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Day and Night Thermal Mass Performance Studies on Wetland Settlement in Palembang

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Abstract

The phenomenon of urban heat island was affected by the thermal mass of the area. The massive development of settlement in the wetland of Palembang had changed the natural thermal mass composition. This paper discussed the effect of the settlement development in the urban thermal environment of the wetland of Palembang. We measured the effect of building, pavement, water body and vegetation factors in the day and night air temperature of the settlement area. Direct field measurement was done using the wet and dry thermometer, anemometer and globe thermometer for 3x24 hours. The result showed that there were differences in day and night air temperature in the area with different thermal mass composition. It was also affected by wind direction and weather conditions. We concluded that the day and night temperature balance of the area could be control by the composition of thermal mass in the settlement area.

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Table of contents

Volume 1722

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Preface

Papers

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Day and Night Thermal Mass Performance Studies on Wetland Settlement in Palembang

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Abstract. The phenomenon of urban heat island was affected by the thermal mass of the area. The massive development of settlement in the wetland of Palembang had changed the natural thermal mass composition. This paper discussed the effect of the settlement development in the urban thermal environment of the wetland of Palembang. We measured the effect of building, pavement, water body and vegetation factors in the day and night air temperature of the settlement area. Direct field measurement was done using the wet and dry thermometer, anemometer and globe thermometer for 3x24 hours. The result showed that there were differences in day and night air temperature in the area with different thermal mass composition. It was also affected by wind direction and weather conditions. We concluded that the day and night temperature balance of the area could be control by the composition of thermal mass in the settlement area.

Keywords: day and night temperature, thermal mass, wetland settlement

1. Introduction

The development of urban areas causes the changing urban form. The changing urban form affects the intensity of sunlight on the surface material so that affects the thermal comfort of the environment [1] [2] and thermal comfort of the building. The thermal comfort of the environment can be controlled by using the hardscape and soft-scape land cover material. The thermal comfort of the building can be controlled by using the effective material with thermal storage mass which can control indoor temperature [3].

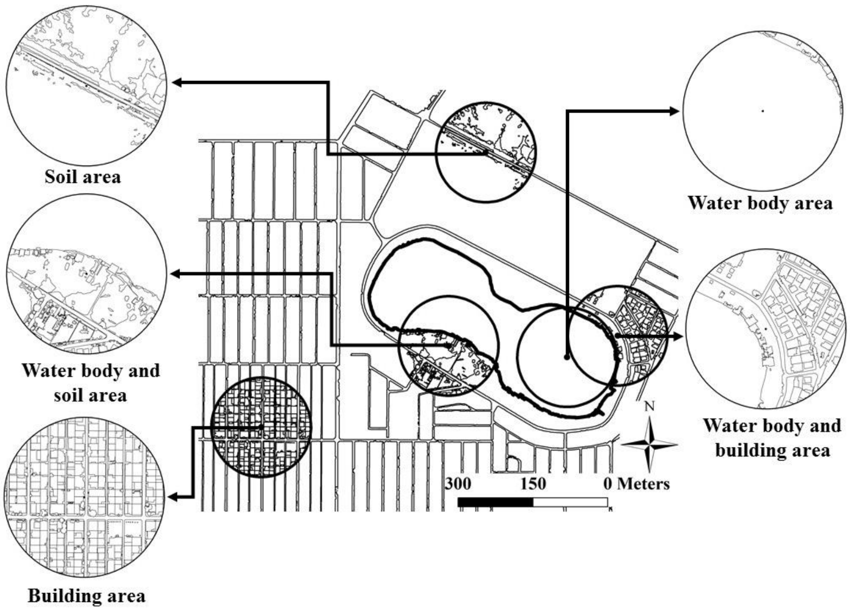
The increase in housing demand in Palembang city encourages the massive development of settlement in wetland areas. The development of the wetland settlement area changes the land cover and the composition of natural thermal mass material so that it affects air temperature and encourages heat island phenomena. The changing of thermal mass composition in wetland settlement in the form of the changing of buildings, open space pavement (asphalt, soil), vegetation and water body [4]. Buildings and open space pavement as hardscape material have the thermal mass characteristics which can absorb and reflect heat during the day and release heat at night so that this material can increase day and night temperatures. Vegetation as a soft-scape material has the thermal mass characteristics which can absorb heat during the day so that this material can reduce daytime temperatures [5]. The water body as soft-scape materials has the thermal mass characteristics which can absorb heat during the day and release heat at night so that this material can reduce daytime temperatures and increase nighttime temperatures. The temperature of the water body material increases during the day so that the temperature of the water body is higher than the air temperature. The increase of water body temperature encourages evaporation, transfer of heat and transfer of mass into the airflow [6].

The thermal mass capability to increase and decrease the temperature is also influenced by the air movement in the form of wind speed and direction. The movement of air is formed due to urban geometry [7] [8] and building density [9] [10] so that air movement depends on aspects of open space and density area. Open space causes wind movement can transmit heat and humidity to the surrounding area while density area causes the wind was trapped in this area and affect the increase of air temperature. The increasing and decreasing in temperature cause the changing of the daytime and nighttime temperature. The changing of temperature during the daytime and nighttime requires time to increasing and decreasing temperature in the form of time delay $\Delta T/\Delta t$ (°C/hour(s)). The changing of daytime and nighttime temperature affect thermal comfort and environmental thermal quality so that it needs the balancing between daytime and nighttime temperatures. Wetland areas have the potential of water bodies and soils that contain water as an element of cooling material so that this material can be used as a potential material for controlling day and night temperatures.

Considering the conditions that have been conveyed, it is required research to see the effect of the composition of the thermal mass material on daytime and nighttime air temperatures in the wetland area settlement. The research is done by comparing the characteristic of the thermal mass material and day-nighttime air temperature between the water body area with other areas. This research result in the thermal behavior in wetland settlement and the characteristic of the thermal mass material which can affect the changing daytime and nighttime temperature.

2. Method

This research was a case study research on the OPI Jakabaring settlement area using comparative analysis methods. The determination of the research area was based on the land cover and thermal mass characteristics of the area with a radius of influence 100 meters. The composition of the area consisted of buildings, pavement (asphalt), soil, vegetations, and water body. This research compared daytime and nighttime air temperature (°C) of the water body area with daytime and nighttime air temperature (°C) of the soil area, the building area, the water body-soil area, and the water body-building area. Field data were collected at 5 (five) measuring points (figure 1.) which were taken every hour for 3 days using the wet and dry thermometer, globe thermometer and anemometer at a height of 150 cm from the ground. Data collection was done by providing a record of wind movement and weather conditions for each data collection so that resulted in the thermal behavior and the characteristics of air temperature (T_a) every hour in each wetland area settlement.



Sources: Badan Informasi Geospasial (BIG) Indonesia, 2017; Badan Perencanaan Pembangunan Daerah Kota Palembang, 2012; aerial photographs, and field survey.

Figure 1. Wetland area point measurement in OPI Jakabaring settlement.

3. Result and Discussion

OPI Jakabaring settlement as wetland settlement had the potential of water bodies as the main elements of the area. The area of OPI Jakabaring settlement had a different composition of land cover and thermal mass material (figure 2.).

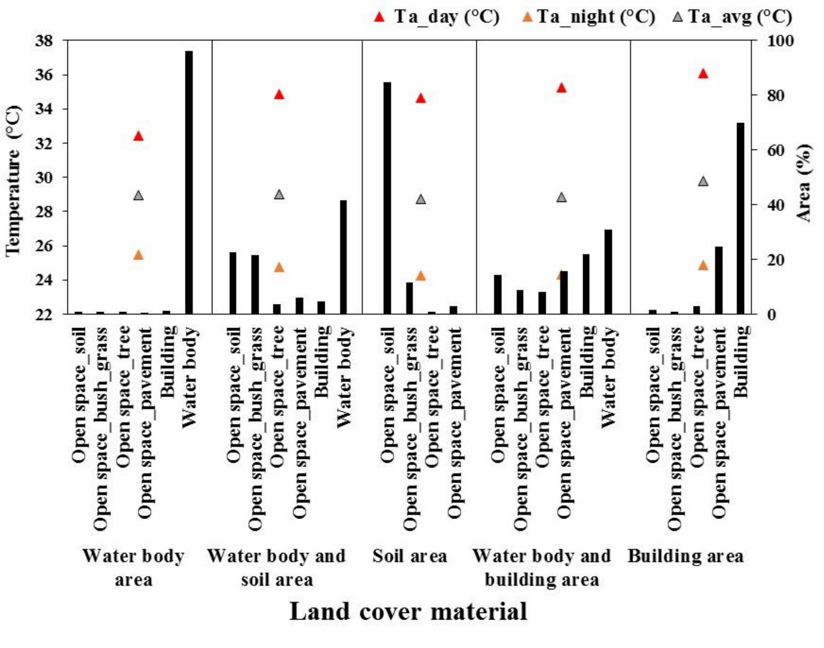


Figure 2. The composition of land cover material that influences day and night temperature.

The composition of land cover material influence the increasing and decreasing air temperature during the day so the area had differences in daytime temperature (T_{a_day}) and nighttime temperature (T_{a_night}) (figure 2. and figure 3.).

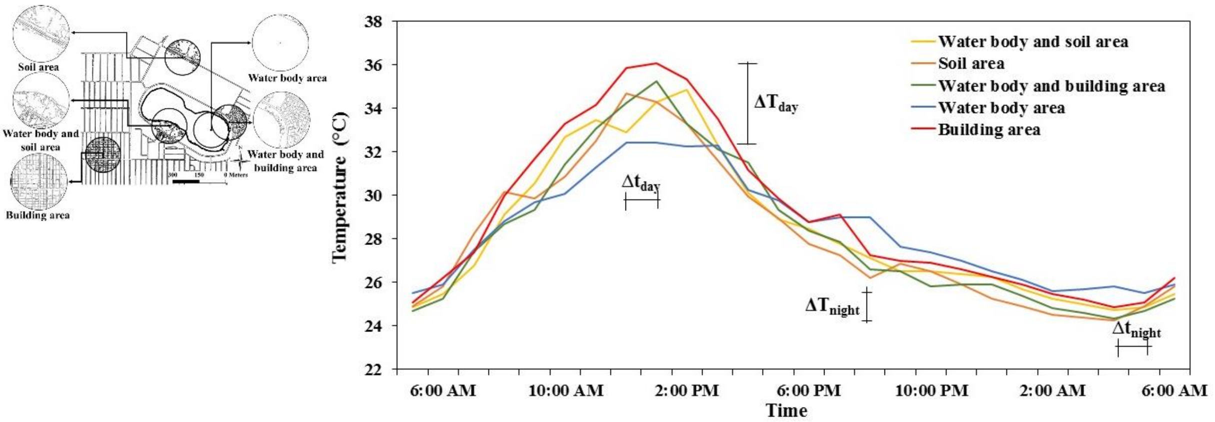


Figure 3. The comparison air temperature in the wetland area.

The characteristic building area as a dense area had different effects with a water body and soil area as open space. The differences in area characteristics had different effects on the increase in daytime temperatures and the decrease at night temperatures (figure 4.). The water body area had the lowest T_{a_day} and highest T_{a_night} while the building area had the highest T_{a_day} and the soil are had the lowest T_{a_night}. The characteristic of the water body and soil area encouraged the evaporation process which occurred in this area and besides that the characteristic of open space caused the air movement to transmit the heat to the surrounding area.

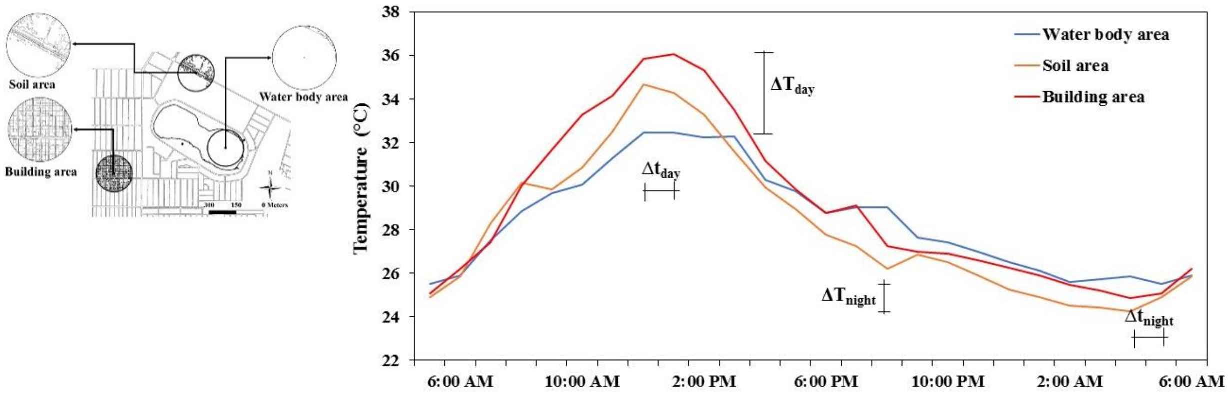


Figure 4. The comparison air temperature between $T_{water\ body\ area}$, $T_{soil\ area}$, and $T_{building\ area}$.

The composition of the water body, soil, and building material affected the increase and decrease of air temperature. The water body area had thermal mass material which effects the increasing and decreasing air temperature slowly so it resulted in T_{a_day} lower and T_{a_night} higher than other areas. The building could increase daytime temperature and this temperature would decrease rapidly so that it resulted in high T_{a_day} and low T_{a_night}. More buildings in the area could cause an increase of T_{a_day} and the decrease of T_{a_night} so that the building area had T_{a_day} higher and T_{a_night} lower than the temperature of the water body area.

The soil area had a different graphic of temperature if it compared with the water body area and the building area. The soil area had an increase of T_{a_day} at one time during the daytime and had a decreasing temperature minimum at one time in the nighttime. The influence of soil material on air temperature depended on the intensity of the sunshine. The soil area had a maximum increase of temperature when the area had maximum sunshine during the day and then the temperature of this area would drop rapidly to a minimum point at nighttime. The increasing and decreasing of temperature in the soil area was affected by thermal mass soil and the characteristics of soil density in wetland settlements.

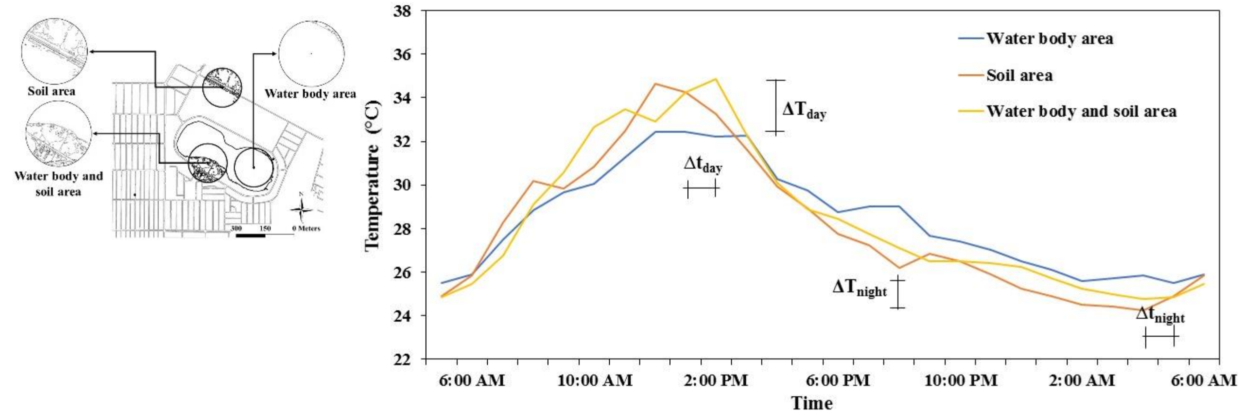


Figure 5. The comparison air temperature between $T_{water\ body\ area}$, $T_{water\ body\text{-}soil\ area}$, and $T_{soil\ area}$.

Figure 5. showed the effect of soil material which containing water elements on wetland areas. The soil area had the highest T_{a_day} and the lowest T_{a_night}. The water body area had T_{a_day} lower than T_{a_day} of the water body-soil area, this showed that the presence of soil material had a strong influence to increase in the air temperature, the more elements of the soil would increase the T_{a_day} and decrease T_{a_night}.

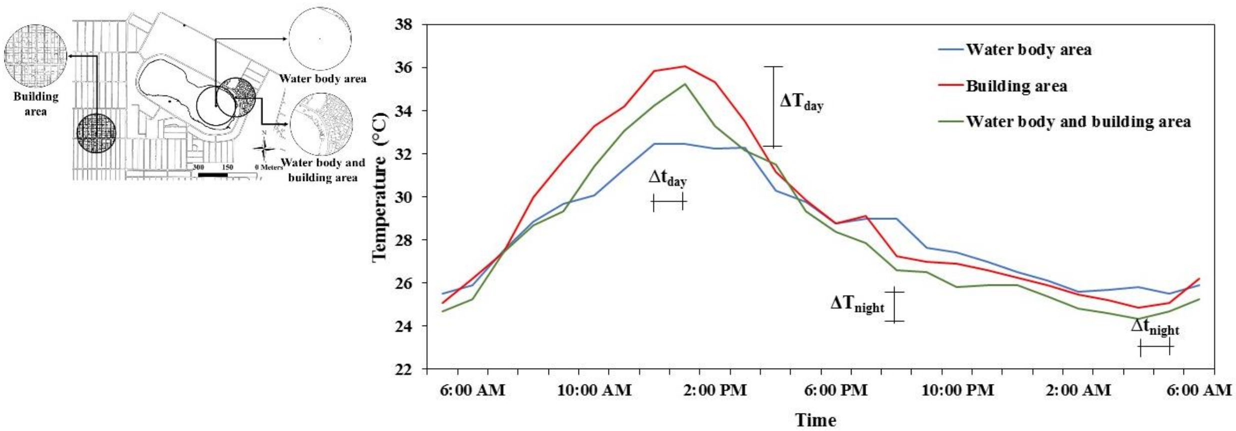


Figure 6. The comparison air temperature between $T_{water\ body\ area}$, $T_{water\ body\text{-}building\ area}$, and $T_{building\ area}$.

Figure 6. showed the effect of building material containing water elements on wetland areas. The water body area had the lowest T_{a_day} and then this temperature would decrease slowly so that the

T_{a_night} of the water body area higher than the temperature of other areas. The building area had the highest T_{a_day} and then the temperature of this area would decrease rapidly so that it caused the T_{a_night} of the building area between the T_{a_night} of the water body area and the T_{a_night} of the water body-building area. The water body-building area had the T_{a_day} between T_{a_day} of the water body area and the T_{a_day} of the building area and then this temperature decreased rapidly so that caused T_{a_night} of the water body-building area was lower than other areas. The water body-building area consisted of the characteristics of the water body and building materials so the air temperature was affected by the characteristic water body and building area. The graphic showed the building's capability to absorb heat and the capability of the water body as a cooling material in this area. During the daytime, the effect of the building is greater than the effect of the water body to increase air temperature so that the T_{a_day} of the water body-building area lower than the T_{a_day} of the building area and higher than the T_{a_day} of the water body area. At nighttime, the configuration of mass building and the heat stored in the building more affected the nighttime temperature so the T_{a_night} of the water body-building area lower than the T_{a_night} of the water body area and the T_{a_night} of the building area. This condition showed that the building had a strong influence to increase T_{a_day} and the water body had a strong influence to maintain the balance of daytime and nighttime temperatures.

The water body area had a ΔT_{day_night} lower than the soil area and the building area. The water body-soil area and the soil area had the same characteristic ΔT_{day_night} so this condition showed that the addition of water body material with the same percentage of soil material gave a small influence on the changing of ΔT_{day_night}. The changing of ΔT_{day_night} would be great if the percentage of the soft-scape material (water body, vegetation) more than the hardscape material (building, pavement, soil). The configuration of the water body and vegetation has a major influence on air temperatures [11] by considering the existence of the building area, green cover, and space ratio [12].

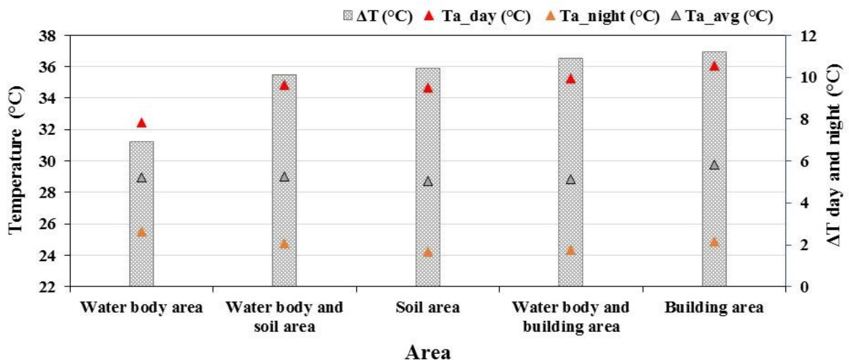


Figure 7. The differences in day and night temperature in the wetland area.

The difference in thermal mass would affect the difference between daytime and nighttime temperature (ΔT_{day_night}) (figure 7.). The building area had the highest ΔT_{day_night} while the water body area had the lowest ΔT_{day_night}. The water body-building area had ΔT_{day_night} between ΔT_{day_night} of the water body area and ΔT_{day_night} of the building area. The water body-soil area had ΔT_{day_night} between ΔT_{day_night} of the water body area and ΔT_{day_night} of the soil area. This condition showed the contribution of the addition of a water body which could increase and decrease air temperature and affect ΔT_{day_night}.

The water body material gave the effect of decreasing T_{a_day} and increasing T_{a_night}, while the soil material and building material gave the effect of increasing T_{a_day} and decreasing T_{a_night} so that the water body-building area had the ΔT_{day_night} between the ΔT_{day_night} of the water body area and the

ΔT_{day_night} of the building area. The area with the same composition between soft-scape and hardscape material had the ΔT_{day_night} almost the same with the area with dominant hardscape material.

Buildings were an element of material that could absorb and release heat on a vertical area (wall) and horizontal area (roof) so that the area of material that affected the thermal quality of the environment wider than other materials. The density of buildings caused the wind movement to be obstructed by the building so that heat was trapped in the area and affected the great increase of T_{a_day} and the small decrease of T_{a_night}. The mass of the building affected the increasing air temperature [11] because the heat absorption and the wind movement transmitted heat to the surrounding area.

The water body was an element material that consists of the main elements of water so that the water body could carry out the evaporation process. The evaporation process affected the absorption and releasing of heat so that could affect the decreasing of T_{a_day}. The thermal mass characteristics of the water body caused the water body could absorb and release heat slowly so that affected a small decrease of T_{a_night}. The characteristics of the water body as open space encouraged the air movement to transmit heat and moisture to the surrounding area, thus affecting the air temperature [13].

The soil was a land cover material that contains water so that the soil could carry out the evaporation process. The evaporation process of the soil affected the heat absorption process during the day so that it affects T_{a_day}. The soil characteristics as non-dense material elements affected heat absorption and heat release so that soil material could increase T_{a_day} and decrease T_{a_night}.

The areas that consist of elements of water body and soil needed the energy to carry out the process of evaporation so that the use of this energy affected the absorption and releasing of heat to surrounding during the day. The soil material as non-dense elements that contain water needs energy to the evaporation process more than the water body. The increase of the amount of soil material affected the increase in energy needs for the evaporation process, a great amount of soil material would cause greater soil influence on air temperature.

This condition showed that the configuration of the water body, soil and building material could decrease T_{a_day} and increase T_{a_night} so that the balancing of T_{a_day} and T_{a_night} could be reached. The decrease of T_{a_day} and the increase of T_{a_night} could be achieved by adding water body material while the increase of T_{a_day} and the decrease of T_{a_night} could be achieved by adding soil and building material.

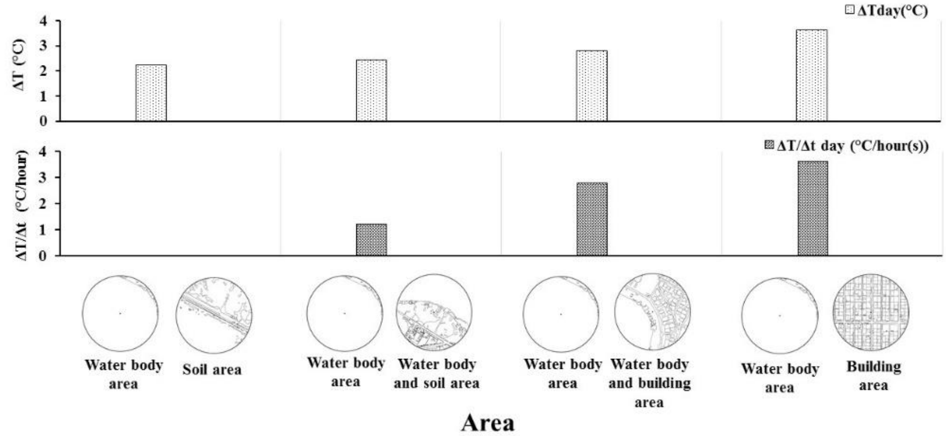


Figure 8. The comparison of ΔT_{day} and $\Delta T/\Delta t_{day}$ between water body area and another area.

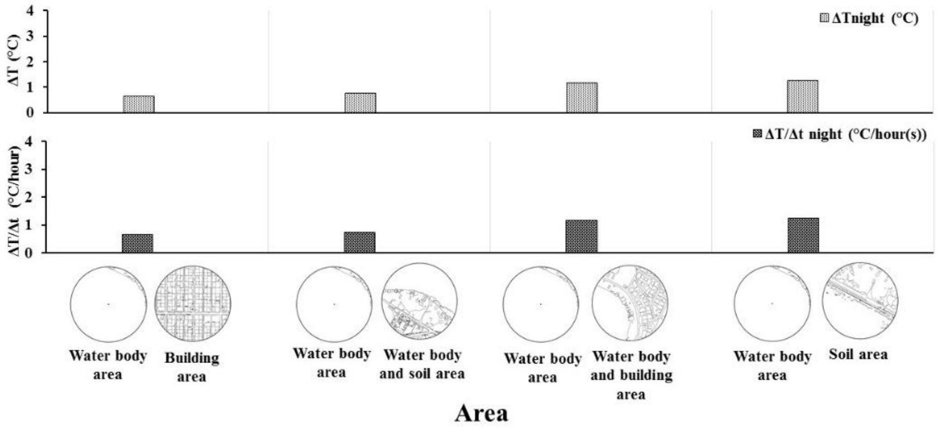


Figure 9. The comparison of ΔT_{night} and $\Delta T/\Delta t_{night}$ between water body area and another area.

The increase of T_{a_day} and decrease of T_{a_night} affect ΔT_{day_night} and time delay ($\Delta T/\Delta t$) in the form of the time required to increase and decrease the day-nighttime temperature (figure 8. and figure. 9.). The comparisons of ΔT_{day_night} and time delay ($\Delta T/\Delta t$) were made by comparing the temperature of the water body area with temperature in other areas.

The building area had the highest ΔT_{day} and the smallest ΔT_{night} while the soil area had the smallest ΔT_{day} and the highest ΔT_{night}. This condition showed the character of material between building, soil and water body would result in the difference of day-nighttime temperature. The building area which had the dominant building as a hardscape material would give a great influence on temperature differences with the water body area while the soil area which had the dominant soil material as a soft-scape material would give a small influence on temperature differences with the water body area.

The configuration of the water body, soil and building material would affect the increasing and the decreasing of $\Delta T/\Delta t_{day}$ and $\Delta T/\Delta t_{night}$. The existence of soil material in the water body-soil area and the existence of building in the water body-building area caused the increasing of day and night temperature so that this area had the high differences of $\Delta T/\Delta t_{day}$ and low differences of $\Delta T/\Delta t_{night}$ with water body area. This condition showed that the soil material and the building material affect the increasing of $\Delta T/\Delta t_{day}$ and decreasing of $\Delta T/\Delta t_{night}$.

The characteristic of thermal mass material affected the increasing and decreasing of $\Delta T/\Delta t_{day}$ and $\Delta T/\Delta t_{night}$ so that formed wetland thermal behavior. The day-nighttime temperature behavior of the water body-soil area was almost the same as the building area. The temperature behavior of the soil area was almost the same as the temperature behavior of the water body area. The temperature behavior of the water body and building area was different from that area. The characteristic of thermal behavior can be used as a basis for controlling day-nighttime air temperature. The controlling of day-nighttime air temperature is carried out by setting the composition of the land cover material. The area with high $\Delta T/\Delta t_{day}$ and low $\Delta T/\Delta t_{night}$ could be controlled by reducing the usage of soil material and building material as well as the addition of water body material.

4. Conclusions

Wetland settlements should be able to maintain the characteristics of the area so that the changing of land cover did not significantly change the air temperature of the area. The changing of land cover caused the changing of the thermal mass capacity of the area which affects the day-nighttime air temperature. This thermal mass capability was also affected by air movements and weather conditions that affected the capability of materials to absorb and release heat.

The water body could absorb heat during the day and release heat at night so that ΔT_{day_night} of the water body area smaller than other materials. The building materials and pavements (asphalt) could absorb heat during the day and release heat at night so that this material could increase T_{a_day} and T_{a_night}. The soil material gave the influence more than the water body because of the characteristics of the non-dense material and the evaporation process which affected the absorption and release of heat during the day and night.

This study resulted in the thermal behavior in wetland area settlements with great material influence were water body, soil, and building. The water body had a great influence to balance T_{a_day} and T_{a_night}. The balance of T_{a_day} and T_{a_night} could be achieved by balancing the composition of building materials, pavement, soil, vegetation, and water body, especially the balance of using of soil material and water body in wetland settlements.

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