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Short communication

Trend analysis of temperature and precipitation in central Tanzania using regression and non-parametric approaches

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Climate change is altering global temperature and precipitation patterns, endangering food security, water resources, and socio-economic stability worldwide (Nicholson, 2017; Tierney *et al.,* 2015). These changes drive more frequent and severe extreme weather events, such as erratic rainfall and prolonged droughts, which undermine agriculture and livelihoods, particularly in regions with limited adaptive capacity (Funk *et al.,* 2015; Ongoma *et al.,* 2018). Africa is especially vulnerable due to its reliance on rain-fed farming and inadequate infrastructure, facing heightened risks due to their semi-arid climate, rising temperatures, and unpredictable rainfall (Gebrechorkos *et al.,* 2019; Rowhani *et al.,* 2011). Agriculture, water, and food security are highly vulnerable to shifts in rainfall and temperature. Increasing droughts and extreme rains disrupt livelihoods, highlighting the need for long-term climate studies to guide adaptation. Dependence on rain-fed farming, socio-economic constraints, and limited research make this zone critical for resilience strategies. In Tanzania, where agriculture employs over 70% of the population, declining rainfall and intensifying extremes exacerbate food insecurity, particularly in these semi-arid regions (Craparo *et al.,* 2015; Rowhani *et al.,* 2011).

Various studies have been reported on trend analysis of rainfall and temperature across the globe using parametric and non-parametric approaches including innovative trend analysis (Khan *et al.,* 2024; Yewale and Jadhav, 2025; Abdulfattah *et al.,* 2025). While climate research in East Africa has grown, central Tanzania remains underexplored, particularly in assessing long-term climate trends critical for agriculture and water management (Nicholson, 2017; Yang *et al.,* 2014). By focusing on these regions, this study addresses this gap, offering robust insights into climate trends. The findings aim to inform agricultural policy, enhance water resource management, and strengthen disaster risk reduction, fostering resilience in one of Tanzania's most climate-sensitive regions (Conway *et al.,* 2017; Gebrechorkos *et al.,* 2019).

Study area and data

Fig. 1 shows Tanzania's central zone with a semi-arid climate, 22–31°C temperatures, and 600–1000 mm rainfall. For this study, forty-four years (1981 to 2024) data of minimum and maximum temperature (°C) and precipitation (mm) for three central Tanzanian regions: Dodoma (Latitude 6.167° S, Longitude 35.750° E), Singida (Latitude 4.81091° S, Longitude 34.7242° E), and Tabora (Latitude 5.07882° S, Longitude 32.83365° E) were obtained from NASA's Prediction of Worldwide Energy Resources (POWER) project, accessed via the Data Access Viewer (DAV). Derived from satellite observations, these high-quality, long-term data provide reliable insights for analysing climate trends and variability in the region.

Trend analysis

The study employs simple linear regression, the Mann-Kendall test, and Sen's slope estimator to analyze rainfall and temperature trends in Central Tanzania across Dodoma, Singida, and Tabora. These methods were selected for their complementary strengths in trend analysis. Linear regression identifies linear trends and their statistical significance, serving as an effective initial assessment despite assumptions of data normality (Rowhani *et al.,* 2011). The Mann-Kendall test, a non-parametric method, detects monotonic trends without requiring specific data distributions, making it ideal for variable hydroclimatic data (Gebrechorkos *et al.,* 2019; Ongoma *et al.,* 2018). Sen's slope estimator quantifies the magnitude of trends while being robust to outliers and missing data (Nicholson, 2017). Together, these approaches ensure robust

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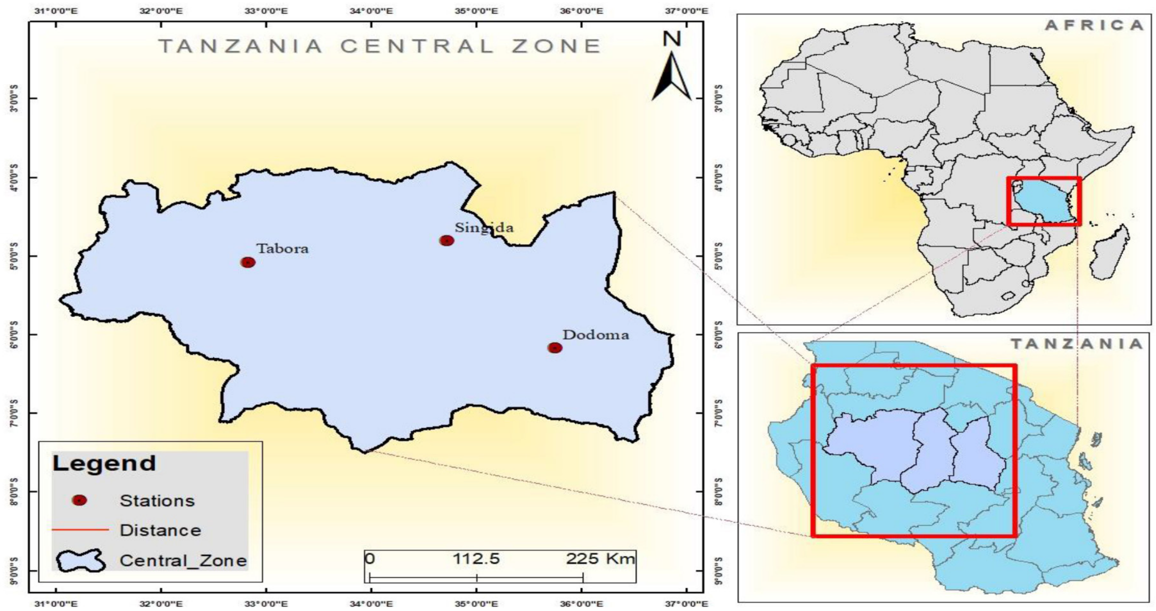

Fig. 1: Map of the study area

Table 1: Linear trend equations of precipitation and temperature at three locations

Parameters	Trend equation	Significance (5%)
	Dodoma	
Maximum temperature	$T_{max,t}=a-0.007t$	Non-significant
Minimum temperature	$T_{min,t}=a+0.0175t$	Significant
Precipitation	$P_{(t)}=a+11.432t$	Significant
	Singida	
Maximum temperature	$T_{max,t}=a-0.011t$	Non-significant
Minimum temperature	$T_{min,t}=a+0.0137t$	Significant
Precipitation	$P_{(t)}=a+13.396t$	Significant
	Tabora	
Maximum temperature	$T_{max,t}=a-0.013t$	Non-significant
Minimum temperature	$T_{min,t}=a+0.003t$	Non-significant
Precipitation	$P_{(t)}=a+10.402t$	Significant

trend detection and quantification, supporting climate adaptation strategies in the region. Data analyses were performed using R (Version 4.5.1) and ArcGIS.

Trends of precipitation and temperature

Linear trends: Table 1 shows climate trends from 1981–2024 for Dodoma, Singida, and Tabora based on linear regression equations. Precipitation increased significantly at all sites, highest in Singida (13.40 mm year^{-1}). Minimum temperatures rose significantly in Dodoma (0.0175 °C year^{-1}) and Singida (0.0137 °C year^{-1}), while maximum temperatures declined slightly but without statistical significance. Overall, the results indicate rising rainfall and warming, with implications for agriculture and water resources in central Tanzania.

***Non-parametric analysis*:** Table 2 presents the Mann-Kendall test and Sen's Slope Estimator results for annual trends in precipitation, maximum temperature, and minimum temperature in Dodoma, Singida, and Tabora. Precipitation exhibits significant increasing trends ($p < 0.05$) in all regions, with Sen's slopes of 10.30 mm year^{-1} (Dodoma), 10.40 mm year^{-1} (Singida), and 8.09 mm year^{-1} (Tabora). Minimum temperature trends are statistically significant in Dodoma ($p = 0.0011$, slope = 0.0187 °C year^{-1}) and Singida ($p = 0.0018$, slope = 0.0151 °C year^{-1}), but not in Tabora ($p = 0.2882$). Maximum temperature trends are non-significant ($p > 0.05$) with minimal slopes across all regions.

The analysis of precipitation and temperature trends in Dodoma, Singida, and Tabora reveals significant increases in annual rainfall (8.09–13.40 mm year^{-1}) and minimum temperatures (0.0137–0.0175 °C year^{-1}), while maximum temperatures showed slight, statistically insignificant declines. These findings are consistent with recent research highlighting increased rainfall and warming minimum temperatures in East Africa. The results emphasize the importance of region-specific climate adaptation strategies, particularly for agriculture and water management (Gebrechorkos *et al.,* 2019; Ongoma *et al.,* 2018; Nicholson, 2017). However, the results underscore persistent rain poverty, characterized by highly variable and poorly distributed rainfall, which limits its benefits for agriculture (Funk *et al.,* 2015; Rowhani *et al.,* 2011). For instance, Singida exhibits the steepest rise in precipitation but also the highest variability, indicating that increased rainfall does not necessarily translate to improved water availability or crop productivity (Craparo *et al.,* 2015). Additionally, the warming of minimum temperatures exacerbates agricultural stress by reducing soil moisture and shortening growing periods, increasing vulnerability in this semi-arid, rain-fed farming region (Conway *et al.,* 2017; Tierney *et al.,* 2015). To address this, region-specific adaptation strategies, including improved water management, drought preparedness, and resilient farming systems, are essential to mitigate the risks of increased rainfall yielding poorer agricultural outcomes in semi-arid central Tanzania (Conway *et al.,* 2017; Yewale and Jadhav, 2025). These results contribute to a clearer understanding of climate variability in central Tanzania and

Table 2: Mann-Kendall test and Sen's slope estimator results

Parameters	Kendall's tau	P-value	Sen's slope	95% confidence interval
Dodoma				
Precipitation	0.4545	0.00001	10.30	(6.092, 14.18)
Maximum temperature	-0.0849	0.4241	-0.0066	(-0.021, 0.0097)
Minimum temperature	0.3423	0.0011	0.0187	(0.0075, 0.0288)
Singida				
Precipitation	0.3974	0.0001	10.40	(5.41, 17.25)
Maximum temperature	-0.3366	0.3366	-0.0097	(-0.028, 0.0096)
Minimum temperature	0.3279	0.0018	0.0151	(0.0056, 0.0247)
Tabora				
Precipitation	0.2093	0.0463	8.09	(0.028, 15.29)
Maximum temperature	0.0180	0.8714	0.0015	(-0.020, 0.020)
Minimum temperature	0.1120	0.2882	0.0074	(-0.0057, 0.0199)

its implications for rain-fed farming systems. Continued monitoring and research are necessary to anticipate future shifts and support resilience strategies in semi-arid environments.

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Data availability: Precipitation and Temperature data were obtained from the website of NASA Prediction of Worldwide Energy Resources, link: https://power.larc.nasa.gov/data-access-viewer/

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