International Journal of Energy and Environmental Research
Vol.4, No.2, pp.7-15, May 2016 2016
Published by European Centre for Research Training and Development UK (www.eajournals.org)

ENVI- MET SIMULATION ON COOLING EFFECT OF MELAKA RIVER

Golnoosh Manteghi[1*], Hasanuddin Lamit[1], Dilshan Remaz[1], Ardalan Aflaki[2]

[1]Centre for Study of the Built Environment in the Malay World" (kalam), Faculty Built Environment, University Technology Malaysia, 81300, Johor, Malaysia
[2] Faculty Built Environment, University Malaya, 50603, Kuala Lumpur, Malaysia

ABSTRACT: *The creation of a concentrated local microclimate within urban environments is regarded as crucial, as urbanisation precipitates increased heat stress in the hot and humid climates. Previously, the heat in Malacca city has been recorded, but not much attention has been paid to the cooling effect of city's water bodies. Whereas the evaporative effect of water is seen as an alternative for mitigating the environmental ambient temperature. Rivers are a source of coolant for the microclimate of the surrounding area. Other researchers pointed out that evaporative cooling via water bodies or features represents the most efficient passive manner of cooling buildings or urban spaces. In order to determine the role of water body upon microclimates, a simulation programme, Envi-met, was used. The utilization of the software is intended to analyse the temperature distribution of a common urban layout with and without water and with greenery. Our literature review suggests that vegetation and water bodies can be effective ways of reducing urban temperatures by 0.5 to 4.0°C. Based on the findings, it can be concluded that the increase of evapotranspiration in cities, derived from vegetation and water body, can effectively mitigate the effect of urban heat islands.*

KEYWORDS: Envi-Met Simulation, Water Body, Greenery, Cooling Effect

INTRODUCTION

Urbanisation, which changes the global landscape, represent major change in global land use and have a considerable impact on the environment (Weng and Yang, 2004). The global urban population sharply rose from 13% in 1900 to 46% in 2000 and is likely to reach 69% by 2050. Simultaneously, the thermal setting of urban enviroments has gotten worst over the decades, owing to quick development and increased heat discharge via structures and vehicles the (Taha, 1997, Dimoudi and Nikolopoulou, 2003). Urban areas tend to experience relatively higher temperatures compared to the surrounding countryside. The gradient between temperatures being recorded form an urban space as opposed to ones recorded from nonurban green space is termed the urban heat island effect (UHI) (Oke, 1992).Several studies have revealed that the heat island effect is influenced by the density of structures absorbing solar radiation, the use of highly absorbent materials, the lack of green spaces, the characteristics of urban canyons, and the production of anthropogenic heat (Oke et al., 1991b, Oke et al., 1991a, Santamouris et al., 2011).

Water bodies in urban areas have a major influence on the UHI effect due to the thermal properties of water and evaporation. Usually the temperature of a water body is lower than the temperature of the surrounding built-up area, and the differences between them can be 2-6°C. This proves that urban water bodies have a great influence on the urban climate.

The effects of water on microclimate and comfort can be evaluated by using environmental modeling. This was conceived with the aim to understand many of the current environmental

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

problems; it allows to quantify the effects due to zone changes (land coverage) on meteorological parameter and on quality of life con-sequences, through microclimate models as Envi-met (Perini and Magliocco, 2014). Envi-met models have been used in several studies to evaluate the effects of the characteristics of cities on their microclimate. Krüger et al. (2011) studied the relationship between the morphology of urban areas and alteration to microclimate and air quality in a city; Ali-Toudert and Mayer (2007)analyses the relation between outdoor thermal comfort and the design of an urban street by using the three-dimensional microclimate model ENVI-met; they found that vertical profiles and different orientations of street are mildly influential upon air temperature, while strongly affecting heat gained by a human body: a larger opening presented by the sky to the canyon, the higher the heat stress will be. For canyons having narrow openings to the sky, orientation is crucial: E–W canyons remain the most stressful, and eschewing it improves the underlying thermal conditions (Ali-Toudert and Mayer, 2007). Yang et al. (2013) compared the field measurements of thermal behaviors of multiple ground surfaces, and the data obtained with an ENVI-met model. The results demonstrated that the ENVI-met model accurately model the diurnal thermal behavior of multiple ground surfaces and their influence upon adjacent air temperature and humidity.

The aim of the study presented is to quantitatively investigate the influence of water body and vegetation on temperature distribution in the typical city area. A simulation tool, ENVI-met Version 3.1 BETA V, is used to forecast the microclimatic changes within urban environment. The atmospheric conditions are (temperature, humidity, wind speed, and wind direction). To investigate the effects water, different configurations are simulated, to evaluate the role of water body in the study area. 19 different points are analyses with the aim to quantify the effects of different atmospheric conditions in the study area.

The study case area (Melaka water body) is being studied in order to get a better picture on the influence of is evaporative cooling from adjacent waterways, which might differ from its surroundings. Furthermore, the work also intends to discuss the possible effect of evaporative cooling upon water and vegetation on the ambient temperature as a function of distance.

METHODOLOGY

Simulation software and settings

With the aim to forecast the microclimatic changes within urban environment, the work began by creating a simulation model using ENVI-met Version 3.1 BETA V software that is capable of simulating microclimatic conditions of urban settings. It must also be capable, in the context of fluids and thermodynamics, of simulating the flow around structures and determine the intricate heat exchange processes of multiple surfaces (ENVI-met, 2014; http://www.geographie.ruhr-uni-bochum.de/agklima/envimet).The basic case study being used in this work is the urban setting and water body of Malacca city center (see Fig 1). From this basic case, two more scenarios were posited, with the differences being limited to switching water bodies with pavements and greenery. In all cases, the wind direction is 45◦ (blowing North–East). The simulations were run for 21st June, incidentally the days when the temperature was the highest. According to ENVI-met 3.1 Manual (Bruse, 2009) a numerical model needs initialisation time, which cannot be at noon, since the model would not be able to "guess" the right start conditions. The simulations ran for 24 hours, commencing and completed at 6 am. In this work, examples of constant variables are structure, materials, and layout, while wind speed and initial air temperature were defined as fixed variables. Site-specific input data in the software are Point: Melaka, 2° 16' N - 102° 15' E, Simulation day: 21st of June. The setting of the air temperature, wind speed, relative humidity are based on the mean values of the weather data recorded from meteorological department of Melaka. 19 points were chosen as representatives of various points throughout the site (Fig. 2). Figs 1 and 2 displays the layout and 19 chosen points on the ENVI-met.

Figure 1. View of the selected study area (Ceneter of Melaka).

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

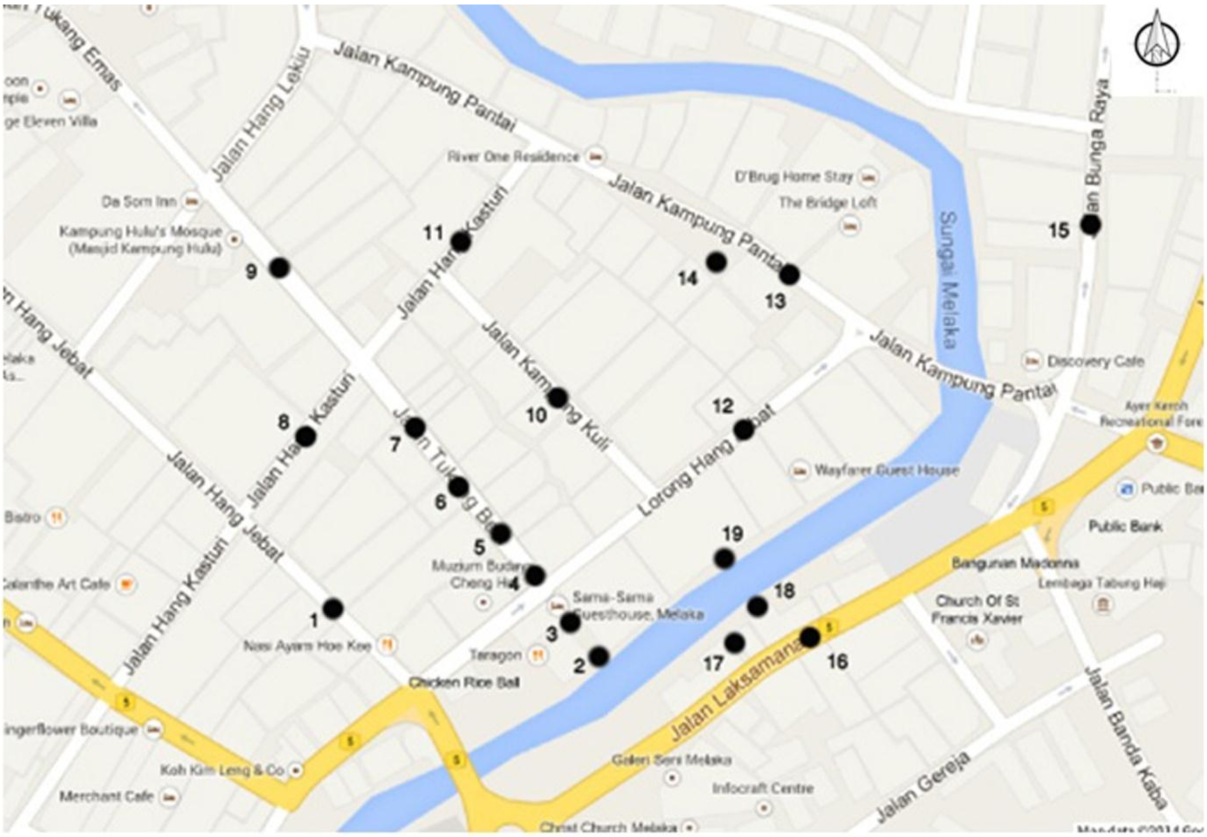


Figure 2. Locations of 19 selected points in the study area.

Table 1 show some basic settings employed in the simulations.

Table 1 show some basic settings employed in the simulations.

Some basic settings employed.

Temperature (K)	26.2 °C
Wind speed at 10 m (m/s)	1.6
Wind direction	45°
RH (%)	86%
Roughness length in 10m	0.1
Total simulation time (h)	24

Evaluated scenarios

Three scenarios were proposed for the purpose of comprehensively investigating the coolant effects of water bodies around Malacca (see Fig. 3).

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

Scenario 1- Original water body

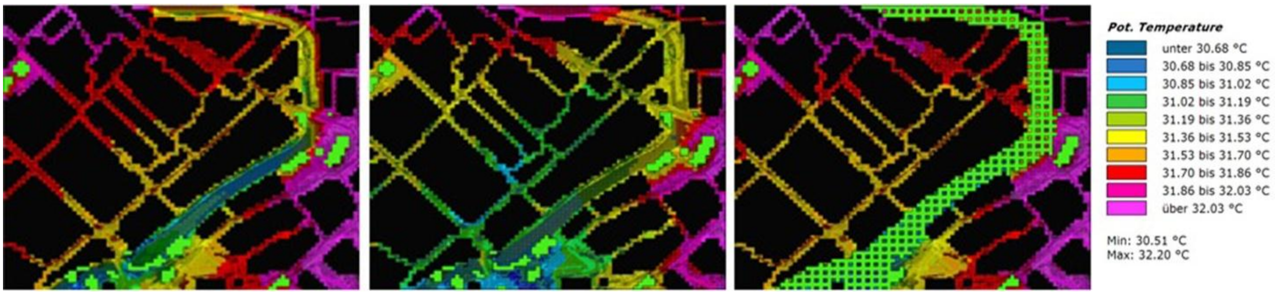
This scenario represents the basic case where the current is microclimatic conditions of the study area and its surroundings are simulated.

Scenario 2- Pavement

This scenario involves he removal of rivers and its replacement with pavements. The microclimatic conditions of the replacements and its corresponding surroundings were then duly investigated.

Scenario 3- Greenery

This scenario involves the removal of both rivers and pavements and its replacement with grass. The corresponding microclimatic conditions were then examined. The metafiles generated by the simulation in the three aforementioned scenarios are then used to investigate the effect of cooling upon the microclimates.



(a) Scenario 1- original water body
(b) Scenario 2- Pavement
(c) Scenario 3- Greenery

Figure 3. The generated metafiles, by Envi-met simulation in 3 scenarios

FINDING AND DISCUSSION

The comparisons of average temperatures of the three scenarios calculated from 21 June were presented in Figs. 4 and 5. Comparing the three scenarios indicates that greenery may have better ability in reducing ambient air temperature as opposed to water bodies.

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

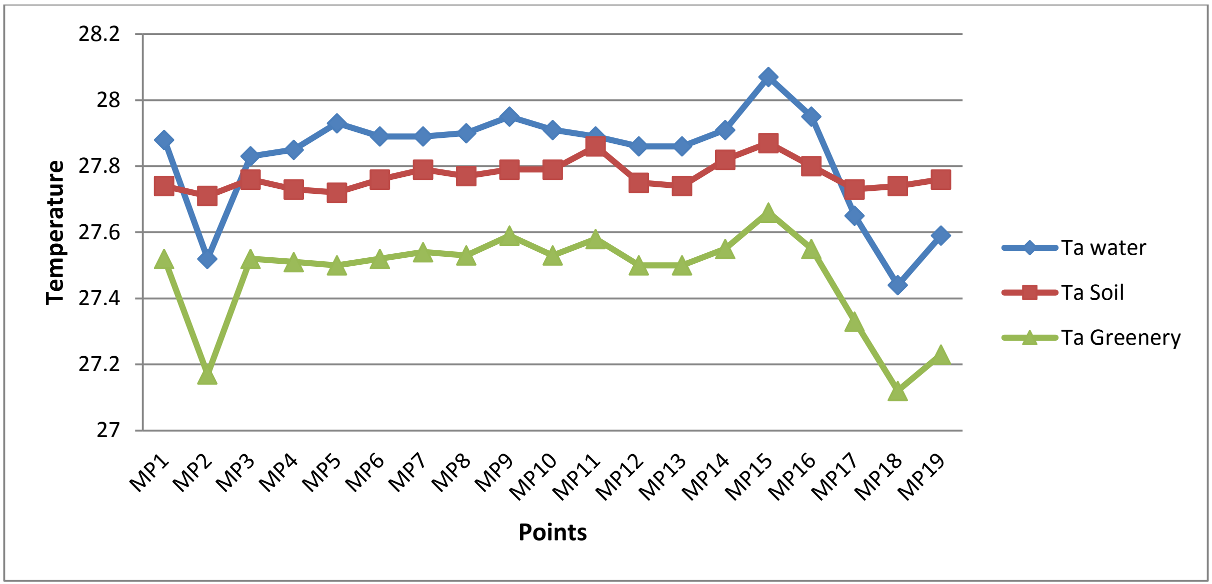


Figure 4. Comparison of 3scenarios on 21 th June at 19 selected points in the study area.

Fig. 4 indicates that the lowest average temperature in water body and greenery was around 25. 4 ºC and 27.1 ºC, respectively, detected at point 2 and 18, while for the rest of the points, the average temperature is slightly higher as they are situated further away from the water body. Greenery scenario was also determined to adhere to this rule. It is therefore surmised that both greenery and evaporative cooling effects from the water body may very well be quite active, with certain exceptions. Some possible factor that precipitated this reaction is that the points were exposed to direct strong sunshine, which increases the ambient air temperatures.

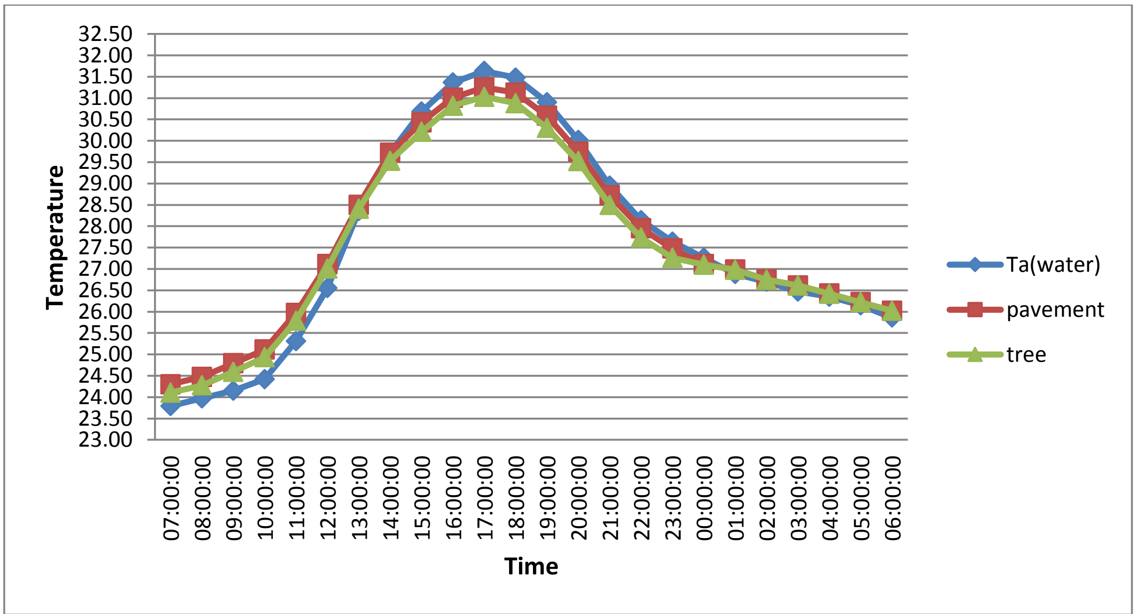


Figure 5. Comparisons of diurnal average temperatures on 21th June.

Our results are indicative of the fact that water has a cooling effect upon the surroundings; however, its effect is limited by its distance. The average temperature was recorded to be highest at point 15, which is 0.5 °C more than the average temperature obtained at point 2, 18, representing the nearest points to the water body. It is because these points are at the edge of the river, and the other points are inside the street canyons and far from the water body. The anthropogenic heat(s) generated by vehicles might have affected the readings.

The fluctuation of average temperatures of pavements is minimal, and its standard deviations are less for points within the water and greenery as opposed to those obtained from points within pavements (See Fig. 4).

Further comparisons of temperature profiles for 3 scenarios during a clear day (21 June 2013) are shown in Fig 5. During the 24 hours, during the daytime before noon, the water body had lower ambient temperatures. After 12:00 until 00:00, the inverse situation occurred. The possible reason is that water will start to release the gained heat during the daytime.

It seems that the effect of greenery in decreasing temperatures is less than the effect of the water during 12:00 to 00:00. The pavement before 12:00 has the highest temperature, but after that still the water had the higher temperature until 00:00.

The profile of ambient air temperatures derived via section views (see Fig. 6&7) seems indicative of this fact as well. For most of the day, temperature profiles indicate a proportional relationship between water body and greenery and air temperature. Lower temperature profiles were prevalent adjacent to the greenery.

It is obvious that the water and greenery is responsible for the creation of a lower temperature zone within its leeward area. The closer it is to a green area, the lower its temperature will be. When the greenery is totally removed and plotted with pavement, there was no area with recorded low temperatures. However, when pavements were replaced by greenery, the high temperature zones were replaced with lower temperature ones.

Fig. 7 shows the day time scenarios of the simulation. It differs from the night time ones at 17:00 in of the context of vertical temperature distribution, where it compared 3 scenarios of the cooling effect of the greenery not being prevalent in daytime.

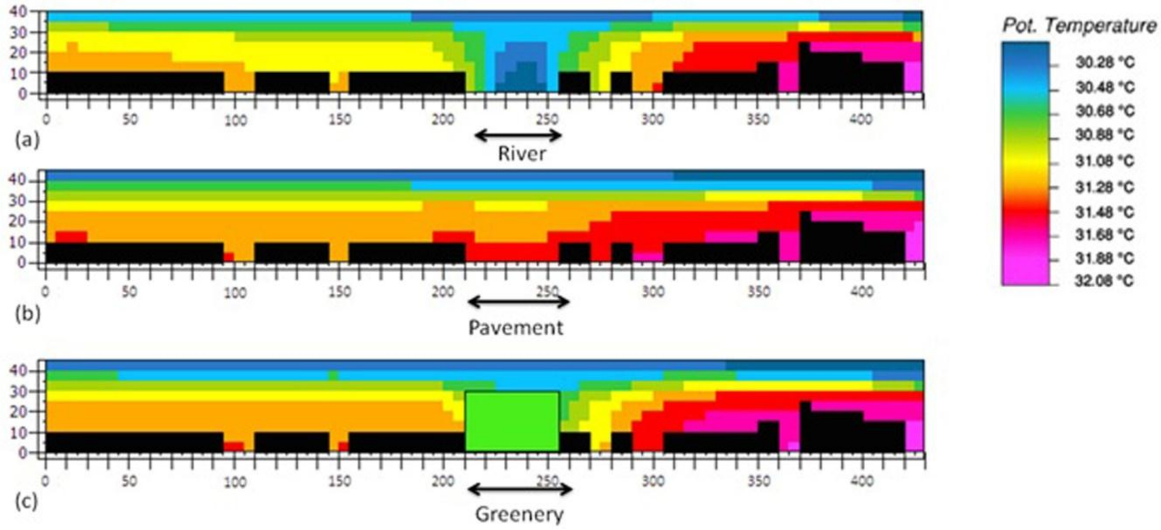


Figure 6. The comparison of section views of scenarios with river (a), without river (b), and with greenery replacing river (c) at 17:00 h.

ISSN 2055-0197(Print), ISSN 2055-0200(Online)

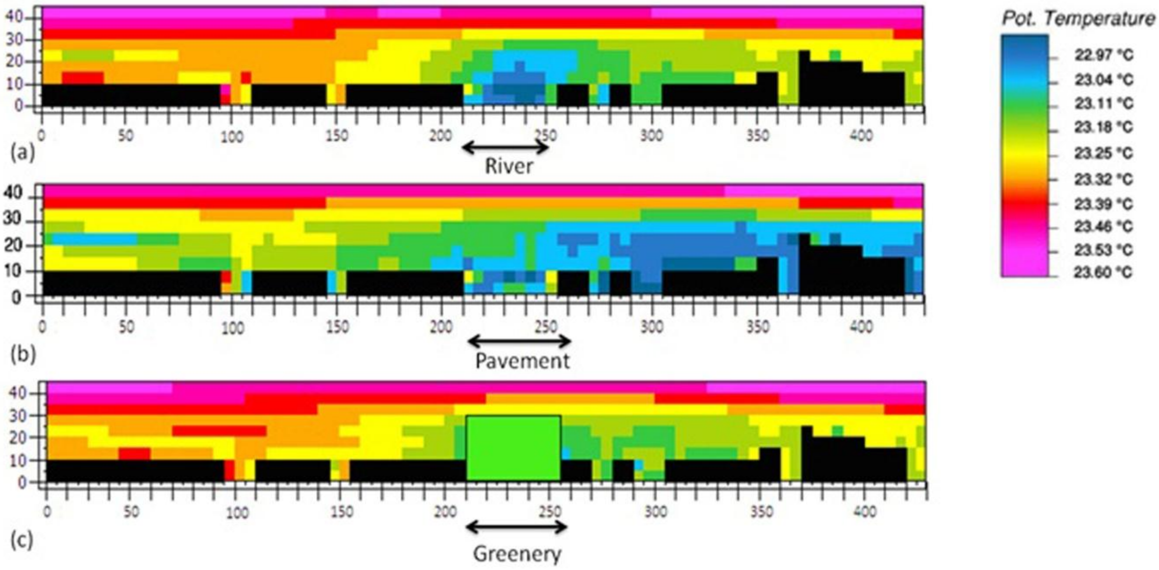


Figure 7. The comparison of section views of scenarios with river (a), without river (b), and with greenery replacing river (c) at 05:00 h.

CONCLUSION

The cooling effects of water and greenery were confirmed via simulation. It was also concluded that the cooling effects of water and greenery upon the surrounding areas are strongly correlated to distance between the greenery area and the water body with the area in question.

It was determined that the best cooling effect on the surrounding area was achieved via greenery. This is proven via quantitative analysis, which shows that greenery scenario is 0.3° C lower compared to the other scenarios. This effect diminishes when greenery is replaced with pavements.

The average temperatures for the 2 scenarios of greenery and water are lower than pavements. For the surrounding area, the closer it is to water of greenery, the lower its temperature. 0.5 °C difference of average temperature was observed at points around greenery and water. This difference was caused by green areas, which ultimately lead to reduction of cooling energy and thermal comfort for residents.

Data obtained from field measurement campaign should support data generated from the Envi-met simulation. Moreover, the Envi-met simulation also illustrated that the loss of greenery might result in bad thermal conditions, not only in the original area but also the surroundings, especially when greenery is replaced by hard surfaces or structures. In summary, the importance of water and greenery was proven via simulations under tropical climates. More concerns should be paid on water bodies and greenery in cities as opposed to replacing them with urban structures.

Acknowledgements

This research was supported by "Centre for Study of the Built Environment in the Malay World" (kalam). The author would like to express her sincere thanks to Mohd Hannafiah Hamid, who provide his assistance computational analysis.

REFRENCES

ALI-TOUDERT, F. & MAYER, H. 2007. Effects of asymmetry, galleries, overhanging facades and vegetation on thermal comfort in urban street canyons. Solar Energy, 81, 742-754.

BRUSE, M. 2009. ENVI-met 3.0: Updated model overview. University of Bochum. Available at: www. envi-met. com.

DIMOUDI, A. & NIKOLOPOULOU, M. 2003. Vegetation in the urban environment: microclimatic analysis and benefits. *Energy and buildings,* 35**,** 69-76.

KRUGER, E., MINELLA, F. & RASIA, F. 2011. Impact of urban geometry on outdoor thermal comfort and air quality from field measurements in Curitiba, Brazil. *Building and Environment,* 46**,** 621-634.

OKE, T., JOHNSON, G., STEYN, D. & WATSON, I. 1991a. Simulation of surface urban heat islands under 'ideal'conditions at night Part 2: Diagnosis of causation. Boundary-Layer Meteorology, 56, 339-358.

OKE, T., TAESLER, R. & OLSSON, L. E. 1991b. The tropical urban climate experiment (TRUCE). *Energy and buildings,* 15**,** 67-73.

OKE, T. R. 1992. *Boundary layer climates,* Psychology Press.

PERINI, K. & MAGLIOCCO, A. 2014. Effects of vegetation, urban density, building height, and atmospheric conditions on local temperatures and thermal comfort. *Urban Forestry & Urban Greening*.

SANTAMOURIS, M., SYNNEFA, A. & KARLESSI, T. 2011. Using advanced cool materials in the urban built environment to mitigate heat islands and improve thermal comfort conditions. *Solar Energy,* 85**,** 3085-3102.

TAHA, H. 1997. Urban climates and heat islands: albedo, evapotranspiration, and anthropogenic heat. *Energy and buildings,* 25**,** 99-103.

WENG, Q. & YANG, S. 2004. Managing the adverse thermal effects of urban development in a densely populated Chinese city. *Journal of Environmental Management,* 70**,** 145-156.

ISSN 2055-0197(Print), ISSN 2055-0200(Online)