Thermal comfort assessment over the past two decades in different landscape areas within Palembang City

N Rusdayanti¹, M Karuniasa²,⁴, and N Nasrullah³

¹Magister Program in Environmental Science, School of Environmental Science, Universitas Indonesia, Jl. Salemba Raya No. 4, Kenari, Senen, Kalarta Pusat 10430, Indonesia
²School of Environmental Science, Universitas Indonesia, Jl. Salemba Raya No. 4, Kenari, Senen, Kalarta Pusat 10430, Indonesia
³Department of Landscape Architecture, IPB University, Jl. Raya Dramaga, Babakan, Dramaga, Bogor, 16680, Indonesia
⁴Corresponding author: mahawan.karuniasa11@ui.ac.id

Abstract. Urbanization has an impact on changing landscapes to built-up land so that it triggers changes in microclimate conditions and potentially disrupts the thermal comfort of urban communities. For two decades, the condition of air temperature and thermal comfort at two locations (Sukarami and Sako) in Palembang city with different landscape changes have been assessed in this study. The variations of air temperature over the past two decades were reported. The Temperature Humidity Index (THI) was an indicator for assessing thermal comfort and its values are categorized as comfortable, quite comfortable, and uncomfortable. The results showed that the air temperature in Sako increased by about two times greater than the increase at Sukarami which was 1.1 ºC and 0.5 ºC. This study clearly reveals that thermal comfort conditions have worsened in the last two decades. During 1999, the THI values were dominated by quite comfortable categories at both locations. After two decades, in 2019, the percentage of days in the quite comfortable category of both locations decreased by almost 60% at Sukarami and more than 80% at Sako. The main factor this difference occurs is the landscape changes with depletion of vegetation area at both locations.

1. Introduction

The United Nations Populations Fund noted that more than half of the world's population are urban dwellers with the proportion of the global population living in cities reaching 54% in 2014 [1]. The population of cities is expected to reach 60% or 5 billion people by 2030 and is projected to almost double in the next 40 years in the least developed countries [2]. Increased urban population growth has an impact on changes in the landscape or space allocated for human activities. Changes in landscape and environment, such as density and composition of buildings, urban surface materials, absence of vegetation cover, or green zones can affect the microclimate of an area by modifying atmospheric variables and triggering local and global climate change [3]. The presence of vegetation and green space can reduce air temperature (about 3.5 °C) through reduced hot air flow, evapotranspiration of plants and canopy shade [4].

Increasing air temperature in urban areas can cause many problems, including reducing the comfort of urban communities and endangering their health. Extreme heat causes increased thermal stress, reduced human physical activity, and increased human morbidity and mortality [5]. Thermal comfort is a term used to express the influence of physical environmental conditions of the atmosphere or climate...
on humans which are closely related to micro-climatic conditions such as solar radiation, atmospheric pressure, temperature, wind speed and humidity [8]. Thermal comfort that humans perceive will affect their activity and behavior, health, and their level of productivity [6].

Palembang City is one of the metropolitan cities in Indonesia which continues to experience rapid regional development with an average population increase of 1.4% annually [7]. The increase in population is in line with the increasing demand for residential and built land areas. Based on data from the Regional Development Planning Agency of Palembang City in 2015, for 6 years from 2010 to 2015, Palembang City experienced an increase in the area of built land by 20% of the total area. Data from the Meteorology, Climatology and Geophysics Agency (BMKG) shows that Palembang City is one of the cities that has a significant trend of increasing air temperature compared to several other metropolitan cities. This study aims to assess the conditions of air temperature and thermal comfort at two locations (Sukarami and Sako) in Palembang City with differences in landscape changes and available land cover.

2. Materials and method
The study area of this research is in Palembang, South Sumatra. Two different locations identified air temperature and humidity in the last two decades (1999-2019). These two locations illustrate the different changes and availability of land. The first location is in Sako District with a population density of 5271 people/km² in 2020 and the area is dominated by residential areas, asphalt roads, few trees, and concrete surfaces. The second location is in Sukarami District with a population density of 4218 people/km² and the area is dominated by the grass land cover, scattered trees, and sparse building composition. This study uses data measured by BMKG stations in the two locations, which are daily air temperature and humidity throughout the year from January to December in 1999, 2009, and 2019.

In this study, the indicator for measuring thermal comfort is the Temperature Humidity Index (THI). Temperature Humidity Index is an index compiled based on temperature and humidity conditions to express the level of thermal comfort [8]. It was measured by the following equation [9]:

\[
THI = 0.8 T_a + (RH \times T_a / 500)
\]

Where:
THI = Temperature Humidity Index, Ta = Air temperature (°C), and RH = relative humidity (%).

THI is the most commonly used thermal comfort index because it has been applied in several other studies and is a relevant index for the assessment of thermal comfort in tropical regions. THI values vary diurnal and seasonally according to variations in temperature and humidity in this case, people living in lowlands. The tropics may be able to tolerate a higher THI value [9]. The results of the THI value are categorized into three categories of thermal comfort, namely, comfortable, quite comfortable, and uncomfortable that shows in Table 1 [10]. The land cover of the two locations was identified using Landsat 8 image data sourced from Google Earth Engine (GEE) and United States Geological Surveys (USGS) with unsupervised classifications into several classifications.

| THI value  | Category          |
|------------|-------------------|
| THI ≤ 24   | Comfortable       |
| 24 < THI ≤ 26 | Quite comfortable |
| THI > 26   | Uncomfortable     |

3. Results and discussion

3.1. Air temperature
Both locations show an increase in air temperature over the last two decades (Figure 1.). Initially, the average temperature at Sako in 1999 was 26.7°C, then after a decade passed, in 2009, the temperature increased to 0.7°C and to 27.4°C. Then in 2019, the air temperature was recorded at 27.8°C. In two
decades, the increase in air temperature reached 1.1°C. Whereas in Sukarami, the increase in the average air temperature for two decades was only close to half of the increase in Sako, which was 0.5°C. Initially in 1999 the average air temperature in Sukarami was recorded to be higher than that of Sako, namely 27.1°C but the increase in air temperature in the first decade was only 0.1°C and in the second decade it was only 0.4°C so that the recorded air temperature is now more lower than Sako, which is 27.6°C. The trend in air temperature shows an increase of 0.055 in Sako and 0.045 in Sukarami over the past two decades.

An increase in air temperature of one degree celsius is actually a serious problem. Globally, this affects the balance of the environment and is one indication of climate change. Several studies have shown that there is a strong relationship between increased air temperature and the emergence of heat-related illness, for example, heat stress and mortality especially in urban areas [11]. Tropical populations tend to tolerate warming through acclimatization as well as variations in food habits, clothing, etc., however, rising temperatures still cause problems for the human environment, increased discomfort, heat-related illnesses and death. The results of another investigation in one large city show that hot temperatures cause heat stress and other health problems, especially in the outdoor environment [12]. The factors that cause an increase in air temperature are changes in land use and human activities [13]. The two locations have different increases in air temperature which can be caused by changes in land use changes.

### 3.2. Thermal comfort
Thermal comfort outdoors is closely related to air temperature and humidity. When the air temperature increases it has an impact on the value of thermal comfort. This study clearly reveals that thermal comfort conditions have deteriorated in the past two decades at both locations. In Sukarami in 1999, there were only two days in the comfortable category, the rest were in the uncomfortable and quite comfortable category, while in Sako there were no days that were classified as comfortable. Initially, in 1999, the percentage of days categorized as quite comfortable was 61% in Sukarami and 59% in Sako, and the remaining percentage were in the uncomfortable category (Figure 2). After a decade, in 2009, the percentage of days with a fairly comfortable category on site became 31% in Sukarami and 39% in Sako (Figure 3). After two decades, in 2019, the percentage of fairly comfortable days in both locations decreased by almost 60% in Sukarami and more than 80% in Sako (Figure 4).
The decrease in the percentage of quite comfortable day category can be caused by a significant increase in air temperature. The microclimate variables that determine and have the most influence on outdoor thermal comfort are air temperature, solar radiation and humidity [14]. High humidity and excess solar radiation which increases air temperature will reduce the level of thermal comfort outdoors. One example of the relationship between microclimate and outdoor activities is that the variability of temperature and humidity in different seasons has been shown to affect tourism, such as the number of arrivals, length of time to visit and average occupancy rate, as well as tourist activities [6]. In addition, pedestrian activity in nine cities around the world has increased walking speed in relation to the desired climatic conditions [15]. The thermal conditions of open spaces in urban environments are important because many people spend a lot of time in a day at these locations and it affect human behavior and productivity levels [1].

Figure 2. Percentage of thermal comfort category days in 1999 at (a) Sako and (b) Sukarami

Figure 3. Percentage of thermal comfort category days in 2009 at (a) Sako and (b) Sukarami

Figure 4. Percentage of thermal comfort category days in 2019 at (a) Sako and (b) Sukarami
3.3. Land cover change

Changes in landscape or land cover are a dominant factor that can increase urban temperatures. There are many cities that experience the urban heat island phenomenon. This phenomenon occurs when hot air temperatures are concentrated in urban areas and the temperature will progressively decrease when around suburban or rural areas [16]. This is due to differences in land use between urban and suburban areas. Sako and Sukarami also have different land use compositions from year to year. Figure 5 shows the land cover in Sako and Sukarami in 1999. In that year, Sako and Sukarami were dominated by vegetation land cover with vegetation land cover more than half of the total area of each district. The area of vegetation land cover and built-up land cover in Sako is around 1050 hectares and 590 hectares, while in Sukarami it is around 2200 and 1600 hectares.

![Figure 5. Map of land cover in 1999 at (a) Sako and (b) Sukarami](image)

After a decade passed, in 2009, both locations were dominated by built-up land cover (Figure 6). The area of built-in land cover in Sako increased by almost 60% from the area of land cover built in 1999, while in Sukarami it increased by almost 50% from 1999. Initially, the land cover in Sako was vegetation with a dense canopy. A dense canopy that resembles a forested environment has the lowest temperature when compared to grass and concrete with a difference in air temperature that can reach 3-5°C [15]. In 2019, the land area for vegetation is decreasing in both locations. Sako only has a vegetation area of about 21% of the total area of Sako, while Sukarami only has about 26% of the total area of Sukarami. Other factors besides the lower vegetation land cover in Sako, the higher population density in Sako could also be the reason for a more significant increase in temperature in the Sako region. High population density will make population activity even higher so that it has the potential to affect the atmospheric environment [16].
There are many studies shown that planting vegetation in urban area can reduce air temperature near the ground. Likewise, taller and denser trees have the most positive effect on thermal comfort while the surface of the city that is built has a negative effect on thermal comfort [17]. In full, microclimate is closely related to vegetation starting from the physical properties of plants, location and vegetation cover, planting density and crown density, plant elements, leaf types and planting patterns and arrangements [2]. Therefore, in urban planning, recommendations for a more precise and comprehensive approach are needed for different plant characteristics, different landscape patterns, and the effects of different elemental arrangements in terms of improving the microclimate. Thus, urban planning and proper vegetation arrangement can prevent urban air temperature increases and also climate change.
4. Conclusion
One indicator of climate change is an increase in global air temperatures. The increase in global air temperature is supported by an increase in local air temperature, one of the local areas where the air temperature increases is Palembang City. In the last two decades, the air temperature in two locations (Sako and Sukarami) in Palembang City has increased. The air temperature in Sako is twice as high as the Sukarami district. The factors that can influence this are differences in changes in surface land cover and population density in the two regions. Increased air temperature can affect the thermal comfort of the community. Initially, the two locations were dominated by days with a fairly comfortable thermal comfort category, but after two decades it was dominated by uncomfortable days. The area of land cover in the two locations in the initial year was dominated by vegetation land cover, but after two decades, the two locations were dominated by built-up land cover. Therefore, urban planning requires recommendations for a more appropriate and comprehensive approach related to vegetation cover and distribution to improve the microclimate and prevent urban air temperature increases and also climate change.

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