Urban River Landscape Factors Impact On Urban Microclimate In Tropical Region

Yuswinda Febrita¹, Sri Nastiti N. Ekasiwi² and I. Gusti Ngurah Antaryama³

¹ Doctoral program in Architecture, Department of Architecture, Faculty of Civil, Planning, and Geo Engineering, Sepuluh Nopember Institute of Technology (ITS) Surabaya, Indonesia 60111
² Department of Architecture, Faculty of Civil, Planning, and Geo Engineering, Sepuluh Nopember Institute of Technology (ITS) Surabaya, Indonesia 60111
³ Department of Architecture, Faculty of Civil, Planning, and Geo Engineering, Sepuluh Nopember Institute of Technology (ITS) Surabaya, Indonesia 60111

E-mail: yfebrita@ulm.ac.id¹, nastiti@arch.its.ac.id², antaryama@arch.its.ac.id³

Abstract. Urban rivers are used by architects and urban planners to control urban temperatures. Body of water is an important factor to lower the temperature in the Urban Heat Island in the tropics. Previous researches have shown that temperature near a body of water is lower by 2 °C compared to the surrounding area during the day. Water bodies also have the potential to cool the environment by wind flow. Evaporation from a body of water helps in lowering temperature, but contributes to humidity. In this case, the study aims to determine the influence of each factor of urban river landscape of the urban microclimate through literature review. The results showed that the presence of the composition and configuration of urban river landscapes (orientation of the region, building placement patterns, vegetation placement patterns, and the ratio of building height to street width (H/W)) has an effect on the displacement of the cooling effect from urban rivers to the surrounding area. Design considerations Urban river landscapes are needed to maximize the benefits of river cooling.

Keywords – Urban microclimate; Urban Heat Island; Urban river landscape factors.

1. Introduction

Urban climatology is one of the fields that must be synthesized by architects and planners. They need meteorological information to obtain: emergency management and disaster preparedness, inspection and evaluation of building performance and sustainable design and planning that integrates urban climate knowledge (regional, local/ mesoscale climate and microclimate) with planning/design tools used to produce maps of urban climate functions that provide visual tools that synthesize information on topography, urban morphology and urban climate [1]. A common issue in urban climate is the phenomenon of urban heat island (UHI). It has been known urban centre temperatures are higher compared to the suburban areas. Heat island intensity depends upon meteorological elements (air flow, air temperature, solar radiation, precipitation, cloud cover, evapotranspiration, etc.), aspects of urban structure (e.g., the density of built-up areas, size of cities and urban geometry) and locational [2]-[3]. There are two substantial scales to measure the urban heat islands, which are urban boundary layer (UBL) and the urban canopy layer (UCL) [4]. The results showed that the presence of the composition and configuration of urban river landscapes (orientation of the region, building placement patterns, vegetation placement patterns, and the ratio of building height to street width (H/W)) have an effect on the displacement of the cooling effect from urban rivers to the surrounding area. Design considerations Urban river landscapes are needed to maximize the benefits of river cooling.
land cover and land use [13]. Land use, urban structures, location and water bodies have significant impacts on the urban land surface temperature (LST) [14].

Water bodies represented cooling effect on urban temperatures [15]-[16]. Cooling near the river is only significant for the day with the cooling highest in the morning and cooling lower at midday [16]. Water bodies have a characteristic that water surface temperature few degrees less than the built environment surrounding and provide to cool the air by convection process [17]. Urban landscapes with water bodies, as wetlands, rivers and lakes support to ‘urban cooling islands’ (UCI) and can reduce urban ambient temperatures by 1-2K [18]. The urban form of water bodies surrounding (e.g., architectural form, land cover, terrain height and surface roughness) may affect the cooling effects [16].

Therefore, this paper build taxonomy body of knowledge in urban climate inquiries and develops the conceptual framework of water bodies/urban river landscape factors effects on urban microclimate in tropical cities in order to mitigate the phenomenon of UHI effect and human comfort.

2. Methods
This research is a review of previous research, by reviewing some research about urban climate and with the roles of urban river landscape factors on urban microclimate, which is based on the results of the mentioned investigation and also from the previous published works. These kinds of results can assist in planning urban landscapes and design of riparian corridors for the most effective cooling by urban rivers. The literatures reviews have been made to identify urban river landscape factors effect on urban microclimate. In this research achieved to tropical and sub tropical regions as Japan, South Corea, China, Brazil, Singapore and Malaysia. The research has established a contain analysis on the literature which represents the urban river landscape factors influencing urban microclimate. Presenting to Table 1, the factors have been classified into four classifications; urban structure factors, urban properties factors, urban climate factors and heat transfer factors within which, each cluster involves a number of factors (see Table 1). The content analysis table showed that previous studies have mostly studied the factors of air temperature, wind velocity and water body, in different with the street orientation, building density and evaporation factors.

The value analysis table provides the depth of citation (DoC) at the last row of the table. The depth of citation refers to cumulative importance level of each factor according by previous researches. Fig. 2 illustrates the depth of citation of urban river landscape factors in a bar chart. We can see, air temperature and water body (DoC = 13 from 13) has been much related to urban climate researches therefore therefore, this factor should be indetail examined in future experimental and simulation microclimate researched in coastal cities in tropical regions. In different, some factors (street orientation, building density and evaporation) have accepted a minimum frequency of depth of citation (DoC = 1 from 13) referenced by preceding urban microclimate investigates.

3. Urban Climate Taxonomy
The research examined literature to construct taxonomy body of knowledge in urban climate studies. Urban climate affects global and regional climate and makes urban livable [19]. Four significant controls on urban climate are: 1) urban cover (paved, built-up, vegetation, water and bare soil), 2) urban structure (street widths and street spacing and buildings dimensions and the spaces between buildings), 3) urban fabric (construction and natural materials), 4) urban metabolism (heat, pollutants due to human activity and water) [4]. Three horizontal scales of urban climate; microclimate (typical scales stretched one metre to hundreds of metres and refers to the climate of buildings, streets, the trees, gardens, and so on), localclimate (typical scales one to several kilometres), and mesoclimate (typical scales of tens of kilometres) [20]. Urban density, surface properties, urban form and geometry, vegetation, and water level affected urban open spaces microclimate [21]. Figure 1 illustrates the sub-branch of urban climate studies. Human comfort issues in urban climate studies through urban environment and urban atmosphere. Urban atmosphere and urban environment research appeared into distinct areas of researches, including climate element, climate scale, urban layer, energy balance and composition and configuration urban landscape urban.

3.1. Street Canyon Design And Urban Microclimate
Creating an urban climate has an important role in designing urban streets canyon, because over than a quarter of urban areas are mostly covered by streets [22]. The most defining features influencing the microclimate of urban street canyon are building height to street width ratio (H/W) and street orientation. Street design and H/W ratio of the street in microclimate on air temperature and street surface influencing by Sky View Factor (SVF). The street geometry and SVF make the air temperature variation lower than the surface temperature [23]. The higher H/W ratio leads lower air temperatures and larger SVF induces higher air temperatures [24]. A major problem in
street design for designers and urban planners is to compress the temperature extremes of the season during the summer period. It is important to entryway to sky in winter and to cover street from the sun. These concepts provide instructions for being open to sky, compact and synchronously [25]. The shadow variable affects the wind flow on the street level [26]-[27]. For nighttime cooling levels and daytime heat storage levels for street canyons, it is important to notice to the building materials for the canyon surface [27].

![Figure 1. Taxonomy of urban climate studies.](image)

3.2. Vegetation
Increasing the amount of vegetation in urban areas is considered an important UHI mitigation measure. Vegetation lowers the air temperature because shading and evapotranspiration [28]. Transpiration represents the water losing of a plant as evaporate to the atmosphere. This requires energy, hence cooling the leaves and the air around them. The shading from the trees influence the atmosphere cooling by reducing solar radiation [29]. In addition, green spaces will regularly restore the surface porosity, increasing the amount of water bodies for evaporative cooling [16]. Two kinds of urban greening measures have been identified: urban greenspaces and green walls and roofs.

The cooling effect by green spaces has been investigated in a number of studies. The range of the greenspace influence is usually assumed to be one park width from the greenspace [30], although it to be much smaller [31]. The larger parks and more heavily vegetated parks generally have a larger cooling effect than small parks and parks with more paved surfaces [32]. Larger parks are cooler [29]. The cooling effect by parks on surrounding even differs by vegetation type. Although the trees can have a cooling effect throughout the day, this is offset throughout the night, when heat change among parks and the cooler air over them is obstructed [32].

Similarly, there is proof that the air temperature under individual the trees (e.g. the trees on parking spaces and street trees) is lesser than the air temperature measured on non-green urban sites during the day [33], [34]. The cooling effect of grass depends largely on the amount of irrigation [35], [36]. Furthermore, Santamouris (2014) presents a review of several studies and concludes that as green roofs are discharged on medium or high rise buildings, its mitigation potential at street level is nearly negligible [37]. Living walls and green facades have similar effects on the thermal urban environment [38].

3.3. Built Form
The building geometry and density are of concern in this category. The high H/W ratio can reduce overheating due to solar radiation in summer. Although a dense urban fabric provides shading at street level, it also catcher heat resulting from lowered SVF and multiple solar reflections, it may reduce impairing ventilation cooling and
air flow [39]. The daytime Urban Heat Island is closely related to site shading factor. Areas with the highest building density were investigated to have the lowest daytime UHI, whereas low density urban morphologies indicated the highest UHI during the day [40]. The high density city configurations toward a rise in night time Urban Heat Island, because of the high thermal capability of the combined mass of the buildings [41]. Open spaces and wide streets encourage air flow which increase the occasion to ventilate the inner parts of a city and lower temperatures [39]. The orientation of streets with regard to the main wind directions is also of interest. The opening up the streets to a river allows a larger cooling effect than streets that are shut off from the river [29]. The medium to high-rise buildings can block sea breeze during the daytime, thereby inhibiting ventilation cooling [42].

3.4. Properties Of Surface

The utilize of ‘cool materials’ has obtained attention as an UHI mitigation measure in the past decade. Characterized Cool material is high solar reflectance (albedo), infrared emissivity [43] and/or porosity [44]. Darker (low albedo) materials absorb more solar radiation than lighter materials (high albedo). This warms the surface, which finally warms the atmosphere [45]. Various studies have shown that reflective roofs and pavements lesser air and surface temperatures during the day [44]-[45]. The high albedo pavements lower than the air temperature. However, they record that the increased reflection of solar radiation from pavements can increase heat stress for pedestrians. As a result, these authors suggest using reflective materials on roofs, rather than on pavements and walls. The release of solar radiation constrained by high vertical walls, reflective pavements were found to increase air temperatures during the day [46]. No influence on night time temperatures was observed. The infrared emissivity specifies how well a surface radiates energy away from itself [43]. Emissivity is measured on a scale of 0 to 1.0, like albedo. Conventional pavement materials, as concrete and brick, asphalt, had emissivity values over 0.90 and hence effectively released and stored energy. Not much attention has been paid to the emissivity of materials as a means of mitigating the UHI [47]. This is likely caused by the fact that the emissivity is not easily changed; except from a few metals, such as aluminium and silver, most materials, including soil, vegetation and water, have a high emissivity [48]. Coatings to increase the albedo of materials, do not affect the emissivity of the material [49]. Whereas impervious surfaces, in combination with efficient drainage, lead to a decrease in surface moisture available for evaporation, the water stored in voids of pervious materials allows cooling through evaporation. The inclusion of porous materials in the urban environment is primarily promoted by two measures: porous paving and green roofs. The porous asphalt indicated higher daytime surface temperatures than the traditional dense-graded asphalt and concrete pavements, but the lowest night time temperatures [50]. When surrounded by high walls, porous concrete and porous asphalt increased maximum daytime air temperatures. In addition, it was found that these porous pavements do not lower night time temperatures [41].

3.5. Water Body Effects on Urban Microclimate

Urban planners and architects have used water bodies in their designs to control urban temperatures [51]. In general, previous studies have shown that there is a decrease in maximum temperature during the day due to water bodies, temperatures and therefore the heat stress near and downwind to the water bodies are 1 to 2 °C lower than surrounding area [51]-[55]. Water bodies have a great capacity for air temperature, heat storage and evaporation effect [29]. A downwind cooling effect also occur in wetlands [51]. The temperature of the urban landscape shows a higher range than the diurnal temperature of water, i.e. the maximum temperatures suppression, and limitations of nocturnal cooling [55]. Toward lower temperatures, evaporation obtaining from benefits of open water bodies, but it assist to humidity. The decrease in human comfort is caused by higher humidity levels. In an effort to maintain an oasis effect during the day, water bodies offer a good source of moisture, specifically, when the area covered is a larger-scale and drier urban environment [51].

The appearance of water bodies has the potential to mitigate the UHI effect through sensible heat transfer and evaporation among the air and water[56]. The most efficient UHI reduction effect during summer depends on and water bodies[13]. Urban rivers, ponds and lakes, and novel water facilities will be discussed below.

A restored stream in Seoul (South-Korea) affects the local thermal environment, including heat mitigation [56]. A small urban river in Sheffield (UK) provides significant cooling both over the river and on the river banks during spring and summer. This cooling effect was largest in the mornings and on highly vegetated banks. The cooling effect increases with greater solar radiation and higher ambient temperatures, and decreases with higher water temperatures. The level of cooling 40 metres from the river was found to be negligible [29]. The cooling effects of the Ota River in Hiroshima City (Japan) were discernible at least a few hundred metres. Again, it was found that the cooling effect is virtually absent during the night [14].
In Rotterdam (The Netherlands), the city centre is hotter than the harbour among daytime. But at night, the city centre and the harbour have approximately the same temperature and both cools down more slowly than the suburban surroundings [58]. The cooling effect of ponds in courtyards in Oregon (USA) to be the largest in the afternoon [59]. The urban cold island intensity (UCII) and efficiency of 197 ponds and lakes in Beijing. They found that larger water bodies increase the cooling intensity, but reduce the cooling efficiency (UCII per ha). This means that a larger number of small bodies of water with the same total area of water can have a more beneficial effect[60].

Contrasted to areas without water bodies in sub-tropical areas, Water bodies can have a significant cooling impact by lowering the ambient temperature by 4°C. In addition, one potential mitigation for UHI is water ponds that promote the evaporative cooling by [61]-[62]. Evaporative cooling is one of the most useful ways to lower temperatures in urban spaces in the tropics. [61]. In the tropical regions, the water bodies positive impact could process better at low temperatures and low humidity provide a positive effect.

4. Urban River Landscape Factors Influence Urban Microclimate in Tropical Region

Critical literatur review has been created to recognize the urban river landscape factors effect on urban climate. This time, The research extent to tropical and subtropical regions.

The study has arranged a content analysis on the literature which represents the urban river landscape factors impacting microclimate. According to Table 1, the factors have been classified into four classifications; urban structure factors, urban properties factors, urban climate factors, and heat transfer within which, each classification implicates a number of factors (see Table 1).

Table 1. Urban Climate Environmental Factors In Urban River Landscape on Urban Microclimate Studies

| Citation | Urban Structure | Urban Climate Environment | Elements of Urban Climate | Heat transfer | Climate Location |
|----------|-----------------|---------------------------|-------------------------|---------------|-----------------|
| John A., Iwamoto S., 1990 [63] | | | | | Subtropical/ Hakone, Japan |
| Nakamura S., Sekine T., Narita K., 1991 | V V V | V V | V V | V V V | Subtropical Hiroshima, Japan |
| Kim Y., Ryu Y., et al., 2006 [64] | V | V | V | V | Subtropical Continental Humid/ Seoul, South Korea |
| Huang L., et al., 2008 [64] | V V V | V V | V V | V V | Subtropical Continental Humid/ Nanjing, China |
| Chen L., Zhao L., 2009 [65] | V | V V | V V | V V | Subtropical Continental Humid/ Guangzhou, China |
| Sugimoto H., Narita K., et al., 2009 [66] | V | | V V | V V | Subtropical |
| Ye Y., Wei Q., Huang X., et al., 2010 [67] | V | | V | V | Subtropical Continental Humid |
| Wong N.H., Tan C., Natalya A.E.S., et al., 2011 | V V | V V | V V | V V | Tropic warm humid/ Singapore |
| Han T., Chen H., et al., 2011 [69] | V V V V | V | V V | V V | Subtropical Continental Humid |
| Mazzu E., Souza M., 2012 [70] | V V V V | V V | V | V | Tropical/ Sao Jose do Rio Pires, Brazil |
| Chen K., 2012 [69] | V V | V | V | V | Subtropical Continental Humid |
| Kull U., et al., 2014 [71] | V V | V | V | V | Subtropical Continental Humid |
| Menghan W., 2016 [72] | V V V | V V V | V V V | V V V | Tropic Warm Humid/ Malacca, Malaysia |
As a result of previous research, the appearance of urban landscape on the riparian of a river influential in transferring the cooling effect from the urban river to the city. The cooling effect due to water bodies at the micro scale in tropical climates is influenced by urban river landscape composition variables such as the percentage of land cover components (building density and water body area), urban river landscape configuration (area orientation, building placement pattern, vegetation placement patterns and value comparison ratio of building height per road width H/W) that will affect the intensity and efficiency of cooling and distribution from water bodies/ rivers to urban environments [73]. It is important to conduct forward research on the influence of urban river landscape factors to spread the cooling river effects to the environment around urban rivers.

Figure 2. DoC of urban river landscape factors in urban climate researches

5. Discussion And Conclusion

This review focused on studies that discuss about the conceptual framework of the factors of urban river landscape that effect on urban microclimate in the tropics areas.

- The horizontal effect of urban river landscape on the microclimate is influencing by composition and configuration of urban structure and urban properties (e.g., density of buildings, rivers, orientation of the region, building placement patterns, vegetation placement patterns, and the ratio of building height to street width) to maximizing the water body cooling effect.

- To distribute the cooling impact of urban rivers, the factors of wind direction and speed are important.

- Designing urban river landscapes by presenting the appropriate air flow and utilizing access to the sun is essential in order to create a comfortable microclimate in urban areas. This can affect the energy consumption of buildings and the urban climate.

The next research, the results of this study will be used as a simulation of urban micro-climate studies in coastal areas such as Indonesia.

References

[1] G Mills et al 2010 Climate Information for Improved Planning and Management of Mega Cities Needs Perspective Procedia Environmental Sciences 1 pp 228–246
[2] Oke T R 1987 Boundary layer climates New York Routledge
[3] Santamouris M 2006 Environmental Design Of Urban Buildings Earthscan London
[4] Oke T R 2006 Towards better scientific communication in urban climate Theoretical and Applied Climatology 84 pp 179–190.
[5] Gosling S N et al 2014 A glossary for biometeorology Int.J Biometeorol pp 277–308
[6] Yuan C and Ng E 2012 Building porosity for better urban ventilation in high-density cities—A computational parametric study Build. Environ. 50 pp 176–189
[7] Gál T and Unger J 2009 Detection of ventilation paths using high-resolution roughness parameter mapping in a large urban area Build. Environ. 44 pp 198–206
[8] Karleski T, Santamouris M, Synnec A, Assimakopoulos D, Didaskalopoulos P and Apostolakis K 2011 Development and testing of pcm doped cool colored coatings to mitigate urban heat island and cool buildings Build Environ 46 pp 570–576
[9] Matthews T, Lo AY and Byrne JA 2015 Reconceptualizing green infrastructure for climate change adaptation Barriers to adoption and drivers for uptake by spatial planners Landsc. Urban Plan 138 pp 155–163
[10] Emmanuel R, Loconsole A 2015 Green infrastructure as an adaptation approach to tackling urban overheating in the glasgow clyde valley region UK Landsc Urban Plan 138 pp 71–86
[11] Jim C Y and Chan M W H 2016 Urban greenspace delivery in hong kong Spatial-institutional limitations and solutions Urban Green 18 pp 65–85
[12] Demuzere M, Orru K, Heidrich O, Oezalp E, Geneletti D, Orru H, Bhave A, Mittal N, Felleu E and Faehnle M 2014 Mitigating and adapting to climate change Multi-functional and multi-scale assessment of green urban infrastructure J. Environ. Manage. 146 pp 107–115
[13] Connors J P, Galletti Christopher S and Chow Winston T L 2013 Landscape configuration and urban heat island effects: assessing the relationship between landscape characteristics and land surface temperature in Phoenix Arizona Landscape Ecol. 28 pp 271–283
[14] Zhou X and Chen H 2018 Impact of urbanization-related land use land cover changes and urban morphology changes on the urban heat island phenomenon Sci. Total Environ. 635 pp 1467–1476
[15] Murakawa S, Sekine T and Narita K 1991 Study of the Effects of a River on the Thermal Environment in an Urban Area Energy and Buildings 15-16 pp 993–1001
[16] Hathway E A and Sharples S 2012 The interaction of rivers and urban form in mitigating the Urban Heat Island effect A UK case study Building and Environment 58 pp 14–22
Ishii And Iwamoto 1991 A Comparison Of Field Surveys On The Thermal Environment In Urban Areas Surrounding A Large Pond When Filled And When Drained Energy And Buildings 16 pp 965–971
[64] Huang L, Li J Zhao D and Zhu J 2008 A Fieldwork Study On The Diurnal Changes Of Urban Microclimate In Four Types Of Ground Cover And Urban Heat Island Of Nanjing China Building And Environment 43 pp 7–17
[65] Chen Z, Zhao L, Meng Q, Wang C, Zhai Y and Wang F 2009 Field Measurements On Microclimate In Residential Community In Guangzhou China Frontiers Of Architecture And Civil Engineering In China 34 pp 462–468
[66] Sugawara H, Narita K et al 2009 Cooling Effect by Urban River The seventh International Conference on Urban Climate Yokohama Japan 29 June - 3 July 2009
[67] Xu J, Wei Q, Huang X, Zhu X and Li G 2010 Evaluation of human thermal comfort near urban waterbody during summer Building and Environment 454 pp 1072–1080 https://doi.org/10.1016/j.buildenv.200910025
[68] Wong N H W, An C L T, Dyah A Indyani, S N Usuf K J and An E T 2011 Influence of Water bodies on Outdoor Air Temperature in Hot and Humid Climate 81–89 Xu J Wei Q Huang X Zhu X and Li G 2010 Evaluation Of Human Thermal Comfort Near Urban Waterbody During Summer Building And Environment 454 pp 1072–108
[69] Han G 2011 Field measurements on micro-climate and cooling effect of river wind on urban blocks in Wuhan city IEEE pp 4446–4449
[70] Massierd: Cristina L Souza D 2012 Influence of a Waterbody in the Urban Microclimate PLE2012 - 29th Conference Opportunities Limits and Needs Towards an environmentally responsible architecture Lima Peru 7-9 November 2012
[71] Kim D, Cha J G and Jung E H 2014 A Study on the Impact of Urban River Refurbishment to the Thermal Environment of Surrounding Residential Area Journal of Environmental Protection 5 pp 454-465
[72] Manteghi G et al 2016 Envi- Met Simulation On Cooling Effect Of Melaka River International Journal Of Energy And Environmental Research 42 pp 7–15
[73] Febrita Y, Ekasiwi NE, Antaryama IGN 2018 The Influence of Urban Rivers on Heat Island Phenomenon International Journal of Innovative Research and Knowledge Volume-3 Issue-8 May-2018 pp 122-131