Perceived and Observed Climatic Risks and Adaptation Responses in Agro-Pastoral Systems of Tanzania

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Abstract

Understanding adaptation strategies requires that risks and vulnerability are identified and analyzed. This study sought to understand adaptation strategies for the agro-pastoral system under current risks and vulnerability to climate change in Tanzania. A sample of 377 respondents was taken across the four-point transect from the Morogoro region in the Eastern to the Kigoma region in the Western parts of Tanzania. The study compared the perceptions of the risks and vulnerability of agro-pastoralists with quantitative trends from climatic data obtained from the Tanzania Meteorological Authority. Indicators of risks and vulnerability to climate change across the transect were considered as a proxy for perceptions. They included a temperature rise and an increase in extreme events such as recurrent droughts, floods, and diseases. Analysis by Mann–Kendall trend test revealed a statistically significant decrease in annual rainfall in dry-sub-humid (ZMK = -2.039) and a significant increase in seasonal rainfall in the semi-arid zone (ZMK =1.712). The comparative analysis reveals the mismatch between perceptions and trends of risks and vulnerability in understanding and implementing adaptation strategies. Consequently, the mismatch may provide inadequate information to agro-pastoralists in designing and implementing plausible adaptation strategies. In this regard, collaborative data collection and management have the potential to inform decisions about risk reduction strategies across agroecological zones, such as adjustments in planting dates and methods, holding different livestock types, and splitting herds into sub-herds. Furthermore, the study calls for further exploration that would redefine existing adaptation strategies with consideration of contexts and location.

Keywords: vulnerability, perceptions, climate-related risks, agro-pastoralism, adaptation strategies, agroecological zones

Introduction

Climate change affects agropastoralist communities in semi-arid and sub-humid regions, and how these groups adjust to the phenomenon depends on their assessments of its risks (Cuni-Sanchez *et al.,* 2019; Kabote *et al.,* 2017). The Sixth Assessment Report of the United Nations' Intergovernmental Panel on Climate Change (IPCC) on impacts, adaptation, and vulnerability provides scientific evidence on Africa's climate impacts and risks (Arias *et al.,* 2021). The report further shows that despite nearly negligible contribution to drivers of climate change, there is high confidence that the continent's ecosystems, food, water, cities and settlements, economy, health, and migration are highly impacted and exposed to risks. The United Nations Environmental Program (UNEP) reports that despite the low capacity of African countries to respond to unwelcome results of climate change, the onset of Covid-19 has compounded the negative impacts (UNEP, 2021). Authors from across Africa have reported evidence of the vulnerability and risks of agro-pastoralism as a livelihood system and an adaptation option (Amadou, 2020; Ebhuoma, 2021; Nkuba *et al.,* 2020; Nnamani *et al.,* 2020; Ologeh *et al.,* 2021; Smith *et al.,* 2019; Zazu & Manderson, 2021).

Sub-Saharan African (SSA) agropastoralists are equally vulnerable to climate change. Adger (2006) defined vulnerability as "how susceptible people are to harmful stresses and their ability to respond or adapt to these stresses" (Adger, 2006). Uncertainty in water availability is regarded as a critical constraint in the sustainability of productivity of the agro-pastoral system predominant in the semi-arid and dry sub-humid agro-ecological zones of SSA (Falkenmark & Rockström, 2004; Kgosikoma *et al.,* 2018). According to the IPCC, high spatial and temporal variability of rainfall and recurrent droughts and floods are responsible for accelerating the vulnerability of agro-pastoral communities across SSA (Muthoni *et al.,* 2019; IPCC, 2022) and extends further to the East African region (Richardson *et al.,* 2022; Rufino *et al.,* 2013) including in several agroecological zones of Tanzania (Mkonda, 2022; Mongi *et al.,* 2010; Nnko *et al.,* 2021).

Agroecological or indicative zoning is defined as the establishment of bio-physical characteristics and qualities of the various natural land units such as climate, soils, terrain forms, land cover, and water resources (De Pauw, 1984). Based on this definition, Tanzania is divided into seven (7) agroecological zones: coastal, arid lands, semi-arid, plateau, southern and western highlands, northern highlands, and alluvial plains. Each zone has ecological and climatic characteristics that accommodate different agricultural production and livestock-rearing patterns. Nevertheless, agroecological zones vary in their potential to support crops, livestock, or combinations of these. The main determinants of the variation have been climatic factors (Sivakumar & Valentin, 1997).

Tanzania's agroecological zones' climatic patterns are thought to be influenced by two major macro-level regimes. Tanzania's climate is influenced by two natural areas: the Eastern Congo forests, which are tropical rainforests located in the eastern portion of the Democratic Republic of the Congo (DRC), and the Indian Ocean, which is in the country's east. While Tshimanga *et al.* (2022) provided comprehensive studies that shed insight into the nature of this influence, there is still a dearth of evidence that should guide future research. Borhara *et al.* (2020), Giannini *et al.* (2008), and Palmer *et al.* (2023) have provided evidence of the significant interannual rainfall variability that Tanzania, a country in Eastern Africa, has been experiencing. In order to make well-informed judgments on adaptation methods, it is necessary to investigate this aspect in order to gather scientific evidence and local views of vulnerability across agroecological zones (Tesfahunegn *et al.,* 2016).

Reducing risks, addressing vulnerability, and enhancing adaptation across livelihood systems, including agro-pastoralism, are the current focus in combating the negative impacts of climate change (IPCC, 2022; FAO, 2018). Enabling an environment for a well-adaptive system includes the development of a well-framed, inclusive, and equitable policy that considers diversity in all aspects. Such a conducive policy ought to include favorable legal regulations and accommodative strategies, programs, plans, and projects. For enhanced adaptation, it is essential to foster an understanding of how vulnerability has evolved in the agro-pastoral farming systems over the past. Therefore, assessing trends in long-term historical climate data and the perceptions of the local communities would assist in adjusting and enhancing the existing adaptation strategies (Sraku-Lartey *et al.,* 2020). Such perceptions, when given through the engagement of agro-pastoralists, minimize the risk of falling below the critical threshold of disaster and maximize the probability of survival. The importance of engaging local communities in studying the vulnerability factors has been highlighted as it could offer important insights into the nature of vulnerability that the analyses of scientific data alone cannot capture (Sraku-Lartey *et al.,* 2020; Zampaligré *et al.,* 2014).

Although studies conducted elsewhere to understand agro-pastoralists' adaptive responses and capacity to climate change are many (for example, (Dong *et al.,* 2011; Nyong *et al.,* 2007; Sewando *et al.,* 2016; Silvestri *et al.,* 2012), the development of adaptation strategies varies by case and demands engaging deeply with vulnerability contexts (Eriksen *et al.,* 2021).

The Tanzania National Adaptation Programme of Action (NAPA) (URT, 2007) identifies potential adaptation measures in crop production, including adjustments in management practices such as planting density, fertilizer application, and planting date and for the livestock sector, among others, advocating zero grazing, controlled movement of livestock and sustainable range management. However, studies have indicated that the traditional coping and adaptation strategies of agro-pastoral systems have become insufficient to sustain local livelihoods in northern and central Tanzania (Kimaro *et al.,* 2018; Sewando *et al.,* 2016). Although studies have been conducted elsewhere to assess the vulnerability of agro-pastoralism, they vary from case to case across the globe, hence the need to undertake context and site-specific analyses (Dong *et al.,* 2011). While a previous study by Mwakaje (2013) focused on the dynamics in the agro-pastoralists economic well-being, it lacked the comparative and empirical stack of evidence emanating from analyses of communities' vulnerabilities and the requisite adaptation strategies.

With the ever-increasing vulnerability of agro-pastoral farmers, the need for establishing and implementing evidence-based adaptation strategies cannot be overstated (Mogomotsi *et al.,* 2020). While the understanding of adaptation strategies requires a thorough review of the best locally acceptable, economically feasible, and environmentally friendly options, unfortunately, the available information regarding adaptation strategies in the agro-pastoral system in Tanzania is fragmented or is in isolation. Furthermore, Eriksen *et al.* (2021) argue that adaptation strategies, if not well defined, may reinforce, redistribute, or create new vulnerabilities. The authors argue that any transformation may worsen vulnerability if adaptation is not rethought considering that local contexts bear heavy weight in determining the appropriateness of alternative adaptation strategies. Noting this gap in the literature, this paper argues that there is a need to engage the communities in understanding and/or explaining agro-pastoralism's current risks and vulnerability in the adaptation dynamics. The specific objectives are to (i) identify and analyze adaptation strategies on the agro-pastoral system across selected agroecological zones of Tanzania and (ii) examine the relationship between knowledge and perception of climate change by agro-pastoralists and the long-term rainfall trends of the major seasons in selected agroecological zones of Tanzania.

Materials and Methods

Study area

The study was conducted in four agroecological zones, namely, alluvial plains (Ngerengere, Morogoro region), semi-arid (Bahi, Dodoma region), Plateaux (Sikonge, Tabora region), and western highlands (Kazuramimba, Kigoma region) (Fig. 1).

Four points were established and each was located approximately 300 km from the other on the hypothetical transect. The description of the four agroecological zones is presented in Table 1.

Table 1: Description of points along agroecological transect in Tanzania

Transect point number	Name	Region	Coordinates (Latitude, longitude)	Approx. distance from the origin (km)	Agroecological zone
1	Ngerengere	Morogoro	-6.63187, 38.05664	0	Alluvial plains (Sub-humid)
2	Bahi	Dodoma	-6.10232, 35.35675	300	Semi-arid
3	Sikonge	Tabora	-5.62145, 32.71728	600	Plateaux (Dry sub-humid)
4	Kazuramimba	Kigoma	-5.00339, 29.98718	900	Western highlands (Wet sub-humid)

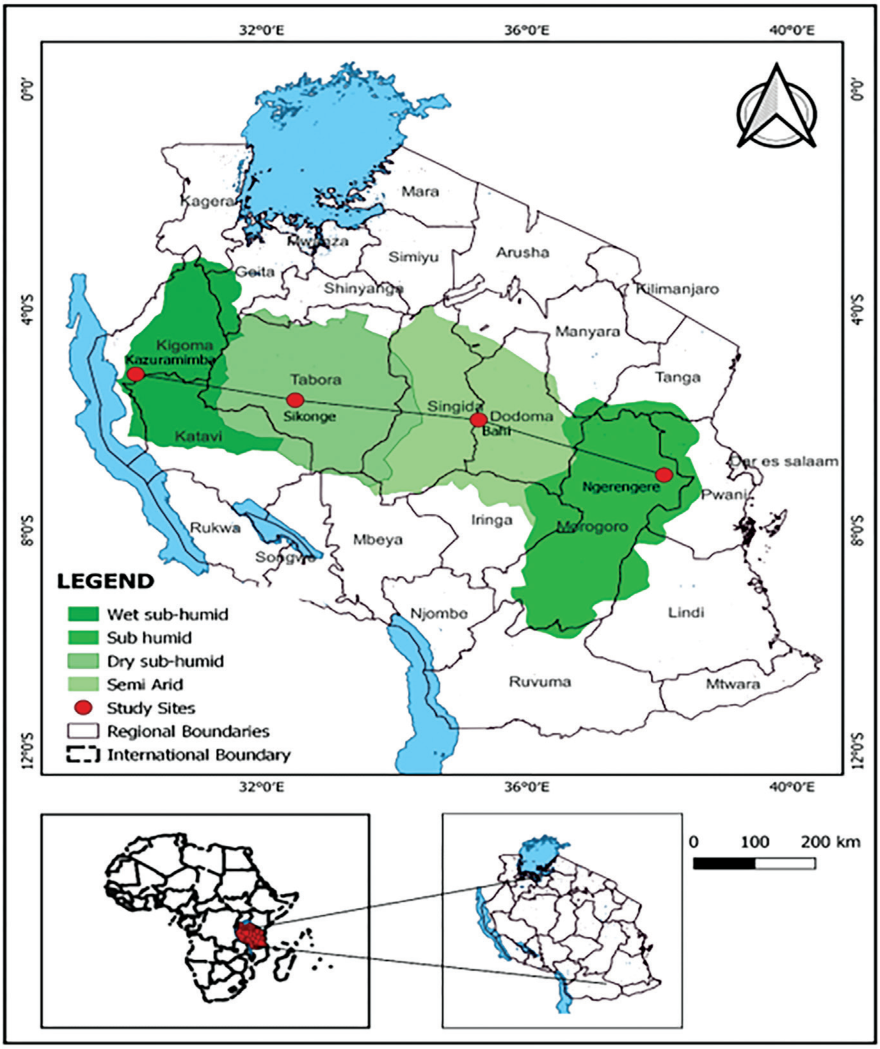

Figure 1: The study area (*Source:* Authors)

Data collection methods

The quantitative and qualitative primary and secondary data were collected. The study used mixed data collection methods: questionnaire survey, key informant interviews, and literature review. Quantitative secondary data were mainly historical monthly and annual rainfall obtained from the Tanzania Meteorological Authority (TMA). The historical rainfall data for the three out of four transect points were available for 40 years (1962-2001), albeit with a few missing values for uniformity's sake. However, Kazuramimba's data was only available for nineteen years (1973-1992), so it was excluded from the comparative trend analysis. For missing data, the Amelia II program version 1.7.6 (Honaker *et al.,* 2011) in R was used to impute the missing values. Quantitative primary data were collected by administering questionnaires to 377 target respondents. The sample size was estimated from the known population of each transect point of the agroecological zone based on the 2012 population census and a 3% growth rate as of 2015. As a result, 377 respondents were sampled from the semi-arid (81), wet sub-humid (185), sub-humid (49), and dry sub-humid (62). Quantitative data for ground-truthing the historical data were collected using a questionnaire at each transect point. The questionnaire survey targeted agro-pastoralists and was mainly on the perceptions of experienced individuals in the transect points about changes in temperature, rainfall, and effects on crop and livestock production. Two focus group discussion (FGD) sessions per transect point composed of between 9 and 12 people. Selection of participants for FGD was based on convenience, age, sex, and educational background. Four key informant interviews with people considered knowledgeable of the area were also held at each transect point.

Data analysis

Visualization and analysis of qualitative data were performed using a variety of tools. Demographic data were compared through line charts, bar charts, and stacked charts. Word clouds were generated to visually compare the perceptions about indicators of climate change at each transect point. For quantitative data, the Mann-Kendall test was used for the significance of time-series trends in total annual and seasonal rainfall. The Theil-SEN slope estimator was used in estimating the slope of the trend. The Mann-Kendall test is less sensitive to outliers and can detect both linear and non-linear trends, and has been used in related studies in sub-Saharan Africa (Da Silva *et al.,* 2015; Gebre *et al.,* 2013).

The Mann-Kendall test statistic is given as:

$$S = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} sgn(x_j - x_i) \quad ....(1)$$

Where S is the Mann-Kendall test statistic; x_i and x_j are the sequential data values of the time series in the years i and j (j > i) and *N* is the length of the time series. *A* positive *S* value indicates an increasing trend and a negative value indicates a decreasing trend in the data series. The sign function is given as:

$$sgn(x_j - x_i) = \begin{cases} +1 \; if \; (x_j - x_i) > 0 \\ 0 \quad if \; (x_j - x_i) = 0 \\ -1 \; if \; (x_j - x_i) < 0 \end{cases} ....(2)$$

For N larger than 10, ZMK approximates the standard normal distribution (Yenigun *et al.,* 2008) and is computed as follows:

$$Z_{MK} = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & if \; S > 0 \\ 0 & if \; S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & if \; S < 0 \end{cases} ....(3)$$

The presence of a statistically significant trend is evaluated using the ZMK value. In a two-sided test for trend, the null hypothesis Ho should be accepted if | ZMK | < Z1-α/2 at a given level of significance. Z1-α/2 is the critical value of ZMK from the standard normal table (e.g. for 5% significance level, the value of Z1-α/2 is 1.96).

Results and Discussion

Demographic characteristics of respondents at the transect points

The demographic characteristics of the respondents, years of stay, education level, and sex are presented in Figures 2 and 3 below. Findings indicated that more respondents have stayed at different transect points between 11 and 30 years, except for Kazuramimba where respondents have stayed for a short period of time i.e., between 1 and 10 years (Fig. 2). The implication of this finding at Kazuramimba is that most of the residents are not indigenous in the area; they have migrated from other parts of Tanzania for different reasons. In this case, length of residence (years of stay) is very important in assessing the perceptions and attitudes of local community on climate change and variability. However, these results are contrary to those by Sraku-Lartey *et al.* (2020) who indicate that perception of climate change is not influenced by origin, gender or level of education, but rather it is significantly influenced by age.

The percentages of respondents with primary education at Sikonge, Bahi, Kazuramimba, and Ngerengere were 42, 60, 62, and 73%, respectively. Sikonge had the highest percentage of respondents (53.3%) with non-formal education, followed by Kazuramimba (26%), Bahi (21%), and Ngerengere (8.1%) having the lowest rate. Most women only completed their primary and non-formal education (Fig. 3).

Age of respondents, level of education and gender were important demographic variables

Figure 2: Percentage of respondents by year of stay at the transect point and gender

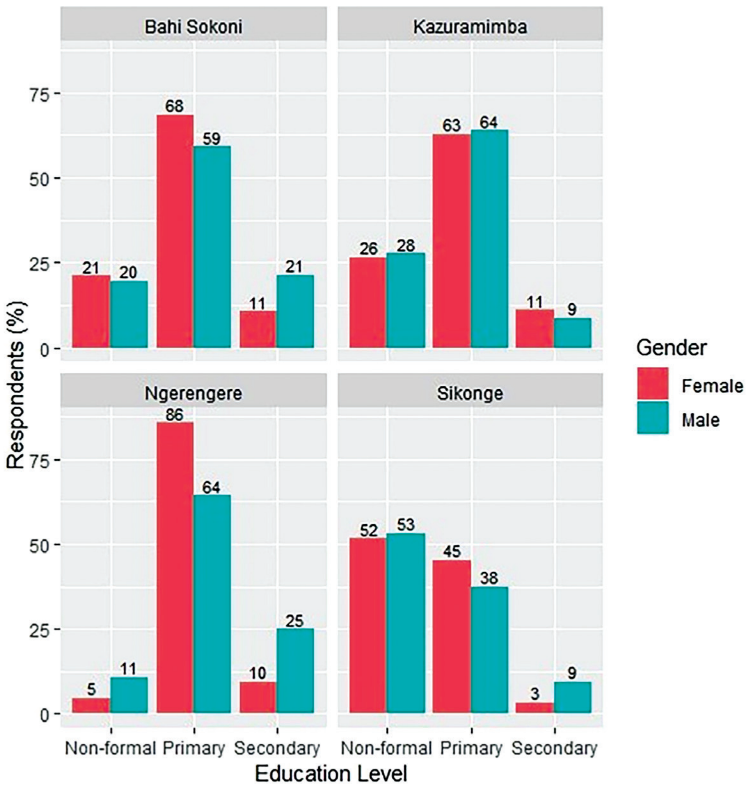

Figure 3: Percentage of respondents by education level, sex, and transect points

used to establish the nature of respondents in the study area. Age of respondents determines the knowledge accumulated about the area. The older the respondent the more the knowledge accummulation. Level of education determines the ability of the respondents to analyse issues and contribute to difficult arguments. The gender diffferences represents the division of labour in the community as well as access and control of resources. The results show that the age, level of education and gender proportions varied from one transect point to another.

Trend analyses of seasonal and annual rainfall

Findings indicate that Bahi and Ngerengere had an increasing trend for annual and seasonal rainfall (Table 2, Figures 4 and 5). Moreover, for seasonal rainfall (i.e., the amount accumulated from onset to cessation), Bahi showed a statistically significant increasing trend. In contrast, Sikonge showed a significant decreasing trend in annual and a non-significant decreasing trend in seasonal rainfall. Alemu & Bawoke (2020) demonstrated increasing rainfall variability as well as shifting rainfall patterns with increases and decreases in the annual and seasonal rainfall, which is in line with the trend analysis results. Our findings provide valuable information to better understand the spatial distribution and temporal patterns of rainfall across the agro-ecological zones, to enable management of water resources and ensure a sustainable agro-pastoral production system.

In addition to the statistical tests shown in Table 2, the rainfall trends at the three transect points between 1962 to 2001 are illustrated in Figure 4 and 5.

Table 2: Trends of annual and seasonal rainfall totals across local weather stations along the transect

Station	Annual		Seasonal	
	ZMK	Slope	ZMK	Slope
Ngerengere	0.618	2.36	0.781	1.26
Bahi	1.293	3.11	1.712*	3.26
Sikonge	-2.039*	-3.75	-1.083	-3.75

*ZMK is Mann–Kendall trend test, the slope is the Sen's slope estimator; *, is statistically significant at a 0.05 probability level; ns is a non-significant trend.*
Source: *Tanzania Meteorological Authority.*

It can be observed that Sikonge exhibits a decreasing trend in both seasonal and annual rainfall. In Tanzania, similar findings on rainfall trends between seasons and years have been reported (Kassile, 2013; Lema & Majule, 2009; Msongaleli *et al.,* 2017). However, with Tanzania's 1997–1998 El

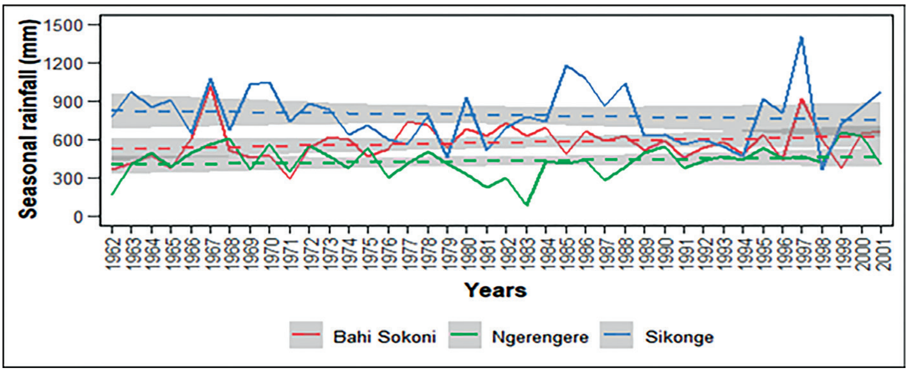

Figure 4: Raw data of seasonal rainfall totals across local weather stations

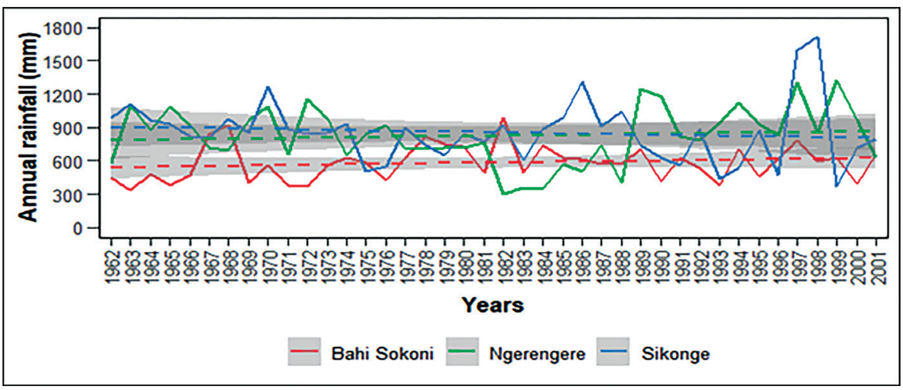

Figure 5: Raw data of annual rainfall totals across local weather stations

Nino, the seasonal rainfall reached its highest point in 1998 with 1335 mm and 438 mm at Sikonge and Ngerengere, respectively contrary to reported trends. More recently, Borhara *et al.* (2020) demonstrated the heterogeneity of the climatology of Tanzania's rainfall and revealed negative precipitation trends between observational data and climate model data for Tanzania, thereby augmenting the challenges faced by climate models in the representation of natural variability. Therefore, to account for the uncertainties encompassing rainfall, it is important to revisit and examine different trend analysis methods and varying time intervals (e.g., monthly, annual, and decadal).

Respondents' Perceptions of Indicators of Climate Change

The generation of cloud words (Figure 6a-d) indicated some variation on what the respondents termed climate change indicators and associated weights across the transect points and agroecological zones.

Agro-pastoralists' perception of climate change causes, indicators, and effects is a necessary component for developing policies that guide climate change mitigation and adaptation efforts. Established knowledge and perception of local farmers on indicators enable the formulation of policy interventions and adaptation strategies. From the results shown in Figure 6 (a-d), it can be seen that most respondents are aware of the climate change indicators in their areas across the transect points. The size of words in the Figure corresponds with its frequency of appearance in the dataset. At three points (a-c) drought is a commonly mentioned indicator (emphasized by its position in the middle of the word cloud and font size). At the other three points (a, b, and d), the temperature is manifested at equal proportions as an indicator of climate change. Despite the variability in identifying indicators of climate change, it can be seen that respondents were able to list the most important indicators such as high temperatures, lower or irregular rainfall, prolonged dry season, excessive rainfall, and strong winds (Fig. 6). They were able to discuss the effects of these changes on their crops explaining the potential effects of the changing climate on food security.

Although, from a theoretical point of view, there may be wrong interpretations of what is presented as "indicators" of climate

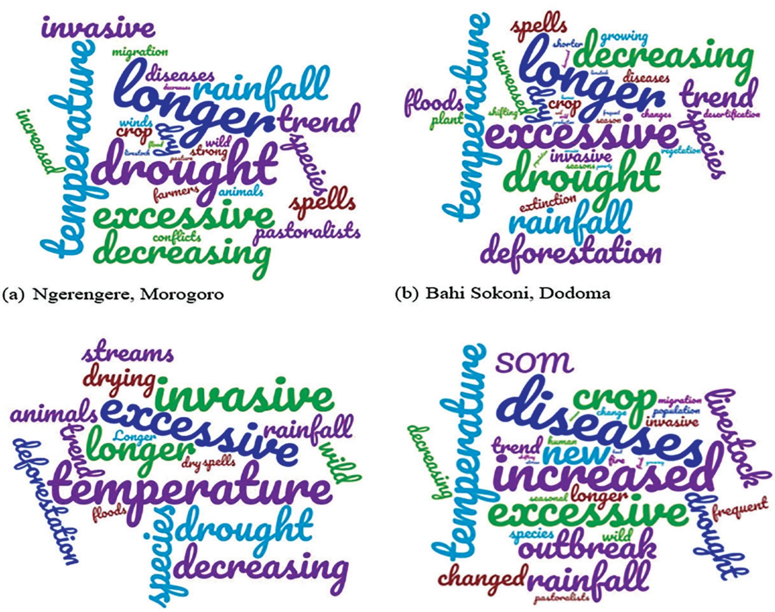

Figure 6: Comparative visualization of respondents' perception of indicators of climate change

change, they mean a lot in practical or field views. From the latter, we can see that there are different connotations and interpretations that are location-specific and require location-set priorities to enhance climate change adaptation.

Figure 7 summarizes the study area's top ten perceived climate change indicators. Longer droughts and excessive temperatures were major indicators of climate change throughout the entire study area. Based on their importance, others were decreasing rainfall trends, longer dry spells, and excessive floods. Despite the mention, the latter indicators relate closely to rainfall trends. Figure 7 further analyzes the perceived indicators by disaggregating them at different transect points.

invasive species, studies have shown that *Salvia verbenaca* L. Cultivars (Javaid, *et al.,* 2018); *Prosopis juliflora, Stellaria media* and *Lantana camara* (Muhammad *et al.,* 2023); and two Solanaceae species (*Physalis angulata* L. and P. *Philadelphica Lam.* var. immaculata Waterfall) (Ozaslan *et al.,* 2017) were considered invasive speciaes in semi-arid areas.

This study showed the importance of reducing the geographic scale in investigating and enhancing climate change adaptation, even though many authors (Cuni-Sanchez *et al.* 2019; Gebeyehu *et al.* 2021; Gebre *et al.* 2013) provide large-scale time-series data analyses and ground information over an extensive area.

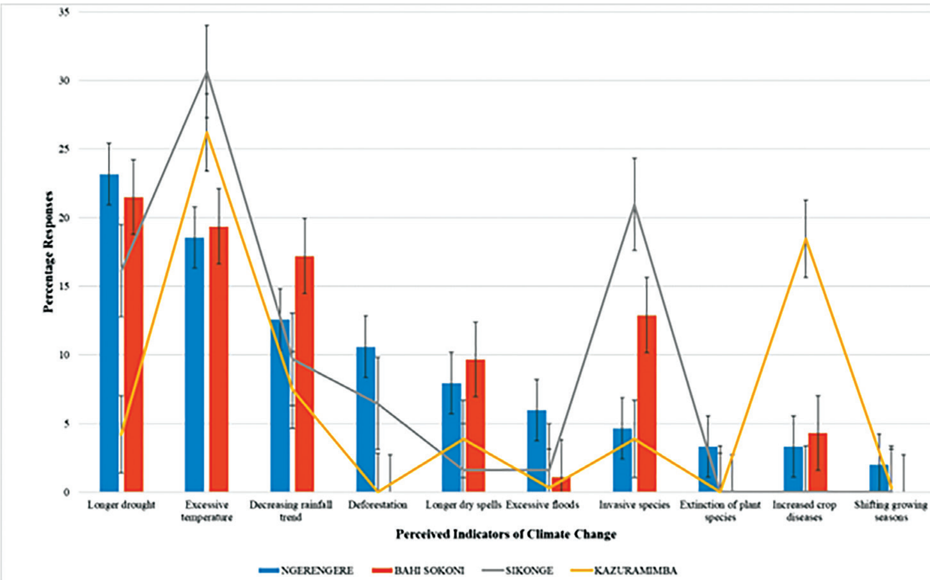

Figure 7: Comparative descriptive analysis of respondents' perception of indicators of climate change across the four transect points

Respondents from Sikonge and Kazuramimba, in the dry and wet sub-humid agroecological zones, respectively, were more concerned about the elevated temperature. Those in the eastern portion of the transect line (Ngerengere and Bahi Sokoni) were less concerned about this indicator. Figure 8 further shows that invasive species and increased crop diseases were major concerns in Sikonge and Kazuramimba, respectively, compared to the other transect points. Although the respondents could not mention the specific names of the

Adaptation strategies adopted by agro-pastoralists

Table 4 demonstrates that the agro-pastoralists in the study areas adopt different adaptation strategies because each agroecological zone has a varied level of sensitivity. Our findings show that agropastoralists' resilience to the negative effects of climate variability and change varies depending on where they live. In response, agro-pastoralists in the agroecological zones under study employed a variety of strategies, such as altering planting dates, diversifying their crops, and cultivating drought-tolerant cultivars and varieties; increasing the amount of land under cultivation, increasing irrigation, and using agricultural inputs like pesticides and fertilizers; generating non-farm revenue; and engaging in agroforestry. These findings align with those of Ali & Rose (2021); Mkonda (2022) and Mwinkom *et al.* (2021) which demonstrated the impact of diversity in agro-pastoral or farmer sites on the ability of households to adapt. Furthermore, the incapacity of agropastoralists to make logical decisions about the selection of adaptation techniques may be associated with their existence in varied agroecological zones. Accordingly, increased financial and technical capacity is necessary for crop and livestock production to succeed in various agroecological zones, which would reduce agropastoralists' uncertainty when making decisions (Joseph, 2022; Kimaro *et al.,* 2018; Leal Filho *et al.,* 2020). The results of this study are consistent with those of earlier studies (Aryal *et al.,* 2021; Yusuph *et al.,* 2023) that demonstrate the significant potential for reducing crop failures and climate risk through modifications to farming practices and sustainable land management. Furthermore, Weldegebriel & Amphune (2017) demonstrate that non-farm households are more likely to implement adaptation strategies, suggesting that diversifying one's source of income can improve adaptability. The results of our study, which show that a small percentage of agro-pastoralists (14.4%) engage in agroforestry and non-farm income-generating activities, contrast with those of Destaw & Fenta (2021), who contend that enhancing income-generating activities and providing access to climate information are essential components of strategies for adapting to climate change.

Table 4: Adaptation strategies disaggregated across agroecological zones [(%)]

Adaptation strategies	Agroecological zone (n=377)				Total
	Semi-arid	Sub-humid	Dry sub-humid	Wet sub-humid	
Crop based management	16.4	6.0	12.8	19.2	54.4
Land/soil-based management	9.2	5.6	3.6	12.8	31.2
Non-farm income and agroforestry	2.8	2.0	7.6	2.0	14.4

The implications for climate change adaptation strategies by agro-pastoralists

The results of this investigation show that climate change perception and sensitivity are context-specific and that agropastoralists' approaches to designing and implementing suitable adaptation methods are influenced by a number of factors. Our findings, thus, offer the information needed to support and maximize the resilience to shocks and climate change adaptation capacity of smallholder farmers and agropastoralists. Numerous studies have documented agropastoralists' views of and responses to climate variability and change (e.g., Mkonda, 2022; Moroda *et al.,* 2018; Muricho *et al.,* 2019). These research all showed that there are different perspectives on climate change, which offers important information about how environmental factors and educational attainment affect the selection of adaptation tactics. Furthermore, these studies identify several obstacles to adaptation and provide recommendations to surmount them, such as fostering stakeholder collaboration and advocating for necessary government backing. The ensuing analyses of vulnerability and perception thus highlight the crucial importance of incorporating deliberate and context-specific (Wilson, 2022) changes to reduce risks and address vulnerability. In that regard, the need to redefine adaptation strategies emanates from the understanding that historically, agro-pastoralists have had to adapt to climate change using multiple traditional adaptation strategies (Silvestri *et al.* 2012), but lacked consideration of trajectories of vulnerability. The government needs to alter its present policies to create a more favorable policy setting in order to support the increased resilience of agro-pastoral communities in agroecological zones throughout Tanzania, and this study gives it a boost to achieve that.

Our findings are consistent with those reported in Gebeyehu *et al.* (2021), where a transition towards sustainable, longer-term, risk-reducing strategies, including rangeland management, water harvesting, and small scale-irrigation schemes, is proposed to address contemporary challenges among agro-pastoral communities. Related research efforts documented in the literature highlight the role of in-depth adaptation analysis (Mayanja *et al.* 2020) in informing policies and institutions geared toward strengthening the existing agro-pastoralists' adaptation capacity. Similarly, Mihiretu *et al.* (2019) recognize the role of combining and enhancing emerging adaptation strategies on top of existing traditional strategies to accommodate context-specific changes in the climate status quo.

Conclusion

This study showed that agro-pastoralists across the transect in Tanzania are aware of their vulnerability to climate change and how it affects their livelihoods. Their perception and the analytical information from in-situ data on climate change and variability have helped establish the mismatch in understanding levels of vulnerability. Current adaptation strategies appear spontaneous and short-term and seem to focus more on climate variability than climate change. Lack of integration and/or sole reliance on scientific data or knowledge and perception renders the established adaptation strategies precarious. The accumulated local knowledge based on the perception of agro-pastoral farmers across the transect, if combined with the actual (scientific) data, could be used to redefine adaptation strategies to stabilize and secure their production. Well-informed decisions on the feasible adaptation strategies to apply generally depend on information derived from the spatio-temporal analyses of climatic information and perception. Drawing from the aforementioned conclusive narrative, the study suggests the following policy and research initiatives: (1) Create a participatory data management framework for sustainable data collection, storage, and analysis in the selected transect points; (2) Develop medium- and long-term adaptation strategies based on informed policies and other frameworks that provide technical and financial assistance; (3) Integrate local knowledge in specific vulnerability contexts with corresponding scientific data to address newly identified requirements for adaptation.

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