DIACHRONIC ANALYSIS OF LAND COVER AND EARTH SURFACE TEMPERATURE IN THE CITY OF DAKAR OVER THE PAST 30 YEARS

Policybrief

Source: Think tank UCAD

Consortium

Abstract

This study evaluated the impact of land use and land cover changes on land surface temperature (LST) in Dakar between 1986 and 2023. By employing a classification approach combined with spectral indices, the analysis revealed substantial urban expansion, accompanied by a decline in vegetation and wetland areas. This enabled an in-depth examination of the relationship between LST and various land cover types. The findings indicate a weakly positive correlation between LST and the Normalized Difference Built-up Index (NDBI), with a significantly pronounced urban heat island effect compared to surrounding areas. Public awareness campaigns are recommended to highlight the value of green and blue infrastructure and to promote their conservation for the well-being of Dakar's urban population.

Introduction

Urbanization presents significant environmental challenges, notably by altering land surface characteristics, which in turn modifies local thermal conditions and causes urban areas to become warmer than their rural surroundings (Awuh et al., 2019). Over time, changes in land use and land cover (LUC) driven by human activities have led to wide-ranging environmental impacts, including disruptions to the surface energy balance and variations in land surface temperature (LST) (Mirza & Sajjad, 2022).

LST reflects the interaction between the Earth's surface and the atmosphere, with heat exchanges that directly influence human comfort and health. It is shaped by meteorological factors such as solar radiation, wind speed, and the physical properties of surface materials. The Urban Heat Island (UHI) effect – characterized by higher temperatures in urban areas compared to adjacent rural zones – is strongly linked to anthropogenic activities and dense built-up environments, underscoring the close relationship between urban development, LST, and UHI phenomena (Jiang & Tian, 2023).

Numerous studies have demonstrated that integrating Land Surface Temperature (LST) and land cover (LC) data through remote sensing and statistical analysis offers valuable insights by generating spatially continuous datasets at the city or regional scale. This integration enables the visualization of spatial relationships between temperature distribution and land use patterns, including infrastructural characteristics (Awuh et al., 2019). Statistical and comparative methods are useful for exploring causal links between

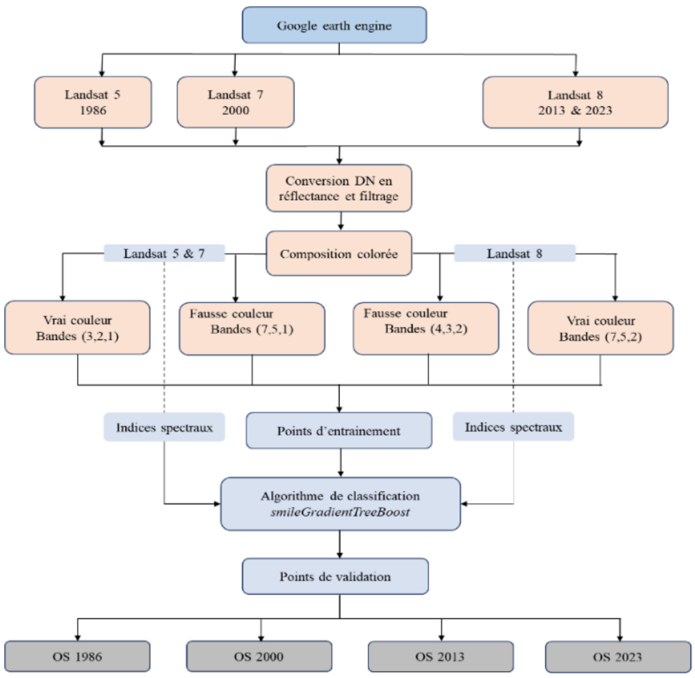
LST and standardized land use/land cover indices, such as the Normalized Difference Vegetation Index (NDVI), Normalized Difference Built-Up Index (NDBI), and Normalized Difference Water Index (NDWI).

In the case of Dakar, the city has undergone substantial population growth over the past three decades, leading to accelerated urbanization to meet housing and infrastructure needs. Since urban growth is typically accompanied by significant landscape transformations, this study seeks to address two central research questions: (1) What changes have occurred in land cover classes in Dakar over the past thirty years? and (2) How has land surface temperature evolved in response to these land cover changes?

Method

The image preprocessing and classification process began with the conversion of raw digital numbers into surface reflectance values to ensure data comparability across different time periods. This step was followed by filtering procedures to eliminate pixels affected by clouds and other anomalies, thereby enhancing the reliability of the satellite image measurements.

To analyze land cover, several spectral indices were utilized: the Normalized Difference Vegetation Index (NDVI) for assessing vegetation health, the Normalized Difference Built-up Index (NDBI) for identifying built-up areas, the Normalized Difference Water Index (NDWI) for detecting water bodies, and the Bare Soil Index (BSI) for characterizing soil exposure. These indices provided a comprehensive understanding of land cover dynamics as observed from satellite imagery.



Various spectral indices are employed to analyze land cover characteristics using satellite imagery. The Normalized Difference Vegetation Index (NDVI) quantifies vegetation cover, the Normalized Difference Built-up Index (NDBI) assesses the density of built-up areas, the Normalized Difference Water Index (NDWI) detects water bodies, and the Bare Soil Index

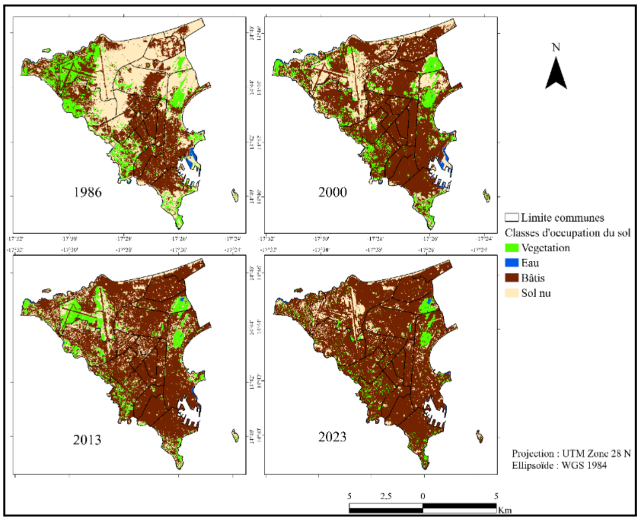
(BSI) captures variations in soil exposure. Together, these indices provide valuable insights into the spatial distribution and changes in land cover.

Land Surface Temperature (LST) is derived from the thermal infrared bands of Landsat 5, 7, and 8. Digital numbers (DNs) from these sensors are converted into temperature values through standardized radiometric and thermal conversion formulas. This enables the identification of surface temperature patterns and the detection of high-temperature zones, which are critical for evaluating thermal dynamics across landscapes.

The Urban Heat Island (UHI) effect is assessed by comparing LST values between urban and non-urban areas. Additionally, the Urban Thermal Field Variation Index (UTFVI) is calculated to measure intra-urban temperature differences and determine the intensity of heat islands within cities. Land cover classification is conducted using supervised classification techniques, and model performance is validated through overall accuracy metrics and the kappa coefficient. These methodologies together facilitate a comprehensive analysis and quantification of environmental phenomena from satellite images.

Results and Conclusion

Land use analysis over the period 1986, 2000, 2013, and 2023 reveals substantial changes in Dakar's urban landscape. Built-up areas expanded significantly, from 32.18 km² in 1986 to 63.85 km² in 2023, reflecting rapid urbanization and increased impervious surface coverage. Correspondingly, Land Surface Temperature (LST) mapping indicates a steady rise in average temperatures, from 32.23°C in 986 to 37.69°C in 2023.



Urban heat island (UHI) analysis highlights a marked temperature increase in densely urbanized zones, particularly in central and industrial districts of Dakar. In contrast, natural areas – such as vegetation and water bodies – play a mitigating role by buffering temperature extremes. The growing extent of built-up and bare soil areas, coupled with reduced permeability, has intensified localized heat accumulation, emphasizing the need for sustainable urban planning and the preservation of natural spaces.

The Urban Thermal Field Variation Index was applied to evaluate the impact of urban heat islands (UHIs) on the environment. Findings indicate a worsening of ecological conditions over time, with pronounced UHIs particularly evident in Dakar's industrial zones in both 2013 and 2023. Statistical analyses demonstrated clear correlations between land surface temperature (LST) and both land cover types and spectral indices.

The study also examined LST variations across different land cover categories – vegetated areas, wetlands, and built-up zones. Results revealed that vegetated land and wetlands exhibited the lowest average temperatures, whereas built-up areas and bare soils recorded the highest maximum temperatures. These findings underscore the critical role of vegetation and wetlands in moderating urban temperatures and mitigating heat stress.

Implications and Recommendations

- Establish a database and a monitoring system for green and blue infrastructure across the city of Dakar;
- Develop multi-stakeholder and multi-scale strategies for managing and/or developing green and blue infrastructure;
- Systematically integrate green and blue infrastructure into urban planning for better future land management and to avoid excessive use.
- Promote thermal comfort in Dakar by strengthening green and blue infrastructure to improve the living environment and health of the population.

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VILLE DE DAKAR