ORIGINAL RESEARCH PAPER

Engineering

EVALUATING URBAN GREENING SCENARIOS ON URBAN HEAT ISLANDS EFFECTS

KEY WORDS: Surface temperature; Mean Radiant Temperature (MRT); Green canopy; Cool pavement.

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ABSTRACT

An Urban Heat Islands (UHI) are one of the most common phenomena of the 21st century. Climate change, and the associated rising trend of urban temperature is exaggerating the creation and extension of urban heat islands (UHI). This paper investigates various urban greening scenarios in the line with developing the resilient Sydney strategical document. Two different cooling street strategies are investigated in this research including high reflective pavement and green canopy cover. ENVI-Met software has been applied for simulating and quantifying microclimate processes at the urban scale before and after introducing urban greening scenarios. The results of this study show that applying the light-coloured pavement instead of asphalt surface will decrease surface temperature by up to 20°C. Planting short to medium height trees in the side walks will decrease the air temperature by up to 3°C and surface temperature by up to 11°C.

INTRODUCTION

An Urban Heat Island (UHI) which is an urban area where has significantly higher temperature compare to the surrounding rural areas are one of the most common phenomena of the 21st century (Nikrouz Mostofi & Hasanlou, 2017). The differences in temperature can be felt by human body through air and surfaces (Hove; et al., 2015). The higher temperature normally made by man-made materials which are used in buildings and constructions such as dark roofs, impermeable pavements and concrete walls (Karimipour, Tam, Burnie, & Le, 2022). Because these materials especially concrete and cement have the higher absorption rate than the natural ones, these elements absorb heat during daytime and reflect it in night-time. Surface incapability of reflecting the sun radiation to the atmosphere is another cause of absorbing heat which is resulted in higher UHI. So, Dark surfaces can be considered as the other cause of UHI. These types of surfaces absorb the most part of the heat and do not let it to be reflected to the air. Shortage of green area at the city scale is the other reason of catching heat in the buildings and therefore higher temperature (Zhang, Xie, Gao, & Yang, 2014). A row of green canopy creates shade for hot surfaces in summer time and it keeps soil moisture and cool (Zhu, Ji, & Li, 2017). Considering the causes of trapping heat in the urban areas, the corresponding cooling strategies should be proposed to help reduce the effects of UHI in the urban regions. It is also worthy to mention that as the UHI impacts are varied from region to region, the associated cooling techniques also should be justified for any specific area (Karimipour, Tam, Le, & Burnie, 2021).

This research aims at identifying various urban greening scenarios and analyse their impacts on the UHI effects. Taking benefit of quantity surveying, this study weight up the proposed scenarios and suggest the most feasible one.

MATERIALS AND METHODOLOGIES

Pilot Site

The pilot site of this study is Richmond Road from Blacktown city, Sydney, Australia. This region encompasses a good mixture of urban features such as buildings, asphalt road, green canopy and bare land, so it can be a good sample of the greater Western Sydney area. Blacktown is a modern bustling city of 54 residential suburbs, home to over 395,000 people, making it the largest city by population in NSW (Blacktown City Council, 2022).

Urban Texture Simulation

ENVI-met version 4.3.1 has been used in this study for quantifying the microclimate processes and simulating the flows of heat from/to the air. ENVI-met is a comprehensive software designed to investigate the various environmental, climatological and anthropogenic elements of a landscape on microclimate. In addition, this is one of the very few model which analyse the whole parameters in one picture and consider the various climate processes between the elements (ENVI_MET, 2017).

An Area Input File with a 3-dimensional geometry is needed for running out an ENVI-met model. The required parameters for this model are: specific humidity, 24 hours temperature, solar radiation data, wind speed and direction and soil classes. Local climate data also should be added to the model for running the ENVI-met. For this study, the model was run in the 1st January one of the hottest summer time in greater Western Sydney area. The model duration was 24 hours, but the comparison was based on 4 sample hours including 9am, 3pm, 9pm and 3am. These 4 hours are a good collection of all microclimate conditions in Western Sydney's summer time. The default values of the ENVI-met have been kept unchanged for the other required parameters of the model such as Lateral Boundary Condition, solar radiation, clouds and turbulence. That's because by providing the geographical location of the studied site, all the required parameters have been simulated automatically by the software itself.

For evaluation of the urban green scenarios on the UHI effects, three different scenarios have been selected and simulated as below:

- ***Scenario 0:*** Baseline, the current condition of the study area.
- ***Scenario 1:*** Green canopy, which is planting a row of trees on the both sides of the main street.
- ***Scenario 2:*** Cool pavement, which is scenario 1 plus replacing the current dark grey pavement/asphalt parking with the light colour concrete.

RESULTS AND DISCUSSIONS

Air Temperature Analysis

Figure 1 represents the effects of the green canopy scenario and its comparison with the base scenario on the January 1st, at 3pm. According to this figure, the difference in the air temperature varies between 0.2°C and 1.3°C based on the location. The most temperature change is 1.3°C observed under the new planted trees.

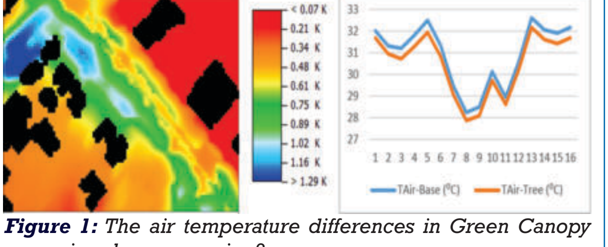

Figure 1: *The air temperature differences in Green Canopy scenario vs base scenario- 3pm*

The differences between cool pavement scenario and base scenario at 3pm of 1st January is illustrated in Figure 2. According to this figure, the maximum difference which is 3.14°C is observed in asphalt road where it is affected by the aggregated effects of tree shadows and light-coloured pavement.

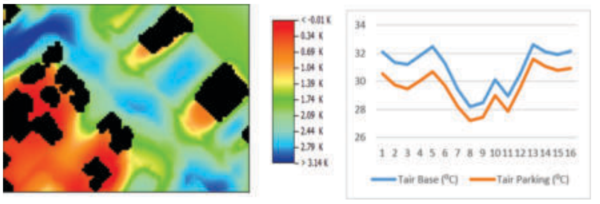

***Figure 2:** The air temperature difference in cool pavement scenario vs base scenario- 3pm*

Surface Temperature Analysis

The differences of Mean Radiant Temperature (MRT) in the cool pavement scenario versus base scenario for the daytime and night-time of the 1st January has been illustrated in Figure 3. According to this figure, by using the cool pavement materials in the street side walk, the radiant temperature reduces noticeably at day-time. However, the different surfaces react unlikely at different times of the day. For example, the highest temperature difference in night time is seen in asphalt road (30°C) under the new planted trees. However, in the day time, the most affected areas are the asphalt surfaces which are replaced by the cool pavement materials, with MRT 61.9°C, versus the average MRT of 39°C. Therefore, the average difference in the Mean Radiant Temperature at day-time is 22.7°C. This high variance shows the heavy impact of high albedo surface and shading on the radiant temperature of various surfaces. The variation in radiant temperature is almost low in night time compared to the daytime. The maximum reduction in the radiant temperature at night-time is at around 3°C peaked on the asphalt road and the replaced pavement areas. The correlation between two figures at 3pm is 84% and at 3am is 73%. This close correlation confirms that the different cells follow almost the same trend at various time.

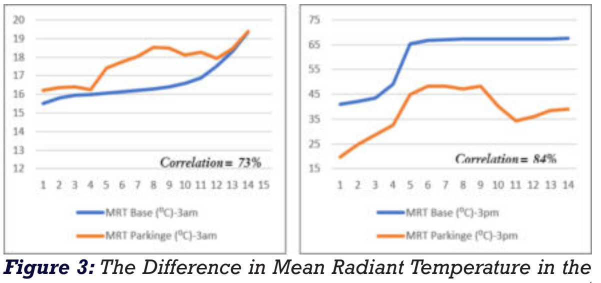

***Figure 3:** The Difference in Mean Radiant Temperature in the cool pavement scenario vs the base scenario at 3pm of the 1st January*

CONCLUSION

This paper evaluates the various urban greening strategies at the largest suburbs of Sydney metropolitan areas. The study compared the proposed cooling street scenarios and suggest the best set of strategies for mitigating the UHI effects. By using Envi-met microclimate processing software, this study combined various variables together to reach out the most suitable strategy for decreasing the sensible temperature at the city level. This research suggests a set of urban greening measures and their associated cooling potentials for the greater Western Sydney area. This set of strategies are the ones we found suitable for the Sydney's area climate condition, and can be considered as the guide for the other cities. However, for applying them in the identical geographic conditions the physio climatological parameters such as wind speed, sun and shadow hours, and natural green cover should be surveyed and replaced accordingly. By applying the suggested cooling street strategies, the summer time air temperature can be reduced by up to 3°C, and the surface temperature by up to 20°C.

The future studies in this field can be focused on developing the cost-effective high-albedo surfaces. Although the impacts of these surfaces on the cooling streets are well known and documented, their applying at the large scale is still a matter of question. If the new cost-effective material is introduced and testified, the problem of UHI effects in the cities can be minimized. Also, identifying and introducing the urban friendly specious of plants and trees would be another area to work on, as we need to know efficient, shadowy and low water usage specious to be planted on the sidewalk, rooftops, and walls of our cities.

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