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Vegetation Arrangement Evaluation of Microclimate in Urban Public Open Space

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ABSTRACT: *Planning a public open space requires the optimization of the arrangement of landscape elements. One of the main constituent elements is vegetation. Vegetation minimizes direct surface solar radiation and optimizes wind speed. The shape and configuration of vegetation also affect the temperature, humidity and wind patterns. The purpose of this paper is to discuss the impact of vegetation on the micro-climate of open public spaces and explore the possible configuration of vegetation to maximize the cooling effect on public open spaces in Kendari. To examine this issue, field surveys have been conducted at two adjoining study sites. Moreover, the thermal comfort aspect from the perception of visitors is also measured. The comfort index of this study is measured by using the Thermal Humidity Index (THI) formula. The study site is divided in grids of total 21 sample plots. The study shows that the percentage of canopy cover of tree vegetation at Taman Walikota is 64% and 33% in the square of TuguReligi. Another result shows that the dense vegetation can decrease the air temperature around 2^{o}C-4^{o}Cand slower the wind speed. In other words, a dense vegetation of trees and shrubs can retain airflows and trap hot temperature on the surrounding area. Moreover, the level of thermal comfort based on the THI index generally feels comfortable in the afternoon at both locations.*

KEYWORDS :*vegetation, open space, microclimate, Thermal Humidity Index.*

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I. INTRODUCTION

Indonesia is one of the tropical countries with a fairly rapid population growth. Some cities in Indonesia experience high population growth. According to the population data, Kendari is a city with the medium category with population growth in 2017 around 3,42%. The development of the population is in line with the physical changes in the city. The evident from Central Bureau of Statistics of Kendari year of 2017 shows the growth of built-in urban areas covering residential areas or offices, which in 2013 ranged from 13,018 Hectares to 13,969 Hectares in 2017(Central Bureau of Statistic of Kendari, 2018). Most of the land area in Kendari has shifted its function to settlement, offices, and roads which reaches 47% of the total land of 25,598 Hectares. If this growth is not well controlled, then a slight change in the function of the land will have a negative impact that triggers the occurrence of global warming. This situation brings a negative impact on the sustainability of the environment and the quality of human life. As a result, Kendari will be a hotter city, uncomfortable for outdoor activities, and use more energy for air conditioning.

The conditions where the air temperature becomes higher is generally known as the 'urban heat island' (UHI) effect. This term refers to the observed temperature difference between urban and environments and the surrounding areas (Voogt, 2002). International research indicates that localized temperature increases are associated with the UHI effect which already exceeds those predicted by climate change models over coming decades (Grimm, et all, 2008). Several preliminary studies reveal that Kendari has shown an upward trend in the temperature condition over the past few years. In 2010, the average air temperature in Kendari was recorded at 24^{o}C, and in 2017 at 28^{o}C. Posit on the average temperature, Kendari is classified into a hot city. In compared to rural areas where minimal infrastructure is built, cities and suburbs can show different air temperatures. The average air temperature in Kendari suburbs in 2017 is 27^{o}C or lower by 1^{o}C. This is in line with statements about the UHI phenomenon in urban areas where the air temperature in urban areas will be higher than the surrounding areas.

In response to the UHI phenomenon, the Indonesian government issued provision of green space by urban area which is at least 30% consisting of 20% public green open spaces and 10% consists of private green open spaces. The proportion of 30% is the minimum amount to ensure the balance of the ecosystem of the city, both the balance of the hydrological system and the balance of microclimates, as well as other ecological systems that can increase the availability of clean air needed by the community, as well as to increase the aesthetic value of the city. Data retrieved from the Ministry of Public Works and People's Housing in 2015 reveal on how the majority of big city utilize green open space in only 7% - 10% less from a suggested number which is 30%.

According to Murdiyarso and Suharsono (1992), the city climate greatly determines the comfort of the city, because directly climate parameters will affect human activity and metabolism. But not all climate parameters can be used directly to determine comfort, some parameters include temperature, wind speed, relative humidity. Thermal comfort is a term used to express the influence of the physical or atmospheric physical environment on humans. A comfortable condition is when some human energy is released for productive work and efforts to regulate body temperature are at a minimum level. Comfort is a condition that varies greatly between individuals, so it is often subjective. Besides being influenced by climatic conditions, comfort is also largely determined by the physical activity of humans, clothing, and food. To express comfort quantitatively, it is usually used "Temperature Humidity Index". Quantitatively it is stated as THI, which was first discovered by Thom (1959) and modified by Nieuwolt(1977) for the tropical climate. The use of the THI calculation is for planning the development of a green and environmentally friendly urban system. In the urban climate, the design and architecture of city buildings have focused on human/bioclimate comfort (Emmanuel,1993; Mertens,1999). THI is formulated empirically, among others, as follows:

$$THI = 0.8\ T + (RHxT) / 500 \quad (1)$$

Where T is the air temperature (Celcius), and RH is the relative humidity (%). In general, tropical people feel uncomfortable at THI above 27^{o}C. In Indonesia, THI criteria used are as follows:

Table 1. THI thermal perception

THI Criteria	Thermal perception
< 29	Comfortable
29 – 30,5	Uncomfortable
> 30,5	Very uncomfortable

Source: Frick and Sukiyanto (1998)

Green spaces with vegetation have great environmental benefits. Trees and other plants are beneficial for reducing the air temperature on the environment, making vegetation a simple and effective way to reduce urban heat islands. Vegetation cools microclimates by shading heat-absorbing materials, increasing the albedo1 (or reflectivity) of surfaces, providing evapotranspiration cooling and altering wind patterns (McPherson,1994; Taha,1997). Its form and configuration influence solar radiation, temperature, water humidity and wind flow of an urban setting.

There is a small correlation between vegetation and solar radiation. Vegetation prevents incoming solar radiation and overshadowing materials that absorb heat. In this way, trees can reduce surface and ambient temperatures as well as decline the heating temperature of buildings and other infrastructure. Trees can also intercept diffuse radiation which is reflected from the sky and surfaces; such as glass, cement, and roof, altering heat exchange in urban systems (Akbari, 2002). The vegetation canopy can optimize the thermal comfort of humans outside building with direct shade and also by reducing solar radiation reflected from the ground and buildings (Shashua-Bar, Pearlmutter, and Errel, 2011). The shade quality provided by the tree is determined by factors such as placement, altitude and canopy architecture, and leaf size and structure (Kotzen,2003).

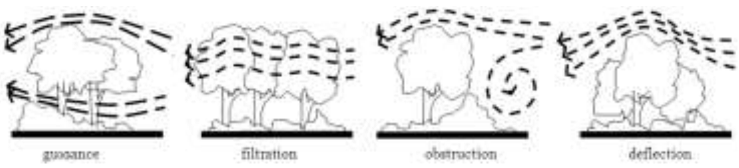


Fig. 1.Vegetations influences the pattern of air movement

Source: Boutet, 1988 in Wardoyo, 2011

Wardoyo, Suprapti, and Wediningsih (2008) posits that evapotranspiration from vegetation can reduce air temperature and increase relative humidity. Meanwhile, vegetation can also influence air movement pattern through guidance, filtering, blockage, and deflection (fig.1). Vegetation in open spaces has low reflectance properties that help reduce air temperature within the city. Vegetation can alter wind patterns and advection. In general terms, it has been estimated that in a low-density suburban context increases tree cover by 10-20% (Heisler and DeWalle,1988).From the trend mentioned above, the main objective of this study was to identify microclimate based on field observations and THI index to obtain thermal comfort for visitor in public open space in Kendari.

II. MATERIALS AND METHODS

2.1 Study area

The public spaces studied are located in Kendari (3◦S, 122◦E, 30 m above sea level), a medium-sized city in the southeast of Celebes Island, Indonesia, with a population of 350,000 and an area of 296 km2 (Central Bureau of Statistics of Kendari, 2017). The city includes tropical savanna regions according to the Koppen classification (the amount of rain in wet months cannot keep up with the rainfall in the dry months). The study areas are conducted in two different locations that located side by side each other. This is an area that extends from southeast to northwest. Basically, the research location consists of two open spaces adjacent to each other, namely Taman Walikota (the city park) and the square of TuguReligi (fig. 2). The total area of observation is about 11,4 Hectare, with length 630 m and width 180 m. These locations are the most popular and most visited public spaces in Kendari. In addition, it is located strategically and well known as a center of activities by citizens.

Fig. 2. Study area: A (Taman Walikota), B (square of TuguReligi)

Both locations are separated by a highway. On public holidays, this road is closed to the public by car-free day events so that these two public open spaces are connected and make it easier for visitors to move around. Within the area of Taman Walikota (Taman Kota), many visitorsvisits this area to exercise due to the availability of jogging track, furthermore children can choose some playground equipment such as gym, swing, and slide. The square of TuguReligi is more widely used as a crowded gathering point for the citizen, at this place visitors can choose some culinary stalls that located on the edge of the square.
The following are some points to consider in the analysis of landscape composition at the study sites.

1. Shade and types of vegetation: The shaded green space is much cooler than the open area. Tree shade can reduce the air temperature on the surrounding area as the spreading of the green area can be seen from aerial photos. Vegetation types planted in both research areas are trees, grasses, and shrubs. The dominant tree species are mahogany (Swietenia Mahogany) and almond indian tree (Terminalia Catappa). Both of these trees dominate the planted tree species as the images of planted vegetation can be seen in the following figures:

(a) (b) (c) (d)

Fig. 3. Vegetation types and density in Taman Walikota (a)(b); the square of TuguReligi (c)(d)

2. The density of Vegetation: Vegetation density also affects cooling. More solid vegetation increases evapotranspiration, which reduces air temperature. The space of green area in Taman Walikota is more than in the square of TuguReligi. The level of vegetation cover seen from the width of the tree canopy in the two

open spaces is quite different. The tree canopy in Taman Walikota covered 64% of the total observed area, 4.5 Ha, while for the square of TuguReligi covered 33% of the total observed area, 6.6 Ha.

3. Buildings and land cover. The number of areas covered by the building or artificial materials in the square of TuguReligi is higher than Taman Walikota. Most of the materials used to cover the soil surface in the square of TuguReligi consist of materials with high albedo value, i.e, asphalt, and pavement. On the east of the square, there is the biggest monument of Kendari, TuguReligi. Meanwhile, the gathering point at Taman Walikota located in the middle of the park. In this area, there are monuments, ponds, and structures of tents. The land cover in this area is dominated by ceramics.

(a) (b) (c) (d)

Fig. 4. Building and artificial land cover in Taman Walikota (a)(b); square of TuguReligi (c)(d)

2.2 Applied Methods: field survey of microclimate parameters and THI index

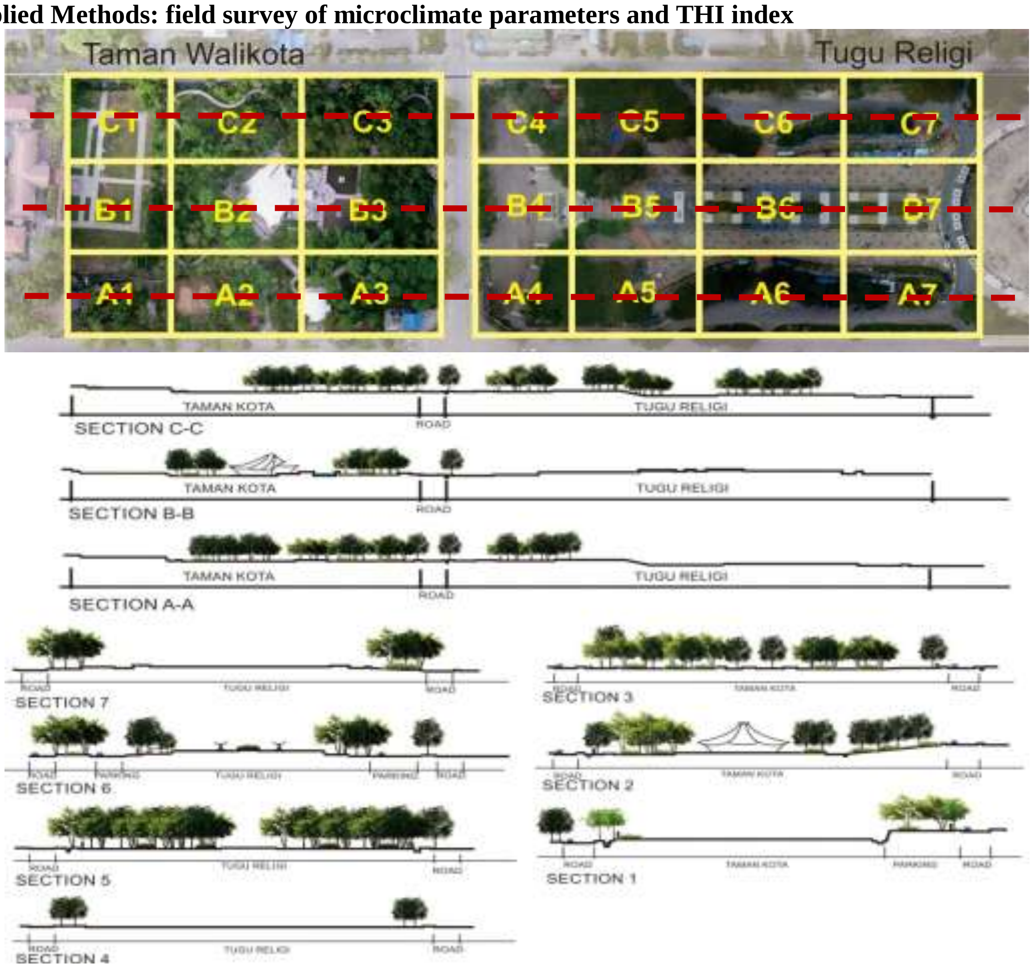


Fig. 5. Grid arrangement section

The first research methodology that was applied is a field survey of microclimate parameters then followed by an analysis of thermal comfort obtained from both research locations. The collection of microclimate data in the research field using some equipment such as thermometers, anemometers, and barometers. Furthermore, the analysis of thermal comfort of visitors in public open spaces is predicted using the THI method. To facilitate the analysis of microclimate parameter and THI, the study sites were divided using several vertical and horizontal lines depicting the position of vegetation and open space. The measurement grid for THI analysis is shown in Figure 5. Microclimate data in the field is taken on every predetermined vertical and horizontal grid. Based on the extent of each location, Taman Walikota area is divided into 9 grids, while the TuguReligi square is divided into 12 grids. Microclimate data was taken in three times at morning, daytime and afternoon. Data retrieval is done in 3 days on the condition of the clear sky in October 2018.

III. RESULT AND DISCUSSION

From preliminary observation of air temperature spread in some areas in the Kendari conducted in July 2018, the recorded temperature in CBD (Central Bussines District) area of Kendari reaches 36◦C-37◦C during the daytime. While at the research location, the highest temperature was recorded at 34◦C-35◦C. The result shows that public open space is an urban area has lower air temperature than on the CBD area or downtown area. This situation happens due to the arrangement of public space when the city is still widely used natural elements such as vegetation, uncovered land and water, while the CBD area is an area with a high density of buildings and less green areas.

3.1 Field survey of microclimate

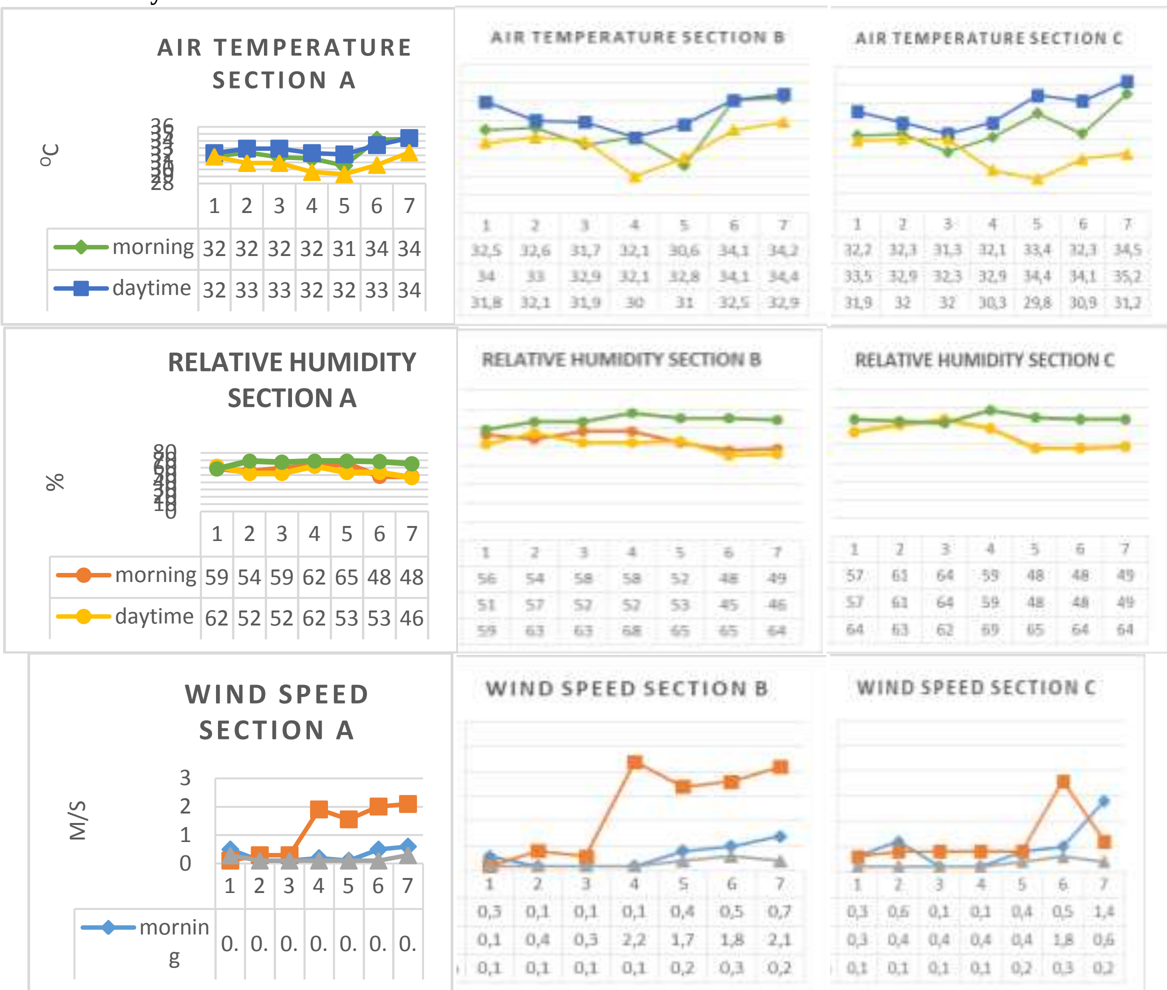
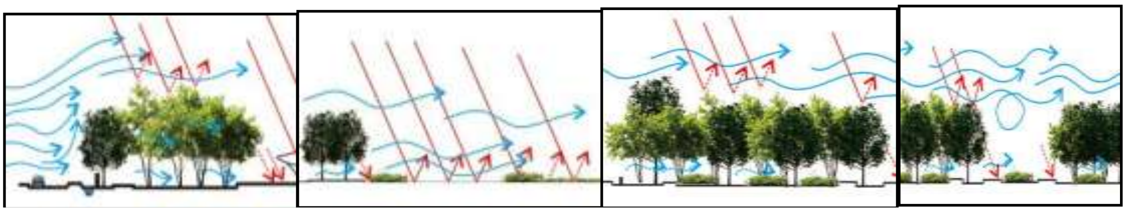


Fig. 6. The graphic result of microclimate parameters based on grid and section

The microclimate data are shown in fig. 6 is microclimate parameters, that consist of the average value of air temperature, wind speed, and relative humidity found from field measurement. From the graphics above it is seen that the average air temperature in Taman Walikota (grid number 1,2, and 3) tends to be lower all the time compared to the square on TuguReligi (grid number 4,5,6, and 7). Ideal results are seen in observations during the daytime. The air temperature in the square of the TuguReligi tends to increase in the area that closer to the monument building (grid 6 and 7) since those are the area where the vegetation is less and the soil surface fully covered by artificial surface (fig. 7b). Seen from horizontal section A and section C, the tendency of the average air temperature is lower because there are many vegetations planted in this area. Tree density is also an important component to reduce air temperature. Solid vegetation helps to reduce air temperature by filtering out solar radiation. The area of vegetation affects the local air temperature. Large areas of vegetation can keep air temperatures in lower places, due to the presence of hard-exposed materials or structures in green areas which is attributableto an increase in air temperature.

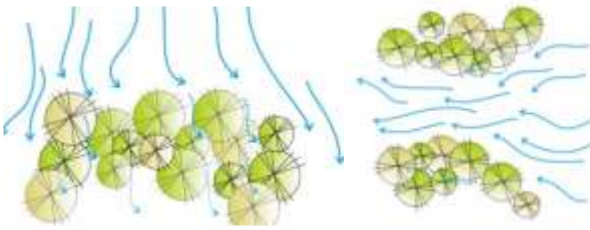
In the case of Taman Walikota, the air temperature is lower than inother areas, for example on the road that surrounds the park. This is caused by the density of vegetation which is high enough to make the air temperature in almost the entire region to cool, although in certain parts there is no vegetation and the surface using artificial material (Fig.7a). In case of wind speed, it is seen that the wind speed in this area is quite low, especially in the middle area in which the wind moves very slowly due to the high vegetation density (Fig. 7c).



(a) (b) (c) (d)

Fig. 7. Vegetation structure(a) trees intercept incoming solar radiation and also obstructed the wind coming from open space such as street; (b) uninterrupted vegetation and artificial land cover on the surface causing heat and improve the reflection of solar radiation; (c), highly dense vegetation reduced wind speeds and blocking solar radiation, shrubs hinder the wind flow at the bottom of the tree canopies; (d) trees planted with high density at surrounding open area blocked wind flow to form a turbulence pattern between trees.

Wind flow plays an important role in providing a cool feeling on the surface of the skin (Fig 8). A very dense vegetation configuration can direct and block the flow of the wind. The humidity will be high and the wind speed decreases. The wind speed is quite low in the middle of Taman Walikota (Fig. 7d), with a normal value of relative humidity levels for tropical climates. Meanwhile, the square of TuguReligi can be categorized as hot and dry areas when considered from the value of wind speed and relative humidity. The lower the relative humidity the higher the air temperature. But with higher wind speed especially in the middle (section B), this condition will not be so influential, comfort will still be felt by humans.



(a) (b)

Fig. 8. The effect of vegetation on the wind: (a) obstruction and filtration, vegetation blocking and reducing speed (b) guidance, vegetation forms canal and increasing wind speed

3.2 THI (Temperature Humidity Index)

Based on the results of the THI analysis from the table below. It can be seen that the grid which belongs to the comfortable category is only found at the location of the square of TuguReligi, B5 and C6. Both are surrounded by vegetation. However, the predicted number of grids in the very uncomfortable category also dominated by the square TuguReligi area, which is 5 grids, namely A6, A7, B6, B7, and C7, as well as one grid in the Mayor's Park, namely B1. Areas that are predicted to be very uncomfortable in the Taman Walikota and square of TuguReligi are areas with less vegetation. In general, the THI value of the Taman Walikota was indicated to be lower at 29.68 compared to TuguReligi worth 29.72. According to the THI result that in the morning, the area that tends to be a little more comfortable for visitors' activities is Taman Walikota since it is filled by a various vegetation, such as trees, shrubs, and grasses that filter solar radiation and provide better oxygen.

Table 2. THI Result

Location	Grid	Morning		Daytime		Afternoon	
		THI	Indication	THI	Indication	THI	Indication
Taman Walikota	A1	29,22	uncomfortable	29,81	uncomfortable	29,13	uncomfortable
	A2	29,41	uncomfortable	29,75	uncomfortable	28,98	comfortable
	A3	29,07	uncomfortable	29,75	uncomfortable	28,83	comfortable
	B1	31,04	very uncomfortable	30,66	very uncomfortable	29,16	uncomfortable
	B2	29,98	uncomfortable	30,14	uncomfortable	29,72	uncomfortable
	B3	30,14	uncomfortable	29,75	uncomfortable	29,51	uncomfortable
	C1	29,41	uncomfortable	30,46	uncomfortable	29,57	uncomfortable
	C2	29,76	uncomfortable	30,15	uncomfortable	29,60	uncomfortable
	C3	29,05	uncomfortable	29,80	uncomfortable	29,59	uncomfortable
average		29,68	uncomfortable	30,03	uncomfortable	29,34	uncomfortable
Tugu Religi	A4	29,13	uncomfortable	29,80	uncomfortable	27,73	comfortable
	A5	28,36	uncomfortable	29,09	uncomfortable	27,46	comfortable
	A6	30,66	very uncomfortable	30,27	uncomfortable	28,65	comfortable
	A7	30,85	very uncomfortable	30,65	very uncomfortable	30,09	uncomfortable
	B4	29,42	uncomfortable	29,04	uncomfortable	28,10	comfortable
	B5	27,66	comfortable	29,74	uncomfortable	28,85	comfortable
	B6	30,66	very uncomfortable	30,37	uncomfortable	30,24	uncomfortable
	B7	30,70	very uncomfortable	30,65	very uncomfortable	30,54	very uncomfortable
	C4	29,42	uncomfortable	29,63	uncomfortable	28,41	comfortable
	C5	29,94	uncomfortable	30,66	very uncomfortable	27,71	comfortable
	C6	28,92	comfortable	30,34	uncomfortable	28,69	comfortable
	C7	30,97	very uncomfortable	31,03	very uncomfortable	28,98	comfortable
average		29,72	uncomfortable	30,11	uncomfortable	28,79	comfortable

The THI value during the daytime shows that there is not a single grid in both locations that are indicated as comfortable. This condition does not allow visitors to engage in activities at this time. This is influenced by the high air temperature and air humidity which is generally above 50%. Meanwhile, THI result very uncomfortable criteria occur both in Taman Walikota and in the square of TuguReligi are still the same as the result in the morning. This is influenced by high daytime temperatures and low wind speeds during the daytime. In addition, the average value of THI still shows the similar pattern as the morning condition, although being in the uncomfortable category the THI value in Taman Walikota is slightly lower than the square of TuguReligi.

Entering the afternoon, the number of grids that have THI values in the comfort category is increasing. In Taman Walikota, the number of grids with comfortable categories is 2 grids out of a total of 9 grids. Although the other THI criteria are in the less comfortable category, none of the values obtained very uncomfortable category. While in the square of TuguReligi, the number of grids included in criteria comfortable is recorded as many as 9 grids out of a total of 12 grids. The THI grid value which is classified as very uncomfortable is higher than the value obtained in the Taman Walikota, which is 30.54 on the B7 grid. This grid located in an open area close to the Religi Monument, which has no vegetation and ground surface material covered by paving and asphalt.

Based on the THI grid pattern in the region, it can be predicted that the areas that are comfortable for the end of the activity and what areas should be avoided to keep feeling comfortable. Physical activity should be avoided during the day because the THI values obtained in the entire study area are classified as uncomfortable. From the results of the analysis, activities in the area should be done during the afternoon i.e. above 16.30. because the condition of THI in the afternoon was based on the results of micro-climate observations at that time. If visitors want to do activities in the morning, for example exercising, these activities should be done in the Mayor's Park, because on average THI values and areas analyzed are more comfortable than in TuguReligi square.

IV. CONCLUSION

Public open space is a very important part of the city as it acts as a place to socialize. Comfortable open space encourages more people to do outdoor activities. To obtain a comfortable public place, the officials need to design an open space planning with optimal vegetation through green open space. The current study shows vegetation-covered public spaces have a lower air temperature of about 2^oC-4^oC compared with areas that are not covered by vegetation. So that, vegetation proves to create a cool shady area. In addition, the wind flow is also attributable to the conditions of more comfortable and cooler, but with overly dense vegetation configurations can lead otherwise to a difficulty of air to move in, this situation can occur a higher percentage of relative humidity. Based on the THI analysis, it is recommended that visitors to the Taman Walikota and square of TuguReligi to avoid physical activity during the day in all areas. While the best time for physical activity is in the afternoon.

V. ACKNOWLEDGMENTS

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REFERENCES

[1]. Report. (2018). Kendari in Figures. Kendari: Central Bureau of Statistic of Kendari.
[2]. Voogt, J. (2002). Urban heat island. In T. E. Munn, Encyclopedia of Global Environmental Change, Vol 3 (p. 660-666). Chichester: Wiley.
[3]. Grimm, N., Faeth, S., Golubiewski, N., Redman, C., Jianguo, W., Xuemei, B., and Briggs, J. (2008). Global Change and The ecology of Cities. Science, p. 756-760.
[4]. Murdiyarso D, Suharsono H. (1992). The Role of Urban Forests in City Climate Control. Million Trees for Improving City Climate. Proceedings of One Day Seminar of Urban Climate. Bogor: PERHIMPI, p. 61-72.
[5]. Thom, E. C. (1959). The Discomfort Index. Weatherwise, 12(2), 57-61
[6]. Nieuwolt S. (1977). Tropical Climatology. London: Wiley
[7]. Emmanuel, R. (1993). A hypothetical ‘shadow umbrella for thermal comfort enhancement in the Equatorial urban outdoors. Architectural Science Review, 36(4), 173-184.
[8]. Mertens, E., (1999). “Bioclimate and city planning – open space planning,” Atmospheric Environment, 33(24- 25): 4115-4123.
[9]. Frick, H. And Suskiyatno, B. (1998). Basics of Eco-Architecture. Kanisius: Yogyakarta
[10]. McPherson, E. (1994). Cooling urban heat island with sustainable landscapes. In: R. Platt, and R. Rowntree, R. Muick, The Ecological City: preserving and restoring urban biodiversity. Amherst: University of Massachusetts Press.
[11]. Taha, H. (1997). Urban climates and heat islands: albedo, evapotranspiration, and anthropogenic heat. Energy and Buildings, vol 25, no. 2, p. 99-103.
[12]. Akbari, H. (2002). Shade trees reduce building energy use and CO2 emissions from power plants. Environmental Pollution, p.s119-S26.
[13]. Shashua-Bar, L. Pearlmutter, D. and Errel, E.. (2011). The influence of trees and grass on outdoor thermal comfort in a hot-arid environment. International Journal of Climatology, 1498-506.
[14]. Kotzen, B. (2003). An investigation of shade under six different tree species of the Negev desert towards their potential use for enhancing micro-climatic condition in landscape architectural development. Journal of Arid Environments, p. 231-74.
[15]. Wardoyo, J., Suprapti, A., and Wediningsih, H. (2008). Vegetation Configuration as Microclimate Control Strategy In Hot Humid Tropic Urban Open Space. 9th SENVAR-2nd ISESEE. Selangor: UiTM Shah Alam.
[16]. Heisler, G., DeWalle, D. (1988). Effect of windbreak structure on wind flow. Agriculture, Ecosystems and Environments, p. 41-69.

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