

Climate variability and evolving adaptation strategies among agro-pastoral communities in Taita Taveta County, Kenya

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ABSTRACT

Climate variability poses substantial risks to agro-pastoral livelihoods in Kenya's Arid and Semi-Arid Lands (ASALs), where crop and livestock production depend heavily on rainfall, water availability and pasture conditions. This study examined reported climatic trends, household vulnerability and adaptation strategies among agro-pastoral communities in Taita Taveta County, Kenya. The study is framed using the vulnerability approach described by the Intergovernmental Panel on Climate Change. A convergent parallel mixed-methods design was reported, combining a household questionnaire survey with field observations, focus group discussions, key informant interviews and monthly climate records from Voi Meteorological Station for 1988–2018. A sample of 300 participants was randomly selected. Descriptive findings indicate that drought and changing rainfall patterns were widely perceived as important livelihood stressors where 99% of respondents attributed it to changes in rainfall patterns and 93.7% associated it to declining rainfall amounts. Climate-trend analysis indicate that monthly temperature regression slopes were positive in most months, although February had a near-zero negative slope. The reported R^2 values were low, ranging from 0.000004 to 0.1648, indicating that time alone explained only a limited proportion of monthly temperature variation. The reported agricultural adaptation responses included planting suitable crops, farmer education, irrigation, reducing cultivated area and diversifying into non-farm business. Livestock-related responses included training, reducing herd size and adopting improved breeds. The findings point to the importance of climate information, extension services, water management and livelihood diversification in supporting agro-pastoral resilience. This study concluded that drought and changing rainfall patterns were widely perceived as livelihood concerns. This research recommended strengthening access to locally relevant seasonal forecasts and climate information, and ensuring that advisories are communicated through channels accessible to farmers and livestock keepers.

Keywords: Adaptation; Agro-Pastoralism; Climate Variability; Household Livelihoods; Taita Taveta County, Vulnerability

I. INTRODUCTION

Climate variability and change affect agricultural production and rural livelihoods through shifts in temperature, rainfall amount and timing, and the frequency or intensity of climate extremes. These pressures are especially consequential in Arid and Semi-Arid Lands (ASALs), where households depend on climate-sensitive activities such as rain-fed crop production and livestock keeping. Across sub-Saharan Africa, drought and unreliable rainfall can contribute to water scarcity, reduced crop yields, pasture shortages, livestock losses and food insecurity (Intergovernmental Panel on Climate Change (IPCC), 2022, 2023).

Kenya's ASALs cover a large proportion of the country and support communities whose livelihoods depend on natural resources and climate-sensitive production systems (Oguge & Oremo, 2018). Taita Taveta County contains diverse agro-ecological zones, from the relatively wetter Taita Hills to drier lowland areas. The county experiences a bimodal rainfall pattern, with long rains generally occurring from March to May and short rains from October to December. Differences in elevation, soil properties and rainfall distribution affect crop choices, livestock management and access to water. These conditions make localized assessment important because climate-related risks and adaptation options are not uniform across the county.

Agro-pastoral households face overlapping climatic and socioeconomic pressures. Dependence on rain-fed farming or livestock alone can increase exposure to drought, while limited access to capital, extension services, markets, water infrastructure and timely climate information can constrain adaptive capacity. Livelihood diversification, suitable crop varieties, water harvesting, irrigation, livestock management and non-farm income may help households manage climatic shocks, although access to these options varies (Amwata et al., 2016; Opiyo et al., 2015).

Research has examined climate projections and rainfall variability in Kenya, including work focused on Taita Taveta County (Kotikot et al., 2024; Nyambariga et al., 2023). However, local evidence remains useful on how households perceive climate variability, how climatic stress intersects with livelihood vulnerability, and which

adaptation responses are reported by agro-pastoral communities. This study therefore brings together local meteorological records and household-level evidence to inform context-specific adaptation planning.

1.1 Research Objectives

- i. To describe monthly temperature and rainfall trends recorded at Voi Meteorological Station between 1988 and 2018.
- ii. To assess household perceptions of climatic variability and its reported implications for crop production, livestock keeping and livelihoods.
- iii. To identify the adaptation strategies reported by agro-pastoral households and discuss socioeconomic conditions relevant to their adaptive capacity.

II. LITERATURE REVIEW

2.1 Theoretical Review: IPCC vulnerability framework

The study is framed using the vulnerability approach described by the Intergovernmental Panel on Climate Change. In this framework, vulnerability is understood through the interaction of exposure, sensitivity and adaptive capacity (IPCC, 2022, 2023). Exposure concerns the presence of people and livelihood assets in places affected by climate hazards, such as drought, heat or rainfall variability. Sensitivity describes how strongly a household's livelihood is affected by those hazards; for example, reliance on rain-fed crops or natural pasture may increase sensitivity to prolonged dry spells. Adaptive capacity refers to the resources and abilities that enable households to anticipate, respond to and recover from climate-related impacts. Relevant resources may include education, access to extension services and climate information, savings or credit, water infrastructure, markets and diversified income.

2.2 Empirical Review

2.2.1 Climate variability in dryland and agro-pastoral systems

Temperature and rainfall are central to crop growth, pasture availability and livestock water requirements. Studies of Kenya have documented changes in rainfall variability and highlighted the consequences of irregular seasonal rainfall for agricultural planning (Kotikot et al., 2024). Climate projections for Taita Taveta have also examined possible future temperature and rainfall conditions and their implications for food systems (Nyambariga et al., 2023).

2.2.2 Climate stress and livelihood vulnerability

Agro-pastoral households can be sensitive to drought because crop production, livestock health and household food supplies depend on water and vegetation. Evidence from Kenya's drylands shows that vulnerability to food insecurity is shaped by livelihood dependence and household resources (Amwata et al., 2016). Research on pastoral drought responses has documented the importance of coping strategies and the constraints faced by households when climate stress persists (Opiyo et al., 2015). More broadly, climate impacts are unevenly distributed because exposure and adaptive capacity differ across social groups and places (IPCC, 2022; Ngcamu, 2023).

2.2.3 Adaptation strategies and adaptive capacity

Adaptation strategies in agro-pastoral settings may include changes in crop choice, water management, agricultural training, livestock management, mobility and non-farm income generation. Rainwater harvesting and small-scale irrigation can support production when rainfall is unreliable, although infrastructure, cost and access may limit uptake (Oguge & Oremo, 2018). Livelihood diversification can spread risk, but its benefits depend on viable employment, markets and access to resources. The effectiveness of any adaptation strategy should be assessed against household circumstances and local ecological conditions rather than assumed from adoption alone.

2.3 Research gap

The reviewed literature establishes the importance of climate variability, vulnerability and adaptation in Kenya's drylands. The present study adds a local household perspective from Voi and Mwatate Sub-Counties alongside reported monthly climate records from Voi Meteorological Station. Its contribution is descriptive and context-specific: it documents household perceptions, reported livelihood effects and adaptation choices.

III. METHODOLOGY

3.1 Research design

The study adopted a convergent parallel mixed-methods design (Creswell & Plano Clark, 2011), in which qualitative and quantitative data were collected concurrently, analyzed separately, and subsequently integrated to corroborate and complement the findings. The study was also guided by a pragmatic paradigm, which emphasizes

knowledge as emerging from actions, situations, and their consequences rather than from fixed conditions, thereby facilitating the development of practical solutions to research problems (Creswell, 2014). The pragmatic paradigm supported the use of multiple methodological approaches, enabling a comprehensive exploration of the research problem while maintaining flexibility and emphasizing problem-centred inquiry (Foster, 2023).

3.2 Study area

The study was conducted in Taita Taveta County in southeastern Kenya. The county contains varied ecological settings, including the Taita, Mwambirwa and Sagalla Hills, lower plains and the Taveta foothills. The manuscript describes substantial differences in rainfall and temperature between lowland and highland areas, with approximate annual rainfall ranging from 440 mm in lowland areas to as much as 1,900 mm in highlands. Long rains generally occur from March to May and short rains from October to December (Rotich & Musyimi, 2023).

3.3 Target population

The target population comprised household heads or adult household representatives in agro-pastoral communities in the selected study locations, together with key informants with relevant knowledge of agriculture, livestock and local adaptation. The sampling frame was informed by administrative and population information, including the 2019 Kenya Population and Housing Census (Kenya National Bureau of Statistics, 2019). A population of 300 participants was targeted.

3.4 Sampling procedure and sample size

A sample size of 300 respondents was determined using the Krejcie and Morgan (1970) method. This sample size is consistent with established sample-size determination principles for survey research, in which the required sample is determined by factors such as population size, confidence level, and margin of error (Adam, 2020). The sample size was calculated using the Krejcie and Morgan (1970) method.

$$S = \frac{X^2 \times N \times P(1-P)}{d^2(N-1) + X^2 \times P(1-P)}$$

Where:

S = Required sample size

N = Population size

X² = Chi-square value for 1 degree of freedom at the desired confidence level

P = Population proportion (assumed to be 0.5 when unknown, for maximum sample size)

d = Margin of error

From the selection a total of 300 participants were selected where, 151 households from Voi Sub-County and 149 households from Mwatate Sub-County were interviewed.

3.5 Data collection instruments and procedures

Quantitative data was collected using structured questionnaires as per the study objectives and contained items addressing respondent's background characteristics, climate related experiences, indigenous knowledge practices, their perceived contribution to climate adaptation and challenges affecting their continued use. The household questionnaire included closed- and open-ended items on respondent characteristics, livelihood activities, perceived climatic changes, effects on farming and livestock, adaptation practices and challenges to adaptation. A Likert-type questions were used for perceptions and the questionnaire was pretested with farmers in neighbouring Kitui County where 35 respondents were involved. This was done one month before taking the actual data and the pretest responses were excluded from the main dataset.

3.6 Data analysis

Quantitative data were coded, cleaned, and analyzed using the Statistical Package for the Social Sciences (SPSS Version 29) and MS Excel 2013. Given that the study did not involve hypothesis testing, data analysis was primarily descriptive in nature. Summarizing respondents and descriptive statistics of frequencies, percentages, and measures of central tendency, cross-tabulation techniques were further utilized to examine patterns and relationships across relevant respondent categories and study wards.

Finally, the quantitative and qualitative findings were integrated during interpretation to enable triangulation and provide a more comprehensive understanding of agropastoral knowledge in climate change adaptation among smallholder farmers in Taita-Taveta County, Kenya. The mixed-methods approach enhanced the depth, validity, and richness of the study findings by combining statistical trends with participants' lived experiences and local knowledge systems.

3.7 Ethical considerations

Ethical principles were observed throughout the study to protect the rights, dignity, privacy, and welfare of the participants. The necessary research authorization and ethical approval were obtained from the relevant institutions before data collection commenced. Research permits were obtained from the National Commission for Science, Technology and Innovation (NACOSTI). Permission was also sought from relevant county authorities and local administrative leaders. Informed consent was obtained from all participants after explaining the purpose of the study, the procedures involved, and their rights as participants. Participation was voluntary, and respondents were informed of their right to decline participation or withdraw from the study at any stage without penalty. Confidentiality and anonymity were maintained by ensuring that personal identifying information was not disclosed in the analysis, reporting, or publication of the findings. The data collected were used exclusively for the stated research purposes and stored securely with access restricted to the researcher. The study was conducted with respect for local customs, cultural practices, and the livelihoods of the agro-pastoral communities.

IV. FINDINGS & DISCUSSION

4.1 Respondent characteristics and livelihood systems

As indicated in Table 1, farming was the main occupation for 242 respondents (81.5%) and 21.5% engaged in off-farm income-generating activities. Mixed crop–livestock farming was reported as the main farming system by 44.8% of respondents; crop-only and livestock-only activities accounted for 18.5% and 11.4%, respectively. These reported patterns suggest that households commonly combine crop and livestock activities. The frequencies indicate that some respondents engaged in more than one livelihood system.

Table 1

Livelihood systems

Characteristic / category	Frequency (n)	Reported percentage
Main occupation: farming	242	81.5%
Off-farm income-generating activity	64	21.5%
Main farming activity: crops	55	18.5%
Main farming activity: mixed crops and livestock	133	44.8%
Main farming activity: horticulture	1	<1%
Main farming activity: livestock	34	11.4%

4.2 Household perceptions of climatic variability

Respondents in Voi and Mwatate reported widespread experience of drought and changes in rainfall where 286 respondents (95.3%) considered drought as common, 278 (92.67%) believed drought duration was increasing, 297 (99%) perceived changes in rainfall patterns, and 281 (93.7%) perceived declining rainfall amounts. The high reported prevalence of perceived rainfall change indicates that climate variability is salient to respondents' farming decisions. These perceptions are consistent with the broader literature describing rainfall variability as a challenge for agricultural planning in Kenya (Kotikot et al., 2024).

4.3 Temperature trends in the Voi station record

Table 2 depicts that the monthly linear regression equations for temperature over 1988–2018, slopes are positive for 11 months and slightly negative for February. Reported R^2 values range from approximately 0.000004 to 0.1648, indicating that the fitted linear time trend explains little of the month-to-month or year-to-year variation for most months.

Table 2*Temperature trends in the Voi station record*

Month	Reported equation	Reported R ²
January	$y = 0.0367x + 31.198$	0.0712
February	$y = -0.0002x + 33.38$	0.000004
March	$y = 0.0205x + 33.492$	0.0293
April	$y = 0.0221x + 31.675$	0.0400
May	$y = 0.0077x + 30.399$	0.0087
June	$y = 0.0101x + 29.382$	0.0300
July	$y = 0.0162x + 28.385$	0.1143
August	$y = 0.0250x + 28.160$	0.1219
September	$y = 0.0071x + 29.858$	0.0103
October	$y = 0.0119x + 31.384$	0.0143
November	$y = 0.0076x + 31.676$	0.0049
December	$y = 0.0440x + 30.260$	0.1648

4.4 Rainfall trends

The rainfall trend analysis (Table 3) for Voi Meteorological Station from 1900 to 2018 indicates predominantly declining rainfall trends across the months. Negative regression coefficients were observed in January, February, March, April, May, June, July, August, November and December, suggesting a general tendency towards decreasing monthly rainfall over the study period. The steepest negative slopes occurred in November (-1.7115), January (-1.4503) and April (-1.3748), indicating comparatively stronger rates of decline in these months. October was characterised by an upward trend, with a positive slope of 0.4339, while September showed an almost negligible upward trend (0.0058).

The coefficients of determination (R^2) ranged from 0.00002 in September to 0.0515 in April. This indicates that the fitted linear trends explained only a small proportion of the variation in monthly rainfall. April had the highest R^2 value (0.0515), followed by November (0.0336) and January (0.0219). These results suggest substantial variability in monthly rainfall that is not explained by the linear time trends alone. Overall, the results suggest a general tendency towards declining monthly rainfall at Voi, particularly during November, January and April, with slight increases in September and October.

Table 3*Rainfall trend analysis for Voi Meteorological Station (1900–2018)*

Month	Trend Equation	R ²
January	$(y = -1.4503x + 67.597)$	0.0219
February	$(y = -0.2691x + 27.384)$	0.0034
March	$(y = -0.9088x + 96.332)$	0.0161
April	$(y = -1.3748x + 103.7)$	0.0515
May	$(y = -0.1248x + 23.423)$	0.0038
June	$(y = -0.0630x + 5.3692)$	0.0117
July	$(y = -0.0883x + 8.1952)$	0.0059
August	$(y = -0.0883x + 8.1952)$	0.0059
September	$(y = 0.0058x + 7.8684)$	0.00002
October	$(y = 0.4339x + 22.391)$	0.0141
November	$(y = -1.7115x + 161.25)$	0.0336
December	$(y = -0.3398x + 130.33)$	0.0018

4.5 Reported impacts on crop and livestock production

The study describes drought and unreliable rainfall as pressures on crop yields, growing seasons, livestock water availability and pasture. It also identifies 2021–2022 as a period of severe crop and livestock losses. Mixed farming can spread some production risks, but both enterprises may still be affected by a prolonged drought when water and pasture are scarce. This is consistent with research on climate-related pressures on agricultural productivity (Lawrence et al., 2023; Ortiz-Bobea et al., 2021).

4.6 Household vulnerability

Respondents who were classified as highly vulnerable were 160 (53.3%) , while 94 (31.3%) were vulnerable and 26 (8.7%) as less vulnerable; a further 21 (7%) were described as unclassified or more flexible in responding to climatic fluctuations. The IPCC vulnerability framework provides a useful way to interpret these patterns through

exposure, sensitivity and adaptive capacity (IPCC, 2022, 2023). This study identified income, education, household size, livelihood dependence, access to water and markets, and access to financial resources as potentially relevant factors.

4.7 Adaptation strategies

For agricultural adaptation, 190 respondents planted suitable crops (63.3%), 37 reported farmer education or training (12.3%), 23 used irrigation (7.8%), 19 reduced the area cultivated (6.3%) and 14 shifted to another business (4.7%), Table 4a.

Table 4a

Agricultural adaptation strategies

Agricultural adaptation strategy	Frequency	Reported percentage
Plant suitable crops	190	63.3%
Farmer education/training	37	12.3%
Irrigation	23	7.8%
Reduce cultivated area	26	8.7%
Shift to another business	21	7.0%

For livestock adaptation, Table 4b, only 89 participants responded with 17 adopting improved breeds (19.1%) while 29 undertaking livestock education (32.6%) and 43 reducing livestock numbers (48.3%).

Table 4b

Livestock adaptation strategies

Livestock adaptation strategy	Frequency	Percentage
Adopt improved breeds	17	19.1
Livestock education/training	29	32.6
Reduce livestock population	43	48.3

The prominence of suitable crop choices in the reported agricultural responses suggests that farmers are adjusting production decisions to perceived climatic conditions. Training and irrigation may also support adaptive capacity, while reducing cultivated area or diversifying into business may represent responses to resource constraints as well as adaptation. Access to water-harvesting infrastructure, extension services and viable markets may be important enabling conditions (Oguge & Oremo, 2018; Opiyo et al., 2015).

4.8 Integration of findings

Taken together, the survey results indicate that respondents widely perceived drought and rainfall change as important challenges and reported a range of crop and livestock responses. The station regression equations generally indicate positive temperature slopes. The household perceptions and station data offer complementary forms of evidence, but they should not be treated as interchangeable.

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

This study examined household perceptions of climate variability, reported climate trends and adaptation strategies among agro-pastoral communities in Taita Taveta County. The manuscript's household findings indicate that drought and changing rainfall patterns were widely perceived as livelihood concerns. Reported agricultural responses included planting suitable crops, farmer training, irrigation, reducing cultivated area and diversifying into non-farm business. Reported livestock responses included adopting improved breeds, training and reducing herd size. The monthly temperature equations show positive slopes for most months, .

The findings underline the value of strengthening climate-information services, agricultural and livestock extension, water management and livelihood options for agro-pastoral households. They also demonstrate the need for transparent reporting of valid denominators and reproducible methods for classifying household vulnerability.

5.2 Recommendations

Strengthen access to locally relevant seasonal forecasts and climate information, and ensure that advisories are communicated through channels accessible to farmers and livestock keepers. Support practical agricultural and livestock extension on suitable crop varieties, soil and water conservation, fodder management, animal health and drought preparedness. Improve access to affordable water harvesting, storage and small-scale irrigation where technically and

environmentally appropriate. Promote viable livelihood diversification and market access so that households can reduce dependence on a single climate-sensitive source of income. Ensure that adaptation programmes account for differences in household resources, labour availability, education and access to services rather than assuming that all households can adopt the same strategies. For future research, combine quality-controlled meteorological time series with clearly defined household indicators and documented qualitative evidence.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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