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Article 1

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EFFECT OF GREEN FACADE ON THE URBAN MICROCLIMATE WITH DIFFERENT STREET CANYON

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EFFECT OF GREEN FACADE ON THE URBAN MICROCLIMATE WITH DIFFERENT STREET CANYON

Abstract

Using simulation tools, this study investigates the effect of green walls (GWs) on the urban heat island (UHI) phenomenon within different street sizes. It can be planted without taking up more area and could enhance the microclimate environment, which is why it has a wide range of use potential in urban areas. Because Mina City has a threat of UHI, it was chosen for this study. The temperature within various street sizes in the research region was evaluated using only software called ENVI-met that simulates climate, and three common scenarios were chosen. In the first experiment, green walls extending over an area of 50 m in the south facades of the street building, including a 3m Street width, are simulated to show the effect of GWs on UHI. In the second experiment, the Street width changed to 6 m, and the GWs are placed in the same condition. The last experiment is the same with a 9m street width. Temperature decreases from each green wall were contrasted with the street canyon situation as it was at the time of evaluation 1's highest heat. In comparison to evaluation 1, the temperature decreases achieved by evaluation alternatives 2, 3, 4, and 5 were 2.17 °C, 1.97 °C, 1.78 °C, and 0.90 °C, accordingly. Conclusion: A well-planned urban green wall can significantly improve UHI in tropical Lebanon.

Keywords

Microclimate, Green walls (GWs), ENVI-met, urban heat island (UHI), Street Canyon

1. INTRODUCTION

Each country is expected to commit to the seventeen Sustainable Development Goals (SDG) in accordance with the worldwide 2030 Sustainable Development Plan, which aims to improve humankind as a whole. Towns and societies that are sustainable are strongly connected to (SDG) 11. The most beneficial effects of green walls on the UHI are the subject of several research that are written annually.

Accelerated modernization and development have had a bad effect on urban regions in a number of ways, including decreased air cleanliness and thermal environment, increased heat load, higher cooling power system, and worsened life quality of urban residents. In recent times, a growing range of cities has begun to take action in response to these signals. By reducing human satisfaction with rising air temperatures value, the UHI factor has a severe negative impact on the health of city dwellers.

Direct and indirect consequences of greater air temperatures are present. People's reduced thermal comfort in metropolitan areas without connection to chillers is probably the most obvious consequence of UHI, it decreases the clean air in cities, improves fuel use for conditioning, and endangers the ecology by causing heated water to move mostly from city areas. A green wall with their green plants has an impact on the urban microclimate to some extent. However, these plants are fixed on the facades of buildings and the number of building facades is limited. Sometimes the width of the street changes from time to time. We must see the various width of the street if it will affect the effect of the green walls on the microclimate.

All the topics that are studied in research have literature related to them that talks about the same selected topics or have some common ideas with the desirable thesis. This topic “effect of green facade on the urban microclimate with different street sizes” has different literature connected to it that is divided into five categories or classifications. The selected topic could be divided into urban streets. Thus, some of the literature is related to green walls and talk about them, their needs, their organization and types, and the other literature are related to the urban heat island with their different options and different importance and how it is the impact of the green walls on urban microclimate.

1.1. Urban Streets

Studies on urban transport performance, connectivity, trendiest, and appearance is based on street nodes. As there are no overpasses or underpasses in such frameworks, they are typically referred to as planar frameworks since they may be depicted in multiple directions. Planar simplifications can be helpful; however, they can also affect the outcomes of actual street network research because metropolitan street networks in the actual world usually have rank breakups like tunnels and bridges and those are their appearing 3 directions.(G. J. E. Boeing, Analytics, & Science, 2020).The urban street has different canyon dimensions as showing in figure 1(Sevtsuk, Kalvo, & Ekmekci, 2016).

Urban streets are often designed using specific ordering methods or else they will develop naturally as a result of accumulation; however, their arrangements and directions play a key role in defining the architectural coherence and flow of a town. Those systems in fact shape the relationships between people and the transit systems that pass through these, serving as a key tenet in the pursuit of a specific layout by urban designers. Until its inception, system direction, and shape especially have a major influence on urban planning.(G. J. A. N. S. Boeing, 2019).

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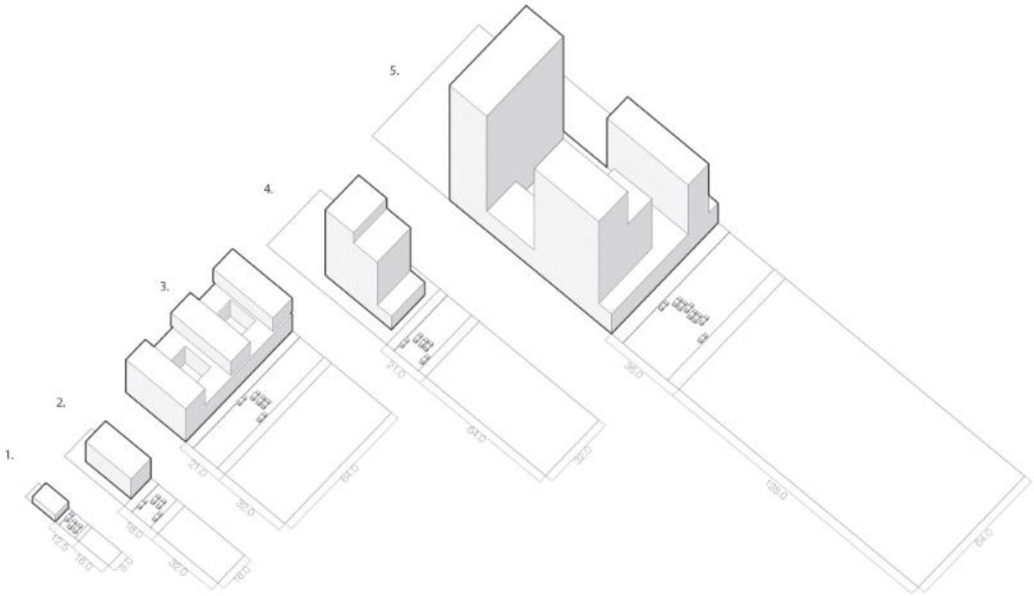

Fig.1: urban street has different canyon dimensions,(Sevtsuk et al., 2016)

1.2. Green Walls

The term "green walls" refers to any methods for using a variety of plants to green a vertical surface, such as a wall, blind wall, partition wall, etc. This includes all techniques for growing plants on, up, or inside a building's wall (Manso, Castro-Gomes, & reviews, 2015).

The VGS have many different types, structural system and fixation such as living wall systems and green facades. These two types also include additional types and techniques of fixation explained in details in the figure 2 below.

In addition to these, the building's exterior elements are the most crucial factor to take into account while designing a vertical green system (Perini, Ottelé, Haas, & Raiteri, 2013).

Understanding the criteria of the facade and designing in accordance with them are essential for producing a design that is appropriate for the climate in a VGS to be implemented (Şimşek, Şenyiğit, & Planning, 2020).

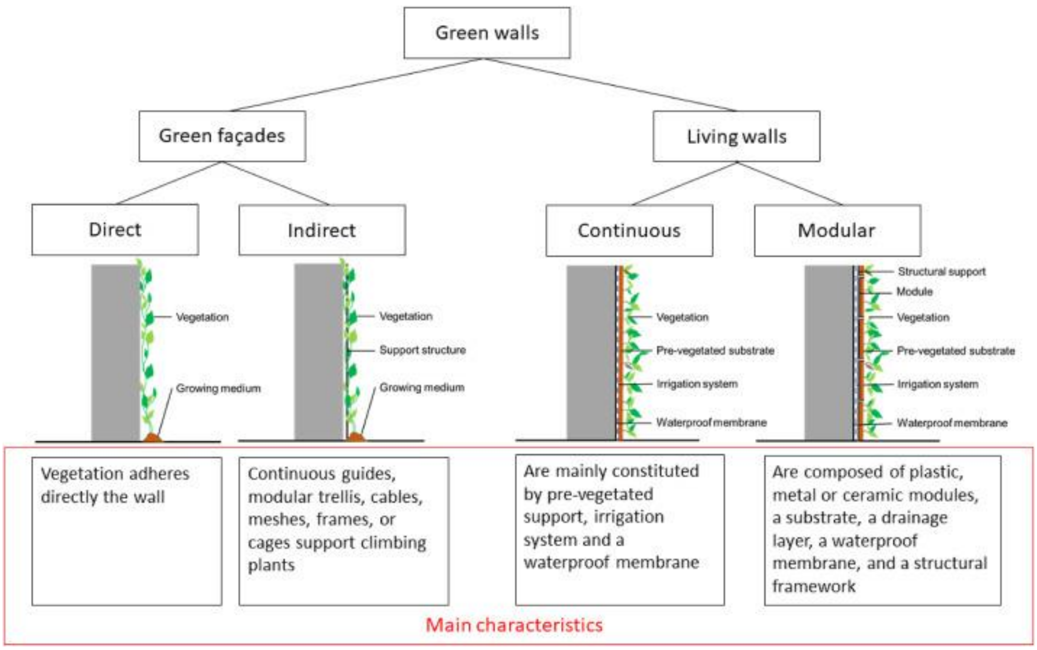

Fig.2: Classification of green walls, Ref.(Susca, Zanghirella, Colasuonno, & Del Fatto, 2022).

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1.3. Urban Heat Island

Urban heat island (UHI), which refers to a hot concentration in urban centers than in their country environs, is one of these changes brought on by urbanization that are significant. A growing focus has been placed on UHI research because to the potential threats that UHI may pose. About the municipality and urban planners, appropriate amount of UHI can aid in effectively determining the possible thermal danger and guiding urban planning and growth (H. Li et al., 2018).

UHI provides possible dangers to human well-being in addition to being intimately linked to a variety of environmental problems such as harm to species diversity, improving energy use, power emissions, and climate variability. Although there two major categories of UHI: atmospheric and surface (SUHI). By contrasting 2 in-situ thermometers from meteorological data, atmospheric UHI has usually been found (K. Li, Chen, Wang, & Gong, 2019).

In regards to the climatic condition, the heat island impact may be mitigated by lowering anthropogenic radiation and minimizing warm air. Bodies of water are typically helpful for reducing urban heat due to their evaporation action and larger heating value of water (Hsieh & Huang, 2016).The UHI has 2 types of effect o the city as shown in diagram 1(Faragallah & Ragheb, 2022).

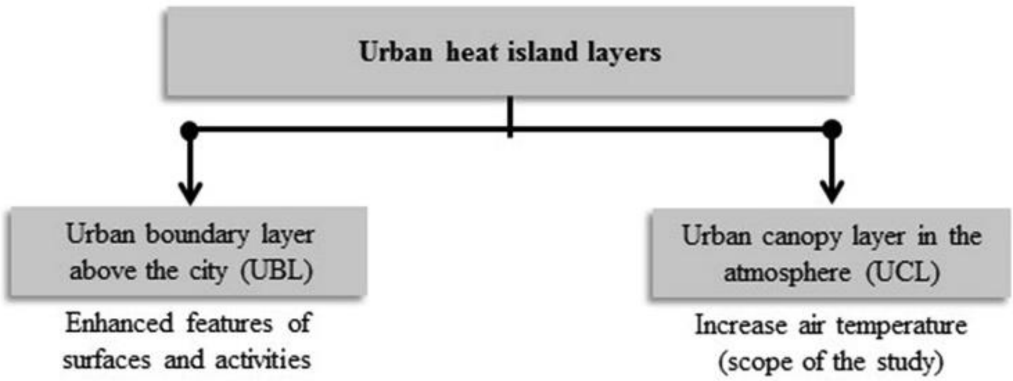

Diagram 1: Types of urban heat island effect in the city, Ref.(Faragallah & Ragheb, 2022)

1.4. Microclimate

Any location in which the atmosphere is different from that of the nearby region is referred to as a microclimate. In comparison to the nearby countryside, towns and urban areas have a larger degree of regional climate variation, which is linked to as an urban microclimate. Differences in temperature rise, moisture, wind velocity, and wind conditions are among the characteristics of an urban microclimate. Urban microclimates can be caused by a number of human-made reasons. The coefficient of thermal expansion, and various heat capacities of urban surfaces could impact how much energy is recorded, as can the materials used in the construction and building processes. Meanwhile, in usual metropolitan locations, lower watering, adjacent water areas, and less evaporation by vegetation might result in less passive heat transfer with the ambient atmosphere. (Hong et al., 2021).

1.5. The Impact of The Green Walls on Urban Microclimate

Building microclimates with green facades are starkly opposed to the weather outdoors. Microclimates must be taken into account in ecological studies in order to completely comprehend and more accurately forecast how the species diversity and services of the Green Facade are related to the atmosphere and climate change (De Frenne et al., 2021).

The median values reveal that green walls reduce hot daylight hours weather conditions across most climate zones, with the exception of Csb and Af. Green walls in the latter boost temperature difference by 0.8 °C, whereas they have a negligible (0.1 °C) impact in either. Just Csa and Csb are mentioned in the chosen case studies on the impact of green walls on UHI during the colder months. The daily thermal performance in Csa has been determined to have decreased by a median of 0.8 °C. Moreover, it caused the ambient temperature in Csb to rise by 2.3 °C during the day and fall by 0.2 °C during the night. Vertical vegetation can represent distinct temperature behaviors throughout various 24-hour full days based on its position because of changes in sun angle and direction during the day as well as the ensuing variance of arriving radiation emitted on every outer wall, making the impact of green walls on UHI a dynamic phenomenon. The impacts of green walls based on the most recent climate, green wall type, and orientation, to name a few, were explored in the following because for various different climates, the impact with one or the other whether component could be significant for UHI reduction, as showing in table 1. (Susca et al., 2022).

Table 1: Variation in Air Temperature,(Susca et al., 2022).

Climate zone	Variation in air temperature [°C] [a]			
	Cooling season		Heating season	
	Daytime	Nighttime	Daytime	Nighttime
Af	−0.1 (−0.1; 0.0)	−0.2 [c] (−0.3; −0.1)	–	–
Am	−3.5 [c] (−3.8; −2.0)	−2.5 (−3.0; −0.5)	–	–
Aw	−3.2 [f] (-; -)	−1.5 [f] (-; -)	–	–
BSh	–	–	–	–
BSk	−2.2 (−3.9; −0.5)	−2.7 [f] (-; -)	–	–
BWh	−4.8 (−11.8; −1.0)	−3.7 (−8.0; −1.0)	–	–
Cfa	−0.2 (−0.2; −0.2)	−0.3 (−0.5; 0.0)	–	–
Cfb	−2 (−2.4; −1.5)	−0.4 (−1.3; 0.5)	–	–
Csa	−1.6 (−4.0; 1.7)	−2.6 (−2.9; −2.2)	−0.8 [h] (−2.2; 0.6)	–
Csb	0.8 (0.6; 0.9)	−0.1 (−0.8; 0.5)	2.3 (2.1; 2.6)	−0.2 (−0.2; −0.2)
Cwa	−3.3 (−3.5; −3.0)	−2.1 (−2.2; −2.0)	–	–
Dfa	–	–	–	–
Dfb	−2.4 (−2.8; −2.0)	−1.9 (−2.0; −1.7)	–	–

The whole information of the computational models that were undertaken to evaluate the possibility of green facade in minimizing the impact of heatwaves in Core European cities is shown in this section. The varying impact of facade greening on the overall radiative heating rate between both the day and the night is shown in figure 5 (Alsaad, Hartmann, Hilbel, & Voelker, 2022).

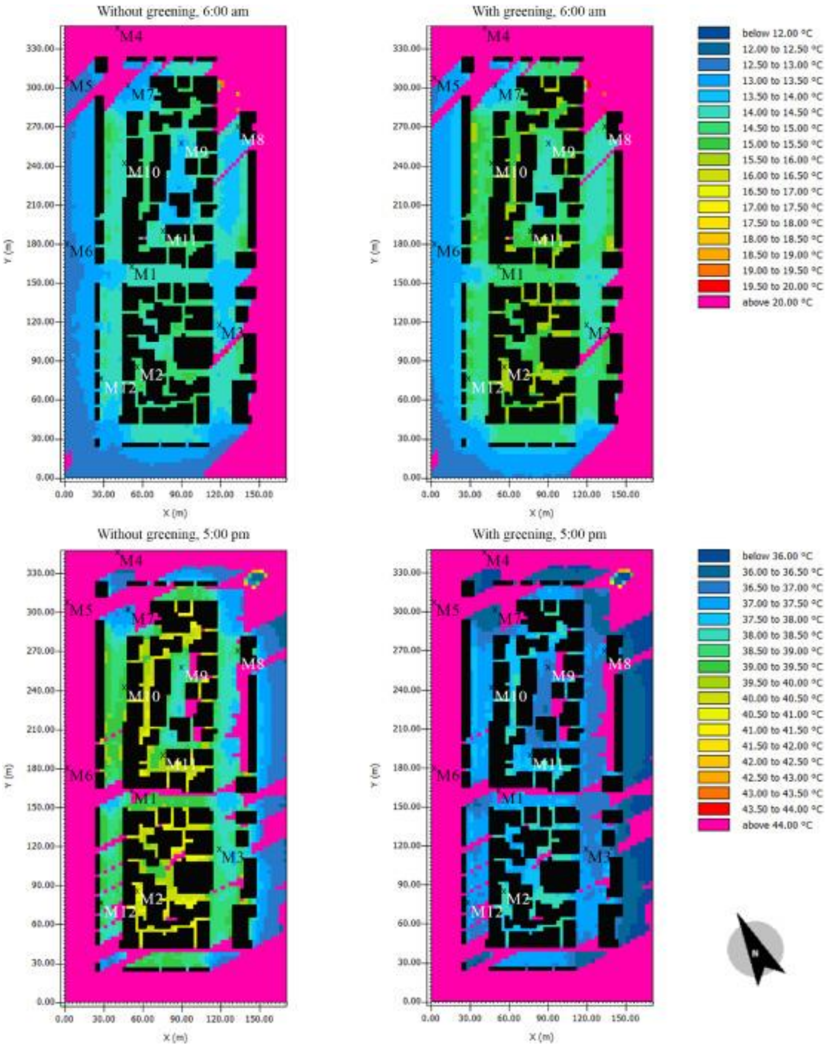

Fig.3: Mean radiant temperature without (left) and with facade greening (right) on the last day of the simulations at 6:00 am and 5:00 pm,Ref.(Alsaad et al., 2022).

2. METHODOLOGY

The study design is simulated studies, and the methodology is a quantitative research strategy. To comprehend this exclusive effect on green faced on UHI, the investigation borrows ways from the ethnographic type, jointly with simulated outdoor heating changes depending on street canyon, like a study for microclimate.

2.1. Simulation

A continuous simulation is a representation of how a system or process might function in the real world. Simulations must use models; the model represents the fundamental different traits of the selected software program, while the simulation shows the development of the model. The simulation is routinely done digitally.

2.2. Envi-met

Accurate representation simulation programs include ENVI-met, it has developed considerably, it is capable of simulating microclimates in a sensible manner. It is used as a simulation study for urban design, aiding in the provision of conceptual and strategic predictive modeling. A considerably enhanced version of the basic laws of turbulent flows and thermodynamic parameters, ENVI-met is a non-hydrostatic forecasting model. It is one of the really popular modeling software for evaluating the atmosphere to seasonal weather range at every site. Also, the integration of ENVI- met biometeorological outputs provides a thorough picture of the microclimate in the urban canopy level. Conditions including the temperature of the surface air, wind velocity, and moisture content are estimated by the application. More over half of the simulations of the vegetative heat generation have incorporated it. Using the rules of particle physics, thermodynamic parameters, and transport phenomena, ENVI-met can model the connections between surface, vegetation, and atmosphere in an urban setting. The sophisticated vegetation design in ENVI-met is one of its distinguishing features. In this system, vegetation isn't just represented as poroelastic to solar irradiance and wind velocity, although they may also collaborate with their surroundings by evapo - transpiration. A high degree of detail allows for thorough categorization of the plant and measurement of physiologic vegetative mechanisms, allowing for many situation contrasts which would be unachievable inside the physical realm (Liu et al., 2021).

3. APPLIED STUDY

Mina street Located in Tripoli (figure 5), North Lebanon. Contain the new mina buildings. This street is very important to mina city because are the main road for the city, and called Port Saiid Street. With altitude and longitude 34.4484816, and 35.8153259, as showing in the figure 4.

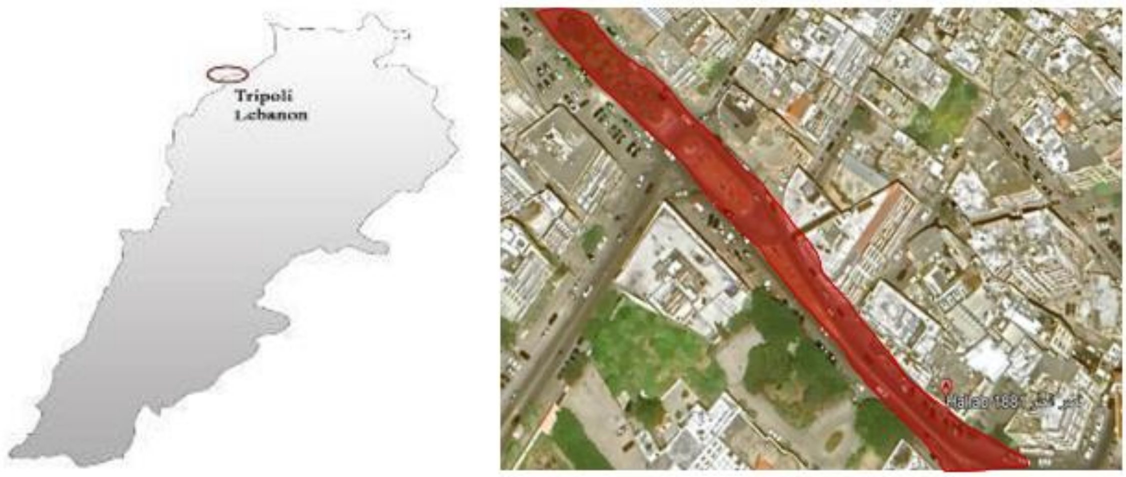

Fig.4: Port Saiid Street location, Ref. Author (2023).

Simulation

The project has a south west street, the simulation starts with the same condition of the building as shown in figure 5 and then for the building with adding green façade in west direction with 3 m street width for the evaluation 2 (figure 6), evaluation 3 is with 6 m street width (figure 7), and evaluation 4 with 9 m street width (figure8), and evaluation 5 is with 12 m street width (figure 9).

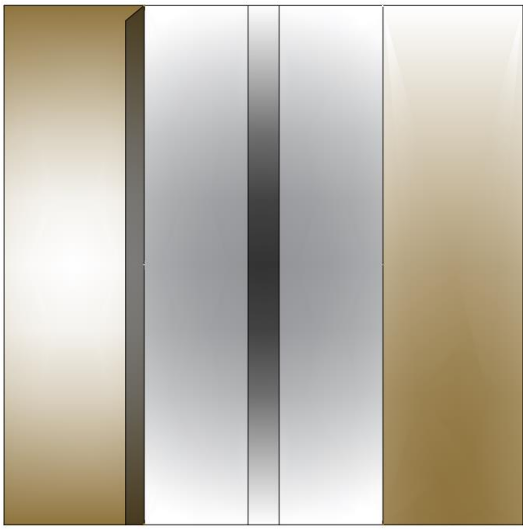

Fig.5: Evaluation 1, Ref. Author (2023).

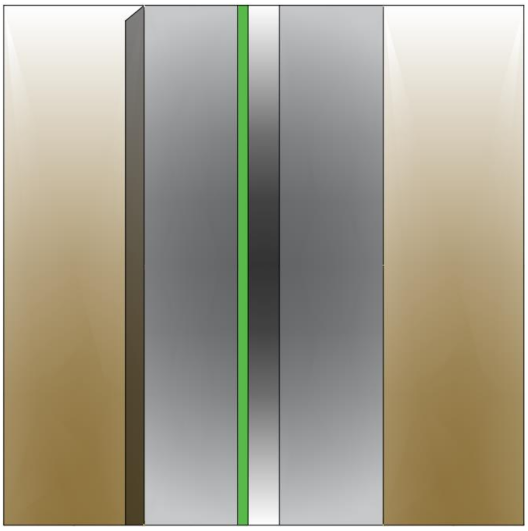

Fig.6: Evaluation 2, Ref. Author (2023).

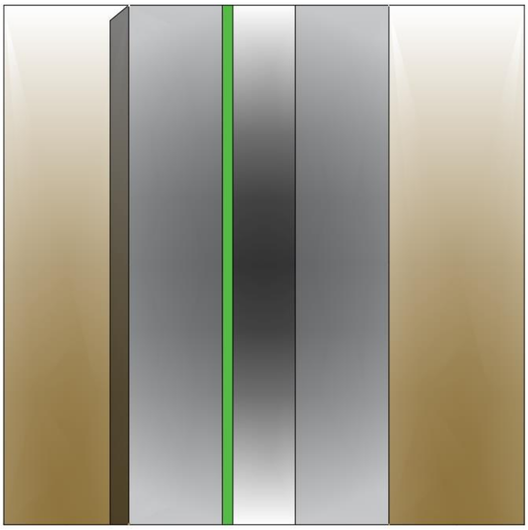

Fig.7: Evaluation 3, Ref. Author (2023).

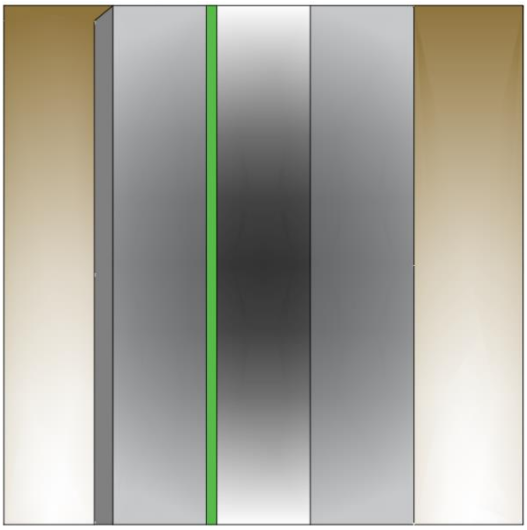

Fig.8: Evaluation 4, Ref. Author (2023).

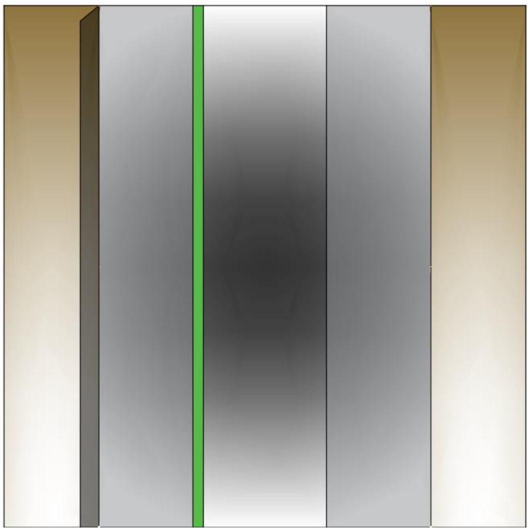

Fig.9: Evaluation 5, Ref. Author (2023).

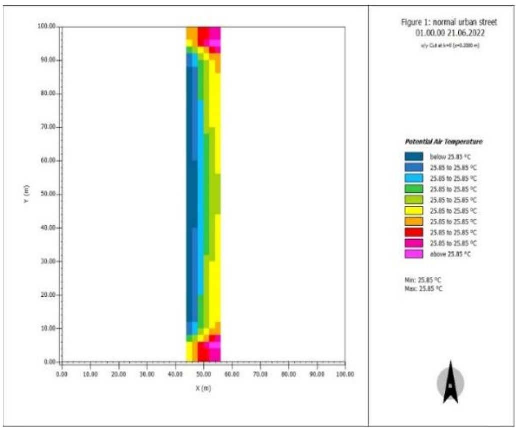

Fig.10: Evaluation 1, Ref. Envi-met (2023).

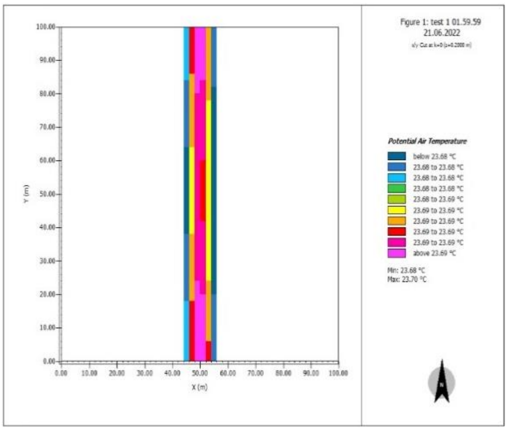

Fig.11: Evaluation 2, Ref. Envi-met (2023).

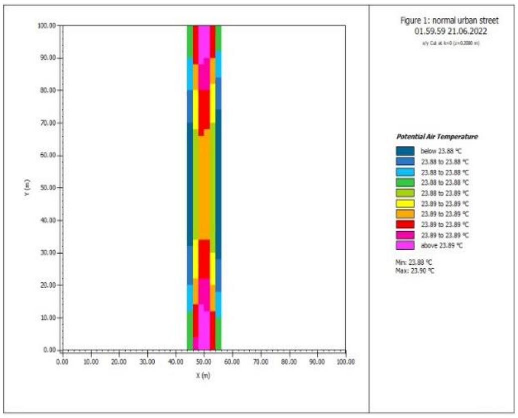

Fig.12: Evaluation 3, Ref. Envi-met (2023).

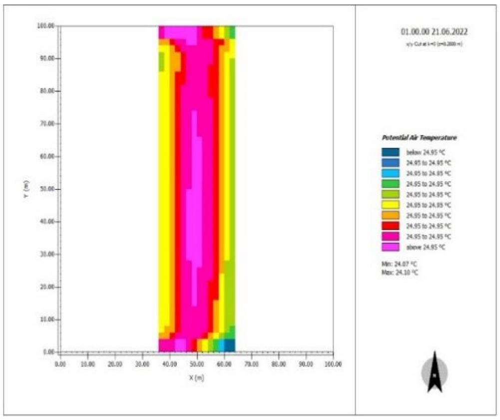

Fig.13: Evaluation 4, Ref. Envi-met (2023).

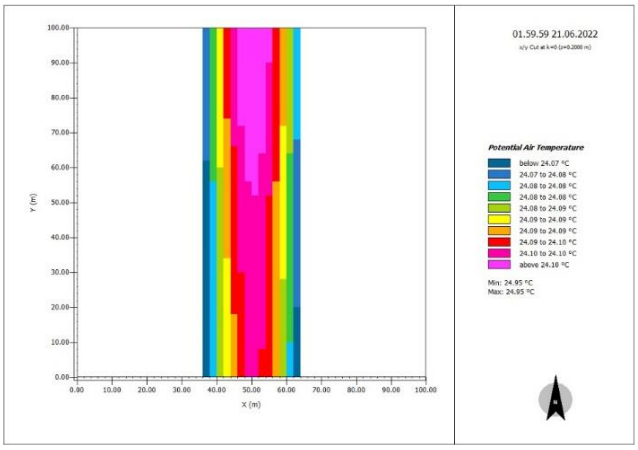

Fig.14: Evaluation 5, Ref. Envi-met (2023).

The 1st evaluation (figure 10) notice that the potential air temperature is 25.58°C for min and 25.58°C for max, evaluation 2 (figure 11) with green wall adding is 23.68°C for min and 23.70°C for max, evaluation 3 (figure 12) is 23.88°C for min and 23.90°C for max, evaluation 4 (figure 13) is 24.07°C for min and 24.10°C for max, and the last evaluation 5 (figure 14) is 24.95°C for min and 24.95°C for max.

The potential air temperature decrease in the evaluation 1 from 25.58°C to 23.68°C for min and from 25.58°C to 23.70°C for max in evaluation 2 with same street canyon and green wall adding, than increase in evaluation 3 to 23.88°C for min and 23.90°C for max when the street canyon grow up to 6 m and where the street canyon grow up to 9 m in evaluation 4 the potential air temperature increase to 24.07°C for min and 24.10°C for max , and for the last evaluation 5 it is increase to 24.95°C for min and 24.95°C for max.

4. DISCUSSION

Figures 10, 11, 12, 13 and 14, compare effect of green facade on the urban microclimate with different street canyon in the Port Saiid Street on lowering the potential air temperature. The evaluation 2 provide the most optimum lowering potential air temperature with a reduction of 2.17°C for min and 2.15°C for max with green wall on the south façade with 3 m street canyon when compared to the others street canyons in terms that the evaluation 3 decrease 1.97°C for min and 1.95°C for max with green wall on the south façade with 6 m street canyon, the evaluation 4 decrease 1.78°C for min and 1.45°C for max with green wall on the south façade with 9 m street canyon, and for the evaluation 5 decrease 0.90°C for min and 0.9°C for max with green wall on the south façade with 12 m street canyon. This paper has more information and data about green wall. This paper didn’t discuss deeply the Plant species, the type of green wall, interior light and the distance between the wall and the green wall. It didn’t talk about what type of green wall can be the more effect on UHI.

5. CONCLUSION

The implementation of green walls will offer a variety of advantages at once, including sound insulation, support to urban ecosystems, emission elimination, and aesthetic improvement. look into the possibility of green walls to reduce UHI in various climates.

In a humid tropical city in Lebanon, this study looked at how green walls on a facade might affect on UHI. The findings can serve as a factual foundation for encouraging extensive vertical greening, offer guidance for making the best site selection decisions, and shed insight on the underlying process of green-facade energy impacts. The findings from the studies showed that green walls are universally effective in reducing potential air temperature by up to 2.17 °C every high - temperature day, with a potential to reduce UHI. Especially notably, green walls have the better heat capacity for lowering air temperature heating potential. Green wall installation just at urban scale has to be prioritized in strategies intended to reduce UHI in order to completely eliminate UHI. The UHI reduction potential may reach as great as 2.17 °C in small streets that are flanked by tall buildings, in which the greatest reductions in air temperature might be found. Narrower application sizes, on the other hand, are unlikely to yield meaningful outcomes in this regard.

This research has covered the density one of factor that effect the energy saving through VGS, but not all, and it focuses just in the green wall facade. This paper bears more information and data about green wall. The installation of green walls ultimately reduces the consumption of energy in buildings and UHI. Yet, it is crucial to organize work in order to broadly use green wall innovation in urban areas because isolated implementations could have positive impacts at the micro-scale and therefore are rarely likely to have appreciable impacts at the higher densities. As a result, it is crucial that urban judgment properly create by-laws and regulatory requirements, focusing on scientific approaches, to maximize their impact in both reducing and responding to climate change.

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