ASSESSMENT AND PREDICTION OF LAND SURFACE TEMPERATURE (LST) OF DAMATURU METROPOLIS FROM 2022-2042

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Abstract:

The mounting issue of urban heat and climate warming within cities has become a pressing concern, with Damaturu being no exception. Land surface temperature (LST) estimation and prediction play a crucial role in comprehending climate dynamics and formulating effective mitigation and adaptation strategies. This paper presents an analysis of randomly selected Landsat satellite images spanning from 2013 to 2022. Rigorous image correction techniques and spatial data analysis were employed to extract temperature values of Damaturu metropolis during this period, utilizing ArcGIS 10.8 and QGIS 3.10.6 software. Consequently, using the forecast tool and the Artificial Neural Network model in SPSS, future trends of Land surface Temperature in Damaturu metropolis from 2022 to 2042 were projected, leveraging the model's demonstrated efficacy in utilizing past trends to predict future events. The performance and implications of the employed prediction model were assessed by examining various indicators. The findings reveal a gradual increase in LST starting from 2027, raising concerns regarding potential temperature amplification and its impact on local ecosystems, human health, and socio-economic activities. This underscores the significance of ongoing afforestation programs and the urgent need for enhanced climate change adaptation strategies. However, the findings also indicate the potential impact of afforestation programs, specifically the Yobe State tree plantations, on temperature stability between 2016 and 2022. The study contributes to a better understanding of the relationship between afforestation initiatives and temperature dynamics, providing valuable insights for climate change adaptation strategies. Furthermore, this study will support the state government in achieving SDG 13 target 2, which entails integrating climate change measures into national policies, strategies, and planning. While the forecasts offer valuable insights, it is important to acknowledge the inherent uncertainties in climate modelling, emphasizing the need for flexibility and adaptation in policymaking processes.

Keywords: Land surface temperature (LST), Prediction and Temperature Amplification, Sdg 13: Climate Change Adaptation Strategies

I. INTRODUCTION:

In the periods of 2014, Damaturu was a victim of Arm conflict, forcing its' inhabitant to seek refuge in neighboring states. upon subsidence of the conflict in 2018 returnees started trooping in from their various locations. Correspondingly, people from hotspot location of this arm conflicts seek refuge in the state capital which has today increase in population prior to the arm conflict attack in 2014. This has led to great urban expansion which has reflected on the climate condition and has influence increase in land surface Temperature values, the climate has drastically change over the years and it has affected peoples' lives and agriculture.

Land surface temperature (LST) serves as a crucial measure of thermal radiance emitted from the Earth's land surface. By utilizing remotely sensed thermal infrared data, LST provides valuable insights into surface conditions (Tian et al., 2023). Isma'il, & Jajere (2014), projected the urban growth of Damaturu up to the year 2030 using linear regression statistics. Their findings indicated that Damaturu's urban area would expand from 54 km2 in 2009 to 99 km2 by 2030, representing an 82% increase in urban range and a 102% increment in built-up thickness. This expansion would result in the conversion of farmlands, impacting agricultural activities in nearby towns. The reduction in shrubs and vegetation cover due to urbanization raises concerns about the potential increase in urban heating and land surface temperature in the area. However, the existing studies in the area have largely overlooked the impact of land surface temperature on critical factors like tree loss and gain, desertification, and urban expansion (Babagana-Kyari, & Maina-Bukar, 2018). This research aims to bridge that gap by examining and forecasting future LST values, employing the SPSS forecasting tool and the Artificial Neural Network (ANN) modeling techniques (Rengma & Yadav, 2022). The generated 20-year dataset, spanning from 2022 to 2042, will empower policymakers to effectively address climate change, desertification, deforestation, and urban heat. By taking proactive measures aligned with Sustainable Development Goal 13 (SDG 13), this study will assist the state government in integrating climate change strategies into national policies, strategies, and planning, ensuring a sustainable future for Damaturu and beyond.

Land surface temperature (LST) plays a crucial role in various applications and can be assessed using satellite remote sensing imageries and metadata. The derived land surface temperatures are particularly significant for atmospheric models, as they aid in calculating heat exchanges between the top atmosphere and surface temperatures, as well as the air temperature near the surface (Rengma & Yadav, 2022).

Kolo, Adnan, & Umar, (2020) also observed a significant change in land use in Damaturu, attributed to population growth and development since the establishment of Yobe state. As the state capital, Damaturu has attracted a considerable influx of people and businesses, leading to the construction of institutional, residential, and commercial buildings. The authors noted a substantial conversion of agricultural land into built-up areas, and the rate of change accelerated between 1998 and 2017. These findings align with the conclusions of Isma'il, & Jajere (2014)

In summary, the literature highlights the importance of assessing land surface temperature using remote sensing techniques. Studies indicate the potential impact of urban growth on land use, agricultural activities, and vegetation cover, suggesting a possible increase in urban heating and land surface temperature in Damaturu. These insights provide a foundation for the current research, which aims to bridge the gap by examining and forecasting future land surface temperature values in the area.

II. STUDY AREA

Damaturu LGA is located in the northeastern part of Nigeria within the geographical coordinates of latitude 11°44'N and longitude 11°58'E (Musa, 2015). It serves as the capital and largest city of Yobe State. The LGA shares borders with other LGAs in the state, Tarmuwa to the North, Gujba to the South, Fune to the West and Kaga of Borno state to the East

Figure 1:

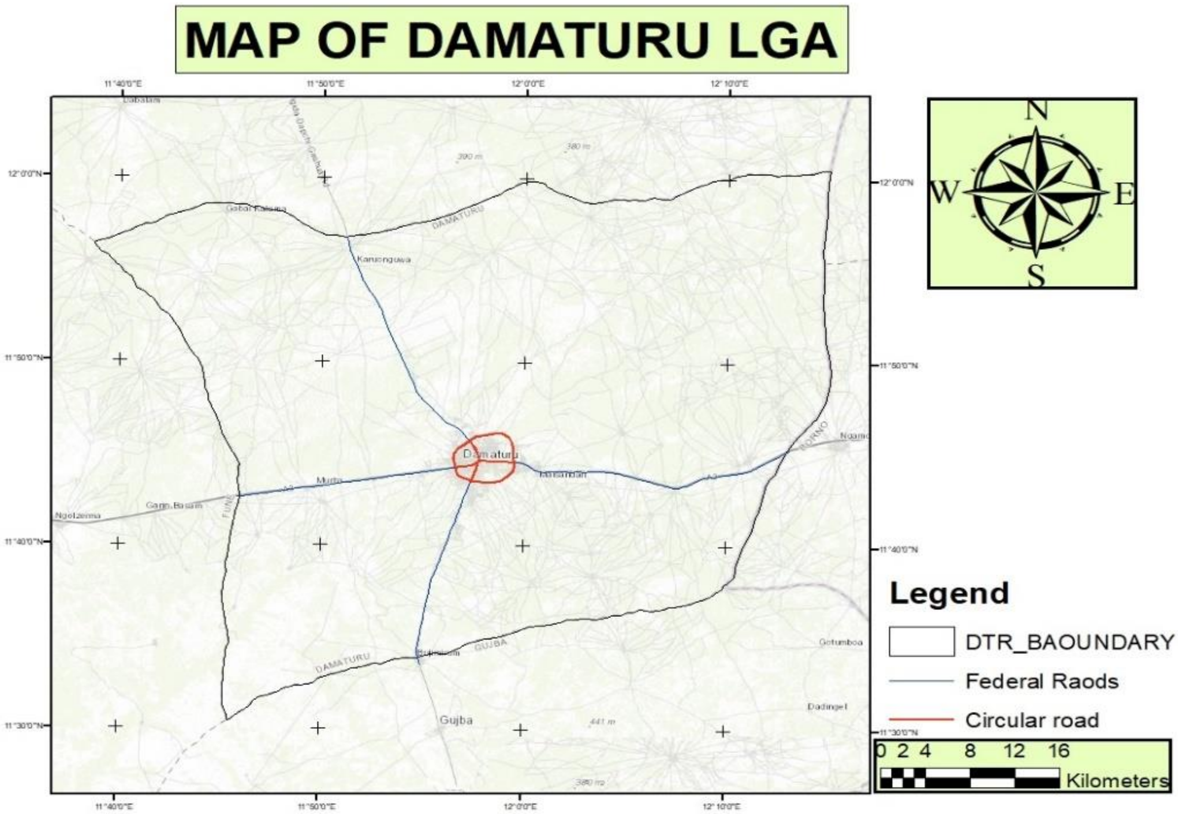


Figure 1: Map of Damaturu

In terms of socioeconomic dynamics, the study area exhibits a mix of agricultural, residential, and commercial activities. Agriculture is a prominent economic sector, with a significant portion of land allocated to farming. The cultivation of crops such as millet, sorghum, cowpea, maize, and vegetables contribute to the local economy and food production. Livestock rearing, including cattle, sheep, and goats, also plays a crucial role in the livelihoods of many residents (Sidi & Yerima, 2018); (Bukar, Bukar, Bakari, & Mbaya, 2020).

Damaturu town, being the administrative and commercial hub of the LGA, experiences urbanization and economic growth. It is home to various commercial establishments, markets, and infrastructure that cater to the needs of the local population and surrounding communities. The presence of residential areas, ranging from small rural settlements to larger towns, reflects the diverse population and cultural dynamics of the region ((Bukar, Bukar, Bakari, & Mbaya, 2020).

Temperature-wise, the study area experiences a tropical climate with distinct seasons. Damaturu LGA, situated in the northeastern part of Nigeria, faces hot and dry conditions for a significant part of the year. The average annual temperature ranges from 28°C to 35°C (82°F to 95°F). During the dry season, typically occurring from November to March, temperatures can be particularly high, often exceeding 40°C (104°F). The hot and arid climate significantly influences agricultural practices, water resources, and human activities in the area (Musa, 2015). Damaturu LGA primarily consists of flat to gently undulating land, with occasional hills and rocky outcrops. The landscape is characterized by vast plains and plateaus, providing relatively flat areas for agricultural cultivation. The topography also influences the drainage patterns and water flow within the LGA. Shallow depressions and small rivers contribute to the hydrological system, affecting water availability and land use decisions (Sidi & Yerima, 2018).

The study area includes natural land covers such as shrubs, grasslands, and patches of trees. These areas serve as grazing grounds for livestock and support local biodiversity ((Bukar, Bukar, Bakari, & Mbaya, 2020). In the system of governance, Damaturu LGA operates under the local government administration of Yobe State. The LGA is headed by an elected Chairman responsible for overseeing the affairs of the local government and representing the interests of the residents. The local government administration is responsible for providing basic amenities, infrastructure development, education, healthcare services, and other essential public services to the residents of Damaturu LGA.

III. METHODOLOGY

Figure 2:

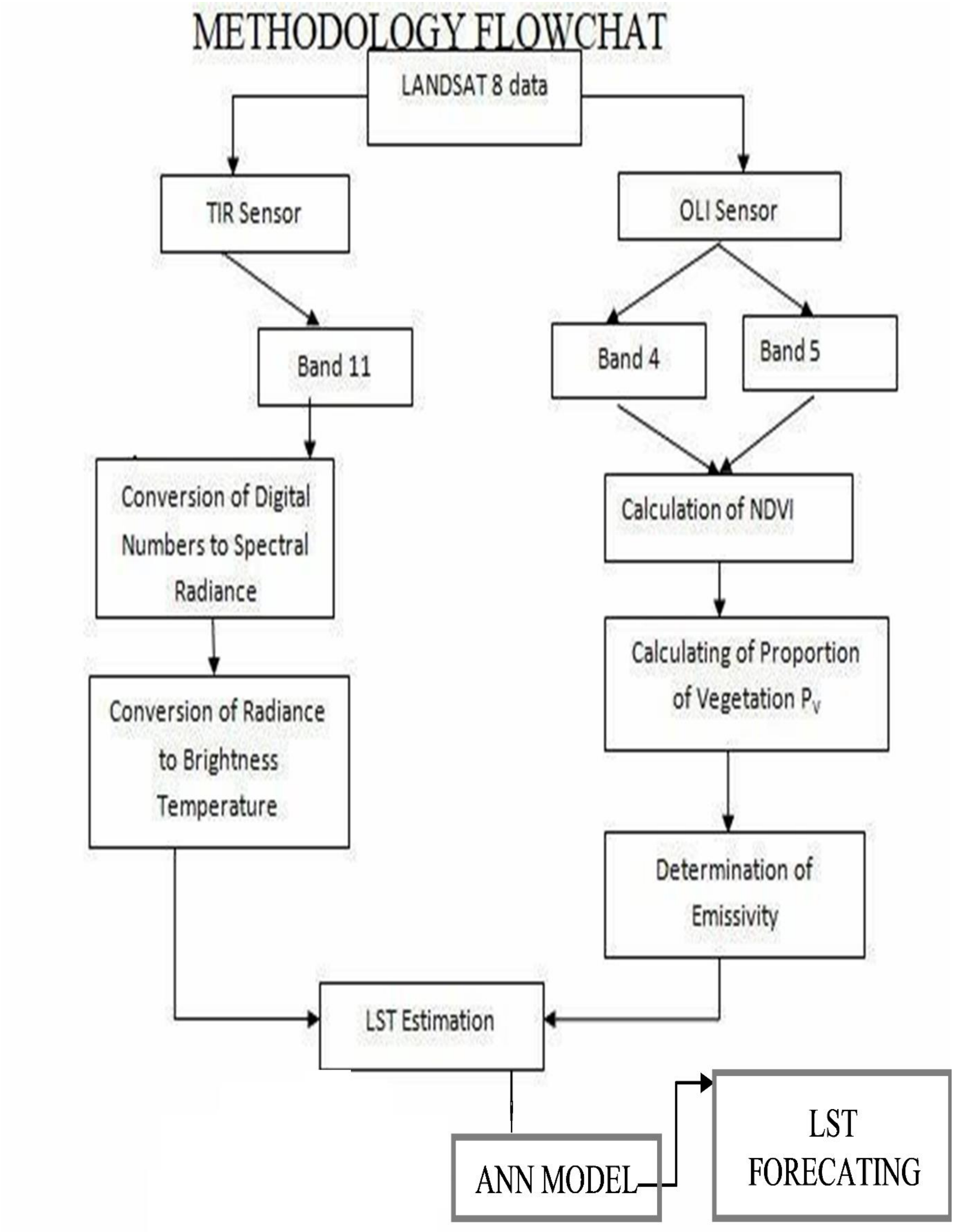


Figure 2: Methodology flowchart.

Data Acquisition and Preprocessing

Landsat satellite images covering the study area were obtained from the United States Geological Survey (USGS), considering their spatial and temporal resolutions (Tian et al., 2023). These images provide a valuable source of information for monitoring LST. Preprocessing techniques, including atmospheric correction and radiometric calibration, were applied to remove atmospheric effects and sensor-specific biases (Tian et al., 2023). Atmospheric correction methods were utilized to account for atmospheric conditions and improve the accuracy of temperature estimation. Radiometric calibration was performed to ensure consistency across different images and sensors.

Image Conversion, Rasterization, and Temperature Extraction

Rasterization allows for easier data manipulation and extraction of temperature values. Temperature values were then extracted from the raster data, ensuring spatial alignment with ground truth measurements (Tian et al., 2023). Various techniques can be employed for temperature extraction, such as the brightness temperature values provided by Landsat thermal bands or the split-window algorithm. In this study, a robust approach was adopted to extract temperature values accurately.

Data Storage and Management

The extracted temperature data were stored in an Excel database for further analysis (Tian et al., 2023). This facilitated efficient data management and organization, enabling easy retrieval and processing of temperature information.

Forecasting using SPSS and Artificial Neural Networks (ANN)

To forecast future LST, the SPSS forecasting tool was utilized. SPSS provides a comprehensive set of forecasting techniques that can capture trends and patterns in the data. Additionally, artificial neural networks (ANN) were employed as a powerful tool for modeling complex relationships between variables and predicting future temperature trends (Rengma & Yadav, 2022). ANN algorithms, such as multilayer perceptron (MLP), were trained using historical temperature data to generate forecasts for future time periods. The utilization of the SPSS forecasting tool and artificial neural networks (ANN) enhances the accuracy and robustness of temperature forecasting in this study. SPSS offers a range of statistical techniques specifically designed for time series analysis and forecasting, allowing for the identification of temporal patterns and trends in LST. ANN, on the other hand, is a machine learning approach that can capture non-linear relationships and intricate dependencies between variables, enabling more accurate predictions of future temperature trends (Rengma & Yadav, 2022).

IV. RESULTS & DISCUSSION

3.1 Baseline Temperature:

In 2016, the baseline LST in Damaturu was estimated to be 32 degrees Celsius. This initial value provides a reference point for assessing temperature variations in subsequent years. To visually represent the trends in land surface temperature, the study includes Figure 2. It provides a visual depiction of how the land surface temperature has evolved in the area, offering more insights into the climate patterns, temperature fluctuations, and potentially the impact of environmental factors on the land surface temperature of Damaturu. Analyzing these trends may help researchers identify patterns, anomalies, or long-term changes in temperature, which could have implications for the local environment, ecosystems, and human activities

Figure 3:

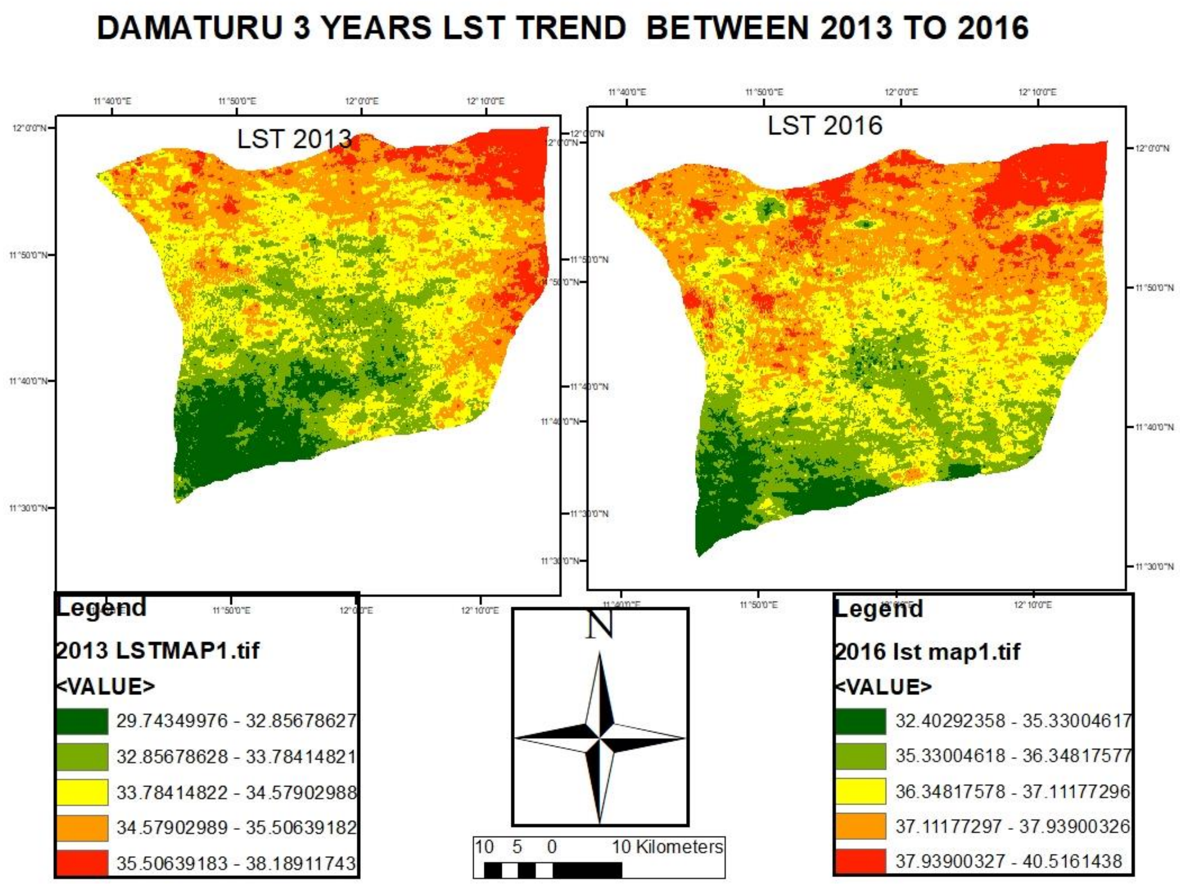


Figure 3: Trends in Land Surface Temperature in Damaturu

In 2013, the LST in Damaturu was on average recorded as 31 degrees Celsius. This indicates a slightly lower temperature compared to the baseline value of 32 degrees Celsius in 2016. For the year 2018, the LST remained consistent with the baseline value of 32 degrees Celsius, indicating no significant change in temperature compared to 2016. It's worth noting that the data is limited and does not include values for every year between 2013 and 2022. However, based on the available data, it suggests some variation in LST over the years, but not a consistent trend or clear pattern. This could be as a result of the influence of various factors, including natural climate variability, local weather patterns, and regional environmental conditions. These factors can introduce fluctuations that might obscure any underlying long-term trends. However, between 2016 and 2022, the LST values remained relatively stable, ranging from 31 to 35 degrees Celsius.

Figure 4:

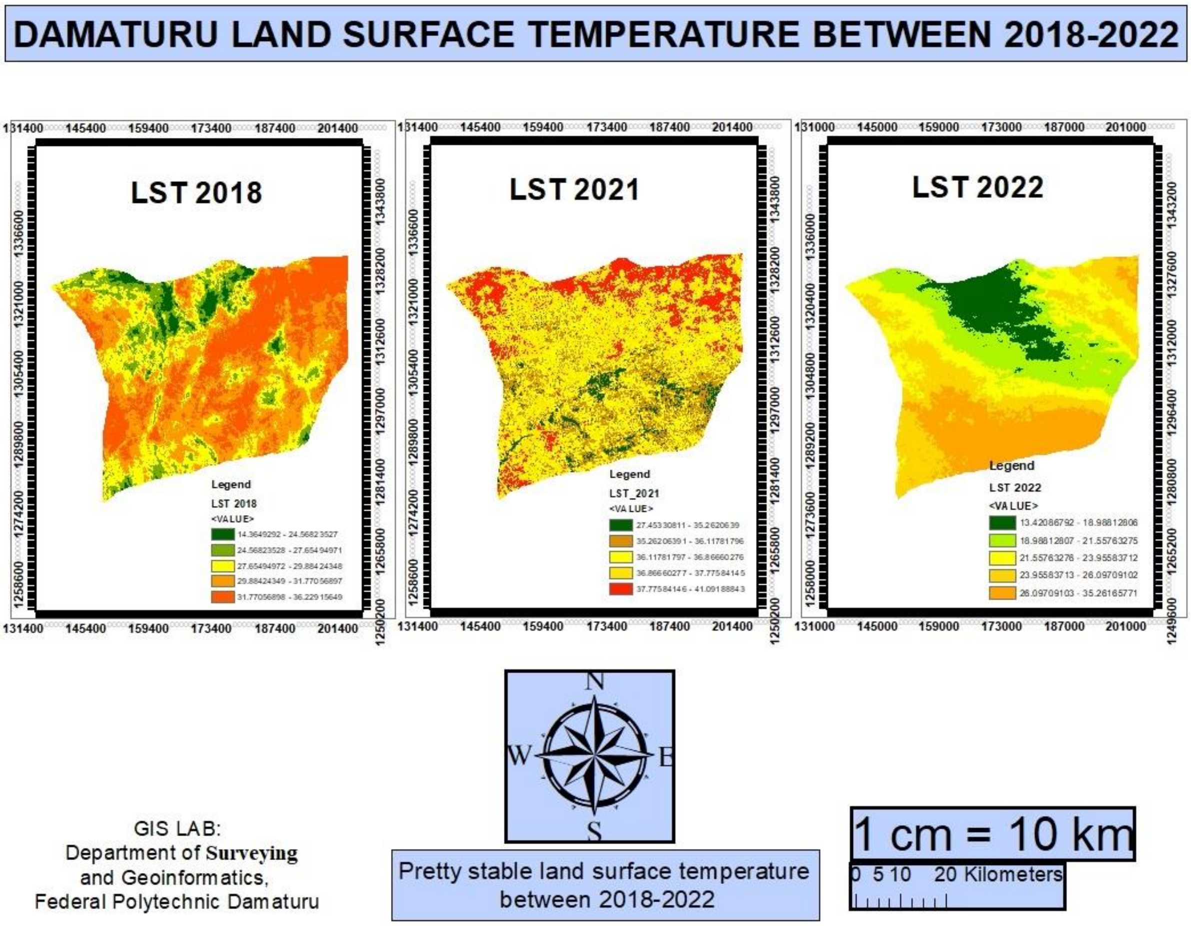


Figure 4: LST 2018-2022

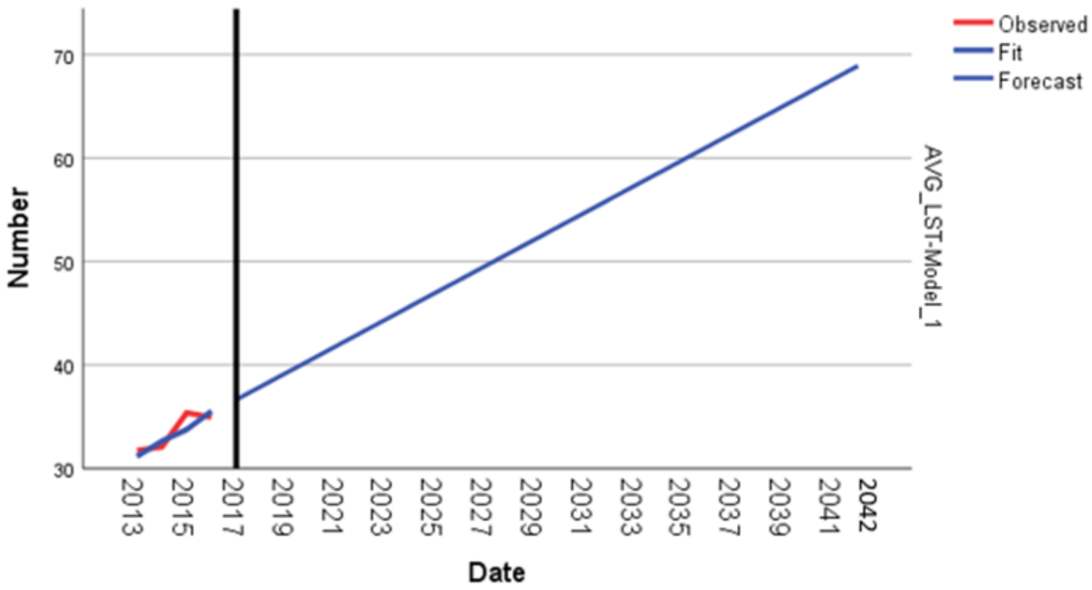
This period of temperature stability coincides with the implementation of afforestation programs, suggesting a potential relationship between vegetation cover and land surface temperature regulation. The Yobe State tree plantations and the Great Green Wall intervention likely contributed to maintaining stable temperatures by reducing the urban heat effect and enhancing ecosystem services.

Transition Period:

From 2023 to 2026, a transitional phase was observed in the LST data, with temperatures ranging from 31 to 36 degrees Celsius. This period signifies a potential shift in climate dynamics or the influence of localized factors on surface temperatures. It highlights the need for further investigation into the drivers of temperature variations and their relationship with afforestation efforts.

Figure 3: Average Land surface Temperature trend between 2013- 2042

Table 1: Model Fit



Fit Statistic	Mean	SE	Minimum	Maximum	Percentile 5	10	25
Stationary R-squared	.868	.	.868	.868	.868	.868	.868
R-squared	.662	.	.662	.662	.662	.662	.662
RMSE	1.345	.	1.345	1.345	1.345	1.345	1.345
MAPE	2.453	.	2.453	2.453	2.453	2.453	2.453
MaxAPE	4.583	.	4.583	4.583	4.583	4.583	4.583
MAE	.836	.	.836	.836	.836	.836	.836
MaxAE	1.622	.	1.622	1.622	1.622	1.622	1.622
Normalized BIC	1.286	.	1.286	1.286	1.286	1.286	1.286

Table 2: Model Statistic

Fit Statistic	Percentile 50	75	90	95
Stationary R-squared	.868	.868	.868	.868
R-squared	.662	.662	.662	.662
RMSE	1.345	1.345	1.345	1.345
MAPE	2.453	2.453	2.453	2.453
MaxAPE	4.583	4.583	4.583	4.583
MAE	.836	.836	.836	.836
MaxAE	1.622	1.622	1.622	1.622
Normalized BIC	1.286	1.286	1.286	1.286

The average LST Model used in this study shows promising results in estimating and predicting land surface temperature (LST) in Damaturu metropolis. The model exhibits a stationary R-squared value of 0.868, indicating that it explains approximately 86.8% of the stationary variation in LST. Additionally, the R-squared value of 0.662 suggests that the model can account for about 66.2% of the total variation in LST. The root means square error (RMSE) of 1.345 indicates the average magnitude of the prediction error in LST. This suggests that, on average, the model's predictions deviate by 1.345 units from the actual LST values. The mean absolute percentage error (MAPE) of 2.453 indicates that the model's predictions deviate by approximately 2.453% from the actual LST values on average. The maximum absolute percentage error (MaxAPE) of 4.583 represents the maximum deviation in LST predictions.

Furthermore, the mean absolute error (MAE) of 0.836 signifies the average absolute difference between the observed and predicted LST values. The maximum absolute error (MaxAE) of 1.622 indicates the maximum deviation between the observed and predicted LST values.

The normalized Bayesian information criterion (BIC) of 1.286 suggests a relatively good fit of the model, considering its goodness-of-fit and complexity. The high R-squared and stationary R-squared values indicate a strong relationship between the model's inputs and the observed LST values. The relatively low RMSE and MAE values imply that the model's predictions are generally close to the actual LST values.

The forecasted LST values for Damaturu metropolis from 2022 to 2042, utilizing the lower confidence level estimates, reveal potential temperature trends and implications for the region. These lower confidence level estimates provide a more conservative range of temperatures, which may align closer to the measured LST values and account for uncertainties in the forecasting model.

Table 3: Average LST forecast 2013-2022.

Model		2013	2017	2018	2019	2020	2021	2022
AVG_LST-Model_1	Forecast	31	37	38	39	41	42	43
	UCL	32	42	44	46	47	49	50
	LCL	28	31	32	33	34	35	36

Forecast

Table 4: Average LST forecast 2023-2028

Model		2023	2024	2025	2026	2027	2028
AVG_LST-Model_1	Forecast	44	46	47	48	50	51
	UCL	52	53	55	56	58	59
	LCL	37	38	39	40	42	43

Forecast

Table 5: Average LST forecast 2029-2034

Model		2029	2030	2031	2032	2033	2034
AVG_LST-Model_1	Forecast	52	53	55	56	57	59
	UCL	60	62	63	65	66	68
	LCL	44	45	46	47	48	49

Forecast

Table 6: Average LST forecast 2029-2034

Model		2035	2036	2037	2038	2039	2040
AVG_LST-Model_1	Forecast	60	61	62	64	65	66
	UCL	69	71	72	74	75	76
	LCL	50	52	53	54	55	56

Forecast

Table 7: Average LST forecast 2041-2042

Model		2041	2042
AVG_LST-Model_1	Forecast	68	69
	UCL	78	79
	LCL	57	58

Starting from 2017, the projected LST values based on the lower confidence level estimates indicate a temperature range of 31°C to 36°C on the average. As we progress through the years, the temperatures gradually increase, reaching 42°C in 2022 which is pretty stable considering the region being a temperate region. These values, representing the lower end of the forecast range, suggest a cautious estimate of the potential future LST in Damaturu metropolis.

Continuing to the period from 2023 to 2042, the forecasted LST values based on the lower confidence level estimates consistently indicate higher temperatures. Starting from 2027, a gradual increase in LST was observed, with temperatures rising to 57 degrees Celsius by 2042.The range varies from 37°C to 59°C on the average, gradually increasing over time. These values, although considered the lower bound of the forecast, provide insights into the potential temperature scenarios that the region might experience.

It is important to note that utilizing the lower confidence level estimates as the predicted LST values assumes a more conservative approach, considering the potential variability and uncertainties in the forecasting model. While the lower confidence level estimates may not capture the extreme high-end temperatures, they provide a more reliable and cautious estimate of the future LST in Damaturu metropolis.

The implications of these forecasted LST values based on the lower confidence level estimates are significant. The gradual increase in temperatures over time raises concerns about potential temperature amplification and its impact on local ecosystems, human health, and socio-economic activities. Higher temperatures can affect agricultural productivity, water availability, and overall quality of life in the region. These forecasted LST values emphasize the importance of ongoing afforestation programs and the urgent need for enhanced climate change adaptation strategies in Damaturu metropolis. Afforestation initiatives, such as the Yobe State tree plantations and the Great Green Wall intervention, may play a crucial role in mitigating the potential impacts of rising temperatures. These programs can contribute to temperature stability, as indicated by the findings between 2016 and 2022, and provide valuable insights for climate change adaptation strategies.

It is crucial for policymakers and stakeholders to consider the forecasted LST values based on the lower confidence level estimates in their decision-making processes. While the lower confidence level represents a more conservative estimate, it helps account for uncertainties and provides a range of potential temperature scenarios. This approach ensures flexibility and adaptability in formulating effective mitigation and adaptation strategies.

Implications and Future Directions:

The findings of this study have significant implications for climate change adaptation and afforestation programs. The observed temperature stability between 2016 and 2022 suggests that the Yobe State tree plantations and the Great Green Wall intervention played a role in mitigating temperature variations. However, the subsequent transition period and temperature increases indicate the need for continued efforts in afforestation and climate change adaptation strategies. Future research should focus on integrating additional data sources, advanced modeling techniques, and ground-based measurements to enhance the accuracy and reliability of LST estimation in Damaturu. Furthermore, assessing the effectiveness of afforestation programs in mitigating temperature variations and their socio-economic implications should be explored.

Policy Implications:

The findings present several insights and underlined issues for policymakers:

1. **Climate Change Adaptation:** The rising LST underscores the need for prioritizing climate change adaptation strategies. Heat mitigation measures, urban planning for reducing the urban heat effect, and promoting green spaces and sustainable infrastructure can help Damaturu cope with increasing temperatures.
2. **Health and Vulnerable Populations:** The significant increase in LST raises concerns for public health, particularly vulnerable populations. Developing heatwave response plans, providing adequate healthcare facilities, and creating awareness about heat-related illnesses are crucial steps to mitigate health risks.
3. **Energy Consumption and Demand:** As temperatures rise, the demand for cooling systems and energy consumption will increase. Policymakers should promote energy-efficient practices, incentivize energy conservation, and explore renewable energy sources to mitigate strain on the energy grid and reduce greenhouse gas emissions.

4. **Water Resources Management:** Higher temperatures lead to increased evaporation rates and water stress. Sustainable water resources management through conservation measures, efficient irrigation techniques, and water recycling and rainwater harvesting is essential for ensuring water availability and resilience.
5. **Agricultural Impacts:** The changing climate and rising temperatures pose challenges for agriculture and food security. Policymakers should support climate-smart agricultural practices, provide access to drought-resistant crop varieties, improve irrigation systems, and establish early warning systems to ensure food security.
6. **Research and Monitoring:** Continuous research and monitoring of climate trends, including LST, are crucial. Investment in climate monitoring systems, collaboration with scientific institutions, and real-time data gathering can inform evidence-based policies and decision-making.
7. **Collaboration and International Commitments:** Addressing climate change requires collaboration and international commitments. Active participation in international climate agreements, knowledge sharing, and resource mobilization can facilitate effective climate change mitigation and adaptation strategies.

Conclusion:

This study provides valuable insights into the estimation and prediction of land surface temperature in Damaturu. The findings highlight the importance of afforestation programs in maintaining temperature stability and the need for ongoing climate change adaptation strategies. The rising temperatures underscore the urgency for policymakers to prioritize heat mitigation measures, health protection, energy efficiency, water resource management, agricultural resilience, research, and international collaboration. While the forecasts offer valuable insights, uncertainties inherent in climate modelling necessitate flexibility and adaptation in policymaking processes. By addressing the challenges posed by increasing temperatures, Damaturu can build resilience and create a sustainable future for its residents.

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