American Journal of Science and Learning for Development

ISSN 2835-2157
Volume 2 | No 8 | Aug -2023

Literature Survey for Land Surface Temperature Using Parameters that Include the Normalised Differential Vegetation Index and the Impervious Surface Area

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Abstract: *Land surface temperature (LST) is a crucial parameter for studying and understanding urban heat islands, climate change impacts, and land surface processes. To accurately assess LST, researchers have explored the integration of various parameters, including the Normalized Differential Vegetation Index (NDVI) and Impervious Surface Area (ISA). This literature survey aims to review existing studies that have employed NDVI and ISA as parameters for analyzing LST. The NDVI, derived from remote sensing data, quantifies the vegetation vigor and density by measuring the difference in reflectance between near-infrared and red wavelengths. NDVI has been widely used as a surrogate for vegetation cover, which affects the thermal behavior of land surfaces. On the other hand, ISA represents the proportion of impervious surfaces, such as roads, buildings, and pavements, within a given area. These surfaces have distinctive thermal properties that significantly influence LST patterns. The reviewed literature demonstrates that integrating NDVI and ISA as parameters for analyzing LST provides valuable insights into the complex relationships between land use/land cover, vegetation, and urban heat. Studies have shown that areas with higher NDVI tend to have lower LST, indicating the cooling effect of vegetation. Conversely, increased ISA is associated with higher LST, reflecting the heat-trapping nature of impervious surfaces. Furthermore, the combination of NDVI and ISA has enabled the identification of urban heat islands and the assessment of their spatial-temporal dynamics. Overall, this literature survey highlights the importance of incorporating NDVI and ISA as parameters in the study of LST. It underscores their relevance in urban planning, environmental management, and climate change mitigation strategies by providing a comprehensive understanding of land surface thermal characteristics and their underlying factors.*

Keywords: *Land surface temperature (LST), Normalized Differential Vegetation Index (NDVI), Impervious Surface Area (ISA), Urban heat islands, Climate change impacts, Land surface processes.*

1. INTRODUCTION

The urban heat island (UHI) phenomenon refers to higher temperatures observed in urban areas compared to the surrounding rural areas, primarily due to urbanization and the prevalence of non-evaporating impervious materials, soil, and limited vegetation. These elevated temperatures in UHIs have significant implications, including increased energy demands for air conditioning, heightened pollution levels, and potential alterations to precipitation patterns. Consequently, understanding the magnitude and spatial patterns of land surface temperature (LST) in relation to different surface materials is a critical focus in urban climatology studies. Remote sensing techniques, such as airborne or satellite thermal infrared sensing, provide a synoptic and consistent approach for investigating surface UHI effects on a regional scale by characterizing LST. Satellite-measured LST has been extensively employed in heat-balance studies, climate modeling, and global change research as it reflects the effective radiating temperature of the Earth's surface. Thermal remote sensing plays a vital role in establishing the spatial structure of urban thermal patterns and their association with urban surface characteristics. LST serves as a fundamental input parameter for various studies in climatology, hydrology, agriculture, and change detection. It can be derived easily from remotely sensed data and facilitates the examination of the spatial relationship between LST and different land use/land cover (LULC) types within urban areas. Given LST's sensitivity to vegetation presence and soil moisture content, it is a valuable tool for detecting changes in LULC.

2. PARAMETERS THAT AFFECTS LST

Over the past decade, numerous studies and experiments have been conducted in cities worldwide to identify the parameters that influence land surface temperature (LST). The main parameters found to have a significant impact on LST are surface materials, vegetation, geometric effects, and soil moisture. Surface materials, particularly impervious materials such as concrete and asphalt commonly used for pavements and roofs, exhibit distinct thermal properties, including heat capacity, thermal conductivity, albedo, and emissivity. These materials significantly alter the heat balance of urban areas, leading to higher temperatures compared to surrounding rural areas. The low albedo of urban surfaces, which refers to the ratio of reflected light to incoming light, contributes to the heat island effect. The presence or absence of vegetation plays a crucial role in the formation of urban heat islands. Urban areas with limited vegetation experience higher temperatures as vegetation provides shade and evaporative cooling. The lack of vegetation prevents the cooling effects, leading to increased surface and ambient temperatures. The geometric configuration of urban areas, including the arrangement, orientation, and spacing of buildings, also influences the formation of urban heat islands. Urban morphology affects wind flow patterns, heat absorption, and surface emittance. Tall buildings can create an "urban canyon effect" by absorbing sunlight and trapping heat within the urban environment. Vehicular movement within urban areas also contributes to heat and air pollution, further impacting urban morphology. Soil moisture is another important parameter influencing LST. Remote sensing techniques have shown that soil moisture affects soil dielectric constant, which in turn impacts microwave brightness temperature. Lower microwave frequencies are particularly sensitive to soil moisture, allowing for its detection and characterization. In summary, surface materials, vegetation, geometric effects, and soil moisture have been identified as key parameters influencing LST. Understanding their roles and interactions is vital for mitigating the urban heat island effect and developing strategies for sustainable urban planning and climate adaptation.

3. LITERATURE SURVEY

Literature Survey for Land Surface Temperature Using Parameters That Include the Normalized Differential Vegetation Index (NDVI) and the Impervious Surface Area (ISA): This literature survey aims to review existing studies that have utilized the Normalized Differential Vegetation Index (NDVI) and the Impervious Surface Area (ISA) as parameters for analyzing land surface temperature (LST). The survey examines the integration of NDVI and ISA in understanding the complex relationships between land use/land cover, vegetation, and urban heat. It explores how higher NDVI values correspond to lower LST, indicating the cooling effect of vegetation, while increased ISA is associated with higher LST due to the heat-trapping nature of impervious surfaces. The survey highlights the significance of incorporating NDVI and ISA as parameters in LST analysis for urban planning, environmental management, and climate change mitigation strategies.

Singh et al. (2016) The objective of this study was to assess the spatiotemporal relationship between temperature and other indices using geospatial technology and ground-based studies. The researchers obtained a Landsat image from the USGS for October 2015, which was digitally classified to generate land use/land cover maps consisting of pervious and impervious classes. To analyze the trend, the two classes were compared with the ambient air temperature as a control. A total of 14 sites were sampled, with 10 located within the city and the remaining on the outskirts for comparison purposes. The findings revealed that the sites within the city exhibited higher temperatures compared to the rural areas, primarily due to the greater presence of impervious cover. The researchers utilized the red and near-infrared bands as effective indicators for extracting impervious surfaces. Additionally, vegetation and built-up indices were considered in the study. The study concluded that the Normalized Difference Impervious Surface Index (NDII) outperformed the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Built-Up Index (NDBI) for analyzing impervious surfaces in relation to temperature.

Burlat et al. (2016) The utilization of object-based image analysis (OBIA) in delineating impervious surface area (ISA) has shown promise, particularly when combined with supervised classification using an SVM classifier and refined with rule-based classification. In the study, the ISA of Iligan City was determined to cover more than half of its total territory, precisely 53%. This extracted ISA played a significant role in understanding the significance of impervious surfaces in the hydrologic cycle and water management.

Zhang et al. (2017) The findings indicated that between 2001 and 2015, the ISA expanded by 163.96 km², with a total expansion of construction land by 259.05 km², representing a 10.26% increase. In 2001, the proportions of ISA in the construction land were 43.92% for urban areas and 21.35% for rural areas, which increased to 49.14% and 34.27% respectively by 2015. The ratio of poor-quality ISA decreased from 22.57% to 14.87%, with the change in the rural area being more pronounced on a per-unit construction land basis. Regarding LST, the urban areas experienced significant increases in inferior low temperature, medium temperature, and inferior high temperature categories, indicating a fast growth rate. On the other hand, the rural areas were predominantly characterized by inferior low temperature and medium temperature categories, with a notable decrease in inferior low temperature.

Mathew et al. (2018) The objective of this study was to analyze the variations in land surface temperature (LST) between urban and neighboring rural areas during different seasons (winter, summer, and monsoon) from 2009 to 2013 using data from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor. The analysis of 8-day night-time LST data revealed the presence of a significant surface urban heat island (SUHI) effect in the Ahmedabad study area. The mean annual SUHI intensity ranged from 6.01 K to 6.56 K during the study period, with an overall mean SUHI intensity of 6.17 K. The SUHI index was employed to compare the SUHI intensity across different periods and seasons. The study also investigated the relationship between LST and various parameters, including the normalized difference vegetation index (NDVI), enhanced vegetation index (EVI), road density (RD), normalized difference built-up index (NDBI), and percent impervious surface area (%ISA). It was observed that there was an inverse relationship between LST and vegetation indices, which varied depending on the season. EVI was found to be a more suitable vegetation parameter for SUHI studies compared to NDVI. %ISA was identified as a significant parameter for analyzing the SUHI effect, and its relationship with LST was found to be independent of the season. The relationship between %ISA and LST showed a consistent increasing trend across all three seasons. Additionally, a positive relationship was observed between LST and NDBI, particularly during the monsoon months.

Alexander et al.(2020) This study aimed to estimate land surface temperatures (LST) in Aarhus, a city located in high latitudes, using the thermal band (TIRS1; Band 10; 10.60–11.19 μm) of Landsat 8 imagery on five dates during the summer months (one in 2015 and four in 2018). Spectral indices based on the normalized difference vegetation index (NDVI) were calculated using all combinations of the first seven bands of Landsat 8, and their relationships with LST were analyzed. Land cover characteristics, including tree cover, building cover, and overall vegetation cover, were estimated using airborne LiDAR data, building footprints, and 4-band aerial imagery, respectively. The correlations between LST, spectral indices, and land cover were examined. The study found temperature differences of up to 3.96 °C between the rural and urban parts of Aarhus, with differences of up to 13.26 °C between the warmer and colder zones based on mean and standard deviation of LST. The spectral index utilizing the near-infrared band (NIR; Band 5; 0.85-0.88 µm) and short-wave infrared band (SWIR2; Band 7; 2.11–2.29 µm) exhibited the strongest correlations (ranging from 0.62 to 0.89) with LST across the entire study area. This index, which is the inverse of the normalized burn ratio (NBR) used for mapping burnt areas, showed stronger correlations with LST than commonly used vegetation indices like NDVI. The percentage of tree cover exhibited a higher negative correlation (Pearson's r: -0.68 to -0.75) with LST compared to overall vegetation cover (r: -0.45 to -0.63). Tree cover and building cover together explained up to 68% of the variation in LST, with correlations ranging from 0.53 to 0.71.

Neinavaz et al. (2020) In the study conducted by author, it was emphasized that land surface temperature (LST) is a crucial climate variable and an important parameter in understanding land surface processes. Additionally, land surface emissivity (LSE) serves as an indicator of material composition. Despite the availability of numerous methods and algorithms for computing LST and LSE using remote sensing data, accurately predicting these variables remains challenging. The normalised difference vegetation index threshold method (NDVITHM) has received significant attention, particularly for agriculture and forest ecosystems. The study aimed to examine the impact of prediction accuracy of vegetation cover proportion (PV) on estimating LSE and LST when utilizing NDVITHM. A field campaign was conducted in August 2015 within the Bavarian Forest National Park in southeastern Germany, coinciding with a Landsat-8 overpass. PV was measured for 37 plots in the field. Four different vegetation indices and artificial neural network approaches were employed to estimate PV and compute LSE and LST. The findings demonstrated that the prediction accuracy of PV was enhanced using an artificial neural network (R2CV = 0.64, RMSECV = 0.05) compared to traditional vegetation indices (R2CV = 0.42, RMSECV = 0.06). Furthermore, the study revealed that variations in the accuracy of estimated PV influenced the calculation results of LSE.

Dutta et al. (2021) The objective of this study was to analyze the spatio-temporal pattern of impervious surface growth in and around Delhi National Capital Territory (NCT) using bi-temporal Landsat images from 2003 and 2014. The researchers employed the linear spectral unmixing (LSU) technique to assess impervious surface growth in the megacity. They also estimated and compared vegetation surface fraction (VSF), land surface temperature (LST), and normalized difference vegetation index (NDVI) to understand the associated changes with impervious surface fraction (ISF). Additionally, the fractional abundance of impervious surface was validated with built-up density, urban expansion, and population density of the area. The study revealed significant growth of impervious land in the peri-urban centers surrounding Delhi. The findings showed a strong correlation between the fractional abundance of impervious surface and vegetation surface fraction, LST, and NDVI. The correlation coefficients indicated good agreement among these variables. The study also found a strong negative correlation between ISF and urban expansion index (UEI), suggesting the potential for urban expansion in less developed areas with abundant pervious surface. Furthermore, a significant polynomial relationship was observed between impervious surface fraction and population density, indicating high ISF (0.9-1.0) in densely populated areas and vice versa.

Abdulwahab et al. (2021) The dynamics of urban heat island (UHI) and their impact on land use and land cover (LU/LC) were depicted in the project for four epochs (2004 to 2019). The variation in land cover changes that occurred over 15 years was detected and identified using open/license source software such as R and GEE, ArcGIS 10.6, Envi 5.3, and other tools. The primary data sources for the project were multi-temporal Landsat satellite images (ETM and ETM+) covering the Mubi region in 2004, 2009, 2014, and 2019. Image acquisition was carried out using software like Global Mapper 19, Google Earth Pro, and Earth Explorer. Data analysis was performed using ArcGIS 10.6, Erdas Imagine 2015, and R software. The analysis revealed that the urban area expanded by 1437.26 hectares (27.34%), while vegetated land, water bodies, fallow land, open land, and rock land experienced reductions in their sizes. The mean land surface temperature (LST) increased from 15.59˚C in 2004 to 20.16˚C in 2009, 20.74˚C in 2014, and finally 24.88˚C in 2019, indicating an overall increase observed throughout the project period due to urban area growth. A lower negative correlation was observed between LST and normalized difference vegetation index (NDVI) when comparing 32 random spatial locations of vegetation land (VL) within the Mubi region.

Kulsum et al. (2022) The paper addressed the assessment of the relationship between land-use dynamics and climate change based on the analysis of land surface temperature (LST), normalized difference vegetation index (NDVI), and normalized difference built-up index (NDBI) using Landsat 4, 5 TM, and 8 OLI/TIRS data from 1989 to 2019. Ground observations were used to validate the satellite-derived temperature. LST was derived using an NDVI-based emissivity method with a non-linear split-window algorithm. A pixel-based approach was employed to establish the relationship among LST, NDBI, and NDVI. The results indicated that increasing impervious surfaces and decreasing greenery were associated with higher LST values. A strong positive correlation (correlation coefficient = 0.573, P value = 0.01) was observed between LST and NDBI for the period 1989–2019, while LST exhibited a strong negative correlation with NDVI (r = -0.431, P value = 0.01). The correlation between NDBI and NDVI was moderately negative (correlation coefficient = -0.284, P value = 0.01). A specific area in Greater Dhaka was identified as having the highest increase in LST, air temperature, and impervious surface, along with the greatest decrease in vegetation and rainfall. The findings suggest that areas adjacent to Dhaka city will likely undergo rapid urbanization in the future.

Simon et al. (2022) The influence of biophysical variables on land surface temperatures (LSTs) in the Dar es Salaam Metropolitan City (DMC) was characterized in this study. Landsat images were analyzed using geographically weighted regression (GWR) and ordinary least square (OLS) models to examine the relationships between biophysical variables (soil-adjusted vegetation index, normalized difference built-up index, and normalized difference bareness index) and LST. The GWR analysis results indicated that LST exhibited a weak to strong negative correlation with the soil-adjusted vegetation index, a moderate positive correlation with the normalized difference built-up index, and a low positive correlation with the normalized difference bareness index. GWR outperformed OLS in predicting LST, with coefficient of determination (R^2) values of 55%, 80%, and 62% for the years 1995, 2009, and 2017, respectively. Furthermore, higher model residuals were observed in areas with high building density compared to those with low building density. This study offers a comprehensive understanding of the impact of biophysical variables on LST in DMC and serves as a reference for site-specific urban land-use planning and the development of strategies to mitigate LST.

Zhang et al. (2023) The paper proposed a composite impervious surface extraction index, called CBI, based on NDBI, NDVI, and MNDWI, aiming to enhance the accuracy of impervious surface extraction. The impervious surface extraction images in various land cover areas were compared with NDBI and NDISI and evaluated through visual and statistical analyses. The results demonstrated that CBI exhibited strong robustness and was less influenced by the type of ground objects and sensors. The Kappa coefficients of CBI were the highest among different sensors and OLI images in various land cover areas, with an overall accuracy above 91%. Particularly, in areas with a high presence of vegetation and water, CBI significantly improved the extraction accuracy. CBI was found to be more suitable for areas with abundant vegetation and water, surpassing the Kappa coefficient by 0.1116 compared to areas with minimal vegetation and water. Moreover, the NDISI algorithm, which utilizes the thermal infrared band, exhibited lower extraction accuracy when applied to smaller study areas, indicating that the algorithm's accuracy is influenced by the size of the study area.

Balha et al. (2023) The research conducted an analysis of the hydrological impacts of historical and future land use land cover (LULC) in a specific region within the Yamuna River basin. The study evaluated and validated the GIS-Curve Number (CN) approach for calculating effective impervious area (EIA) in larger ungauged basins using spatial data to measure directly connected impervious area (DCIA). The Soil and Water Assessment Tool (SWAT) was employed at daily intervals to simulate hydrological responses under different land-use scenarios for the years 2005, 2010, 2016, and a predicted scenario for 2031.The sensitivity analysis of the model identified the SCS runoff curve number (CN2) and effective hydraulic conductivity in the main channel (CH_K2) as the most sensitive parameters. The study confirmed that EIA is a preferable parameter for runoff calculation compared to Total Impervious Area (TIA). The observed and simulated discharge exhibited a good match during both calibration and validation stages ($R^2 \geq 0.85$, NSE ≥ 0.83, and PBIAS < 5).The findings revealed that surface runoff is primarily influenced by built-up areas, while evapotranspiration, percolation, and groundwater recharge are affected by dense vegetation, sparse vegetation, and cropland, respectively. The predicted increase in urbanization across all sub-basins is projected to result in higher runoff. The patterns indicated a decrease in evapotranspiration, percolation, and groundwater recharge in the urban areas of the entire basin. Between 2005 and 2031, there was a 49.2% increase in surface runoff accompanied by a decline of -2.25% in percolation. These results suggest a continuous decline in groundwater resources in the basin, which will worsen with further urbanization.

5. SUMMARY

Land surface temperature (LST) is an important parameter in various fields, such as climate studies, urban planning, and environmental monitoring. Many studies have explored the relationship between LST and various parameters, including the Normalized Difference Vegetation Index (NDVI) and the impervious surface area (ISA).The NDVI, which measures vegetation health and density, has been widely used as a proxy for land surface temperature. Studies have shown that NDVI exhibits a negative correlation with LST, indicating that areas with higher vegetation cover tend to have lower surface temperatures. This relationship is particularly important in urban areas, where the presence of green spaces can help mitigate the urban heat island effect. On the other hand, the impervious surface area, which represents the proportion of non-absorbent surfaces such as buildings and roads, has been found to have a positive correlation with LST. Urban areas with higher ISA tend to have higher surface temperatures due to the absorption and re-radiation of solar energy by built-up materials. Researchers have utilized remote sensing data, such as Landsat images, to assess LST variations using these parameters. They have employed techniques such as regression analysis, geographically weighted regression, and composite indices to quantify the relationship between LST, NDVI, and ISA. These studies have highlighted the importance of considering both vegetation cover and impervious surface characteristics when assessing land surface temperature patterns. Overall, the literature survey demonstrates that the NDVI and ISA are valuable parameters for understanding and predicting land surface temperature variations. Integrating these parameters with remote sensing data and advanced analytical techniques can provide valuable insights for urban planning, climate studies, and environmental management strategies.

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