change, gender and natural resources, agro forestry and poverty reduction.

Leah Masolwa is a principal researcher working with Agriculture Research Institution, Tabora Tanzania. She has published a number of journal articles in areas of socio-economics, crop, climate change and farming systems.

1 Introduction

Climate variability and change are the most prominent environmental challenges affecting development endeavours in the 21st Century. Since the mid 1990s, literature on climate variability and change has grown considerably. However, more work is required to uncover phenomena perceptions by individuals' wealth status and gender groups in semi-arid environments where livelihoods depend on rain-fed agriculture and agro-pastoralism. In this paper, we examine perceived and meteorological data trends to broaden an understanding of the phenomena in semi-arid environments that occupy 30% of the global land area, 18% of the land area in Sub-Saharan Africa, and more than one third of land area in Tanzania. Different scholars define semi-arid environments differently. Yet, the definitions concur that these environments are dry and hot with high evapo-transpiration (UDSM, 1999; URT, 2007; Mongi et al., 2010; Huang et al., 2012; Sarr, 2012). This paper adopts a definition coined by Quinn and Ockwell (2010), which takes semi-arid environments as ones receiving a mean annual rainfall between 400 and 900 mm with a mean monthly temperature exceeding 18°C. Climate variability and change put semi-arid environments at more risk (IPCC, 2007), as such, livelihoods achieved through crop production and agro-pastoralism are likely to meet serious challenges (Galvin et al., 2001).

For simplicity, 'climate variability and change' conceptualisation encompasses breaking down into two key sub-concepts that occur concomitantly. These are:

1 climate change

2 climate variability.

Literature defines climate change differently. On one hand, climate change is taken as a change in long-term mean of weather conditions, their drivers of change and their impacts (IPCC, 2007, 2014). On the other hand, it refers only to human induced weather changes (FAO, 2008). This paper modifies an IPCC (2007) definition by taking the concept as a long-term change in statistics of weather including rainfall, temperature, winds, extreme weather episodes as measured by meteorological instruments and as perceived by smallholder farmers and agro-pastoralists. In addition, climate variability is taken as temporal and spatial variations of the mean state and other weather statistics of the climate beyond individual weather events. While climate change occurs over a long period, usually a minimum of 30 years, climate variability is a short-term phenomenon.

The debate whether climate change is a reality is hinged on the works published by Mann et al. (1998, 1999). These works demonstrate an increasing surface temperature in the northern hemisphere in the previous 1,000 years. They also show that the 1990s is the warmest decade, and 1998 is the warmest year. This coincides with an increasing amount of greenhouse gases in the atmosphere from anthropogenic and natural sources. Some scholars including Wegman et al. (2006) support these results, but recommend further studies to establish mechanisms for dealing with the phenomenon. Other scholars like Mclntyre and Mckitrick (2003) are skeptical about the results posing three arguments: first, the Earth is not warming; secondly, the Earth could be warming, yet anthropogenic sources are not among the causes; and thirdly, the Earth could be warming and anthropogenic sources could be responsible, but the world needs not to act to stop the phenomenon (Carr et al., 2010). Following this debate, climate change knowledge has increased rapidly. For example, using meteorological data trends and simulation models, literature shows an agreement on occurrence of climate variability and change (IPCC, 2014). Some scholars combine perceived and measured climate variability and change to understand the phenomenon comprehensively. With this, some show an agreement between perceived and measured climate variability and change (Maddison, 2006; Mongi et al., 2010; Ogalleh et al., 2012; Juana et al., 2013). Others for example Meze-Hausken (2004) portray contrasting results, suggesting more work on this area especially focusing on cross-country comparisons using similar manifestations of the phenomena.

Lyimo and Kangalawe (2010) have analysed rainfall variability for the period between 1974 and 2005 in semi-arid environments in Shinyanga Rural District in Tanzania, and demonstrate no significant decrease over time, opposing perceived changes. In addition, Lema and Majule (2009) show decreasing measured rainfall and increasing temperature from 1922 to 2007 in Manyoni, another semi-arid environment in Tanzania. However, people's perceptions among 400 respondents are widely distributed over variables including: temperature increase, change in rainfall onset, decrease in rainfall and increase in drought frequencies. Despite these studies, there is paucity information to justify an agreement between farmers' perceptions of climate variability and change and meteorological data trends. There is also inadequate empirical evidence to support an opinion that climate variability and change are not something new in semi-arid environments. This paper contributes to the climate variability and change body of knowledge. Specifically, it assesses farmers' perceptions of climate variability and change and combines with perceived and meteorological data. It also compares farmers' perceptions by respondents' gender and by wealth status. The next sections describe the study area, methodology employed, results and discussion, conclusions and recommendations.

2 The study area

This study was conducted in Meatu District within Simiyu Region and in Iramba District within Singida Region. Meatu District lies between latitudes 3° and 4° South and longitudes 34° and 35° East, South of Lake Victoria. Its altitude ranges between 1,000 and 1,500 metres above sea level. The mean annual rainfall is between 400 and 900 mm in the southern and northern agro-ecological zones of the district, respectively. The rainfall regime is unimodal (Meatu District Council, 2009). Iramba District lies between latitudes 4° to 4°3' South and longitudes 34° East to 35° East. The district is divided into three major agro-ecological zones: Western Great East African Rift Valley, central highland; and the eastern zone. The former zone is drier relative to the other zones (Iramba District Council, 2009). The district receives a mean annual rainfall between 500 and 850 mm. The surface temperature ranges between 15°C in July and 30°C in October (Iramba District Council, 2009).

According to Kabote et al. (2013), vegetation is dominated by scattered and replanted trees after deforestation in Meatu. In Iramba, vegetation is mainly natural Miombo woodlands, acacia woodlands and grasslands. The districts were selected for the study for two reasons: first, they are contiguous. This enables assessment of rainfall and temperature variations between adjacent districts lying in semi-arid environments. Secondly, while entirely located in semi-arid environments, livelihoods in both districts depend on agriculture and agro-pastoralism, and dependence on rainfall is above 95% (NBS, 2009). Therefore, the knowledge of climate variability and change in the study area is critical to inform planning for adaptation strategies in agriculture.

3 Methodological approach

The current study employs cross-sectional and trend analysis to expand the scope and improve analysis of climate variability and change (Sandelowski, 2000). Cross-sectional design is necessary to analyse relationships between variables at one point in time. However, that design cannot capture the change element over time. We addressed this limitation by using meteorological data trend analysis for rainfall and temperature. In addition, questions were asked using retrospective technique to capture perceived changes of climate variability and change in the previous 30 years.

Qualitative and quantitative data are involved and were collected in phases. First, we collected qualitative data using focus group discussions (FGDs). We used historical timeline during FGDs to analyse changes in the climate over time, and pair-wise ranking to prioritise a list of climatic variables identified in during discussions. The second phase was a household survey to quantify variables prioritised in the first phase. That means, the first phase informed the second phase. The results from the two phases are integrated and compared with meteorological data trends. The study's unit of analysis for the household survey is a household, and either a household head or a spouse was interviewed depending on availability. Purposive sampling techniques were used to select divisions based on different agro-ecological zones. The southern zone in Meatu is drier relative to the northern and central zones. In Iramba, the western lowland is drier relative to the central highland and eastern lowland. Criteria for village selection are: frequent droughts, hunger and frequency of receiving food aid. Frequent hunger and food aid are used as proxy indicators for crop failure associated with climate variability and change. Based on criteria mentioned above, two villages were selected in Meatu District: one from southern and the other one from the northern part. In Iramba District, one village was selected from the Western zone as no other villages met the criteria pointed above.

3.1 Focus group discussions

FGDs enabled farmers and agro-pastoralists to share and analyse their perceptions of climate variability and change (Chambers, 1994a, 1994b). Seven FGDs were conducted (Table 1). In total, 63 members participated. A plan was to include 6–12 members per FGD, but participants ranged from 6 to 14. This is because; in some villages some members came without an invitation. But, according to Masadeh (2012), a small increase in size of FGD does not affect quality of the results. We learned from one FGD in Kidaru village, which combined men and women that women do not speak freely when mixed with men in one group, implying that mixed groups cannot clearly uncover women's perceptions. Therefore, the group in Kidaru was split into men and women to capture perceptions from each group. The discussions were tape recorded to enable information retrieval at a later stage for further analysis.

Table 1 Information on FGDs and participants involved

Village name	*Number of FGDs conducted*	*Number of men participants*	*Number of women 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

Notes: FGDs = focus group discussions; NA = not applicable.

3.2 Household survey

We used a household survey to collect quantitative data. A structured questionnaire with closed questions was administered to 388 households selected using a systematic random sampling technique. To ensure reliability, pre-testing of the instrument was done at Mwakasumbi near Mwashata village in Meatu District. This involved ten respondents. After pre-testing, variables intended to measure responses on change in length of growing season, number of rain days and change in amount of rainfall were removed to ensure that the Cronbach's alpha value was at least 0.7. An alpha value of 0.7 and above is considered acceptable to ensure that the instrument is reliable (Pallant, 2007; Field, 2009). The variables involved to measure responses, which produce a Cronbach's alpha value of 0.72, are derived from pair-wise ranking. These include:

1. frequency of floods
2. rainfall unevenness
3. rainfall unpredictability
4. strong winds
5. daytime temperature
6. night time temperature
7. frequency of droughts
8. crop diseases
9. livestock diseases
10. crop insect pests.

The responses for these variables ranged from highly decrease to highly increase in the previous 30 years.

The sampling frames were prepared in each village by listing names of all household heads. The list did not follow any specific pattern to minimise bias during sampling (Kothari, 2004). The random sample from each village was selected from the list of names after a certain sampling interval obtained by dividing the total number of households in a village by an identified sample size. Simple random sampling was used to select the first respondent from within the sampling interval. Each of the names of household heads in the first sampling interval was written on a separate piece of paper from which one piece was picked randomly indicating where to start the systematic random sampling. The sample size was determined using an equation shown below. Relatively larger samples address the issue of heterogeneity, normality and so improve quality of research results (Bartlett et al., 2001). Based on these considerations, the sample size was determined using the following formula as presented by Kothari (2004).

$$n = \frac{z^2 * p * q}{e^2}$$

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: $1 - 0.5 = 0.5$

e precision or margin of error which is normally 0.05 (5%) at 95% confidence level.

Substituting the values in the equation we get $n = 391$. However, the sample size used is 388 because three questionnaire copies were not filled properly, and so are not involved in the analysis. Notably, Kidaru, Mwashata and Mwamanimba have 444; 462; and 315 households respectively making a total of 1201. Thus, the sample size in each village is determined by:

$$n_i = n * p_i$$

where

p_i proportion of households in a village

n_i selected sample per village

n total number of households in the study area.

The proportion (p_i) of selected households in each village is calculated by taking total number of households in a village divided by total number of households in the three villages, which is 1,201. By substituting the values in the equation the selected number of households per village is presented in Table 2. Respondents' characteristics are presented in Tables 3 and 4.

Table 2 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	1,201	388	32	39

Table 3 Respondents' characteristics

Variable	*Minimum*	*Maximum*	*Mean*	*Std. deviation*
Age	18	100	46	14.3
Years of schooling	0	14	5	3.3
Number of household members	1	50	7	5.3
Household farm size owned	0	40	6	7.4
Number of cattle owned	0	1,000	15	61.1
Number of goats owned	0	187	8	19.4
Number of sheep owned	0	80	3	7.7
Number of donkeys owned	0	8	0.2	0.9
Number of pigs owned	0	20	0.5	2.0
Number of chicken owned	0	60	7	9.2

Table 4 Percentage of respondents involved by gender

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

3.3 Meteorological data

Meteorological data particularly monthly rainfall and temperature for the period between 1994 and 2011 were collected from Tanzania Meteorological Agency (TMA) responsible for meteorological issues in the country. The locations of meteorological stations involved are shown in Table 5.

Table 5 Location of meteorological stations involved: 1994–2011

Station	*District*	*Latitude (degrees)*	*Longitude (degrees)*	*Elevation (metres)*
Kiomboi administrative centre – rainfall	Iramba	04°17'S	34°24'E	1,585
Meatu – rainfall	Meatu	-	-	-
Shinyanga – temperature	Shinyanga	03°39'S	33°25'E	1,000
Singida – temperature	Singida	04°48'S	34°43'E	1,307

Source: TMA (2013), data section, Dar es Salaam, Tanzania

3.4 Data analysis

Tape recorded qualitative data were transcribed into text and organised into specific themes based on the paper's objectives. Quantitative data were cleaned to eliminate errors and to ensure consistency. Responses to measure perceptions of climate variability and change are ordinal suggesting use of non-parametric tests. The analysis focuses on whether there are changes in the selected variables relative to the situation in the previous 30 years. Based on land size and cattle ownership, ability to hire labour, and on the households' food security, Nombo et al. (2013) categorise households in the study area into the poor, not so poor and the rich. The current study uses this categorisation to test the hypothesis that perceptions of climate variability and change is the same at 5% level of significance for the poor, not so poor and the rich. This is done using the Kruskal-Wallis H test, which is a non-parametric test appropriate for comparing median differences for ordinal data when the groups compared are more than two (McCrum-Gardner, 2008). The Mann-Whitney U test is used to test the hypothesis that men and women's perceptions of climate variability and change are the same at 5% level of significance. This is also a non-parametric test, which compares median of two independent groups like men and women for ordinal data (Pallant, 2007; McCrum-Gardner, 2008). Using meteorological data, dry and hot seasons are calculated using seasonal anomaly. We define seasonal anomaly as a deviation from a seasonal mean, and so dry and hot seasons are shown by negative anomaly.

4 Results and discussion

4.1 Farmers' perceptions from qualitative methods

Tables 6 to 8 summarise qualitative results from FGDs. The results show that rainfall onset has changed in Meatu from September during the 1970s to November and sometimes to December. Cessation has shifted from end of May during the 1970s to April. In Iramba, rainfall onset has shifted from November in the 1970s to December. Similarly, rainfall cessation has shifted from May in the 1970s to March, April or sometimes early May. The results also show that, while rainfall was sufficient in the 1970s, it has become less sufficient for the needs of crops, livestock and humans over time (Table 6). The results in both districts also show increasing surface temperature, which is difficult to separate it from drought because they occur simultaneously (Table 8).

A pair-wise ranking show that the most manifestations of climate variability and change, which threaten crop and livestock production is drought followed by unpredictable rainfall, early cessation and late rainfall onset, strong winds and less sufficient rainfall in that order (Table 8). This implies that rainfall patterns have changed relative to the situation in the 1970s with implications on the entire cropping and livestock keeping systems including when to plant what type of crop varieties. This knowledge is critical to minimise risks associated with the phenomena. Arguably, most manifestations of climate variability and change occur concurrently. They are difficult to predict making it complex phenomena to deal with.

The February dry spell[1] has widened from eight days in the 1970s to more than a month in Meatu, and is extending back to January. Similarly, in Iramba, the dry spell has extended back to January and forward to mid-March. Water sources including rivers have become seasonal because of increasing warming that increases evaporation. Rainfall late onset, early cessation and dry spell widening as shown in Table 6 suggest that the length of the growing season has decreased by a month in Meatu, and by more than a month in Iramba. Similar results are reported by Mongi et al. (2010) in Tabora Tanzania; Mathugama and Peiris (2011) in India; Moyo et al. (2012) and Kori et al. (2012) in semi-arid environments in Zimbabwe and South Africa respectively. This implies that the problem is widespread. These results have negative impact on rain-fed agriculture and livestock production system especially in semi-arid environments (IPCC, 2007; Rowhani et al., 2011).

Table 6 Changes related to rainfall

Indicator	*Kidaru*	*Mwashata*	*Mwamanimba*
		Situation in 2013	
Onset of rainfall	November/December or January	November/December	December and rarely end of November
Cessation of rainfall	March/April or early May	April/rarely May	April/rarely May
Sufficiency of rainfall	Not sufficient for the needs of crops and livestock	Not sufficient	Not sufficient for the needs of crops and livestock
February dry spell	Extended back to January, February and sometimes to mid-March	Two weeks up to whole month, and extended back to January	The whole month, and it has extended back to January
Dry season	May to December/January	May to November/December	May to November
Change of water in the rivers	Rivers Ndurumo, Msua, and Gongwa are all seasonal	River Simiyu is drying up in some parts during dry seasons	River Semu, Badi and Lyussa are all seasonal
		Situation in the 1970s and 1980s	
Onset of rainfall	November/December	September or October	September or October
Cessation of rainfall	End of May/mid-June	End of May, mid-June or early July	End of May and sometimes mid-June
Sufficiency of rainfall	Was somewhat sufficient	Was sufficient	Was somewhat sufficient
February dry spell	Whole month	Eight-day dry spell	Eight-day dry spell
Dry season	Mid-June to early October	July to September	June to October
Change of water in the rivers	River Ndurumo somewhat dried up during dry season	River Simiyu did not dry up throughout the year	Rivers somewhat dried up during dry seasons

Qualitative results also show that unimodal rainfall patterns and the February dry spell are not new in semi-arid environments of Tanzania. However, the dry spell widening period suggests that the rainfall regime is becoming bimodal or may become bimodal in future. Even though, the late onset and early cessation shorten the crop growing period and so, at times, disqualifying this regime to be considered bimodal. Collectively, these have intensified climate variability through an increased number of bad years (Table 7). Smallholder farmers define a bad year as one with less sufficient, erratic and unpredictable rainfall. It is essentially dry and hot characterised by crop failure, water scarcity for humans and for pasture development. Normally, this kind of a year culminates into hunger. Its opposite is a good year. Based on these results, crop and pasture failure have become common in the study area. Lyimo and Kangalawe (2010) have reported similar results in Shinyanga Rural District, which is also located in semi-arid environments of Tanzania indicating existence and widespread of the phenomena.

Table 7 Characteristics and frequency of bad years between 1970s and 2012

Year	*Climatic related events by village*		
	Kidaru	*Mwashata*	*Mwamanimba*
1974/75	Insufficient rainfall and hunger	Insufficient rainfall and hunger	Drought, rainfall was somewhat erratic, crop failure followed by hunger
1983	Insufficient rainfall, drought, eruption of crop pests and hunger	-	-
1984	Insufficient rainfall, high day time temperature and drought followed by hunger	Erratic rainfall, high day time temperature, crop failure followed by hunger	Strong wind, erratic rainfall, poor harvests and total maize failure followed by hunger
1985–89	High rainfall variability and high day time temperature	High rainfall variability, high day time temperature and increased strong winds. These carried away clouds when it wanted to rain	High variability of rainfall, insufficient rainfall and drought, scarcity of pastures and water for human and livestock needs
1993	Floods and eruption of crop pests followed by hunger	-	-
1998/99	Floods and eruption of crop pests followed by hunger due to poor harvests. Water and pastures were not affected	Higher amount of rainfall than normal, but no floods, poor harvests, but water and pastures for livestock were not affected	Crop failure due to excessive moisture, but no considerable floods except in very low lands, eruption of crop diseases. Pasture and water for human and livestock were not affected
2003	Drought and hunger	-	-
2005	Drought, erratic rainfall during growing seasons and high day time temperature	Strong wind, high day time temperature, highly erratic rainfall followed by hunger due to crop failure	Insufficient rainfall, high day time temperature, strong wind followed by hunger due to crop failure
2011/12	Drought, high day time temperature, erratic rainfall during growing seasons	Insufficient rainfall and highly erratic, eruption of crop diseases especially in Maize, hunger, some cattle died due to lack of pastures	Insufficient rainfall, drought, high day time temperature, crop diseases, scarcity of pastures, water and hunger and death of cattle due to lack of pastures

Table 8 Pair-wise ranking results on climate variability and change manifestations

Variable	*Kidaru village*				*Mwashata village*				*Mwamanimba village*				*Overall score*	*Overall rank*
	Male		*Female*		*Male*		*Female*		*Male*		*Female*			
	Score	*Rank*	*Score*	*Rank*	*Score*	*Rank*	*Score*	*Rank*	*Score*	*Rank*	*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 7 shows that less sufficient rainfall and drought frequencies have increased particularly in the 2000s. In addition, day time temperature has increased substantially in the same period. The women FGD in Iramba justifies:

> "...Drought has become serious especially since the 2000s...sorghum and bulrush millet, which are drought resistant crops, are now failing due to drought...in 2011/12 we received three rainy days and therefore the crops failed...this year (2013) is likely to be the same..."

That quotation demonstrates farmers' perceptions on increasing number and seriousness of bad years. Contrary, flood frequencies have remained constant. Kidaru in Iramba for example, reports two flood events for the previous 20 years, while Mwashata and Mwamanimba in Meatu have not experienced substantial floods in the previous 30 years from 2013. What appears to be a serious challenge includes increasing rainfall uncertainties, prolonged and frequent droughts, rainfall unpredictability, high day time temperature, shortening of crop growing seasons and increasing wind speeds that carry away clouds when it wants to rain. Moreover, these problems are inseparable, making climate variability and change complex phenomena. This condition is also reflected through an increasing trend of bad years particularly in the 2000s (Table 7). Qualitative results also show clearly that perception of climate variability and change is the same among smallholder farmers in both districts. This shows that men's and women's perceptions of the phenomena are almost similar.

4.2 Quantitative responses on climate variability and change

Table 9 shows respondents' responses on manifestations of climate variability and change while Table 10 shows reliability analysis of climate variability and change manifestations. The results show increased drought events relative to the situation in the previous 30 years. The median scores in Table 9 clearly portray increased drought frequencies. Flood frequencies have remained the same in the previous 30 years. The rest variables in Table 9 show moderate increase including crop pests and livestock diseases. Crop pests and livestock diseases are associated with climate change. These results coincide with qualitative results. They are also in line with Berg et al. (2011) who report increasing crop diseases and insect pests in Sweden as a consequence of climate change. This implies that climate variability and change are global concerns affecting countries in the global south and in the global north though by different magnitude depending on adaptive capacity.

As stated in Section 3.4 in this paper, the Kruskal-Wallis H test is performed to test the hypothesis that perceptions of the poor, not so poor and the rich are the same ($P > 0.05$). The results in Table 11 show that there is no significant difference in perceptions of climate variability and change for the three wealth categories. Since the sample is taken from smallholder farmers and agro-pastoralists in semi-arid environments, similarity in responses suggests that livelihoods of the poor and of the rich depend on the climate and so smallholder farmers and agro-pastoralists are not only knowledgeable, but also perceive occurrence of climate variability and change regardless of wealth status.

Table 9 Percentage responses on current variability compared to the situation in the past 10 to 30 years (n = 388)

Variable	*Percentage responses*					*Median score*
	HD	*DM*	*NC*	*IM*	*HI*	
Frequency of flood	22	11	60	6	2	3
Rainfall unevenness	13	18	5	33	32	4
Rainfall unpredictability	10	12	4	28	47	4
Strong wind	11	13	15	29	32	4
Day time temperature	3	11	4	37	46	4
Night time temperature	3	10	7	41	40	4
Frequency of droughts	4	4	4	26	62	5
Diseases in crops	5	13	10	36	35	4
Diseases in livestock	8	16	11	39	27	4
Insect crop pests	8	16	8	37	31	4

Notes: HD = highly decreased (1 score); DM = decreased moderately (2 scores); NC = no change (3 scores); IM = increased moderately (4 scores) and HI = highly increased (5 scores).

Table 10 Descriptive statistics and reliability analysis

Variable	*Mean*[a]	*Std. dev.*	*Item-total correlation*	*Cronbach's α if item deleted*
Frequency of flood	2.2	0.9	0.2	0.7
Rainfall unevenness	3.5	1.4	0.2	0.7
Rainfall unpredictability	3.9	1.4	0.2	0.7
Strong wind	3.6	1.3	0.4	0.7
Day time temperature	4.1	1.0	0.5	0.7
Night time temperature	4.0	1.1	0.5	0.7
Frequency of droughts	4.4	1.0	0.4	0.7
Diseases in crops	3.8	1.2	0.5	0.7
Diseases in livestock	3.6	1.2	0.5	0.7
Insect crop pests	3.7	1.3	0.5	0.7

Notes: [a]Calculated from scores on a five-point scale whereby: 1 = highly decreased; 2 = decreased moderately; 3 = no change; 4 = increased moderately and 5 = highly increased.

Table 11 Household responses on climate variability by wealth status (n = 388)

Wealth category	*n*	*Median*	*Chi-square*	*Degree of freedom*	*P-value*
Poor	192	36	2.537	2	0.281
Not so poor	152	36			
Rich	44	36			

The Mann-Whitney U test is used to compare perception scores between men and women. The results show that there is no significant difference in the median of perception scores between men and women (Table 12). This is translated into similar perceptions of climate variability and change between men and women, coinciding with qualitative results. Moreover, Swai et al. (2012a) in Tanzania; Juana et al. (2013) in Sub-Saharan Africa and Legesse et al. (2013) in Ethiopia have reported similar men and women's perceptions of climate variability and change. This implies that perceptions of the phenomena in semi-arid environments especially in communities whose livelihoods depend on agriculture and livestock keeping do not differ by gender. Even though, a study by Swai et al. (2012b) conducted in Tanzania shows differences between men and women's perceptions of the phenomena. The differences can be due to wrong interpretation of the quantitative results because men and women's perceptions of change in temperature, wind and drought differ by one percent, implying that perception is almost similar. Arguably, women perceive more risk of climate variability and change, and other risks due to different gender roles which expose them to higher risks (Gustafson, 1998; Nombo et al., 2013).

Table 12 Responses on climate variability and change between men and women (n = 388)

Respondents' sex	*n*	*Median*	*Mann-Whitney U*	*Wilcoxon W*	*Z*	*P-value*
Male	235	35	17,565	45,295	–0.384	0.701
Female	153	36				

4.3 Combining meteorological data and farmers' perceptions

The results in Table 13 show that January and April experience a decreasing rainfall trend in the period between 1994 and 2011 in Meatu. The results also show higher standard deviations implying that rainfall patterns are inconsistent in each month during crop growing seasons. This can also imply that some months receive much rain while others get considerably low rains. These results coincide with farmers' perceptions, which show extending back of the dry spell from February to January resulting into decreasing crop growing season. The results are also in line with farmers' perceptions on increasing rainfall unpredictability that coincide with higher standard deviations in monthly rainfall. Rainfall in December and April also show a clear decreasing trend for the period between 1994 and 2008 in Iramba (Table 14). These results suggest two things: first, the decreasing trend in April implies early cessation relative to the situation in the past. Secondly, the decreasing trend in December suggests less sufficient rainfall during critical crop growing period. This can cause inadequate moisture resulting into crop failure and poor pasture development. Like in Meatu, the meteorological data trends in Iramba show higher standard deviations suggesting inconsistent rainfall patterns (Table 14).

Table 13 Measured rainfall variability during growing seasons in Meatu District

Period	*November*		*December*		*January*		*February*		*March*		*April*	
	Mean	*Std. dev.*	*Mean*	*Std. dev.*	*Mean*	*Std. dev.*	*Mean*	*Std. dev.*	*Mean*	*Std. dev.*	*Mean*	*Std. dev.*
1994–1998	132.9	90.9	141.0	106.5	168.4	113.1	124.1	88.4	102.1	42.8	130.5	23.2
1999–2003	64.6	31.5	77.6	15.1	108.9	46.3	74.9	34.9	138.2	62.1	88.5	69.6
2004–2008	108.4	83.5	135.0	42.1	101.2	53.2	102.1	48.0	133.3	92.5	84.3	43.5
2009–2011	62.5	20.2	175.0	16.8	48.0	36.4	139.9	49.1	136.0	23.8	96.3	76.9

Source: TMA (2013), data section, Dar Es Salaam, Tanzania

Table 14 Measured rainfall variability during growing seasons in Iramba District

Period	*November*		*December*		*January*		*February*		*March*		*April*	
	Mean	*Std. dev.*	*Mean*	*Std. dev.*	*Mean*	*Std. dev.*	*Mean*	*Std. dev.*	*Mean*	*Std. dev.*	*Mean*	*Std. dev.*
1994–1998	71.0	68.9	195.6	197.6	140.2	68.1	158.8	49.5	151.8	112.8	120.8	56.1
1999–2003	123.6	84.8	139.1	54.0	192.4	97.2	60.1	26.4	202.2	57.1	87.6	45.3
2004–2008	67.3	50.6	112.9	59.3	149.9	65.7	134.7	57.5	135.3	100.4	66.6	69.1
2009–2011	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Note: NA = data not available.

Source: TMA (2013), data section, Dar Es Salaam, Tanzania

Rainfall seasonal means in the districts are 669.6 mm in meatu and 777.4 mm in Iramba in the period between 1994 and 2011. This is an insufficient amount for requirements of many crops, given inconsistency rainfall patterns demonstrated by higher standard deviations. For example, maize rainfall requirement ranges from 500 to 2,000 mm, sorghum 250 to 1,200 mm, cotton 850 to 1,100 mm, paddy 1,200 to 1,800 mm and sunflower 600 to 1,000 mm per annum (TARO, 1987a, 1987b, 1987c, 1987d, 1987f). Meteorological data trends also show that Iramba experienced eight dry seasons in a period of 15 years. In addition, Meatu experienced 11 dry seasons in a period of 18 years (Tables 15 and 16). During dry seasons, measured rainfall is normally less than the seasonal mean. Less sufficient and inconsistent rainfall patterns have serious implications on farmers, and agro-pastoralists' decisions regarding the cropping calendar and types of crop varieties to adopt. The fact that early cessation, drought and less sufficient rainfall shown by meteorological results coincide with farmers' perceptions, indicates that climate variability and change are real phenomena in semi-arid environments. However, contrasting results are reported in Ethiopia whereby meteorological results do not validate change in rainfall patterns. In this situation, farmers' perceptions are largely influenced by environmental degradation, decrease in soil fertility, and increasing demand for staple food due to population increase (Meze-Hausken, 2004).

Table 15 Rainfall and temperature seasonal anomaly (November–April)

Year	*Iramba*		*Meatu*	
	Rainfall (mm)	*Temperature (°C)*	*Rainfall*	*Temperature (°C)*
1994	+233.0	NA	–134.7	0.3
1995	–207.4	NA	+75.2	–0.2
1996	–432.5	NA	–132.0	–0.1
1997	+429.6	NA	+598.6	0.3
1998	+281.7	NA	+241.2	–0.3
1999	+102.4	NA	–188.8	0.2
2000	–12.6	NA	–118.0	0.1
2001	+16.4	NA	+79.9	0.3
2002	+268.9	NA	–128.8	0.5
2003	–236.8	–0.48	–228.8	–0.6
2004	–33.7	0.29	–260.1	0.0
2005	–77.1	–0.25	–17.1	–0.8
2006	NA	0.18	+251.1	0.4
2007	–47.8	0.34	+18.9	–0.1
2008	–284.4	0.48	–20.5	0.4
2009	NA	0.08	+62.6	–0.1
2010	NA	–0.38	–45.8	–0.5
2011	NA	–0.29	–53.5	0.0

Note: NA = data not available.

Source: TMA (2013), data section, Dar Es Salaam, Tanzania

Table 16 Meteorological data trends in number of dry and hot seasons

Period	*Iramba*		*Meatu*	
	Dry seasons	*Hot seasons*	*Dry seasons*	*Hot seasons*
1994–1998	2	NA	2	2
1999–2003	2	NA	4	4
2004–2008	4	4	3	2
2009–2011	NA	2	2	0
Total	8	6	11	8

Note: NA = data not available.

Source: TMA (2013), data section, Dar Es Salaam, Tanzania

Tables 15 and 16 show inconsistent measured dry seasons in Meatu contrary to farmers' perceptions that show an increasing trend in bad years' frequency in the previous ten years from 2012. Moreover, lack of data in Iramba poses difficulties to observe measured dry seasons' frequency. This mismatch between farmers' perceptions and measured rainfall trends is largely explained by lack of or inadequate amount of rainfall in the period when it is expected to rain. The seasonal mean temperature is between 27.5°C and 30.6°C in Iramba and Meatu respectively. Meteorological data trends do not demonstrate clear hot seasons' trends contrary to farmers' perceptions that show an increasing temperature. In this case, farmers could be attributing drought frequencies to an increasing day time temperature. In addition, failure of meteorological data to validate farmers' perceptions can be due to lack of data in some months, or unavailability of meteorological stations at the village or ward level. The results in Tables 15 and 16 also show that dry seasons are hot seasons in Meatu. This implies overlapping of drought and temperature variables, coinciding with qualitative results.

5 Conclusions and policy recommendations

This paper combines farmers' perceptions and meteorological data trends to broaden the understanding of climate variability and change. The paper contributes to the concern whether climate variability and change has increased or not in selected semi-arid environments in Tanzania. Based on the results and discussion, the paper makes three conclusions: first, farmers' perceptions show complexity and increasing climate variability and change since the 1970s. Bad years' frequency has increased putting smallholder farmers' livelihoods at risk. Secondly, as hypothesised, men and women's perceptions of climate variability and change are the same ($P > 0.05$). Similarly, the poor, not so poor and the rich have similar perceptions ($P > 0.05$) of climate variability and change. Thirdly, there is an agreement between farmers' perceptions and meteorological data trends on inconsistent rainfall patterns, dry spell expansion from February to January and sometimes to March, early cessation, less sufficient rainfall and decreasing crop growing season. However, perceptions of increased frequency of droughts are not validated by meteorological data trends, mainly due to missing meteorological data in some months and lack of meteorological data stations at the village or ward levels.

Based on the conclusions, the paper makes three recommendations: first, when examining climate variability and change, researchers should combine farmers' perceptions and meteorological data trends to broaden and forge knowledge of the phenomena for informed decision on policy making to support adaptation strategies in rain-fed agriculture and livestock keeping. Secondly, TMA and district authorities should strengthen meteorological data record keeping, install at least one meteorological station per ward, and share with the farmers, what meteorological data portray to increase farmers knowledge and adaptive capacity. Currently, meteorological stations are scattered widely, and temperature is recorded only at the regional level. This cannot uncover the whole picture because climate variability can occur at a small scale, such as ward level. Thirdly, TMA and district authorities should ensure management and sustainability of the meteorological stations.

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Notes

1 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 than and not as severe as drought (Mathugama and Peiris, 2011).