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Using Geospatial Data for Sustainability Analysis

Overview on the Factors Influencing Rising Land Surface Temperature (LST)

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Abstract

The presented study delves into the realm of geospatial analysis, employing geographic information systems and satellite imagery to examine rising Land Surface Temperature (LST) and its implications for sustainability across urban areas. The study highlights LST's pivotal role in urban climate dynamics, affecting energy balance, air temperature, and atmospheric patterns. Methodologically, the research employs Google Earth Engine for data acquisition and processing. The results showcase LST trends, correlations with urbanisation, deforestation, precipitation, and other factors. Urbanisation fosters distinct heat islands, while deforestation and land use changes impact climate. Precipitation emerges as a key moderator, inversely correlated with LST. The study underscores the complex interplay of these elements, emphasising the importance of strategic urban planning and sustainable practices to mitigate adverse effects. The paper concludes by envisioning future LST trends and advocating collaborative efforts for climate action and sustainable development.

Keywords

Greenhouse gases, urbanisation, deforestation, rain precipitation, SARIMA

1. Introduction

Geospatial analysis utilises geographic information system and satellite imagery to understand geographic trends for sustainability in various sectors. It aids in planning, resource management, and decision-making like tourism and agriculture through tasks such as location assessment and trend analysis (Mathenge, Sonneveld, & Broerse, 2022) (Acharya, et al., 2022). The study focuses on rising LST, a key factor in urban climate dynamics, affecting energy balance, air temperature, and atmospheric patterns (Ibrahim, Abu Samah, & Fauzi, 2012). Changes in LST impact local weather, radiation, and water balance due to factors like vegetation and impervious surfaces. LST plays a vital role in urban climate dynamics, driving ecological shifts and affecting vegetation cycles. These temperature changes greatly influence energy balance and have implications for climate, hydrology, and urban planning amid climate change mitigation (How Jin Aik, Ismail, Muharam, & Alias, 2021).

2. Methodology

To investigate the phenomenon of rising LST, we propose several factors of interest that could be correlated which include urbanisation, deforestation, rain precipitation, vegetation, and ozone. Areas of interest are limited to Selangor, Kuala Lumpur and Putrajaya spanning from 2014 to 2023. The data acquisition process involves specifying time periods and regions of interest (ROI), selecting relevant bands, filtering out clouds and shadows and applying the *reduceRegion* function to quantify the factors of interest on Google Earth Engine, which is a cloud-based geospatial processing platform that is extensively used in this study. The dataset and bands used to obtain respective data are stated in Table 1.

Factor Studied	Dataset	Band(s) used
LST	Landsat 4-9	B6, B10
Urban expansion	Landsat 4-9	B2, B3, B4, B5, B6
Enhanced Vegetation Index (EVI)	Moderate Resolution Imaging Spectroradiometer (MODIS)	EVI
Forest change	Hansen Global Forest Change v1.10	treecover2000, loss
Precipitation	CHIRPS	precipitation
Ozone	TOMS and OMI	ozone

Table 1: Dataset and band(s) used for the study.

3. Result

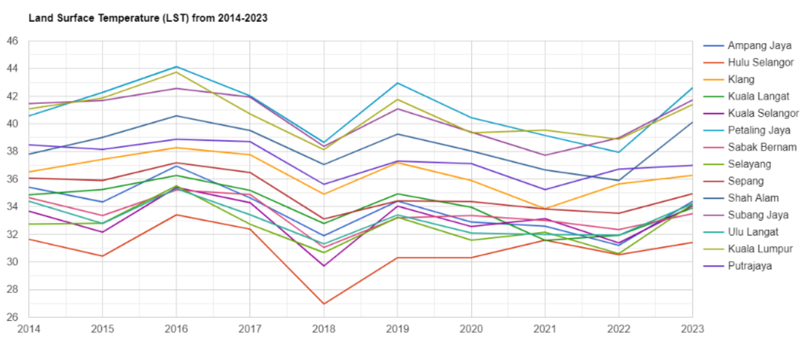
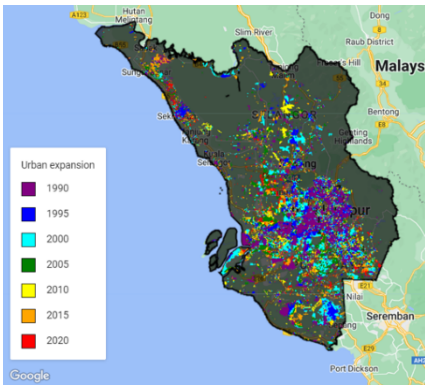


Figure 1: LST from 2014-2023 (Ramadhan, 2023)
(Data source: Landsat 4-9 OLI images courtesy of the U.S. Geological Survey).

Figure 1 illustrates the LST trend for the ROI which exhibits consistent patterns with varying magnitudes. A noteworthy event is evident in 2018, indicating a significant LST reduction universally, which is caused by a sudden drop in temperatures throughout Selangor. This drop was also consistent globally and was caused by the occurrence of La Nina that year (Global Climate Highlights - Globe in 2022, 2022). A slight temperature decrease is observed during the height of the COVID-19 pandemic between 2020 and 2021 which correlates to the global trend attributed to reduced human activities. The main factors studied are urbanisation, deforestation, and rain precipitation. Vegetation and ozone concentrations were also studied, but no significant trend across the different localities were identified.

3.1 Urbanisation

Most of the urban expansion took place in the 1990s and early 2000s, as depicted in Figure 2. Figure 3 illustrates urban area changes across various regions from 2014 to 2023, revealing a generally static trend in urban expansion. Notably, Sabak Bernam experienced decreasing urban area changes, and an intriguing connection emerges between the movement control orders (MCO) in 2020-2022 and corresponding shifts in urban area alterations, implying an intricate interplay involving regulatory actions, economic dynamics, and land utilisation effects.



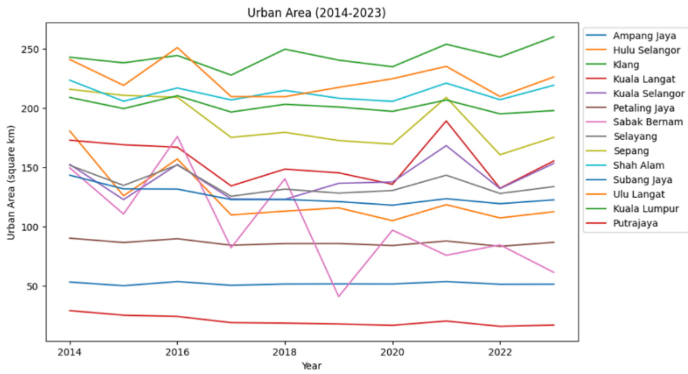
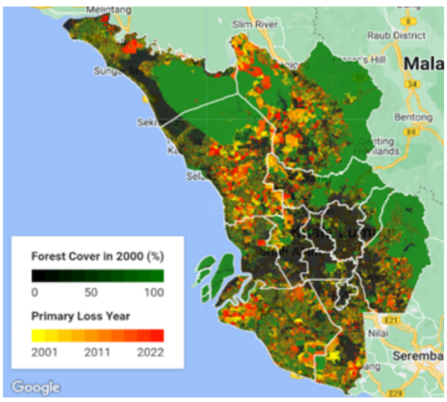


Figure 2: Urban expansion (1995-2020) *Figure 3: Urban Area (2014-2023)*
(Data source: Landsat 4-9 OLI images courtesy of the U.S. Geological Survey)

3.2 Deforestation and Land Use Change



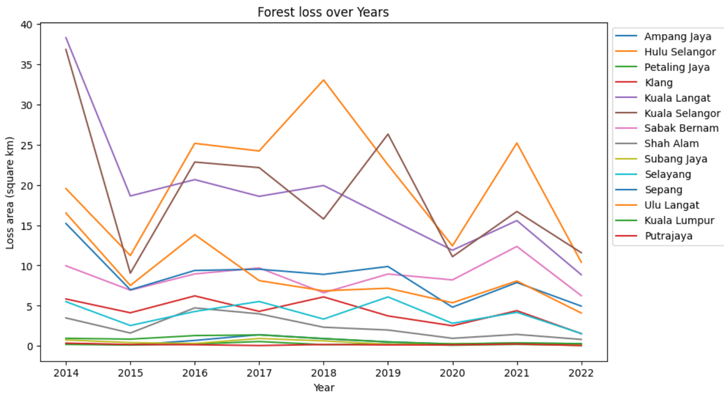


Figure 4: Forest cover % (2000) & primary loss year *Figure 5: Forest Changes (2014-2022)*
(Data source: Hansen Global Forest Change v1.10 (2014-2022) (Hansen, et al., 2013)

Figure 4 displays the extent of forested areas and the areas of forest loss, highlighted between red to yellow from high to low concentration, within Selangor in 2022. The trend depicted in Figure 5 demonstrates a continual decrease in forest loss occurrences over the study period, with 2022 total loss area measuring at 50.87km^2. Notably, most of the forest loss transpired in regions with lower urban population density, where a substantial portion of land is covered by forests in the northern and eastern parts of Selangor.

3.3 Precipitation

Figure 6 shows the precipitation level in the year 2022, indicating a significantly greater rainfall within the Titiwangsa range, located in the northeastern part of Selangor. Figure 7 suggests that areas along this mountain range, such as Hulu Selangor, consistently receive higher precipitation each year, while lowland areas like Sepang receive comparatively less. Remarkably, a consistent trend emerges, as most regions experience simultaneous fluctuations in precipitation levels over the years.

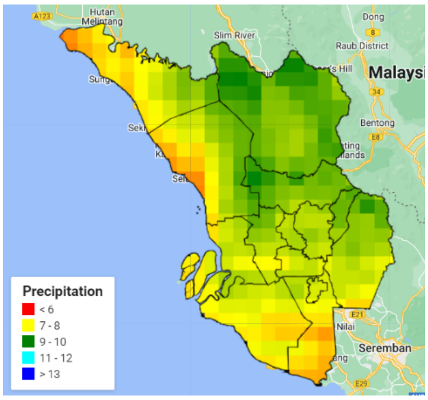


Figure 6: Precipitation Level in 2022

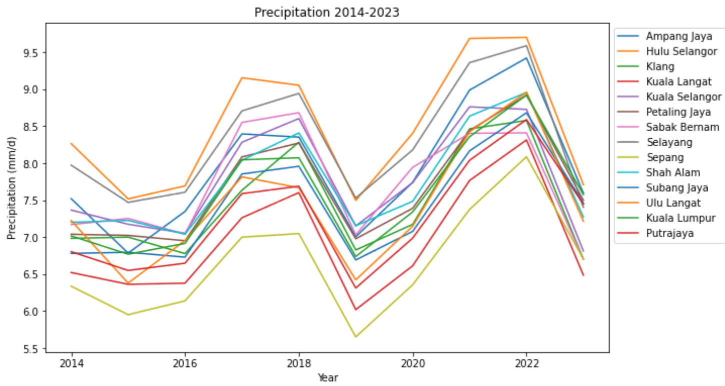


Figure 7: Precipitation (2014-2023)

(Data source: CHIRPS provided by CHC, UCSB).

3.4 Correlation Analysis

The correlation matrix illustrated in Figure 8 represents the relationships between the various factors against LST for different localities. The matrix indicates that higher positive values of urban area and deforestation are generally associated with higher LST. Conversely, rain precipitation is highly negatively correlated with LST. Ozone concentration, while positively correlated, seems to vary from localities. These suggests a complex interplay between a multitude of environmental factors and human activities which ultimately affect the LST as will be discussed in the next section.

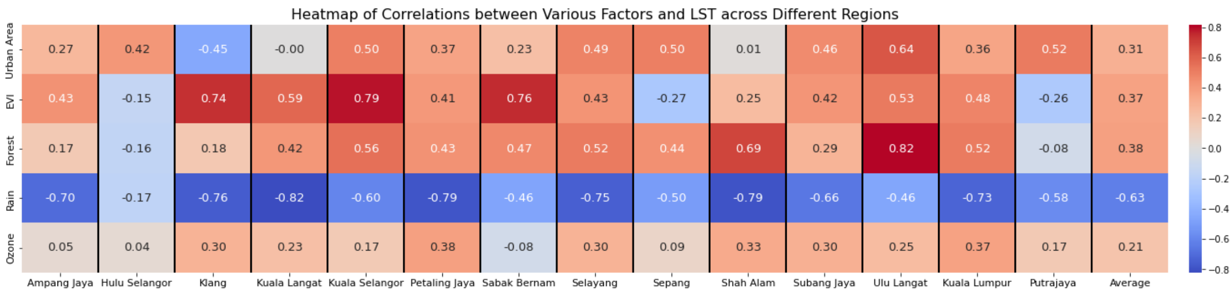


Figure 8: Correlation Matrix of Factors affecting LST.

4. Discussion and Conclusion

Based on the correlation matrix in Figure 8, the three influential factors contributing to the rising of LST are as follows:

4.1 Urbanisation

In these densely populated urban centers, distinct surface urban heat islands (SUHI) emerge, characterized by significantly higher temperatures compared to the surrounding rural areas. This temperature contrast stems primarily from human activities, alterations in land use patterns and the pervasive built environment. The resultant heat islands lead to discernible temperature differentials and potential consequences for local climates, energy usage, and overall urban well-being. Mitigating the adverse impacts of urban expansion on LST necessitates strategic urban planning approaches that emphasize the integration of green spaces, sustainable infrastructure, and climate-friendly architectural designs.

4.2 Deforestation and Land Use Change

Forest loss primarily occurs in sparsely populated regions with ample forest cover, as seen in places like Hulu Selangor, Kuala Selangor, Kuala Langat, and Sabak Bernam – showcasing an inverse relationship with the extent of urban development. An uptick in deforestation was observed during the peak of the pandemic, potentially attributable to shifts in economic activities, reduced enforcement of conservation efforts, and altered land use priorities (Anna Gross, 2020). Deforestation, coupled with land use changes like urbanisation and vegetation, significantly drives climate change. Trees serve as carbon sinks, absorbing CO^2 while deforestation releases stored carbon, elevating greenhouse gases. This diminishes Earth's CO^2 absorption capacity, compounding the issue further.

4.3 Precipitation

Higher precipitation levels are generally associated with lower LST, primarily due to the high cooling effect they exert. Rainwater evaporates, absorbing atmospheric heat and cooling nearby surfaces and air, resulting in marked LST reduction. The negative correlation between precipitation and LST underscores the important role of rainfall in moderating local climates. The significance of this relationship becomes particularly evident during years marked by substantial precipitation drops, such as in 2019, leading to a significant increase in LST. Notably, regions along the Titiwangsa range, with orographic lifting, experience greater precipitation as air ascends over the mountains, leading to decrease in temperatures.

4.4 Future Prediction of LST

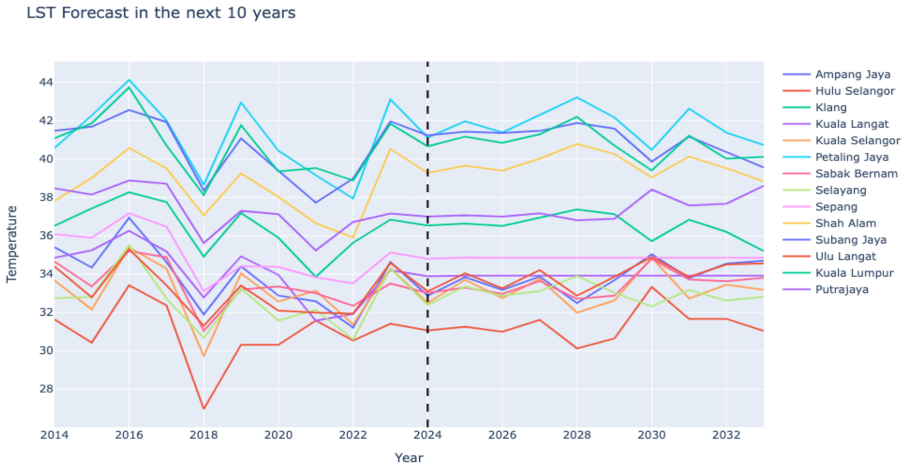


Figure 9: Predictions of LST for the next 10 years

As observed in Figure 9, the predictions for LST in the next 10 years appear to be stable with the occasional fluctuations in different areas over Klang Valley in 2030. The forecasted results were conducted using a featureless SARIMA (time series model) due to the unavailability of future features data. The results do not have any significant spikes without any features therefore cautions must be placed with what goes on in the next 10 years. With the data and factors presented in this paper, actions such as an increased in urbanisation, deforestation and land use change could cause an increase in LST due to their high positive correlation.

4.5 Conclusion

Geospatial analysis is essential for comprehending the spatial and temporal variations of LST and its interactions with factors like urbanisation, vegetation, forest change, rain precipitation and ozone. Elevated LST, driven by land use shifts and greenhouse gas emissions, can bring about climate shifts with potential effects on river and basin hydrology, altering runoff processes. Human-induced climate changes from activities like modifying land use and releasing greenhouse gases can considerably disturb natural water flow, influencing water movement in landscapes (How Jin Aik, Ismail, Muharam, & Alias, 2021). Collaborative endeavours spanning various sectors are essential to drive climate action, lower temperatures, and advance Sustainable Development Goals, requiring the integration of sustainable urban planning, prudent land use, and effective policies to mitigate the urban heat island effect and promote overall sustainability.

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