JOURNAL OF MULTIDISCIPLINARY ADAPTIVE CLIMATE INSIGHTS (MACI) Volume 3, Issue 1, June 2026 - E-ISSN 3009-6332

http://dx.doi.org/10.21622/MACI.2026.03.1.2046

Spatial Community Vulnerability to Drought Disaster in Simanjiro District, Manyara Region

Bernard Mtalemwa [1], and Nicholaus Mwageni [2*]

[1] Dar es Salaam Tanzania.

[2*] Ardhi University, School of Engineering and Environmental Studies, Dar es Salaam, Tanzania.

bernardfrancis843@gmail.com, nicholausmwageni2012@gmail.com

Received: 07 April 2025 Accepted: 02 June 2026 Published: 22 June 2026

Abstract:

Drought is the critical environmental hazard affecting livelihoods in semi-arid regions of Tanzania. Much has been documented on community-level vulnerability; however, spatial analyses of drought hotspots using long-term climate data remain scarce. The study assessed community vulnerability to drought in Simanjiro District, Manyara Region, Tanzania, using a mixed-methods approach that integrated household surveys, key informant interviews, remote sensing, and climate data analysis from 1983 to 2022. Results indicate that drought occurred in 24 out of 40 years (60%), with SPI values ranging from -0.1 to -1.2, confirming persistent moderate drought conditions. The average annual rainfall was low (40–70 mm), and the annual total rainfall declined at approximately 2.43 mm/year, while temperatures increased at rates of 0.0189°C/year (maximum) and 0.0211°C/year (minimum). Severe drought events in 2003 and 2022 resulted in livestock losses exceeding 110,000 and 92,000, respectively. Survey results revealed that 70% of respondents perceived declining rainfall, and 90% of households depend on pastoralism, increasing their vulnerability. Key drivers of vulnerability include overreliance on rain-fed systems, high livestock densities, limited access to early warning systems, and low adaptive capacity. The study concludes that drought risk in Simanjiro is both frequent and intensifying, necessitating strengthened early warning systems, expansion of irrigation infrastructure, livelihood diversification, and improved resource governance to enhance community resilience.

Keywords: Drought, Vulnerability, SPI, Simanjiro, Livelihoods, Early warning.

* Corresponding author

1. Introduction

Drought is a slow-onset disaster posing a serious impact on health, agriculture, economies, energy, and the environment (Aston, 2021). An estimated 55 million people are affected by drought every year, and they are the most serious hazard to livestock and crops in nearly every part of the world (UNCCD, 2022; WWF, 2019). Drought threatens people's livelihoods, increases the risk of disease and death, and causes mass migration (UNCCD, 2022; UNDRR, 2021; WHO, n.d.). Water scarcity affects 40% of the world's population, and as many as 700 million people are at risk of displacement due to drought by 2030 (World Bank, 2023).

Drought has been one of the crucial hazards that has caused significant damage to the community economically, socially, and environmentally (Aston, 2021; Thalheimer et al., 2022; UNDRR, 2021). Tanzania has been highly dependent on rain-fed agriculture, which is highly vulnerable to rainfall amounts and distribution (ILSSI, 2019; Mtwanga, 2022; Randell et al., 2022). As observed in most pastoral communities, many livestock have died due to a lack of food and water in the area. This might be since most of the communities may lack access to modern scientific information and forecasting, as well as awareness, preparedness, and capacity to manage impacts brought by drought (Wens et al., 2021). Hence, the communities become more vulnerable to drought and are greatly impacted whenever it occurs.

Simanjiro District is dominated by pastoralist communities that depend on rainfall and natural resources to provide pasture and water for their livestock (Cosmas et al., 2022; Nkedianye et al., 2020). This leaves communities highly vulnerable to the impacts of drought disasters because recent climate change has increased rainfall variability in the region. In 2022, drought killed 92,000 livestock in Simanjiro District, Manyara Region, Tanzania. It was further stated that such significant impacts result from a high illiteracy rate, inadequate mitigation measures, and a lack of a preparedness plan, which puts the community at high risk of drought disasters (Juma, 2022). Therefore, the study aimed to assess the extent of vulnerability and risk the community faces to drought and to propose better mitigation measures to the community to reduce the severity of drought impacts.

2. Methodology

2.1. Case study selection and sampling

Simanjiro District is one of the six districts of the Manyara Region in Tanzania. It is bordered by Arusha Region to the north, Kilimanjaro Region to the north-east, Tanga Region to the south-east, Kiteto District to the south, and Babati District to the west (Figure 1). This study was conducted in other semi-arid regions of Tanzania, such as Dodoma and Shinyanga. However, Manyara is less studied. Hence, the choice of the case study. Furthermore, the study was conducted in other districts in Manyara Region. However, Simanjiro District was the best representative of other districts due to a higher Standardized Precipitation Index (SPI) value than any other district in the region. The district comprises 15 wards, with Ngorika, Naisinyai, and Liborsoit having the highest risk of drought disasters due to the lowest average monthly rainfall over the past 40 years. Therefore, with frequent drought disaster events within the district, the growing population is put at high risk of food insecurity, malnutrition, death of livestock, and diseases.

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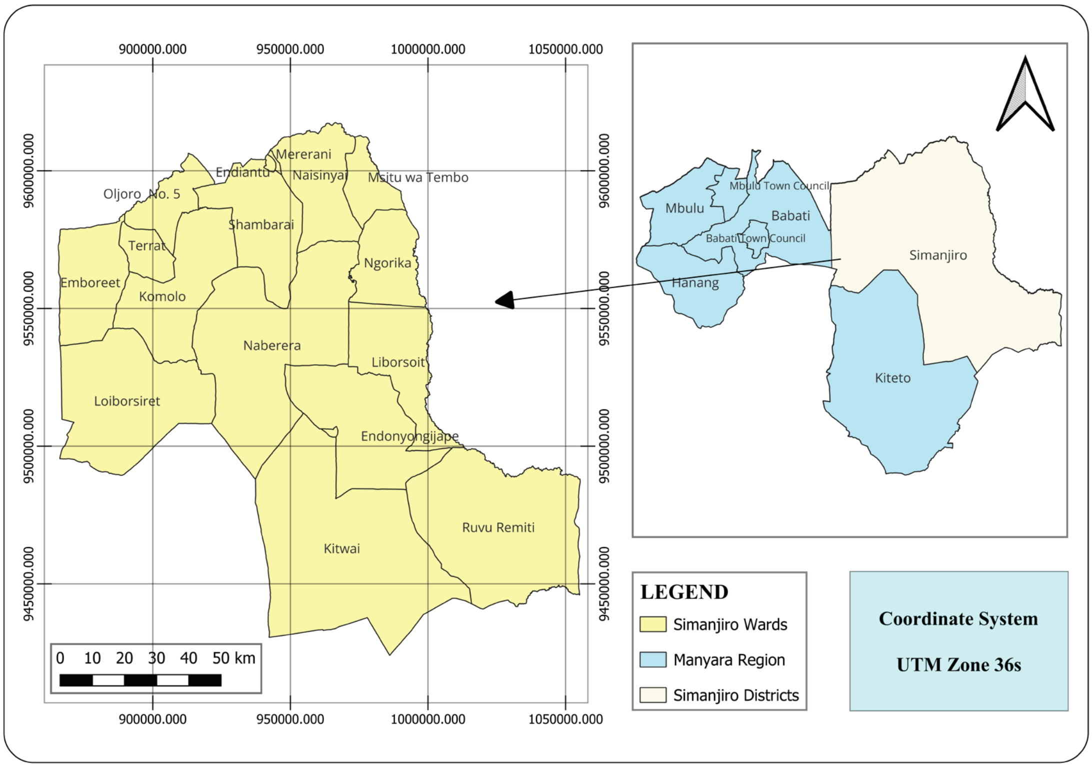

Figure 1: Map of Manyara Region, where Simanjiro District is found

2.2. Sampling procedure

The selection of survey locations and respondents in Simanjiro District was guided by the distribution and intensity of key socio-economic activities, as well as geographical representation across wards. A total of 100 households were purposively selected from three wards, namely Ngorika, Naisinyai, and Loiborsoit. The households were chosen to represent areas with varying levels of exposure to drought-related impacts. In addition, respondents were required to have resided in the study area for at least 30 years to ensure they possessed adequate experience and knowledge of long-term drought trends.

Fifteen (15) key informants from relevant district departments at the district and ward levels were purposively selected. These departments were identified based on their roles and availability of records related to drought impacts, including effects on biodiversity, crop production, livestock populations, environmental conditions, water resources, and social development. The departments and officials involved in the study included the Agriculture and Irrigation Department, Environmental Department, Water Supply Authority (RUWASA), as well as local government officials such as Ward Executive Officers (WEOs) and Village Executive Officers (VEOs).

2.3. Data collection and analysis methods

A mixed-methods design was applied. Data collection involved physical observation, structured interviews, remote sensing techniques, questionnaires, and document review. A questionnaire was administered to 100 households. The households were purposively selected to cover the case study wards, in which 48% were male, and 52% were female. The dominant education level was primary. Also, 46% of the respondents were elders, while 54% were youth. 15 semi-structured interviews with government officials (WEOs, agricultural officers, Rural Urban Water Supply Authority) and elders were conducted to document impacts and coping strategies. Data analysis was conducted using ANOVA to determine statistical differences in climate change. Software used was MS Excel, SPSS, and ArcGIS. Climate datasets (monthly precipitation and temperature) covering 1983–2022 were obtained from CHIRPS, NASA Data Access Viewer, and Climate Engine.

2.4. Determination of the Standardized Precipitation Index (SPI)

To determine drought severity, the standardized precipitation index (SPI) was used to assess precipitation probability over different time scales. The SPI was computed for different time scales, providing early warning of drought and helping assess drought severity. Palmer Drought Severity Index (PDSI), Drought Severity Index (DSI), Standardized Precipitation Evapotranspiration Index (SPEI), and Reconnaissance Drought Index (RDI) were thought to be used in this study; however, the Standard Precipitation Index (SPI) was found to be better due to minimal data requirement, simplicity in analyzing drought severity, multi-timescale flexibility, and sensitivity to short-term changes. The SPI was used to measure precipitation deficits over a range of periods, which may indicate how drought affects the availability of various water resources (McKee et al. 1995; Straitony, 2026).

The time scales used for SPI computation are SPI-3, SPI-6, SPI-12, and SPI-24. In the context of Simanjiro District, where livelihoods are highly dependent on rain-fed agriculture and livestock, the SPI was computed at a 6-month time scale (SPI-6), as this scale captures seasonal rainfall variability and is closely associated with agricultural drought. Given that the study focuses on impacts such as crop failure, livestock losses, and water scarcity, SPI-6 provides a balanced representation of drought conditions influencing both farming and pastoral systems in Simanjiro District. Values of the SPI for a given precipitation are calculated from the equation:

$$SPI = \frac{f(p) - \bar{u}}{d} \quad (1)$$

Where: SPI – standardized precipitation index; f(P) – transformed sum of precipitation; ū – mean value of the normalized precipitation sequence; d – standard deviation of the normalized precipitation sequence.

The study adopted the Standardized Precipitation Index (SPI) classification developed by McKee et al. (1995). SPI values were categorized as follows: ≥ 2.00 (extremely wet), 1.50 to 1.99 (very wet), 1.00 to 1.49 (moderately wet), 0.00 to 0.99 (mildly wet), 0.00 to -0.99 (mild drought), -1.00 to -1.49 (moderate drought), -1.50 to -1.99 (severe drought), and ≤ -2.00 (extreme drought).

2.5. Analysis of exposure, sensitivity, and adaptive capacity

The study adopted the IPCC Vulnerability Framework, which encompasses the analysis of exposure, sensitivity, and adaptive capacity to drought hazards to determine the Extent of Potential Impact (EPI) and the existing adaptive capacity. The EPI was determined as follows;

$$EPI = Exposure \ X \ Sensitivity \quad (2)$$

For both sensitivity and exposure, numerical values were assigned as indicated below.

Highly exposed = 3, Medium exposure = 2, Less exposed = 1

Highly sensitive = 3, Medium sensitivity = 2, less sensitive = 1

The adaptive capacity of the community was assessed based on risk knowledge, institutional arrangements/governance, access and availability of resources, social cohesion and connectedness, and the economic opportunities and financial resources.

The participants in the focus group discussion brainstormed and reached a consensus on a numerical value to assign to adaptive capacity (1, 2, or 3 on a 1-3 scale, and vice versa) for each category element exposed to drought hazard. To determine the level of vulnerability (defenselessness), the vulnerability score was calculated using the following formula;

$$\text{Vulnerability score} = \frac{HSS \ X \ EPI}{AC} \quad (3)$$

Whereby

HSS = Hazard Severity Score
EPI = Extent of Potential Impact
AC = Adaptive Capacity

3. Results and Discussion

3.1. Rainfall trends

Simanjiro District is characterized by a bimodal rainfall pattern, with a short rainy season from November to December (ND) and a long rainy season from March to May (MAM). The MAM season receives the highest rainfall, with average monthly amounts ranging from 50 mm to 170 mm. However, total annual rainfall has been decreasing by

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approximately 2.246 mm per year over the past 40 years. In contrast, rainfall during the October to December (OND) season ranges from 15 mm to 180 mm, with a slight increasing trend of about 0.28 mm per year. The dry season, which spans from June to September, receives the least rainfall, with monthly averages ranging between 3 mm and 15 mm.

The rainfall data revealed that Simanjiro District receives an average annual rainfall of 40-70mm/year. The total annual rainfall trend was found to decrease at rate of 2.433mm/year while other arid areas such as Kahama town in Shinyanga region decrease at the rate of 0.053mm/year Thus, the average annual rainfall in Simanjiro seemed to be low with high decreasing rate of annual rainfall trends compared to other arid regions since an average annual rainfall ranging 50 to 120 mm/year for other arid and semi-arid regions in Tanzania (Mdee, 2022; Sawe et al., 2018), This was also revealed by the responses from questionnaires that shows 70% of people reported that rainfall was decreasing and 30% responded that rainfall is low.

It was observed that most wards in Simanjiro District have experienced average annual rainfall ranging between 30 and 80 mm over the past 40 years, with the majority receiving less than 75 mm. Ngorika, Shambarari, Naberera, and parts of Naisinyai Ward recorded the lowest average rainfall, ranging from 55 to 65 mm, compared to other wards within the district (Figure 2).

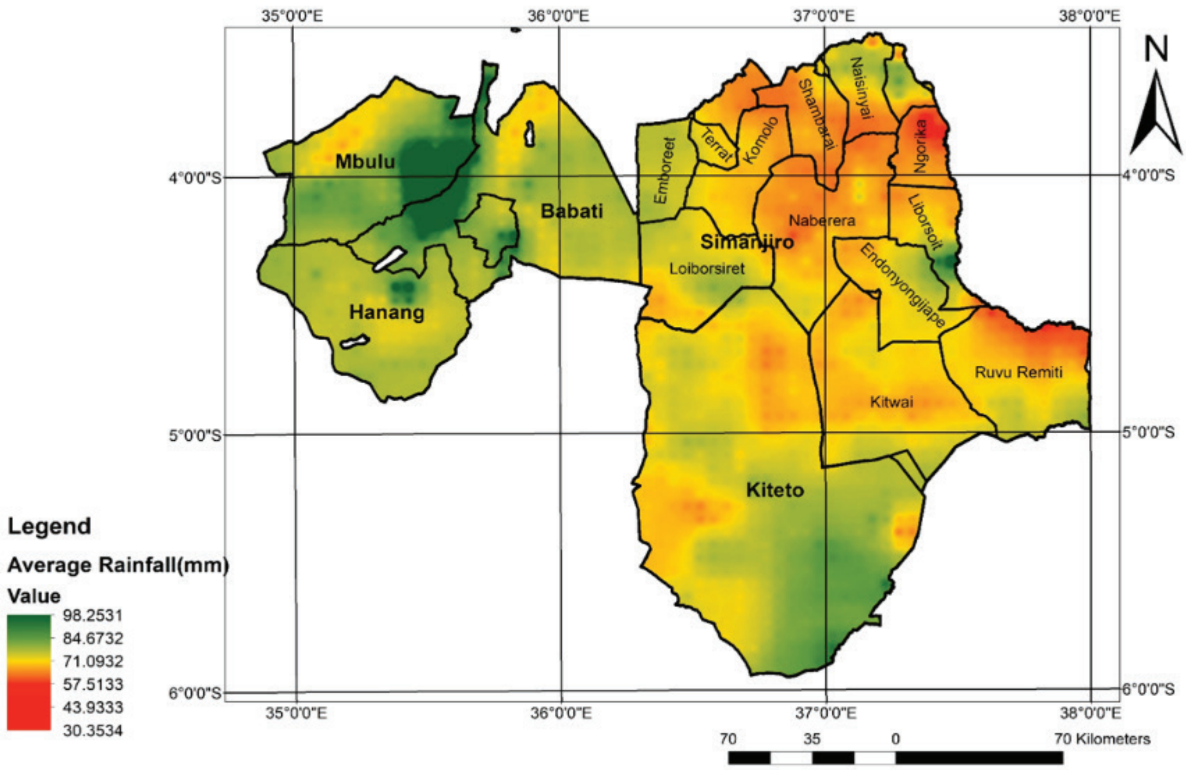

Figure 2: Monthly average rainfall spatial distribution in Simanjiro Ward (1983–2022)

The annual average maximum and minimum temperatures in Simanjiro District show an increasing trend of 0.0189°C/year and 0.0211°C/year, respectively. Consequently, the average monthly maximum temperature rises to about 34°C during February and March (Figure 3). In addition, the number of months receiving average maximum temperatures above 30°C has been increasing over the past 40 years. This trend may be attributed to global climatic change as well as local human activities within the district, such as deforestation and overgrazing (Abera et al., 2024; Kunte & Bhat, 2024; Sawe et al., 2018). Overall, the findings indicate that rising temperatures, combined with declining annual rainfall, are key drivers of agricultural drought in Simanjiro District (Kew et al., 2019; Pal et al., 2023).

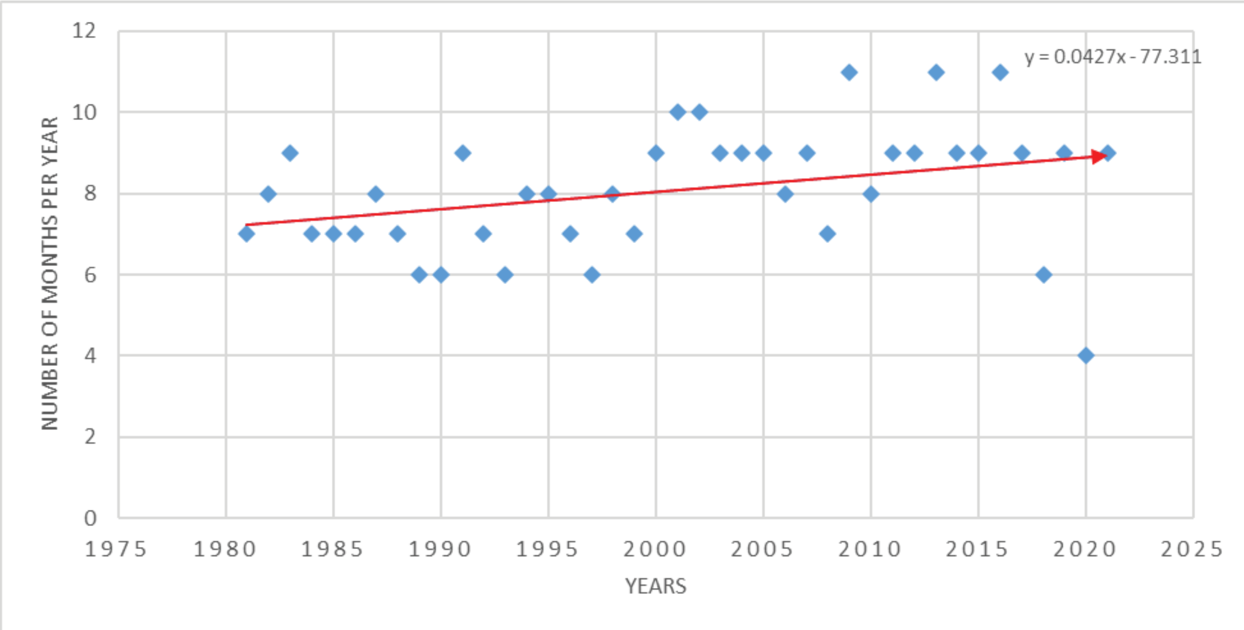

Figure 3: Number of months in a year receiving average maximum temperature greater than 30°C at Simanjiro (1983-2022)

3.2. Drought trends

The SPI index revealed that 24 of the 40 years have experienced drought disasters. The years 2000, 2003, 2017, and 2022 had the lowest SPI index values. The Ward Executive Officers (WEOs) provided further information to substantiate evidence of the occurrence of a drought disaster in the district, reporting that 2003 and 2022 were years when severe drought events occurred, resulting in losses of more than 110,000 and 92,000 livestock, respectively. The study showed that people's perception of drought years was defined as eight years of drought events associated with food and water shortages and crop production losses in Simanjiro District from 2007 to 2014.

The Standardized Precipitation Index (SPI) analysis revealed that 24 out of 40 years experienced drought conditions. The years 2000, 2003, 2017, and 2022 recorded the lowest SPI values, indicating severe drought events. Information provided by Ward Executive Officers (WEOs) further corroborated the occurrence of droughts in the district. Specifically, 2003 and 2022 were identified as years of extreme drought, resulting in the loss of more than 110,000 and 92,000 livestock, respectively. Additionally, the study found that community perceptions aligned with the SPI results, identifying eight drought years between 2007 and 2014. These years were associated with significant impacts, including food shortages, water scarcity, and reduced crop production across Simanjiro District. The difference between the number of droughts identified by SPI (16 drought years) and communities' perceptions (8 drought years) is that SPI captures meteorological drought (rainfall deficit), whereas people respond mainly to impact-based drought—when crops fail, water sources dry up, or livestock die. Thus, the 16 years may include moderate droughts, while the 8 years represent high-impact events.

The spatial distribution of the Standardized Precipitation Index (SPI) (Figure 4) shows that most wards in Simanjiro District experience drought conditions. However, Ngorika, Naisinyai, and Liborsoit wards were identified as experiencing more severe drought conditions over the past 40 years compared to other wards in the district. This implies that, although the entire district is generally classified as arid, Ngorika, Naisinyai, and Liborsoit represent the most arid areas within Simanjiro District.

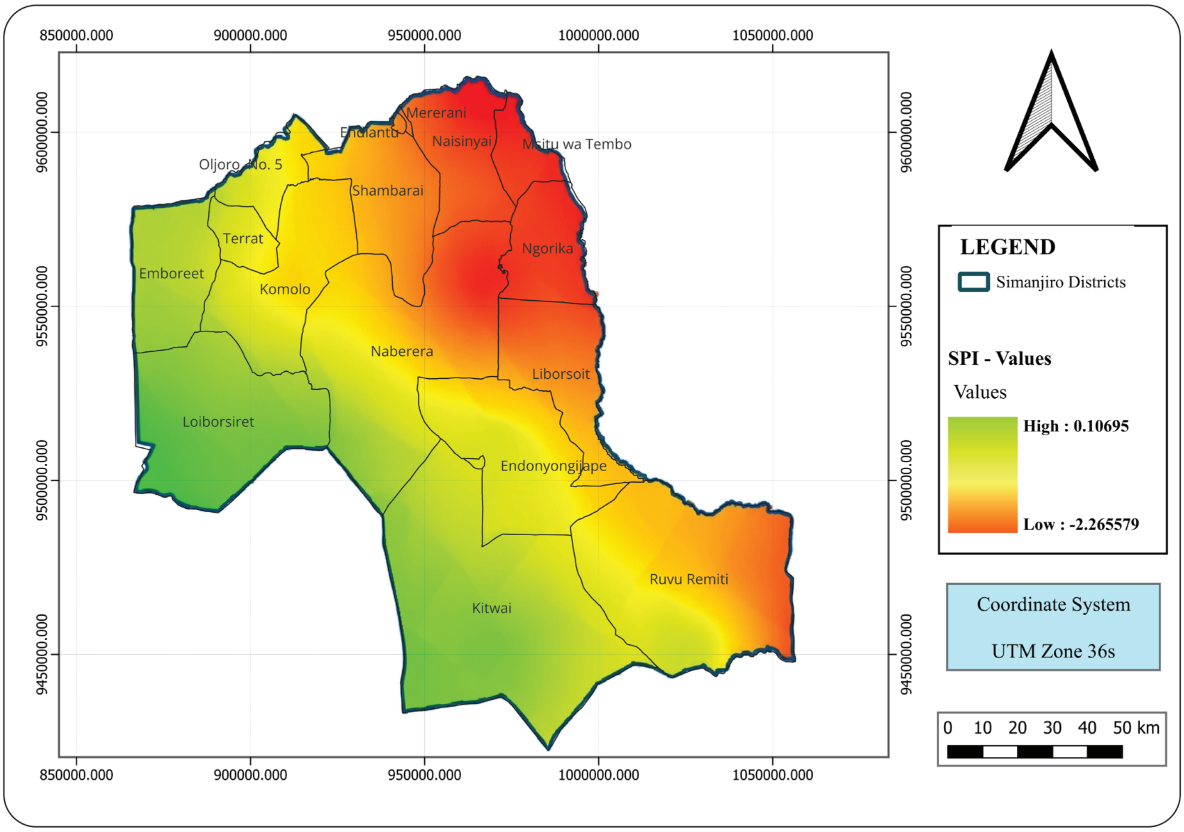

Figure 4: SPI spatial distribution in Simanjiro District

3.2.1. Environmental, social, and economic impacts of drought

The findings revealed that the environment has been affected by drought, which in turn affects the community and ultimately influences the economy of the wards and the district at large (CIWA & SADRI, 2021; Lombe et al., 2024; Musungu et al, 2024). This shows that the effects of drought are interconnected in a chain-like sequence. The direct impacts of drought in the study area were observed on water resources, shrubs, and grassland. Regarding water resources, drought causes a decline in water levels in the Pangani River, which supports a large percentage of the ecosystem components, such as livestock, crops, wild animals, fish, and Birds. During the drought period, most of the fish in the Nyumba ya Mungu dam migrate to other parts of the Pangani Basin, causing a food crisis in the ecosystem. This is because during drought, river and dam temperatures increase by almost 27%, and dissolved oxygen decreases by 17%, which in turn causes competition for oxygen and drives fish species away (Graham et al., 2024). Regarding shrubs and grassland, drought has led to the overgrowth of invasive plant species, pasture drying, and loss of soil fertility. Indirect impacts of drought on the ecosystem involved competition for resources, such that migration becomes a serious issue in the district.

Studies show that drought has been directly and indirectly affecting people's social lives. Where food becomes scarce and expensive, resulting in food insecurity (Gbadegesin et al., 2024; Lombe et al., 2024; Wudil et al., 2022). This is revealed in the study where 90% of the community in Ngorika, Naisinyai, and Liborsoit ward are pastoralists; they highly face the problem of food insecurity since they don't conduct farming, and during this period their economy also declines, meaning that they also don't have enough money to purchase food. This is supported by WEO of Naisinyai Village, who reported that "*We can't even cook food for children anymore at school due to the expensive prices of food during the drought period*".

The district has been affected in various ways, including low crop yields due to rainfall scarcity, trespassing by wild animals on farms in search of water and food, and increased cultivation costs resulting from persistent pests and diseases during drought periods. Interviews with agricultural officers in the respective wards revealed that drought is the major setback hindering agricultural production in both the wards and the district as a whole. Regarding livestock keeping, drought has had severe impacts, including livestock deaths due to inadequate pasture and water, a decline in pastoralists' income, conflicts between pastoralists and farmers, and increased migration in search of grazing land and water. It was reported that drought disasters led to the loss of approximately 92,000 livestock in the district, subsequently pushing many pastoralists into unexpected poverty. This was further exacerbated by a sharp decline in livestock prices, where the price of a bull dropped from TSh 600,000 to TSh 50,000. These findings are consistent with reports from Ethiopia, which indicate that drought leads to significant reductions in livestock holdings and milk production by 8.4% and 25.8%, respectively (Abebe & Alem, 2025).

3.2.2. Relationship between SPI temporal distribution and drought impacts

The SPI and people's perceptions of drought years revealed that the most frequent drought events occurred from 1999 to 2010. The year 2003 experienced the most extreme drought among the years in Simanjiro, with an SPI of -1.8 (5). Furthermore, 2022 was the most recent year to experience a drought. Figure 5 presents the years of extreme drought events and the level of impacts on food shortage, water shortage, and loss of crop production based on people's perception. The allocated number represents the severity of drought, where 4=Extreme, 3=Less extreme, 2=Normal extreme, and 1=No drought effect.

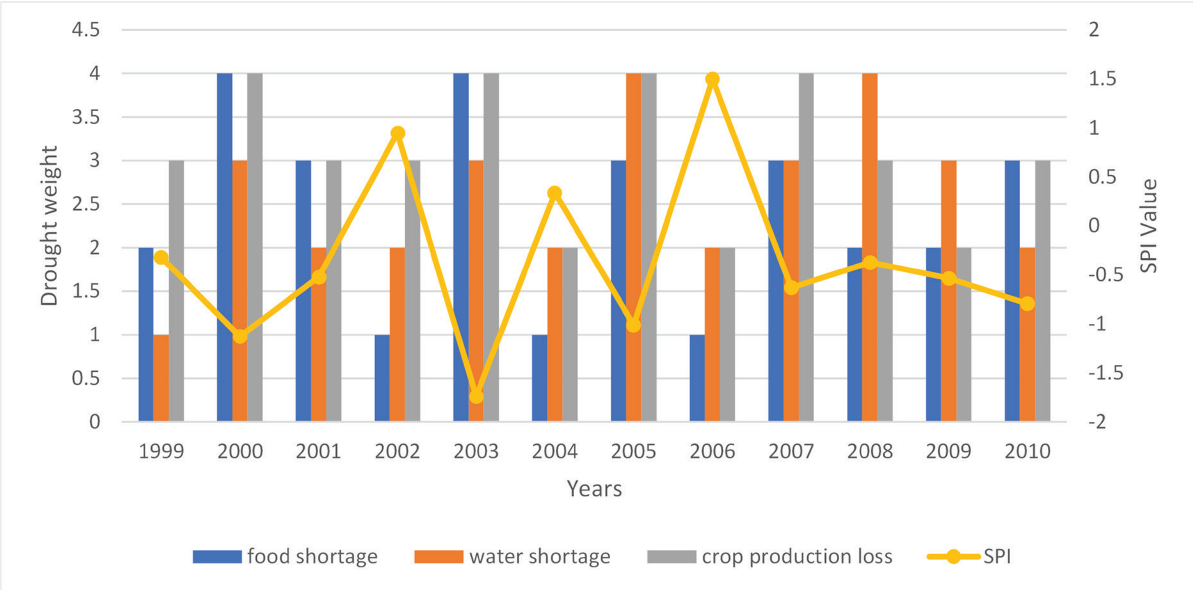

Figure 5: Weight of drought impacts during years of extreme drought from 1983 to 2022

3.2.3. Spatial drought risk vulnerability

Simanjiro District has been experiencing more drought events over the past 40 years than other districts in the region, with SPI values ranging from -0.1 to -1.2. Within Simanjiro District, three (3) wards were selected as a sample space to represent the district as a whole. Through SPI distribution within the district, wards with the lowest SPI values (Ngorika, Naisinyai, and Liborsoit) were selected as the case study for this study. Figure 6 shows the distribution of SPI values within the district.

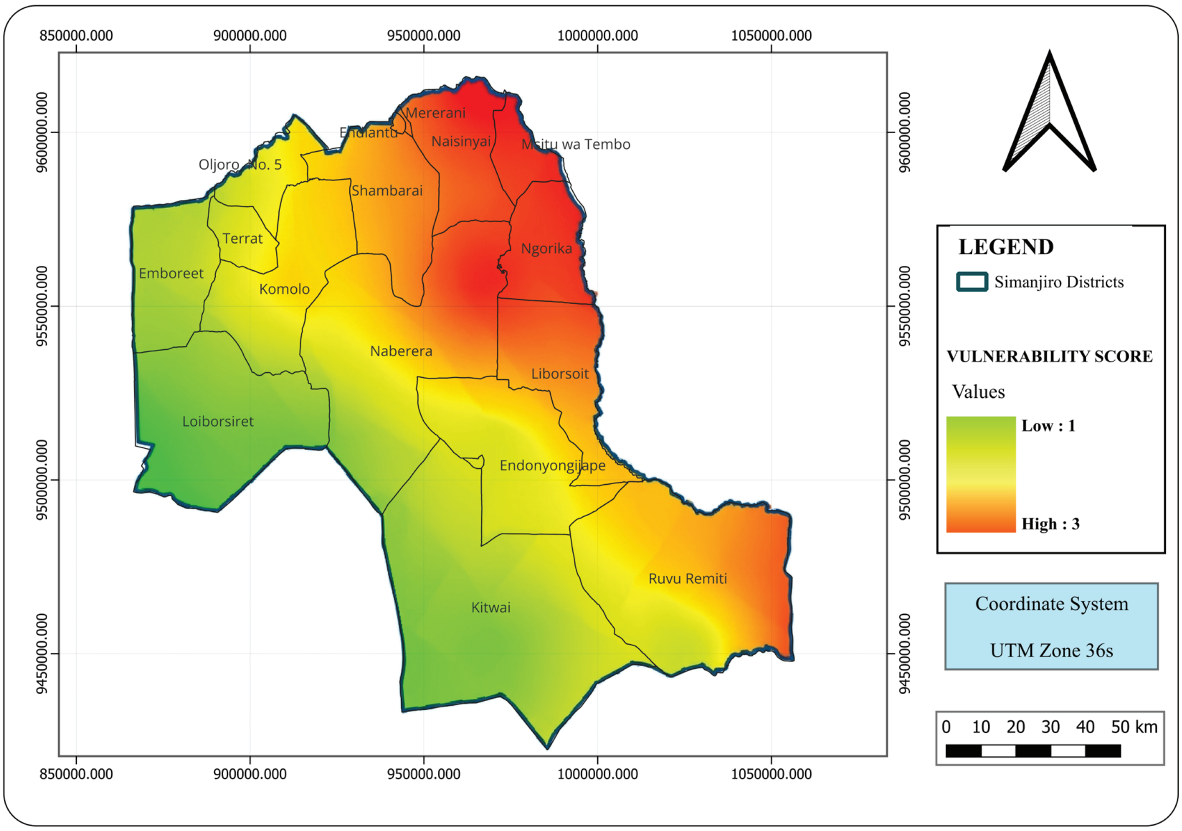

Figure 6: Spatial drought vulnerability distribution in Simanjiro District

Agriculture and livestock keeping are the most vulnerable economic sectors to drought disasters, which in turn affect livelihoods. Despite their importance to the Simanjiro community, there are several reasons that increase susceptibility to drought disasters in each of the mentioned economic sectors. The factors resulting in high susceptibility of the agriculture sector to drought disaster risk include:

1. Over dependency of rain-fed agricultural system;
2. Geographic location (i.e., Naisinyai, Ngorika, and Liborsoit wards are located at lower altitudes;
3. Lack of sufficient technology;
4. Lack of accurate early warning systems;
5. Lack of enough capital.

At the same time, factors that contribute to the high vulnerability of livestock (The pastoralism sector) include an excessive number of livestock and over-dependence on nature. Also, the factors contributing to vulnerability of people's livelihood to drought disaster include:

1. High illiteracy rate;
2. Over-dependence on vulnerable economic sectors for survival;
3. Lack of food reserves.

3.2.4. Existing adaptation measures on drought disaster risk

There are several adaptation measures that have been established in Simanjiro in response to drought-related disaster risk. These adaptation measures have been established to reduce the magnitude of impacts; for example, in the agricultural sector, hybrid crop seeds have been used, education has been provided, and irrigation schemes have been implemented. In livestock keeping, there has been pasture management through plot reservation for grazing during drought disasters, and cattle troughs (a total of six were constructed in different villages in Naisinyai ward to provide water for livestock). Regarding the livelihood sector, adaptation measures include installing a water distribution point (i.e., the main water source is the Pangani Basin and the Nyumba ya Mungu dam). In the environmental sector, the adaptation measure used was afforestation.

4. Conclusion and Recommendation

This study assessed spatial community vulnerability to drought in Simanjiro District using climate data and socio-economic analysis. The findings indicate that drought is a frequent hazard, occurring in 24 out of 40 years, with severe events in 2003 and 2022 causing major livestock losses and livelihood disruptions. Declining rainfall and rising temperatures further intensify drought conditions, increasing stress on ecosystems and pastoral systems. A mismatch was observed between SPI-based drought detection and community perceptions, with local populations primarily recognizing high-impact drought events. This highlights the need to integrate scientific analysis with local knowledge in drought assessment. Agriculture and pastoralism were identified as the most vulnerable sectors due to overdependence on rainfall, high livestock numbers, and limited adaptive capacity. Although some coping strategies exist, they remain inadequate. Strengthening early warning systems, improving water and irrigation infrastructure, and promoting livelihood diversification are essential to enhance resilience to drought.

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