Review on Green Landscape Elements in the Urban Thermal Environment

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ABSTRACT

Recent expansion of the urban populace has given rise to an increase in impermeable surfaces, such as roads and constructed buildings, which hinder the passage of water which influence rise of air temperatures urban heat island which has a direct impact both indoors and outdoors, comfort and the overall health of the residents. This contribute to significant demand for artificial cooling in cities within tropical climates, which in turn leads to higher levels of carbon emissions. Consequently, scholars are now focusing their attention on improving the microclimate within urban areas and reducing the effects of the urban heat. This systematic review is focused on delivering a comprehensive evaluation of the interventions implemented through the utilization of green landscape elements within the urban thermal environment in tropical climatic areas. A thorough analysis of vegetation's role in regulating air temperature is presented, along with suggestions for maintaining urban people's thermal comfort. When vegetation is used effectively in tropical cities, air temperatures can be lowered by up to 4°C with green roofs, 9°C with trees, and 12°C with vertical greening systems. Urban greeneries must be implemented for communities and cities to become sustainable through the ideal fusion of green landscape components. Additionally, the current study will benefit architects and urban planners who are implementing similar green landscape interventions to enhance thermal comfort, reduce carbon emissions, and ultimately improve productivity and wellbeing of residents.

Keywords: Urban, Green Landscape, Thermal Comfort, Climate, Sustainability

1. INTRODUCTION

Urbanization is an indisputable global megatrend, and its impacts extend far beyond the city limits. The United Nations predicts that by 2050, nearly 68% of the world's population will be residing in metropolitan areas, making urbanization a defining characteristic of the 21st century (Yu et al., 2020). Notably, tropical cities account for approximately one-third of the global population. The rapid growth of cities and sprawling urban development have profound consequences for urban areas. They include deteriorating air quality, rising heat stress, increased cooling demands, and adverse effects on public health (Herath et al., 2018).

In the context of Sustainable Development Goals (SDGs), especially SDG 11, which centers on creating sustainable cities and communities, the urgency of addressing these challenges becomes clear. Sustainable urban development is a global imperative, as it not only directly contributes to SDG 11 but also aligns with various indicators across multiple SDGs. The nexus between urbanization and sustainability cannot be underestimated, particularly in tropical climates where unique challenges emerge.

Tropical regions, situated near the equator, enjoy abundant greenery and are naturally endowed with a lush, verdant environment. However, the impacts of urban expansion and population growth in these regions are immense. Climate-sensitive urban planning and design have never been more crucial, and the utilization of green landscape elements emerges as a key strategy (Emmanuel, 2016). The benefits of incorporating greenery, such as improved shading and enhanced wind convection, are profound, particularly in mitigating the urban heat island (UHI) effect in tropical climates (Raji et al., 2015).

The UHI phenomenon, characterized by elevated urban temperatures, significantly affects the well-being and comfort of urban residents. Tropical regions, marked by high temperatures throughout the year, face the challenge of ensuring a comfortable living environment. As urban density increases and energy demand escalates, the need for sustainable solutions becomes paramount. Vertical greening systems (VGS) represent an innovative approach to energy savings, offering consistent benefits in tropical climates (Sarmento, 2012). These systems, along with other green landscape elements, promise to alleviate the adverse effects of rapid urbanization on the urban thermal environment. This systematic review is aimed at providing a comprehensive assessment of the interventions of green landscape elements in the urban thermal environment within tropical climatic locations.

2. METHODOLOGY

The systematic review adopted PRISMA 2020 flow diagram published by Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al, 2021). The process of locating, screening, and determining the eligibility and inclusion standards for the reports that are relevant to the review's topic is illustrated by the flow diagram (see Figure 1). The next subsections discuss each process in more depth.

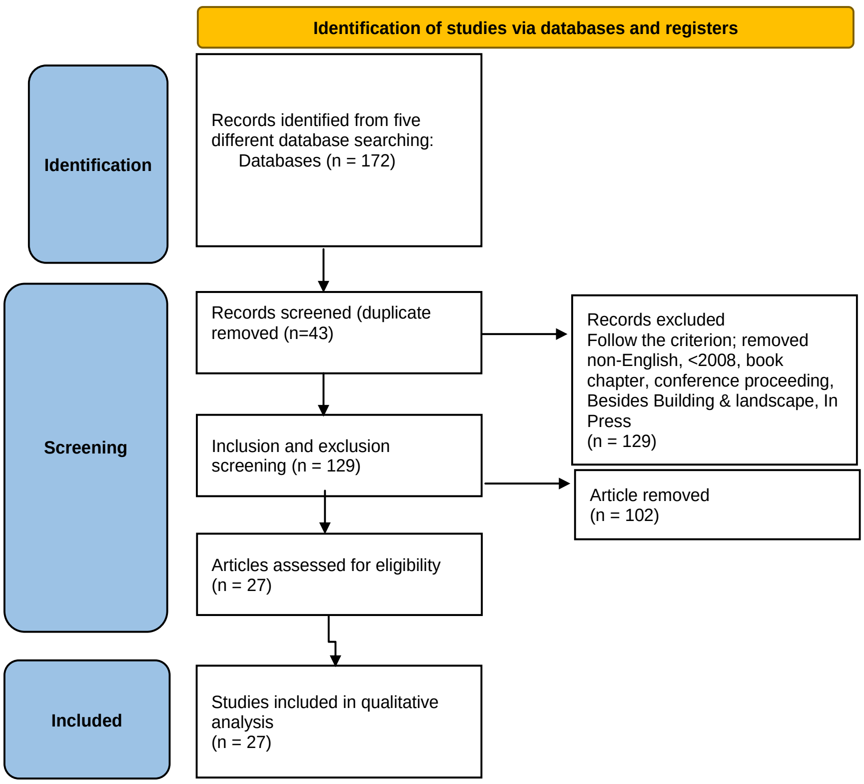

Figure 1: Review Process

2.1 Identification Process

Currently there is vast number of database repository available for research to extract published article. Our study considered five reputable database repository (Google Scholar, Web of Science, Scopus and Science Direct). The review process starts by conducting systematic searches on five different electronic databases based on designed search terms. The study considered "Building Landscape" to serve as the basis for the main keyword selection. Then proceed with sub- keyword to covered whole range of building landscape areas. The formulation of keywords covered from the broader and then narrowed to specific terms. The goal is to review the findings based on a formulated keyword search.

This study limited the extraction results on journals (article and review), conferences, book chapters, reports and online repositories from 2008 to 2022. In the search strategy, nine primary keywords, “Tree and landscape,” “Shrub and landscape,” “landscape and thermal comfort,” “Living wall and landscape”, “Grass and landscape”,” Building and green roof,” “Water bodies and building”, “Vertical greening systems “. Each of these keywords has a main-keyword search.

The search output for “Tree and landscape” and main-keywords resulted in 484 research outputs. The search results for “Shrub and landscape”, “landscape and thermal comfort”, and “Living wall and landscape”, and main-keywords resulted in 878, 761, and 578 research outputs, respectively. Similarly, the search results for “Grass and landscape “, “Building and green roof”, “Water bodies and building” , “Vertical greening systems” and main-keywords resulted in 556, 481, 678 and 673 research outputs, respectively The search process resulted in a total number of 5,095 research outputs. The study moved forward by sorting and removal duplicate literature. This yields the final research outputs to 1,239 eliminating 3856 unrelated studies. Then the study continue with quality assessment resulting in 172 article eliminating 3,684. Then study proceed with initial screening of 172 article which result in removal of 40 articles as duplicate resulting in 129 article for assessment.

2.2 The Search Process

As can be seen in Figure 2, there are more papers related “Conservation of natural resource”, “Green roof”, followed by “Plants”, and “Ecosystem”. This indicates researchers are putting more emphasis on construction design in conservation of natural resources, which also plays a major role in reducing carbon emissions.

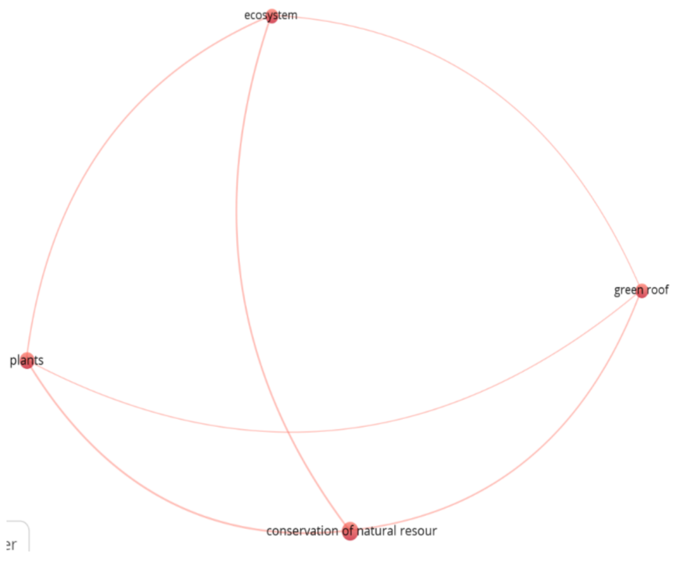

Figure 2: keyword search for tree and landscape

The research also used “Shrub and landscape” as a major keyword for searching related literature demonstrate the colour of each node indicating the grouping of terms offered by VOSviewer, called a cluster as shown in Figure 3 with a total of two distinct clusters. These keyword clusters indicate a significant correlation between the keywords in each group. Cluster 1 (Green) the main area of research is to be found in the term “plant leaves”, “conservation of natural resource” have a higher percentage among the literature discovered in this search. While cluster 2 (Red) search term is directly related keywords collected on research related to “human being” and “animal ecosystem”.

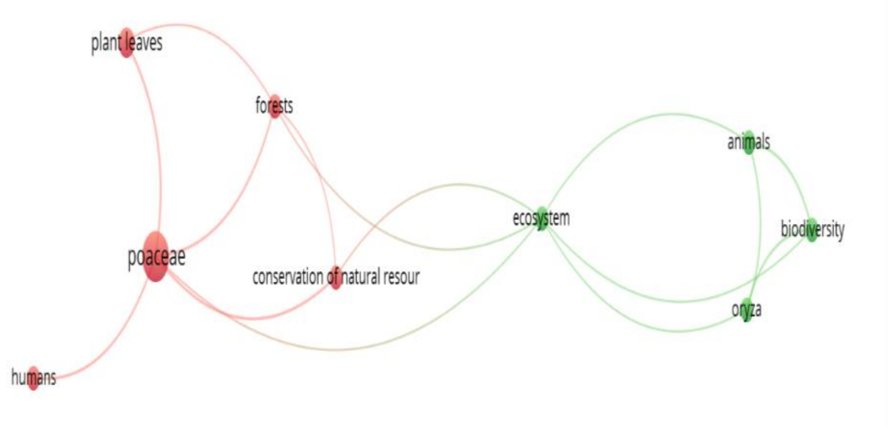

Figure 3: keyword search for Shrub and landscape

Similarly, the search keyword also used "landscape and thermal comfort" as a major keyword for searching related literature demonstrate the red and green colour on nodes indicating the grouping of terms offered by VOSviewer. The red colour indicate correlation between the keywords in each group. The main area of research is to be found in the term "Climate change", "Cold temperature", "Hot temperature", "Animal" have a higher percentage among the literature discovered in this search. While green color represent the search term that is directly related keywords on "Animal", "temperature "and "climate change".

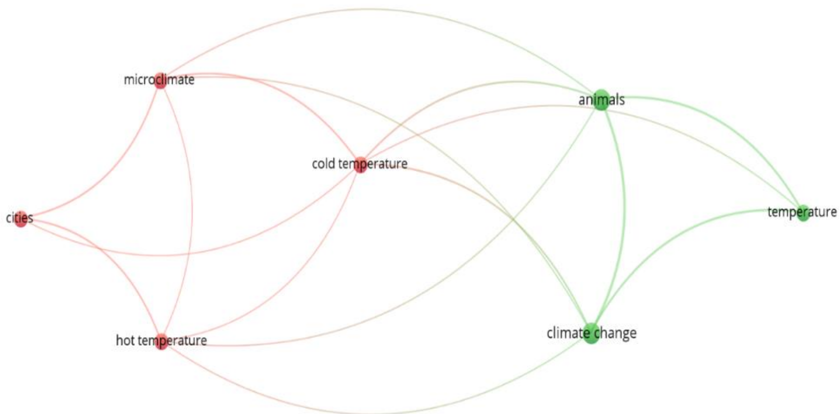

Figure 4: keyword search for landscape and thermal comfort

A living wall is one of the building infrastructures that can help maintain healthy comfort and ensure energy consumption optimally. The "Living wall and landscape" is one of the keywords used to retrieve related literature. The output of this search result in four clusters (see Figure 5 with four different colours i.e green, red, yellow and blue). The red colour indicate correlation or research keywords in the term "Hot temperature", "tree shading", " Cold temperature", "Global warming", "outdoor temperature". The green color represent the search term that is directly related keywords on "indoor temperature", "body temperature "and "climate change". The blue colour focuses on keywords with the practical implementation of the smart thermostat comprising literature related "Human", "Cell wall", "Glymphatic system", "Immunoassay", "Social work". While the yellow colour indicate the research keyword related to "carbon dioxide, "anti-fungal agent" and interconnection with "cell wall".

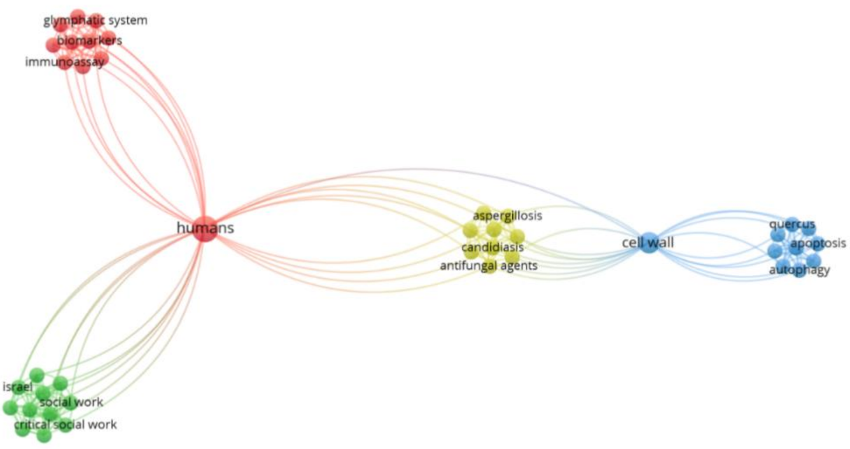

Figure 5: keyword search for living wall and landscape

The keyword used in the related literature search is "Grass and landscape". Grass plays a vital role in both commercial and residential buildings. The search keyword produces two three different colours on related literatures as shown in Figure 6. The red colour focuses on keywords related to "environmental monitoring", "dry planting", and "conservation of natural resources". The green colour keywords give major emphasis on "agriculture" and "animal". While the blue colour concentrate on "human" and "health comfort".

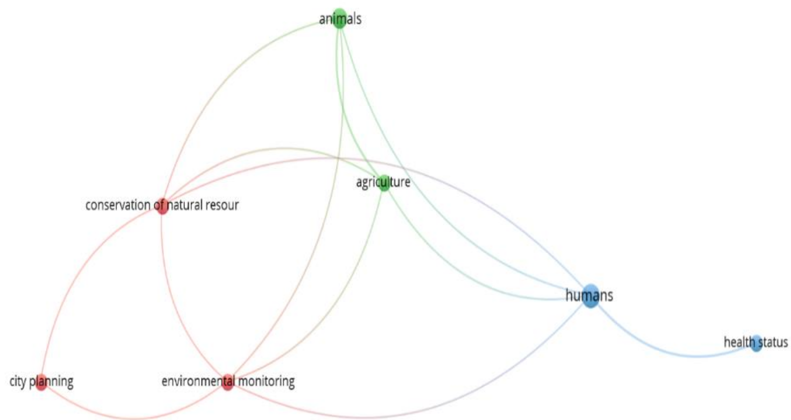

Figure 6: keyword search for grass and landscape

The keyword used in the related literature search is "Building and green roof". Green roof is one of the factors that play a vital role in building and general landscape sectors. The search keyword produces 29 related literatures as shown in Figure 7. The vast majority of this literature is related to "Agriculture", "Humans", followed by "Environmental monitoring", and so forth.

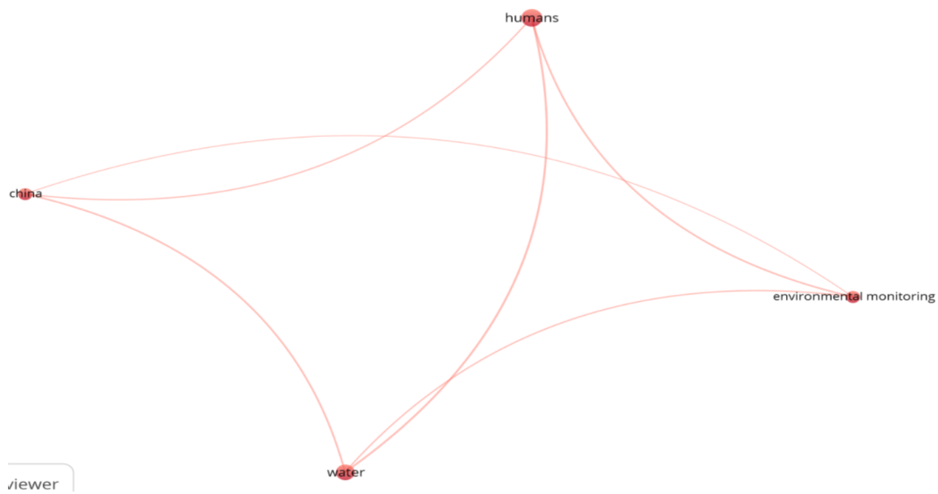

Figure 7: keyword search for building and green roof

Thermal performances of water bodies that can help maintain healthy comfort. The "Water bodies and building." is one of the keywords used to retrieve related literature, resulting in two clusters (red and green) from Figure 8. The red lines indicate correlation of research keywords related literatures comprising literature related "Cities" "Animal", "Ecosystem". Followed by green colour consisting of research keywords on "Water" and "Humans". This keyword produces the least high number of related literatures discovered in this study.

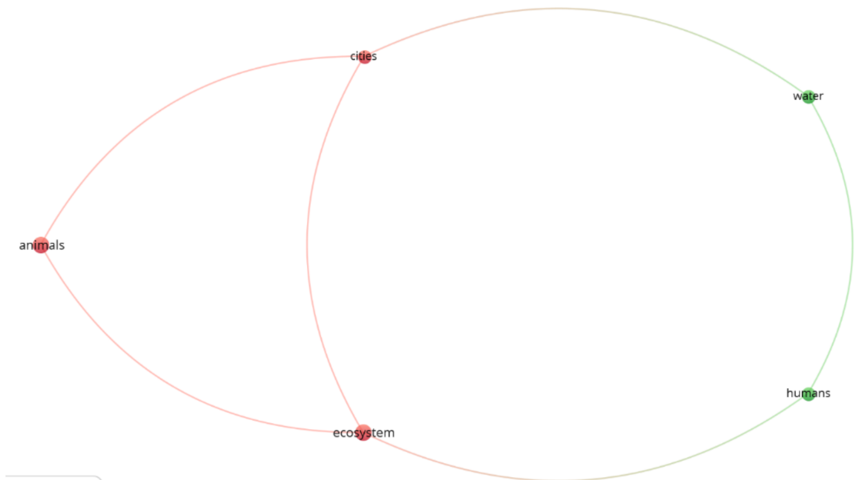

Figure 8: keyword search for water of bodies and building

2.3 Screening Process

As mentioned in section 2.1 total of 172 published articles was identified as primary studies for this review. The study employed two screening processes. The preliminary screening stage began with the removal of duplicate items (see section 2.1). Second, the researchers' established inclusion and exclusion criteria were utilized to filter the papers (see Table 1). The presence of relevant literature (research articles) was the first criterion, as this is the most dependable approach to gathering meaningful information. The current study also excludes thesis, meta-analyses, meta-synthesis, book series, books, chapters, and conference proceedings. This does not mean reliable information cannot be obtained from them but majority does not cover or capture the requirements for analysis and therefore before doing a thorough analysis the study excludes and focus on journal article to make sure that the identified literature satisfies the review standards.

Furthermore, the review was restricted to articles written in English. It is vital to remember that the publication term was limited to eighteen years (2008-2022) in order to cover the trend within the span of these years so as to shed light for future improvement.
In the first process forty tree (43) duplicate articles was discovered the resulting articles from several databases were reduced to one hundred and twenty-nine (129). In the second selection, the titles and major content of each article were examined to see whether the inclusion criteria had been met and whether the articles were relevant to the current study on. After applying all inclusion and exclusion criteria (see Table 1) only twenty-seven (27) articles will be utilized in the next round of eligibility screening.

There are 102 publications that do not fulfill the criteria, leaving 27 for the analysis procedure, as shown in Figure 1.
The suitability of the 40 evaluated papers was rigorously reviewed during this process.

Table 1 - The selection criterion

Criterion	INCLUSION	EXCLUSION
Language	English	Non-English
Timeline	2008-2022	< 2008
Literature Type	Journal (Article)	book chapter, conference proceeding
Publication	Final	In press

Authors & Year	Title & Journal	Field of Study	Issues	Method	Significance
1. (Nikologianni, Mayouf& Silvia Gullino, 2022)	Title: Building Information Modelling (BIM) and the impact on the landscape: A systematic review of evolvements, shortfalls, and future opportunities Journal: Cleaner Production Letters.	Landscape Architecture and Design	The limited scope of previous research, the disconnect between BIM and landscape design, the neglect of climate change concerns, and the need for more comprehensive and up-to-date studies in this area.	A hybrid approach, involving the systematic review of research papers published between 2010 and 2021	The paper aims to critically review the impact of BIM on landscape design, highlighting its developments, shortcomings, and future prospects.
2. (Jean-Christophe, Céline & Gilles Vuidel, 2012)	Title: A software tool dedicated to the modeling of landscape networks Journal: Environmental Modelling & Software	Ecology & Landscape Management, Graph Theory	Addresses the challenge of modeling landscape connectivity, particularly the complexities associated with representing and quantifying interactions between species and their environment within ecological landscapes.	Graph-based Modelling	To provide a systematic and mathematical approach, through graph-based modeling, to understand and quantify landscape connectivity, which is vital for ecological research, landscape management, and graph theory applications.
3. (Namkyung Oh &Junghyae Lee, 2020)	Title: Changing landscape of emergency management research: A systematic review with bibliometric analysis Journal: International Journal of Disaster Risk Reduction	Emergency Management Research	Understanding historical evolution and identifying fundamental elements of effective strategies of emergency management research.	A systematic review of emergency management publications using the bibliometric analysis	Provides insights into the evolution of emergency management research, offers a better understanding of effective strategies, and identifies emerging trends.
4. (Lorenzo, Julio & Francisco Ayugac, 2005)	Title: Analysis of the Materials and Exterior Texture of agro-industrial Buildings: a photo-analytical Approach to Landscape Integration Journal: Elsevier	Design & architecture	Addresses the challenge of effectively integrating agro-industrial buildings into their surrounding environment in a visually harmonious manner, considering factors like texture and public preferences.	Analysis of Texture in Design	Potential to improve design practices by enhancing aesthetic understanding, providing practical tools for design decisions, and emphasizing the importance of public engagement in architectural projects.
5. (Lorenzo, Julio & Francisco Ayugac, 2003)	Analysis of the exterior colour of agro-industrial buildings: a computer-aided approach to landscape integration Journal: Elsevier	Design &Architecture	lack of detail regarding the specific computer analysis method and the psychological aspects considered	Computer Analysis &Psychological Aspect	The paper's significance lies in its practical contribution by providing a method for project designers to select appropriate color schemes, based on

					computer analysis and human integration preferences, to enhance the aesthetic integration of agro-industrial buildings into the landscape.
6. (Manal, Claudine & Jacques Teller, 2018)	Title: The Historic Urban Landscape approach to urban management: a systematic review Journal: International Journal of Heritage Studies	Heritage Conservation &Urban Development	the limited focus on operationalizing the value-based approach within local contexts and the challenges associated with this transition.	a systematic review of the literature on the Historic Urban Landscape (HUL)	Exploration of the practical challenges of implementing a value-based approach to heritage conservation within urban development, offering insights that can inform more effective and culturally sensitive policies and practices in preserving cultural heritage.
7. (Patrizia, Daniele, Gabriele & Stefano Benni, 2007)	Title: Rural Buildings and their Integration in Landscape Management Journal: CIGR Ejournal	Architectural & Urban Planning, Land Management Planning	Addresses the challenge of assessing and managing the impact of construction and redevelopment projects on rural landscapes to determine whether they enhance or detract from the landscape's quality and aesthetics.	Conceptual Model, Critical Analysis.	The paper's significance lies in its promotion of a holistic approach to rural building design that integrates landscape quality considerations with architectural, scientific, and regulatory factors, contributing to more environmentally and aesthetically sustainable development.
8. (Marcos Llobera, 2001)	Title: Building Past Landscape Perception With GIS: Understanding Topographic Prominence Journal: Journal of archaeological Science	Archaeology, Geographical Information System (GIS)	Gap in methodological advancements within archaeological landscape research, particularly in the context of Geographic Information Systems (GIS). Highlights the need for improved methods to match theoretical developments.	application of **Geographic Information Systems (GIS)** within archaeological landscape research	The paper's significance lies in its pioneering attempt to use GIS technology as a tool within archaeological landscape research. It represents an effort to bridge the methodological gap and advance the field's research techniques.
9. (Zhenyu, Jungho , Jinyoung& Michael Hodgson, 2014)	Title: Building type classification using spatial and landscape attributes derived from LiDAR remote sensing data	Urban Planning & Management	Addresses the issue of classifying buildings into specific types (single-family houses, multiple-family houses, and non-residential	Spatial Attribute Classification, Classification & experiments	Ability to provide a valuable tool for urban planning and management by demonstrating the feasibility of using LiDAR remote sensing data to

	Journal: Landscape and Urban Planning		buildings) using LiDAR remote sensing data. This classification is a valuable task for urban planning and management practices.		accurately classify buildings into different types, aiding in informed decision-making processes.
10. (Tobias, Hélène, Nora, Claudia, Matthias, Thanasis, Tobias, Jørgen& Peter H. Verburgg, 2016)	Title: The driving forces of landscape change in Europe: A systematic review of the evidence Journal: Land Use Policy	Landscape Research	The challenge of understanding and comprehensively identifying the drivers of landscape changes, which are critical for ensuring landscape sustainability in the face of global transformations.	systematic review method, synthesizing findings from 144 studies	The study's significance lies in its systematic synthesis of research on landscape change drivers, providing valuable insights and recommendations to guide future research, policy development, and landscape management efforts for enhanced sustainability.
11. (Anber, Rehan, M. Shahria, Hirushie&KasunHewage, 2021)	Title: Evaluation of financial incentives for green buildings in Canadian landscape Journal: Renewable and Sustainable Energy Reviews	Energy Policy Planning, Sustainable Development	Lack of understanding regarding the distribution and effectiveness of Financial Incentives (FIs) for green buildings in Canada, highlighting the need for clarity and evaluation in this area of energy policy planning.	Identification of FIs, Distribution Analysis	The study's significance lies in its potential to inform policymakers and government authorities in Canada about the effectiveness of Financial Incentives (FIs) for green buildings, enabling them to make informed decisions to promote sustainable development and carbon mitigation strategies in the country.
12. (Chaminda, Somya& Teresa Cerratto-Pargman, 2020)	Title: Mapping the current landscape of citizen-driven environmental monitoring: a systematic literature review Journal: Sustainability: Science, Practice and Policy	Environmental Science & Monitoring	Citizen engagement and participation in environmental monitoring through the concept of citizen observatories.	Systematic Analysis of Literature, Qualitative Analysis	Exploration of citizen observatories as a means to empower nonprofessional scientists and promote their active engagement in environmental monitoring, potentially fostering more informed and participatory approaches to addressing environmental challenges.

13. Patrizia, Daniele, Stefano, Enrica, Giovanni Pollicino, 2011)	Title: The FarmBuiLD model (farm building landscape design): First definition of parametric tools Journal: Journal of Cultural Heritage	Architectural Research & Design	Effectively characterizing the morphological aspects of rural buildings, which is essential for architectural analysis and design but can be challenging due to the diversity of rural contexts.	Literature review, validation and calibration	Provision of a systematic approach for characterizing the architectural aspects of rural buildings, offering flexibility for designers to meet contemporary and future functional and aesthetic needs within rural contexts.
14. (Jacob H.P. van der Vaart, 2005)	Title: Towards a new rural landscape: consequences of non-agricultural re-use of redundant farm buildings in Friesland Journal: Landscape and Urban Planning	**Rural Development and Landscape Architecture**	Conversion of farm buildings in rural areas impacts the architectural, economic, social, and landscape aspects of these regions, raising questions about their future and rural heritage preservation.	Data Collection, Analysis	The study's significance lies in its examination of the transformation of traditional farm buildings in rural areas, providing insights into the changing rural landscape, the motivations of owners/residents, and the potential impact on rural heritage and future rural development.
15. (Judith, Paul, Sabine, EvelieneSteingröver, 2016)	Title: Landscape services as boundary concept in landscape governance: Building social capital in collaboration and adapting the landscape Journal: Landscape Policy	**Landscape Governance and Environmental Management**	How to foster collaborative landscape governance and build trust between farmers and regional governments in the GouweWiericke region, given initial low levels of trust resulting from past processes.	Case Analysis	The study's significance lies in its demonstration of how the landscape services concept can be used as a boundary concept to facilitate collaborative landscape governance, bridging social boundaries and fostering collective action for landscape resource management, with implications for broader landscape governance approaches.
16. (Malte, Niklas, Michael & Marius Rosenberg 2014)	Title: How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective Journal:	**Industrial Engineering and manufacturing, information technology**	The study is how the German manufacturing industry is responding to increasing global competition, labor cost challenges, and the need for product quality and production cost	Journal analysis, cluster analysis	examination of how the German manufacturing industry is embracing Industry 4.0 practices to remain competitive, offering valuable insights for decision-makers

			improvements through the adoption of Industry 4.0 practices.		and contributing to the evolving research stream of Industry 4.0.
17. (Salla, Kaisa, Petri, Pilvi, Aija& Nora Fagerholm, 2023)	Title: 3D visualisations for communicative urban and landscape planning: What systematic mapping of academic literature can tell us of their potential? Journal: Landscape and Urban Planning	**Urban and landscape planning, human-computer interaction, information technology**	Lack of a comprehensive understanding of the usability, benefits, and appropriate uses of 3D visualizations in participatory and collaborative urban and landscape planning processes, along with the heterogeneity of planning contexts and the scarcity of well-documented usability evaluations in the existing literature.	Systematic Mapping, Data Usage	Exploration of how 3D visualizations can enhance public participation and collaboration in urban and landscape planning, with the aim of bridging the gap between technological advancements and practical usability in planning processes.
18. (Parinaz, Wendy, Cindy &KarineDupred, 2019)	Title: Creating a dementia-friendly environment through the use of outdoor natural landscape design intervention in long-term care facilities: A narrative review Journal: Health & place	**Landscape Architecture, health care design**	Lack of comprehensive research on the impact of outdoor natural landscape designs, aligned with dementia-friendly environment (DFE) characteristics, on the well-being and behaviors of individuals with dementia in long-term care (LTC) facilities.	Narrative Literature Review	enhance the quality of care and well-being of individuals with dementia residing in long-term care (LTC) facilities by synthesizing existing knowledge about the positive effects of outdoor natural landscape design aligned with dementia-friendly environment (DFE) characteristics
19. López Sánchez, M., Tejedor Cabrera, A., & Linares Gómez Del Pulgar, M. (2020)	Title: Guidelines from the heritage field for the integration of landscape and heritage planning: A systematic literature review Journal: Landscape & Urban Planning	**Landscape Planning**	Lack of comprehensive analytical synthesis of insights related to heritage and landscape, emphasizing the need to bridge this gap and strengthen the connections between these fields for more effective landscape planning.	Systematic Review	Enhance the integration of heritage considerations into landscape planning, promoting a holistic approach to understanding and managing landscapes as cultural expressions and collective spaces.
20. (Elisabeth, Mike &IoanFazey, 2011)	Title: Is research keeping up with changes in landscape	**Landscape research**	Alignment between innovative directions in	Quantitative Analysis	Identify areas where academic landscape research can

	policy? A review of the literature Journal: Journal of environmental Management		landscape policy development and academic landscape research, along with issues related to geographical representation and stakeholder involvement in research efforts.		contribute to policy development and highlight the need for stronger collaboration between policy and academia in the field of landscape research.
21. (William, Max W, Felix, Radhika and Jan C Minx, 2018)	Title: The literature landscape on 1.5 0C climate change and cities Journal: Current Opinion in Environmental Sustainability	**Urban policy and climate mitigation**	Challenge of synthesizing policy insights from the rapidly growing and diverse urban literature, particularly in the areas of transport, buildings, waste management, and urban form, with a focus on mitigating climate change.	Systematic review	The significance of the study lies in the importance of considering a broader range of demand-side options in urban climate mitigation efforts, which are currently underrepresented in the literature
22. (Udayasoorian&RamalingamSenthil, 2021)	Title: A review of the impact of the green landscape interventions on the urban microclimate of tropical areas Journal: building and environment	urban microclimate control	Urban heat island (UHI) effect and its adverse impacts on urban microclimates, thermal comfort, air quality, and overall well-being in rapidly urbanizing tropical cities.	comprehensive literature review and synthesis of research findings	The significance of this review article lies in its provision of valuable insights and recommendations for urban planners and architects to effectively use vegetation-based strategies for mitigating the urban heat island (UHI) effect, improving urban microclimates, enhancing thermal comfort, and reducing carbon emissions in tropical cities, ultimately contributing to more sustainable and livable urban environments.
23. (Kamińska et al., 2021)	Title: The Landscapes of Sustainability in the Library and Information Science: Systematic Literature Review Journal: sustainability	Library and information science	Examination of sustainable development from the perspective of library and information science, considering its economic, social, environmental, and cultural dimensions.	Systematic literature review,	The significance lies in exploring how library and information science contributes to the understanding and promotion of sustainable development

24. (Sharifah Khalizah, Nik Hanita Mohamad & Sabrina Idilfitri, 2012)	Title: Modification of Urban Temperature in Hot-Humid Climate through Landscape Design Approach: A review Journal: elservier	Sustainable landscape design	Improvement of urban thermal comfort in warm and humid climates through sustainable landscape design approaches at the local and micro scales.	conceptual review	Providing guidance to landscape architects, policymakers, and urban designers on how to incorporate sustainable landscape design practices to enhance outdoor thermal comfort in hot and humid tropical urban areas, ultimately contributing to a better quality of life for residents.
25. (Shisong, Mingyi, Wenji, Yungang ,Mob , Shanshan, Yile, Ziqiang&Chaoyi Zhang, 2020)	Title: Multi-level monitoring of three-dimensional building changes for megacities: Trajectory, morphology, and landscape Journal: ISPRS Journal of Photogrammetry and Remote Sensing	remote sensing and geospatial analysis	The need for accurate and efficient 3D building change detection methods in urban areas, especially megacities, to update geographic databases, monitor urban sprawl, assess disasters, and manage energy budgets.	graph cuts algorithm	The significance of this study lies in its development of an automated 3D building change detection approach using LiDAR data, which has practical applications in urban planning, disaster assessment, and the maintenance of up-to-date geo-databases for megacities.
26. (Mohammed Wasim & Erik Johansson, 2019)	Title: Landscape interventions in improving thermal comfort in the hot dry city of Damascus, Syria—The example of residential spaces with detached buildings Journal: Landscape and Urban Planning	urban design, microclimatic simulations	outdoor thermal comfort of detached buildings in a hot, dry climate, specifically in Damascus, Syria	microclimatic simulations with ENVI-met	Potential to improve urban outdoor thermal comfort through urban and landscape design interventions in hot, dry climates like Damascus, Syria, ultimately enhancing the quality of life for residents.
27. (Jin Su, Lorenzo & Julio Hernández-Blanco b, 2018)	Title: A site planningapproach for rural buildings into a landscape using a spatial multi-criteria decision analysis methodology Journal: Land use policy	geographic information systems (GIS)	Complex process of selecting suitable sites for rural buildings, particularly focusing on optimizing the siting of a new single dispersed tourism-related commercial building within the landscape of Hervás, Spain.	Analytical Hierarchy Process (AHP)	The significance of this study lies in its development of a systematic GIS-based approach to optimize the siting of rural buildings, particularly tourism-related commercial buildings, within landscapes.

3.0 DISCUSSION

According to a thorough review of the literature (see Table 2), the urban green infrastructure (UGI) plays a major role in lowering the temperature of the urban environment. The influence of trees is more pronounced at street level than at the building scale, while green roof (GRs) and green wall (GWs) have greater effect at the building scale than at the level of urban canyons. The UHI effects at the urban scale level can be lessened when GRs and GWs are applied on a large scale. The combination of green elements yields better performance and temperature control than either one alone (Kamińska et al., 2021). The following are the various forms of UGI's heat reductions: The maximum temperature reductions achieved by VGS are between 4 and 11 °C for the surface, between 3 and 11 °C for the air, between 2 and 9 °C for trees, and up to 4 °C for GRs. In Dhaka City, Bangladesh, GRs can lower the air temperature by up to 3.5 °C in comparison to nearby non-GR buildings (Nikologianni et al., 2022). Additional benefits of GRs include reduced pain index and carbon sequestration.

When it comes to orientation, it has been found that green materials function better in areas with higher solar radiation. For this reason, the green components should be oriented to help optimize solar radiation. Literature from regions with Mediterranean and subtropical climates, such as China and Spain, shows a similar tendency (Lu et al., 2014). When there is increased humidity due to vegetation, the orientation should take the wind direction into account as well for optimal ventilation to prevent discomfort. Given that the west receives the most solar radiation in a tropical climate; it is most commonly experimented with, followed by the north, east, and south. The park's size, the number of trees, and the constructions all affect the microclimate (Chan & Chau, 2021). Because well-watered trees evapotranspirate, trees have been proven to be useful in reducing air temperature by 3.1 °C to 5.8 °C in all-weather circumstances (Meili et al., 2021). Building surface temperatures were lowered by trees' shading impact. In their discussion of the factors contributing to surface temperature rise brought on by solar radiation, Kamińska et al. (2021) recommended employing asphalt on pavements, reflective coatings, tree shade, and urban forest systems to regulate air temperatures in cities. In a closed space, the increased humidity brought on by plants makes people uncomfortable in the heat. Natural ventilation lowers thermal performance but, by regulating humidity, creates a comfortable interior atmosphere. The lowering of internal surface temperature is also aided by wind speed. Trees at street canyon level can be used as an efficient way to reduce heat stress outside of buildings. The effectiveness of VGS and GRs is highlighted when taking building scale into account.

Temperature, CO2 emission regulations, and heat stress govern the UHI at the macro level, all requiring combinations of green factors (López Sánchez et al., 2020). Plants that lack water have little effect on the microclimate (Jeong et al., 2013). Maintaining the microclimate may be more effectively accomplished by choosing the right greenery and combining them (Conrad et al., 2011). Green components significantly regulate carbon fluxes as carbon capture techniques that are advantageous to city dwellers (Motealleh et al., 2019). Heat stress-related health problems in tropical metropolitan areas can be reduced by a sustainable landscape and cities with as much greenery as feasible (Lu et al., 2014). The choice of plant species is yet another crucial element in the design of urban greening. It is better to have a higher Leaf Area Index (LAI), more coverage, and a higher rate of evapotranspiration. Researchers need to investigate plant-based products further in conjunction with other tactics for reducing temperature, such as cool roofs, insulate panels, and low albedo materials. Study (López Sánchez et al., 2020) indicate taller plant tend to have more leaves which is dynamic parameter in VGS that quantifies the total amount of leaf area in the canopy.

3.1 Thermal performance based on tree

Trees, as one type of vegetation, influence the urban microclimate by moderating temperature at the pedestrian level, at the urban canyon level, and thereby decreasing UHI impact at the city level (see Table 2). The impact of trees in urban areas varies depending on scale, such as a single tree at the building level, a row of trees in urban canyons, a cluster of trees in parks and open spaces, and woods. Shade, photosynthesis, and evapotranspiration are all ways in which trees influence the urban microclimate (Yu & Hien, 2006). In a tropical climate, the air temperature beneath trees is lower than in open space. In an Australian field measurement, trees in an urban park reduced the temperature by 2-2.5 degrees Celsius (Zhang et al., 2019). Trees aid in the reflection, interception, and absorption of solar radiation, as well as the cooling impact provided by shadowing.

By tracking the temperature and humidity around different types of trees for two months, a monitoring system was established to analyze the cooling effect of different types of trees in Malaysia's urban regions (Al Junid et al., 2020). The study found that different species provided different temperature reductions, with Hopeaodarata providing the greatest thermal decline of 9.2 degrees Celsius. Mesuaferrea had the highest relative humidity of about 74.5%, and an increase in relative humidity produces a decrease in air temperature. The impact of thick trees on the surrounding microclimate results in evapotranspiration consequences.

The apparent temperature (AT) and mean radiant temperature (MRT) of the outdoor environment were measured to analyze the effects of trees on the urban microclimate in Bhopal throughout the summer (Kántor & Unger, 2011). The outside microclimate was examined by determining AT equal to the temperature sensed by humans and MRT, a measure of the net radiant heat gain and loss on the human body surface at a certain moment in time and space (Liang & Huang, 2011). According to the study, a 10% increase in canopy tree density reduces the AT by up to 0.3 degrees Celsius. As a result, a canopy with an 80% coverage density will reduce the AT by around 2.5 degrees Celsius.

The thermal comfort index and relative strain index of two typical Nigerian structures with and without vegetation revealed that the building with greenery was more thermally comfortable both inside and outside (Morakinyo et al., 2014). In the building with plants, the duration of uncomfortable conditions was shorter. During working hours, the comfort level was measured in a shaded building for 2 hours and in an unshaded building for 5 hours. Another experiment in Malaysia with two houses found that the shading impact of trees contributed to an internal air temperature reduction of up to 4 degrees Celsius in the house with more vegetation than the buildings with less vegetation (Misni, 2018).

A comparison of the thermal comfort of four different urban open spaces in Bhopal during the summer revealed that gardens with trees and vegetation were thermally more comfortable than the other situations. Field measurements of air temperature in parks revealed that they were 3.1 degrees Celsius, 0.4 degrees Celsius, and 6.7 degrees Celsius colder than the market, lakefront, and open grassland, respectively. The MRT reduction in parks was up to 0.7 degrees Celsius in zones with 10% tree cover and 2.2 degrees Celsius in zones with 70% tree cover. The physiological equivalent temperature (PET) was 0.8 degrees Celsius and 2.6 degrees Celsius cooler in areas with 10% and 70% tree cover, respectively. The MRT and PET are heavily influenced by tree cover and their evapotranspiration effect. Thus, a natural setting provides more comfortable thermal conditions, both physiologically and psychologically, than other urban open areas (Ali & Patnaik, 2018). Yahia & Johansson (2012) investigated four urban vegetation scenarios (basic case, base case with extension, base case with trees on streets, and base case with street trees and horizontal shading devices). The best scenario was identified as trees with shading devices, which had a lower PET value of 10.5 degrees Celsius and a standard effective temperature (SET) value that was up to 4.4 degrees Celsius lower than the base case. Trees are known to have a good impact on the environment. Another summer study in Taiwan's urban parks found a difference in SET of nearly 9 degrees Celsius between shaded and unshaded regions. Temperatures in downstream places rose due to plant overpopulation. Furthermore, wind speed and shading are the two most important aspects influencing users' thermal comfort (Hsieh et al., 2016). In Malaysia, field measurements and simulated results revealed that a combination of trees with a high canopy density and a high LAI of 9.7 and cool material with a high albedo of 0.8 produced the best results. These combinations can reduce average air temperature by up to 2.7-3.5 degrees Celsius (Shahidan et al., 2012). Trees with a high sky view factor reduce air temperature greatly in open metropolitan settings.s MRT is reduced by trees with medium to low sky view factors. Trees paired with other mitigating methods such as shading and wind movement could significantly reduce the impacts of UHI. The existence of an urban green environment benefits the surrounding built-up environment.

Thermal measurements in Singapore's urban green areas revealed that the average temperature of the green environment was 1.5 degrees Celsius lower than that of the surrounding built-up environment (Yu & Hien, 2006). Simulated results revealed energy savings of up to 10% in cooling load when building environments were located closer to the green urban areas.
The planting pattern and positioning of trees have a significant impact on the cooling effect. More trees do not usually result in greater cooling benefits. Overcrowding of trees may obstruct wind flow, increasing temperature and humidity, particularly in tropical climes. Though continuous trees produce greater shade, correct wind movement should be considered by strategically planting small trees or bushes below the canopy. Combining grasses for additional evaporative cooling boosts the thermal effect of trees.

The surrounding geometry affects the cooling effect of trees in addition to the planting pattern and plant trait. Trees with a higher height-to-width ratio have a lower cooling impact than trees with a lower height-to-width ratio. The cooling impact of trees, along with horizontal shade devices, can give greater thermal comfort in the surrounding environment. Green spaces such as forests and parks have an impact on the surrounding neighborhood, and the closer the distance, the greater the cooling effect.

3.2 Thermal performance based on vertical garden

A vertical garden, also known as a VGS, is the cultivation of plants on building envelopes or support structures (Safikhani et al., 2014). Integrating vegetation into building construction by placing plants on building facades is becoming more fashionable. It is classified as a construction material since it improves building sustainability while also providing significant ecological and environmental benefits. According to a study that compared the performance of VGS in four distinct regions, the cooling and energy benefits of VGS are weather-dependent (Dahanayake & Chow, 2019). Based on the building technique, support structure, and type of plants and substrates utilized, VGSs are divided into two categories: green façades and LW.

The classic or direct green façade, double skin green façade, perimeter flowerpots, and LWs are further divided into panels, modules, or blankets. Vertical gardens can be found as early as the seventh century, with evidence of Babylon's vertical hanging gardens. Historically, the VGS was used for aesthetics, shading, and cooling. Many researchers investigated the advantages and properties of VGS in various climatic conditions (Besir & Cuce, 2018). In a tropical climate, the VGS was primarily used for passive cooling, energy savings, and thermal comfort. For better performance and environmental sustainability, VGS design should take into account the characteristics, components, foliage, air cavity thickness, and local climate (Perini & Ottelé, 2012). Greening systems on building envelopes act to provide sufficient greeneries for people in high populations, land shortage, and high land cost places.

An actual building experiment was carried out in Jakarta, Indonesia, by Othman et al. to evaluate the temperature reduction effect of a VGS in a tropical climate. They measured the temperature and humidity inside and outside buildings with and without GWs. The maximum temperature of buildings with a green cover without a green cover was 2.3 degrees Celsius inside and 2.55 degrees Celsius outside.

Buildings using VGS outperformed buildings without VGS in terms of thermal performance. The temperature in the greenery building was 3.79% lower than in the non-greenery building. The humidity in a VGS-equipped building was lower than in a non-VGS-equipped structure (Othman & Sahidin, 2016). An experimental investigation in Indonesia utilizing miniature building models found that outdoor and inside surface temperatures may be reduced to a maximum of 9.9 degrees Celsius and 6.5 degrees Celsius, respectively. The highest fall in outdoor and inside air temperature was 5.7 degrees Celsius and 1.9 degrees Celsius, respectively. As a passive cooling design strategy, this temperature drop helped to reduce the building's cooling load (Widiastuti et al., 2018). The performance of a bio façade wall with potted Psophocarpus tetrogonobulus was compared to that of an equivalent room with a bare wall facing the same west direction. According to the findings, the average outside surface temperature of the vegetated wall was 11 degrees Celsius lower than that of a normal bare wall. Both rooms had nearly identical indoor surface temperatures. The air temperature of the rooms with and without plants was monitored, and it was discovered that installing a bio façade reduced indoor air temperature by 0.6 degrees Celsius.

The performance of the VGS depends on the selection of appropriate plant species. An experimental investigation in Indonesia on the thermal effect of two plant species, Amaranthus hybridus and Brassica juncea revealed that the temperature reduction was more prominent with Amaranthus. The average indoor air temperature and landscape air temperature reductions were 1.2 ◦C and 1 ◦C with in Amaranthus and 0.2 degrees Celsius and 0.6 degrees Celsius, respectively, with Brassica (Nugroho, 2014). Different forms of VGS can have varying degrees of influence on the surrounding microclimate. The thermal performance effect of two varieties of VGS-green façade and Living Wall (LW) was examined in the corridors of a five-story office building in Malaysia. The temperature and humidity levels were monitored in the VGS looking north. When compacted to the reference wall without vegetation, the average air temperature reduction with the green façade was 0.6 C and with the LW was 0.8 degrees Celsius.

The maximum air temperature dropped by 8.4 degrees Celsius in the green façade and 11.9 degrees Celsius in the LW. Modular LWs performed better because their dense vegetation screened more sunlight than the green façade. In contrast to temperature, the LW raised mean relative humidity by 1.1%, which was only 0.3% higher than the reference wall in the case of the green façade. This distinction resulted from greater solar radiation penetration through green façade cable systems than modular LW systems (Jaafar et al, 2015). The inside passage had a constant temperature drop of up to 5 degrees Celsius (Jaafar et al., 2013). Another experimental comparative study in Malaysia's hot, humid climate investigating the difference between bare wall, green façade, and LW utilizing test boxes revealed that the LW reduced temperature better. The temperature reduction with the LW was 8 degrees Celsius in the air cavity, 6.3 degrees Celsius in the cavity surface, 4 degrees Celsius in the indoor air without ventilation, 3.5 degrees Celsius in the indoor air with ventilation, and 4 degrees Celsius in the indoor surface, compared to 6.5 degrees Celsius, 3 degrees Celsius, 2.5 degrees Celsius, 5.5 degrees Celsius, and 3.5 degrees Celsius for the green façade system.

The performance of eight different LW systems was compared to a bare concrete wall in Singapore based on surface temperature, ambient temperature, and relative humidity. The study found that the LW system with modular panels might reduce surface temperatures by up to 10 degrees Celsius. The indirect green façade system had a minimum temperature of 4.36 degrees Celsius due to the lack of substrate insulation and cooling impact. At 0.15m away from the LW modular system, the highest reduction in ambient air temperature of up to 3.33 degrees Celsius was observed. A LW performed better thermally in Sri Lanka, with maximum outer surface, inner surface, and internal air temperature reductions of 10.16 degrees Celsius, 3.31 degrees Celsius, and 2.11 degrees Celsius, respectively (Rupasinghe & Halwatura, 2020). The comparable values in the indirect system were 8.65 degrees Celsius, 2.32 degrees Celsius, and 1.82 degrees Celsius, respectively, while in the direct technique, they were 6.36 degrees Celsius, 1.82 degrees Celsius, and 0.66 degrees Celsius.

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Wong et al. (2009) conducted a UHI simulation utilizing a ten-story hypothetical skyscraper in Singapore. Their research found that increasing the amount of green cover reduced the air temperature in the surrounding area. More plant coverage resulted in improved performance, as evidenced by the reduced MRT. Plants with lower shading coefficients performed better in terms of thermal insulation and shading. The simulation was run for three alternative scenarios: an opaque wall, a wall with windows, and a glass façade, each with a different vegetation coverage of 0, 50, and 100%.

When compared to the wall with no flora, the opaque wall with 100% covering had a mean temperature reduction of roughly 10 degrees Celsius. The inclusion of ventilation improves the analysis throughout all seasons. The majority of the studies were completed within one month, with only a couple lasting six months. The behavior of a system and plant material over the course of a year is yet unknown.

Certain common aspects can be considered in general for installing VGS tropical location to have control on microclimate. As far as the temperature reduction and plant characteristics are concerned, the plants with high LAI have a greater number of leaf layers and coverage with more temperature reduction capacity in general. The air cavity between 0.5 and 1 m performed well than cavities with less than 0.5m. Regarding the orientation west façade had more reduction in temperature than the east and south. The incidence of solar radiation and wind movement is essential for the evaporative and shading effect and to avoid high humidity levels in a tropical climate.

3.3 Thermal performance of green roofs (GRs)

The vegetation planted atop a building's flat or sloping rooftop is referred to as GR. Extensive GRs have smaller plants and thin substrate layers, whereas intensive GRs have thick substrate and larger plants. The heat reduction and energy savings in urban buildings, as well as the mitigation of the UHI impact, are two major contributions of GRs in the urban environment. Other advantages of GRs include storm water management, visual appeal, increased production, improved habitation, noise reduction, and lower pollution. GRs regulate the thermal performance of buildings through the shade, evaporative cooling, and insulating capabilities of plants and the growing medium. In tropical areas, a rooftop garden reduces UHI. Rooftop gardens in Sri Lanka resulted in a temperature decrease of 10-15 degrees Celsius (Halwatura & Jayasinghe, 2007). A field measurement found a maximum reduction of 18 C in surface temperature after installing an extensive GR on the rooftop of a building in Singapore. The extended GR system's thin substrate layer, dark substrate color, and low-lying plants resulted in lower thermal performance than the intensive GR system. The thin layer of widespread GR, on the other hand, readily released trapped heat and provided greater nighttime cooling. The large system prevented around 60% of the heat gain (Nyuk Hien et al., 2007). The performance of the GR is determined on the plant species chosen.

A field measurement on three rooftop greenery setups in Singapore using three different species estimated that the MRT over the GR was lower than the concrete roof. An intense GR experiment was carried out on the rooftop of a low-rise commercial building in Singapore. For six different plant species, the ambient temperature and relative humidity (RH) were recorded on both indoor and outdoor surfaces. Plants with a greater LAI reduced temperature more effectively than plants with a lower LAI. The largest surface temperature drop was up to 30 degrees Celsius), while the ambient air temperature was 4.2 degrees Celsius (Hien et al., 2007). The GR lowered the interior temperature fluctuation range. Priya & Senthil (2021) experimental investigations in Mauritius revealed a drop in indoor roof surface temperature of up to 4 degrees Celsius. The IAT variation of GRs was between 19 and 23 degrees Celsius, which was lower than the 16-32 degrees Celsius of conventional roofs. The installation of a GR reduces both the indoor and outdoor temperatures of buildings. In July, a GR erected in Malaysia with the plant species Ipomoea pescapre lowered the IAT by up to 1.73 degrees Celsius, and outdoor and indoor surface temperatures by up to 4.62 degrees Celsius and 7.86 degrees Celsius, respectively (Ismail et al., 2012). An experimental study on a university rooftop in Singapore studied the contribution of GRs to temperature reduction over a typical roof. The highest and average temperature reductions measured were 1.3 and 0.5 degrees Celsius, respectively. The largest surface temperature reduction was 15.3 degrees Celsius, and the average was 7.3 degrees Celsius. At night, the air temperature was about equal (Qin, 2013). In Singapore, the extended GR had a lower life cycle cost than the exposed roof, both with and without energy savings, with a net energy savings of up to 14%. Intensive GRs, on the other hand, always had a higher lifecycle cost than exposed flat roofs, with net energy savings of just up to 4%. If not properly maintained, a GR has some drawbacks. Without proper maintenance, it may result in non-point source pollution in hot and humid cities (Chen, 2013). The green roof then contains ten times the sediment and nutrient content of a bare top. As a result, the maintenance cost of GR is higher than that of other greeneries.

To investigate their usefulness in minimizing UHI behavior in Colombo's tropical environment, simulation research was done using Envimet software to replicate the actual conditions under six different UGI scenarios. Temperatures were reduced by 1.87 degrees Celsius with trees on curbsides, 1.76 degrees Celsius with 100% GR, 1.79 degrees Celsius with 50% GR, 1.86 degrees Celsius with 50% green wall, and 1.9 degrees Celsius with a combination of trees on curbsides, 50% GR, and 50% GW. The combined UGI resulted in the greatest temperature drop, followed by the GW and GRs (Herath et al., 2018). An examination of the thermal effect of vegetation in different regions using a two-dimensional microscale model indicated that GRs reduced surface temperature by up to 12.8 degrees Celsius in Riyadh and a high of 26.1 degrees Celsius in Mumbai. The greatest and average daytime temperature decreases in Mumbai for all green projects were 8 degrees Celsius and 6.6 degrees Celsius, respectively, and 4.4 degrees Celsius and 2 degrees Celsius for GWs. The performance of greening systems improves with increasing temperature. For all green case initiatives in Mumbai, the energy demand for cooling was lowered from 11 h to 6 h, and for the GW, the reduction was up to 3 h (Alexandri & Jones, 2008).

The GR performs similarly to the LW, except that it is mounted horizontally. GRs, like the VGS system, have a significant influence on OST and OAT. Evaporation and insulation continue to be essential processes in GR cooling. The green roof has a limited influence on several measures when compared to LW. The performance of GRs is determined by a variety of parameters, including the type of system employed, plant species, sun radiation, substrate types, and soil water content.

A GR provides for a considerably broader selection of plant material applications than a living wall system, since it can accommodate a variety of shrubs, grasses, and trees. In terms of plant material qualities, plants with a high evapotranspiration rate and low shrub albedo should be chosen over plants with a high LAI. When two tests with intense GR placed in the same climatic backdrop were compared, a difference in surface temperature reduction of up to 15 degrees Celsius in one and 30 degrees Celsius in the other was noted. The discrepancy in findings could be attributed to the different types of plants employed, with one having flowering plants and grass and the other having trees and shrubs. As with VGS, the function of GRs and the consequences vary depending on the combinations of the contributing elements stated. The impact of GR is limited to the top floor and roof level rather than the pedestrian level. It is critical to frequently evaluate GR for sedimentation and nutrient concentration.

3.4. Thermal performance of grass and shrubs

Shrubs are plants having a thick, bushy, or open canopy structure with multiple woody stems with no main stem structures. Shrubs can typically reach heights of 3 m. Some plant species have been trained to climb and maintain themselves on walls. Grasses are monocotyledonous plants with slender blade-shaped leaves. Green landscapes, whether natural or manmade, include both grasses and plants. Though they are commonly employed as aesthetic features in urban design, their contribution to temperature reduction and thermal comfort has piqued the interest of climate experts. Few studies have been conducted to investigate the role of grasses and shrubs in urban environments and their contribution to urban thermal comfort in tropical climates. Grasses have been utilized to manage the temperature in and around GWs and GRs. Trees and turfgrass were excellent at regulating air temperature during the day (Gómez-Navarro et al., 2021). In Thailand, the use of grasses on the tops of buildings lowered the quantity of heat transported to the inside. The use of grass on the roof reduced the warmth and moisture of the soil through evaporation.

The rooftop with 0.20 m soil depth and manila grass reduced heat transfer by 81.05% compared to the exposed roof. In the same experiment, a rooftop with 0.20m soil depth and savanna grass had 8.75% less heat transfer than a rooftop with manila grass, demonstrating the significance of the grass utilized. Savanna grass species reduced heat transfer better than manila grass species.
Simulation research at the National University of Singapore assessed the efficacy of rooftop greeneries utilizing shrubs, trees, and turf in ten distinct university locations (Radhakrishnan et al., 2019). It was discovered that using denser flora, such as turfs, resulted in a higher cooling impact. The cooling load energy savings with turfs were 9.08%, 18.85% with shrubs, and 20.01% with trees. Trees saved the most energy, followed by bushes and turfs. Perera et al., (2021) investigated the use of grass as GWs in Colombo. Only three of the nine plant species showed good growth and survival rates, including two types of grasses: Axonopus fissifolius, Elusine indica, and an evergreen succulent Roheo spathacea. The greatest temperature drop was recorded with Axonopous grass, which reduced temperatures by up to 5.06 degrees Celsius and improved thermal comfort in an urban setting.

Grass application has been shown to be more effective when combined with trees than when used alone. Bhopal, Ali & Patnaik (2019) investigated the thermal comfort between parks, the lakefront, open grassland, and a market route. Among the four species, open grassland had the highest PET of 46.7 degrees Celsius, followed by market road (41.8 degrees Celsius), lake (39.9 degrees Celsius), and parks (38.5 degrees Celsius). Grassland experienced the smallest temperature reduction and contributed the least to PET reduction. However, grasses combined with trees in parks lead to enhanced PET reduction. A similar study in Singapore used simulation to examine the effects of various landscape features such as grass, trees, water bodies, different albedo materials, and combinations of the elements on thermal comfort and urban microclimate (Yang et al., 2018). The addition of grass as a stand-alone element reduced the surface temperature by 8 degrees Celsius, the air temperature by 0.25-0.5 degrees Celsius, and the MRT in sunny areas by 4-8 degrees Celsius. Even if this is less than the remainder of the scenario, it is better than the worst-case scenario and water bodies. Grass in combination with trees reduced temperature by 10 degrees Celsius in OST, 0.75 degrees Celsius in AT, 16 degrees Celsius in MRT, and 12 degrees Celsius in PET.

In three separate residential areas of Kolkata, simulation research was conducted to examine several UHI mitigation measures such as cool roofs, cool pavement, green cities, and cool cities (Chatterjee et al., 2019). In the green city plan, existing conditions were reproduced with additional trees and grasses, which proved to reduce air temperature by up to 0.7 degrees Celsius, 0.8 degrees Celsius, and 1.1 degrees Celsius in different regions. However, trees contributed more to the cooling impact than grass. Overall, a cool city strategy, which included vegetation, a cool roof, and pavement, lowered more PET than a green city strategy, demonstrating the need to combine interventions in UHI mitigation. Ghaffarianhoseini et al. (2015) used simulation to examine the inclusion of tree grass in the courtyard and its associated cooling effect in Kuala Lumpur. Five distinct situations were examined by including 100% grass, 25% trees, 75% trees, 50% trees, and no trees and grass. It was discovered that grass had just a minor impact on air temperature, with a reduction of up to 0.13 degrees Celsius, whereas trees had a greater impact, with a drop of up to 2.5 degrees Celsius in 75% coverage.

A Singapore study investigated the cooling effect of five distinct types of vegetation: grass, shrub, trees, and trees over shrubs, and secondary forest. Among the five secondary forests, trees had a more substantial effect of 1.7 degrees Celsius, followed by shrubs with a 0.9 degrees Celsius reduction and trees with a 0.6 degrees Celsius decline. Due of insufficient shade and evapotranspiration, grass and shrub as standalone factors had no meaningful effect. As a result, the amount of the cooling impact varies with vegetation. The use of shrubs in the rooftop garden demonstrates that shrub thermal performance is independent of LAI and is related to evaporative rate and shrub albedo (Tan et al., 2015). Plants with three different species on three plots revealed that, despite having a height of 1.5 m and a LAI of 7.21, plants in plot 2 had a lower MRT reduction than plants in plots two and three, which had LAIs of 2.78 and 3.59, respectively. Phyllanthus cochinchinensis was applied on plot 1, Heliconia American dwarf on plot 2, and Sphagneticola trilobata on plot 3. The evapotranspiration rate of plots 1 and 3 was higher than plot 2, and the shrub albedo of plots 1 and 3 was 0.28, which was higher than plot 2, which was only 0.16. Thus, compared to LAI, MRT reduction in shrubs on the GR was more linked with shrub albedo and evapotranspiration rate. Although the temperature reduction of shrubs and grasses is not as significant as that of trees, GW, and GR, it works effectively when combined with other factors. Using shrubs and grasses in conjunction with trees works better than the other factors in terms of temperature reduction. The use of shrubs and grass is not restricted to the ground, but can also be extended as GWs and GRs. The cooling impact of shrubs and grasses, like that of GRs, is dependent on evapotranspiration rate rather than LAI because shade is not the primary element in reducing temperature here. Shrubs can be employed as an individual feature to shade walls at lower elevations. If grasses are employed in shaded areas, the humidity level may rise, necessitating sufficient ventilation to combat the humidity rise. Grasses may demand more water if they are planted in full sun.

3.5. Thermal performance of water bodies

Cities' blue areas, such as rivers, ponds, lakes, springs, and canals, are said to cool the surrounding environment. Water bodies often have lower surface temperatures than the surrounding hard surfaces during hot weather (Steeneveld et al., 2014). At night, however, water bodies behave differently. It takes longer than the surrounding air to cool down at night, therefore it is warmer than the air and likely to increase UHI during the summer nights (Hathway & Sharples, 2012).

Water bodies should be carefully located within urban limits to capture wind and trees to increase the cooling performance of surrounding water. As a result, the evaporative cooling of urban water bodies is also affected by the surrounding geometrical surfaces and vegetation (Ong et al., 2011). When the distance between water bodies and vegetation diminishes, the cooling effect of the surrounding environment increases. The cooling effect of open space is affected by street geometry and river width. The lower PET is due to the larger aspect ratio of the roadway canyon and the bigger river.In general, water reduces temperature in subtropical, Mediterranean, and other climates by evaporation, heat exchange between air and water surface, and radiation absorption. Furthermore, the impact of ventilation and water movement influences the thermal effect of water (Jacobs et al., 1997). However, because tropical climates have different humidity and wind conditions than subtropical climates, the behavior of water bodies requires a greater understanding. Water bodies have an impact on urban microclimate (Lai et al., 2019). It was discovered that urban geometry increased PET reduction more than the presence of water bodies, showing that water bodies have less impact on microclimate in a tropical region. Waterbodies, in particular, are helpful in hot and dry areas.

A quantitative study examined the impact of various landscape elements on microclimate in Singapore's high-rise urban residential districts. Thermal comfort was evaluated in seven different conditions using a field and simulation experiment. It was discovered that water bodies had no effect on lowering heat stress, PET, air temperature, MRT, and surface temperature in a tropical climate. It could be because of the high humidity and low wind speed at the measured site, or because the water body isn't large enough to manage the surrounding microclimate. Several studies investigated the impact of larger bodies of water such as rivers and streams. According to an assessment of the river's effect on urban microclimate, the waterway's influence on cooling effect is dependent on a variety of elements such as building density, direction, placement pattern, street geometry, and so on. In tropical areas, wind movement is critical for boosting the cooling impact of waterways (Febrita et al., 2021). The temperature drop near a canal was measured in Singapore's Kallang and Sungei districts. Every 30 m distant from the river, the air temperature dropped by only 0.1-0.2 degrees Celsius. It was discovered that the change in air temperature near bodies of water is proportional to their distance. A comparable study in Melaka discovered a temperature drop of 0.25-0.30 C every 25 meters up to 50 meters away from the river (Manteghi et al, 2018). The cooling effect was reduced after 50 m, although it continued until 95 m.

The influence of the garden city concept in Putrajaya was assessed using modeling of water bodies, which reduced the daily mean air temperature at 2 m by 0.14 C (Morris et al., 2016). However, it was less than the 0.39 degrees Celsius drop caused by vegetation. During the day, the thermal influence of bodies of water was less visible than that of vegetation. Due to its great thermal retention capacity, the water body also had high temperatures at night and in the morning, extending uncomfortable circumstances on the surroundings, whereas trees provided continuous cooling results. When comparing thermal comfort in four different open spaces in Bhopal - lakefront, parks, grasslands, and market lane - lakeside measured 39.9 degrees Celsius, which was lower than market lane and open garden but higher than parks, which recorded 38.5 degrees Celsius. Participants noticed that the lakefront was marginally less comfortable in terms of thermal comfort. In Malaysia, the use of water as a layer on glass walls impacted the temperature of the inside (Qahtan et al., 2011). When two test rooms with and without water film on glazed walls were compared, the surface temperature was reduced by 7.2-14 degrees Celsius and the internal air temperature was reduced by 2.2-4.1 degrees Celsius. They proposed that in tropical regions, water films can be utilized on the east and west façades, but the cost and humidity issues should be taken into account. Roof water showering is used to reduce sensible heat in the air as well as heat release from building surfaces (Wong et al., 2009). According to the literature, aquatic bodies do not contribute as much to temperature decrease as greeneries do. However, when sufficient ventilation is provided, the cooling impact of waterbodies can be conveyed to the surrounds. Larger bodies of water have a greater influence on temperature lowering than smaller bodies of water. Waterbodies' effects could be boosted further by using trees to give additional cooling. It is always preferable in urban planning to situate spaces downwind of water bodies with streets oriented perpendicular to it to allow cooled air to go a greater distance than to create streets parallel to it and hinder wind flow.

4. STUDY RECOMMENDATION

The effective use of trees, VGS, and GRs is critical for heat regulation in both indoor and outdoor situations. As a result, future research should concentrate on end-user preferences in selecting plant species and planting strategies for GWs to maintain temperature control. As a result, VGS could be the focus of future study. A few suggestions for improving the deployment of green landscape features in tropical locations are presented below.

4.1. Trees

The recommendations for using trees for temperature regulation are given below.

- Trees are an effective way to control outdoor thermal comfort and decrease UHI, and they can be planted strategically in areas where pedestrian thermal comfort is required. It has a smaller impact on indoor temperature control than VGS.
- Trees, when combined with other features such as horizontal shading devices and low albedo materials, give an additional cooling impact.
- Plant overcrowding should be avoided in pedestrian circulation regions because it reduces wind flow, resulting in increased humidity and stagnant air conditions, which causes more human thermal discomfort.
- Trees having a dense canopy density of more than 70% should be used for increased temperature decrease and shading. They help to lower heat by increasing evapotranspiration - trees with an LAI greater than six demonstrate greater temperature reduction.
- Trees with shrubs provide more cooling and better control over the UHI impact than a single isolated tree in streets and open spaces.
- To reduce the temperature at the neighborhood and city levels, dense, multi-layered vegetation structures such as a forest and parks must be considered, rather than only trees at street level.
- Plant species with a higher canopy density appear to perform better. Temperature reductions were greater in the presence of species such as Hopea odarata, Mesua ferrea, and Ficus benjamina.
- A dense canopy reduces sun radiation incidence and causes vitamin D insufficiency and other health problems.

4.2. Green roofs

The following are the recommendations for using GRs for temperature regulation.

- When used on a broad scale, GR helps to minimize the effects of UHI. A GR in a single building delivers fewer thermal benefits because it only affects the top floor and does not reach the lower or pedestrian levels.
- It is preferable to select species with a higher evapotranspiration rate and lower albedo than those with a higher LAI.
- To minimize sedimentation and nutrient concentration, a GR requires frequent maintenance and care.

4.3 Grass and shrubs

The following are the recommendations for using grasses and shrubs to manage temperature.

- Because of low shade and a negligible evapotranspiration effect, using both shrubs and grasses has less of an impact on the thermal efficiency of urban areas.
- Grass can be used in conjunction with trees to reduce air temperatures marginally while also assisting increased wind movement to overcome high humidity in a tropical location.
- Grass as a solo element will demand greater water supply when exposed to sun radiation than grass in the shade. Proper ventilation is necessary in shady areas to combat high humidity levels.

- Shrubs can be utilized as a stand-alone element to shade lower-height building walls. Shrubs in conjunction with trees can reduce temperature even further, although they may inhibit wind flow, resulting in high humidity.
- To improve thermal comfort in tropical climates, grass selection characteristics primarily include albedo and evapotranspiration rate.
- In tropical climates, species such as Axonopus compresses, Elusine coracana, and Phyllanthus cochinchinensis show superior heat performance.

4.4 Waterbodies

The following are recommendations for using waterbodies for temperature regulation.

- Smaller bodies of water affect temperature lowering and thermal comfort in tropical regions. Furthermore, wind movement around bodies of water improves the thermal comfort of neighboring areas. Because the temperature on the downwind side of the water bodies is substantially lower, houses can be built on the leeward side of the water bodies.
- Additionally, street landscaping might be arranged perpendicular to the water bodies to convey the cooling wind a greater distance.
- In tropical areas, integrating water bodies with trees is used to improve thermal comfort. Trees with nearby bodies of water reduce air temperature even further by passing air over the water's surface. It is critical to remember that the design of the vegetation should aid in the flow of the wind into a more favorable microclimate.
- Larger bodies of water, such as lakes, rivers, and canals, perform better at temperature lowering than smaller bodies of water. Thus, upgrading larger bodies of water with chosen vegetation and their position should be prioritized in urban design to achieve thermal comfort.

5. CONCLUSION

The current review demonstrates the critical significance of UGI in controlling the microclimate of urban environments. The UGI measures are intended to improve the health and well-being of city people. UGI reduces carbon fluxes while minimizing heat fluxes in the built environment.
Greening cities reduce energy usage for thermal comfort while simultaneously lowering carbon emissions. It is crucial to examine the key performance of landscape features throughout the urban area design phase. The following are the final remarks:

- Trees improve thermal comfort in outdoor places at an urban canyon size, with IAT and OAT decreased by up to 10 and 12 degrees Celsius, respectively.
- Trees are advantageous to the cooling of ambient air and the reduction of CO2 emissions in metropolitan areas. Tree shading is useful at controlling surface temperatures.
- Trees with optimal canopy cover and LAI give different health benefits and UV protection, in addition to surface temperature decrease and UHI mitigation.
- GWs have a greater impact on temperature decrease in a single structure and its environs than GRs and trees.
- In tropical metropolitan areas, GRs can chill the ambient air by up to 3.5 degrees Celsius and have an annual carbon sequestration capacity of up to 125 tons of carbon per hectare.
- Grasses and shrubs improve the microclimate when planted alongside trees and other greenery rather than alone.

- Waterbodies improve the microclimate during the day but have the opposite impact at night. Buildings must so be oriented on the leeward side of huge bodies of water.
- Water bodies can reduce air temperature by roughly 0.3 degrees Celsius for every 30 m from the water's surface.
- Glazed walls with a water film reduce wall surface temperature by up to 14 degrees Celsius and IAT by up to 4 degrees Celsius, respectively.
- In developing countries, green landscapes are important for controlling the increased temperatures of metropolitan surroundings in a sustainable manner.

There is also significant potential in retrofitting existing urban spaces with vegetation to control heat stress in the urban environment. Although plant materials lower the temperature of both indoor and outdoor environments, various other environmental parameters must be addressed for human thermal comfort. As a result, future studies should use numerous UGIs and other temperature control methods and materials such as panels, low albedo materials, orientations, structural designs, and so on to link the temperature reduction level with the users' thermal comfort range. A few examples are as follows:

- Aside from temperature reduction, understanding the lifecycle cost and maintenance of green landscape features is critical for effective applications to mitigate the consequences of climate change through a comfortable microclimate.
- End-user preferences must be considered, which is lacking in the selection of plant materials, making it a less favoured option by those concerned with upkeep, cost, and water.
- Clear government laws on VGS, as well as incentives to promote such programs, will increase the use of green landscape elements in urban infrastructure.
- To measure the effects of green elements on energy and the environment, a multidisciplinary approach is required, encompassing solar geometry, atmospheric conditions, wind patterns, climates and seasons, plantations, and social activities.

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