Spatial characteristics of open park spaces and perceived warmness in a tropical city

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Abstract

Background: Rapid urbanization in Kuala Lumpur Metropolitan City (KLMC) has resulted in urban heat island (UHI) effect that deteriorated public health of the urban dwellers. In a motive of identifying the heat sources, this study reported the perceived warmness and the characteristics of Open Park Spaces (OPS) that induce the reported warmness of the surrounding environment in Kuala Lumpur Metropolitan City (KLMC), a tropical city of Malaysia.

Methods: A cross sectional survey using structured questionnaires is conducted on randomly clustered respondents in selected localities of KLMC from January to May, 2018. Pearson correlation is performed to examine the relationship between perceived characteristics of OPS and perceived warmness of the surrounding environment according to three time slots of a day.

Results: The outcomes demonstrated that respondents felt warm during nights (89%) compared to morning (75%) and afternoon (87%). Meanwhile, the existing OPS are reported to be equipped with a mix of biodiversity such as birds, rodents and insects (89%), a mix of natural plants and animal populations (88%), water bodies (88%), variety of plants (86%), well-maintained grass surfaces (80%), ornamental flowers (79%) as well as wooded pasture (78%) in their neighbourhood. As the maximum warming sensation is reported to be felt at nights, especially in the presence of water bodies ($r= 0.318$, $p<0.01$) and wooded pasture ($r= 0.222$, $p<0.01$) in the vicinity, the integration of heat amelioratorss across the existing water bodies and wood pasture deemed essential to reduce the surrounding heat impacts.

Conclusion: The findings of this preliminary investigation are useful for urban designers and policy makers to make tacit evidence-based decisions.

Background

The century of urbanization has resulted many cities around the world to experience urban heat island (UHI) phenomenon that devastated the public health and socioeconomic status of the urbanites [1, 2]. Being a concomitant impact of both urbanization and population explosion, UHI magnify the thermal contrast between urban and rural areas [3, 4]. UHIs are commonly observed in densely-built areas which are associated to a larger number of buildings, compact and massive urban structures with narrow street canyons, reduced sky view factor, non-reflective and impermeable surface materials, lack of transpiring vegetation, transport flows, increased energy consumption as well as higher concentrations of urban pollutants [5, 6]. The aforementioned urban complexity trap and absorb the heat from escaping into the open space, thus creating a steep temperature gradient between urban and rural areas at nights [7]. Upon intensification, UHIs induce deleterious impacts on anthropogenic energy emissions [8], thermal comfort levels [9], air quality [10], biodiversity [11] and public health [12].

Being the cultural, financial and economic hub of Malaysia, Kuala Lumpur Metropolitan City (KLMC) is among the rapidly developing metropolitan regions in the Southeast Asia. In alignment with its physical growth, periodical temperature observations revealed that KLMC was getting warmer by 0.6 °C per decade

[13]. By employing weather station network, Elsayed reported an increase of 1.5 °C in UHI Intensity (UHII) in 2004 compared to a similar study done by Sani in 1985 [14]. On an important note, this study identified the appearance of more heat islands in the city center due to the absorption and retention of heat by urban materials. Later on, Yusuf et al. reported an average gain of 8.4 °C in surface temperature between 1997 and 2013 in selected zones of KLMC [15]. On top of this, urban community of an expanding city such as KLMC is deemed prone to heat impacts in the form of increased occurrences of heat waves, thermal discomforts and heat-related health implications [16]. From a large-scale survey involving 1050 respondents, Wong et al. identified that majority of the respondents reported respiratory problems (90.2%) followed by heat exhaustion (83.1%) and heat cramps (72.9%) as the health externalities of urban heat in KLMC [17]. Beside a substantial impact on the deterioration of urban quality and liveability, very little studies are dedicated on the UHI mitigation measures in the local context [18, 19].

Integration of Open Park Spaces (OPS) in urban areas to counteract the deleterious impact of UHI is deemed a feasible UHI mitigation measure in the tropical context. Particularly, OPS refer to a heat mitigation strategy in which parks are integrated with open spaces that caters for sports and recreation, preservation of natural environments, provision of green space and urban stormwater management [20, 21]. OPS, in the presence of greeneries, ameliorate urban heat by creating cooling buffer zones which also provide shade from direct solar radiation [22, 23]. Besides, empirical evidence have shown that cooling effects from the parks can reach up to 1–7 °C based on ground-based temperature measurements [24]. According to [25], parks incorporated with greeneries provide higher levels of thermal comfort, with approximately 0.94 °C of reduced daytime temperatures. It should be noted that existing literature on the potential of parks to combat urban heat mainly centered on urban parks [26], urban gardens [27], green roofs [28], vertical greenery [29], urban trees [30] and pocket parks [31] in accordance with the size and shape. Nonetheless, the potential of OPS as a viable mean for UHI reduction is still subjected to further investigation in the tropical context.

Despite the exacerbation of UHI phenomenon in KLMC, little attempts are invested on its mitigation practices. In reference to this, the present preliminary study aims to investigate the potential of OPS to mitigate urban heat effects in a tropical setting. The first objective is to examine the perceived warmness of the surrounding environment among the local residents of selected study areas in KLMC. The second objective is to investigate the existing characteristics of OPS that induce the reported warmness of the surrounding neighbourhood to provide insights for heat mitigations. The outcomes of this exploratory initiative are expected to highlight the potential of OPS in mitigating UHI impact for evidence-based city planning.

Methods

Design and settings

This cross sectional study used structured questionnaires to identify the perceived warmness of the surrounding environment and the existing characteristics of OPS that induce the reported warmness of

the surrounding environment to provide insights for heat mitigations among the local residents of selected study areas in KLMC. Particularly, KLMC experiences tropical rainforest climate, which is hot and humid all-year round (Fong et al. 2019). Maximum temperatures hover between 32 and 35 °C and it typically receives minimum 2,600 mm of rain annually. With approximately 1.79 million population as of 2018, it encompasses eleven districts that covers an area of 243 km^2 as shown in Fig. 1.

Instrument

A structured questionnaire is developed after reviewing relevant literature on the components of OPS that have the potential to mitigate urban heat [26, 27, 30, 31]. The questionnaire was subsequently face validated with the local experts. Basically, the questionnaire consists of two main sections. First section queried respondents' demographic information such as gender, working sector, education level, monthly income, type of residence and house price. Meanwhile, second section consists of questions on the characteristics of OPS. Seven items were listed in relation to the components in an OPS. Respondents are required to state their level of agreement using a five-point Likert scale on the characteristics an OPS that have the potential to mitigate urban heat in KLMC in accordance with three time slots of a day, namely morning, afternoon and night.

Data collection and analyses

Respondents are sampled using a randomized cluster approach. The inclusion criteria for the selection of respondents is that they must be local residents living in the study area during the data collection period. Data was collected from January to May, 2018. The collected data is analyzed in SPSS software (Version 25). A descriptive analysis is conducted to express the categorical variables in frequencies and percentages. Besides, Pearson correlation is performed to examine the relationship between perceived characteristics of OPS and perceived warmness of the surrounding environment according to three time slots of a day.

Ethical approval

The ethical clearance was acquired from University of Malaya Research Ethics Committee (Ref. No: UM.TNC2/UMREC–691) before conducting the study. Informed consent was verbally obtained and this procedure was approved by the research committee. All the data were anonymized and analyzed without identifiers.

Results

Participant background

A total of 200 eligible responses are collected from the study area. Female respondents (58%) are of predominance compared to the males. Majority of them are working in the private sector (55%) and completed diploma (43%). More than half of their income is within MYR (Malaysian Ringgit) 2,501 - 4,000

(54%). Besides, majority of the respondents are staying in terrace houses (51%) that covers an area between 501 - 800 square feet (51%), with house price ranging between MYR 300,001 - 500,000 (41%). The sociodemographic characteristics of the respondents are presented in Table 1.

Table 1 Sociodemographic characteristics of the respondents

Category	Frequency (N)	Percentage (%)
Gender		
Male	84	42
Female	116	58
Occupation		
Government	45	23
Private	109	55
Self-employed	41	20
Others	5	2
Education		
Primary	16	8
Secondary	63	32
Diploma	86	43
Undergraduate	29	14
Masters	6	3
Monthly income (MYR)		
< 2,500	48	24
2,501 – 4,000	107	54
4,001 – 8,000	40	20
> 8001	5	2
Type of current residence		
High rise	17	9
Terrace	101	51
Semi-detached	63	31
Detached	19	9
House price (MYR)		
< 100,000	3	2
100,001 – 300,000	19	9
300,001 – 500,000	82	41
500,001 – 700,000	76	38
700,001 – 900,000	20	10
House area (square feet)		
< 500	12	6
501 – 800	101	51
801 – 1,000	74	37
▯ 1,001	13	6

*MYR = Malaysian Ringgit

The perception of warmness and characteristics of OPS in KLMC

The agreement of the respondents on the perceived warmness and characteristics of OPS are dichotomized, in which responses for ‘agree’ and ‘strongly agree’ are added up and treated as agreement

to the reported characteristics. Meanwhile, the responses for 'neutral', 'disagree' and 'strongly disagree' are considered as disagreement and, therefore excluded from the analysis. The perception of warmness and characteristics of OPS in KLMC is displayed in Table 2.

Table 2 The perception of warmness and characteristics of OPS in KLMC

	Strongly disagree N (%)	Disagree N (%)	Neutral N (%)	Agree N (%)	Strongly agree N (%)
Perception of warmness in KLMC					
I feel warm in the morning.	-	6 (3)	44 (22)	105 (53)	45 (22)
I feel warm in the afternoon.	-	-	26 (13)	114 (57)	60 (30)
I feel warm in the night.	1 (1)	3 (1.5)	17 (9)	109 (54)	70 (35)
Characteristic of OPS in KLMC					
Has foreign, ornamental and kitchen plants.	-	-	29 (14)	110 (55)	61 (31)
Planted with colourful flowers.	-	3 (1.5)	40 (20)	106 (53)	51 (25.5)
Has water bodies like ponds, fountains, canals, etc.	-	2 (1)	23 (12)	122 (61)	53 (26)
Availability of wooded pasture.	-	3 (2)	42 (21)	115 (58)	40 (20)
Has well maintained grass surfaces.	2 (1)	5 (3)	32 (16)	113 (56)	48 (24)
Has a mix of natural plants and animal populations.	-	-	23 (12)	124 (62)	53 (26)
It has several animals like birds, insects, etc.	-	-	21 (11)	115 (57)	64 (32)

The findings indicated that the majority of the respondents expressed that they felt warm during nights (89%) compared to morning (75%) and afternoon (87%). Although no temperature measurements conducted to verify with their expressed perceived warmness, the findings are still in agreement with the other studies reported for KLMC that stipulate urban heat is mostly apparent during nights (Elsayed, 2012; Ramakreshnan et al., 2019). In terms of characteristics of OPS, respondents agreed that all the listed seven items are existing in the OPS located in various localities in KLMC. Particularly, the available OPS in their neighbourhood are reported to be equipped with a mix of biodiversity such as birds, rodents and insects (89%), a mix of natural plants and animal populations (88%), water bodies (88%), variety of plants (86%), well-maintained grass surfaces (80%), ornamental flowers (79%) as well as wooded pasture (78%). Although there are minimal differences in the responses between all the reported characteristics of an OPS, the respondents seem to highlight the availability of ecological attributes of the parks as a shared space with the nature.

Association between characteristics of OPS and perceived warmness in KLMC in accordance with three time slots of a day

A Pearson correlation analysis is performed between the reported characteristics of OPS and perceived warmness in KLMC to elucidate its potential in mitigating UHI in KLMC as shown in Table 3.

Table 3 Pearson correlation between perceived characteristics of OPS and perceived warmness in KLMC in accordance with three time slots of a day

Characteristic of OPS in KLMC *vs* Perception of warmness in KLMC	Morning	Afternoon	Night
Has foreign, ornamental and kitchen plants.	**0.270****	**0.147***	0.049
Planted with colourful flowers.	0.051	-0.040	-0.042
Has water bodies like ponds, fountains, canals, etc.	**0.223****	-0.058	**0.318****
Availability of wooded pasture.	-0.067	-0.043	**0.222****
Has well maintained grass surfaces.	**0.287****	0.120	0.062
Has a mix of natural plants and animal populations.	**0.156***	**-0.171***	0.048
It has several animals like birds, insects, etc.	-0.010	0.077	0.113

*correlation significant at 0.05 level (2-tailed)

** correlation significant at 0.01 level (2-tailed)

Results showed that OPS with plants (r= 0.270, p<0.01), water bodies (r= 0.223, p<0.01), well-maintained grass surfaces (r= 0.287, p<0.01) and with a mix of plants and animal populations (r= 0.156, p<0.05) are significantly correlated with perceived warmness in the morning. Open and exposed spaces in the parks due to scarcely designed landscaping plants and water bodies can cause most of the areas of the park to be exposed to direct solar radiation in the morning. This eventually cause the surrounding temperatures to spike up and inducing a warming sensation to the surrounding people. To alleviate this, OPS should be integrated with trees canopies that would decrease the exposed areas to direct sunlight and provide shade for thermal comfort. Nevertheless, characteristics such as plants availability (r= 0.147, p<0.01) and a mix of plants and animal populations (r= -0.171, p<0.05) are significantly correlated with perceived warmness in the afternoon. At night, it is believed that OPS with water bodies (r= 0.318, p<0.01) and with wooded pasture (r= 0.222, p<0.01) have a significant relationship with perceived warmness in KLMC. It should be noted that water bodies that absorb heat during the daytime can act as heat reservoirs that release them during the nights [32]. Therefore, heat ameliorators such as plants and trees can be planted across the existing water bodies to reduce the heat impacts. In summary, the findings suggested that the existing features of OPS need to be upgraded with relevant designing approaches to alleviate the warming sensation experienced by the residents in KLMC.

Discussion

This preliminary study reported the perceived warmness of the surrounding environment and the existing characteristics of OPS that cause the reported warmness of the surrounding environment to provide insights for heat mitigations in KLMC. The findings revealed that respondents felt warm during nights (89%) compared to morning (75%) and afternoon (87%). On the other hand, the existing OPS are reported to be equipped with a mix of biodiversity such as birds, rodents and insects (89%), a mix of natural plants and animal populations (88%), water bodies (88%), variety of plants (86%), well-maintained grass surfaces (80%), ornamental flowers (79%) as well as wooded pasture (78%) in their neighbourhood. As the maximum warming sensation is reported to be felt at nights, especially in the presence of water bodies ($r= 0.318$, $p<0.01$) and wooded pasture ($r= 0.222$, $p<0.01$) in the vicinity, the integration of heat ameliorators across the existing water bodies and wood pasture is essential to reduce the surrounding heat impacts. The findings affirmed that the existing features of OPS need to be upgraded to alleviate the warming sensation experienced by the residents in KLMC.

It should be noted that these findings need to be interpreted based on its limitations. Albeit this preliminary study included a low sample size, careful clustered sampling was done to ensure that the respondents gathered in this study are representative of the population in KLMC. Due to preliminary nature of the research, the outcomes and analyses of this study need further research. The findings from this study is purely from the perspective of local residents within the selected study area. An in-depth research is needed to quantify the potential of each characteristics of OPS to mitigate UHI. The findings from this study would benefit researchers, stakeholders and policy makers who are working closely with urban sustainable development to shape KLMC into a World Class Sustainable City as stipulated in the 2030 Agenda for Sustainable Development.

Conclusion

In summary, this study investigated the potential of OPS to mitigate urban heat effects in a tropical setting by exploring the perceived warmness of the surrounding environment and the existing characteristics of OPS that induce the reported warmness among the local residents of selected study areas in KLMC. The findings revealed that respondents felt warm during nights (89%). As the maximum warming sensation is reported to be felt at nights, especially in the presence of water bodies and wooded pasture, the incorporation of heat reducing elements across the existing water bodies and wood pasture is essential to reduce the surrounding heat impacts. The outcomes highlighted that the existing features of OPS have to be improved to reduce the warming sensation experienced by the residents in KLMC.

Declarations

Declarations

None

Abbreviations

KLMC: Kuala Lumpur Metropolitan City; OPS: Open Park Spaces; UHI: Urban Heat Island

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Author's contribution

Conception, design and supervision of the study: **NRH**, **NA** and **NMS**; Data acquisition and analysis: **WNAWAA**, **AMA** and **CSF**; Original draft and revision: **CSF** and **LR.** All authors read and approved the final manuscript for publication.

Competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Availability of data and materials

The datasets generated and analyzed during the study are not publicly available, but can be obtained from the corresponding author on a reasonable request.

Ethics approval and consent to participate

The ethical approval was obtained from University of Malaya Research Ethics Committee (Ref. No: UM.TNC2/UMREC–691).

Informed consent

Participants were informed about the objectives and consent were verbally obtained prior to the study to minimize use of papers. The ethics committee approved this procedure.

Consent for publication

Not applicable

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Figures

Figure 2

Selected study areas in Kuala Lumpur Metropolitan City