JOURNAL OF ARCHITECTURE, PLANNING & CONSTRUCTION MANAGEMENT
Volume 16 Issue 1, 2026 E-ISSN: 2462-2222 ISSN: 2231-9514

SUSTAINABLE ROOFTOP GARDEN FOR MITIGATING URBAN HEAT ISLAND (UHI) IN KLANG VALLEY

Received: 04 Sep 2025 | Revised: 16 Apr 2026 | Accepted: 16 Apr 2026 | Available Online: 30 Jun 2026

DOI: 10.31436/japcm.v16i1.1012

Batrisyia Adilah Gani[1], Maisarah Ali[2*]

[1] Department of Civil Engineering, Kulliyyah of Engineering, International Islamic University Malaysia,

[2*] Department of Civil Engineering, Kulliyyah of Engineering, International Islamic University Malaysia,

*Corresponding author: Maisarah Ali
Corresponding author's email: maisarah@iium.edu.my

ABSTRACT

The rapid urbanisation in the Klang Valley, Malaysia, has exacerbated the Urban Heat Island (UHI) phenomenon, leading to elevated temperatures, poor air quality, and reduced livability. Rooftop gardens have emerged as a sustainable solution, utilising unused vertical spaces to reintroduce greenery into dense urban areas. This research investigates the effectiveness of rooftop gardens in mitigating UHI through environmental field monitoring and expert interviews. The case study is conducted on one rooftop at a Shopping Centre in the Klang Valley, comparing microclimatic conditions between densely and less-vegetated rooftop areas. The findings indicated significant reductions in air temperature and more stable relative humidity in vegetated areas. Interviews with industry professionals further revealed key environmental and design considerations, implementation challenges, and potential solutions to support wider adoption. This study concludes that rooftop gardens are an effective and multifunctional tool for sustainable urban development in tropical regions such as the Klang Valley.

Keywords: Green Roof, Klang Valley, Microclimate, Rooftop Garden, Urban Heat Island (UHI).

1.0 INTRODUCTION

The Urban Heat Island (UHI) effect is a growing environmental concern in rapidly developing cities, particularly in tropical regions such as Malaysia. The transformation of natural landscapes into impervious surfaces, such as asphalt and concrete, significantly increases ambient temperatures in urban centres. In the Klang Valley, Malaysia's economic hub, this temperature disparity contributes to increased energy consumption, heat-related health risks, and declining quality of life. Studies have identified the Klang Valley as one of the most heat-affected zones in the country, with UHI intensities exceeding 5°C during peak hours due to high-rise buildings, limited green cover, and concentrated energy use (Chee Sam & Sohaili, 2016; Ilham et al., 2012).

Rooftop gardens have emerged as a viable solution to enhance sustainability in urban areas. As a growing trend in urban design, they offer a promising solution to mitigate environmental, social and economic challenges. Rooftop garden is set as a sustainable solution by the United Nations, as it aligns with the Sustainable Development Goals (SDGs). The SDGs they achieved are Target 11, Sustainable Cities, and Target 13, Climate Action (He & Wen, 2023). By transforming traditional rooftops into functional landscapes, these gardens can help minimise urban heat, improve air quality, enhance biodiversity and provide habitats for local wildlife.

Furthermore, rooftop gardens promote human well-being by providing accessible green spaces that can positively impact mental health and community engagement.

According to Ismail et al. (2018), there is an increasing trend in developing countries of using rooftop gardens as a solution to mitigate the UHI effect. Despite the benefits, the adoption of rooftop gardens in Malaysia remains limited, primarily due to a lack of empirical research on the effectiveness of rooftop gardens as a climate adaptation strategy in the Klang Valley's urban environment (Tang et al., 2023). Therefore, this paper aims to explore the potential of rooftop gardens as a sustainable solution for UHI mitigation in the Klang Valley. The research aims to evaluate their impact on the microclimate through environmental monitoring and to gain insights into the operational roof gardens in the Klang Valley by interviewing experts.

2.0 LITERATURE REVIEW

Urban Heat Island (UHI) phenomenon is a climatic condition in which urban areas exhibit significantly higher temperatures than their rural surroundings. This temperature disparity results from the transformation of natural landscapes into urbanised environments dominated by artificial surfaces, limited vegetation, and high-density infrastructure (Chee Sam & Sohaili, 2016). This phenomenon is also prevalent in developing cities due to being an economic hub, lots of buildings and human activities take place.

2.1 Urban Heat Island Factors and Effects

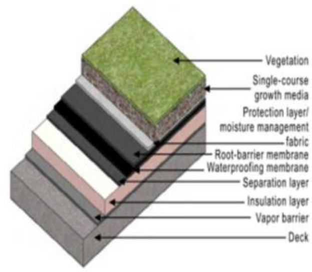
UHI caused by the increase in construction in urban areas suggests that the centres of cities are prone to UHI. This happens because of the thermal capacity of building materials, reduced heat reflux from the underlying, reduced surface water drainage, increased anthropogenic heat, and reduced green spaces in cities (Irfeey et al., 2023). Physical development activities led to the clearance of vegetation to create space for further development. In Malaysia, notably in the Klang Valley, significant research has been conducted to investigate urban heating. As per Ilham Elsayed (2012), who investigated the urban heat island in the city of Kuala Lumpur, Malaysia, Sunday recorded the highest UHI intensity (5.5°C). Compared with the 1985 study, the intensity increased by 1.5°C. This value indicates that urbanisation intensified the heat island effect in developed areas. Beyond structural and environmental causes, UHI is also intensified by anthropogenic heat emissions. Vehicles, industrial machinery, residential heating and cooling systems, and other energy-consuming activities emit waste heat into the environment. In high-density areas, these emissions collectively raise local temperatures (Tang et al., 2023). For example, air conditioning units commonly used in Malaysian homes and offices release hot air into the streets, contributing to an ironic feedback loop: the hotter it gets, the more air conditioning is used, producing more heat and worsening the urban temperature problem.

Since then, UHI has led to higher energy consumption, as urban residents in Malaysia's tropical climate rely more on cooling systems. Not only that, but it can also accelerate greenhouse gas emissions due to continued dependence on fossil fuels (Ibrahim et al., 2012). UHI further affects human comfort, especially for the elderly, children, and those with pre-existing medical conditions. Heat stress, heatstroke, and dehydration become more common during hot months, especially in densely populated, low-income areas with limited access to cooling (Tang et al., 2023). Moreover, Walters et al. noted that this added heat can cause more serious problems, such as changes in local weather patterns, less rain, and reduced water availability. Urban plants may suffer, and the heat can damage important infrastructure such as roads and power systems (Walters et al., 2022). This is especially worrying in fast-developing places like the Klang Valley, where buildings are replacing green spaces. If cities do not plan properly for these changes, the costs of repairs and health impacts will continue to rise.

2.2 Roof Garden and Its Mechanism

Rooftop gardens are composed of several key elements, such as plants, a substrate to provide nutrients, a water system to promote root growth, and a drainage layer to shed excess water. Rooftop gardens are primarily classified as extensive, intensive, or semi-intensive systems (Tang et al., 2023). Extensive rooftop gardens are lightweight, with shallow substrates and low-maintenance plants such as grasses or sedum. At the same time, intensive systems are heavier, with deeper soil that supports shrubs, trees, and recreational spaces. Meanwhile, intensive gardens fall in between, offering moderate to high soil depth and more plant diversity, balancing accessibility with maintenance needs (Tang et al., 2023). Table 1 shows the differences between the types of roof garden and their classification.

Table 1: Types of roof garden with their classification
(source: Abass et al., 2020; Hossain et al., 2019)

Green System	**Intensive** 	**Semi-intensive** 	**Extensive** 
Depth (mm)	150 – 1200	120 - 200	Less than 150
Weight (kg/m^2)	250 – 500	120 – 200	60 – 150
Cost	High	Medium	Low
Maintenance	High	Medium	Low
Separate drainage layer	No	Yes	Yes
Vegetation	Ornamental and succulent plants	Ornamental, meadow species, turf grass and woody perennial	Ground-level plant

Malaysia has introduced many developed high-rise buildings with rooftop gardens, particularly in residential buildings. Due to the scarcity of land, podiums, amenity facilities, parking areas, and other areas are equipped with gardens. In addition to residential areas, rooftop gardens are also recognised in commercial, office, and public areas (Ismail et al., 2018; Tang et al., 2023). Figure 1 shows roof gardens located in Malaysia, while Table 2 lists some green roof projects in Malaysia.

Fig. 1: (A) Extensive green roofs (Herriot-Watt University), (B) Intensive green roofs (Laman PKNS, Shah Alam), (C) Semi-intensive green roofs (Bandar Rimbayu, Shah Alam)

Table 2: List of some green roof projects in Malaysia
(source: Ismail et al., 2018; Tang et al., 2023)

Building	Location	Building Type	Green Roof Type	Accessibility
Secret Garden	Selangor	Commercial	Intensive	Public access
Tun Razak Exchange City Park (TRX)	Kuala Lumpur	Commercial	Intensive	Public access
Bandar Rimbayu	Selangor	Commercial	Semi-intensive	-
Suasana Sentral Condominium	Kuala Lumpur	Residential	Extensive	Private access
Sime Darby Oasis	Selangor	Commercial	Extensive	-
Herriot-Watt University Malaysia	Putrajaya	Institutional	Intensive	-
The Saffron	Kuala Lumpur	Residential	Intensive	Private access
Laman PKNS	Selangor	Commercial	Intensive	-

Various studies have been conducted to demonstrate the effectiveness of the UHI context. The field study conducted by Chee Sam & Sohaili (2016) on a building in Putrajaya concluded that the green roof was cooler by 4.3°C than the bare rooftop. Temperature reduction in roof gardens is mostly due to evapotranspiration, a natural process in which water is absorbed by plant roots and released into the atmosphere through stomata on leaves. This process consumes latent heat, leading to a localised cooling effect. Rooftop vegetation, when properly irrigated and maintained, can significantly reduce surrounding air temperatures by promoting evapotranspiration, especially during daytime when solar radiation is at its peak. (Hamdan & Rashid, 2008)

In tropical regions like Malaysia, where humidity is consistently high, evapotranspiration from green roofs contributes to both thermal comfort and the balance of the hydrological cycle, not only to building cooling. Green roofs provide direct shading to building surfaces, protecting rooftops from solar radiation. This reduces the amount of heat absorbed by the roof membrane and, subsequently, the interior of the building. Additionally, the substrate (soil or growing medium) and vegetation layers act as thermal insulators, decreasing indoor heat gain and lowering the need for mechanical cooling (Getter & Rowe, 2006). Not only that, studies by Niachou, A. et al. (2001) have shown that green roofs can reduce rooftop surface temperatures by 30 to 40°C during peak heat conditions compared to bare concrete roofs.

3.0 METHODOLOGY

3.1 Fieldwork – Environmental Monitoring

Environmental monitoring was conducted at the Secret Garden Rooftop of 1 Utama Shopping Centre, Petaling Jaya. The site was chosen for its accessible rooftop layout and variety of vegetation types. Two distinct zones were identified: a densely vegetated garden area and a less vegetated rooftop section. Air temperature (°C) and relative humidity (%) were measured using calibrated HOBO Pro V2 Data Loggers over three consecutive days from 12th to 14th April 2025. The data loggers monitor the environmental parameters for 12 hours, from 8:00 a.m. until 8:00 p.m., with 15-minute intervals.

Each data logger was placed at representative locations as shown in Figure 2. The purpose was to observe microclimatic differences influenced by vegetation coverage. The placement of equipment was based on the landscape supervisor's suggestions for the Secret Garden. Weather conditions, including rainfall, were recorded in Table 3.

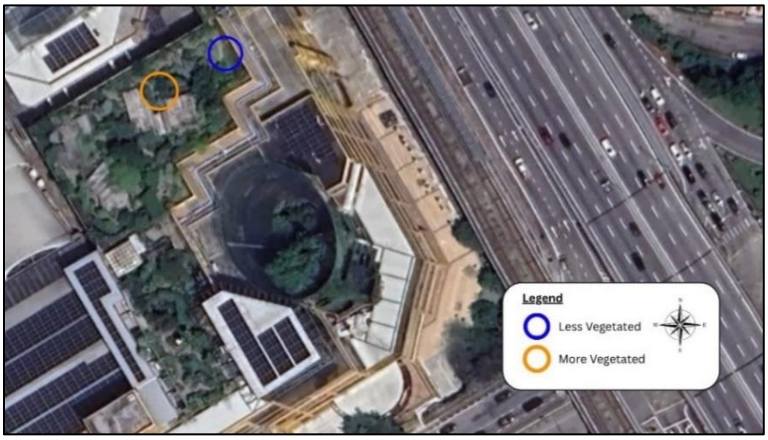


Fig. 2: Location of the data logger in the less densely vegetated area at Secret Garden

Table 3: Summarised weather conditions
(Source: Weather Spark)

Date	Day	Weather Condition			
		8:00-11:59 a.m.	12:00-2:45 p.m.	3:00-6:59 p.m.	7:00-10:00 p.m.
12/04/25	1	Light rain and fair	Fair	Fair	Fair
13/04/25	2	Partly Cloudy	Showers in the Vicinity	Thunderstorm with Heavy Rain	Thunderstorm with Light Rain
14/04/25	3	Fair	Fair	Thunderstorm with Rain	Thunderstorm with Light Rain

3.2 Semi-Structured Interviews

For this study, semi-structured interviews were conducted with two experts involved in the management and development of green areas. The interviews followed a semi-structured format, allowing for open-ended discussions guided by a set of key questions. Topics included the environmental benefits of rooftop gardens, practical challenges in their upkeep, public engagement, and the overall role of rooftop greenery in urban development. Interviews were conducted either in person or via online platforms, depending on participant availability. Thematic analysis was later used to identify common perspectives and extract meaningful insights relevant to the study objectives.

4.0 RESULTS

4.1 Environmental Monitoring

The environmental monitoring results, which are temperature and relative humidity, are interpreted using a combination graph of the three-day average of recorded air temperature values. This is to compare microclimatic differences between densely and less-vegetated rooftop areas.

4.1.1 Air Temperature

Figure 3 shows the combination of average dense and less vegetated air temperature between 8:00 a.m. and 8:00 p.m. The average air temperature over three days was recorded for both locations to enable a clearer, more accurate comparison between the less-vegetated and densely vegetated rooftop areas.

Notably, densely vegetated zones of the rooftop consistently showed lower temperatures than less-vegetated areas. At 8:00 a.m., both locations were at 26°C, the lowest temperature recorded by the data loggers. Temperature gradually increased at 15-minute intervals, reaching its peak in the afternoon before declining towards the evening. The highest average temperature recorded occurred at 3:15 p.m., with the less-vegetated area peaking at 35°C, while the vegetated zone reached 33°C. Throughout the day, vegetated areas remained consistently cooler, with differences up to 2°C compared to the less-vegetated section, particularly during the afternoon.

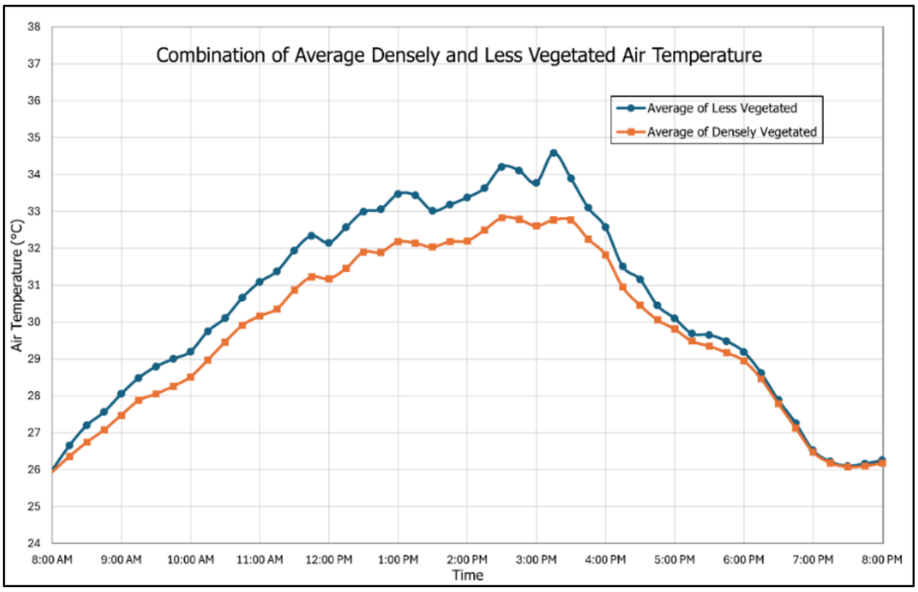


Fig. 3: Graph Combination for the air temperature of average less and densely vegetated areas

4.1.2 Relative Humidity

Figure 4 below compares average relative humidity (RH) between densely and less-vegetated rooftop zones throughout the day. At 8:00 a.m., the highest RH was recorded, with 92% at the least vegetated section, and 90% of the densely vegetated section. This is likely due to lower heat accumulation during the early hours, allowing both rooftop zones to retain higher moisture levels before the temperature began to rise. As shown, the vegetated area maintained slightly higher RH levels between 10:00 a.m. and 2:00 p.m., likely due to moisture release from plants and soil, helping buffer midday humidity drops. During this period, the percentage difference is between 1-3%. The difference suggests that evapotranspiration from plants and soil contributed to the additional atmospheric moisture.

However, at 4:00 p.m., the less vegetated area showed unexpectedly higher RH, and this trend continued until 8:00 p.m. These variations highlight the dynamic influence of vegetation on humidity patterns and its interaction with temperature changes across the day.

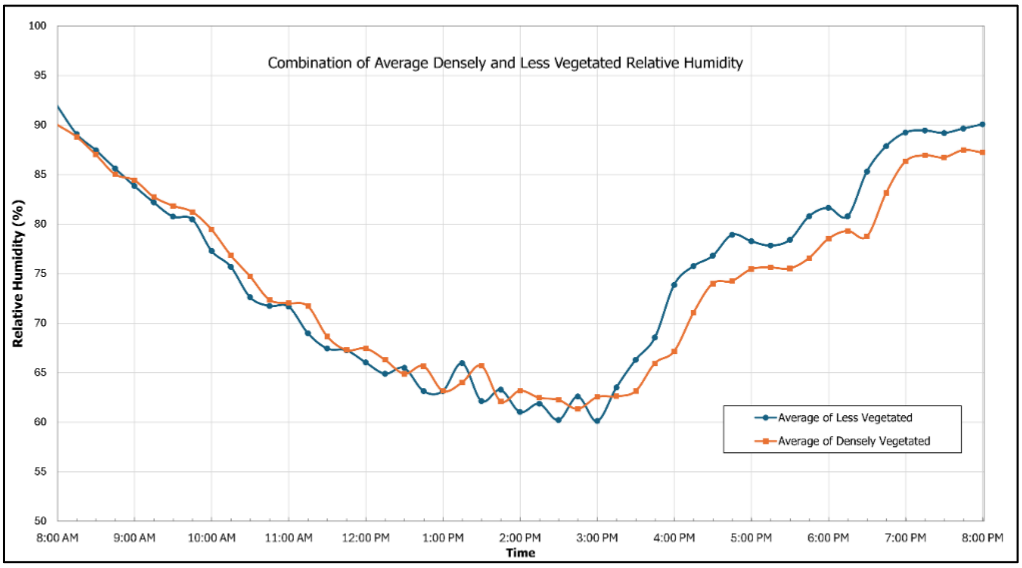


Fig 4: Graph Combination for the Relative Humidity of average less and densely vegetated areas

4.3 Semi-Structured Interview

Qualitative data were collected through in-depth structured interviews conducted in 2025 with two interviewees from different fields. In-depth interviews provide an understanding and description of people's personal experiences regarding the roof gardens' advantages, maintenance and challenges. The data was analysed thematically, i.e., organising the responses by themes. **Table 4** below shows summaries of the in-depth interview findings.

Table 4: Summarised Semi-Structured Interview

Questions	Interviewee A	Interviewee B
Part A: Demographic of Interviewee		
Occupation	Landscape Supervisor	Retail Development
Educational background	-	MS, Sustainable Urban Management
Working experience	More than 20 years	3 years
Part B: General Information of Green Roof		
Location of roof garden	Secret Garden, 1 Utama Shopping Centre	TRX City Park

Questions	Interviewee A	Interviewee B
When was the green roof installed?	Open to public in 2009	Open to public in 2023
What is the type of the rooftop garden	Intensive rooftop	Intensive rooftop
What is the purpose of building rooftop garden?	Marketing, to attract people to shopping in the mall	Focus on built environment and its community
Part C: Role of Rooftop Garden in UHI mitigation		
Do you think green roof can reduce urban temperatures?	Yes	Yes
Have you noticed any temperature differences?	Not so sure, but theoretically, rooftop has low temperature, as it windier	A bit hard to say, because no temperature monitoring is installed
Do rooftop gardens make buildings more eco-friendly and save energy?	Yes, but no energy data or analysis has been done to confirm it.	Yes, though no direct temperature monitoring has been done.
Besides temperature reduction, what other benefits that you observed	The rooftop garden supports urban farming, attracts birds and bees, and offers a peaceful space for visitors to relax and learn about plants.	The rooftop park is used for recreational activities, promotes biodiversity, and includes a rainwater harvesting system for sustainable water use.
Part D: Challenges and Maintenance of Rooftop Garden		
What are the maintenances of the green roof?	The maintenance was done for 4 days, Mondays to Thursday	The maintenance took place every day, during day and night, if it's during the day, they will put signage to indicate section is closed
What are the maintenance elements of the green roof?	Maintenance includes daily irrigation, pruning, removing dead leaves, and topping up soil.	Maintenance includes automated and manual irrigation, pruning, weeding, and pond cleaning.
Did you get any government support for the rooftop garden?	No	No
Are there any challenges encountered?	Mentioned plant theft and visitors plucking plants as the main challenges.	Not particularly, but the challenges to make the park more aesthetics, such as how to hide the plant room, air vents
Do you receive any feedback or comments from the customer about the rooftop garden?	Visitors often describe the garden as calm and educational, with interest in the labelled plants.	Visitors enjoy the space, but some complaints were made about slippery walkways and mosquitoes.
Do you see a growing demand in green roof in Malaysia construction?	Yes, green roof designs are becoming more popular in nearby developments.	Yes, especially in projects that integrate community and green features.

5.0 DISCUSSIONS

The results show that rooftop gardens deliver measurable microclimatic improvements by lowering temperatures, i.e., more vegetated areas have cooler temperatures than less vegetated areas (Tang et al., 2023). These findings indicate that vegetation helps reduce heat accumulation and moderate daily thermal fluctuations.

According to Chee Sam & Sohaili, roof gardens typically maintain higher humidity levels than bare rooftops. In which the increment of relative humidity shows the cooling effect of the surrounding area (Tang et al., 2023). However, after 4:00 p.m., the RH in the densely vegetated area decreased, indicating unusual patterns that external factors may have influenced during the monitoring, such as rainfall. It was observed that the data logger in the less-vegetated area was positioned closer to a wall and more exposed to rainfall and surface moisture, which could have led to artificially elevated RH readings. In contrast, the vegetated zone, with better moisture absorption through soil and plant coverage, may have regulated humidity more effectively, preventing excess moisture accumulation in the sensor area. Thus, the less-vegetated area has higher RH than the densely vegetated area.

Expert perspectives reinforced the environmental data, highlighting that while rooftop gardens can function as effective thermal buffers, their performance depends on careful plant selection, irrigation, and long-term maintenance. The emphasis on financial and technical barriers reflects broader literature, which identifies cost and lack of guidelines as the main constraints in Malaysia. Nevertheless, both experts recognised sustainable features and benefits, such as improved aesthetics, mental well-being, and biodiversity, proving that rooftop gardens are more than just climate adaptation tools.

6.0 CONCLUSION

This study demonstrates that rooftop gardens in the Klang Valley can reduce rooftop air temperature by up to 2°C while increasing relative humidity, thereby improving thermal comfort in tropical urban environments. 2°C temperature difference (reduction) between densely vegetated and less vegetated rooftop zones is quite significant for an urban area such as Klang Valley, which is located in an equatorial climate zone. This suggests their potential to help reduce heat in urban areas, though further studies are needed to confirm their broader impacts. The reduction in surrounding-area temperature can be significant if more roof gardens are introduced.

Combined with expert insights, the findings highlight both the measurable environmental benefits and the broader ecological and social value of rooftop gardens in Klang Valley.
Despite promising results, several barriers hinder widespread adoption. These include high initial costs, structural constraints, lack of localised design standards, and limited maintenance expertise. To unlock the full potential of rooftop gardens, policymakers, architects, and developers must collaborate to establish clear technical guidelines, financial incentives, and public education programs. Ultimately, rooftop gardens should be viewed not merely as aesthetic enhancements but as essential infrastructure for sustainable urban living

in Malaysia. As urban areas continue to grow, integrating green roofs into planning and building codes will be crucial in creating climate-resilient cities that are both livable and environmentally responsible.

REFERENCES

Abass, F., Ismail, L. H., Wahab, I. A., & Elgadi, A. A. (2020). A Review of Green Roof: Definition, History, Evolution and Functions. *IOP Conference Series: Materials Science and Engineering*, *713*(1), 012048. https://doi.org/10.1088/1757-899X/713/1/012048

Chee Sam, L., & Sohaili, J. (2016). *Urban Heat Island Mitigation by Introducing a Green Roof System*.

Getter, K. L., & Rowe, D. B. (2006). The Role of Extensive Green Roofs in Sustainable Development. In *HORTSCIENCE* (Vol. 41, Issue 5). https://journals.ashs.org

Hamdan Bin Ahmed, M., & Rashid, R. (2008). *Thermal Performance of Rooftop Greenery System in the Tropical Climate of Malaysia*.

He, J., & Wen, K. (2023). *Impact and management of rooftop garden - An example from China* (pp. 516–530). https://doi.org/10.2991/978-94-6463-344-3_58

Hossain, M. A., Shams, S., Amin, M., Reza, M. S., & Chowdhury, T. U. (2019). Perception and Barriers to Implementation of Intensive and Extensive Green Roofs in Dhaka, Bangladesh. *Buildings 2019, Vol. 9, Page 79*, *9*(4), 79. https://doi.org/10.3390/BUILDINGS9040079

Ibrahim, A. S., Mohamed Shuhaimy, N. F., Abu Bakar, A., Hj Mohd Ariffin, N. A., & Mohd. Din, S. A. (2012). *The effects of landscape design elements and mosque design on the thermal environment of the main prayer hall: a case study of the Tuanku Mizan Zainal Abidin Mosque, Putrajaya*. https://core.ac.uk/outputs/300429595/?source=1&algorithmId=15&similarToDoc=300449123&similarToDocKey=CORE&recSetID=1d9eb1c6-d406-47d4-b59b-0bba1feca061&position=3&recommendation_type=same_repo&otherRecs=187152280%2C199242464%2C300429595%2C231761854%2C573841257

Ilham S. M. Elsayed, I. S. M. E. (2012). A Study on the Urban Heat Island of the City of Kuala Lumpur, Malaysia. *Journal of King Abdulaziz University - Meteorology, Environment and Arid Land Agriculture Sciences*, *23*(2), 121–134. https://doi.org/10.4197/MET.23-2.8

Irfeey, A. M. M., Chau, H. W., Sumaiya, M. M. F., Wai, C. Y., Muttil, N., & Jamei, E. (2023). Sustainable Mitigation Strategies for Urban Heat Island Effects in Urban Areas. *Sustainability (Switzerland)*, *15*(14). https://doi.org/10.3390/su151410767

Ismail, W. Z. W., Abdullah, M. N., Hashim, H., & Rani, W. S. W. (2018). An overview of green roof development in Malaysia and a way forward. *AIP Conference Proceedings*, *2016*. https://doi.org/10.1063/1.5055460

Niachou, A., Papakonstantinou, K., Santamouris, M., Tsangrassoulis, A., & Mihalakakou, G. (2001). Analysis of the green roof thermal properties and investigation of its energy performance. *Energy and Buildings*, *33*(7), 719–729. https://doi.org/10.1016/S0378-7788(01)00062-7

Tang, Y. Y., Slimani, Y., Al-Ghazal, M. A., Talukdar, G., & Maharjan, A. K. (2023). Sustainable Urban Development in Malaysia: Enhancing Green Roofs with Integrated Technologies. *Civil and Sustainable Urban Engineering*, *3*(2). https://doi.org/10.53623/CSUE.V3I2.335

Walters, S. A., Gajewski, C., Sadeghpour, A., & Groninger, J. W. (2022). Mitigation of Climate Change for Urban Agriculture: Water Management of Culinary Herbs Grown in an Extensive Green Roof Environment. *Climate*, *10*(11). https://doi.org/10.3390/cli10110180