Trends In Climate Variability in Trans-Nzoia County, Kenya: A 34-Year Analysis (1990-2023)

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Abstract- This study analyzed climate variability trends in Trans-Nzoia County, Kenya, from 1990 to 2023, focusing on temperature and precipitation patterns. Using data from the Kenya Meteorological Department, Digital Data Portal, and CHIRPS, the research employed descriptive analysis, GIS visualization, and statistical trend analysis. Results revealed significant climate variability, with annual precipitation showing a moderate positive trend ($y = 18.418x - 34912$, $R^2 = 0.4048$), indicating an average increase of 18mm per year. Seasonal analysis showed MAM (March-April-May) as the wettest season (40mm average), while DJF (December-January-February) was the driest (13mm average). Temperature data indicated increasing variability, with the highest minimum temperature recorded in April 2019 (11.692°C) and the lowest in August 1991 (7.068°C). The study identified 2020 as an exceptional year with precipitation exceeding 3000mm, suggesting extreme weather events. Community perceptions were mixed, with 49.7% noting climate improvements while 35.3% observed deterioration. These findings underscore the need for robust climate adaptation strategies in this agricultural region, particularly given the increasing unpredictability of rainfall patterns and temperature fluctuations that directly impact food security and livelihoods.

Indexed Terms- Climate Variability, Trans-Nzoia County, Precipitation Trends, Temperature Patterns

I. INTRODUCTION

Climate change represents one of the most pressing global challenges of the 21st century, with far-reaching implications for ecosystems, human societies, and economic systems worldwide (Bilgili & Tokmakci, 2025). The phenomenon encompasses long-term shifts in temperature, precipitation patterns, and the frequency of extreme weather events, driven by both natural variability and anthropogenic factors (Ljungqvist et al., 2024). In Sub-Saharan Africa, climate variability poses particular challenges due to the region's dependence on rain-fed agriculture and limited adaptive capacity (Piguet, 2022).

Trans-Nzoia County, located in northwestern Kenya and often referred to as the country's "breadbasket," exemplifies the vulnerability of agricultural regions to climate variability. The county's economy relies heavily on agriculture, with maize, wheat, and dairy farming constituting major economic activities. Understanding local climate trends is therefore critical for agricultural planning, water resource management, and community resilience building (Soita et al., 2024).

Previous studies have documented climate variability across Kenya, with Ayugi and Tan (2019) analyzing surface air temperature trends from 1971 to 2010, revealing significant warming particularly in arid and semi-arid lands. However, localized studies focusing on specific counties remain limited, creating a knowledge gap that hampers effective local-level adaptation planning. This study addresses this gap by providing a comprehensive analysis of climate variability in Trans-Nzoia County over a 34-year period (1990-2023).

The integration of community perceptions with scientific data analysis is crucial for understanding the full impact of climate variability. As Derbile et al. (2022) noted, local communities' experiences and observations provide valuable insights that complement meteorological data, particularly in regions where formal weather monitoring infrastructure may be limited. This study therefore combines quantitative climate data analysis with community perceptions to provide a holistic understanding of climate trends in Trans-Nzoia County.

II. LITERATURE REVIEW

2.1 Global and Regional Climate Variability Trends

Climate variability manifests differently across global regions, with varying impacts on local ecosystems and communities. Bilgili and Tokmakci (2025) conducted a comprehensive analysis of temperature and precipitation trends across Europe and globally from 1970 to 2023, revealing alarming upward trajectories in average global temperatures with significant regional variability. Their findings indicated intensified warming in northern and central Europe, disrupting local ecosystems and agricultural calendars. While their study provided valuable insights into macro-level climate trends, it lacked focus on localized African contexts and the integration of cultural coping mechanisms.

In the Asian context, Kumar et al. (2023) analyzed surface temperature increases over India from 1980 to 2020, linking rising temperatures to urbanization, deforestation, and increased greenhouse gas emissions. They projected further temperature rises under various Shared Socioeconomic Pathways (SSPs), providing a strong macro perspective on climate trends. However, their work did not address how local belief systems and cultural practices adapt to or mitigate rising temperatures, a gap this study aims to fill in the African context.

2.2 African Climate Variability Studies

Within Africa, climate variability studies have revealed diverse patterns across different regions. Chisanga et al. (2023) assessed rainfall variability in Zambia from 1981 to 2022 using the Cumulative Sum (CUSUM) technique, finding decreasing annual rainfall and greater unpredictability during planting seasons. Their study revealed heightened vulnerability in rain-fed agricultural regions, recommending early warning systems and adaptive farming methods. However, they did not address the cultural dimensions of resilience or the influence of spiritual systems on climate adaptation.

Focusing on East Africa, Qureshi et al. (2023) analyzed climate variability across agro-climatic zones using mixed-method approaches combining GIS tools and farmers' interviews. They discovered significant shifts in temperature and rainfall trends affecting crop choice and planting cycles, with recommendations focused on climate-smart agriculture training. While valuable, their study lacked emphasis on indigenous or religious knowledge frameworks that guide local adaptation.

2.3 Kenyan Climate Studies

In the Kenyan context, Ayugi and Tan (2019) evaluated surface air temperature trends between 1971 and 2010 using statistical trend analysis and anomaly detection. Their findings showed significant warming, particularly in arid and semi-arid lands, proposing stronger decentralization of national climate policy. However, they overlooked local community-based and belief-driven climate responses, which are crucial for effective adaptation at the grassroots level.

Odhiambo (2023) investigated the relationship between climate variability and malaria transmission across different altitudes in the Lower Lake Victoria Basin, Kenya. Using geospatial health data and climate records, he established correlations between warming trends and mosquito habitats. While addressing climate-health links, the study did not explore community spiritual frameworks in understanding or responding to environmental health risks.

Parracciani et al. (2023) assessed projected impacts of climate change on vegetation across Kenya using species distribution models. Their findings indicated northward shifts of vegetation zones and potential species loss in protected areas, recommending dynamic conservation planning. However, they did not consider how local cultural and spiritual institutions contribute to conservation efforts, a gap this study addresses.

2.4 Climate Variability in Agricultural Regions

Agricultural regions worldwide face unique challenges from climate variability. Abreu et al. (2023) analyzed rainfall patterns in northeastern Brazil using Mann-Kendall tests and Sen's slope estimator, demonstrating notable seasonality shifts with decreasing rainfall during traditionally wet months. These changes disrupted agriculture and water resource planning, emphasizing the need to incorporate climate variability into local planning models. While offering valuable insights on rainfall unpredictability, the study focused purely on statistical modeling without sociocultural adaptation considerations.

Madane and Waghaye (2023) used innovative trend analysis to evaluate rainfall changes in Punjab State, India from 1951 to 2021. They found that rainfall patterns had shifted, becoming more concentrated in fewer days with higher intensity, negatively affecting irrigation planning and food production. While comprehensive, their study did not address how traditional agricultural calendars and spiritual rituals can adapt to these changes.

III. RESEARCH METHODOLOGY

3.1 Study Area

Trans-Nzoia County is located in northwestern Kenya between longitude 34°38' and 35°23' East and latitude 0°52' and 1°18' North, covering approximately 2,495.5 square kilometers. The county comprises five sub-counties: Kiminini, Saboti, Endebess, Cherang'any, and Kwanza, with Kitale as the headquarters. The area enjoys a temperate climate with distinct wet and dry seasons, with long rains from March to June and short rains from October to December (Shirazi & Hezarkhani, 2022).

3.2 Data Collection

Climate data for precipitation was obtained from the World Climate website (https://www.worldclim.org/) and Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS). Temperature data (minimum and maximum) was collected from the TERRACLIMATE data portal. The dataset comprised mean monthly precipitation, minimum temperature, and maximum temperature for 33 years (1990-2023). Data validation was conducted using records from the Kenya Meteorological Department.

Primary data on community perceptions was collected through structured questionnaires administered to 384 respondents selected through stratified random sampling. The sample included community leaders (194), traditional healers (101), and cultural informants (89), all aged 50 years and above with at least 30 years residence in the county.

3.3 Data Analysis

Climate data was analyzed using Google Earth Engine and ArcGIS Pro 3.3 software. The analysis involved clipping, mosaicking, transformation of raster images to vector format, and data extraction to Excel spreadsheets. Trend analysis was performed using linear regression, with seasonal patterns analyzed for DJF (December-January-February), MAM (March-April-May), JJA (June-July-August), and SON (September-October-November) periods.

Community perception data was analyzed using SPSS Version 26, generating frequencies and percentages. Descriptive statistics were used to summarize demographic variables and climate perceptions.

IV. RESULTS

4.1 Precipitation Trends

Analysis of annual precipitation from 1990 to 2023 revealed significant interannual variability with an overall positive trend. The linear regression equation $y = 18.418x - 34912$ ($R^2 = 0.4048$) indicates an average annual increase of approximately 18mm. The year 2020 showed exceptional precipitation exceeding 3000mm, significantly higher than the long-term average, suggesting extreme weather events possibly linked to El Niño or La Niña conditions.

Seasonal analysis showed distinct patterns across the four seasons. MAM emerged as the wettest season with an average of 40mm, attributed to increased frontal activity and transitional weather patterns. JJA followed with slightly above 30mm, while SON recorded values just below JJA levels. DJF was the driest season with an average of 13mm, characterized by stable high-pressure systems suppressing cloud formation.

4.2 Temperature Variability

Temperature analysis revealed increasing variability over the study period. The highest minimum temperature (11.692°C) was recorded in April 2019, while the lowest (7.068°C) occurred in August 1991. Maximum temperatures peaked at 27.664°C in February 2005, with the lowest maximum (19.833°C) in July 1992. These fluctuations suggest both warming trends and cyclical patterns influenced by larger atmospheric systems.

4.3 Community Perceptions

Of the 187 respondents who completed questionnaires, perceptions of climate change were mixed. A total of 49.7% reported improvements in climate conditions (26.2% significant, 23.5% slight), while 35.3% noted deterioration (18.2% significant, 17.1% slight). Additionally, 15.0% perceived no noticeable change.

Regarding climate-related changes affecting traditional practices, 42.2% reported prolonged droughts affecting sacred forests and shrines, 23.5% noted disappearance of sacred rivers and springs, 16.6% experienced increased flooding, 11.2% observed declining plant species, and 6.4% mentioned unpredictable rainfall disrupting seasonal ceremonies.

4.4 Extreme Events Analysis

The study identified several extreme weather events during the period. Notably, 1993, 1995, 1999, and 2002 experienced relatively higher rainfall, while 1992, 2005, and 2017 recorded significantly lower totals. The 2020 precipitation spike represents the most dramatic anomaly in the dataset, requiring further investigation for causative factors.

CONCLUSION

This study provides comprehensive evidence of significant climate variability in Trans-Nzoia County from 1990 to 2023. The overall increasing trend in annual precipitation, coupled with high interannual variability, presents challenges for agricultural planning and water resource management. The R^2 value of 0.4048 indicates that less than half of precipitation variance can be explained by the linear trend alone, emphasizing the complex nature of climate dynamics in the region.

Temperature patterns show increasing variability with recent years recording higher minimum temperatures, suggesting a warming trend consistent with global climate change patterns. The seasonal analysis reveals MAM as the most reliable season for precipitation, while DJF remains consistently dry, information crucial for agricultural planning.

The divergent community perceptions reflect localized climate experiences and highlight the importance of integrating local observations with scientific data. The significant proportion reporting climate-related impacts on traditional practices underscores the broader cultural implications of climate variability beyond purely environmental concerns.

RECOMMENDATIONS

Based on the findings, the following recommendations are proposed:

1. Establish additional weather stations across Trans-Nzoia County to capture micro-level climate variations and improve forecast accuracy for agricultural planning.
2. Develop county-level climate adaptation strategies that combine scientific climate projections with traditional ecological knowledge and community observations.
3. Promote climate-resilient crop varieties and farming techniques that can withstand increasing precipitation variability and temperature fluctuations.
4. Implement comprehensive water harvesting and storage systems to capture excess rainfall during wet periods for use during increasingly unpredictable dry spells.

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