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*Corresponding author(s)
email: nurwidyaaw@gmail.com

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The Effects of Green Open Spaces on Microclimate and Thermal Comfort in Three Integrated Campus in Yogyakarta, Indonesia

Nurwidya Ambarwati[1,2]*, Lies Rahayu Wijayanti Faida[2], Hero Marhaento[2]

1. *Pusat Pengendalian Pembangunan Ekoregion Jawa, Siliwangi St. No.100, Nusupan, Nogotirto, Sleman, Indonesia*
2. *Faculty of Forestry, Universitas Gadjah Mada, Agro 1st, Bulaksumur, Sleman, Indonesia*

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Abstract

This study aims to assess the effect of green open space (GOS) on the microclimate and thermal comfort in three integrated campuses namely Universitas Gadjah Mada (UGM), Universitas Muhammadiyah Yogyakarta (UMY), and Universitas Pembangunan Nasional (UPN) Veteran. In order to achieve the research objective, three main steps were conducted. First, we mapped the GOS area and density of the three integrated campuses using a high-resolution satellite imagery. Second, three microclimate parameters such as air temperature, relative humidity, and wind speed were measured to each detected green spaces in the morning (08:00 am), at noon (01:00 pm), and afternoon (5:00 pm). Subsequently, the results of microclimate measurements were used to calculate the level of thermal comfort using Thermal Humidity Index (THI) method. Third, we carried out statistical analysis to investigate the correlation between the distribution and the density of GOS and the microclimate conditions. The results showed that a negative (-) correlation occurred between the pattern and density of GOS with temperature and wind speed indicating that clustered GOS significantly reduces the air temperature as well as the wind speed. On the contrary, the relative humidity has been increased. UPN campus has the highest temperature and wind speed and the lowest humidity among other campuses. According to the results of THI, a 100% of the UPN areas are uncomfortable, while at UGM and UMY 42,08% and 11,28% of their area are uncomfortable, respectively. This study found that the existence of GOS has an effect on microclimate depending on pattern and density.

1. Introduction

Special Region of Yogyakarta (DIY) has several leading universities that attract prospective students from within and outside the city to study. Based on data from Bappeda DI Yogyakarta (2021) the number of students in both public and private universities in 2021 will reach 387,310 people. Zubaidah et al. (2015) explained that the high migration of students entering DIY and students from DIY would have an effect on increasing the volume of vehicles in DIY. Based on data from the community mobility report (Google Mobility Reports, 2022) during the Covid 19 pandemic, mobility in the workplace increased by 6% from baseline and in parks in the form of city parks, national parks, public beaches, pet parks, and open fields. an increase of 45% from the baseline. This increase in the volume of vehicles will have an impact on increasing air pollution, because according to Puspitawati (2014) exhaust gases from motorized vehicles are a source of air pollution in DIY, reaching 60-70%. These exhaust emissions can then cause the greenhouse effect (Kurnia, 2021; Primary, 2019).

Greenhouse effect is a condition where the temperature of the earth's surface increases drastically due to the trapping of long-wave sunlight by greenhouse gases (CO2, CH¬4, CFC, O¬¬3, and N¬¬¬¬20) and causes climate change (Pratama, 2019). Facing the problem of vehicle increasing volume due to the migration of students who enter DIY every year so that it can cause changes in the micro-climate in the campus environment, the strategic role of universities in reducing global warming or controlling micro-climate change is to carry out the concept of a sustainable campus or green campus (Mukaromah, 2020). One of the indicators of achieving a green campus is to control the microclimate through environmental management by providing green open space (RTH). Microclimate is the climate of the lowest air layer but can also be interpreted as climate in narrow areas such as forests, cities, villages, and swamps (Daldjoeni, 1986).The elements of microclimate consist of temperature, relative humidity, light intensity, and wind speed (Susanto, 2013). Green open space plays a role in regulating climatic conditions by delivering air masses and reducing air movement (Perini et al., 2018). Green open space is the allocation of space in an area for the growth of vegetation that has many benefits, including producing fresh air, absorption of CO¬2, and a place for biodiversity such as flora and fauna (Irvine et al., 2013) Vegetation or plants help in reducing carbon dioxide so that it can improve the microclimate (Lobaccaro & Acero, 2015).

Areas with a tropical climate require vegetation as a natural cooler to provide comfort during the summer or dry season (Priya & Senthil, 2021; Zhang et al., 2019). Several studies have discussed the benefits of green open space in the campus environment. Hami & Abdi (2021) found that most of college students spent much time in front of computer inside their classroom, so they need a fresh air and some green open spaces for outdoor activities to maintain their health and stress level. However, in order to maintain a healthy campus environment, Lau et al. (2014) found that for a compact campus, it recommended to limit the size of an open space that may handicap circulation and accessibility. On the other side, a small open space can provide more intimate contact and also a more controllable microclimate for physical comfort.

Universitas Gadjah Mada (UGM), Universitas Muhammadiyah Yogyakarta (UMY), and Universitas Pembangunan Nasional (UPN) Veteran (campus I) are three large integrated campuses in Yogyakarta that have adopted the green campus concept. Until now, there has been no attempt to evaluate the implementation of green campuses and their micro-climatic impacts in these three campuses. Thus, we aim to assess the effect of green open space conditions on the microclimate and comfort level in these three integrated campuses in DIY. The results of our study are expected to encourage the campus management and policies in environmental management, especially related to the provision of green open space as a microclimate controller and to increase thermal comfort. Thermal comfort is a state of mind that expresses satisfaction with the atmospheric conditions of the environment (ISO 7730, 2005 in Bouzidi et al. (2023)). This study will provide information on how the green open spaces in three different campuses affects the microclimate and the comfort level.

2. Data and Methods

2.1. Research Material

Materials used in this study consisted of primary and secondary data. The primary data were obtained from direct measurement, while the secondary data were obtained from the satellite image and documents of relevant institutions. Table 1 describes the materials needed in this study.

Table 1. Research Material

Name	Scale/ Resolution	Source
Canopy density and pattern, land use map	1:5.000	High Resolution Satellite Image (CSRT), Geospatial Information Agency (BIG)
Air temperature and relative humidity	March-April	Thermohydrometer
Wind speed data	March-April	Velocity meter
Field coordinates		GPS receivers
Documentation		Camera

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The research locations are Universitas Gadjah Mada (UGM), Universitas Muhammadiyah Yogyakarta (UMY), and Universitas Pembangunan Nasional (UPN) Veteran (campus I). All the campuses are located in locations with relatively similar characteristics, including in areas with the same average rainfall conditions of 1500-2000 mm/year (Bappeda DI Yogyakarta, 2021) flat topography, the same slope of 2%, and is located at an altitude of 600 masl, and relatively the same climatic conditions, namely the Oldeman climate type D3. UMY represents microclimate conditions and thermal comfort levels in the western part of DIY campus, central part of UGM, and UPN Veteran Yogyakarta (Kampus I) eastern part of DIY. Figure 1 shows the research locations of the study.

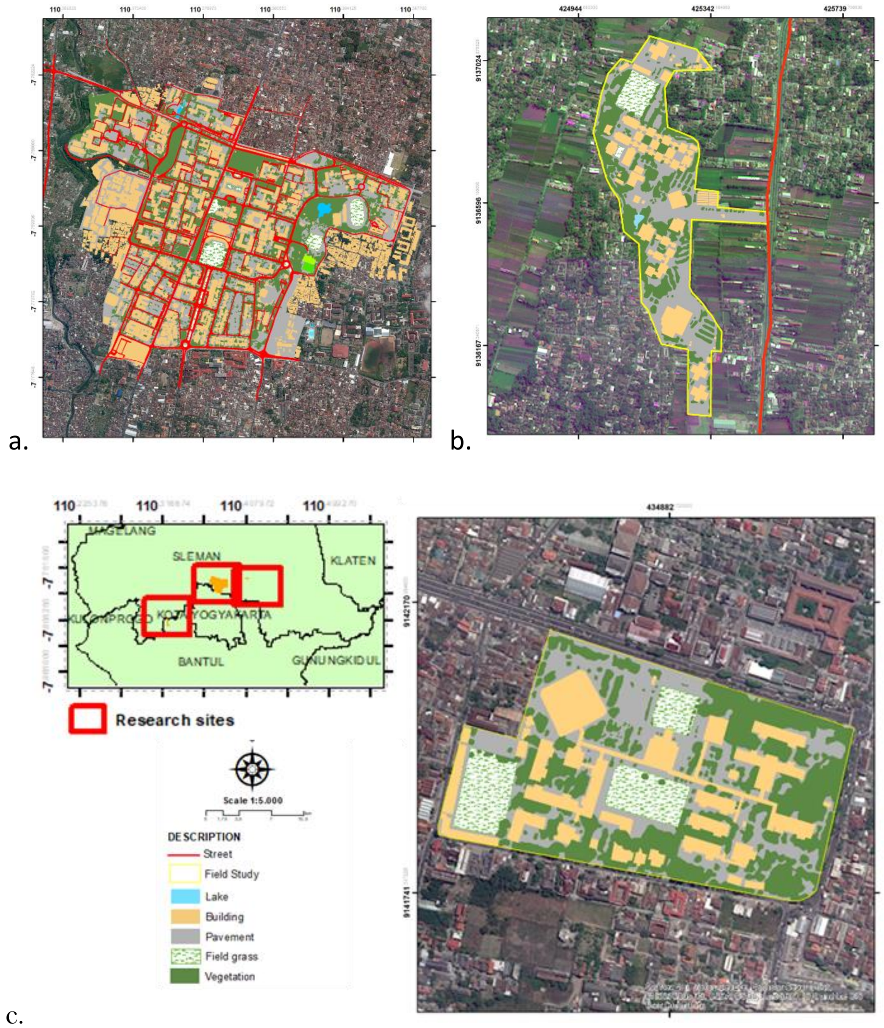

Figure 1. a) UGM land cover map; b) UMY land cover map;
c) Land Cover Map of UPN Veteran Yogyakarta (Campus 1)

2.2. Effect of Green Open Space on the Microclimate

In order to measure the effects of green open space on the microclimate, three main steps were conducted as stated in Figure 2. First, we mapped the green open space area and density using high resolution imageries with the classification of buildings, road pavements, tennis courts, ponds, fields, and vegetation/green open space. From the results of land cover classification, we then calculated the density of green open space with the following formula.

$$\text{Vegetation Density} = \frac{\textit{Vegetation Coverage Area}}{\textit{Area of Study}} \text{x } 100\% \text{.................................... } \textit{equation (1)}$$

Furthermore, we classified the density of green open space into four categories following the classification in the Table 2 as follows.

Table 2. Classification Green Space Density

No	Percentage Coverage (%)	Density Vegetation
1	>39	High
2	25-39	Moderate
3	<25	Low
4	0	Not Vegetated

Source: Budiyanto (2006)

Figure 2. Research Methodology Flowchart

Next, we identified the pattern of green open space based on Government Regulation Number 63 of 2002 namely clustered, dispersed, and longways green spaces. After interpretation the pattern of green open scape, in order to measure the patterns in the fields, we created grid to each campus and deployed the stratified random sampling point as visualized in Figure 3. The results of the field data and interpretation data were then tested for accuracy using a confusion matrix table.

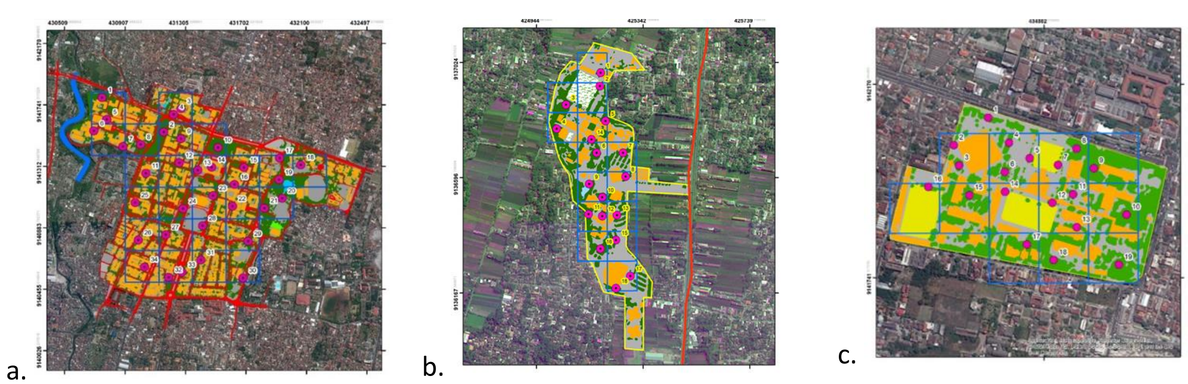

Figure 3. Point sample climate data collection micro a) UGM 34 samples; b) UMY 18 samples; c) UPN Veteran Yogyakarta (Campus 1) 19 samples

The data collection of microclimate parameters namely air temperature, relative humidity, and wind speed was carried out simultaneously in each point sample inside the grid when there were no consecutive rain days. Measurements were taken at 07.00-08.00 (morning), 12.00-13.00 (noon), and 16.30-17.30 (afternoon). The research was conducted when the number of the Covid 19 pandemic began to decline in February-March 2022 and community mobility activities began to run normally again. The results of point measurements in each grid are then calculated for the average temperature and humidity. The total number of samples for temperature and humidity data collection at UGM is 25 sample points, UMY is 13 points, and UPN Veteran Yogyakarta (Campus I) is 10 sample points. After processing the data, a statistical analysis was carried out using spearman rank correlation techniques to determine the direction of the relationship between the characteristics of green open space and the microclimate.

2.3. Thermal Comfort of the Academic Community

Comfort level can be determined quantitatively based on the comfort index with parameters of air temperature and relative humidity (Nieuwolt, 1977). In a previous study Suarma et al. (2019) found that factors of climate that influence comfort level namely temperature, humidity, wind velocity, and solar radiation. Relative humidity is the ratio between the measured (actual) water vapor pressure and the saturated water vapor pressure. The comfort index according to Nieuwolt (1977) can be obtained by the following formula.

$$\text{Thermal Humidity Index} = 0.8\,T + (RH \times T) : 500 \qquad \text{equation (2)}$$

Description:
T = Air Temperature (°C)
RH = Relative Humidity (%)

From those calculation formula, we classified the comfort levels according to Nieuwolt (1977). for low latitude tropical climates (as can be seen in Table 3).

Table 3. THI comfort classification table

THI (°C)	Comfort Level Classification
< 27°C	Comfortable
27-29°C	Partly Uncomfortable
> 29°C	Uncomfortable

Source: Nieuwolt, 1975

The THI value was then assigned for each point sample grid at UGM, UMY, and UPN Veteran Yogyakarta Campus 1. The results from the THI were then interpolated using the Inverse Distance Weighted (IDW) method. THI data analysis was carried out using quantitative descriptive methods through the description of the area objectively using numbers with comfort level conditions based on the results of THI classification in each campus.

3. Result and Discussion

3.1 The effect of green open space on microclimate

3.1.1 Micro Climate on Integrated Campus

The measurement results show that range of temperature at UGM is 29,50°C -32.97°C (as can be seen in Figure 4a), relative humidity is 50.67%-73.13% (as can be seen in Figure 5a), wind speed is 0.26 m/s - 1.08 m/s (as can be seen in Figure 6a). The highest temperature at UGM was around the Grha Saba Pramana (GSP) Building. Green open space in this area has a dominant pattern of an elongated shape with low density. Meanwhile, the lowest temperature in the UGM area is 29.50°C on the area dominated by green open space in the arboretum city forest, Faculty of Forestry. The Arboretum of the Faculty of Forestry has a grouped pattern of green open space with the density of green open space is high density.

Range of temperature at UMY is 29.60°C-32.32°C (as can be seen in Figure 4b), relative humidity is 61.60%-69.87% (as can be seen in Figure 5b), and wind speed is 0.45-0.87 m/s (as can be seen in Figure 6b). The highest temperature located in an open area, close to buildings and fields. The pattern of green open space that dominates in this area is dispersed and longways path. The lowest temperature in UMY have high density canopy and clustered green open space pattern. Around the location there are also artificial ponds or lakes within the campus area.

Next, range of temperature at UPN Veteran Yogyakarta Campus is 31.83-34.40°C (as can be seen in Figure 4c), relative humidity is 50.12%-52,07% (as can be seen in Figure 5c), and wind speed is 1.09-2.74 m/s (as can be seen in Figure 6c). Location with highest temperature has an elongated pattern and low-density vegetation. The dominant land cover at this location is high density building and open land or access roads within the campus. Meanwhile, the lowest temperature at UPN area has a clustered pattern and high-density vegetation.

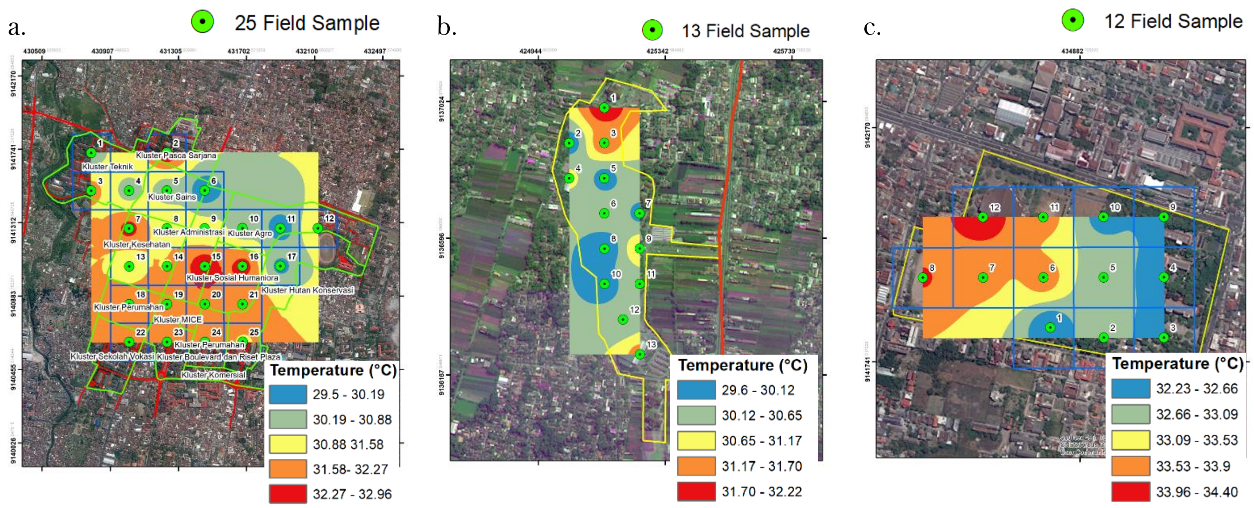

Figure 4. Map of regional air temperature a) UGM. b) UMY, c) UPN Veteran Yogyakarta (Campus 1)

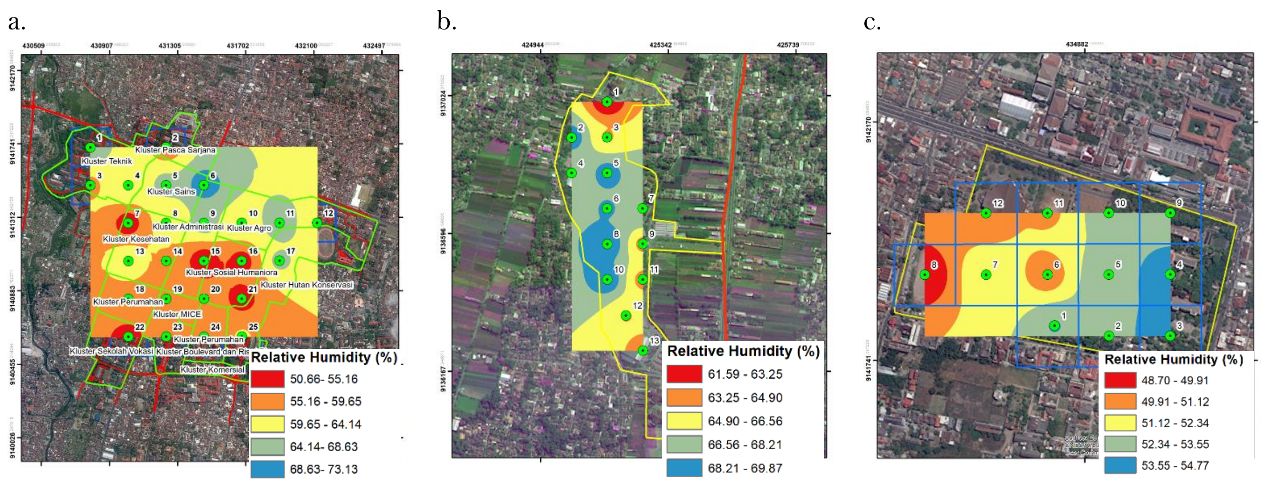

Figure 5. Map of Relative Humidity a) UGM, b) UMY,c) UPN Veteran Yogyakarta (Campus 1)

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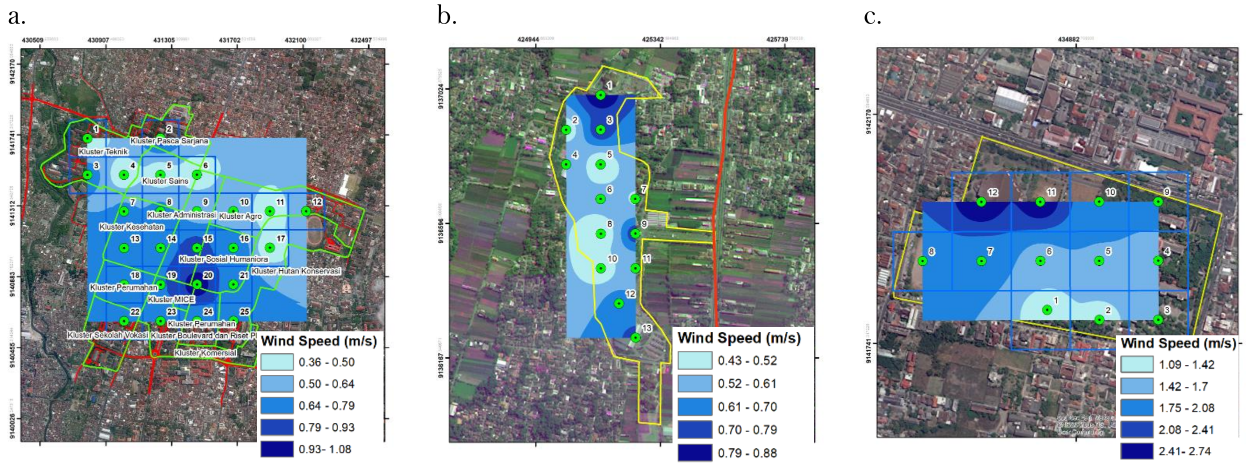

Figure 6. Map of Wind Speed Area a) UGM. b) UMY, c) UPN Veteran Yogyakarta (Campus 1)

3.1.2 Characteristics of Green Space

Green open space with longways pattern and low density at UGM are dominated by Ketapang (Terminalia catappa), Sawo Kecik (Manilkara kauki), Krei Payung (Fillicium decipiens), Cemara Bundel (Cupressus papuana), Glodokan Tiang (Polyalthia longifolia), Meranti (Shorea selanica), Ketapang Kencana (Terminalia mantaly), Angsana (Pterocarpus indicus), Trembesi (Samanea saman), Teak (Tectona grandis), and Bungur (Lagerstroemia speciose). The arrangement of green open space along the side of the road and around the field at UGM has an ecological function and creates an aesthetic impression. Ketapang (Terminalia catappa), Trembesi (Samanea saman) (Figure 7) and Bungur (Lagerstroemia speciose) have a wide canopy and can reduce NO, CO, and Pb pollution with the ability of the leaves to absorb toxins. The wide canopy will affect the formation of the microclimate by lowering the temperature around the location. Glodokan Tiang (Polyalthia longifolia) is a tree that has a high trunk, branches, and a flexible crown so it is not easily broken. This tree is suitable to be placed along the side of the road because it can reduce wind speed. Characteristics of trees that are not easily broken will minimize the occurrence of fallen trees due to strong winds.

The dispersed pattern with low density at UGM is dominated by Angsana (Pterocarpus indicus) (Figure 8), Green Sapodilla (Chrysophyllum caimito), Biola Cantik (Ficus lyrate), Guava (Anacardium occidentale), Jackfruit (Artocarpus heterophyllus), and Mango (Mangifera indica). Biola cantik (Ficus lyrate) has a low tree height, broad leaves, and a lush canopy. Green open space with a dispersed pattern at UGM is dominated by fruits such as mango, jackfruit, and guava with leaves that are not wide but have thick crowns. These plants have strong roots so that in case of strong winds it minimizes the occurrence of fallen trees. However, due to the irregular distribution of plants, when compared to green open space with high density, the temperature in moderate density will be higher and relative humidity will be lower.

The high-density clustering pattern at UGM are dominated by Walnut (Canarium littorale) (Figure 9), Longan (Euphoria longana), Cape (Mimusops elengi), Mahogany Saga (Swietenia macrophylla), Sapodilla (Chrysophyllum caimito), Randu (Ceiba pentandra), Merbau (Intsia bijuga), Sawo kecik (Manilkara kauki), and Pinus Merkusi (Pinus merkusii). Based on observations in the field, trees with clustered patterns and high density have several different types of trees. The tree canopy in this green open space is relatively thick or dense, each tree was planted at closer spacing, and there are tree strata in this area. Urban vegetation could be designed by combining multiple layers of shrubs and small trees beneath larger tree canopies (Richards et al., 2020). This typical area will be a significant decrease in temperature such as in urban forest arboretum forestry, wisdom park, and biological forest.

Green open space with an elongated pattern and low density in UMY are dominated by Dadap Merah (Erythrina crista-galli), Angsana (Pterocarpus indicus), Trembesi (Samanea saman), Mango (Mangifera indica),

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Biola Cantik (Ficus lyrate), and Ketapang (Terminalia catappa). Ketapang at UMY is planted in an elongated pattern is used as a shade plant in the parking lot. It is intended that the air temperature under the canopy decreases because Ketapang tree has a wide canopy. The dispersed pattern with low density were dominated by Trembesi (Samanea saman) and Ketapang (Terminalia catappa). Trees planted with a dispersed pattern have relatively thick canopy, not too wide canopy, not stratified, and high enough. The clusterred pattern with high density is dominated by Trembesi (Samanea saman), Mahogany (Swietenia macrophyla), Ketapang (Terminalia catappa), Banyan (Ficus benjamina), and Pole Glodokan (Polyalthia longifolia).

Several types of trees in high density with clustered patterns at UMY have plant types that can absorb lead (Pb) and are suitable to be placed in city parks. The results of the research by Hindratmo et al. (2019) stated that the Mahogany (Swietenia macrophyla) had a fairly high Pb absorption capability with a value of 30.76 ppm. This is influenced by the type of leaves on mahogany which are wide and rougher (not slippery). In addition, based on this research, another plant that has the ability to absorb high Pb in the green open space of the UMY campus is Banyan (Ficus benjamina). In addition to its ability to absorb Pb, trees planted at high density at UMY were also planted in strata with various types of trees with different heights so that they had a dense canopy and thick canopy. This affects the decrease air temperature in this area.

Green open space with a longways pattern and low density in UPN are dominated by Krei Payung (Filicium decipiens), Angsana (Pterocarpus indicus), Tabebuya (Tabebuia aurantica) (Figure 10), Palm (Wodyetia bifurcate), Ketapang (Terminalia catappa), Kepel (Stelechocarpus burahol), and Mindi (Melia azedarach). Several trees that planted in an elongated pattern at UPN Veteran campus 1 around the field have a type of canopy, such as Krei Payung and Palm trees. Some Tabebuya trees at UPN Veteran Yogyakarta Campus I are not big enough and have small leaves so the tree canopy is not wide enough. This causes the temperature around the field at UPN Veteran Yogyakarta Campus 1 is the highest temperature among the three campuses. The dispersed pattern with low density is dominated by the Palm Putri (Veitchia merilli), Jackfruit (Artocarpus heterophyllus), and Mango (Mangifera indica). The clustered pattern with high density is dominated by Mango (Mangifera indica), Sawo Kecik (Manilkara kauki), Jackfruit (Artocarpus heterophyllus), Angsana (Pterocarpus indicus), and Glodokan Tiang (Polyalthia longifolia). Angsana trees that planted in a group at UPN Veteran Yogyakarta already have a thicker canopy compared to the Angsana trees on the edge of the field so that the canopy cover in the green open space area is denser. In accordance with the results in the field, the denser the vegetation, the temperature around the green open space will decrease.

Figure 7. Elongated Medium Density green open space pattern of Trembesi (*Samanea saman)*

Figure 8. Spreads Sparse Density Green open space pattern of Angsana (*Pterocarpus indicus)*

Figure 9. Cluster density/High density green open space pattern of Walnut (*Canarium littorale)*

Figure 10. Elongated Sparse green open space pattern of Tabebuya (*Tabebuia aurantica*)

3.1.3 Correlation between Green Open Space and Micro-climate

Table 4 shows the results of the correlation analysis between the density and pattern of green open space with the microclimate at UGM, UMY, and UPN. It was revealed that the correlation value between density and air temperature is negative (-) meaning an inverse relationship between density and air temperature that the closer the green open space is, the lower the air temperature. Meanwhile, the relationship between the density of green open space and humidity is positive (+) which indicates there is a directly proportional relationship where the denser green open space is, the higher the relative humidity value will be.

Table 4. Correlation of Green Open Space Characteristics with Microclimate

		Temperature	Humidity	Wind Speed
UGM				
Density	Pearson Correlation	-.862**	.797**	-.859**
Pattern	Pearson Correlation	-.697**	.739**	-.665**
UMY				
Density	Pearson Correlation	-.687**	.693**	-.647*
Pattern	Pearson Correlation	-.705**	.708**	-.663*
UPN Veteran Yogyakarta (Campus 1)				
Density	Pearson Correlation	-.847**	.930**	-.717**
Pattern	Pearson Correlation	-.829**	.744**	-.576**

Source: Data processing results, 2022

This condition is the same as the correlation between the green open space pattern and the air temperature which has a value of negative (-). The clustered green open space pattern will have an effect on lower temperatures. On the other hand, the correlation value (+) between the green open space pattern and humidity indicates that the rarer the green open space pattern is, the lower the relative humidity value will be. Table 4 is the result of statistical data processing of the characteristics of green open space with a microclimate:

3.2 Thermal Comfort Level on Integrated Campus

3.2.1 THI at UGM

Figure 11 shows that 57.92% of the area is in the partially uncomfortable category. The locations are around the engineering cluster, science cluster, administration cluster, agro-cluster, conservation forest cluster, and some health clusters.

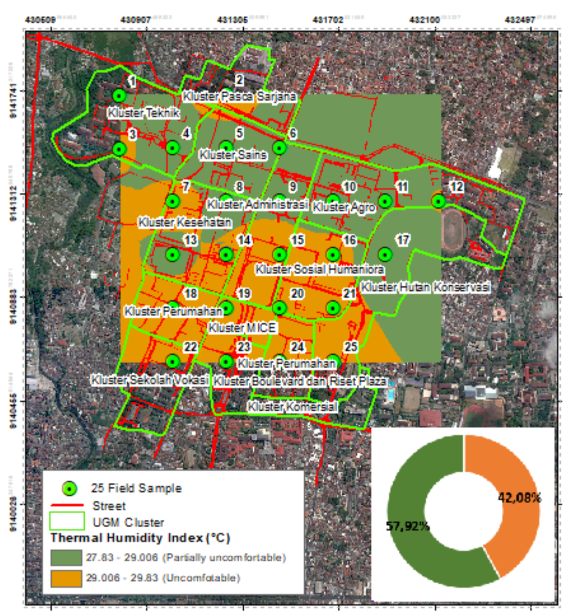

Figure 11. Thermal Humidity Index (THI) Map at UGM

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The temperature and humidity in the area with the category of being partly uncomfortable are controlled by the presence of green open space so that the temperature in this area is still within the threshold of 27-29°C or partly uncomfortable.

The results of the THI at UGM with an uncomfortable classification in the UGM area is 42.08% of the total area. THI with an uncomfortable classification at UGM located in some health clusters, humanities clusters, some administrative clusters, MICE clusters, and lecturer housing clusters. The uncomfortable classification indicates that the air temperature in this area is >29°C. The high air temperature is influenced by the presence of green open space with medium to rare density and elongated and spread patterns in areas classified as uncomfortable.

3.2.2 THI at UMY

The results of the THI calculation at UMY show that an area of 88.53% of the area within the UMY area is classified as partly uncomfortable with a class of 27-29°C and an area of 11.28% has an uncomfortable classification with an average temperature of >29°C. The temperature and humidity survey locations at points 3 and 1 (Figure 12) are open areas with minimal green open space so that the temperature at these locations is high with low humidity. Green open space in this location has an elongated characteristic with a rare to moderate density level. This results in areas 1 and 3 and their surroundings having an uncomfortable classification.

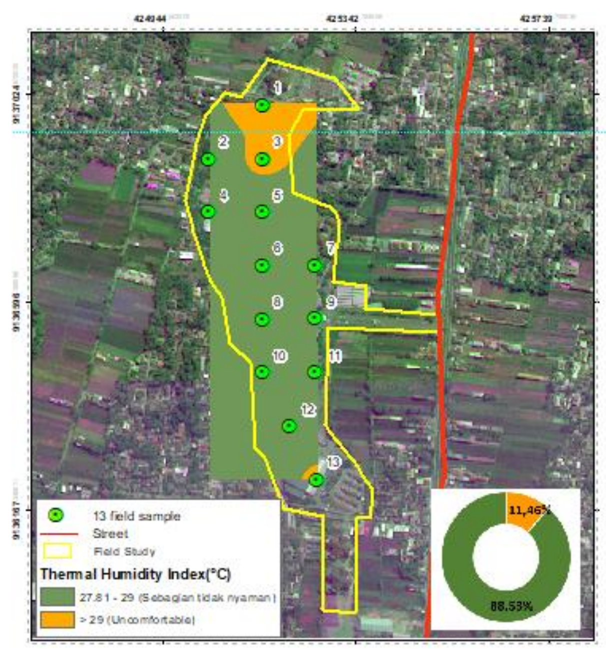

Figure 12. *Thermal Humidity Index* (THI) Map at UMY

3.2.3 THI at UPN Veteran Yogyakarta (Campus 1)

The results of the THI calculation at UPN Veteran Yogyakarta (Campus 1) show that 100% of the thermal comfort level in the campus environment is uncomfortable. This condition can occur because the temperature in the UPN environment is > 29°C. In the UPN 1 campus environment there are three open areas in the form of fields on grids 6, 8, and 10 so that in these locations the temperature is high due to the lack of vegetation cover in the open area. In addition, at UPN there are several survey locations where tree rejuvenation is being carried out by felling the canopy like what happened on grid 9 so that the ambient temperature is increasing. Figure 13 is a picture of THI at UPN Veteran Yogyakarta (Campus 1):

Figure 13. Map of Thermal Humidity Index (THI) at UPN Veteran Yogyakarta (Campus 1)

3.3 Discussion

The results showed that there was a correlation between the presence of green open space with temperature and relative humidity which represented the level of thermal comfort. According to data from UGM Public Relations, UGM has 50% green open space and 70% will be developed, UMY has 30% green open space from the campus area. These three integrated campuses have implemented the Green Campus concept by procuring green space. However, based on the results of the THI analysis (Nieuwolt, 1977) UGM, UMY, and UPN Veteran Yogyakarta (Campus 1) have a level of comfort with some classifications as partly uncomfortable and uncomfortable. This can be because the reference for the classification of the comfort level at the temperature and humidity at the time of measurement using classification from Nieuwolt (1977) is different from the current existing conditions. Therefore, it is necessary to adjust the comfort level classification according to the conditions in the field. In addition, the analysis based on THI is based on physical conditions, it is necessary to add a perception analysis as complementary data from the social aspect by paying attention to what conditions are felt by the academic community on the level of thermal comfort in the campus environment.

Other studies related to this research were conducted by Sodoudi et al. (2018), they do research on the influence of spatial configuration of green areas on microclimate and thermal comfort. The aim of their study is to knowing the surface temperature at each vegetation density and shape or pattern of vegetation. The results show the level of fragmentation of patch density and edge density, shape, and type of vegetation on the cooling effect. The highest cooling effect occurs at 2 pm in the scenario of a green area in the form of methamphetamine parallel to the wind direction and in a tree with a large canopy. The difference with the research in this study is field sampling determination. Sodoudi et al. (2018) determine the sample on each type of vegetation so that so that the thermal comfort known only at that location. Meanwhile, this study determines the sample using a grid method which can be located in green open space (vegetated areas) or non-green open space area. Grid method was used to make data collection easier throughout all of the area because cooling effect of vegetation not only not only felt under the shade of vegetation but also in the surrounding area. This is evidenced by when collecting temperature data around the UGM Wisdom Park, the temperature value is still lower than the temperature in an open area with sparse vegetation because it is affected by the existence of the Wisdom Park.

In 2020, there was a study that specifically related to this topic written by Mallen et al. (2020), study about thermal impacts of built and vegetated environments on local microclimates in an urban university campus. The regression method was used to see the relationship between land cover parameters and air temperature in the summer of 2017. In a contrary, this study using Spearman Rank correlation to knowing the effect of green open space on microclimate. The use of this method is because one of the data used is ordinal data.

The difference between this study and other studies about green open space is at the level of detail. This study specifically mentions about the type of plant in each pattern and density of green open space. This can be used as a consideration for other campus management or other areas in a tropical country to determine the types of plants that are suitable for planting as a green open space in their area. The existence of green open space is important, but it is necessary to add a description about the spatial layout of urban forest and the type of plant to suit the microclimatic conditions of each region. As the result of the research that has been done by Ghaffarianhoseini et al. (2019) Study about analyzing the thermal comfort conditions of outdoor spaces in a university campus in Kuala Lumpur Malaysia concludes that effective redesign of outdoor spaces in the tropics has a significant impact of shading and vegetation. As a result, its improved comfort level. The selection of green open space aims to avoid falling trees due to strong winds, maximize the function of green open space as a lead (Pb) absorber or ambient air controller, and as an aesthetic function in an area.

The results of calculating the level of thermal comfort using the THI method by Nieuwolt (1977) are less relevant for current climate conditions, so it is necessary to update and adjust the thermal comfort class based on temperature and humidity in each study area. This is proven that the results of THI calculations at UPN are 100% uncomfortable, even though in the UPN campus area there are several areas with high density and clustered vegetation. In a previous study, He et al. (2020) found that people either adopt behaviors, either to maintain comfort or they change locations to satisfy their demands. It shows that the level of thermal comfort needs to be validated with the perception of humans living in the area because the level of human adaptation is different in each region's characteristics.

3.4 Limitation

There are various factors that influence the formation of the microclimate, so it is necessary to conduct further research on this study to complement the factors that influence the microclimate. Research on the effect of green open space on the microclimate and comfort level can have some uncertainty about the measurement results due to several things. First, the tools used, namely the thermohydrometer and velocity meter, require instrument calibration to obtain accurate results approaching the conditions in the field. However, the tools used in this study have been calibrated.

Second, it is necessary to learn and practice directly how to use the tool so that the measurement results are not biased. Microclimate measurements are carried out with tools placed at a height of > 1 meter and < 2 meters because there are studies of typical climate characteristics in the lower atmosphere layer (< 2 meters below the ground surface) which is referred to as microclimate (Haurwitz and Austin, in Utomo, 2009). Furthermore, the third is related to the effect of using air conditioning which has the potential to release heat energy from the waste of the air conditioner which makes the outdoor temperature hotter. The results of research by Hermawan (2014) stated that the heat discharged (released) from the AC condenser can reach a maximum temperature of 53.5°C with an average of 47.47°C. This parameter was not included in the study, while buildings in the campus area mostly use air conditioning so that there can be bias in the measurement of microclimate data.

Another factor that influences the formation of a microclimate at UGM, UMY, and UPN Veteran Yogyakarta (Campus 1) is the form of the integrated campus area. UGM has a wider area, clustered or more compact, and wider edge effects so that the microclimate in the form of air temperature, relative humidity and wind speed is more stable than UPN Veteran Yogyakarta (Campus 1). This is related to the influence of the large number of emissions outside the area that cause global warming so that it can affect microclimate conditions in the campus area. UPN Veteran Yogyakarta (Campus 1) has a narrower area and has a smaller edge effect so that the possibility of microclimate influences from outside the area is still large, especially because this campus is associated with the northern ring road which is quite densely traversed by vehicles every day. This resulted in the results of data acquisition showing that UPN Veteran Yogyakarta (Campus 1) had the highest air temperature (32.23-34.41°C) compared to other campuses. Meanwhile, UMY has an elongated area, but the microclimate conditions are almost the same as the conditions at UGM, this can be due to the influence of environmental associations at UMY which are still in the form of rice fields so that it does not have a big effect on microclimate conditions in the UMY area. This study has a limitation that the effect of emissions from outside the area that produces ambient and causes changes in the microclimate within the area is not included in the parameters of the research method.

4. Conclusion

Three large integrated campuses in Yogyakarta (UGM, UMY, and UPN) have adopted the green campus concept. But until now, there has been no attempt to evaluate the implementation of green campuses and their micro-climatic impacts. This study stresses the level of density and pattern of vegetation can affect the microclimate. Future possible studies can arrange spatial layout of green open space and the type or characteristic of vegetation that needed to suit the microclimatic conditions of each campus. A negative (-) correlation occurs between the pattern and density of green open space with temperature and wind speed, which indicates that the denser green open space is with the clustered pattern, the air temperature will decrease, and the wind speed will decrease. On the other hand, there is a positive (+) correlation between the pattern and the density of green open space with humidity which indicates that the denser green open space is, the higher the relative humidity. UPN Veteran Yogyakarta (Campus 1) has the highest temperature and wind speed conditions and the lowest humidity among the three campuses because it has several open spaces (field area) with green open space conditions around the field has not big enough and wide canopy. In addition, the shape of the area at UPN Veteran Yogyakarta (Campus 1) is narrower and has a smaller edge effect so that the possibility of microclimate influences from outside the area is still large, especially because this campus is associated with the North Ring Road which is quite congested by vehicles every day.

The results of the calculation of the level of comfort based on the Thermal Humidity Index (THI) method, in the three integrated campuses show that at UPN Veteran Yogyakarta (Campus 1) 100% of the area is in the uncomfortable category, at Gadjah Mada University, 57.92% of the area is in the partial uncomfortable and 42.08% of the area is uncomfortable, in UMY, 88.53% of the area is categorized as partly uncomfortable and 11.28% of the area is uncomfortable. Uncomfortable conditions in almost all areas of UPN Veteran Yogyakarta (Campus 1) are affected by high temperatures >29°C and evenly low humidity. This study found the level of thermal comfort using the THI method by Nieuwolt are less relevant for current climate conditions, so it is necessary to update and adjust the thermal comfort class based on temperature and humidity in each study area. This is proven that the results of THI calculations at UPN are 100% uncomfortable, even though in the UPN campus area there are several areas with high density and clustered vegetation. It shows that the level of thermal comfort needs to be validated with the perception of humans living in the area because the level of human adaptation is different in each region's characteristics.

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