Decadal Trends in Seasonal Climatic Variables in Dar es Salaam, Tanzania: A Non-Parametric Approach Using the Mann-Kendall Test

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ABSTRACT

Background: Coastal cities like Dar es Salaam face an increasing vulnerability to the adverse impacts of climate variability, including urban flooding, heat stress, and altered water availability. Examining the temporal evolution of key climatic variables is critical to informing adaptive strategies and promoting sustainable urban development.

Methods: Decadal seasonal trends in rainfall, daytime and nighttime temperatures, and relative humidity were analyzed using monthly data from January 2014 to October 2024, sourced from the Tanzania Meteorological Authority. We applied the non-parametric Mann-Kendall trend test and Sen's slope estimator to detect and quantify monotonic trends across five defined seasons.

Results: We observed statistically significant trends across several seasons. Rainfall during the long dry season (JJA) had a slight increase, with a Sen's slope of +0.39097 mm/year and a p-value of 0.00457, suggesting a slight deviation from typical seasonal dryness. Daytime temperatures during JJA declined (Sen's slope = –0.03675°C/year; p = 0.00121), and nighttime temperatures during the short dry season (JF) also showed a significant decrease (Sen's slope = –0.04000°C/year; p = 0.04445). Relative humidity demonstrated only minor, statistically insignificant fluctuations across all seasons, with the highest z-value recorded in OND.

Conclusion: The findings highlight shifting climatic patterns in Dar es Salaam that diverge from conventional expectations, including increased precipitation during dry periods and seasonal cooling. Although the detected trends are modest in absolute magnitude, their statistical significance is noteworthy because consistent directional changes, however small, accumulate over time and may signal early-stage climatic shifts that warrant monitoring.

Keywords: Climate variability, Mann-Kendall trend test, Sen's slope, Urban resilience, Dar es Salaam

1. Introduction

Climate change is increasingly recognized as one of the most critical challenges of the 21st century, driving long-term shifts in global temperatures and weather patterns, primarily due to the retention of solar heat in the Earth's atmosphere (Kakkar et al., 2022). It is marked by rising global temperatures and an increase in the frequency and severity of extreme weather events such as droughts, floods, and heatwaves. This was also broadly highlighted at the global scale in the IPCC synthesis report (IPCC, 2023). Projections indicate that water availability and annual average runoff could decline by 10–30% by the mid-21st century, exacerbating water insecurity in many regions (Kakkar et al., 2022). These changes highlight the critical importance of examining historical climate patterns to guide the development of effective adaptation strategies, particularly in vulnerable regions where socio-economic systems are highly susceptible to climatic stressors (Gadedjisso-tossou & Adjegan, 2021).

IPCC synthesis report highlights that human activities have driven rapid and widespread changes in the biosphere, cryosphere, ocean, and atmosphere. These changes have caused significant losses and damages, particularly affecting vulnerable communities that have contributed the least to climate change (IPCC, 2023). Tanzania is particularly vulnerable to the adverse impacts of climate change, with seasonal variations in recorded rainfall and temperature trends observed across many regions of the country (Mbawala et al., 2024).

Several studies in Tanzania have used the Mann-Kendall test and Sen's slope estimator to analyze climate trends (Mbawala et al., 2024; Mugabe et al., 2024; Ndabagenga et al., 2023). These studies have covered various aspects, including extreme temperature changes, extreme precipitation indices ,agricultural impacts in specific districts and hydro-climatic trends in river catchments (Sigalla et al., 2023).

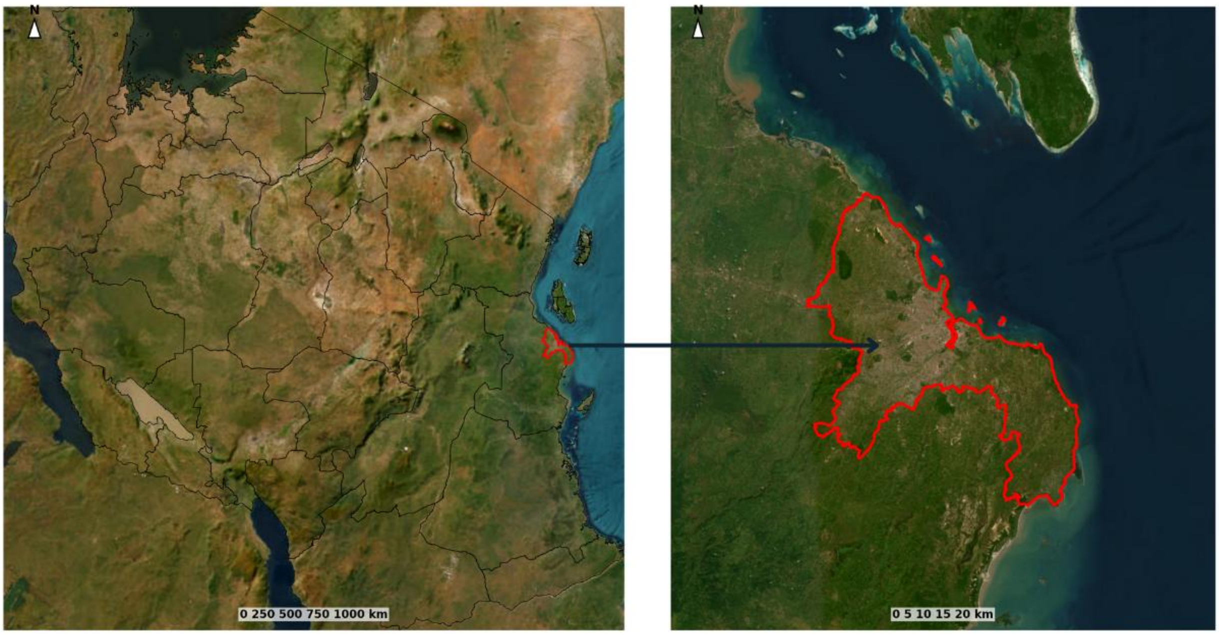
However, there remains a notable gap, as no recent studies have specifically examined the decadal seasonal trends of key climatic variables such as temperature, rainfall, and relative humidity within Dar es Salaam. Decadal trends in temperature, relative humidity, and seasonal rainfall are crucial for comprehending recent shifts in climatic patterns. This study especially examines possible changes in climate variability during the last ten years (2014-2024), in contrast to earlier research. By doing this, it highlights how adaptation strategies based on local climate data are essential for controlling climate-related risks and guaranteeing that solutions are adapted to the unique requirements and vulnerabilities of communities at the local level.

This paper contributes to the growing discourse on urban climate resilience by offering a comprehensive, decade-long analysis of climatic variability in Dar es Salaam, Tanzania's most populous coastal city. By focusing on seasonal trends in temperature, rainfall, and relative humidity from 2014 to 2024, the study provides context-specific insights that are essential for understanding emerging climate patterns and guiding adaptive planning.

2. Materials and Methods

2.1 Study Area

Dar es Salaam, Tanzania's largest city and economic hub, is located along the Indian Ocean coast between latitudes 6°36'S and 7°00'S and longitudes 39°00'E and 39°17'E. It has a humid tropical climate, characterized by bimodal rainfall patterns with peaks in March–May and October–December. The city experiences annual temperatures ranging from 18°C to 34°C and receives an average of approximately 1,100 mm of rainfall per year (TMA, 2023). As a rapidly urbanizing coastal city, Dar es Salaam is highly susceptible to climate-related challenges such as flooding, heat stress, and water insecurity, making it a critical case for localized climate trend analysis. Figure 1 presents a panel map illustrating the study area, with a map of Tanzania on the left and an arrow pointing to a more detailed map of Dar es Salaam on the right.



Tiles (c) Esri - Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS User Community

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Figure 1: Map of Study Area (Author's own contribution)

2.2 Study design and data source

A retrospective, ecological time-series design was used to examine ten-year trends in climatic variables across five seasons. Monthly climate data for Dar es Salaam, spanning January 2014 to October 2024, were sourced from the TMA. This dataset included rainfall (mm), daytime and nighttime temperatures (°C), and relative humidity (%). The TMA pre-validated the complete data, which required no imputation or correction, thus ensuring consistent and reliable trend analysis.

2.3 Data Analysis

2.3.1 Classification of seasons

Analysis was conducted for the five climatological seasons recognized for Dar es Salaam: JF (Short Dry Season), MAM (Long Rainy Season), JJA (Long Dry Season), S (Transitional Period), and OND (Short Rainy Season)

Table 1: Classification of seasons

Season ID	**Months within the Season**	**Season Name**
JF	January and February	Short Dry Season
MAM	March, April, and May	Long Rainy Season
JJA	June, July and August	Long Dry Season
S	September	Transition Period
OND	October, November and December	Short Rainy Season

2.3.2 Mann Kendall test and Sen's slope estimator

The non-parametric Mann-Kendall (MK) trend test was employed to detect the presence of monotonic trends in the time series data without requiring the data to follow any specific distribution. This method is particularly suitable for environmental and climatological data where non-normality and missing values may be present. The corresponding magnitude and direction of the trends were estimated using Sen's slope estimator. All statistical analyses were conducted at a 5% significance level ($\alpha = 0.05$), and trends were interpreted using the computed S-statistics, variance, Z-scores, p-values, and slope estimates.

In the MK test, the S-statistic was calculated as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_j - x_i)$$

where $sgn(x_j - x_i)$ is the sign function, returning +1, 0, or –1 depending on whether the difference is positive, zero, or negative, respectively.

For large sample sizes ($n > 10$), the variance of S was computed using:

$$Var(S) = \frac{n(n-1)(2n+5) - \sum t_p(p-1)(2p+5)}{18}$$

where t_p denotes the number of ties of extent p.

The standardized test statistic Z was then derived as:

$$Z = \begin{cases} \frac{S-1}{\sqrt{\mathrm{Var}(S)}}, & S > 0 \\ 0, & S = 0 \\ \frac{S+1}{\sqrt{\mathrm{Var}(S)}}, & S < 0 \end{cases}$$

The null hypothesis of no trend was rejected if the absolute value of Z exceeded the critical value at the 5% significance level (i.e., |Z| > 1.96).

Sen's slope estimator was used to quantify the magnitude of the trend. For each pair of time-ordered observations, the slope (*Qi*) was calculated as:

$$Q_i = \frac{x_j - x_i}{j - i}, \quad for\ all\ 1 \leq i < j \leq n$$

Where x_i and x_j are data values at time points *i* and *j* respectively. The Sen's slope was then determined as the median of all Q_i values:

$$Sen's\ slope = Qn_{/2}\ \ (if\ n\ is\ odd)$$

$$Sen's\ slope = \frac{Qn_{/2} + Qn/_{2+1}}{2}\ \ (if\ n\ is\ even)$$

This approach provides a robust and unbiased estimate of the linear trend over time, even in the presence of outliers or non-normal data distributions (Mann, 1945; Sen, 1968) .

2.3.3 Statistical software

All analyses were performed in R version 4.5.1 (R Core Team, 2025). The Mann–Kendall test was conducted using the MannKendall() function from the Kendall package, and Sen's slope was estimated using the sens.slope() function from the trend package, which returns the median of all pairwise slopes.

3. Results

3.1 Description of the climatic variables

Monthly variations in climatic variables revealed distinct seasonal patterns and interannual dynamics over the decade. Warmer months consistently occurred from January to March and November to December, while cooler months with lower nighttime temperatures were observed from June to September. Rainfall exhibited significant fluctuations, with higher amounts predominantly in April and May. Notably, heavy rainfall was recorded in November 2023, deviating from typical patterns, and a consistent rainfall shortage occurred from June to September. Relative humidity levels correlated with rainfall, being higher in April, May, and November, and lower from July to September, highlighting the interconnected influence of rainfall and humidity on the regional climate (See Figure 2-3).

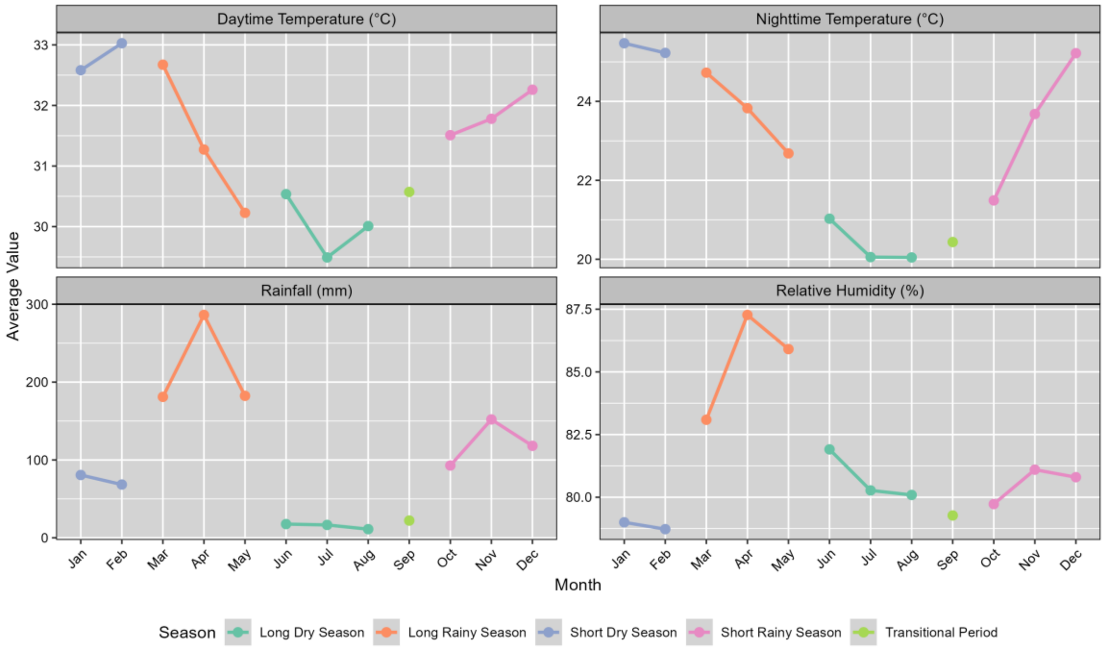

Figure 2:Monthly Climatology of Daytime Temperature, Nighttime Temperature, Rainfall, and Relative Humidity in Dar es Salaam (2014–2024)

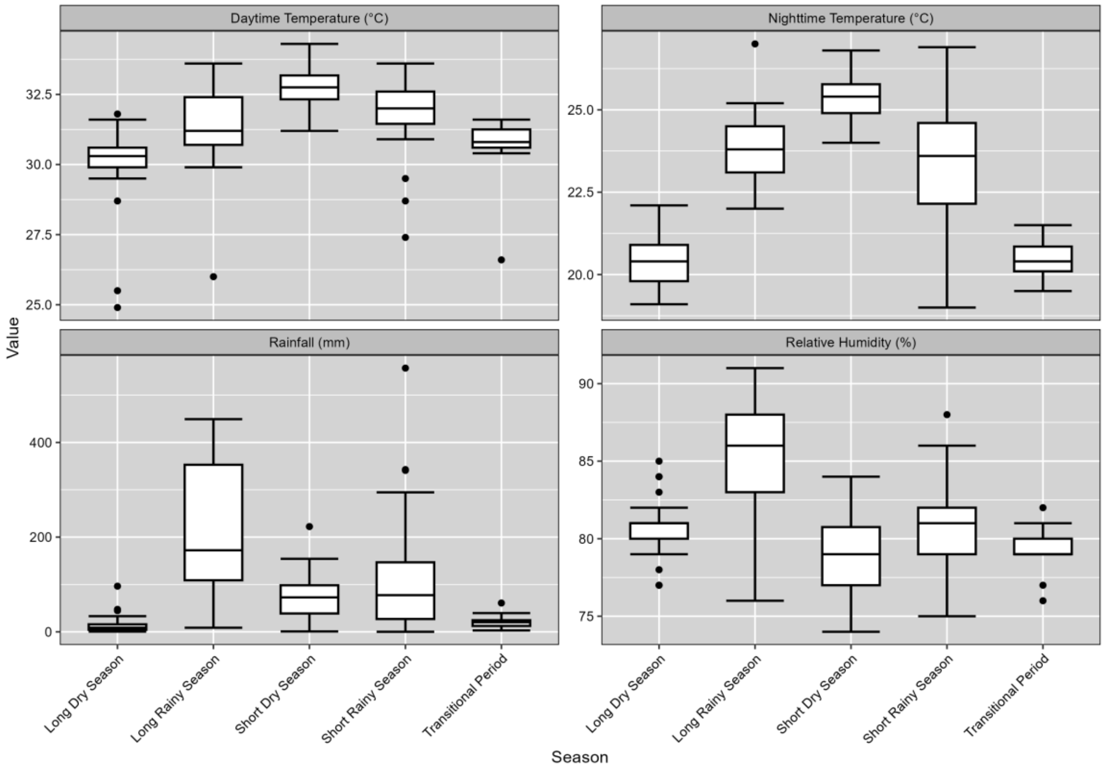

Figure 3. Seasonal Distributions of Climatic Variables in Dar es Salaam (2014–2024) Based on Boxplots

To complement the monthly and seasonal visualizations, annual mean values for each climatic variable were plotted across all five seasons to examine overarching directional tendencies over the decade. As shown in the figure below, the linear trend fits highlight broad shifts in temperature, rainfall, and relative humidity between 2014 and 2024, with notable differences across seasons. These descriptive patterns provide context for the formal monotonic trend tests presented in the following subsection, allowing a clearer interpretation of emerging climate signals in Dar es Salaam (See Figure 4).

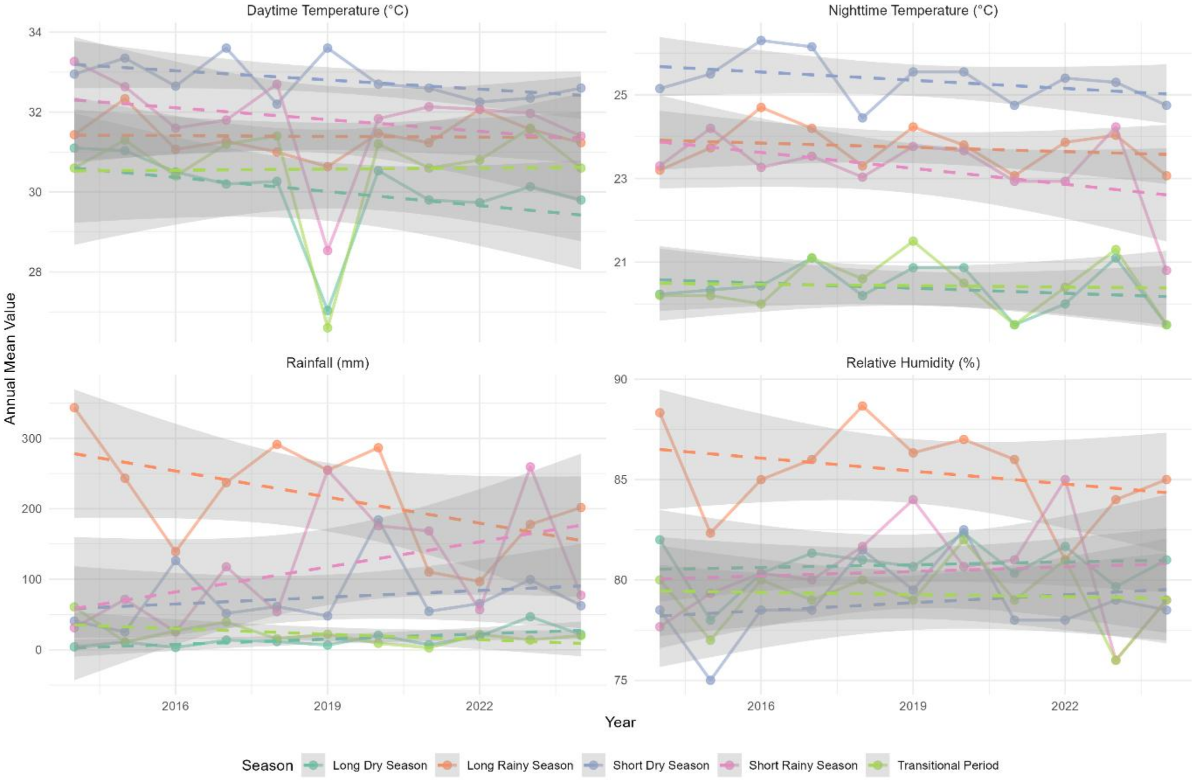

Figure 4. Annual Trends in Climatic Variables by Season (2014–2024). Dashed lines represent linear trend fits with 95% confidence intervals

3.2 Decadal Trend Analysis with Mann Kendall test and Sen's slope estimator

Seasonal trends in rainfall, daytime and nighttime temperatures, and relative humidity across Dar es Salaam. A statistically significant increasing trend in rainfall was observed during the Long Dry season, a period traditionally characterized by minimal precipitation. The Mann-Kendall test yielded a z-score of 2.8362 with a corresponding p-value of 0.00457, indicating a robust trend. The Sen’s slope estimator quantified this increase at +0.39097 mm/year, suggesting a quite small year-to-year rise in rainfall during this typically dry period.

Conversely, a statistically significant decreasing trend in daytime temperatures was identified during the same Long Dry season. The Mann-Kendall test resulted in a z-statistic of -3.2354 and a p-value of 0.00121, signifying a strong downward trend. This was further corroborated by the Sen’s slope of –0.03675°C/year, suggesting a gradual cooling in daytime temperatures during this period. In contrast, nighttime temperatures exhibited a significant decrease during the Short Dry season, with a z-statistic of –2.0098 and a p-value of 0.04445. The Sen’s slope for this trend was –0.04°C/year, revealing a small but statistically significant decline in nighttime temperatures during these months.

Relative humidity did not show any statistically significant trends across all seasons, indicating relative stability in atmospheric moisture content over the analyzed period. While minor fluctuations were observed, none met the threshold for statistical significance (See Table 1)

Table 2: Mann-Kendall Test for Seasonal Climatic Trends (January 2014–October 2024)

Variable	Season	z	p-value	Sen's Slope
Rainfall (mm)	*JF (Short Dry Season)*	0.7895	0.42980	1.83333
	MAM (Long Rainy Season)	-1.1931	0.23284	-3.44500
	JJA (Long Dry Season)	2.8362	0.00457	0.39097
	S (Transitional Period)	-1.4013	0.16112	-1.84286
	OND (Short Rainy Season)	1.8696	0.06154	3.04706
Daytime temperature (°C)	*JF (Short Dry Season)*	-1.7805	0.07500	-0.03750
	MAM (Long Rainy Season)	-0.4035	0.68654	-0.01026
	JJA (Long Dry Season)	-3.2354	0.00121	-0.03675
	S (Transitional Period)	0.1579	0.87450	0.00000
	OND (Short Rainy Season)	-1.4131	0.15763	-0.02857
Nighttime temperature (°C)	*JF (Short Dry Season)*	-2.0098	0.04445	-0.04000
	MAM (Long Rainy Season)	-0.8228	0.41063	-0.01521
	JJA (Long Dry Season)	-0.9015	0.36735	-0.01667
	S (Transitional Period)	0.0000	1.00000	0.00000
	OND (Short Rainy Season)	-0.0170	0.98640	0.00000
Relative Humidity (%)	*JF (Short Dry Season)*	0.6840	0.49395	0.06250
	MAM (Long Rainy Season)	-1.1235	0.26123	-0.06250
	JJA (Long Dry Season)	0.4691	0.63901	0.00000
	S (Transitional Period)	-0.2428	0.80816	0.00000
	OND (Short Rainy Season)	1.4445	0.14860	0.09091

The significant seasonal trends identified by the Mann–Kendall test were further visualized to highlight the direction and magnitude of these changes over time. The plotted panels show the observed values along with their corresponding Sen’s slope lines, clearly illustrating the three variables that exhibited statistically significant monotonic trends. These visual displays reinforce the statistical results by providing an intuitive depiction of how these climatic variables have evolved across the decade, revealing subtle but meaningful shifts in both precipitation and temperature patterns in Dar es Salaam (See Figure 5).

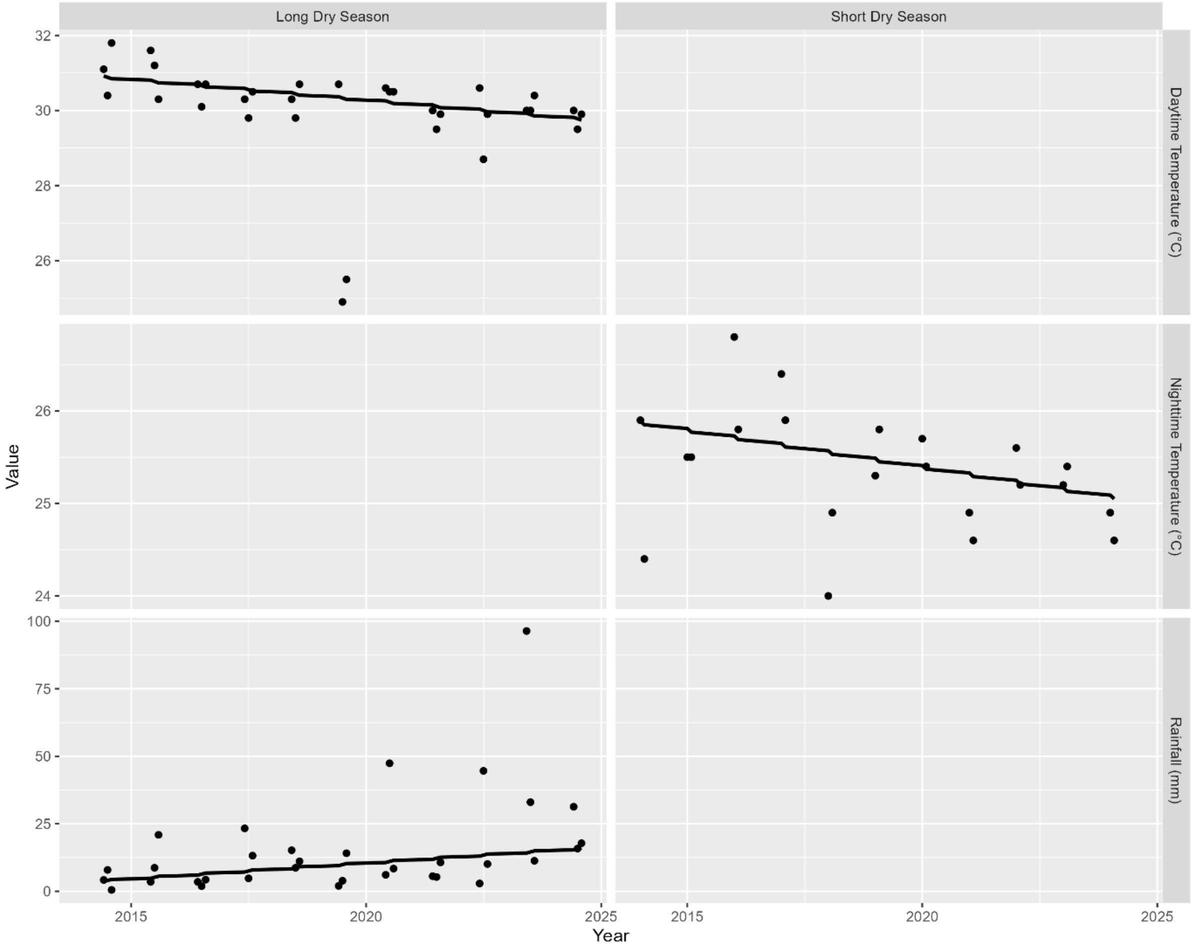

Figure 5. Panel plots of significant climatic trends identified by the Mann–Kendall test. Each panel displays observed seasonal values (points) with Sen’s slope (solid line) for the Long Dry Season (JJA) and Short Dry Season (JF). Only variables with statistically significant monotonic trends ($p < 0.05$) are shown: rainfall (JJA), daytime temperature (JJA), and nighttime temperature (JF).

4. Discussions

This study identified three statistically significant monotonic trends in Dar es Salaam’s seasonal climate over the 2014–2024 period: (i) increasing rainfall during the Long Dry Season

(JJA), (ii) decreasing daytime temperatures during JJA, and (iii) declining nighttime temperatures during the Short Dry Season (JF). Although the detected trends are modest in absolute magnitude, their statistical significance is noteworthy because consistent directional changes, however small, accumulate over time and may signal early-stage climatic shifts that warrant monitoring.

The detected increase in rainfall during the long dry season suggests a shift toward more irregular precipitation patterns. Similar anomalies have been reported in other parts of Tanzania, where unusual dry-season rainfall has been associated with both land-use change and broader climate change drivers (Kashaigili et al., 2013). Large-scale climate modes such as the Indian Ocean Dipole (IOD) and the El Niño–Southern Oscillation (ENSO) increasingly influence rainfall distribution across East Africa (Nicholson, 2017). Positive IOD phases, characterized by warmer western Indian Ocean waters, are known to enhance rainfall even during periods historically associated with suppressed convection (Chobo & Huo, 2024), and climate simulations indicate that such events may become more frequent under warming scenarios (Cai et al., 2014). Regional analyses further show that East Africa has experienced increasingly erratic rainfall patterns due to ocean warming (Nicholson, 2017). Consistent with our findings, previous research documented wetter short rains and a long-term drying of the long rains, with partial recovery in recent decades (Palmer et al., 2023). These shifts have implications for flooding, drought cycles, energy systems, agriculture, and vector- and waterborne disease dynamics, amplifying existing vulnerabilities.

Comparable observations from South Sudan also highlight increasing rainfall during typically dry periods, disrupting agricultural systems and heightening exposure to climate extremes (Zakaria Lukwasa et al., 2022). Studies in coastal Kenya similarly report rising dry-season rainfall associated with intensified moisture convergence (Nguvava & Abiodun, 2023). Local influences, including rapid urbanization and the replacement of vegetated surfaces with impervious materials, may also alter convective processes and enhance localized precipitation (Kimutai et al., 2023).

While increased dry-season rainfall may ease water scarcity, it simultaneously raises concerns about flood risk, particularly in rapidly urbanizing areas with limited drainage capacity. Much of Dar es Salaam’s drainage infrastructure was designed for historical rainfall patterns rather than the heavier off-season precipitation now emerging (UN-Habitat, 2022). When combined with urban growth, low solid waste collection coverage, and climate change, these changes exacerbate flood vulnerability (Sakijege & Dakyaga, 2023). Unusual rainfall patterns also affect sanitation systems in informal settlements. At the same time, increased off-season rainfall may support expanded water-harvesting initiatives if adequate storage systems are integrated into planning (Raimondi et al., 2023). These findings emphasize the need for planners to incorporate updated rainfall baselines into urban design, particularly regarding drainage and water management.

Temperature trends also revealed noteworthy patterns. Daytime temperatures during JJA declined significantly, and nighttime temperatures during JF showed a measurable decrease. Although global temperatures continue to rise, localized cooling in coastal or highly vegetated areas has been linked to sea-breeze penetration, urban greening, and microclimatic regulation (Esperon-Rodriguez et al., 2025). Coastal cities such as Dar es Salaam benefit from maritime influences, which moderate heat extremes through enhanced ventilation. Strengthened wind patterns or increased sea-breeze frequency over the study period may contribute to these cooling tendencies. Similar coastal moderation effects have been documented in Xiamen, where the ocean exerts cooling influence up to nearly 8 km inland (Hong et al., 2025), and in Lake Ontario–adjacent urban areas, where local temperatures can be reduced by as much as 3°C (Jandaghian & Colombo, 2024). Vancouver's coastal features, including Burrard Inlet and False Creek, also play a key role in lowering local temperatures by approximately 2–4°C (Spronken-Smith & Oke, 1998).

Atmospheric aerosols may further contribute to local cooling. Increased particulate emissions from traffic, industry, and biomass burning can enhance atmospheric albedo, reflecting solar radiation and reducing surface heat (Onaiwu & Ayidu, 2025). Aerosols acting as cloud condensation nuclei generate clouds with smaller droplets, increasing reflectivity and thereby strengthening cooling effects (Akinyoola et al., 2024). Their ability to prolong cloud cover by suppressing precipitation can enhance this cooling further (Irfan et al., 2024). These mechanisms may help explain the localized temperature decreases observed in Dar es Salaam. Nighttime cooling during JF may also be linked to reduced nocturnal cloud cover, which increases outgoing longwave radiation. Previous studies in East Africa have documented similar mechanisms contributing to nighttime cooling in coastal regions (Cai et al., 2014; Chobo & Huo, 2024; Nicholson, 2017; Palmer et al., 2023). However, cooling trends should be interpreted with caution. Localized temperature declines do not contradict broader global warming trajectories. Instead, they underscore the complexity of urban microclimates and the need for fine-scale spatial analyses to distinguish urban-core, peri-urban, and coastal influences.

Relative humidity exhibited no significant trend across any season, consistent with findings from other coastal environments where proximity to large water bodies stabilizes atmospheric moisture (Jandaghian & Colombo, 2024). The Indian Ocean likely provides a buffering effect for Dar es Salaam, maintaining moisture availability despite fluctuations in temperature or rainfall. This marine influence may shield the city from humidity volatility commonly observed in inland regions (Camberlin et al., 2017). Nevertheless, even modest fluctuations can substantially affect human thermal comfort, as humidity intensifies heat stress under elevated temperatures (Wang & Gaffen, 2001). Although humidity remained stable during the study period, projected intensification of the global hydrological cycle could increase the frequency of extreme humidity episodes (IPCC, 2023), making continued monitoring essential.

Overall, the study underscores the importance of localized, seasonally resolved climate assessments for coastal urban centers. The emerging shifts documented here, particularly unseasonal rainfall increases and localized cooling, carry direct implications for urban planning, disaster risk reduction, public health readiness, and water resource management. Strengthening observational networks, integrating remote sensing, and developing fine-scale climate analyses will be critical for improving urban climate resilience in Dar es Salaam.

5. Conclusion

In coastal areas like Dar es Salaam that are fast becoming more urbanized, it is essential to comprehend localized climate changes. Urban flooding, water supply, thermal comfort, and public health are all impacted by climate variability. Global and regional patterns have received a lot of attention, but city-specific, seasonal-scale evaluations are still rare despite being crucial for climate-resilient urban development.

The climate of Dar es Salaam seems to be changing seasonally in subtle but noticeable ways. Contrary to predictions, higher rainfall during the dry season and falling temperatures challenge traditional urban calendars, water management strategies, and disaster risk reduction frameworks. In order to effectively prepare for adaptation and future-proof public health systems, urban infrastructure, and economic activity in the face of climate unpredictability, localized and seasonal evaluations are essential. As explained above, this local-level seasonal study offers vital information that can help close the gap between the realities of urban planning and national climate policies. Therefore, for Dar es Salaam to become more resilient, its city master plan has to undergo regular revision and incorporate updated climatic baselines.

6. Limitations of the study

The study has some limitations. It relied on data from a single meteorological station and a relatively short temporal window (2014–2024), which may not fully capture microclimatic variations across the broader Dar es Salaam area, as there is only one local station. Additionally, the study did not investigate potential underlying drivers of the observed trends, such as the effects of urbanization or larger regional climate dynamics. To further understand urban microclimatic variability, future studies should combine lengthier datasets, remote sensing data, and localized ground-truthing. Finally, while statistically significant, the magnitude of detected trends was relatively small. This reflects both the short duration of the dataset and the inherent subtlety of decadal climate shifts. As a result, the observed trends should be interpreted as indicators of directional change rather than large, immediate impacts. Longer-term datasets would allow more precise estimates of climatic significance.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used Grammarly in order to improve readability and clarity of the paper. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Ethics statement

This study did not involve human participants or the use of personal data. All data used were publicly available meteorological records obtained from the Tanzania Meteorological Authority. Therefore, ethical approval was not required.

Author Contributions

IM: Conceptualization, Data curation, Investigation, Methodology, Resources, Validation, Writing - original draft, Writing - review & editing. **HM**: Conceptualization, Methodology, Project administration, Validation, Writing - review & editing. **IHR**: Conceptualization, Data curation, Methodology, Validation, Writing - review & editing. **OP**: Conceptualization, Data Curation, Methodology, Validation, Writing - review & editing. **JGM**: Conceptualization, Formal analysis, Methodology, Software, Validation, Visualization, Writing - original draft, Writing - review & editing. All authors have read and approved the final manuscript and agree to be accountable for all aspects of the work.

R Codes and Data Availability Statement

The dataset used in this study has been made publicly available through DOI: 10.5281/zenodo.17720494. All relevant materials are available to readers without restriction. For further inquiries, please contact the corresponding author.

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Declaration of competing interests

The authors declare no conflicting interests related to this study.

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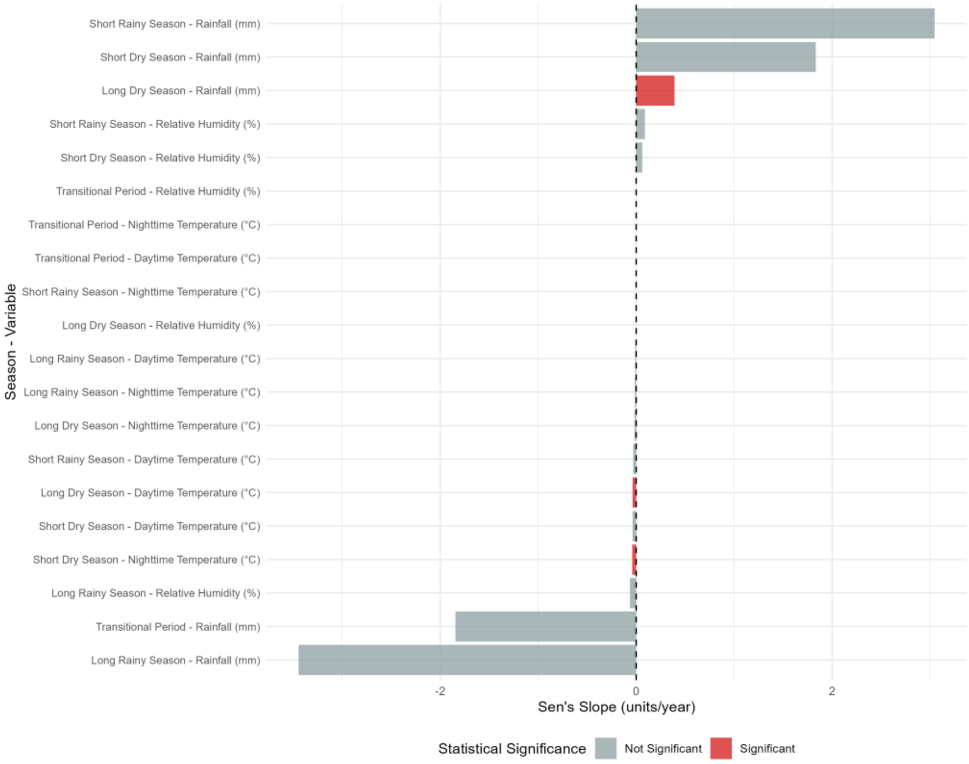
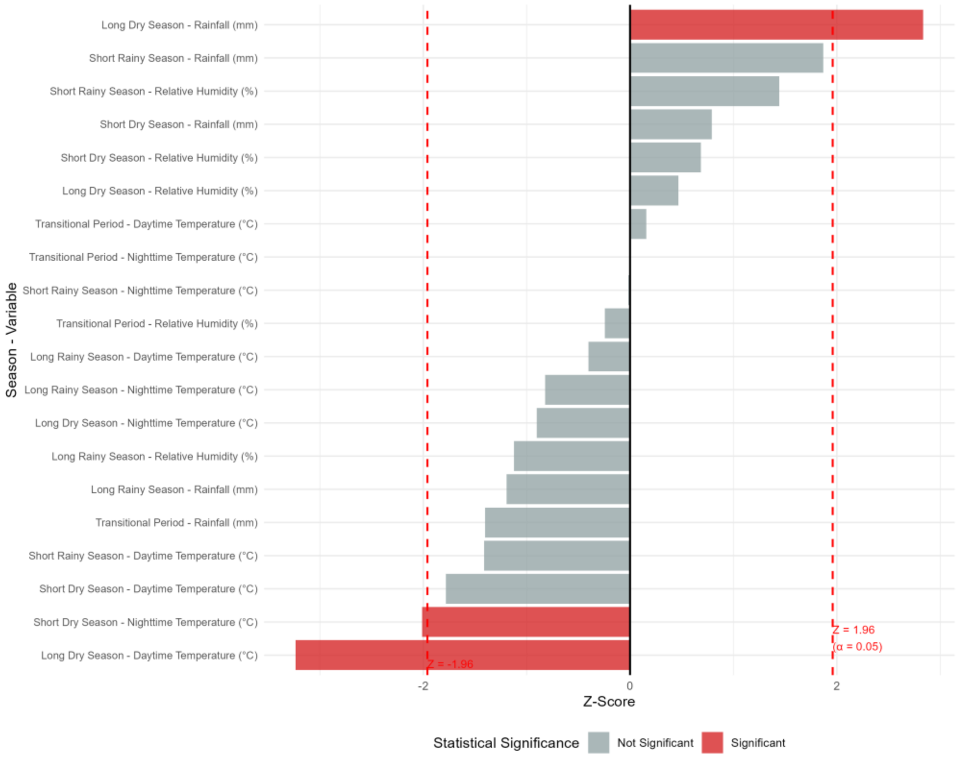
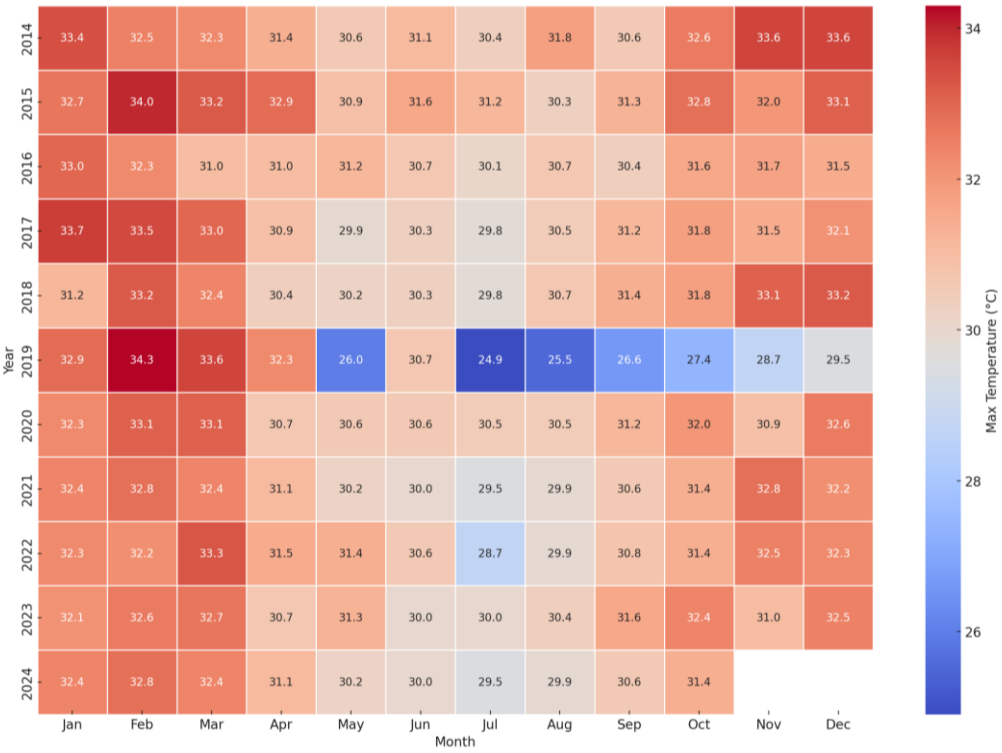
APPENDICES



Appendix 1: Sen's Slope Magnitude Visualization

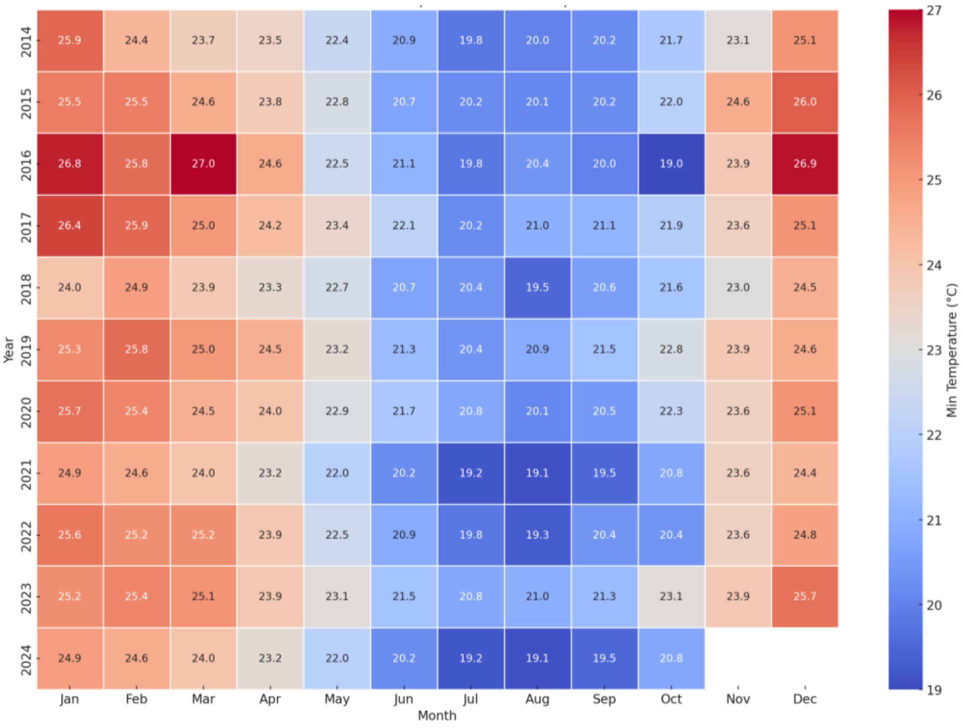


Appendix 1I: Mann-Kendall Z-Scores by Season and Variable (Horizontal dashed lines indicate critical values (±1.96) for α = 0.05)



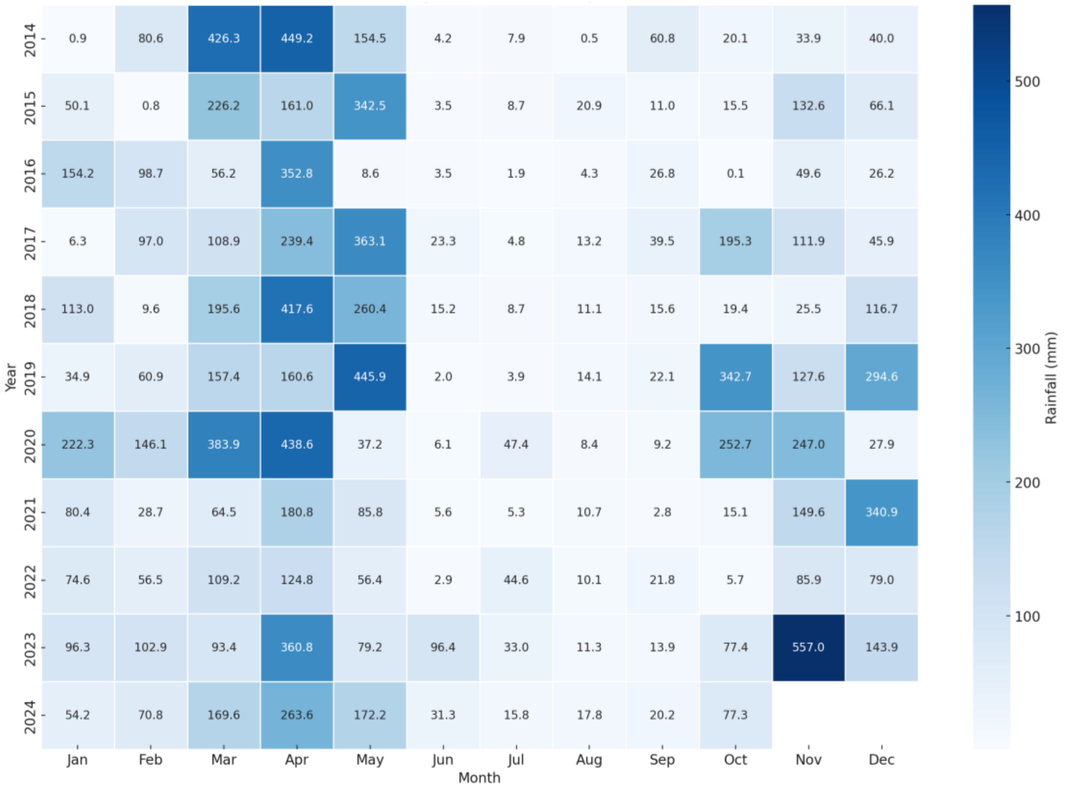
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	33.4	32.5	32.3	31.4	30.6	31.1	30.4	31.8	30.6	32.6	33.6	33.6
2015	32.7	34.0	33.2	32.9	30.9	31.6	31.2	30.3	31.3	32.8	32.0	33.1
2016	33.0	32.3	31.0	31.0	31.2	30.7	30.1	30.7	30.4	31.6	31.7	31.5
2017	33.7	33.5	33.0	30.9	29.9	30.3	29.8	30.5	31.2	31.8	31.5	32.1
2018	31.2	33.2	32.4	30.4	30.2	30.3	29.8	30.7	31.4	31.8	33.1	33.2
2019	32.9	34.3	33.6	32.3	26.0	30.7	24.9	25.5	26.6	27.4	28.7	29.5
2020	32.3	33.1	33.1	30.7	30.6	30.6	30.5	30.5	31.2	32.0	30.9	32.6
2021	32.4	32.8	32.4	31.1	30.2	30.0	29.5	29.9	30.6	31.4	32.8	32.2
2022	32.3	32.2	33.3	31.5	31.4	30.6	28.7	29.9	30.8	31.4	32.5	32.3
2023	32.1	32.6	32.7	30.7	31.3	30.0	30.0	30.4	31.6	32.4	31.0	32.5
2024	32.4	32.8	32.4	31.1	30.2	30.0	29.5	29.9	30.6	31.4		

Appendix III: A heatmap of Monthly and Interannual Variations in Daytime Temperature



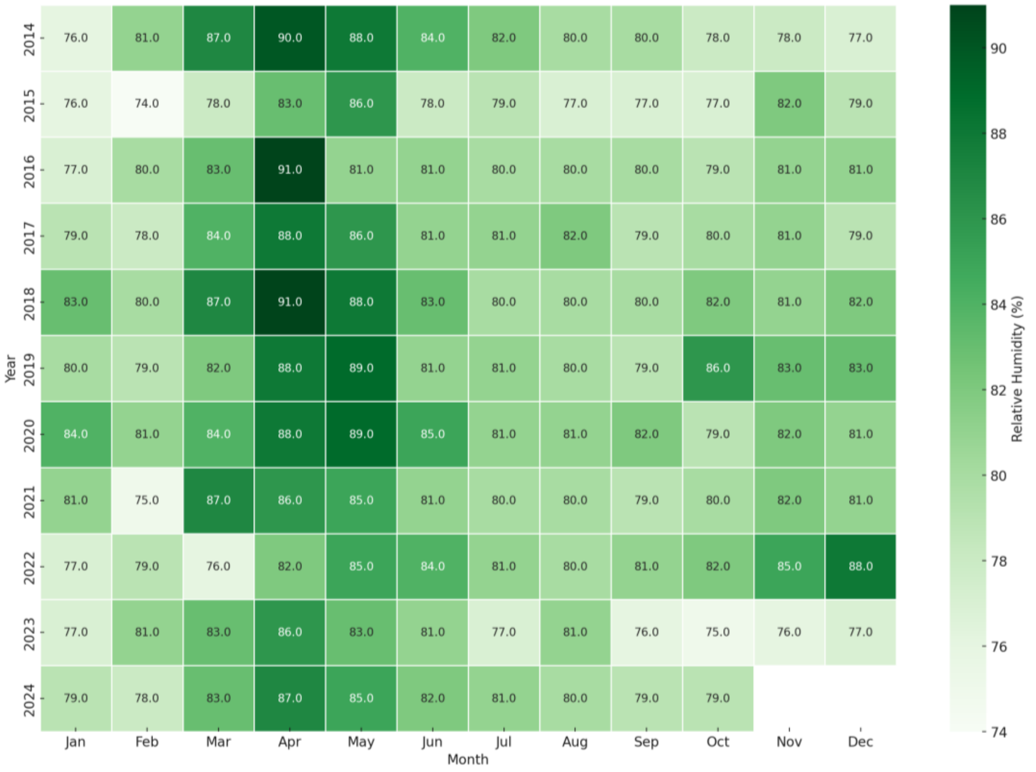
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	25.9	24.4	23.7	23.5	22.4	20.9	19.8	20.0	20.2	21.7	23.1	25.1
2015	25.5	25.5	24.6	23.8	22.8	20.7	20.2	20.1	20.2	22.0	24.6	26.0
2016	26.8	25.8	27.0	24.6	22.5	21.1	19.8	20.4	20.0	19.0	23.9	26.9
2017	26.4	25.9	25.0	24.2	23.4	22.1	20.2	21.0	21.1	21.9	23.6	25.1
2018	24.0	24.9	23.9	23.3	22.7	20.7	20.4	19.5	20.6	21.6	23.0	24.5
2019	25.3	25.8	25.0	24.5	23.2	21.3	20.4	20.9	21.5	22.8	23.9	24.6
2020	25.7	25.4	24.5	24.0	22.9	21.7	20.8	20.1	20.5	22.3	23.6	25.1
2021	24.9	24.6	24.0	23.2	22.0	20.2	19.2	19.1	19.5	20.8	23.6	24.4
2022	25.6	25.2	25.2	23.9	22.5	20.9	19.8	19.3	20.4	20.4	23.6	24.8
2023	25.2	25.4	25.1	23.9	23.1	21.5	20.8	21.0	21.3	23.1	23.9	25.7
2024	24.9	24.6	24.0	23.2	22.0	20.2	19.2	19.1	19.5	20.8		

Appendix IV: A heatmap of Monthly and Interannual Variations in Nighttime Temperature



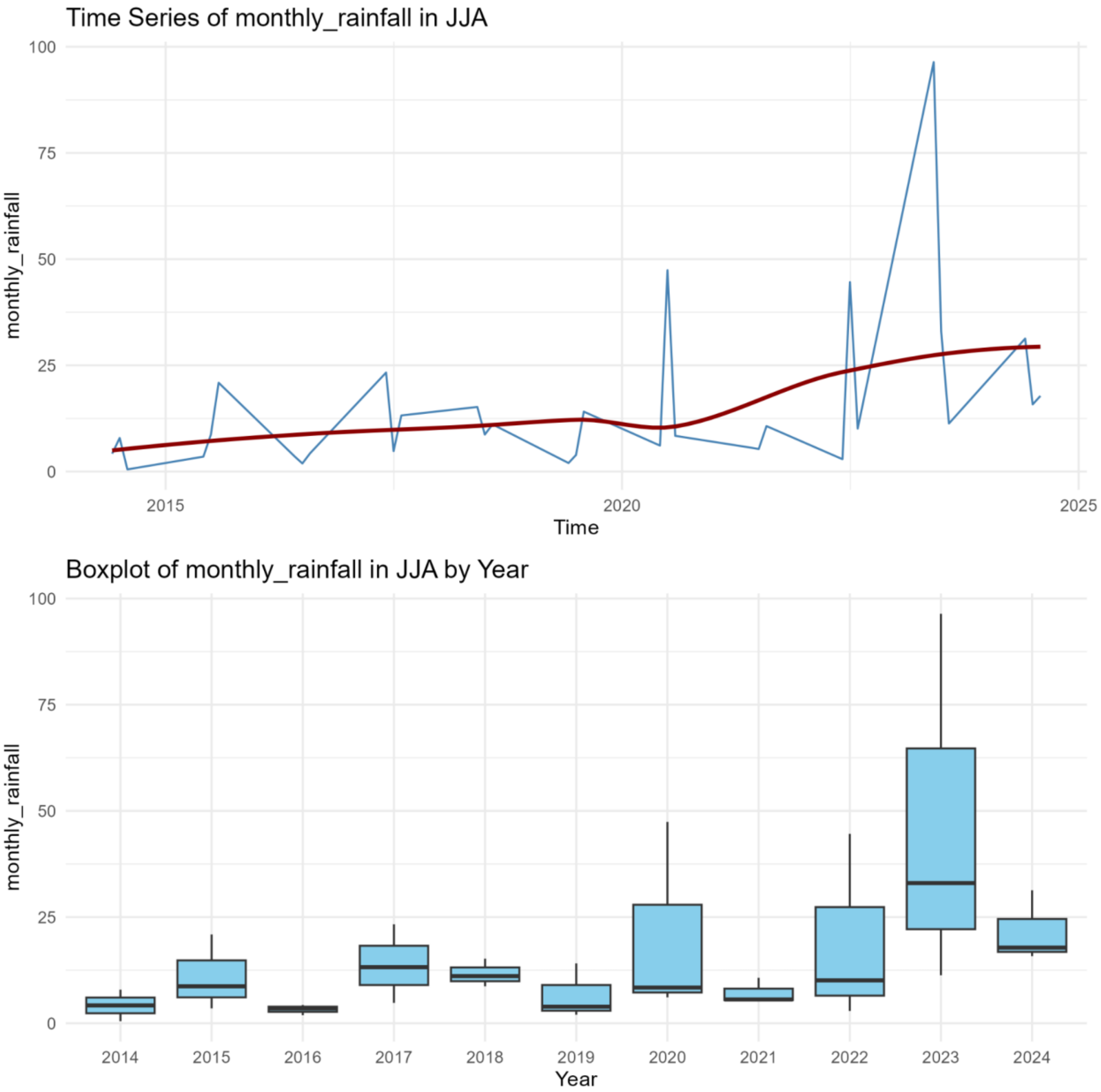
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	0.9	80.6	426.3	449.2	154.5	4.2	7.9	0.5	60.8	20.1	33.9	40.0
2015	50.1	0.8	226.2	161.0	342.5	3.5	8.7	20.9	11.0	15.5	132.6	66.1
2016	154.2	98.7	56.2	352.8	8.6	3.5	1.9	4.3	26.8	0.1	49.6	26.2
2017	6.3	97.0	108.9	239.4	363.1	23.3	4.8	13.2	39.5	195.3	111.9	45.9
2018	113.0	9.6	195.6	417.6	260.4	15.2	8.7	11.1	15.6	19.4	25.5	116.7
2019	34.9	60.9	157.4	160.6	445.9	2.0	3.9	14.1	22.1	342.7	127.6	294.6
2020	222.3	146.1	383.9	438.6	37.2	6.1	47.4	8.4	9.2	252.7	247.0	27.9
2021	80.4	28.7	64.5	180.8	85.8	5.6	5.3	10.7	2.8	15.1	149.6	340.9
2022	74.6	56.5	109.2	124.8	56.4	2.9	44.6	10.1	21.8	5.7	85.9	79.0
2023	96.3	102.9	93.4	360.8	79.2	96.4	33.0	11.3	13.9	77.4	557.0	143.9
2024	54.2	70.8	169.6	263.6	172.2	31.3	15.8	17.8	20.2	77.3		

Appendix V: Heatmap of monthly rainfall in Dar es Salaam from Jan 2014 - Oct 2024

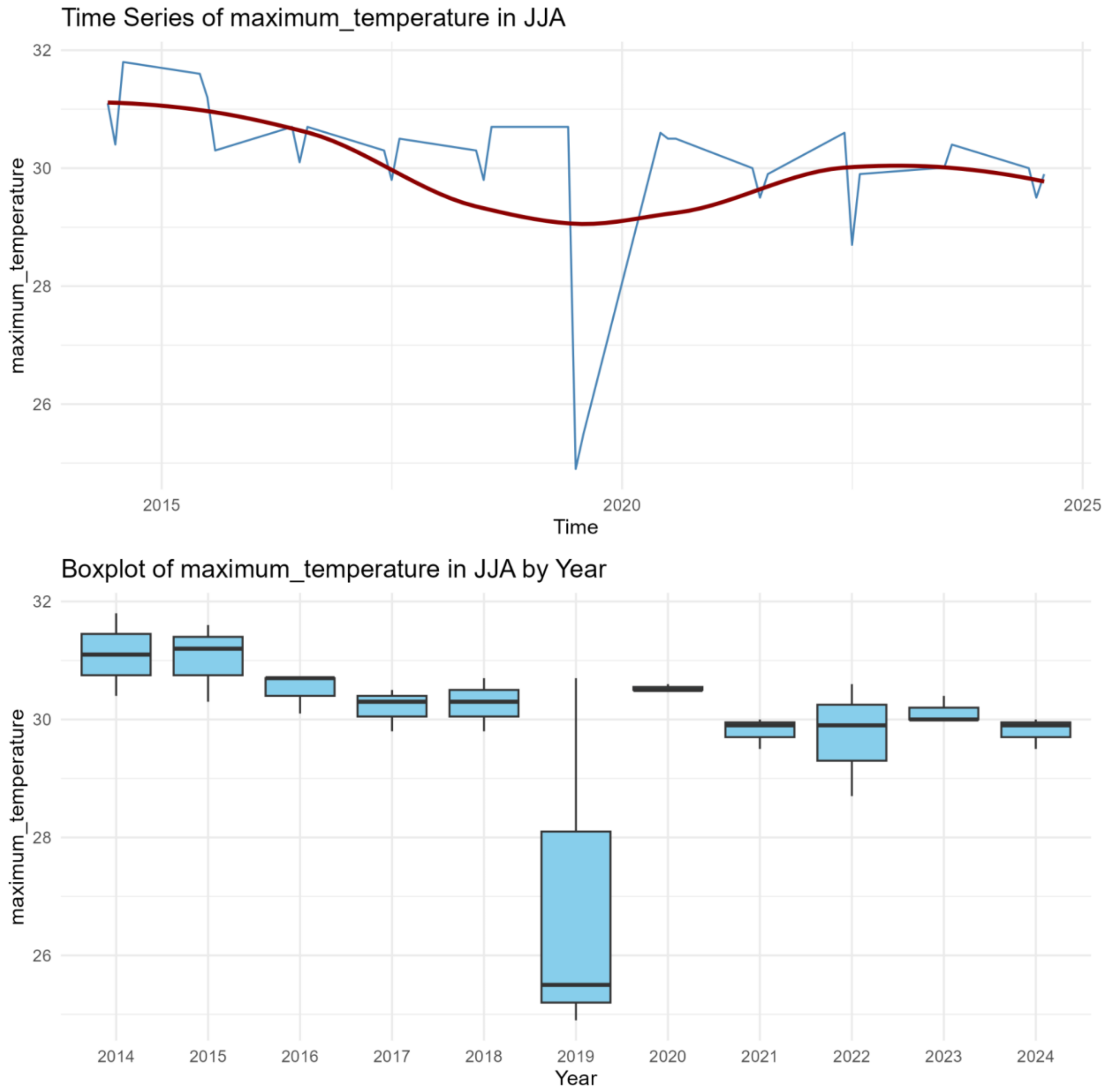


Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	76.0	81.0	87.0	90.0	88.0	84.0	82.0	80.0	80.0	78.0	78.0	77.0
2015	76.0	74.0	78.0	83.0	86.0	78.0	79.0	77.0	77.0	77.0	82.0	79.0
2016	77.0	80.0	83.0	91.0	81.0	81.0	80.0	80.0	80.0	79.0	81.0	81.0
2017	79.0	78.0	84.0	88.0	86.0	81.0	81.0	82.0	79.0	80.0	81.0	79.0
2018	83.0	80.0	87.0	91.0	88.0	83.0	80.0	80.0	80.0	82.0	81.0	82.0
2019	80.0	79.0	82.0	88.0	89.0	81.0	81.0	80.0	79.0	86.0	83.0	83.0
2020	84.0	81.0	84.0	88.0	89.0	85.0	81.0	81.0	82.0	79.0	82.0	81.0
2021	81.0	75.0	87.0	86.0	85.0	81.0	80.0	80.0	79.0	80.0	82.0	81.0
2022	77.0	79.0	76.0	82.0	85.0	84.0	81.0	80.0	81.0	82.0	85.0	88.0
2023	77.0	81.0	83.0	86.0	83.0	81.0	77.0	81.0	76.0	75.0	76.0	77.0
2024	79.0	78.0	83.0	87.0	85.0	82.0	81.0	80.0	79.0	79.0		

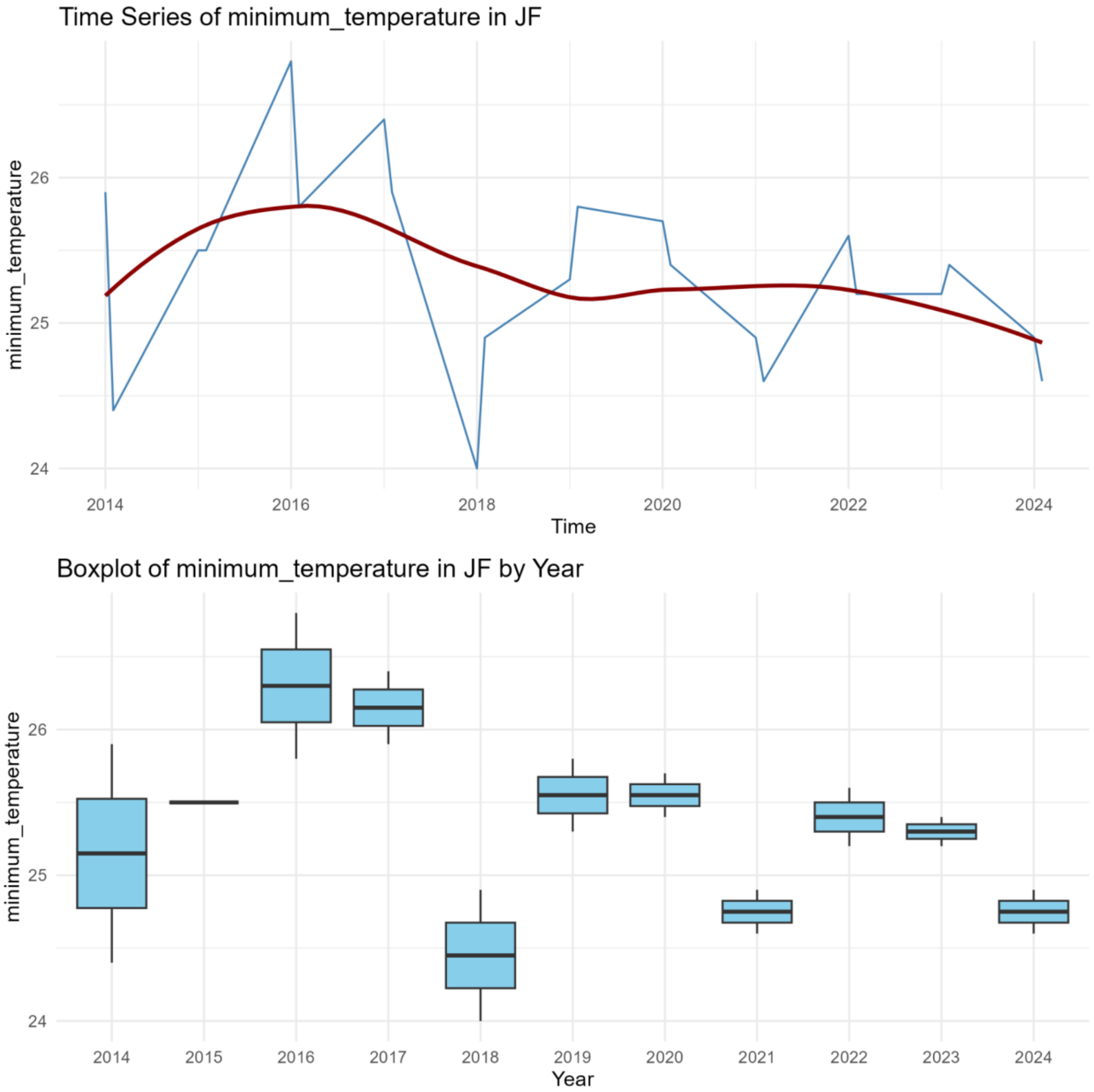
Appendix VI: Heatmap of Monthly Relative Humidity in Dar es Salaam from Jan 2014 - Oct 2024



Appendix VII: Time series plots of rainfall in the long dry season.



Appendix VIII: Time series plot of daytime temperature in the long dry season



Appendix IX: Time series plot of nighttime temperature in the short dry season