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Climate change perception and impacts on cattle production in pastoral communities of northern Tanzania

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Abstract

This study examines pastoralists' perception on climate change and impacts on cattle production from ten study villages of Monduli District in Tanzania. This study drew empirical data from 130 cattle owners and 81 participants from focus group discussions in the study villages. Descriptive statistics and thematic analysis were used to analyze the data respectively. Findings from this study indicate that pastoralists are well aware of the general climate trends in their location, its variability and the impacts of extreme weather events on cattle production. The main climate changes perceived by pastoralists include more erratic and reduced amounts of rainfall, rise in temperature and prolonged and frequent periods of drought. Pastoralists mainly view population pressure and tree cutting as the major causes of climate change. Further, this study found that there are no existing climate risk programmes and early warning systems across the district. Importantly, pastoralists reported the negative impacts of climate change on cattle production. The severe recurrent drought periods result in shortage of forage and water, leading to cattle starvation and malnutrition. Pastoralists reported massive cattle deaths and outbreaks of diseases such as contagious bovine pleuropneumonia and tick-borne diseases. Further, reduction in milk production and poor livestock market prices were also reported as negative impacts on cattle production. Given the range of negative impacts of current climate change and extreme weather events on cattle production, the implications of climate change must be taken into account to ensure longer-term survival and sustainability of pastoralist communities through strengthening of climate risk awareness programs and early warning systems across the district. Further, this study recommends that government and non-governmental organizations should improve institutional support to pastoralists in order to help them deal with the negative impacts of climate change on livestock production.

Keywords: Pastoralist perceptions, Temperature, Rainfall, Drought

Introduction

Global climate change is one of the greatest challenges of the twenty-first century. Evidence is now overwhelmingly convincing that climate change is unequivocal and happening at an unprecedented rate (IPCC 2013; Adhikari et al. 2015; Huang et al. 2016). Climate change impacts are expected to severely affect arid and semi-arid rangelands which cover nearly two thirds of the African continent (Galvin et al. 2001). Many of the impacts of climate change in these areas are characterized by variability in rainfall patterns and extreme weather events such as recurrent droughts, floods and wind storms (IPCC 2007, 2013). These areas for example in sub-Saharan Africa are inhabited by an estimated 386 million people, including pastoralists who depend on natural resources for their livelihood (Conway 2009; IPCC 2015; Thornton et al. 2007; Adhikari et al. 2015).

Tanzania is currently experiencing the adverse impacts of climate change in all sectors of the economy, including livestock production (Shemsanga et al. 2010; URT 2007; Sangeda and Malole 2013). For example, a mean annual increase of temperature of 1.0 °C was recorded since 1960 with decreasing rainfall at an average of 2.8 mm per month or 3.3% per decade countrywide

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(TCAR 2016; Magita and Sangeda 2017). According to climate models for Tanzania, the climate change prediction indicates that the country's temperature is expected to rise by 3–5 °C by 2075 (VPO 2003). Nonetheless, the effects of climate change are already devastating rural livelihoods across the different regions of Tanzania (Sangeda and Malole 2013; Magita and Sangeda 2017; Kangalawe and Lyimo 2010; URT 2007; Joseph and Kaswamila 2017).

The livestock sector is ranked as one of the vital economic sectors in Tanzania that will be severely impacted by climate change if no serious actions are taken to respond to its adverse consequences (MLDF 2015). The sector is central to the livelihood of the majority (86%) of rural Tanzanians, and particularly pastoralists whose livelihoods are wholly or partially dependent on livestock (MLDF 2015, 2011). In addition to being a source of food such as milk, livestock keeping offers a range of other products and services including hides, draught power, a mode of saving and social-cultural symbolism (Thornton and Gerber 2010; MLDF 2011). Climate change is expected to severely affect survival and production of livestock, and cattle in particular are reported to be more impacted than other livestock species due to their feeding behaviour and potential for heat stress (Toulmin 2009; Nardone et al. 2010). Due to scarcity of pasture and water following recurrent drought periods in the country, livestock have already succumbed to several climate-driven perturbations including massive deaths of livestock, loss of body condition and reduced productivity (Maleko and Koipapi 2015; Magita and Sangeda 2017; Chamliho 2017).

Information on climate risks are vital to shape actions against climate change impacts (Zumsteeg 2012; Egeru 2016). In addition, the way that individuals and groups perceive the risk of climate change strongly influences how they deal with the climate's adverse impacts (Adger et al. 2009; Patt and Schröter 2007). Similarly, misconception about climate change and its associated risks may result in maladaptation or no adaptation at all, thus increasing the negative impacts of climate change (Grothmann and Patt 2005). Establishment of climate change perception and its impacts in pastoral communities is critical to inform decision makers and planners to take appropriate actions that will enhance pastoralists' capacity and adaptation to climate change (Debela et al. 2015; Juana et al. 2013; Fosu-Mensah et al. 2012).

Maasai communities in northern Tanzania are increasingly faced with a number of challenges related to (among other things) loss of land ownership due to establishment of new conservation and adminstrative areas and also increase of agricultural activities to meet their increasing food demands (Galvin et al. 2001; Galvin et al. 2004; Msoffe et al. 2011). Global climate change is a significant additional stress to these communities. There is limited understanding of pastoralists' perception of climate change and how these changes impact cattle production in Maasai pastoralist communities. Some studies in the study area have focused on socio-economic vulnerability of Maasai pastoralists (Theodory and Malipula 2014) or on effects of the 2009 drought on cattle mortality and associated response by pastoralists (Goldman and Riosmena 2013). Climate change studies focusing over a long period of time are critical for better assessment of climate change (IPCC 2007). Twenty or thirty-year time frame of assessment has been adopted for other studies (Deressa et al. 2011; Osbahr et al. 2011). This study, therefore, seeks to address the gap in knowledge on pastoralists' perception of climate change and variability for Monduli District over a thirty-year period (1984–2014), and the effects of climate change on cattle production.

Study area

This study was conducted in Monduli District situated between latitudes $3^0.29'59''$ south and longitude $36^0.45'27''$ east. The district is in Arusha region and is part of the Maasai steppe landscape (Kaswamila 2009; ADF 2003). The district has two major agro-ecological zones. The highland zone comprises isolated mountains with average altitude of 2000 m above sea level, characterized by sub-humid weather and an average annual rainfall ranging from 500 mm to 900 mm (ADF 2003; Msoffe et al. 2011). The main economic activities in the highland zone are crop production and livestock keeping. The lowland consists of arid and semi-arid rangelands which cover about 85% of Monduli District. These areas receive an average annual rainfall ranging from 200 to 600 mm, and livestock keeping is the main economic activity. The district has a bi-modal rainfall pattern with the short rains occurring between November and December and the long rains occurring between March and May (Kaswamila 2009; ADF 2003).

Methods

Selection of study villages

Monduli District was selected for this study based on the following criteria (i) homeland to pastoralist communities that depend largely on livestock for their livelihood (ADF 2003) and (ii) comprised of mostly arid/semi-arid lands that have experienced severe climate variability including increasing drought periods and unpredictable rainfall (Theodory and Malipula 2014).

A list of all pastoralist villages in the lowland ecological zone was obtained from the Livestock Department of Monduli District, and 10 villages were randomly selected for this study by drawing names from a hat (Figure 1; mapped using ArcGIS version 10.2

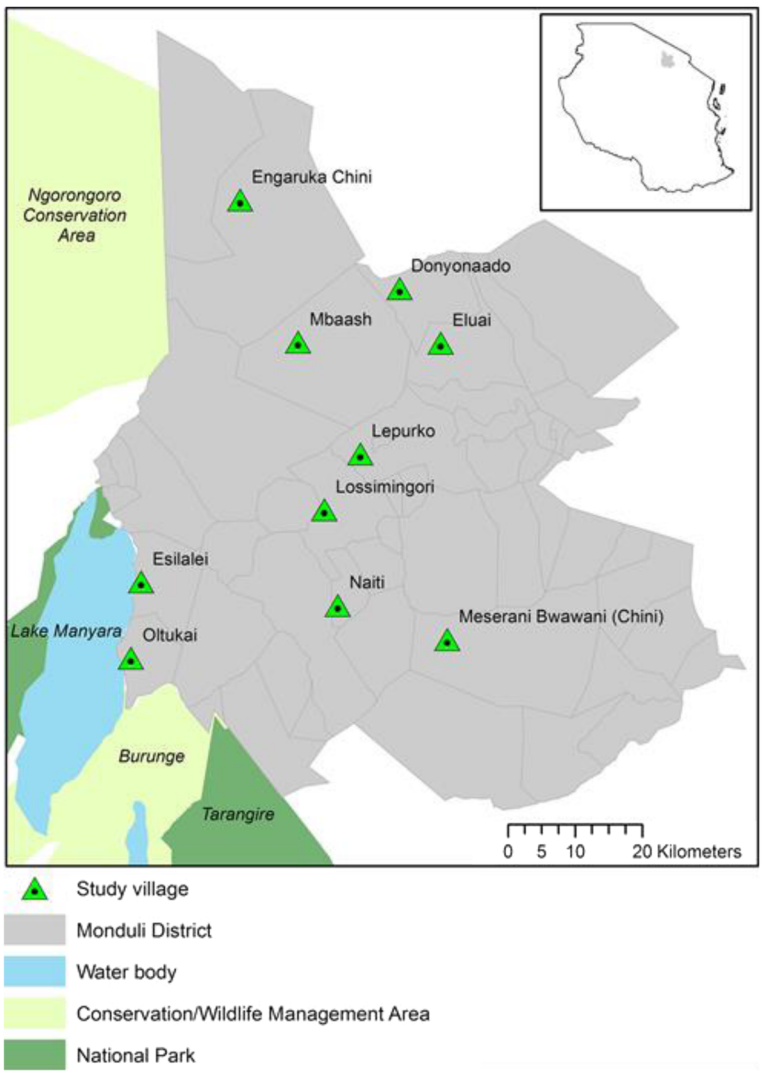

Figure 1 Map of Monduli District Northern Tanzania showing the ten study villages

(Environmental Systems Research Institute, Redlands, CA, USA)). Cattle owners were randomly selected from the sampling frame obtained from the village executive officers. Before the study, the research team visited the selected villages for formal introduction of the project.

Data collection

An in-depth investigation of pastoralist perception, experiences and observations of climate change for over thirty-year period (1984–2014) was undertaken with cattle owners and with village executive leaders and livestock officers of Monduli District in northern Tanzania.

Ethical considerations

Ethical clearance for this research was obtained from the human research ethics committee at the University of Sydney, Australia (protocol number 2014/455), and Tanzania Commission for Science and Technology (COSTECH; No.2013-241-NA-2014-175).

Cattle owners' survey

This study was part of a larger study investigating the prevalence of vector-borne diseases and associated management practices in cattle. The sampling strategy and findings have been described in detail elsewhere (Kimaro et al. 2017a, 2017b). Briefly, in order to meet the objectives and sample size requirements for the study, a questionnaire was administered to 130 pastoralists across the 10 randomly selected villages between March and May 2015. Key issues addressed in the questionnaire and reported here include: observations of climate change and variability trends, that include temperature, rainfall and reported years with severe water and pasture shortage for cattle (1984–2014); observed impacts of extreme

weather events on cattle production; perception of climate change; perceived indicators of climate change; and perceived causes of climate change (see Additional file 1). The research team involved the main researcher and two research assistants who underwent training to ensure a common understanding of procedures for questionnaire administration. The individual interviews with farmers were conducted in Kiswahili (national language for Tanzania). In villages where Kiswahili was not the main language of communication, Maasai language was used with the help of a local interpreter.

Focus group discussions

Focus group discussions (FGD) were conducted in each of the 10 villages to elicit information on the understanding and perception of village leaders and livestock officers about climate change and variability, and the adverse impacts on cattle production across the district. A group size of 6–12 participants is recommended to generate rich discussion, capture common themes and permit easier management of the data collection process (Guest et al. 2006; Howell 2016; Braun and Clarke 2013). Therefore, approximately 8–12 participants were purposely selected from each study village. The participants for the focus groups were village executive leaders including village elders, some of whom were cattle owners. In addition, animal health workers (i.e. ward/village livestock officers) were targeted for this research, given their knowledge of the livestock health situation in the district. All participants were given a letter of invitation in advance of the group meetings. Focus groups were conducted from January to March 2015 and were carried out by the main researcher and one research assistant who helped in setting up the meetings and kept notes during discussions. A checklist was used to facilitate the discussion and focused on three main issues: perception of the term 'climate change' and its causes; climate change awareness programmes and early warning systems; and impacts of climate change on livestock production. The discussions were conducted in Kiswahili language, and were audio-taped and transcribed into English after every discussion.

Data analysis

Data from the cattle owners' survey were entered into Epi Info version 3.5.4 (Centers for Disease Control, Atlanta, GA, USA) and imported into Microsoft Excel 2010 for cleaning. Missing and invalid entries were re-checked against hard copies. Data were exported and all analysis performed using the Statistical Package for Social Science version 22 (SPSS Inc., Chicago, USA). Descriptive analysis for closed-ended questions was performed using frequency tables and presented in percentages. For comparison, rainfall datasets for the period spanning 1984 to 2014 for Monduli District was obtained from Tanzania Meteorological Agency (TMA 2015). Using these data, the Standardized Precipitation Index (SPI) was calculated using the SPI package in R version 3.1.3 (R Foundation, Vienna, Austria). This index reflects the number of standard deviations by which the observed cumulative rainfall departs from the long-term mean and is considered an appropriate method for monitoring droughts in East Africa (Ntale and Gan 2003). Total annual rainfall, SPI and pastoralist recollection of periods of severe water and pasture shortage were then plotted. For open-ended questions, cattle owners' responses were read several times to identify common phrases and words. Common responses were coded into thematic categories and analyzed using content analysis method (Hardy and Bryman 2004). These responses were analyzed in frequency distributions and percentages.

Data from FGD were retrieved from the digital recorder and transcribed by the research team while in the field. This helped the facilitator to consider how the conduct of subsequent discussions could be improved or further developed. The data collected in each FGD were analyzed using a deductive approach to thematic analysis, within an essentialist framework, guided by the research questions for this study and the questions posed in the discussions (Braun and Clarke 2013). The purpose of this analysis was to report and describe participants' perceptions of climate change and its impact. Data analysis was undertaken using NVivo10 qualitative data management software. Initially, codes were identified through repeated words, phrases and ideas (Braun and Clarke 2013). Two researchers worked on refining the codes; this included merging or creating new codes depending on their relevance in the development of themes and sub-themes. To ensure rigorous analysis, transcripts were carefully re-examined to make sure there was appropriate identification and coverage of themes across the transcripts (Braun and Clarke 2013). Additionally, analysis involved searching for unusual cases (e.g. comments, beliefs) within themes and sub-themes that ensured variations in perceptions were acknowledged.

Results

Respondent demographics

Demographic characteristics of respondents in the cattle owners' survey and FGD are summarized in Tables 1 and 2, respectively. Livestock keeping was the main livelihood strategy for the 130 participants in the survey. Reported herd size for these pastoralists ranged between 2 and 600 cattle (median of 40 breeding cows). A total of 81 individuals were involved in the discussions with number of participants per FGD ranging from 4 to 11.

Table 1 Demographic characteristics of cattle owners ($N = 130$) surveyed in 10 villages in Monduli District, Northern Tanzania in 2015

Demographic Characteristic	Number (%)
Gender	
Male	124 (95.4)
Female	6 (4.6)
Age (years)	
18–35	42 (32.3)
36–54	62 (47.7)
55–75	23 (17.7)
76–95	3 (2.3)
Education	
None	69 (53.1)
Primary	61 (46.9)
Secondary	0 (0)
Livelihood	
Main income source-Livestock keeping	128 (98.5)
Other income generating activities reported	
Crop business	49 (37.7)
Business	5 (3.8)
Employment	3 (2.3)

Table 2 Demographic characteristics of FGD participants ($N = 81$) in ten villages of Monduli District, Northern Tanzania in 2015

Variable	Category	Number	Percentage (%)
Age (years)	25–35	22	27.2
	36–55	40	49.4
	56–85	18	22.2
	> 86	1	1.2
Gender	Male	81	100
	Female	0	0
Education level	No school	13	16.0
	Primary	51	63.0
	Secondary	11	13.6
	College	6	7.4
Designation	Village chairpersons	10	12.3
	Village executive officers	9	11.1
	Deputy village leaders	5	6.2
	Sub village leaders	27	33.3
	Village council members	11	13.5
	Village elders	13	16.0
	Livestock officers	6	1.2
Cattle owner	Yes	76	93.8
	No	5	6.2

All FGD participants were males. The majority of participants (63.0%; 51/81) had primary education while 7.4% (6/81) had college education. The latter mainly included ward livestock officers who were government employees working with pastoralists in their respective villages. Almost all participants owned cattle (93.8%; 76/81). The five participants who did not own cattle were livestock officers.

Cattle owners' survey

Cattle owner and meteorological observations of climate and extreme weather events

A majority of cattle owners (98%; 128/130) reported experiencing a reduced amount of rainfall in their respective villages over the last 30 years. About three-quarters of cattle owners (75.4%; 98/130) reported experiencing erratic and more unpredictable rainfall. Most (98.5%; 128/130) also reported experiencing an increase in temperature over the same period. The majority of cattle owners (92.3%; 120/130) were able to recall and narrate the specific years in which they experienced severe water and pasture shortage in their respective villages (Table 3). Meteorological data show annual variations in precipitation, with frequent troughs depicting years of low rainfall and a general decline in precipitation over the thirty-year period (Figure 2). The SPI shows increasingly long periods of moderate, dry weather ($-1.29 \leq SPI < -0.80$) from 2007 onwards. According to cattle owners, more villages have experienced years with severe water and pasture shortages in recent times.

Cattle owners' perception about the reasons for the observed changes in climate

More than a half of the cattle owners (52.3%; 68/130) identified one or more possible reasons for the observed changes in climate. The majority (67.6%; 46/68) identified environmental destruction, including increased tree cutting in recent times, as the cause. Other explanations given included recent increases in the population of people and their livestock ($n = 12$) and natural changes/normal processes of the Earth ($n = 10$).

Impacts of extreme weather on cattle production

Almost all cattle owners (98.5%; 128/130) reported experiencing negative impacts on their livestock during periods of severe water and pasture shortage. All 128 cattle owners reported massive cattle death. In addition, cattle owners reported low sale prices for livestock leading to severe economic losses ($n = 54$), eruption of cattle diseases such as East Coast fever and '*nadendolit*' (depletion of bone marrow) ($n = 40$) and hassle associated with trekking animals over long distances to search for adequate pasture and water ($n = 34$).

Table 3 Cattle owners ($N = 130$) reported years with severe water and pasture shortage for cattle over the last 30 years 1984-2014 in Monduli District, Northern Tanzania

Study village	Years of severe drought as per cattle owners recollection
Meserani Bwawani	1993, 1995, 1997, 2000, 2001, 2005, 2009, 2011, 2014
Lepurko	1984, 1989, 1993, 1997, 2000, 2005, 2009, 2011, 2014
Esilalei	1984, 1993, 1997, 2003, 2005. 2009, 2011, 2014
Naiti	1997, 2009, 2011, 2014
Mbaash	1996, 2000, 2005, 2009, 2014
Eluai	1996, 1997, 1999, 2003, 2009, 2014,
Oltukai	1990, 1993, 2000, 2003, 2005, 2009, 2011 2014
Lossimingori	1984, 1993, 1995, 1997, 2000, 2003, 2005, 2009, 2014
Donyoonado	1991, 1997, 2005, 2009, 2014
Engaruka Chini	1984, 1991, 2005, 2009, 2014

The term 'climate change'

A majority of cattle owners (73.8%; 96/130) reported that they had heard of the term '*climate change*', of whom only 64 reported to understand what the term means. According to these participants, '*climate change*' was thought to refer to changes in rainfall patterns (often erratic and with a decline in rainfall amount), rise in temperature and recurrent drought periods ($n = 56$). Fewer cattle owners perceived the term '*climate change*' as referring to something related to environmental changes ($n = 4$), Earth's natural changes and processes ($n = 2$), or factories and industries ($n = 2$).

Cattle owners' concern about climate change

The majority of cattle owners (88.5%; 115/130) reported worrying about the future impacts of climate change. When cattle owners were asked what worries them, almost all (95.6%; 110/115) reported that the uncertainties and unpredictability of rainfall, as well as increasing recurrent drought periods being a big concern for pasture

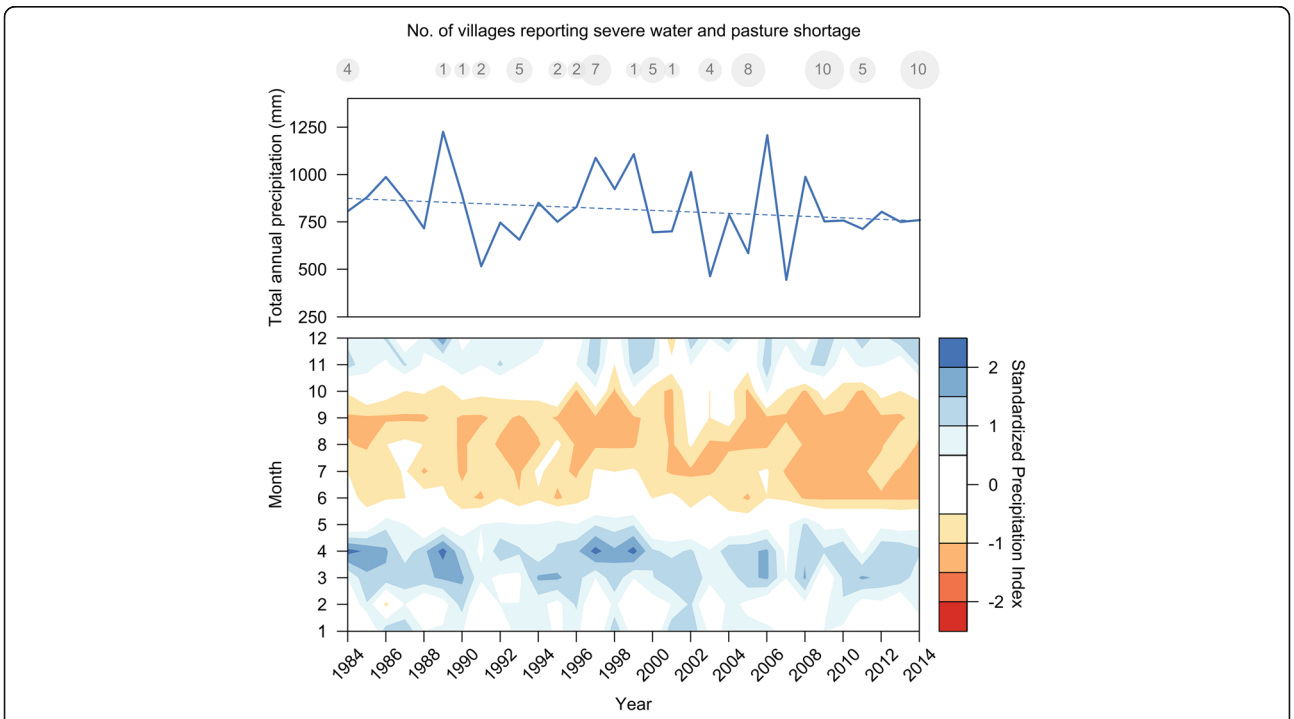

Figure 2 Total annual precipitation and Standardized Precipitation Index (SPI) for Monduli District, Northern Tanzania (1984–2014). Linear trend for rainfall is shown as a blue dashed line. SPI reflects the number of standard deviations from the long-term trend, with blue, white and orange reflecting moist, near normal, and dry periods, respectively. Drought periods are represented by relatively high negative deviations (SPI ≤ – 1.0). For contrast, years recalled by pastoralists as having severe water and pasture shortage are shown as gray bubbles. The size of the bubble corresponds to the number of villages that reported this outcome in a particular year (range: 0–10)

and water availability for their livestock; they foresee that their cattle will suffer severely. Fewer cattle owners (4.3%; 5/115) indicated that they feared climate change impacts on general life.

Focus group discussions

Summaries of the four main themes emerging from the FGD are presented in Table 4. Participants reported on their understanding and perception about climate change as per their experiences. This was particularly explained by participants in terms of changes in climate parameters for instance reduced rainfall amount, increased temperature and increased drought periods in recent times as compared to the past. Participants also reported their perception and observations about possible causes of climate change through increasing population pressure and deforestation. Further, participants reported various sources of information for climate change. The final theme is about climate change impacts on livestock production including outbreaks of livestock diseases.

Effects of climate change

In the focus groups, participants were asked 'what does the term climate change mean to you?' Many participants responded to this question by explaining the alarming changes in climate parameters, such as reductions in rainfall amount, unpredictable and shorter rainfall seasons, increasing temperature and prolonged drought periods. This was highlighted by participants from various groups through selected quotes below:

> *"In the past, we had enough rainfall amounts. For the short rain used to start raining around September and we had a real short dry season afterward, it can be only one month. While rain seasons were really good sometimes it can rain even for three months uninterruptedly. But in recent times, the rainy season may last only for three days and followed by a prolonged dry season". (Village leader, Focus Group-village J)*

> *"We see in recent times temperature has really increased. We can have a little cool weather only in July and a part of August but the rest of the time it is really hot especially from September to November and it can be very hot". (Village leader, Focus Group-village I)*

In addition to the climatic changes described above, some participants also reported observing unusual climatic conditions, especially when the defense force (military) are undertaking military trainings close to their village area. However, this observation was pointed out by participants in two groups only, whose villages are located close to the military base. One village leader said he has noticed some abnormal situations as explained below:

> *"My own observation: In the past few years, we have experienced something unusual in our area. For instances, if the military (Tanzania National Defence Force-Monduli area) have their military trainings in the nearby area to our village. When lots of guns/ bombs explosion happens we find that in those years we will not have a good rainfall. We think maybe the bombs smoke could contribute in the destruction of evaporation in the atmosphere leading to less rainfall and severe drought in those particular years". (Village chairman, Focus group-village H)*

Many participants reported experiencing shrinkage of grazing land and disappearance of vegetation cover in recent times that they link to reduced rainfall, and recurrent drought periods experienced. Some of the response below attests to this observation:

Table 4 Main thematic analysis results summaries. FGD in Monduli District, Northern Tanzania in 2015

Category	Themes and contributing explanations identified during focus groups	
	Main themes	Sub-themes
Climate change experiences	The concerning effects of climate change	• Rainfall variability • Recurrent drought periods and increases in temperature • Shrinking of vegetation cover and grazing land • Soil erosion
	Human population and environmental change as causes of climate change	• Increased population • Deforestation (tree cutting)
Climate change awareness	Variable sources of climate change information and early warning systems	• Media e.g. radio • Monduli Council initiatives • The use of *'indigenous knowledge'* and *'common sense'* • Village initiatives
Climate change and livestock production	The negative impact of climate change on livestock production	• Low productivity e.g. reduced milk production • Poor market for livestock that impacts livelihoods • Livestock disease occurrences • Massive cattle death

"Yes, we see big climatic changes. In the past when we were kids we had lots of grass/vegetation [Village I], we had enough grazing land with enough pastures but nowadays by July or August in every year, there is nothing on the ground. Everyone will leave this place to search for adequate pasture. There is nothing at all. But because of increased droughts, grasses can't really grow well like in the past. In recent times we don't have grasses with strong roots especially in dry season until when we have rainfall in March then we try to plant our crops such as 'ngwara' because 'ngwara' will help to get some fodder for our cattle after harvest". (Village leader, Focus group-village I)

Pasture scarcity in the pastoral communities is increasingly becoming a concerning problem as never before. In the past, pastoralists used to have plenty of pastures for their livestock. Importantly, they see there are no longer quality grass, and the grassland vanishes quite early forcing pastoralists to start migrating away from their homes for better pasture.

Furthermore, participants mentioned soil erosion was increasingly becoming a problem. They reported that land has been left bare without vegetation cover and that this accelerated soil erosion and water flowing freely when it rains. This observation indicates a need for interventions to overcome the problem in the study area. They also talk about some ongoing crop farming activities that also promote environmental destruction. This was explained as below:

"You see [censored] community at the mountain…these communities practice crop farming causing environmental destruction. When it is raining the water comes down with red sand, and that sand enterers the lake and has shown to destroy Lake Manyara. In the lake there is lots of sand coming from the top mountain where agricultural activities are carried out, so we are also destructing the environment". (Village leader, Focus Group-village H)

"We also see there is massive soil erosion. When it rains we see water flowing down the galleys massively and cause a lot of destructions". (Village leader, Focus Group- Village J)

Throughout the discussions, it was clear that participants are well aware of the changes in climate and alarming impacts of these changes for rangelands, soils and waterways happening in their respective villages. It was noticed that participants were very concerned by the trend of increasingly unpredictable rainfall and severe frequent drought periods which affect availability of pastures and water for livestock and degrade the soil and have already impacted on their livelihoods. Pastoralists indicated they are unsure what the future may hold.

Human population and environmental change as causes of climate change

Participants conveyed a number of factors that they thought could be the causes of climate change. Many participants reported that the growing human population contributes to environmental destruction. Participants reported that in previous times they used to see fewer '*bomas*' (Maasai homestead). Conversely, there are many '*bomas*' in recent times which is evidence of the increase in human population. However, during discussions it was noticed that participants did not really associate increasing numbers of livestock with climate change and/or environmental destruction. At times, the facilitator tried to get participants to elaborate on their views about the influence of livestock as a possible cause for climate change but participants did not clearly respond to this query. Rather, participants were concerned about the increased population pressure within the same land area, as commented below:

"As people are increasingly more, there is expansion of human settlement but the land is not increasing, so in recent times there are more farms and more environmental destruction". (Village leader, Focus Group-village A)

Similarly, participants often admitted that in previous times they used to see abundant wildlife such as elephant, lion, and leopard in villages. However, these days, because of human population growth and increased human activity, wildlife have been pushed away. This was explained as follows:

"Lots of vegetation and bush also wild animals like elephant, lion were everywhere in the past. But since 1998-2000 wildlife started moving away due to population increase, increases of human settlements and the grass started decreasing". (Village leader, Focus Group-village D)

Human activities and population pressure have been implicated as causes of climate change (Stephenson et al. 2010). Thus, pastoralists' knowledge indicated a good match with the scientific knowledge. However, the majority of participants were hesitant to reveal about the status of livestock population in relation to causes for climate change. This could be either because pastoralists do not understand the relationship between livestock population and its impacts on climate change or it may relate to cultural customs to hide information about the herd size of cattle to a stranger due to a belief that it may bring a bad luck to their livestock (L. Tiligay,

Personal communication, 2015). However, hiding important information may lead to negative implications especially on livestock development projects.

Around a half of the focus groups mentioned that cutting trees causes environmental destruction and was associated with climate change. However, participants stressed that tree cutting for charcoal production was not a traditional practice. In recent times, because of climatic change impacts on livestock production, pastoralists have been forced to cut down trees to produce and sell charcoal to generate some extra household income. This was confirmed below:

> *"In older days Maasai did not cut trees for charcoal purpose because women had enough milk for selling. However, nowadays because of recurrent drought and food insecurity, people try to diversify their economic means and women are cutting down trees more in these days". (Village leader-Focus Group, village A)*

While many participants stressed that increased human population and tree cutting contribute to the climate change they experience in their villages, other known contributors to climate change were not directly mentioned. For example, greenhouse gases arising from industrial effluents and the direct emissions of methane gases from the digestion processes of ruminants and their manure, were not mentioned (IPCC 2013; Steinfeld et al. 2006). It could be that these contributors are more scientific and intangible concepts that pastoralists are not exposed to. Rather participants would more likely report the observations and experiences in their everyday life.

Variable sources of climate change information and early warning systems

When asked about different sources of climate information to help Maasai cope with the adverse impacts of climate change and extreme weather events, participants mentioned media as one of the modern ways that Maasai could access climate information. However, this was not seen as a reliable option because some households do not have a radio. Participants also indicated that there are no reliable programs on early warning systems in place to help Maasai prepare for harsh climatic conditions. One of the focus group participants had this to say about climate information:

> *"Nowadays people have radios; however, they don't really help much because of bad network and only few have these radios. So there are few people who get this information through radios, but we don't have any other formal arrangement from the district to inform us on extreme weather events and if we could have that would really help us heaps". (Village leader, Focus Group-village H)*

The limited access to information via the radio contrasts with other studies were carried out in urban and/or peri-urban areas where mass media such as radio, television, and newspaper were reported to be the major ways of getting climate risk information (Kabir et al. 2016).

In focus groups, we learned that in the same year a project on climate change awareness and resilience coordinated by a non-governmental organization (NGO) was initiated in collaboration with Monduli District Council. However, the project was still in the very early stages at the time of the focus groups. We noticed that when participants were mentioning the involvement of Monduli District Council in relation to sources of climate information, they were actually referring to this project. Here is one participant explaining about the project:

> *"The village leaders had seminars on climatic change that was coordinated by the Monduli district. The seminar included village leaders, such as village chairman and village council members to be trained or having a seminar on climatic change and was supposed to be shared to communities". (Village leader, Focus Group-village C).*

About two participants mentioned that the Monduli District Council was involved in informing some villages on extreme weather events such as drought. However, mention by only a small number of participants could indicate that council programs on climate change awareness and early warning systems are unreliable.

It was revealed in focus groups that participants use their '*common sense*' or traditional ecological knowledge (TEK) (Berker et al. 2000) and experiences to foresee and think of what kind of weather is likely in particular years. This is what one participant said:

> *"There are no reliable early warning systems by the council. But I can sense and see if we may have floods or droughts this year. It is only the pastoralists themselves work out on their own and sees the changes and start thinking of what to do like moving their cattle somewhere or doing something to cope with the weather disaster". (Village leader, Focus Group-village A)*

The use of common sense also involved relying on some trusted village elders (shine elders) who use '*indigenous knowledge*' to predict what the weather will be like. Similarly, many participants reported the use of the '*indigenous knowledge*' in their communities. This is what one participant explained:

> *"We just use our indigenous knowledge. We have our elders who will look at the stars. They will look if the stars have made a kind of cycle around to see if it will*

rain or not. Because we also look at the moon and see if it makes a red or green colour…this predicts it is going to rain. Sometimes they see the moon is like sitting between two stars and this may predict deaths will happen like many livestock will die or people will go sick". (Village leader, Focus Group-village I)

Pastoralists can use their own understandings, experience, and observations to foresee what is coming ahead in terms of weather condition, and since the use of '*indigenous knowledge*' can be trusted by pastoralists, this is a tangible way that indigenous knowledge plays a role in climate change response and adaptation at the local level. The role of pastoralists' '*indigenous knowledge*' on predicting weather conditions, especially extreme weather events and coping strategies, has been reported elsewhere (Kwanya 2014; Assefa and Hans-Rudolf 2017).

Instead of relying on external agencies, such as the limited council programme, village environmental committees were reported to be responsible for reminding villagers about environmental conservation and good land use management. However, participants asserted that the agenda of environmental conservation was infrequently discussed in village meetings. Many participants reported this type of village arrangement as pointed out below:

"What we do, we try to educate and emphasize to our communities to have a good system on land use and management in which we do separate grazing areas and other land use, so we have specific areas for grazing in dry season and in wet season". (Village leader, Focus Group-village I)

"We do have village environmental committee that is responsible for educating people on environmental protection, so people are not allowed to cut down trees unnecessarily". (Village leader, Focus Group-village E)

Nevertheless, the instructions emphasized by the village committees are not always put into practice for various reasons, as was revealed by participants below:

"We educate our people not to cut down trees unnecessarily, we just address this in our village meetings but people are not taking it so serious". (Village leader, Focus Group-village D)

"What we do, we emphasize on reducing number of livestock by selling them when are in good health in order to buy food for the family in times of drought. Also we talk about tree planting (at least ten trees per family per year), but water scarcity is a major problem so tree planting is not effectively carried out". (Livestock officer, Focus Group-village F)

Throughout the focus groups, it was clear that there is no reliable arrangement for dissemination of climate change information and early warning systems programmes in the district. However, village initiatives through village environmental committees were noted to play some role at the village level. With this observation, it is essential that climate risk information programs are formulated and implemented effectively in pastoral communities.

The negative impact of climate change on livestock production

Many participants reported experiencing severe drought periods. Because of drought, livestock have had to trek long distances in search of adequate feed and water. This has caused deaths for a large number of livestock. They also see cattle as the most affected species in this situation. Participants reported as below:

"We are experiencing a massive loss of cattle, sometimes it can reach even 200 cattle dying at once. For example, one farmer was remained with only few cattle like 10 to 20 in 2009 severe drought. We also see in 2014 drought many cattle died and we had lots of bones scattered in people's bomas. In addition, many sheep died like one farmer had 1000 sheep about 900 died and remained with only few ones". (Village leader, Focus Group-village J)

Many livestock, especially cattle, are suffering and dying because they are browsers of grazing land and there is inadequate pasture. This leaves pastoralists wondering if the situation for rainfall will ever get back to the way it used to be. For example, many participants envisaged that they might end up losing more livestock with long-term climate change. Further participants spoke of how their cattle are producing less milk and meat. Here are participants' explanations:

"What my fellows say it is very true, because since when I moved in this village I was so young at that time when you see cow is milked you will see 'mama yoyo' milked two cows and that milk was enough for even two 'bomas'. In the past cows were very healthy and fatty but nowadays we don't see fatty and big size cows anymore". (Village leader, Focus Group-village A)

The lower milk yield was associated with inadequate feed in quantity and nutritional quality leading to general weakness and lower production in their cattle. Similar impacts on milk production and livestock body condition have been reported in other semi-arid areas of Tanzania (Lyimo and Kangalawe 2010; Kangalawe and Lyimo 2010; Magita and Sangeda 2017).

Climate change has affected pastoralists economically because of the feed shortages. Animals become emaciated with low production especially in the dry season which leads to lower prices for livestock at sale and less milk available for sale. This is attested by this participant:

> *"The low milk production affects us economically because we can't get enough milk for selling, we can't send our children to school, and overall livestock productivity in the dry season leads to very poor market that affects our livelihoods severely".(Village leader, Focus Group-village F)*

Pastoralists were emotional when they explained the impacts of climate change on their livelihood. The problem of poor market was described by pastoralists, who expressed their difficulties in sending their children to school and coping with living standards in general.

In the focus groups, participants associated climate change with eruption of some cattle diseases. About one third of focus groups explained that some diseases were not found in their areas in the past, but with increased animal movements in search of sufficient pasture during severe droughts and interactions among animals these diseases were now observed. Participants thought some of the new livestock diseases were introduced in their areas through this means. For example since the severe drought of 2009, pastoralists associated severe anaplasmosis occurrence with animals' interactions with cattle from other places like a neighbouring country. This was asserted by a few participants as follows:

> *"Yes we have less pasture but also we see more diseases in these days. For example 'nyongo' diseases we did not have it in our area before. We also take our animal to other grazing areas outside our village by doing that we bring new strains, because there is more interactions of livestock and we get new diseases and we now see it in our place could because of more interactions". (Village leader, Focus Group-village A)*

> *"Ndigana (East Coast fever, ECF) is also a problem especially during the rainy season especially from May to July, and in the dry season we see more cases of 'ormilo' (bovine cerebral theileriosis),'orkipei' (contagious bovine pleuropneumonia, CBPP) and* CCPP". (Village leader, *Focus Group –Village F)*

> *"Orkipei (CBPP) is occurs is a lot in drought periods and we think is related to dry season and dust. The extreme temperature caused depletion of bone marrow ('nadendoliti') due to severe hunger". (Village leader, Focus Group-village C)*

Many participants related disease occurrence with climate change particularly during the dry season. It is likely that the interactions of animals when congregating in scarce and shared grazing areas and water points, may facilitate transmission of new or virulent pathogens and/or parasites. Similar observations on livestock disease outbreaks were reported elsewhere, especially in the dry season (Kangalawe and Lyimo 2010; Chamliho 2017).

Discussion

The aim of this study was to investigate pastoralists' perceptions, experiences and understanding of climate change and its associated impacts on cattle production. Findings from this study have revealed that there is a growing realization among pastoralists that climate change and variability is happening in their local areas. Most cattle owners acknowledged that there have been significant changes in climatic conditions over the last three decades. Similarly, the discussions with focus groups revealed that climate is continuously changing and the situation in relation to drought, for example, is getting worse. The concept of '*climate change*' was associated with variability in weather parameters in which the major concern was reduced rainfall amount, as well as erratic and unpredictable rainfall. Pastoralists are exposed to the impacts of climate variability and change, which means their perceptions will be based on their daily experiences and observations. The scientific definition for '*climate change*' as according to IPCC (2007) refers to "*a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer*". Such a definition is more complex than pastoralists may be able to describe; however their long time experiences largely agree with the scientific description of climate change. The decline in rainfall volume and increased variability, as well as increased temperature, have been reported in other regions of Tanzania (Lyimo and Kangalawe 2010; Kangalawe et al. 2011; Magita and Sangeda 2017), Kenya (Silvestri et al. 2012; Opiyo et al. 2014), Ethiopia (Megersa et al. 2014; Debela et al. 2015), and Nigeria (Tambo and Abdoulaye 2013). These findings indicate climate change is a current concern over a wide range of similar communities across Africa.

Findings from this study suggest that pastoralists are not simply more aware of climate change; they also feel deeply anxious about the impacts of climate change on their livestock keeping practices and day-to-day lives. Analysis of meteorological data for the thirty-year period (1984–2014) shows variability and general decline in rainfall over the studied period. Pastoralists were able to recall years in which they experienced severe water and pasture shortages, many of which aligned with years of

low total precipitation and/or extended periods of moderate dry as indicated by the SPI. In addition, the focus groups perceived that there has been a decline in the amount of rainfall, with delayed rainfall starts and early cessation. Previous studies in the study area corroborate cattle owners' experiences of severe drought (Goldman and Riosmena 2013; Galvin et al. 2001). Indeed, pastoralist perception of declines in rainfall have been reported across many countries of Africa (Juana et al. 2013; Maddison 2006; Rao et al. 2011).

Pastoralists were pessimistic about the future of their cattle keeping practices because of unpredictable rainfall patterns. This will severely impact availability of water and pasture and is likely to lead to conflicts over rangeland resources between pastoralists and crop farmers (FAO 2012). The ongoing shrinkage of grazing pasture, uncertainty about rainfall, and feed and water scarcity are no longer conducive to livestock keeping practices, and the frequent migration of livestock is less feasible. Cases for disputes between pastoralists and crop farmers have been increasingly reported in Tanzania and elsewhere in recent times (Lyimo and Kangalawe 2010; FAO 2012). In addition, there have been some administrative requirements when pastoralists need to move from one village to another for grazing (village leader-village A, personal communication, 2015). All these challenges are making the pastoralist communities' normal ways of living more difficult. Establishment of local perception on climate risk is a positive step toward involving pastoralists in formulation of sustainable adaptation options (Debela et al. 2015).

Causes of climate change

In this study, pastoralists attributed climate change to environmental destruction such as tree cutting for charcoal production, as well as increasing human population. Pastoralists perceived that these activities aggravate desertification in Monduli District. Pastoralists reported cutting down trees in an effort to diversify livelihood options so not to rely on livestock production alone. Other studies in similar communities have reported the increasing trend for charcoal production (Nassef et al. 2009; Debela et al. 2015). Recent rapid population growth (human and livestock) was also associated by pastoralists with the climatic variations observed. Human population growth in the study area is estimated to be between 3.8 and 4.3% per year (NBS 2013; ADF 2003). These observations are similar to the existing literature in which deforestation and population pressures are expected to exacerbate climate change (Chakravarty et al. 2012; Angelsen 1999; Megersa et al. 2014). A small proportion of cattle owners perceived climate change to be related to factories and industry activities. In addition, participants in two focus groups stated that the smoke from military trainings interfered with rainfall formation. It is unclear if this was a reference to greenhouse gas emissions caused by industrialization and/or other air pollutions; however such a concept would seem intangible to most pastoralists in the area.

Climate change information

This study revealed that there are no clear district-level programmes on climate information and early warning systems in the study area. Interestingly, during the time of data collection, it was noticed that a local non-governmental organization (namely International Institute for Environment and Development at Arusha region office (IIED)) had just started some initiatives on climate change risks and resilience with involvement of locals. Climate change information is valuable in helping pastoralists cope with the climate uncertainties and its adverse impacts (Luseno et al. 2003; Egeru 2016). Findings from this study revealed the use of '*indigenous knowledge*' by shine elders (these are lead elders with particular knowledge and responsibility in the community) and '*common sense*' as frequent sources of climate information especially for pastoralists to forecast the onset of rainfall or prediction for a bad or a good year. Other studies in similar communities have also reported the use of '*indigenous knowledge*' for predicting rains or droughts (Abate 2016; Kagunyu et al. 2016; Egeru 2016). However, due to increasing climate variability and uncertainties, the traditional forecasting methods are perceived to be less reliable (Kagunyu et al. 2016). The modern/formal pathways represented by radio and television were not seen by participants as a reliable means for gaining climate information. This reflects the fact that the majority of pastoralists are rural dwellers where there is limited access to radio and television. Information on climate risks is vital for improving resilience particularly for the most vulnerable pastoral communities (Kagunyu et al. 2016). When pastoralists are aware of possible extreme weather events and change in weather conditions, they are more likely to respond positively by applying appropriate coping strategies (Silvestri et al. 2012). This is an area which needs to be strengthened since it is an integral part for the development and implementation of adaptive strategies in pastoral communities.

Impacts of climate change on cattle production

Pastoralists revealed the seriousness of climate risk and the potential consequences of climate change. They reported that the recurrent drought periods cause massive cattle deaths, severe feed shortages and water scarcity which leads to serious socio-economic impacts. Other studies in similar communities have reported similar impacts (Goldman and Riosmena 2013; Magita and

Sangeda 2017; Tolemariam et al. 2015), including high cattle losses during severe drought periods (Megersa et al. 2014; Magita and Sangeda 2017; Bushesha et al. 2009). In this study, eruption of cattle diseases was also associated with climate change. Pastoralists outlined cattle diseases such as CBPP (*'orkipei'*), cattle anaplasmosis (*'nyongo'*), ECF (*'ndigana'*), sudden death of cattle (*'alakirikiri'*) and depletion of bone marrow (*'nadendolit'*) as well as severe loss of body condition. Micro-climate conditions, interactions of animals in grazing areas and water points during the dry season, coupled with weak immunity of animals during feed shortages can contribute to epidemics of animal diseases (Dantas-Torres 2015; Rojas-Downing et al. 2015; Kimaro and O Chibinga 2013). Furthermore, climate change can indirectly influence microbial communities (pathogens or parasites) and vectoral ecology which may lead to spread in livestock diseases (Thornton et al. 2009; Baylis and Githeko 2006; Patz et al. 2008; Dantas-Torres 2015). This study calls for further studies that investigate in detail the dynamics of infectious diseases in a changing climate, and suggest livestock adaptation options as an important component to maintain resilience.

Pastoralists admitted that the frequent droughts lead to severe economic impacts due to poor livestock markets. The price of cattle was reported to decline during these periods due to poor condition of the cattle. Further, during this time many households were trying to sell their livestock to earn income for living expenses (Silvestri et al. 2012). Reduction in milk yield was another major problem that pastoralists reported more in recent times due to inadequate feed and water, as well as heat stress. Similar observations for reduced milk production has been reported elsewhere in Tanzania (Sangeda and Malole 2013; Magita and Sangeda 2017; Goldman and Riosmena 2013). Milk is a staple food for pastoralists, thus climate change poses risks to food and nutritional security in these communities, in particular for women and children (Nassef et al. 2009; Opiyo et al. 2014). Pastoralists in this study reported experiencing psychological stress due to the negative effects of climate change on cattle production. This study calls for improvements to adaptive capacity of pastoralist communities, including effective and sustainable animal health services. These services must include animal disease surveillance, coupled with sustainable cattle disease management programs in pastoral communities (Kimaro et al. 2017a).

Limitations

Adopting a mixed methods approach enabled a deeper understanding and insight into how pastoralists in this community understand climate change and its impact. Nonetheless, this study had limitations. The information collected from cattle owner surveys and focus groups is likely to be impacted somewhat by recall bias, and it is possible that pastoralists' ability to synthesize their experiences and observations over a long period would be subjective. Further, the meteorological data utilized for this study came from one weather station near Monduli town, which is rather sub-humid. These may not reflect the climate situation across the district, and likely overestimate rainfall across the studied villages. Finally, the gender imbalance among participants must be acknowledged. Further research is needed to establish womens' views on climate change, particularly given their social and economic inequality.

Conclusion

In conclusion, this study has shown that pastoralists have a good understanding of climate variability and are aware of climate change as per their experiences and observations over the last three decades. For cattle production, the reduced rainfall, recurrent droughts and increased temperature experienced were reported as a major challenge to cattle raising through impacts on pasture and water availability, and disease risks. Subsequent occurrence of cattle starvation and disease outbreaks each leading to cattle deaths, and reduction in milk production and market price, are the distressing and serious consequences experienced by pastoralist communities in northern Tanzania. Thus local observations on climate change should be considered and integrated with scientific knowledge in order to form clear climate change adaptation strategies and policies. Improvement on climate information and early warning systems in pastoral communities is a vital component for building pastoralist resilience, but is currently lacking in Monduli District. Detailed long-term scientific research is needed to quantify and verify the reliability and relevancy of *indigenous knowledge* in forecasting weather patterns. This study informs policy makers and animal health planners on development of appropriate measures including stable institutional support for adaptation and mitigation practices in pastoral communities.

Recommendations

On the basis of this study, we recommend establishment of structured climate change information and early warning systems to better support these vulnerable communities. These plans can be achieved through multidisciplinary approaches involving the Tanzania Meteorological Agency, climatologists, ecologists, epidemiologists, local government and animal health development partners working together through NGOs, civil society and community-based organizations to equip and to enhance the resilience of Maasai communities against climate change impacts.

Additional file

Additional file 1: Cattle owner questionnaire. (DOC 89 kb)

Abbreviations

BCT: Bovine cerebral theileriosis; CBPP: Contagious bovine pleuropneumonia; CCPP: Caprine contagious pleuropneumonia; COSTECH: Tanzania Commission for Science and Technology; ECF: East Coast fever; FGD: Focus group discussions; IEED: International Institute of Environment and Development; NGO: Non-Governmental Organization; SPI: Standardized Precipitation Index; TEK: Traditional ecological knowledge

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Availability of data and materials

As the authors do not wish to publicly share the data, it will be available on request. The cattle owner questionnaire is provided as Additional file 1.

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Authors' contributions

EK, SM, J-AT contributed to the study design. EK conducted surveys and focus groups, analyzed the data and wrote the first draft of the manuscript. All authors worked on revised drafts of the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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References

Abate, T. 2016. Contribution of indigenous knowledge to climate change and adaptation response in southern Ethiopia. *Journal of Earth Science and Climatic Change* 7(11):377.

ADF 2003. Monduli District Water Project Appraisal Report. African Development Fund. https://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/TZ-2003-145-EN-ADF-BD-WP-TANZANIA-MONDULI-DISTRICT-WATER-PROJECT.PDF. Accessed 12 Dec 2016

Adger, W. Neil, Suraje Dessai, Marisa Goulden, Mike Hulme, Irene Lorenzoni, Donald R. Nelson, Lars Otto Naess, Johanna Wolf, and Anita Wreford. 2009. Are there social limits to adaptation to climate change? *Climatic Change* 93 (3): 335–354. https://doi.org/10.1007/s10584-008-9520-z.

Adhikari, Umesh A., Pouyan Nejadhashemi, and Sean A. Woznicki. 2015. Climate change and eastern Africa: A review of impact on major crops. *Food and Energy Security* 4 (2): 110–132. https://doi.org/10.1002/fes3.61.

Angelsen, Arild. 1999. Agricultural expansion and deforestation: Modelling the impact of population, market forces and property rights. *Journal of Development Economics* 58 (1): 185–218. https://doi.org/10.1016/S0304-3878(98)00108-4.

Assefa, Engdawork, and Bork Hans-Rudolf. 2017. Indigenous resource management practices in the Gamo highland of Ethiopia: Challenges and prospects for sustainable resource management. *Sustainability Science* 12 (5): 695–709. https://doi.org/10.1007/s11625-017-0468-7.

Baylis, M, and AK Githeko. 2006. The effects of climatic change on infectious diseases of animals. In Infectious diseases:preparing for the future: Office of Science and Innovation, United Kingdom. http://pcwww.liv.ac.uk/~baylism/Papers%20to%20download/t7_1.pdf. Accessed 17 Sept 2014.

Berker, Filkret, J. Colding, and C. Folke. 2000. Rediscovery of traditional ecological knowledge as daptive management. *Ecological Applications* 10 (5): 1251–1262.

Braun, Virginia, and Victoria Clarke. 2013. *Successful Qualitative Research: a practical guide for beginnners*. London: SAGE Publications Ltd.

Bushesha, Magreth, J. Lee-Thorp, and P. Hopkinson. 2009. Subsistence farmers' responses to climate variability and change in Kyela, Tanzania. *IOP Conference Series: Earth and Environmental Science* 6 (34): 342016. https://doi.org/10.1088/1755-1307/6/34/342016.

Chakravarty, S, SK Ghosh, CP Suresh, AN Dey, and G Shukla. 2012. Deforestation: Causes, effects and control strategies. Global Perspectives on Sustainable Forest Management.

Chamliho, M. 2017. Impact of climate variability on livelihoods of pastoral communities in Longido District-Tanzania. *General Education Journal* 7 (1): 34–47.

Conway, G. 2009. The science of climate change in africa: impacts and adaptation. In *Discussion Paper, 1. Grantham Institute for Climate Change, Imperial College London, London, United Kingdom* http://www.ask-force.org/web/Global-Warming/Convay-Science-Climate-Change-Africa-2008.pdf. Accessed 17 Sept 2017.

Dantas-Torres, Filipe. 2015. Climate change, biodiversity, ticks and tick-borne diseases: The butterfly effect. *International journal for parasitology. Parasites and wildlife* 4 (3): 452–461. https://doi.org/10.1016/j.ijppaw.2015.07.001.

Debela, Nega, Caroline Mohammed, Kerry Bridle, Ross Corkrey, and David McNeil. 2015. Perception of climate change and its impact by smallholders in pastoral/agropastoral systems of Borana, South Ethiopia. *SpringerPlus* 4 (1): 1–12. https://doi.org/10.1186/s40064-015-1012-9.

Deressa, T.T., R.M. Hassan, and C. Ringler. 2011. Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. *The Journal of Agricultural Science* 149 (1): 23–31. https://doi.org/10.1017/S0021859610000687.

Egeru, Anthony. 2016. Climate risk management information, sources and responses in a pastoral region in East Africa. *Climate Risk Management* 11 (Supplement C): 1–14 doi: https://doi.org/10.1016/j.crm.2015.12.001.

FAO 2012. Impact of conflict on pastoral communities' resilience in the horn of Africa: Case Studies from Ethiopia, Kenya and Uganda.

Fosu-Mensah, B.Y., P.L.G. Vlek, and D.S. MacCarthy. 2012. Farmers' perception and adaptation to climate change: A case study of Sekyedumase district in Ghana. *Environment, Development and Sustainability* 14 (4): 495–505. https://doi.org/10.1007/s10668-012-9339-7.

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

Galvin, K.A., P.K. Thornton, R.B. Boone, and J. Sunderland. 2004. Climate variability and impacts on east African livestock herders: The Maasai of Ngorongoro conservation area, Tanzania. *African Journal of Range and Forage Science* 21 (3): 183–189. https://doi.org/10.2989/10220110409485850.

Goldman, M.J., and Fernando Riosmena. 2013. Adaptive capacity in Tanzanian Maasailand: Changing strategies to cope with drought in fragmented landscapes. *Global Environmental Change* 23 (3): 588–597. https://doi.org/10.1016/j.gloenvcha.2013.02.010.

Grothmann, Torsten, and Anthony Patt. 2005. Adaptive capacity and human cognition: The process of individual adaptation to climate change. *Global Environmental Change* 15 (3): 199–213. https://doi.org/10.1016/j.gloenvcha.2005.01.002.

Guest, Greg, Arwen Bunce, and Laura Johnson. 2006. How many interviews are enough?: An experiment with data saturation and variability. *Field Methods* 18 (1): 59–82. https://doi.org/10.1177/1525822X05279903.

Hardy, Melissa A., and Alan Bryman. 2004. *Handbook of data analysis*. London: SAGE Publications.

Howell, K.E. 2016. *An introduction to the philosophy of methodology*. Los Angeles: SAGE.

Huang, Jianping, Mingxia Ji, Yongkun Xie, Shanshan Wang, Yongli He, and Jinjiang Ran. 2016. Global semi-arid climate change over last 60 years. *Climate Dynamics* 46 (3): 1131–1150. https://doi.org/10.1007/s00382-015-2636-8.

IPCC 2007. Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment. https://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4_wg2_full_report.pdf. Accessed 12 Jan 2017.

IPCC 2013. Working group I contribution to the IPCC fifth assessment report climate change 2013: The physical science basis summary for policymakers. http://www.ipcc.ch/report/ar5/wg1/. Accessed 12 Jan 2017.

IPCC 2015. Climate Change 2014 Synthesis Report. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full.pdf. Accessed 20 Dec 2017.

Joseph, L., and A. Kaswamila. 2017. The pastoralists' resilience and innovative adaptation strategies on impacts of climate change in rangelands of Longido District, Tanzania. *International Journal of Environment and Bioenergy, 2017* 12 (1): 47–61.

Juana, James Sharka, Zibanani Kahaka, and Francis Nathan Okurut. 2013. Farmers' perceptions and adaptations to climate change in sub-Sahara Africa: A synthesis of empirical studies and implications for public policy in African agriculture. *Journal of Agricultural Science* 5 (4): 121–121.

Kabir, M.I., W. Smith MB Rahman, M.A.F. Lusha, S. Azim, and A.H. Milton. 2016. Knowledge and perception about climate change and human health: Findings from a baseline survey among vulnerable communities in Bangladesh. *BMC Public Health* 16 (1): 1–10. https://doi.org/10.1186/s12889-016-2930-3.

Kagunyu, Anastasia, Simiyu Wandibba, and Joseph G. Wanjohi. 2016. The use of indigenous climate forecasting methods by the pastoralists of northern Kenya. *Pastoralism* 6 (1): 1. https://doi.org/10.1186/s13570-016-0054-0.

Kangalawe, R., S. Mwakalila, and P. Masolwa. 2011. Climate change impacts, local knowledge and coping strategies in the great Ruaha River catchment area, Tanzania. *Natural Resources* 2 (4): 212–223.

Kangalawe, R.Y.M., and James G. Lyimo. 2010. Climate change, adaptive strategies and rural livelihoods in semiarid Tanzania. *Natural Resources* 4 (3): 266–266.

Kaswamila, Abiud. 2009. Human-wildlife conflicts in monduli district, Tanzania. *International Journal of Biodiversity Science and Management* 5 (4): 199–207. https://doi.org/10.1080/17451590903557526.

Kimaro, E.G., S.M. Mor, P. Gwakisa, and J. Toribio. 2017a. Seasonal occurrence of *Theileria parva* infection and management practices amongst Maasai pastoralist communities in Monduli District, northern Tanzania. *Veterinary Parasitology* 246: 43–52.

Kimaro, EG, and O Chibinga, C. 2013. Potential impact of climate change on livestock production and health in East Africa: A review. Livestock Research for Rural Development Development 25 (116). http://www.lrrd.org/lrrd25/7/kima25116.htm. Accessed 10 Jan 2018.

Kimaro, E.G., J.L.M.L. Toribio, and S.M. Mor. 2017b. Climate change and cattle vector-borne diseases: Use of participatory epidemiology to investigate experiences in pastoral communities in northern Tanzania. *Preventive Veterinary Medicine* 147: 79–89 doi: https://doi.org/10.1016/j.prevetmed.2017.08.010.

Kwanya, Tom. 2014. Mainstreaming Indigenous Knowledge in Climate Change Response: Traditional 'Rainmaking' in Kenya. In *The 8th International Conference on Knowledge Management in Organizations: Social and Big Data Computing for Knowledge Management*, ed. Lorna Uden, Leon S.L. Wang, Juan Manuel Corchado Rodríguez, Hsin-Chang Yang, and I. Hsien Ting, 603–615. Dordrecht: Springer Netherlands.

Luseno, Winnie K., John G. McPeak, Christopher B. Barrett, Peter D. Little, and Getachew Gebru. 2003. Assessing the value of climate forecast information for pastoralists: Evidence from southern Ethiopia and northern Kenya. *World Development* 31 (9): 1477–1494 doi: https://doi.org/10.1016/S0305-750X(03)00113-X.

Lyimo, J.G., and R.Y.M. Kangalawe. 2010. Vulnerability and adaptive strategies to the impact of climate change and variability. The case of rural households in semi-arid Tanzania. *Environmental Economics* 1 (2): 89–97.

Maddison. 2006. The perception of and adaptation to climate change in Africa CEEPA discussion paper no. 10, Centre for Environmental Economics and Policy in Africa, University of Pretoria, Pretoria. https://openknowledge.worldbank.org/bitstream/handle/10986/7507/wps4308.pdf?sequence=1&isAllowed=y. Accessed 15 Feb 2018.

Magita, S.Y., and A.Z. Sangeda. 2017. Effects of climate stress to pastoral communities in Tanzania: A case of Mvomero District. *Livestock Research for Rural Development* 29 (160) http://www.lrrd.org/lrrd29/8/sang29160.html. Accessed 19 Oct 2017.

Maleko, D.D., and M.L. Koipapi. 2015. Opportunities and constraints for overcoming dry season livestock feed shortages in communal semi-arid rangelands of northern Tanzania: A case of Longido District. *Livestock Research for Rural Development* 27 (70) http://www.lrrd.org/lrrd27/4/male27070.html. Accessed 14 May 2017.

Megersa, B., A. Markemann, A. Angassa, J.O. Ogutu, H.P. Piepho, and A.V. Zarate. 2014. Impacts of climate change and variability on cattle production in southern Ethiopia: Perceptions and empirical evidence. *Agricultural Systems* 130: 23–34. https://doi.org/10.1016/j.agsy.2014.06.002.

MLDF 2011. Livestock sector development Programme. Ministry of Livestock and Fisheries Development. https://tanzania.go.tz/egov_uploads/documents/Livestock_Programe_sw.pdf. Accessed 12 Juni 2017.

MLDF 2015. Tanzania Livestock Modernization Initiatives United Republic of Tanzania: Ministry of Livestock and Fisheries and Development. http://livestocklivelihoodsandhealth.org/wp-content/uploads/2015/07/Tanzania_Livestock_Modernization_Initiative_July_2015.pdf. Accessed 16 Sept 2017.

Msoffe, Fortunata U., Shem C. Kifugo, Mohammed Y. Said, Moses Ole Neselle, Paul Van Gardingen, Robin S. Reid, Joseph O. Ogutu, Mario Herero, and Jan de Leeuw. 2011. Drivers and impacts of land-use change in the Maasai steppe of northern Tanzania: An ecological, social and political analysis. *Journal of Land Use Science* 6 (4): 261–281. https://doi.org/10.1080/1747423X.2010.511682.

Nardone, A., B. Ronchi, N. Lacetera, M.S. Ranieri, and U. Bernabucci. 2010. Effects of climate changes on animal production and sustainability of livestock systems. *Livestock Science* 130 (1): 57–69 doi: https://doi.org/10.1016/j.livsci.2010.02.011.

Nassef, M, S Anderson, and C Hesse. 2009. Pastoralism and climate change enabling adaptive capacity. Overseas Development Institute. http://www.fao.org/fileadmin/user_upload/drought/docs/Climate%20Change.pdf. Accessed 15 Dec 2017.

NBS. 2013. *National Bureau of statistics: Population and housing census 2012; population distribution by administrative areas*. Dar es Salaam: NBS http://www.nbs.go.tz/. Accessed 12 Feb 2016.

Ntale, Henry K., and Thian Yew Gan. 2003. Drought indices and their application to East Africa. *International Journal of Climatology* 23: 1335–1357. https://doi.org/10.1002/joc.931.

Opiyo, Francis E.O., Oliver V. Wasonga, and Moses M. Nyangito. 2014. Measuring household vulnerability to climate-induced stresses in pastoral rangelands of Kenya: Implications for resilience programming. *Pastoralism* 4 (1): 1–15. https://doi.org/10.1186/s13570-014-0010-9.

Osbahr, Henny, Peter Dorward, Roger Stern, and Sarah Cooper. 2011. Supporting agricultural innovation in Uganda to respond to climate risk: Linking climate change and variability with farmer perceptions. *Experimental Agriculture* 47 (2): 293–316. https://doi.org/10.1017/S0014479710000785.

Patt, A.G., and D. Schröter. 2007. *Perceptions of environmental risks in Mozambique: Implications for the success of adaptation and coping strategies. The World Bank Development Research Group Sustainable Rural and Urban Development Team Policy Research Working Paper*, 4417.

Patz, Jonathan A., Sarah H. Olson, Christopher K. Uejio, and Holly K. Gibbs. 2008. Disease emergence from global climate and land use change. *Medical Clinics of North America* 92 (6): 1473–1491. https://doi.org/10.1016/j.mcna.2008.07.007.

Rao, K.P.C., K. Kizito WG Ndegwa, and A. Oyoo. 2011. Climate variability and change: Farmer perceptions and understanding of intra-seasonal variability in rainfall and associated risk in semi-arid Kenya. *Experimental Agriculture* 47 (2): 267–291. https://doi.org/10.1017/S0014479710000918.

Rojas-Downing, M. Melissa, A. Pouyan Nejadhashemi, T. Harrigan, and S.A. Woznicki. 2015. Climate change and livestock: Impacts, adaptation, and mitigation. *Climate Risk Management* 16: 145–163. https://doi.org/10.1016/j.crm.2017.02.001.

Sangeda, A.Z., and J.L. Malole. 2013. Tanzanian rangelands in a changing climate: Impacts, adaptations and mitigation. *Net Journal of Agricultural Science* 2 (1): 1–10.

Shemsanga, C., A.N. Omambia, and Y. Gu. 2010. The cost of climate change in Tanzania: Impacts and adaptations. *Journal of American Science* 6 (3): 182–196.

Silvestri, Silvia, Elizabeth Bryan, Claudia Ringler, Mario Herrero, and Barrack Okoba. 2012. Climate change perception and adaptation of agro-pastoral communities in Kenya. *Regional Environmental Change* 12 (4): 791–802. https://doi.org/10.1007/s10113-012-0293-6.

Steinfeld, Henning, and Environment Livestock, Initiative Development, Food, and Nations Agriculture Organization of the United. 2006. *Livestock's long shadow: Environmental issues and options*. Rome: Food and agriculture organization of the united nations.

Stephenson, Judith, Karen Newman, and Susannah Mayhew. 2010. Population dynamics and climate change: What are the links? *Journal of Public Health* 32 (2): 150–156. https://doi.org/10.1093/pubmed/fdq038.

Tambo, Justice Akpene, and Tahirou Abdoulaye. 2013. Smallholder farmers' perceptions of and adaptations to climate change in the Nigerian savanna. *Regional Environmental Change* 13 (2): 375–388. https://doi.org/10.1007/s10113-012-0351-0.

TCAR 2016. Climate policy -Irish aid. Tanzania Climate Action Report for 2015. https://www.irishaid.ie/media/irishaidpublications/TZA-Country-Climate-Action-Reports-Tanzania-2015.pdf. Accessed 15 Jan 2018.

Theodory, T.F., and M. Malipula. 2014. Climate change and socio-economic vulnerability among Maasai pastoral communities in Northern Tanzania. *Journal of Policy and Leadership* 2: 1–19.

Thornton, P., M. Herrero, A. Freeman, O. Mwai, E. Rege, P. Jones, and J. McDermott. 2007. Vulnerability, climate change and livestock—Research opportunities and challenges for poverty alleviation. *SAT eJournal | ejournal.icrisat.org* 4 (1): 1–23.

Thornton, P.K., J. van de Steeg, A. Notenbaert, and M. Herrero. 2009. The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. *Agricultural Systems* 101 (3): 113–127 http://dx.doi.org/10.1016/j.agsy.2009.05.002.

Thornton, Philip K., and Pierre J. Gerber. 2010. Climate change and the growth of the livestock sector in developing countries. *Mitigation and Adaptation Strategies for Global Change* 15 (2): 169–184. https://doi.org/10.1007/s11027-009-9210-9.

TMA 2015. Rainfall Data 1984–2014 of Monduli District, Northern Tanzania. Accessed from Tanzania Meteorological Agency Dar-es-Salaam Tanzania16 January 2016.

Tolemariam, Taye, Adugna Eneyew, and Fikadu Mitiku. 2015. Development agents' perception about the effect of climate risk on livestock production. *Livestock Research for Rural Development* 27 (98) http://www.lrrd.org/lrrd27/5/taye27098.htm. Accessed 20 Jan 2018.

Toulmin, C. 2009. *Climate change in Africa*. New York; London: Zed books in association with International African Institute, Royal African Society, Social Science Research Council.

URT 2007. United Republic of Tanzania, National adaptation programme of action (NAPA). Vice resident's office, division of environment. Government printers, Dar es Salaam. 2007. http://unfccc.int/resource/docs/napa/tza01.pdf. Accessed 15 July 2017.

VPO 2003. Initial National Communication under the United Nations Framework Convention on Climate Change. Vice-President's Office, United Republic of Tanzania, Dar-es salaam, Tanzania http://unfccc.int/resource/docs/natc/tannc1.pdf. Accessed 18 Dec 2018.

Zumsteeg, S. 2012. *Individual perception of climate risks*. AXA Ipsos Public Affairs https://cdn.axa.com/www-axa-com%2Fdb84fbc6-41bb-4190-99f0-1e44d76cebf5_survey-axa-ipsos_climate-risks.pdf. Accessed 20 Jan 2018.