The Role of Vegetation to Mitigate Surface Urban Heat Island in Urban Areas: A Review

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Abstract: ***The objective of this study is to assess the effectiveness of vegetation in reducing urban temperatures and mitigating the Surface-UHI (SUHI) effect. This review synthesizes existing research on vegetation's cooling effects in urban areas. A comparative analysis of predictive models, including Long Short-Term Memory (LSTM) networks, was conducted to assess their accuracy in predicting urban temperature reductions. LSTM models were particularly focused on for their robustness and high predictive capability. The review identifies significant cooling contributions of trees, parks, and green roofs in urban settings through shading, evaporative cooling, and reduced heat absorption. Among the predictive models analyzed, LSTM networks achieved the highest accuracy with an R-squared (R2) value of 0.99, indicating their robustness in predicting vegetation impacts on urban temperatures. These findings highlight the importance of integrating vegetation in urban planning to mitigate the UHI effect, reduce heat stress, improve air quality, and enhance urban livability. This study uniquely applies LSTM networks to predict vegetation's impact on urban temperatures, achieving unprecedented accuracy. This approach provides valuable insights for urban planners and policymakers.***

Keywords: Urban Heat Island, Vegetation, Surface Urban Heat Island, Urbanization, Temperature

1. Introduction

Urbanization has brought about profound transformations in the landscape, with expanding cities experiencing a surge in infrastructure development, population density, and energy consumption [1]. However, this rapid urban growth has also given rise to a significant environmental challenge known as the SUHI effect [2]. SUHI manifests elevated temperatures in urban areas compared to their surrounding rural counterparts, primarily due to the modification of land surfaces, the prevalence of impervious materials, and increased energy usage [3].

In the quest for sustainable urban living, researchers and urban planners have increasingly turned their attention to the vital role that vegetation plays in mitigating the adverse impacts of SUHI [4]. The concept of using vegetation as a strategic tool to counteract urban heat has gained prominence, acknowledging the multifaceted benefits that green spaces bring to urban environments [5,6]. This paper delves into the intricate relationship between vegetation and SUHI, exploring how plants contribute to cooling urban landscapes and examining real-world examples of successful implementation. Planning and grappling with the urgent need for climate-responsive urban planning, understanding the role of vegetation in mitigating SUHI emerges as a critical aspect of creating resilient and livable urban spaces for the future.

1.1. Understanding Surface Urban Heat Island

The SUHI impact alters the microclimate and energy balance of urban areas due to a complex web of interrelated factors [7]. The process of urbanization results in the substitution of natural vegetation with impermeable surfaces such as asphalt and concrete. These surfaces can absorb and store heat, which contributes to a rise in current temperatures. Furthermore, the buildup of heat in urban contexts is further exacerbated by human heat sources, which include buildings, automobiles, and industrial activity [8].

SUHI refers to the phenomenon where urban areas experience higher temperatures than their surrounding rural areas. This temperature disparity is primarily attributed to human activities and modifications to the land surface associated with urbanization [9]. SUHI is a localized form of the broader UHI effect, which encompasses both surface and atmospheric temperature increases in urban environments [10]. Figure 2 shows the UHI effect, which is a result of heat from traffic congestion, contributes to a decrease in atmospheric air quality [11] [Figure 1].

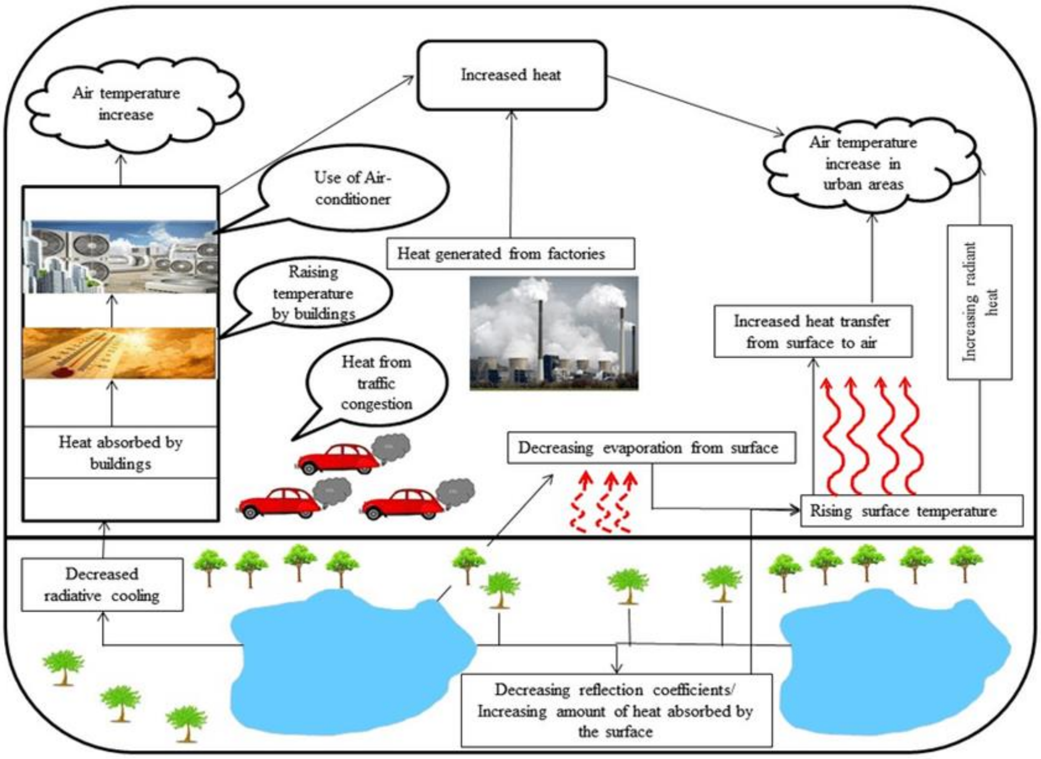

Figure 1: Urban Heat Island (UHI) effect causes [11].

Key factors contributing to SUHI include:

- Urban Infrastructure: The extensive use of impervious materials such as asphalt and concrete in urban areas leads to reduced water absorption and increased heat retention [12].
- Building Heat: The concentration of buildings and infrastructure in cities results in heat generated from human activities, industrial processes, and air conditioning systems, contributing to elevated temperatures [13].
- Modification of Land Cover: Urbanization often involves the removal of natural vegetation and the conversion of permeable surfaces to impermeable ones, altering the surface's heat absorption and radiation properties [14].
- Reduced Green Spaces: The loss of vegetation, parks, and green spaces diminishes the cooling effects of evapotranspiration and shade that plants provide [15].
- Energy Use: Heating, cooling, and lighting in metropolitan areas use a lot of energy, which increases the total heat load, particularly during times of peak demand [16].

1.2. Factors Contributing to SUHI in Urban Areas

SUHI in cities is caused by a web of interrelated variables. Increased heat retention is a result of the loss of land's inherent heat-absorbing and -releasing capabilities brought about by fast urbanization and the widespread use of impermeable surfaces such as asphalt and concrete [17]. The materials used in buildings and infrastructure, with their higher thermal conductivity, contribute to elevated temperatures [18,19]. Additionally, the albedo effect plays a role, as darker urban surfaces absorb more sunlight, intensifying heat absorption. Human activities, including industrial processes, transportation, and energy consumption, release anthropogenic heat into the environment [20]. The lack of green spaces, which act as cooling agents through processes like evapotranspiration, further exacerbates the heat island effect [21]. Urban geometry and the arrangement of buildings can trap heat by hindering natural ventilation [22]. Waste heat from various sources, microclimatic variations, and even weather conditions, such as calm winds and cloud cover, influence the intensity of SUHI [23]. Moreover, insufficient urban planning and the absence of mitigation strategies contribute to the persistence of SUHI. Recognizing and addressing these factors is crucial for implementing effective measures to mitigate SUHI and foster sustainable urban development [24].

Some factors contribute to the UHI (see Figure 2) [25]:

- Urban geometry modifies the built environment's heat exchange balance by influencing how shadows and wind patterns are arranged. The quantity of sunlight that materials receive and the heat that is stored in their thermal mass are both affected by it. Changes to the velocity and direction of airflow inside urban canyons may be brought about by the complex process of heat radiation exchange between the mass of the building and the environment.
- The urban cover and surface materials of buildings influence the heat absorption and reflection of the structures. As a result of the interaction of materials with sunlight, as well as the materials' colour, texture, density, and thermodynamic parameters, the movement of heat in an outdoor space may be altered in complex processes.
- Urban landscape, as opposed to natural surroundings, influences the balance of heat and water exchange in the constructed environment. Urban vegetation helps lower air temperatures via photosynthesis and evaporation. The kind, location, and intensity of urban vegetation also impact the turbulence in the lower atmosphere.
- Urban metabolism, or waste heat produced by humans in

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cities, is mostly associated with the amount of energy used for motorized mobility and interior air conditioning [Figure 2].

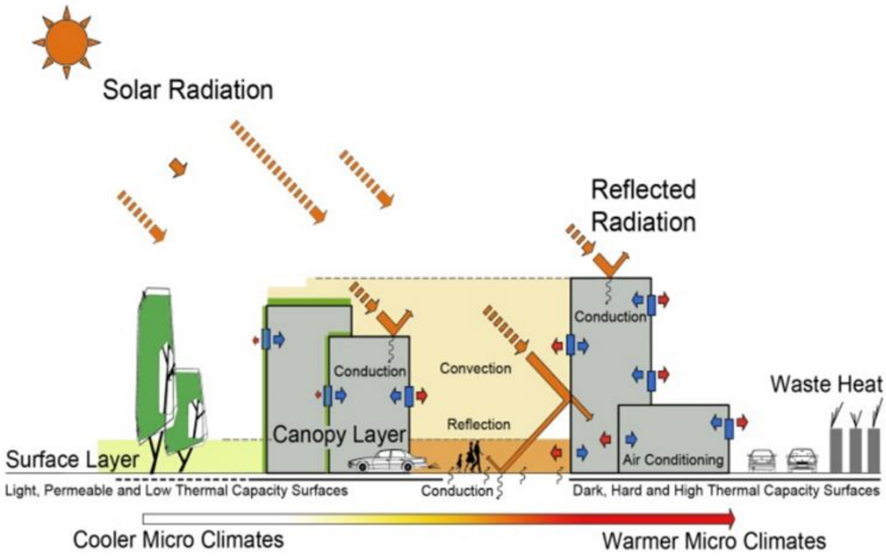

Figure 2: UHI major factors [25].

1.3. The Role of Urban Vegetation in Reducing the Effects of the SUHI

Vegetation plays a pivotal role in mitigating the SUHI effect in urban areas through various mechanisms. Trees and greenery provide essential shade, reducing direct exposure to sunlight and cooling impervious surfaces [26]. The process of evapotranspiration, where vegetation releases water vapour, acts as a natural cooling mechanism, significantly lowering air and surface temperatures. Additionally, the reflective properties of vegetation, known as albedo, help prevent excessive heat absorption by urban surfaces [27]. The presence of green spaces alters local airflow patterns, providing microclimatic regulation and creating cooler environments within the urban landscape [28]. Trees act as windbreaks, reducing wind speed and improving natural ventilation. Beyond temperature regulation, greenery enhances biodiversity, contributing to overall ecological health and urban resilience [29]. Integrating vegetation into urban planning, promoting green roofs and walls, and stabilizing existing green spaces are vital strategies for designing cooler, more sustainable, and livable urban areas [30].

2. Related Work

This section establishes the groundwork for the present study by providing a comprehensive review and analysis of prior research. The structure of the related work section presents past studies.

Mokarram et al.'s study (2023) [31] leveraged neural networks and remote sensing to investigate urbanization's impact on temperature trends in northern Iran. Using MODIS imagery from 2001, 2010, and 2019, the study revealed escalating thermal pollution evidenced by elevated Land Surface Temperature (LST), SUHI, and Urban and Suburban Thermal Vulnerability Index (UTFVI) values, alongside a decline in Vegetation Index NDVI values. The SUHI index peaked at 11.72 in 2019, with spring marking its zenith and winter its nadir. Employing LSTM models, the study achieved remarkable R-squared (R2) values of 0.99 and 0.98, surpassing MLP and RBF models, underscoring LSTM's prowess in forecasting accuracy and validation performance.

Marando et al. (2022) [32] created a model that details 601 European towns' Urban Green Infrastructure (UGI) microclimate regulating Ecosystem Services (ES). To determine how UGI could help reduce urban heat island effects in various settings, the model mimics the temperature differential between a baseline and a no-vegetation scenario. Urban Greenhouse Gas (UGG) mitigation may reduce city temperatures in Europe by an average of 1.07 ◦C and as much as 2.9 ◦C. However, a tree covers of 16% is necessary to produce a 1 ◦C reduction in city temperatures.

Okumus and Terzi's research (2021) [33] applied a supervised machine learning approach to analyze Istanbul's urban architecture's effects on SUHI. The Ridge Regression Model Implicated Building Coverage Ratio (BCR), Surface/Volume Ratio (SVR), Canyon Geometry Factor (CGF), and NDVI as critical variables, collectively accounting for 71% of LST anomalies. Notably, NDVI and BCR emerged as primary drivers of SUHI development, while SVF and CGF exhibited minimal influence, highlighting the nuanced interplay between urban morphology and thermal dynamics.

Herath et al. (2021) [34] evaluated Urban Heat Reduction Strategies (USPs) in Melbourne, Australia, using the Air Pollution Model (TAPM). Simulations revealed varying effectiveness of USPs in mitigating heat, with green roofs excelling in nocturnal heat reduction and high-albedo roofs demonstrating daytime cooling efficacy. The study highlighted the multifaceted nature of urban heat mitigation strategies and the need for context-specific interventions.

Garzón et al. (2021) [35] employed PCA, MLR, and weighted Naïve Bayes Machine Learning (NBML) to discern SUHI trends in Cartago, Colombia. Utilizing Sentinel-2 data, the fractional vegetation cover model exhibited superior performance, underscoring its utility in SUHI analysis. The NBML methodology demonstrated promise in identifying problem areas for targeted interventions, emphasizing the importance of adaptive strategies in urban heat management.

Al-Saadi et al. (2020) [36] investigated daily low and high air temperatures in rural and urban settings to assess UHI intensity. Analyzing fractional areas and their ratios to vegetated regions, the study found an increasing trend in both lowest and maximum UHI values over the research period. Variations in NDVI indicated fluctuations in vegetation cover, with UHI values ranging from -0.7 to 0.3 °C and, notably, a significant upward trend in extreme UHI values.

Sun et al. (2020) [37] delved into SUHI dynamics in Cartago, Colombia, using LST data from Sentinel-2 and Landsat satellites. Employing PCA and MLR techniques, the study identified the Normalized Difference Water Index (NDWI) and Normalized Difference Build-up Index (NDBI) as pivotal metrics influencing SUHI trends. The fractional vegetation cover model, leveraging Sentinel-2 data, outperformed alternative models, underlining the importance of comprehensive satellite data and sophisticated modelling techniques in SUHI analysis.

Mukherjee and Debnath (2020) [38] explored the link between COVID-19 and Urban Heat Island (UHI) dynamics in New Delhi, India, using MODIS temperature data and COVID-19 monitoring data. Daytime LST exhibited a strong correlation with confirmed COVID-19 cases, with an 81% value of R2 and a statistically significant p-value. The study underscored the intricate relationship between urban heat and public health, with LST serving as a key indicator of epidemiological trends.

Firozjaei et al. (2020) [39] assessed the feasibility of spectral indices in measuring Daytime Surface Air Heat Island Intensity (SAHII) in fourteen cities. The index-based built-up index (IBI) emerged as the most effective method for SAHII quantification, boasting an R2 value of 0.98 and low RMSE. The study validated the efficacy of the LST-SIISC feature space for SAHII measurement, emphasizing the importance of innovative approaches in urban heat research.

Imran et al. (2019) [40] assessed how well urban vegetation patches like mixed forests (MF), grasslands (MFAG), and shrublands (MSAG) mitigated urban heat island (UHI) impacts in Melbourne during a particularly extreme heatwave. The mosaic approach of the WRF model increased the proportions of vegetated patches per grid cell by 20%, 30%, 40%, and 50%, respectively. A drop of 0.6-3.4 °C in near-surface (2 m) UHI (UHI2), 0.4-3.0 °C in MSAG, and 0.6-3.7 °C in MFAG was seen at night as the fraction increased from 20% to 50%, but no cooling effect on near-surface temperature was observed during the hottest portion of the day.

2.1 Summary of Related Work

In this section, a summary of the previous studies which are considered in the related work section is depicted in Table 1 [Table 1].

Table 1: Summary of related work

Authors	*Method*	*Research Findings*
Mokarram et al. (2023) [31]	Neural networks, remote sensing	LSTM models achieved remarkable R-squared (R2) values of 0.99 and 0.98, surpassing MLP and RBF models.
Marando et al. (2022) [32]	Modeling	UGI could reduce urban heat island effects in Europe by an average of 1.07°C and as much as 2.9°C, with a tree cover of 16% necessary for a 1°C reduction in city temperatures.
Okumus and Terzi (2021) [33]	Supervised machine learning	NDVI and BCR emerged as primary drivers of SUHI development in Istanbul, collectively accounting for 71% of land surface temperature anomalies.
Herath et al. (2021) [34]	Air Pollution Model (TAPM) simulations	Results highlighted the need for context-specific interventions in urban heat mitigation.
Garzón et al. (2021) [35]	PCA, MLR, weighted Naïve Bayes Machine Learning (NBML)	The fractional vegetation cover model exhibited superior performance in SUHI analysis in Cartago, Colombia. NBML method demonstrated promise in identifying problem areas for targeted interventions.
Al-Saadi et al. (2020) [36]	Statistical analysis	The increasing trend in both lowest and maximum UHI values from -0.7 to 0.3 °C was observed over the research period, with fluctuations in NDVI indicating changes in vegetation cover.
Sun et al. (2020) [37]	Principal Component Analysis (PCA), Multiple Linear Regression (MLR)	NDWI and NDBI were identified as pivotal metrics influencing SUHI trends in Cartago, Colombia. The fractional vegetation cover model outperformed alternative models.
Mukherjee and Debnath (2020) [38]	Statistical analysis, correlation	A strong correlation between daytime LST and confirmed COVID-19 cases was observed in New Delhi, India with an 81% value of R^2.
Firozjaei et al. (2020) [39]	Spectral indices analysis	The IBI emerged as the most effective method for SAHII quantification, boasting an R2 value of 0.98 and low RMSE.
Imran et al. (2019) [40]	Modelling, simulations	The WRF model's mosaic technique resulted in a 20%, 30%, 40%, and 50% increase, respectively, in the percentage of vegetated patches per grid cell.

3. Comparative Analysis

3.1. Effect of herbal treatment

Table 2 presents a comparative analysis of different authors' techniques and their corresponding R-squared (R2) values. In 2023, Mokarram et al. leveraged MODIS imagery to investigate Land Surface Temperature (LST) and Surface Urban Heat Island (SUHI) trends in Northern Iran, achieving remarkable R-squared (R2) values of 0.99 for LST and 0.98 for SUHI. Sun et al. (2020) focused on Cartago, Colombia, using satellite-derived LST data and reported an R-squared

(R2) value of 0.78. Mukherjee and Debnath (2020) explored the correlation between COVID-19 cases and daytime Land Surface Temperature (LST) in New Delhi, India, obtaining an R-squared (R2) value of 0.81. Firozjaei et al. (2020) assessed Daytime Surface Air Heat Island Intensity (SAHII) in fourteen cities, achieving an R-squared (R2) value of 0.98. Lastly, Garzón et al. (2021) investigated SUHI trends in Cartago, Colombia, yielding an R-squared (R2) value of 0.78 [Table 2].

Table 2: Comparison Analysis

Authors	*Year*	*R-squared (R2) Value*	*Temperature Data*	*Location*
Mokarram et al. [31]	2023	LST: 0.99, SUHI: 0.98	MODIS imagery	Northern Iran
Garzón et al. [35]	2021	0.78	SUHI trends	Cartago, Colombia
Sun et al. [37]	2020	0.78	LST data from satellites	Cartago, Colombia
Mukherjee and Debnath [38]	2020	0.81	MODIS temperature data	New Delhi, India
Firozjaei et al. [39]	2020	0.98	Daytime SAHII	Fourteen cities

These studies underscore the importance of understanding temperature dynamics across various locations and provide valuable insights into urban heat island phenomena through diverse methodologies and datasets.

4. Conclusion

The pivotal role of vegetation in mitigating the SUHI effect within urban areas is underscored in this work. The ability of vegetation, such as trees, shrubs, and green spaces, to regulate temperature, enhance evapotranspiration, and provide shade, emerges as a promising solution for reducing surface temperatures and alleviating heat stress in urban environments. Furthermore, the review highlights the multifaceted benefits of urban greenery beyond temperature regulation, including improved air quality, enhanced biodiversity, and enhanced aesthetic appeal. However, despite the recognized benefits, challenges such as limited space, soil quality, and maintenance requirements remain significant barriers to widespread implementation. The comparative analysis of various authors' techniques sheds light on the effectiveness of different approaches in understanding and mitigating the SUHI effect in urban areas. By comparative analysis, it is demonstrated that the robustness of LSTM networks has achieved an impressive R-squared (R2) value of 0.99 which is the highest among the compared models. This review provides insights into the critical role of vegetation in mitigating SUHI and offers recommendations for future research and urban planning initiatives aimed at promoting resilient and sustainable cities.

References

[1] I. D. Stewart, E. S. Krayenhoff, J. A. Voogt, J. A. Lachapelle, M. A. Allen, and A. M. Broadbent, "Time evolution of the surface urban heat island," Earth's Future, vol. 9, no. 10, p. e2021EF002178, 2021. [Online]. Available: https://doi.org/10.1029/2021EF002178.

[2] T. Chakraborty, A. Hsu, D. Manya, and G. Sheriff, "A spatially explicit surface urban heat island database for the United States: Characterization, uncertainties, and possible applications," ISPRS Journal of Photogrammetry and Remote Sensing, vol. 168, pp. 74-88, 2020. [Online]. Available: https://doi.org/10.1016/j.isprsjprs.2020.07.001.

[3] M. Morabito, A. Crisci, G. Guerri, A. Messeri, L. Congedo, and M. Munafò, "Surface urban heat islands in Italian metropolitan cities: Tree cover and impervious surface influences," Science of the Total Environment, vol. 751, p. 142334, 2021. [Online]. Available: https://doi.org/10.1016/j.scitotenv.2020.142334.

[4] H. Liu, B. J. He, S. Gao, Q. Zhan, and C. Yang, "Influence of non-urban reference delineation on trend estimate of surface urban heat island intensity: A comparison of seven methods," Remote Sensing of Environment, vol. 296, p. 113735, 2023. [Online]. Available: https://doi.org/10.1016/j.rse.2023.113735.

[5] Z. Zhao, A. Sharifi, X. Dong, L. Shen, and B. J. He, "Spatial variability and temporal heterogeneity of surface urban heat island patterns and the suitability of local climate zones for land surface temperature characterization," Remote Sensing, vol. 13, no. 21, p. 4338, 2021. [Online]. Available: https://doi.org/10.3390/rs13214338.

[6] D. Pearlmutter, D. Theochari, T. Nehls, P. Pinho, P. Piro, A. Korolova, S. Papaefthimiou, et al., "Enhancing the circular economy with nature-based solutions in the built urban environment: Green building materials, systems and sites," Blue-Green Systems, vol. 2, no. 1, pp. 46-72, 2020. [Online]. Available: https://doi.org/10.2166/bgs.2020.932.

[7] Y. Guo, J. J. Han, X. Zhao, X. Y. Dai, and H. Zhang, "Understanding the role of optimized land use/land cover components in mitigating summertime intra-surface urban heat island effect: A study on downtown Shanghai, China," Energies, vol. 13, no. 7, p. 1678, 2020. [Online]. Available: https://doi.org/10.3390/en13071678.

[8] A. Piracha and M. T. Chaudhary, "Urban air pollution, urban heat island and human health: a review of the literature," Sustainability, vol. 14, no. 15, p. 9234, 2022. [Online]. Available: https://doi.org/10.3390/su14159234.

[9] B. Yuan, X. Li, L. Zhou, T. Bai, T. Hu, J. Huang, D. Liu, Y. Li, and J. Guo, "Global distinct variations of surface urban heat islands in inter-and intra-cities revealed by local climate zones and seamless daily land surface temperature data," ISPRS Journal of Photogrammetry and Remote Sensing, vol. 204, pp. 1-14, 2023. [Online]. Available: https://doi.org/10.1016/j.isprsjprs.2023.03.007.

[10] Q. Yang, Y. Xu, X. Tong, X. Huang, Y. Liu, T. C. Chakraborty, C. Xiao, and T. Hu, "An adaptive synchronous extraction (ASE) method for estimating intensity and footprint of surface urban heat islands: A case study of 254 North American cities," Remote Sensing of Environment, vol. 297, p. 113777, 2023. [Online]. Available: https://doi.org/10.1016/j.rse.2023.113777.

[11] "Modelling Traffic Congestion based on Air Quality for Greener Environment: An Empirical Study," 2023. [Online]. Available: [URL if available].

[12] L. Nicoletti, M. Sirenko, and T. Verma, "Disadvantaged communities have lower access to urban infrastructure," Environment and Planning B: Urban Analytics and City Science, vol. 50, no. 3, pp. 831-849, 2023. [Online]. Available: https://doi.org/10.1177/23998083221127680.

[13] T. He, R. Zhou, Q. Ma, C. Li, D. Liu, X. Fang, Y. Hu, and J. Gao, "Quantifying the effects of urban development intensity on the surface urban heat island across building climate zones," Applied Geography, vol. 158, p. 103052, 2023. [Online]. Available: https://doi.org/10.1016/j.apgeog.2023.103052.

[14] D. Hidalgo-García and J. Arco-Díaz, "Spatiotemporal analysis of the surface urban heat island (SUHI), air pollution and disease pattern: an applied study on the city of Granada (Spain)," Environmental Science and Pollution Research, vol. 30, no. 20, pp. 57617-57637, 2023. [Online]. Available: https://doi.org/10.1007/s11356-023-26930-5.

[15] R. Anindita, E. Martono, and E. Nurjani, "Urban cooling island vs urban heat island, who is the winner? Study of the green spaces effect in cooling down of urban heat in Kapanewon Depok, Sleman, Yogyakarta, Indonesia," in E3S Web of Conferences, vol. 468, p. 10012, 2023. [Online]. Available: https://doi.org/10.1051/e3sconf/202346810012.

[16] T. Zheng, "Investigation into sustainable technologies for mitigating urban heat island effects in subtropical monsoon climate," PhD diss., University of Nottingham, 2023.

[17] H. K. Jabbar, M. N. Hamoodi, and A. N. Al-Hameedawi, "Urban heat islands: a review of contributing factors, effects, and data," in IOP Conference Series: Earth and Environmental Science, vol. 1129, no. 1, p. 012038, 2023. [Online]. Available: https://doi.org/10.1088/1755-1315/1129/1/012038.

[18] L. Li, Y. Zha, and R. Wang, "Relationship of surface urban heat island with air temperature and precipitation in global large cities," Ecological Indicators, vol. 117, p. 106683, 2020. [Online]. Available: https://doi.org/10.1016/j.ecolind.2020.106683.

[19] K. J. Krakowiak, R. G. Nannapaneni, A. Moshiri, T. Phatak, D. Stefaniuk, L. Sadowski, and M. J. Abdolhosseini Qomi, "Engineering of high specific strength and low thermal conductivity cementitious composites with hollow glass microspheres for high-temperature high-pressure applications," Cement and Concrete Composites, vol. 108, p. 103514, 2020. [Online]. Available: https://doi.org/10.1016/j.cemconcomp.2020.103514.

[20] J. Lai, W. Zhan, J. Voogt, J. Quan, F. Huang, J. Zhou, B. Bechtel, et al., "Meteorological controls on daily variations of nighttime surface urban heat islands," Remote Sensing of Environment, vol. 253, p. 112198, 2021. [Online]. Available: https://doi.org/10.1016/j.rse.2020.112198.

[21] C. Pereira, I. Flores-Colen, and M. P. Mendes, "Guidelines to reduce the effects of urban heat in a changing climate: Green infrastructures and design measures," Sustainable Development, vol. 32, no. 1, pp. 57-83, 2024. [Online]. Available: https://doi.org/10.1002/sd.2436.

[22] M. Mohammad and A. Goswami, "Quantifying diurnal and seasonal variation of surface urban heat island intensity and its associated determinants across different climatic zones over Indian cities," GIScience & Remote Sensing, vol. 58, no. 7, pp. 955-981, 2021. [Online]. Available: https://doi.org/10.1080/15481603.2021.1958933.

[23] P. Zeng, C. Zong, Z. Duan, and X. Wei, "Exploring the spatial interplay between built-up environments and surface urban heat island phenomena in the main urban area of Shanghai," Energy and Buildings, vol. 301, p. 113739, 2023. [Online]. Available: https://doi.org/10.1016/j.enbuild.2021.111428.

[24] K. Li, Y. Chen, and S. Gao, "Comparative analysis of variations and patterns between surface urban heat island intensity and frequency across 305 Chinese cities," Remote Sensing, vol. 13, no. 17, p. 3505, 2021. [Online]. Available: https://doi.org/10.3390/rs13173505.

[25] E. Sharifi and S. Lehmann, "Correlation analysis of surface temperature of rooftops, streetscapes and urban heat island effect: Case study of central Sydney," Journal of Urban and Environmental Engineering, vol. 9, no. 1, pp. 3-11, 2015. [Online]. Available: https://doi.org/10.4090/juee.2015.v9n1.003011.

[26] F. Marando, M. P. Heris, G. Zulian, A. Udías, L. Mentaschi, N. Chrysoulakis, D. Parastatidis, and J. Maes, "Urban heat island mitigation by green infrastructure in European Functional Urban Areas," Sustainable Cities and Society, vol. 77, p. 103564, 2022. [Online]. Available: https://doi.org/10.1016/j.scs.2021.103564.

[27] A. M. Irfeey, H. W. Chau, M. M. Sumaiya, C. Y. Wai, N. Muttil, and E. Jamei, "Sustainable mitigation strategies for urban heat island effects in urban areas," Sustainability, vol. 15, no. 14, p. 10767, 2023. [Online]. Available: https://doi.org/10.3390/su151410767.

[28] J. K. N. Tan, R. N. Belcher, H. T. W. Tan, S. Menz, and T. Schroepfer, "The urban heat island mitigation potential of vegetation depends on local surface type and shade," Urban Forestry & Urban Greening, vol. 62, p. 127128, 2021. [Online]. Available: https://doi.org/10.1016/j.ufug.2021.127128.

[29] M. F. Abdulateef and H. A. Al-Alwan, "The effectiveness of urban green infrastructure in reducing surface urban heat island," Ain Shams Engineering Journal, vol. 13, no. 1, p. 101526, 2022. [Online]. Available: https://doi.org/10.1016/j.asej.2021.04.006.

[30] M. Morabito, A. Crisci, G. Guerri, A. Messeri, L. Congedo, and M. Munafò, "Surface urban heat islands in Italian metropolitan cities: Tree cover and impervious surface influences," Science of the Total Environment, vol. 751, p. 142334, 2021. [Online]. Available: https://doi.org/10.1016/j.scitotenv.2020.142334.

[31] M. Mokarram, F. Taripanah, and T. M. Pham, "Investigating the effect of surface urban heat island on the trend of temperature changes," Advances in Space Research, vol. 72, no. 8, pp. 3150-3169, 2023. [Online]. Available: https://doi.org/10.1016/j.asr.2023.08.012.

[32] F. Marando, M. P. Heris, G. Zulian, A. Udías, L. Mentaschi, N. Chrysoulakis, D. Parastatidis, and J.

Maes, "Urban heat island mitigation by green infrastructure in European Functional Urban Areas," Sustainable Cities and Society, vol. 77, p. 103564, 2022. [Online]. Available: https://doi.org/10.1016/j.scs.2021.103564.

[33] D. E. Okumus and F. Terzi, "Evaluating the role of urban fabric on surface urban heat island: The case of Istanbul," Sustainable Cities and Society, vol. 73, p. 103128, 2021. [Online]. Available: https://doi.org/10.1016/j.scs.2021.103128.

[34] P. Herath, M. Thatcher, H. Jin, and X. Bai, "Effectiveness of urban surface characteristics as mitigation strategies for the excessive summer heat in cities," Sustainable Cities and Society, vol. 72, p. 103072, 2021. [Online]. Available: https://doi.org/10.1016/j.scs.2021.103072.

[35] J. Garzón, I. Molina, J. Velasco, and A. Calabia, "A remote sensing approach for surface urban heat island modeling in a tropical Colombian city using regression analysis and machine learning algorithms," Remote Sensing, vol. 13, no. 21, p. 4256, 2021. [Online]. Available: https://doi.org/10.3390/rs13214256.

[36] L. M. Al-Saadi, S. H. Jaber, and M. H. Al-Jiboori, "Variation of urban vegetation cover and its impact on minimum and maximum heat islands," Urban Climate, vol. 34, p. 100707, 2020. [Online]. Available: https://doi.org/10.1016/j.uclim.2020.100707.

[37] T. Sun, R. Sun, and L. Chen, "The trend inconsistency between land surface temperature and near surface air temperature in assessing urban heat island effects," Remote Sensing, vol. 12, no. 8, p. 1271, 2020. [Online]. Available: https://doi.org/10.3390/rs12081271.

[38] S. Mukherjee and A. Debnath, "Correlation between land surface temperature and urban heat island with COVID-19 in New Delhi, India," 2020. [Online]. Available: https://doi.org/10.13140/RG.2.2.30087.70567.

[39] M. K. Firozjaei, S. Fathololoumi, N. Mijani, M. Kiavarz, S. Qureshi, M. Homaee, and S. K. Alavipanah, "Evaluating the spectral indices efficiency to quantify daytime surface anthropogenic heat island intensity: An intercontinental methodology," Remote Sensing, vol. 12, no. 17, p. 2854, 2020. [Online]. Available: https://doi.org/10.3390/rs12172854.

[40] H. M. Imran, J. Kala, A. W. M. Ng, and S. Muthukumaran, "Effectiveness of vegetated patches as Green Infrastructure in mitigating Urban Heat Island effects during a heatwave event in the city of Melbourne," Weather and Climate Extremes, vol. 25, p. 100217, 2019. [Online]. Available: https://doi.org/10.1016/j.wace.2019.100217.