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LAND SURFACE EFFECTS AND THERMAL PERFORMANCE IN HOT-HUMID CLIMATE AREA

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ABSTRACT: This study aims to evaluate the effects of land surface characteristics to the microclimate condition and indoor thermal performance on an office building in urban and suburban areas by analyzing temperature, humidity, and air velocity, and also natural ventilation system. The research method is performed with the measurement of the thermal condition using LSI-LASTEM Multi Logger, HOBO data logger, and HOBO data logger with an external sensor. The results show that indoor thermal condition in urban and suburban areas is uncomfortable level with the average of indoor temperature is around 29°C in the suburban area and over 31°C in the urban area. Average of relative humidity is about 72% in the suburban area and 77% in the urban area. Average of air velocity is lower than 0.3 m/s in both regions. The temperature in the urban area higher than that in the suburban area of around 2°C. Indicates that, changes in land surface characteristics can influence the thermal performance and microclimate conditions in urban and suburban areas.

Keywords: Thermal Comfort, Natural Ventilation, Landsurface Effect, Office Building

1. INTRODUCTION

Along with the growth of population and development in all sectors have an impact on the emergence of various environmental problems such as pollution is increase and temperature become warmer, loss of various habitats, a decline of the diversity of flora and fauna and a decrease in environmental quality.

The development of urban continues to increase which results in parks or green lines changing functions to concrete surfaces, asphalt, and stretch of buildings. In addition, urbanization continues to increase so that urban has experienced significant environmental changes such as the increasing concentrations of greenhouse gases in the atmosphere, where most of them are produced from the combustion process of fossil energy. Increased urbanization has an impact on Urban Heat Island (UHI); urban human activity has a significant contribution to greenhouse gases. The global greenhouse gas emissions rose by 70% during the period 1970 to 2004 due to human activities in urban [1].

Green areas in the urban environment can contribute to the mitigation of the Urban Heat Island, reducing temperature and energy consumption, especially on summer [2-4], the level of temperature reduction depends on the season and time of the day, characteristics and magnitude of the green area [5-8].

In hot weather conditions, energy consumption increases in buildings due to the usage of Air Conditioning (AC). Utilization of AC contributes significantly to increasing global energy consumption; more than 40% of global energy consumption comes from the building sector and one-third of the energy consumption of buildings is used for room cooling (AC), which produces more than 30% of the global annual greenhouse gas emissions [9]. On the other hand, more than 60% of CO_2 gas in the atmosphere is produced from the fossil energy combustion process and around 30 % comes from the deforestation process or land surface change from natural element to the concrete surface and building because of the less vegetation means less carbon dioxide conversion to oxygen [10].

The increase of CO_2 gas in the atmosphere causes the increasing temperature and climate change effect. The increasing urban temperature has a significant impact on indoor thermal comfort. Thermal comfort is important both for one's well-being and productivity. There are many factors affecting human thermal comforts, such as the temperature of surfaces, air temperature, humidity, air movement and personal variables like clothing insulation, activity, and metabolism rate. Modification of land cover from natural element to artificial elements in urban areas can cause local wind and surface temperatures to rise several degrees higher than the temperature of the surrounding rural areas [11]. Therefore, this paper will discuss the effect of the land surface characteristic on the indoor thermal performance in urban and suburban areas.

2. METHODS

This research analyzes indoor thermal condition in the office building, which is located in urban (high density) and suburban (low density); description of the study object can be seen in table 1. Urban is the area around inner-city of Ternate with the density of building and transportation is high, open space and greenery are limited. Suburban is characterized by the area outside the zone of Ternate City with the density of building and transportation is low density, land use condition is dominant from a plantation and green lands areas (see figure 1 and 2).

Fig. 1. Map of the Study Object.

The study objects are consist of 2 building offices in the urban area; public works (PUW) in coord. 0°46'55.6"N 127°22'49.7"E and national education (NED) in coord 0°47'05.4"N 127°22'32.7"E, and also 2 building offices in suburban; search and rescue agency (SAR) in coord. 0°45'43.2"N 127°19'02.2"E and cultural heritage conservation center (HCC) in coord. 0°45'37.8"N 127°19'01.0"E. The four offices are Indonesian government offices at the Ternate City, North Maluku Province. Building material uses concrete structure, the wall from brick material, the roof from metal, and ceramic as a flooring material.

Fig. 2. Building Density around the Study Object. (source: google maps)

The research method is a quantitative method by using several instruments for measuring thermal parameters: temperature, relative humidity, and wind velocity (see figure 3), which are LSI-LASTEM thermal comfort multi logger for measuring air temperature, relative humidity, and mean radiant temperature, and also two types of loggers were used: HOBO temp/Relative Humidity (RH) logger (Hobo-1) for measuring temperature and relative humidity and using HOBO temp/RH/Light/External logger (Hobo-2) for measuring temperature, relative humidity and air velocity. Instrument position: LSI system is placed in the center of the room, Hobo-1 on the table around the employee, Hobo-2 around the openings or wind flow area with the position height is ±100 cm on the floor (see Figure 5)

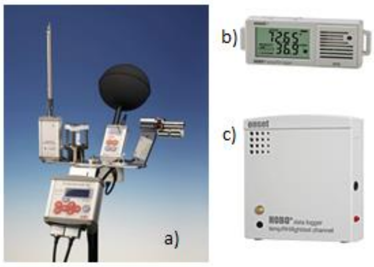

Fig. 3. Research Instruments: (a) LSI-LASTEM, (b) Hobo-1, (c) Hobo-2.

Measurement of indoor thermal is observed on the daytime of weekday during office activity from 10:00 a.m. to 2:00 p.m. with the sunny day conditions or peak of hot weather. At the same time measurements of thermal condition, the response of employees to the weather are also asked through a questionnaire, whether the thermal condition was acceptable or unacceptable.

Table 1. The Condition of the Study Object

Office	Level	Orientation	Location	Description
NED	2	East	Urban	High density
PUW	3	NNE	Urban	High density
SAR	1	WSW	Suburban	Low density
HCC	2	ENE	Suburban	Low density

Fig. 4. Building Condition of the Study Object.

Fig. 5. Collecting Data Process.

3. DISCUSSIONS

3.1. Thermal Performance in Building

The most dominant factor influencing human convenience is thermal comfort, which includes: air temperature, humidity, and wind speed. If the air temperature around a human is higher than normal body temperature (37°C), then the blood flow to the limbs will increase the skin temperature, so that the process of releasing heat in the body into the air occurs and the body will perspire and cool itself.

Figure 6 suggests that the indoor temperature condition where the average temperature is around 29^{o}C in the suburban area and over 31^{o}C in the urban area. This condition indicates that the temperature condition is up to a comfortable level. Based on the thermal comfort standard for a hot-humid tropic area is about 24^{o}C-26^{o}C with the relaxing activity and a thin dress [12]. Temperature condition in the offices located in the suburban area range from 28.71 to 29.37°C in SAR and from 28.45 to 29.86°C in HCC office. For urban area. It ranges from 29.88 to 31.02°C in NED office and from 29.08 to 31.76°C in PUW office (see Table 2). Indicates that maximum temperature in the urban area is higher than that in the suburban area of around 2°C. The average temperature in both offices in the urban and suburban area is almost the same even though the building orientation (see table 1) differ in each office. It indicates that the effect of building orientation on temperature is not significant.

Table 2. Indoor Temperature Condition

Temperature (°C)	Suburban		Urban	
	SAR	HCC	NED	PUW
Average	28.97	29.23	30.40	30.48
Min	28.71	28.45	29.88	29.08
Max	29.37	29.86	31.02	31.76

Resource: Survey result in 2017

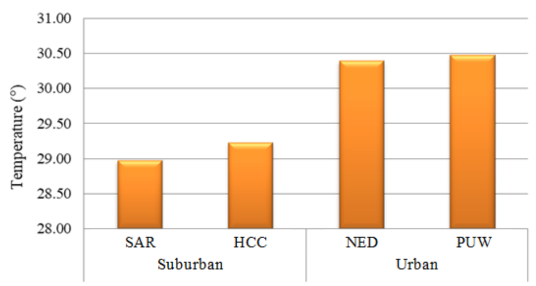

Fig. 6. Average of Indoor Temperature.

Relative humidity and air temperature have a significant impact on occupant comfort because the sensation of comfort in cold conditions is related to the balance of human body heat, namely the balance of heat produced by metabolic processes and heat loss due to heat transfer; radiation, conduction, convection, and evaporation. Generally, in cold conditions, humidity is low and has a little direct effect on thermal comfort, although there are indirect effects, such as the change of clothing insulation value. In hot conditions, the human body is necessary to increase heat losses for maintaining thermal comfort because the efficiency of evaporation is decreased if the relative humidity is increased, the relative humidity is very important parameter during the summer condition, if the air continues to increase to the saturated condition, and then the less water can evaporate into that air. The efficiency of evaporation is increased with wind velocity, in summer it is often desirable to increase wind velocity but the opposite in winter.

Table 3. Indoor Relative-Humidity Condition

Humidity (%)	Suburban		Urban	
	SAR	HCC	NED	PUW
Average	69.87	72.35	76.96	75.48
Min	67.17	71.87	76.40	72.30
Max	74.20	72.81	77.47	79.07

Resource: Survey result in 2017

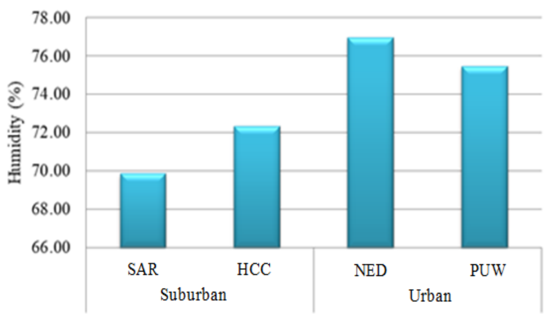

Fig. 7. Average of Indoor Relative Humidity.

Figure 7 shows that the relative humidity in the office building is average 72% in a suburban area and 77% in an urban area. Indoor Relative Humidity condition in the suburban area range from 67.17% to 74.20% in SAR office, from 71.87% to 72.81 in HCC office. In suburban area range from 76.40% to 77.47% in NED office and from 72.30% to 79.07% in PUW office (see Table 3). It is generally over 60%. It indicates that the relative humidity is uncomfortable level. RH comfort is about 40-60% [12].

High humidity can cause feelings of discomfort because high humidity can inhibit the process of sweating where sweat functions to cool the surface of the skin. If the condition is too hot, the body releases water on the surface of the skin. Water cools in the wind and decreases the temperature of the skin, but when the moisture level is almost reached to the condensation point, sweating loses its cooling effect. In addition, high levels of humidity can cause health effects.

In case the humidity is high, the wind speed is needed for expediting the evaporation. The air flow is a factor affecting evapotranspiration rates. The increasing air movement can improve evaporation and transpiration because moving air is less saturated than stagnant air. This is because of the movement of the air itself. Once saturated air moves, it is replaced by drier, less saturated air which can then absorb water vapor.

Table 4. Indoor Air-Velocity Condition

Windspeed (m/s)	Suburban		Urban	
	SAR	HCC	NED	PUW
Average	0.13	0.23	0.26	0.26
Min	0.03	0.21	0.24	0.11
Max	0.26	0.26	0.28	0.84

Resource: Survey result in 2017

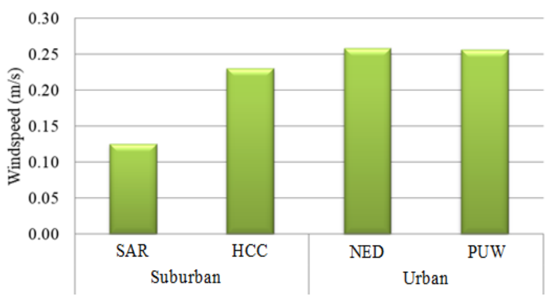

Fig. 8. Average of Indoor Air Velocity.

Table 4 and figure 8 show that the average of indoor air velocity is generally lower than 0.5 m/s of around 0.23 m/s in the suburban and 0.26 m/s in the urban area. It portrays that the air velocity in the office building is under a comfortable level, the standard is about 0,6-1,5 m/sec with the relaxing activity and a thin dress [12]. For natural ventilation system, adequate air flow is needed to accelerate wind circulation in the room. It can be increased by cross ventilation and stack effect. The affectivities of the cross ventilation system are depending on wind condition around the building. The sufficient wind speed can improve cross ventilation performance and force cool air into the room through an inlet (window, door, etc.) and then force warm air to out from building through an outlet. Stack ventilation is where the air is driven through the building by vertical pressure differences developed by thermal buoyancy.

Figure 9 shows that the indoor thermal preference is felt by occupants in office buildings, where almost 70 % employees expect to decrease indoor temperature until the comfortable level and about 70% employees expect to increase of air velocity (see figure 10). Indicates that the performance of natural ventilation is not effective because the dimension ventilation is limited and the position of inlet does not match to wind flow direction so that wind circulation is not optimal in the office building. Impact, the usage of mechanical ventilation is increased and then increase in energy consumption.

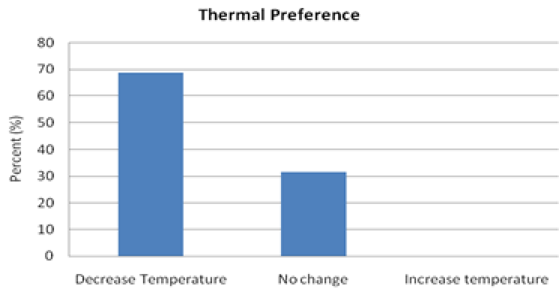

Fig. 9. Thermal Preference of Employees [13].

An office with the indoor temperature condition is too warm making its employees feel tired and if the condition is too cold condition causing the concentration of employees is drift, restless, and easily distracted. Even a minor deviation from the comfortable condition can influences stressful, performance, and safety. Employees already under stress are less tolerant of uncomfortable conditions. Therefore, improving indoor thermal until a comfortable level is essential in the offices building.

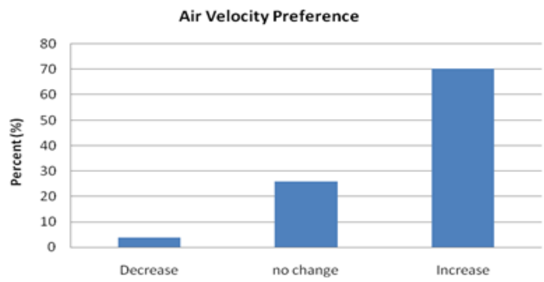

Fig. 10. Air Velocity Preference of Employees[13].

3.2. Natural Ventilation Strategy

Application of natural ventilation in America has been successful in many buildings including in the office building where its energy consumption decrease until more than half compared to that consumption in building using AC [14]. However, measurement result shows that thermal condition in the office building in Ternate is an uncomfortable level, with temperature generally exceeds 29°C and more than 50% of employees feel comfortable warm and too warm during the daytime. It suggests that the utilization of natural ventilation is not effective. Office buildings in Ternate City are usually designed for the mechanical ventilation system so that the cross ventilation strategy is not adoption.

Natural ventilation is widely used to improve indoor air quality because it can improve the health quality of residents. The good of indoor air quality is free from the pollution; dirty air can cause health problems such as irritation in eyes, nose, and throat, and also can cause respiratory or cardiovascular diseases [15]. Thus, planting vegetation around the building is very important, not only for reducing temperature but also for filtering dirty air so that the fresh and clean air flow into the building.

The area of Ternate city is majority cover by a volcano (Gamalama Mountain), this mountain is almost every year experiences small eruptions and produces ash and dust pollution covering the city. A large eruption was occurred in 1775 causing around 1.300 people death. On December 4, 2011, Gamala Mountain was an eruption and ejecting material up to 2.000 m into the atmosphere and causing thousands resident were fled. In this condition is very difficult to use natural ventilation, so that strategy ventilation system in Ternate City is the combination of natural and mechanical ventilation. In normal condition, natural ventilation is operated by cross ventilation system (open-close ventilation system), but during the eruption, the mechanical ventilation or air conditioning is used for preventing dust pollution into the room. Moreover, the air exchange rate is as an extremely important factor to take into account to avoid pollutants concentrations indoors. Air exchange is achieved through ventilation in order to ensure a healthy indoor environment [16-19].

In too hot condition, natural ventilation is difficult to realize for reducing the temperature until the comfort level in a building, then, AC is used. The usage of air conditioning causes the increasing of energy consumption in the building, and further, it contributes to increasing concentration CO_2 in the atmosphere if the use of energy from fossil fuels. Therefore, it is necessary to develop clean energy such as wind power and solar cell so as not contribute to the increase of CO_2 in atmospheric.

3.3. Effect of Land-surface to the thermal condition

Indoor thermal conditions are influenced by outdoor thermal conditions. Outdoor temperatures are influenced by the land cover composition. Land cover characteristics, open space or park, the density of greenery, water element, and human activities have essential effects on urban temperature change. Several studies of environmental improvements suggest that dense vegetation is effective for reducing temperatures and increasing human comfort. Buildings surrounded by greenery have lower ambient temperature than those which are distant from the greenery. Trees and water element are useful for improving the urban temperature. Climate change can be mitigated by land cover improvement, reduction of anthropogenic heat, and the utilization of wind by improving local wind circulation [20].

Green spaces and gardens contribute significantly to improving the microclimate and reducing the rate of pollution in the city so that the parklands are the lungs of the city [2]. Increasing the prevalence of green spaces through the installation of street trees, city parks and rooftop gardens has consistently demonstrated a reduction in the urban heat island effect [21]. Tree shade can also reduce air conditioning costs of buildings by 20-50% providing suitable tree placement. Shading effects of the trees gave cooling energy savings of around 30% [22]. Vegetation is effective to decrease temperatures in the urban area so that buildings surrounded by plants have lower environmental temperature than those of buildings that are distant from plants. Temperature reduction depends on the land cover composition, magnitude of the park, building density [23-26].

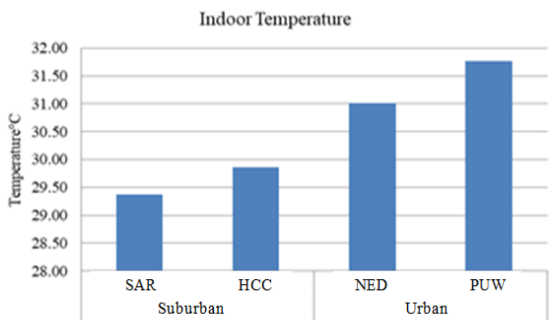

Fig. 11. Maximum of Indoor Temperature.

Based on the research results show that there are differences temperature on the urban area and suburban area of about 2°C, and also there are differences temperature in each office in suburban and urban areas. The maximum temperature in the suburban area, which observed in HCC office is over 0,5°C compared to that in SAR office. This condition is similar in the urban area, where the maximum temperature in the NED office is higher than that in the PUW office of about 1,74°C (see figure 11). This condition is caused by land surface characteristics around the building; offices with the shady vegetation have lower temperatures.

Table 5. Temperature Condition on Land surface Characteristic

Land Surface	Temperature (°C)		
	Suburban	Urban	Deviation
Real Condition	26.6	28.9	2.3
Mixed Forest	25.9	28.2	2.3
Deciduous BF.	25.8	28.3	2.5
Evergreen BF.	25.3	27.8	2.5
Water Bodies	21.4	26.7	5.3

Research before from author: the effect of vegetation and water body to the temperature change where the results show that vegetation can reduce the temperature in urban and suburban areas. Table 5 shows that the temperature deviation between in the suburban with the urban area is about 2°C on the land surface of vegetation and about 5°C on the water bodies. Temperatures decrease from existing condition of about 1^oC in the evergreen broadleaf forest at both urban and suburban areas and water bodies reduce temperatures by about 2°C in urban and by about 5°C in suburban. It means that changes in land surface characteristics can influence the thermal performance and microclimate conditions in urban and suburban. Thus, the combination of vegetation and water elements around the building are useful to improve the thermal condition. Vegetation's absorb CO_2 and sunlight, artificial ponds can increase evaporation, and a mixture of them is effective to increase surface evapotranspiration. Therefore, natural ventilation can be improved by a combination of cross ventilation and clerestory ventilation with the open-close system and land surface improvement by planting vegetation around the building to decrease solar heat gain that penetrates into the room especially during summer condition.

4. CONCLUSIONS

The average indoor temperature is around 29^oC in the suburban area and over 31^oC in the urban area. Average of relative humidity is about 72% in a suburban area and 77% in an urban area. Average of indoor air velocity is lower than 0.3 m/s in both regions. This condition indicates that the thermal condition is up to a comfortable level.

The performance of cross ventilation is not effective because of the dimension of ventilation is limited and the position of inlet does not match to the wind flow direction so that wind circulation is not optimal in an office building.

Changes land surface characteristics in hot-humid climate area can influence the thermal performance and microclimate conditions in urban and suburban areas. Offices with shady vegetation have lower temperatures. The temperature in urban is higher than that in the suburban area of about 2°C.

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