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Factors that Accelerate Vulnerability to Climate Change Impact among the Agro- Pastoralists in Arumeru, Tanzania

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Abstract*:* This study sought to establish factors that accelerate vulnerability to climate change impact among Agro- Pastoralists in Arumeru District, Tanzania, using the Cross- Sectional Survey Design. The sample size was 202 respondents selected through random and purposive sampling procedures. In each village, 30 households of 18 years of age and above were sampled. Data was collected using household survey, focus group discussion and key informant interviews. Data was analysed through the thematic approach and descriptive statistics. The study identified some factors that accelerated vulnerability to Climate Change Impact. The study recommended that there is a need to fully involve local communities in planning and decision making on how to effectively mitigate climate change impacts on people's livelihood. There is also a need for increased consciousness of the possible impacts of climate changes. Finally, the agro-pastoralist should employ several strategies to reduce risk, such as planting drought-resistant crops like cassava to yield in the dry seasons.

Keywords: Agro-pastoralists, factors, accelerate-vulnerability, and climate change impacts.

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Introduction

While climate change and variability may be caused by natural processes or by human influences, natural processes include volcanoes, internal variability in climatic factors or sun radiation. On the other hand, human activities that influence climatic change include, release of greenhouse gases and changing concentration of suspended particulate matter in the atmosphere (Rosso, 2018). Literature indicates that the increasing climate variability and continuing impact of climate change negatively affect the biophysical systems and socio-economic systems (Adger, Huq, Brown, Conway, & Hulme, 2003; Thomas, 2005; Meena, Lugenja and Stephenson, 2006; Bouchama et al. 2007; Holman & Naess, 2008; Costello et al. 2009; Yanda & Mubaya, 2011; IPCC 2013; IPCC 2014; Sharma, Upgupta & Kumar., 2015; Joseph, Kaswamila, & Mbassa, 2017; Gaskin et al.,2017; Sharma et al., 2018; Velo & Zafitsara,2020; Akhmatov et al., 2021). Therefore, policy-makers and community leaders need to encourage reduction of Greenhouse Gase (GHG) emissions and stimulate adaptation to reduce vulnerability to climate changes.

Recently, scientific community and policy-makers have been putting more emphasize in conducting research on climate change related aspects, which will enable the implementation of mitigation measures (Burton, Huq, Lim, Pilifosova & Schipper, 2002; Klein, Schipper & Dessai, 2005). However, there has been a shift toward a more balanced approach between mitigation and adaptation in climate research during the last decade or so. Given many challenges at varying spatial and temporal scales, a variety of approaches is necessary to reduce and manage risks (Klein et al., 2005; Field et al., 2014). This is because the success of climate change adaptation and resilience strategies depends on the extent of cooperation within social systems and across scales (Eriksen, Brown, & Kelly, 2005, Field et al., 2014; Akhmatov et al., 2021).

Therefore, effort should be taken to consider socioeconomic system sturdiness in terms of health and resilience status and the possibility of reducing exposure to anticipated hazards should be assessed (IPCC, 2012; Sharma et al., 2018; Velo & Zafitsara, 2020). For example, in the case of the communities who dwell in the flood plains of rivers, their poverty levels should be addressed and measures should be taken to shift them away from the flood plains or to change the design of their dwelling houses to elevated areas so as to manage their exposure to flood hazard, thereby reducing their overall vulnerability (Gaskin et al., 2017; Joseph et al., 2017; Velo & Zafitsara, 2020).

There are studies in developing and developed countries on impact of climate change. However, very little has been done so far on factors that accelerate the vulnerability of climate change in agro-pastoralist communities, especially in the Arumeru District. Lack of studies on this area makes it necessary to conduct a study whose results may enable practitioners to determine the appropriate measures to reduce the vulnerability and mitigate its impact. This is because the adaptation actions are based on local conceptualities and can result in multiple co-benefits (Seto, 2014; Leith and Vanclay, 2015).

Despite the adoption of various climate change strategies in agro-pastoralist communities, still there is emcee on how indigenous participated in exploring strategies, hence few are actively involved in mitigating the impacts of climate change. In this context, understanding factors accelerating the vulnerability is very important so as to support the planning and implementation of climate-resilient measures for sustainable development. This should go hand in hand with the understanding of factors that accelerate the vulnerability. It is from this perspective that the study emerged to explore factors accelerating the vulnerability to impacts of climate change. The study was carried out in four villages, viz: King'ori, Ngongongare, Mbuguni and Kisimiri Juu, which are administratively in Arumeru District (See Fig. 1). These villages were selected due to the fact that they were dwelt by the agro-pastoralists and they experienced impacts of climate change (Joseph, 2017).

Arumeru District is located between longitudes 35^0 37´and 35^0 47´ East and latitudes 3^0 17´ to 3º 27´ South. It borders Simanjiro District to the East, Hai District to the Northwest, Kiteto District to the South, and Monduli District to the North. Mbuguni, one of studied villages, is found at 3° 34' 0" South and 36° 57' 0" East. King'ori is at 3° 17' 0" South and 36° 59' 0" East while Ngongongare is at 3º18´S and 36^0 51´E and is found in the East part of the District (Joseph, 2017).

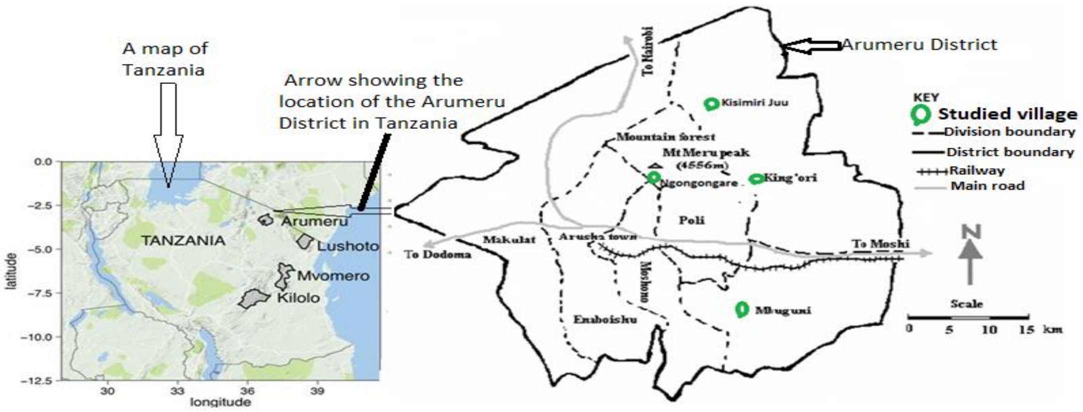

Figure 1: The map showing the studied villages

Arumeru District has three agro-ecological zones namely high-potential area, medium-potential area and low-potential area.

The term 'high-potential area' is used to describe areas that depend on rainfall pattern (bimodal rainfall), temperature which is 15^0C during winter and 32^0C during warmer periods and soil fertility which can be used for intensive agricultural production (Kajembe et al., 2005).The term 'highland' (normally a physically identified area recognized by altitude) is commonly used to describe fertile high-potential mountainous areas. High-potential areas are densely populated with volcanic ash (nitrosol soils) moderately developed and bimodal rainfall ranging between 1000 and 1500 mm per annum. The areas have high altitudes at 1500 of or higher above sea-level (a.s.l.) on the Eastern slopes of Mount Meru and are densely populated due to relatively fertile soils and higher levels of precipitation.

The medium-potential areas refer to land resources with physical limitations for intensive small-scale farming, if compared to the high-potential area. Crops grown there include maize, intercropped with beans, coffee and banana with a semi-extensive livestock system. Livestock are mainly free-grazed and few are stall-fed. Precipitation in this zone is slightly lower than that found in high-potential areas and ranges from 800 to 1000 mm per annum. Altitude ranges from 900 to 1500 m a.s.l. Soil in these areas is browner, less leached and slightly more fertile than soils in the low-potential areas (Kajembe et al., 2005).

The 'low-potential areas,' commonly referred to as 'lowlands', mainly consist of plains surrounding the mountains with altitudes of 900 m a.s.l. or less. These areas are relatively dry, compared to the high- and medium-potential areas. The amount of rainfall is less than 800 mm per annum. It is normally erratic and bimodal (Nkonya, Schroeder, Norman, 1991). The soil is volcanic ash and more developed than in high- and medium-potential areas (Cunard et al., 1985).

Climate

The study area receives an annual rainfall ranging between 500 mm and 1,200 mm. The area has a bimodal type of rainfall, for example short rains falling from November to January and long rains falling from March to June (Thompson *et al.*, 2002). There is usually a long dry spell towards the end of January or early February. Two peaks of rainfall are experienced in December and in April (Kajembe *et al.*, 2005) (See Fig. 2).

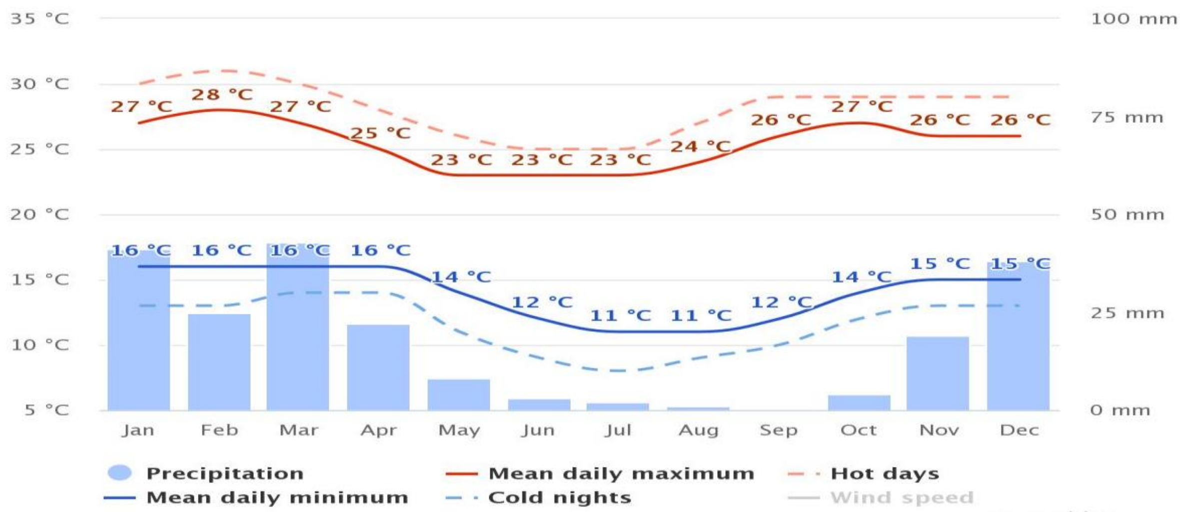

Figure 2: Showing the trend of precipitation and temperature

As shown in Figure 2, the "mean daily maximum" (solid red line) shows the maximum temperature of an average day for every month for Arumeru District. Likewise, "mean daily minimum" (solid blue line) shows the average minimum temperature. Hot days and cold nights (dashed red and blue lines) show the average of the hottest day and coldest night of each month of the last 30 years. Monthly precipitations above 150 mm during wet season and the precipitation is below 30 mm during dry season. The average temperatures range between 25^0 C and 15^0 C. the highest temperatures occur in October just before the start of the rainy season and falls gradually in December remaining relatively constant until May. Between May and August, temperatures are at their lowest levels (Thompson *et al.*, 2002; Kajembe, *et al.*, 2005).

Methodology

Research Design

The study employed the cross-sectional research design in collecting, analyzing and interpreting the data.

Population and Sampling Procedures

The study was conducted in Arumeru District whose population is 516,814. Arumeru District has 71 villages from which four, namely King'ori, Ngongongare, Mbuguni and Kisimiri Juu were purposely selected. The four villages had 17, 868 people. In each village, 30 households of 18 years of age and above were sampled from the village register using a simple random sampling method. For example, in Kingori village with 958 households, the interval of 32 households was used to pick one respondent till 30 respondents were obtained; in Ngongongare with 735 households, the interval of 24 was used. For Mbuguni village with 879 households, the interval of 30 households was adopted and for Kisimiri village with 1003 households the interval of 33 households was employed. Purposive sampling was used to obtain eight Village Extension Officers (two extension officers from each of the four villages selected for the study) and four District officers (two environmental officers and two District livestock officers) who were involved in key informants' interviews. The purposive sampling was opted against other types of sampling due to the fact it involved selecting individuals knowledgeable and experienced with a phenomenon of interest (Cresswell & Plano, 2011). Therefore, a total of 12 key informants were used in this study.

Instrumentation
Data was gathered through a questionnaire survey, focus group discussion, key informant interviews, and field visits. The questionnaires consisted of both closed and open-ended items. The interview was conducted using interview guides. Focus group discussions composing of 10 participants in each village were conducted making it to be the third data collection method used in this study. Direct field visits and observations were also used in this study. The observation method enabled the researcher to systematically select, watch, listen, read, touch, and record the behaviour of biodiversity and agro-pastoralists impacted by the climate change. Through field study, the author was able to observe how rivers and dams were dry causing much vulnerability agro-pastoralists communities.

Validity and Reliability
Validity was attained through critical preparation of research instruments which involved questionnaires that were pretested before data collection. A triangulation methodological approach, the use of aforementioned data colleting instruments, was employed which ensured the reliability of findings obtained in this study.

Statistical Treatment of Data
The qualitative data was analyzed through the thematic approach whereby common themes were assembled together. The quantitative data was analyzed through the Statistical package for Social Sciences.

Ethical Considerations
Ethical considerations were observed during data collection in different ways. Before data collection, permission was sought from the District and Village administrative organs. Consent forms were filled by respondents prior to data collection. All the information was treated confidentially and anonymously.

Findings and Discussion
This section presents results that were guided by a research question which states: what are the factors that accelerate vulnerability to impacts of climate change among the Agro-pastoralists in Arumeru District?

This question sought to explore the main factors which influence the vulnerability to climate change impact among the pastoralists. The results show that there are numerous factors including precipitation variability, temperature increase, eruption of diseases such as malaria, the physical change of landscapes, shortage of water sources, prolonged drought which causes the death of livestock and strong wind which destroy settlements as indicated in Figure 3.

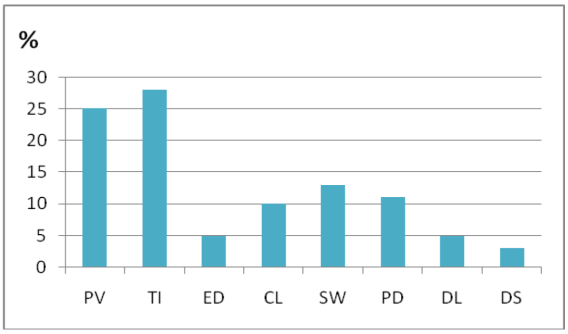

Figure 3: Factors that accelerate vulnerability in Arumeru district – Tanzania

Key: PV = Precipitation Variability; TI = Temperature Increase; ED=Eruption of diseases, CL=Change of landscape; SW=shortage of water; PD =Prolonged drought; DL=Death of livestock; DS= Destruction of settlements/houses

Precipitation Variability

The results reveal that 25% (120 respondents) perceived that precipitation variability is one of the natural factors that accelerated the vulnerability to impact of climate change in the area. Therefore, inconsistencies in rainfall trends have an impact on both natural ecosystems and socio-economic systems including the agro-pastoralists livelihoods in the Arumeru District. Furthermore, rain variability was spotted in the study area since 1972–2019 and in some years rain either delayed or prevailed before the expected season (See Fig. 4) (Joseph, 2017).

In the *high altitude zone,* the rainfall trend remained constant fluctuating between 900 and 1100mm per season until after 1972 when the trend went down to between 40 mm and 900mm per season (See Fig. 4). In the *middle altitude zone*, the study revealed that the seasonal rainfall decreased from between 1500mm to above 2000mm in the early 1960s to values below 1000mm after 1972 (Blocher et al., 2021). Recently, the rainfall has dropped to 500mm. In *the low altitude zone*, the trend of seasonal rainfall is constant for several parts fluctuating between 500 and 1000mm per season. The trend showed a declining trend, falling from above 500 mm in the late 1970s to about 400mm in the 1980s and to below 300mm after the 2020s. Contextually, this result is in line with that of Blocher *et al.* (2021) asserts that increasingly unpredictable rainfall, shifting agro-ecological zones, and increased dry periods could reduce the production of certain crops while boosting the production of other crops.
USAID (2012) asserts that from 1960 to 2006, annual rainfall in Tanzania has decreased at an average rate of 3.3 percent per decade. Akhmatov et al., (2021) asserts that rainfall patterns have become more variable, with an increase in the amount of precipitation falling in isolated events. This result is an indication that precipitation variability has an impact on climate change. Furthermore, agro-pastoralists interviewed indicated the climate changes impacts may shrink rangelands, change plant species distribution, and cause livestock deaths during high temperature.

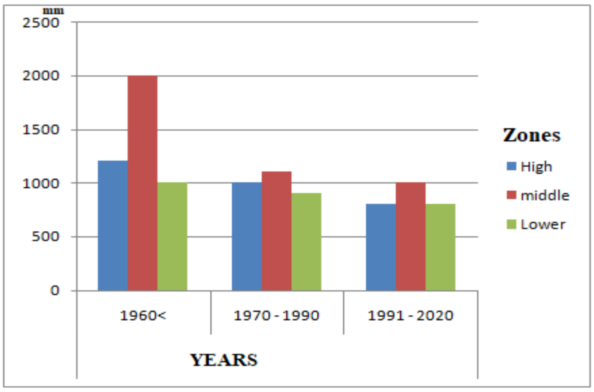

Figure 3: The rain variability as per altitude in the study area since 1960s< -2020s

Temperature Increase

Overall, in the four villages combined, 28% of questionnaire respondents (N=120) pointed to an increase in temperature as one of parameters that influenced vulnerability on agro-pastoralists livelihoods in the study area. It was revealed that since the 1980s, average temperature has been getting higher incessantly throughout between 0.1°C and 0.5°C per decade. The northern region where the Arumeru district is situated has warmed more than the south, and the strongest trends are observed there. This trend is a robust result among climate models and greenhouse gas emissions scenarios. In Tanzania, as seen in Figure 5, the RCP2.6 results indicate both the annual mean surface temperatures (*left*) and the mean number of very hot days (right) which define the days of which temperatures exceed 32°C. Moreover, the number of very hot days can be expected to increase significantly in some areas. Climate models show an increase of more than 40 very hot days. As many as 60 more very hot days can be expected in other areas of Tanzania by the middle of the 21st century (Blocher *et al.,* 2021; Akhmatov *et al*., 2021).

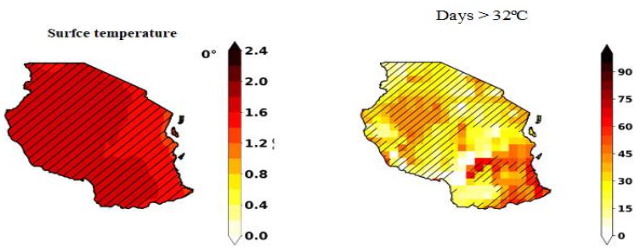

Figure 5: Heating by mid-century for RCP2.6, scaled to 2.4 degrees warming and 95 extreme heat days

USAID (2012) asserts that the average annual temperatures have increased by 1°C since the 1960s and are projected to rise by 1-2.7°C by 2060s and 1.5-4.5°C by the 2090s compared to the 1970-1999 baseline. The results from interviews indicate that agro-pastoralists have been observing the increase in temperature which has led to a decline in livestock and crop productions due to heat produced by temperature. The harvested crops a no longer enough to sustain the livelihood of family members.

Eruption of Diseases

The results indicate that 5% (N=120) of the respondents perceived eruption of diseases for livestock and human being as one of factors influence the vulnerability to the agro-pastoralists in the study area. The discussants in the four villages signified that climate change in terms of temperature variability has caused the emergence of malaria which was not there before. It was pointed that malaria is currently one of major causes of illness and loss of people's life. It was noted that about 60 percent of deaths in children in the Arumeru District was caused by malaria (Joseph, 2017).

On the one hand, the spread of certain *pathogens* and *vectors*, *wind-borne paste ruminants*, *dermatophilosis*, *infective spores of anthrax and blackleg* diseases affecting livestock were revealed. The identified crop diseases that emerged include bacteria in banana plantations (*mnyauko in the Swahili language*), bana-by wiva and Obnoxious weeds. These diseases have led to a decline in crop production hence hunger which brought more vulnerability upon the agro-pastoralists to impacts of climate change. Yanda and Mubaya (2011) and Akhmatov et al., (2021) asserts that diseases such as avian influenza, bovine tuberculosis, brucellosis, foot and mouth disease which are transmitted through close contact with animals, have been reported to have associated with climate change.

The results from key Informants indicate several serious drought epochs that have hit the District. The first was in 1972, followed by that of 1995 and the last drought was in 2008. These events have led to the eruption of diseases such as foot and mouth (scientifically *known as aphtae epizooticae*), bone marrow disease (*nodo e nobility in Maasai tribe*), the Rift Valley Fever (scientifically *known as genus phlebovirus*), skin diseases (*alarrirri in Maasai language*) and lung diseases (*orkipei in Maasai language*) leaving pastoralists devastated and poor. In this context, climate change conditions are encouraging agriculture and domestication of livestock through inconsistent and unpredictable rain, dry spells the occurrence of pests and diseases, and extreme weather conditions (Akhmatov et al., 2021). The result openly signifies the extent to which agro-pastoralists have been vulnerable to climate change impacts.

Shortage of Water

Generally, 13% of the respondents (N=120) perceived shortage of water as a factor that influenced the vulnerability of agro-pastoralists in the study area. The main reason for water shortage in the study area is attributed to prolonged drought, erratic rainfall and high temperatures as evidenced by climatic variation in the District (Blocher *et al.,* 2021).

Uncertainty of water availability (See Figure 6) has led to some agro-pastoralists becoming more vulnerable to the extent of shifting to distant areas where they can obtain water. The study revealed that scarcity of water in the study vicinity has resulted in some agro-pastoralists walking long distances *(> 35km*) to get water for livestock use.

Dry dam in Mbuguni village

Dry river in Ngongongare village

Figure 6: Water scarcity (dam and river are dry) due to less precipitation and prolonged drought

The results from the discussants stated that the lack of water sources to facilitate irrigation and for domestic use is an overarching encounter for the Arumeru District. The distance to reach water points for domestic use only varied from one village to another, for example, Ngongongare villagers had to walk *1- 5 km*, for King'ori *1- 6km* and for Mbuguni *1-9km* to obtain water for household consumption at Tsh. 200 per bucket *(20-litre capacity*).

Saringe (2011) asserts that reduced rainfall results in water scarcity, the disappearance of natural springs and the drying of dams in most rangeland areas. On the other hand, Joseph et al., (2017) argued that drought is certainly one of natural threats for water availability and quality, affecting production in rangelands and subsequently, livestock performance in the already difficult context of arid areas. Thornton et al., (2008) argue that water scarcity in rangelands is increasing at an accelerating pace and affects between 1 and 2 billion persons and that climate change will have a substantial effect on global water availability in the future. Not only will this affect livestock drinking water sources, but it will also have a bearing on livestock pasture production systems and pasture yield. UNDP (2007) asserts that water scarcity poses unprecedented challenges to human security.

Prolonged Drought

Generally, in four villages together, 12% (N=120) spotted prolonged drought as a factor that accelerated vulnerability of climate change to agro-pastoralists in Arumeru District. The study revealed that the greater incidence of droughts, together with underlying social, economic, and environmental risks means that dry spells have an increasingly disparaging effect on the people due to the fact that the surrounding communities lack water for use. It was noted that wells, rivers and ponds dry due to extensive use and evaporation.

Discussants in the study area mentioned that changes in climate parameters were mostly noted in such years as 1972, 1974, 1984, 1994, 1997, 1998, 2004, 2005, 2009, 2010, 2014 and 2017. The interviewees stated that they used to seed their seasonal crops in March of every year hoping that they would experience rainfall, but unfortunately, they ended facing drought which led to dry-up of crops due to intensive heat-induced upon them. In addition, the study revealed that prolonged drought in the study area was influenced by different parameters including altered weather patterns, excess water demands, deforestation, soil degradation, and an increase in temperature for a long time, a short period in precipitation, strong wind which dries up moisture as well to other factors.

Kijazi and Reason (2009) asset that the outcome of climate change are manifest through increases in extreme climatic conditions such that drought, changes in rainfall season and intensity. Drought condition is coupled with rainfall deficit and poor rainfall distribution. Drought is the major reason for both water and food shortages. Drought worsens agricultural development and unsustainable land use. In the recent decade, Tanzania experienced severe drought 1999/2000 which extended to 2005. On the other hand, IUCN (2014) asserts that climate change-related impacts, such as temperature rise, precipitation pattern changes and extreme weather events, including drought, water stresses and floods, are increasing community and ecosystems vulnerability.

Evidence on the numerous drought caused by an increased temperature and shortage of rainfall (Blocher *et al.,* (2021) show negative changes in annual mean rainfall trend by decade (1981–2016). Figure 7 indicates rainfall (blue) and temperature (red) anomalies more than the long-term standard (1981–2016). An apparent upward linear inclination in temperature is apparent.

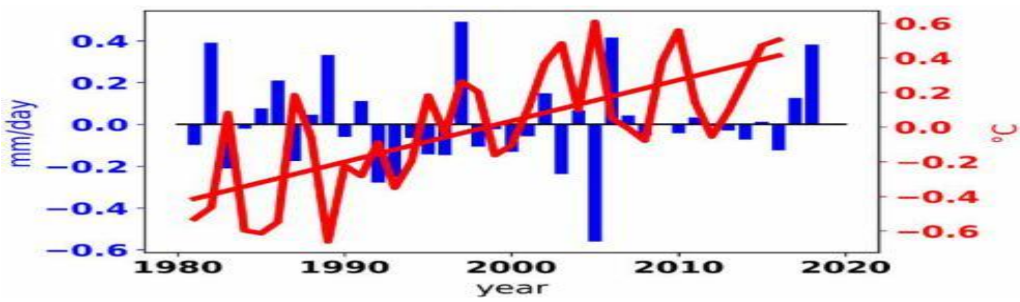

Figure 4: Averaged rainfall and temperature anomalies

Source: Adopted from Blocher *et al.,* (2021

One of focus group discussants in King'ori village, explaining on the increase in temperature in the area, stated that,

Currently, temperatures have amplified, compared to previous years of the 1990s and backward which is the past now, King'ori had more calm (cool) months than warm months. At the present, warm months contain amplified than that of calm (cool) months. For instance, it was not easy to have a tremendously warm situation during this month of July since the month was the coolest of the entire months in the year. The weather this month has changed and we cannot use blankets to protect our bodies while sleeping at night due to extreme warming. The increase of temperature has led to prolonged droughts which have caused to shortage of pasture and water in our village (Anonymously, November, 2021).

Household and Community Vulnerability

The key informants and discussants mentioned unstable households and communities in terms of income and infrastructure as some of major constraints which influenced vulnerability in the area. It was particularly stated that the comprehensive connections between socioeconomic factors and the environment is significant in determining the vulnerability and the capacity of the households to mitigate the impact of climate change in the agro-pastoralist communities. The communities' ability to cope with external shocks such as floods and droughts depends on the ability to access stable resources, infrastructures and health facilities. It was concluded that the poor socioeconomic circumstances found in the Arumeru District make the agro-pastoralists vulnerable to a diversity of climate change catastrophes.

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Climate change impacts such as severe flooding, drought and loss of soil fertility affect the accessibility of basic resources like clean water, shelter, adequate food supplies and income which are essential for survival of agro-pastoralists (Joseph, 2017). Doty, Grajeda, Phillips and Shrestha (2011) state that poor baseline health conditions and inadequate access to healthcare lead to high incidence rates of communicable and preventable diseases like malaria, HIV/AIDS and waterborne diseases. With adequate infrastructure and human and financial resources, governments can prepare populations for expected increases in disease exposure and respond to emergency situations (Joseph et al., 2017; Doty et al., 2011).

Biological Constraints

Discussants further revealed that the presence of biological factors is among the constraints that accelerate vulnerability among the agro-pastoralist community. They stated that tolerances of a person and communities to climate change and extremes differ, depending on biological qualities possessed. The biological characteristics enable the capacity of organisms to cope with the increasing climate change stress (Aitken et al., 2008; Aitken et al., 2011; Hellmann, Prior & Pelini, 2012; Hellmann, Byers, Bierwagen and Dukes (2008). Aitken et al., (2008) commented that the ecosystem constraints can arise from non-native species, including pests and disease, which compete with endemic species. In this context, it can be proven that biological factor of a system can influence the vulnerability to impact of climate change among the agro-pastoralists communities.

Conclusions and Recommendations

Conclusion

The study concluded that there are several factors that accelerate vulnerability to climate change impacts among the Agro-pastoralists in Arumeru District. The identified factors include precipitation variability, increase in temperature, eruption of diseases, shortage of water, prolonged drought, household and community status and biological constraints. These factors will continue to cause more vulnerability in the livelihoods of agro-pastoralists, if the non-governmental organisations, community-based organisations, stakeholders, local and central governments will not provide technical and financial support to the affected community.

Recommendations

The study recommends that there is a need to fully involve local communities in planning and decision making on how to effectively mitigate climate change impacts on people's livelihood. The participatory approach creates awareness on the appropriate strategies to mitigate climate change impacts to agro-pastoralist communities. Moreover, the involvement of the local community in planning and decision making is recommended because it promotes transparency and accountability of the leaders during the execution of the projects to cope and mitigate the impacts of climate change.

Finally, the agro-pastoralist should employ various strategies to reduce risk, such as planting drought-resistant crops such as cassava to yield in the dry seasons.

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