Analyses Water Bodies Effect in Mitigation of Urban Heat Effect: Case Study Small Size Cities Kuching, Sarawak

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Abstract. United Nations in 2019 predicted by 2050, approximately 70% of humans will live in urban areas. The development without a proper plan can lead to degradation of the environment and increasing the urban heat effect. The urban heat effect is where the condition is the temperature in urban areas higher than rural. It becomes highly essential subject areas due to the continuous urban growth to fulfill the demand of the migration population from rural areas to urban areas. In general, prior work is limited to a subset of urban green space in mitigation of urban heat island. Hence, the effect of water bodies has not been studied extensively, particularly in the tropical rainforest climate. Thus, understanding this is a key to uncover the origin of the influence land use/land cover in water bodies’ effects on urban heat effect. For this study, the following critical data from Landsat 5 TM in the year 1988 and Landsat 8 TIR OLI. The first step this studied applied pre-processing, namely geometric correction, radiometric correction, and atmosphere correction. The second stage generates the land surface temperature (LST) for the year 1988 and 2019. The third stage performs 200 samplings, which 100 samplings to north and 100 to the south from Sarawak river. The measurement of LST takes from water bodies following next every 100 meters until it reached 1000 meters. The result did not demonstrate a direct correlation between distance water bodies and LST. The land use and land cover type of active influence on the LST pattern than the distance waterbody effect. However, the distance for water below 200 meters shows a strong relationship between LST. It notable that a close correlation exists between the LST distance of water bodies at this below 200 meters. The effect of the waterbody in reducing the LST at urban heat was active at a distance of 200 meters and below. There were clear benefits to be seen in the mitigation of urban heat islands. The theoretically should provide further interest to urban planners and policymakers to develop sustainable cities.

Keywords: Water Bodies, Cooling Effect, Urban Heat Effect, Remote Sensing and GIS

1. Introduction

United Nations [1] stated the 55% world population are living in city areas in 2018, and this number predicted to increase to 68% in 2050. Urban development required the transformation of natural regions to build up humans resulted in an environmental and ecological problem, especially urban heat islands [2]. Urban heat island has been adverse effects such air, and water pollutions [3], increase of energy [4] and water [5] consumption, extra heat stress on population [6] and can cause of morbidity and mortality [7]. The water bodies in an urban environment is a crucial natural landscape for UHI mitigation. However, the functions as UHI mitigation are frequently unnoticed or less attention compare to urban green space [2]. The water bodies, namely include rivers, streams, canals, fountains, waterfalls,
waterfalls, lakes, reservoirs, ponds, wetlands, and seashores lines [8]. Water bodies efficiently emissivity and successfully consume shortwave radiation via evaporation. On another hand, at the same time, the water surface energy can be transported across conduction, convection, advection with water bodies [9]. In hot condition climate, water bodies have similar effects as urban green space. The still little studied to understand water bodies' impact on the urban environment [8]. Here the studies which investigated the impact of water bodies in urban heat effect. In Zhijie Wu and Yixin Zhang [10] discovered the water effective distance 750 meters and below to reduce temperature urban. Saaroni and Ziv [11] showed the small scale of water bodies 100-meter able to reduce heat during the daytime.

Kim et al. [12] discovered that the stream has transformed sensible heat flux and applied to reduce the temperature in Seoul, Korea. Völker et al. [8] found that the average cooling for water bodies compared to urban reference sites was 2.5 °C through a systematic literature review. On another hand, Cai et al. [14], Sun et al. [13], and Du et al. [15] discovered the water bodies’ cooling effects are influenced by the size, shape, and location. Besides that, Sun et al. [13] and Hou et al. [16] discover that the way and position may well significantly impact the cooling effects of wetlands in urban provinces. On another hand, Cai et al. [14] found water bodies ‘cooling impacts on LST and urban form factors such as sky view factor and mean building height in Chongqing, China. In the contest, Malaysia and tropical climate studies there only studies [17] done research explored the role of green and water bodies in reducing the temperature in urban areas. The results of the temperature decrease between 0.61 to 1.79 °C reached 480 meters. There are very few published results about water bodies in mitigation of urban heat effects, especially in a tropical climate. Many studies, as mentioned above, only limited to a subset of examined the cooling effects of water bodies on the LST.

Nevertheless, previous studies little focused cooling effects from water bodies to surrounding areas. In literature review showed there nobody examined the influence of land use and land cover with water bodies. On another hand, most of the study effects of water bodies and wetland cooling effect to urban heat island, however there no study to examine the impact of land cover change to the degree of effectiveness of these to cool the urban heat island. To achieve this study, we utilized two difference data Landsat 5 TM on date 25 May 1988 and 15 May 2019. It is crucial to consider the influence of water bodies with the temperature for service of temperature mitigation on urban areas — the objective of this study to examine water bodies’ cooling effects on the LST small medium-size cities. The second objective to test whether the cooling effects influence the relationship between land cover/land used and last to examine the relationship of the LST and the distance from water bodies.

2. Study Area

Kuching relocated to Borneo, which capital city of the state of Sarawak, Malaysia. The history mentioned that civilization began at surrounding Sungai Sarawak. The main reason for most development surrounding Sungai Sarawak. The region's climate is a tropical rainforest with annual precipitation of 4600 millimeters [18]. The average temperature value of 19 °C to 36 °C [19]. The Northeast season in September until March and the southeast from May until August. The northeast season's significant wet season at Kuching and southeast season is dry. In 2018, the Kuching population was 570, 407 [1]. The literature review has recommended focusing on small-medium cities with a population below 2 million [20]. The primary motivation of the author to choose Kuching as an area study.
3. Methodology

This study applied two of the data Landsat 5 TM for the year 1988 and Landsat 8 OIL TIR for the year 2019. Table 1 shows a detailed dataset used in the study.

| Sensor  | Thermal Band | Resolution                  | Spatial resolution | Data Acquisition |
|---------|--------------|----------------------------|--------------------|------------------|
| Landsat 5 | Band 6       | 100 meter resample to 30 meter | 30 meter           | 25 May 1988      |
| Landsat 8 | Band 10      | 120 meter resample to 30 meter | 30 meter           | 15 May 2019      |

Both data required for pre-processing atmosphere correction, geometric correction, and radiometric correction. The second stage required retrieval of land surface temperature at Landsat 5 and Landsat 8. The step of retrieval of land surface temperature at Landsat 5 and Land 8 was applied based following the step on paper [21]. The sample at data was conducted at 200-point sampling at the same coordinate for each 1988 and 2019. The 100 points to North from Sarawak River and the 100 points to the south and the distance between the end 100 meters, as shown in the figure below.
4. Result and Discussion

Figure 4 shows the map of LST for the years 1988 and 2019. The maps show the increase of SUHI pattern from 1988 and 2019. The SUHI pattern increase from the center of the city to the suburban area. The increasing of SUHI significant increase the LST statistics as mentioned in the table below: The min of LST in 1988 with value 18.83 increased to 22.24, and following the max of value LST 28.76 in 1988 rose to 36.06 at 2019. The data mean of LST also increases from 23.00 to 26.64. The increase in data statistics because of influence growing the SUHI at area study. The transformation from natural areas to build up a significant rise in LST surrounding area study. The data was captured both in May, which no significant influenced by the monsoon season.
Table 2. Data statistics of LST for the year 1988.

| Data statistics | The year 1988 Value (Degree Celsius) | The year 2019 Value (Degree Celsius) |
|-----------------|-------------------------------------|-------------------------------------|
| Min of LST      | 18.83                               | 22.24                               |
| Max of LST      | 28.76                               | 36.06                               |
| Mean of LST     | 23.00                               | 26.64                               |

Table 3. Data statistics of LST for the year 2019.

| Data statistics                        | The year 1988 Value (Degree Celsius) | The year 2019 Value (Degree Celsius) |
|----------------------------------------|-------------------------------------|-------------------------------------|
| Mean of LST at Urban Areas             | 26.83                               | 33.24                               |
| Mean of LST at Vegetation Areas        | 22.54                               | 26.78                               |
| Mean of LST at Water bodies            | 21.20                               | 25.93                               |

Table 3 shows the mean of LST at every mainland cover in area study. The urban areas value highest is 26.83 and 33.24 for the year 1988 and 2019, following means of LST at vegetation areas 22.54 for the year 1988, 26.78 for the year 2019, and the lowest is water bodies with 21.20 for the year 1988 and 25.93 for the year 2019. Transformation of from nature to build up building was the modification of surface properties cause to more absorption of solar radiation, reduce convective cooling, and lower water evaporation rates. Because of this, the LST at urban higher than vegetation and water bodies [9].

Figure 5. Profile of LST.

Figure 5 described the profile of LST based on the location distance of water bodies (Sarawak river) for the year 2019. This result does show a clear trend with the distance from water bodies the temperature of the LST effect from 0 meters to 200 meters from water bodies. However, the pattern of LST fluctuation because of the influence of land-use type. The temperature at the land-use type commercial area was higher than land-use green park recreation areas. The regions which contain vegetation has low temperature compared to the urban area even this distance at 1000 meter from water bodies. In the profile, above grapy shows contrasts between land use metropolitan area and vegetation. The results are similar to what has been achieved by [11;22]. Zhijie Wu and Yixin Zhang [11] discovered that LST increases as the distance from the water body increases. The temperature is stable after 250 meters.
Hathway and Sharples [23] determine the cooling effects of a river is a 22 m wide and able can range to 30 m from the riverbank in Sheffield. The latest studied shows Zhijie Wu and Yixin Zhang [11] found that active distance cooling is 700 meters and below at south-eastern Jiangsu Province in China.

Figure 6. The correlation between temperature and distance from water bodies.

Figure 6 shows the result of the correlation between temperature and distance from water bodies. There was no correlation found between these subgroup interims the distance of water bodies to reduce the heat of SUHI. On statistical analyses show the $R^2$ was 0.311 for the year 2019 and 0.266 for the year 1988. Other variables, such as land use and land cover, need to consider examining the cooling effect water with urban heat island. The detailed explanation will discuss the next paragraphs.

Figure 7. The distance and LST at a distance of 200 meters.

Unfortunately, the distance and LST at a distance 200 meters below showed a strong correlation with $R^2$ was 0.95 for the year 2019 and 0.92 for the year 1988. This correlation well explained the land
cover/land use factor has a weak influence on distance factor in reducing the LST compare to the distance 200 and above, as shown in Figure 7.

![Image](image_url)

**Figure 7.** Relationship between distance water bodies, LST and land-use type.

The result illustrated in Figure 7 shows the relationship between distance water bodies, LST and land-use type. The temperature at Sarawak River, which represents water bodies at land use classification, shows the lowest temperature, which 26.09 degrees for the year 2019. For the first 50 meters shows the second-lowest temperature for years follows 100 meters. However, the cooling effect of water bodies is not useful for distance after 200 meters and above. The results show a fluctuance temperature trend for range 300 meters until 1000 meters. The primary influence is the land use type. For example, for distance 800 meter for the year 2019, which land-use type is vegetation – Grass with 27.36. The second example, the third-lowest value of temperature at 1000 meters because of the influence of land cover/land use to reducing the temperature. The distance sample at point 500 meter shows a higher temperature with 31.87 degrees Celsius, which relocated the commercial areas such as shop lot and hotel. Cai et al. [14], Sun et al. [13], and Du et al. [15] found a similar result, but in the studies case, the water bodies’ cooling effects are influenced by the size, shape, and location. Besides that, Sun et al. [13] and Hou et al. [16] discover that the distance water bodies vital to influence of the land surface temperature. The results similar with what [13] and [14] found even the at tropical climate and small medium size cities under population 2 million.
Figure 9 shows the sampling points, which starts at Sarawak river waterfront at 0 meters, and the distance of each of point is 100 meters. The result illustrated in the table above shows the relationship between distance water bodies, temperature, and land use type. The temperature at Sarawak River, which represents water bodies at land use classification, shows the lowest temperature, which 26.09 degrees for the year 2019. For the first 50 meters shows the second-lowest temperature for years follows 100 meters. However, the cooling effect of water bodies it not useful for distance after 200 meters and above. The results show a fluctuance temperature trend for range 300 meters until 1000 meters. The primary influence is the land use type. For example, for distance 800 meter for the year 2019, which land-use type is vegetation – Grass with 27.36. The second example, the third-lowest value of temperature at 1000 meters because of the influence of land cover/land use to reducing the temperature. The distance sample at point 500 meter shows a higher temperature with 31.87 degrees Celsius, which relocated the commercial areas such as shop lot and hotel. Cai et al. [14], Sun et al. [13], and Du et al. [15] found a similar result, but in the studies case, the water bodies’ cooling effects are influenced by the size, shape, and location. Besides that, Sun et al. [13] and Hou et al. [16] discover that the way and position may well significantly impact the cooling effects of wetlands in urban provinces. The factor such as urban form, namely sky view element and mean building height discovered by Cai et al. [14], influences LST.

5. **Conclusion**

The water bodies' effects of Sarawak river on LST in small medium-size cities, Kuching has been examined by applied the Landsat 5 TM and Landsat 8 thermal band. The water body effect was useful until 200 meters and below. The water bodies cooling impact can reduce the temperature of 1 until 1.03 degrees Celsius. The water bodies have potential in urban planning in urban heat effect mitigation. Besides that, the distance of water bodies, land use, and land cover type have significant factors to influence capable of cooling water bodies. The result showed urban areas in which commercial spaces have a higher value of land surface temperature compared to vegetation and water bodies. However, the influence of land cover and land use in LST at location 200 meters and above weakened. The study
recommends the water bodies important same as vegetation green space in lowering the temperature in urban areas. The policymaker, urban planner, and designers shall value the water bodies cooling effects on neighboring regions. The improve of knowledge by the quantity of spatial variation of LST can help understand the duty of water body with the urban ecosystem in services urban heat effect mitigation for Malaysia achieve low Carbon city or smart city besides reducing the negative effect of urban heat effect.

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