Urban Residents Perceptions on the Thermal Comfort of Settlements in Yogyakarta Peri-Urban Areas

Djaka Marwasta[1] and Anditya Sutami[2]

[1,2]Department of Environmental Geography, Faculty of Geography,
University of Gadjah Mada, Yogyakarta-Indonesia
[1]E-mail: jakamar@ugm.ac.id, [2]E-mail: anditya.sutami@gmail.com

Abstract

Yogyakarta urban areas is one of the sprawled city in high intensity, especially to be settlements and services function. Regarding to settlement area, comfortability is the most priority requirement for dwellers to decide to settle. One parameter of comfortability is thermal comfort that is the convenience based on meteorological indicators. The aims of this study is to examine thermal comfort in Yogyakarta peri-urban area, both of physically using the measurement of meteorological parameters and perceptually by knowing the public perception about thermal comfort in their residence.

This research used mixed method of field survey and structured interview. Physical comfort are measured by meteorological parameter (Thermal Humidity Index/THI). Meanwhile, perceptual comfort is obtained from questionnaire method of Likert Scale and processed with descriptive statistic.

Based on the results, it showed that daily thermal comfort based on THI are lower than perceptual comfort. The average of THI value is 26.63^0C (moderate comfortable), when perceptually mostly respondents stated that the environment of the settlements is comfortable.

Keywords: physical comfort, settlement, perception, peri-urban

INTRODUCTION

Yogyakarta Urban Area experiences very fast physical development (Marwasta, 2014), especially in peri-urban areas (PUA). The transformation of the rural land use into urban land use or the so-called urban sprawl (Yunus, 2000; Pryor, 1968)) is the main process taking place in this region. In peri-urban areas experience the centrifugal movement of the population, that is the shifting of residence and community activities from the city center to areas around the city and suburbs. The impact can be observed by settlement density outside the city center.

One of the problem on settlement in urban areas as an impact of high density is the heat island effects (Oke, 1973), where the temperature conditions are hotter than the rural areas. One indicator of this phenomenon that is easily felt immediately is the temperature that is getting hotter. These conditions greatly affect to the living comfort for local residents. However, humans have their own perception which is often different from the results of physical measurements.

Thermal comfort is a condition of comfort that a person feels towards his environment because of the balance of heat exchange between the body and the environment (Fanger, 1982). Air temperature has an important influence on the perception of comfort. Air is a vital medium that plays a role in the heat mechanism and turbulence affects the cooling process. This study tried to compare the comfort conditions of the residential environment based on physical measurements and perceptual comfort according to residents perception.

RESEARCH METHOD

The level of thermal comfort based on climate is measured using two main variables, namely: (1) air temperature, and (2) relative air humidity. To represent climate characteristics in the study area, systematically random sampling was taken, based on two microclimate variables at certain points. Systematic random sampling is done with the consideration that the sample taken can represent the character of the population (Yunus, 2010). Sampling is carried out using the grid method, it is deemed necessary to be carried out in this research so that the sample can be spread geographically, especially in the measurement of temperature and humidity variables.

Meteorological parameter data retrieval is carried out at crossroads under shady conditions, including data on air temperature, relative air humidity, and wind speed. Climate data collection was carried out at three times a day, namely morning (06.00-07.00), afternoon (12.00-13.00), and afternoon (17.00-18.00). Data collection was carried out for a week consecutively in the dry season, by consideration that the air temperature is estimated to be close to the average temperature in a year. The instrument used is the Lutron LM-8000 multifunctional weather gauge which can measure air temperature, relative humidity, and also wind speed in an environment in a short time. The total location of measurements is 30 locations.

The level of comfort based on microclimate can be measured by the method of Thermal Humidity Index (THI). The method uses two microclimate variables, namely air temperature and relative humidity. Thom (1959) proposed a way to determine the level of thermal discomfort experienced by humans at a particular location, and then known as a discomfort index. THI value to determine human comfort is obtained based on human physiology that is related to the condition of the surrounding human environment. THI equation is as follows:

THI = T−0,55 (1 − 0,01 RH) (T − 14,5)
explanation: THI: Thermal Humidity Index
T: Air Temperature (°C)
RH: Relatif Humidity (%)

In addition to physical variables, the level of settelement comfort can also be measured by the perception of housing residents. For this purpose, an interview was conducted with the aim of knowing the perceptions of the population living in the study area. To represent the characteristics of the population, a sample of 72 households is taken. The amount of samples are taken evenly in each measurement grid in the study area.

Perceptions of thermal comfort were obtained by Likert Scale instrument. Likert scale can be used to determine the perception, opinion, or attitude of a person or group of people towards a particular phenomenon or phenomenon (Djaali, 2008). With a Likert Scale, the variables to be measured regarding the perception of the thermal comfort of settlements are translated into variable indicators. The indicator then becomes the basis for the preparation of questionnaire items in the form of statements. Data obtained from the Likert Scale questionnaire is ordinal data. Each statement has a strata from very negative to very positive.

RESULTS AND DISCUSSION

a. Meteorogical Parameters Identification

Measurement of thermal comfort index with THI requires two main parameters, namely air temperature and relative humidity. The value of air temperature and relative humidity in an area are affected by the effects of solar radiation continuously at a given time (Mather, 1974). In addition, wind speed data is also noted to support THI data because wind speed also influences to increase comfort and reduces hot. Measurements were carried out during the dry season, because the effect of the heat island was taking place during the day to late afternoon in a cloudless and clear sky.

The results of daily temperature measurements are divided into three time points, namely: morning, afternoon and evening. The data displayed in the bar graph in Figure 1 shows a significant temperature difference between the three time points. In the morning, the daily temperature recorded was at 26.39 degrees Celsius. In the daytime, the temperature shows at 33.5 degrees Celsius, which is the highest number in a day. In the afternoon, the temperature dropped to 29.71 degrees Celsius. The average daily temperature in the study area is 29 degrees Celsius.

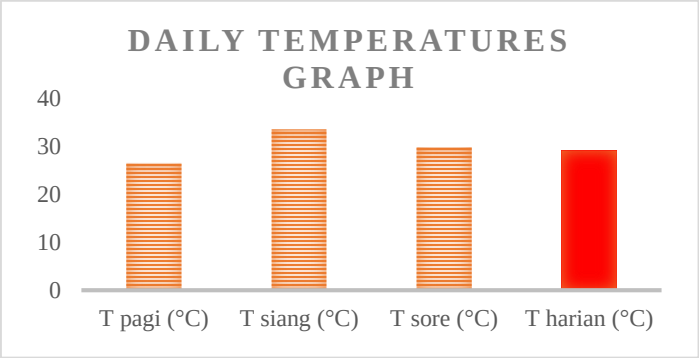

Figure 1. Daily Temperatures Graph in Research Area

Daytime has the highest daily temperature because solar radiation that directly illuminates the earth brings peak energy and causes heat to be absorbed by the earth. The land tends to absorb heat longer so that it increases the temperature until daylight. In the afternoon the temperature is still quite high. This is due to the highest temperature at 2 or 3 hours after the highest insulation. The highest isolation occurs at 12.00 AM so the temperature reaches its peak in the range of 2.00-3.00 PM.

The Isotherm Map (Figure 2) describes the average air temperature of the study area. In that map, the air temperature displayed is the daily temperature of the morning, afternoon and evening measurements. The same color displays the region with the same daily temperature. Temperature differences appear between the northern and southern regions. Most of the northern region has a daily temperature that is in the range of 28.5 - 29 degrees Celsius while in the south the temperature is slightly higher with coverage 29 - 29.5 degrees Celsius.

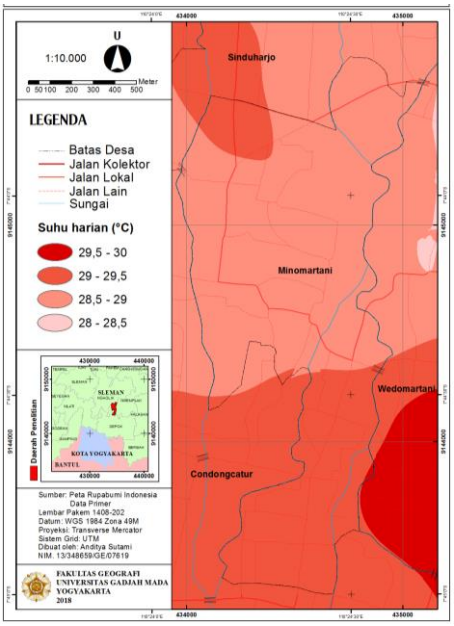

Figure 2. Isoterm Map of Research Area

One of the factor that causes temperature differences is land cover. In the study area, 72 percent of the land area consists of housing that contains roof tiles, brick walls, glass windows, asphalt roads, and cemented paving blocks. These elements have albedo characteristics that are smaller than natural materials such as soil and vegetations.

Temperature differences can be caused by the density of settlements and the number of trees. On the isotherm map, the disparity that occurs is bordered between the north and south regions, where it occurs between real estate in the south and mixed settlements in the north. Mixed settlements means the settlements that have varying uniformity and densities, in contrast to the real estate housing which has a uniform planning pattern.

Meanwhile, a small portion in the northwest part of the study area has the same range as the southern region. The high air temperature in this area is influenced by the high flow of passing vehicles on the main road in the area. Combustion of motorized fuels also contributes to thermal energy in the neighborhood.

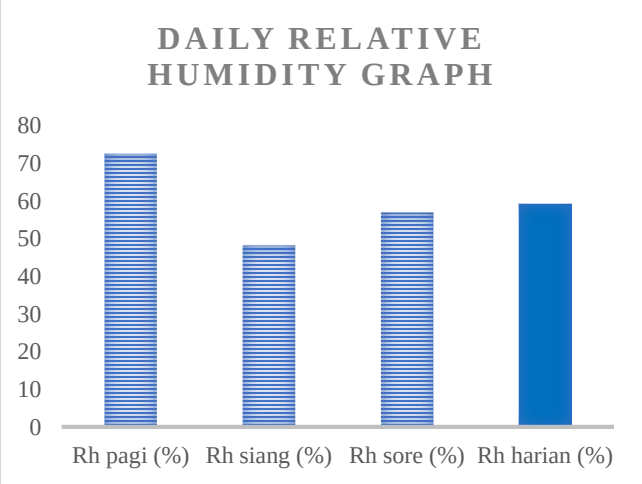

Figure 3. Daily Relative Humidity Graph in Study Area

Relative humidity is the ratio between the amount of water vapor in the air and the maximum amount of water vapor that can be received at the same temperature. Relative humidity or often symbolized RH is displayed in percent. Relative humidity in the study area has variations at each measurement time, as well as daily temperature.

In Figure 3, it can be seen that the morning have relative humidity as 72.47%, which is the highest in a day. During the day relative humidity is at 48.20%. Afternoon is higher than daytime with 56.93%. This pattern is inversely to the daily temperature variation, where the lowest is the morning and the highest in the afternoon. This variation can be observed on the moisture iso-map in Figure 4.

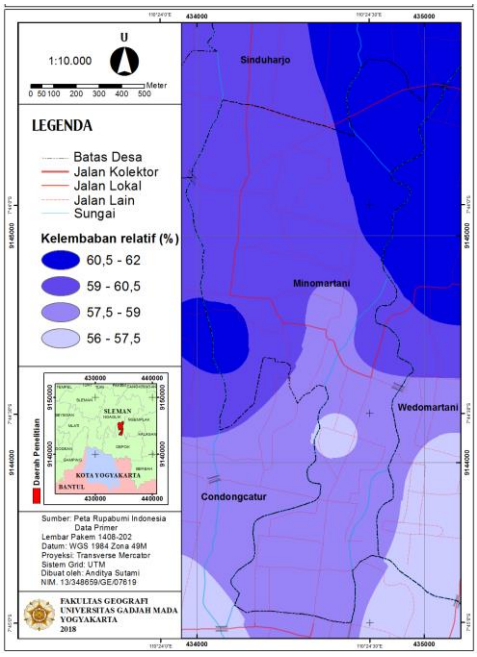

Figure 4. Relative Humidity Iso-map of Study Area

b. Thermal Humidity Index

Thermal comfort is a measurements of comfort based on the interaction between physiological properties in the body and the surrounding environment (Thorm, 1959; Din, 2014). Sometimes, a sense of comfort felt by one person is different from others. In this study, data measurement was taken in the neighborhood, so that the response in the body was considered the same. The level of thermal comfort is calculated by THI.

The difference in THI varies in each time. In the morning, THI reached the lowest value of 24.94. During the day the THI value rise to the highest value of 30.02. In the afternoon, a THI value is 27.15. This can be seen in Figure 5. This pattern has similarities with daily temperature and is inversely proportional to relative humidity. It should be noted that the low THI value indicates that the comfort level is better.

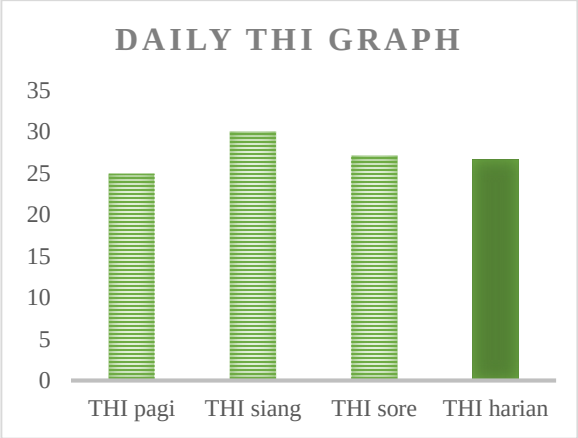

Figure 5. Daily THI Graph of Study Area

The scope of the THI area can be observed in Figure 6. Similar to the isotherm and iso humidity, the THI map highlights the area with the same THI range within a certain time. THI is higher in the real estate area and the northern part of the Research Area. Thermal comfort is felt better in parts of mixed settlements because much space for shady trees and sparsely concrete buildings or paving blocks.

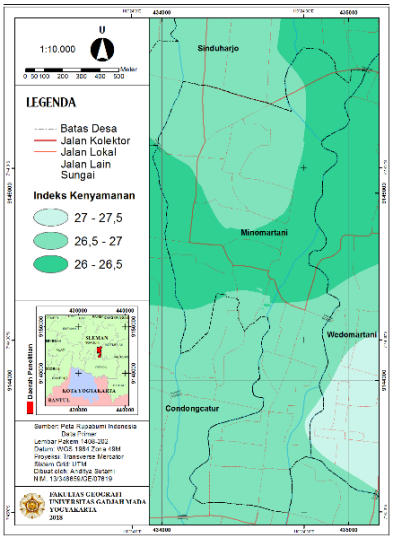

Figure 6. THI Map of Study Area

Thermal comfort conditions based on THI can be categorized as comfort levels based on Thorm classification. Thom (1959) made a classification where the value of THI 20-26.4 was a rather comfortable category, and if more than 26.4 was uncomfortable. Based on Thom's classification, the study area include in between rather comfortable and uncomfortable category, indicated by the gradation of green in figure 6. In the real estate area and northern part of study area have uncomfort category.

Another classification for THI was proposed by Din et al (2014) who considered that environmental adaptation in the tropics for thermal comfort was different from subtropical regions. In the proposed classification, the class of "rather comfortable" have a wider range of THI, from 20.00 - 30.00, while for uncomfortable is higher than 30.10. This is because humans in the tropics tends to be more tolerant on higher temperatures. With the classification proposed by Din et al, the daily thermal comfort conditions in the study area fall into a rather comfortable category. However, during the day, the comfort conditions are in the uncomfortable category.

Table 1. THI Classification

Kategory	**Thom (1959)**	**Din et al (2014)**
Very Comfort	THI ≤ 14,9	THI ≤ 14,9
Comfort	15,0 ≤ THI ≤ 19,9	15,0 ≤ THI ≤ 19,9
Medium Comfort	20,0 ≤ THI ≤ 26,4	20,0 ≤ THI ≤ 30
Uncomfort	THI ≥ 26,5	THI ≥ 30,1

Source: Thorm, 1959; Din et al, 2014

c. Residents Perception on Settlement Thermal Comfort

Residents in the study area as people who live and stay in that settlements, can feel the condition of the environment better than others. Daily activities in the residential environment make a consistent interaction between the physiology of the human body and the surrounding environment (Sridjono, 2001). Due to compare physical data on thermal comfort, it is necessary to collect social data in term of human perceptions on thermal comfort. Perception is things that are known based on the five senses. The variables taken are perceptions of air temperature, humidity, wind conditions, sunlight reception, number of trees, air cleanliness, and ultimately thermal comfort.

Air temperature is divided into five scales from 'very hot', 'hot', 'medium', 'cool', and 'cold'. Most residents feel that the temperature in the environment is hot. The people's perception of the daily temperature in the environment is in the score of 189 or between 'medium' to 'hot'. Some residents stated that heat was felt especially during mid day to late afternoon. Conditions in dry season that rarely occur make the heat of the day feel stinging.

The scale for humidity conditions is divided into 'very dry', 'dry', 'moderate', 'moist', and 'very moist'. The scale chosen by the majority of the population is 'medium'. The perception of the population in the study area states that the humidity level is at a score of 200 with the position

between 'moderate' to 'dry'. Perceptions related to humidity run proportionally to temperature, that is to the left or negative. This condition can be caused by a dry season that rarely rains so that the weather is quite hot and lacks moisture.

Sunlighting affects the dynamics of temperature and humidity. The more sunny, the body can feel hottrt and causing discomfort. Perceptions related to the reception of sunlight in study area are divided into five scales, namely 'very hot', 'hot', 'moderate', 'little hot,' and 'not hot'. The majority of the population feel that the sun in the environment includes 'hot'. Residents feel that sunlight tends to be 'hot' with a score of 175.

According to some residents, in the dry season, the sun's rays are more intense than the rainy season. This intense feeling is felt more by the people who live in the real estate area, which is crowded with buildings and have limited trees. Stinging heat at mid day during dry dry season is supported by sunlight that directly hits the earth's surface without clouds. The condition of this clear, cloudless sky, according to the peoples, also supports the rise of air temperature.

Wind conditions can affect the level of thermal comfort. The blazing sunshine during the day provides heat energy to the earth's surface. The body physiologically also receives heat so that during the day often the feeling of hotness and discomfort arises. However, wind conditions that continue to blow can reduce discomfort due to heat. This is due to the movement of the wind that hit the body to move the hot air that is felt by humans, and bring cooler air. When the body still carries heat energy and is exposed to air that is cooler than the body, it gives a pleasant cool impression.

Perceptions of wind conditions are divided into five scales, namely 'no wind', 'breeze', 'medium', 'tight wind', and 'very fast'. The highest scale chosen by the residents of study area is 'breeze'. According to residents in the study area, the average wind conditions are in a medium scale with a score of 200. This means that in general, the peoples feels the wind sometimes moves even breezy and not so tight. This condition is quite helpful to provide a cool feeling in the middle of the air temperature which is felt rather hot.

Shady trees in the surrounding of a residential area have a very vital role (Hadi, 2012). The more shady trees the environment feels cool and comfortable. The scale of perception about the coverage of trees is divided into five, namely "very rare", "rarely", "medium", “shady", and “very shady". Most peoples in study area stated that vegetation coverage in study area is 'medium', and 'shade' as well.

According to residents in the study area, most of the locations of their neighborhoods already have shady trees. Community perception has a score of 246 with the category 'shady'. Shady trees are mostly found in the northern part which consists of mixed settlements. In the real estate area, shady trees are only found on major highways and some green open space points. Most of the residential areas in real estate still rarely have shady trees.

Air cleanliness is an important factor for living. If the air is dirty and a lot of pollutants, it can cause diseases that are bad for health. Citizen’s perception of air cleanliness is divided into five scales from 'very dirty' to 'very clean'. That is indicated by the majority of the people’s perception, they feel that the air in the environment includes into 'clean' category. According to the residents of study area, the settlement environment has good air cleanliness which is shown from a positive score worth 268 leading to the 'clean' category. The location of study area is indeed in the environment with the landuse are mostly settlements, and the rest is a small portion of irrigated rice fields. The absence of an industrial plant or a waste place makes this environment have relatively clean air.

Perceptions of thermal comfort are divided into five scales from 'very uncomfortable', 'uncomfortable', 'moderate', 'comfortable', to 'very comfortable'. The most scale chosen is 'comfortable'. This is marked by a positive score of 246 which mean as the 'comfortable' category.

Conditions where thermal comfort is very good is an priority option for residents to choose their outdoor activities. Outdoor activities in residential areas are carried out during thermal conditions that are supportive and comfortable. It can be observed in the pie chart of Figure 7, when people felt most comfortable doing activities between 6:00 a.m. and 8:00 p.m. (42%) and also 08.00 - 10.00 a.m. (20%). Conversely, when the temperature peaked at 2:00 p.m. - 4:00 p.m., it became the last choice for residents to have outdoor acitivities (1%). Some residents prefer to active around in the afternoon at 4:00 p.m.

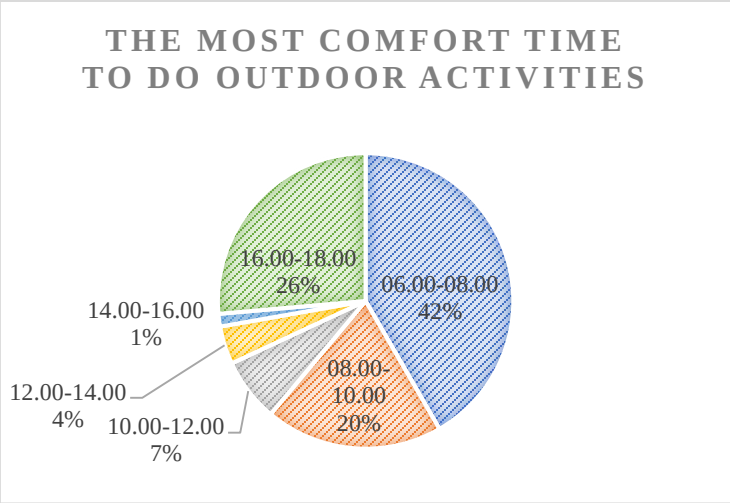

Figure 7. Best Time to Do Outdoor Activity

The level of thermal comfort data in the study area, both with physical data by THI calculations and social data with people's perceptions provide relatively similar results. From the classification of Din et al (2014) shows that THI in settlement environment of the study area is categorized as rather comfortable. Similar to the physical data, the results of the perception of the residents of study area show a level between 'medium' to 'comfortable'. However, the results of this study indicate that the perceived value of convenience is quite higher than THI data, even not too significant distinct.

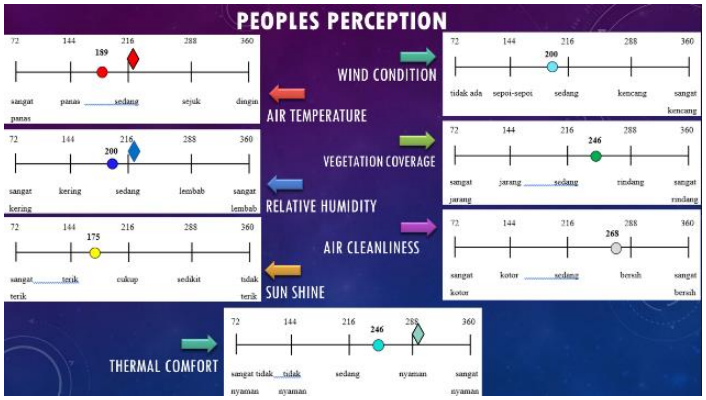

Figure 8. Comparison between Physical Measurement and Perceptual Assesment of Thermal Comfort

The level of thermal comfort data in the study area, both with physical data (THI) calculations and social data with peoples perceptions assessment, provide relatively similar results. From the classification of Din et al (2014) shows that THI in the settlement environment in study area is categorized as rather comfortable. Similar to the physical data, the results of the perception of the residents of study area show a level between 'medium' to 'comfortable'. However, the results of this study indicate that the perceived value of convenience is quite higher than THI data.

CONCLUSION

1. Thermal comfort of the residential environment in the study area that has been studied by measuring THI shows that daily THI in the study area has a value of 26.63. The level of thermal comfort of study area belongs to medium comfort category ' except during the day which is categorized as 'Not Comfortable'. Thermal comfort conditions in the realm estate area are slightly less than in other regions. This can be caused by the lack of shady trees in the settlement as a result of limited space.
2. Peoples perception in the study area about their settlement environment is that there are has a temperature that tends to be hot, humidity is slightly dry, the sun tends to be hot, the wind conditions are a little soft, the trees tend to be shady, and the air is clean. The level of thermal comfort felt by the peoples is in a rather comfortable category.

RECOMMENDATION

1. It is very necessary to provide green open spaces on residential planning that have a variety of positive benefits. In the construction of housing can add a green area by making a green space, vines along the walls and yard.
2. Further research related to thermal comfort can be carried out in a wider study area because it can produce more varied data information.

BIBLIOGRAPHY

Din, M. F. M., Lee, Y. Y., Ponraj, M., Ossen, D. R., Iwao, K., Chelliapan, S. (2014). Thermal Comfort of Various Building Layouts with A Proposed Discomfort Index Range for Tropical Climate. *Journal of Thermal Biology*, 41, hlm. 6-15.

Djaali. (2008). *Psikologi Pendidikan*. Jakarta: Bumi Aksara.

Fanger, P. O. (1982). *Thermal Comfort, Analysis and Application in Environmental Engineering*. Florida: Krieger.

Hadi, R., Lila, K. A., Gunadi, I G. A. (2012). Evaluasi Indeks Kenyamanan Taman Kota (Lapangan Puputan Badung I Gusti Ngurah Made Agung) Denpasar, Bali. *E-Jurnal Agroekoteknologi Tropika*, 1(1), hlm. 34-45.

Marwasta, D., (2014). Proses, Dampak, dan Formulasi Indeks Spasial Perembetan Daerah Kekotaan Yogyakarta. *Ph.D Thesis*. Yogyakarta: Fakultas Geografi UGM.

Mather, J. R. (1974). *Climatology: Fundamentals and Applications*. New York: McGraw Hill.

Oke, T. R. (1973). City Size and The Urban Heat Island. *Atmospheric Environment*, 14, hlm. 769-779.

Pryor, R. J. (1968). Defining The Rural-Urban Fringe. *Social Force*, 47(2), hlm. 202-215.

Sridjono, H. H. (2001). Pengaruh Ruang Terbuka Hijau Kota (RTHK) Terhadap Iklim Mikro dan Indeks Ketidaknyamanan: Studi Kasus pada RTHK Kawasan Taman Parkir Kudus Plasa dan Kawasan Taman Tugu Identitas di Kabupaten Kudus. *Master Thesis*. Yogyakarta: Universitas Gadjah Mada.

Thom, E.C. (1959). The Discomfort Index. *Weatherwise*, 12, hlm. 57–61.

Yunus, H S., (2000). *Struktur Tata Ruang Kota*. Yogyakarta: Pustaka Pelajar.

Yunus, H. S. (2010). *Metodologi Penelitian Wilayah Kontemporer*. Yogyakarta: Pustaka Pelajar.