Samarawickrama, Sumanthri, et al (eds), 2018, "Sustainability for people - *envisaging multi disciplinary solution": Proceedings of the 11th International Conference of Faculty of Architecture Research Unit (FARU), University of Moratuwa, Sri Lanka, December 08, 2018 Galle* pp. 123–131. ©

IMPACT OF SURFACE COVER AND SURROUNDING AREA ON MICROCLIMATE OF URBAN WETLAND PARK, NUGEGODA

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Abstract

Urban Wetland Park at Nugegoda was examined under this study. The work investigated three objectives. Effectiveness of different ground surface finishes to the microclimate (positively or negatively), wind pattern (wind directions and wind velocity) of the selected area to find out the effectiveness of wind pattern to the microclimate and the effectiveness of surrounding area over the wetland park, considering the build mass, traffic struck area and the water body. Temperature and relative humidity were obtained using HOBO data logger. Wind velocity was measured by anemometer and wind direction was measured using compass. The work observed an increase of air temperature in the investigated park by 5.34 ^{o}C above corresponding ambient air temperature. The heat which was generated in built mass, came attached to the air flow and it caused a rise in the temperature of park. Zone 01 and zone 02 records 2.5 ^{o}C higher temperature than zone 03. Zone 01 and 02 are directly exposed to the build mass, but in-between zone 03 and road area has a vegetated land. This vegetated land has caused a temperature drop in zone 03. The work highlights the significance of vegetated land as a buffer zone for negative effect from built mass. Surface cover is a significant factor which determines the deviation of temperature within a park.

Keywords: *Microclimate, Ground surface cover, Surrounding environment, Thermal comfort*

1. Introduction

"Wetlands" are water-rich natural areas that occur along rivers and in deltas. Those are the same places where most urbanization occurs. Urban expansions and the correspondingly lower groundwater levels put pressure on wetlands and associated nature, around the world. (Ehrenfeld, 2000). Currently, most of the wetlands are being cumulated because of human activities. As a result of decreasing these wetlands, the temperature of urban context is being increased. This will affect human behavior, as Li et al. (2018) mentioned atmospheric variables, such as temperature, precipitation, and sensible and latent heat fluxes are important for human society. Integration of green spaces in urban planning and building designs may, therefore be essential for adaptation to and mitigation of thermal impacts of both local and global warming processes (Feyisa et al., 2014).

"Microclimate" is the climate near the ground, that is the climate in which plants and animals live. It differs from the macroclimate, which prevails above the first few meters over the ground, primarily in the rate at which changes occur with elevation and with time. Whether the surface is bare or vegetated, the greatest diurnal range in temperature experienced at any level occurs there. Temperature changes drastically in the first few tens of millimeters from the surface into the soil or into the air. Changes in humidity with elevation are greatest near the surface (Norman J. Rosenberg, Blaine L. Blad, Shashi B. Verma, 1983). Temperature, humidity, atmospheric pressure and wind speed influence the cooling function of urban wetlands, while solar radiation modifies the humidification function of urban wetlands. Nowadays there are some constructed wetlands that can be seen in urban areas and also there are some wetlands which are partially converted to the man-made wetland parks. There are some important factors which directly affect the microclimate in the wetland. The ground surface cover is one crucial factor. There were many kinds of materials that are used as ground cover. Turf, paving, sand, concrete, timber, rubble, and different kinds of hard materials are used on constructed wetland parks. These materials are directly affecting to the micro-climate in surrounding areas. (Huang, Li, Zhao, & Zhu, 2008, p.8).

2. Objectives of the study

The primary objective is to, find out how the ground surface cover has an effect on the microclimate, according to the materials which are used for ground surface finishing such as rubble, interlock paving, concrete, soil, sand, lawn. Then to study the temperature and relative humidity (RH) variation of areas which are covered by above mentioned materials.

Another objective was to study the effectiveness of wind pattern over the microclimate.

3. Effects of Urban Cool Island and Water-cooling island (WCI)

As Du et al. (2016) mentioned, Urban Cool Islands (UCI) have great interest of mitigation of UHI and according to the previous researches verified that parks and greenspaces can provide UCI effects. A water body had exact water-cooling island (WCI) value. Wilson et al. (2003) mentioned that, a water body has high thermal capacity, low thermal conductivity, radiance (Costanza et al., 1998, Chang et al., 2007, and Cao et al., 2010, as cited in Du et al., (2016) and Zhou and Shu, (1994) found that a water body absorb less heat than buildings and other surfaces. Nevertheless, water area (WA) is a limited resource. Designing of water bodies can give a value to adjustment of micro-climate in landscape planning.

4. Outdoor thermal comfort and micro-climate

Thermal comfort of highly dense built area is different from that of highly vegetated park area. According to Gaspari & Fabbri (2017), outdoor thermal comfort depends on some inter-related factors such as characteristics of built environment, the relationship between materials and energy use, global climate change and local micro-climate.

5. Impact of Surface cover on air temperature

According to Johansson, Emmanuel, & Rosenlund (2004) mentioned that, concrete, asphalt and stone materials which have high heat capacity, absorbed solar radiation in urban surfaces will be stored in the material. Also, that study mentioned that, surface material properties have such a big influence over the urban climate.

The physiological equivalent temperature (PET) is a thermal index derived from the human energy balance and PET is preferable to other thermal indexes like the predicted mean vote because of its unit (°C) (Matzarakis, Mayer, & Iziomon, 1999). According to Deb (2010), PET can be calculated simply by the software RayMan, which is made freely available by its author.

The ground surface finish and surrounding area also affects the microclimate of a wetland. Build mass, water, and the roads are main factors of surrounding environment. The microclimatic conditions are also affected by the wind. The research question will be on whether the effect on the microclimate of a wetland is being affected by the ground surface cover and the surrounding area and if so, how the phenomena takes place.

Table 12, Ranges of the physiological equivalent temperature (PET) for different grades of thermal perception by human beings and physiological stress on human beings.
(Source: Matzarakis and Mayer, 1996)

PET	Thermal perception	Grade of physiological stress
4°C	Very cold	Extreme cold stress
8°C	Cold	Strong cold stress
13°C	Cool	Moderate cold stress
18°C	Slightly cool	Slight cold stress
23°C	Comfortable	No thermal stress
29°C	Slightly warm	Slight heat stress
35°C	Warm	Moderate heat stress
41°C	Hot	Strong heat stress
	Very hot	Extreme heat stress

6. Method and selection criteria of Urban wetland park, Nugegoda

Nugegoda is a highly urbanized suburb, situated near Colombo metropolitan region. It is a collection of commercial and residential buildings, and a densely congested and traffic struck road network. Different materials are used as a surface cover such as rubble and interlock paving, concrete and cement structures, lawn, sandy soil, and vegetation. The pilot study on this area shows extensive difference from ambient climate data. The park records higher temperature values.

An extensive difference can be observed with the materials that were used in the park. Front area is mainly covered by hard landscape materials than upper parts of the park. End portion of the park has been covered with concrete sleepers as ground cover (Figure 1, Place G). Middle part of the park shows no difference apart from the seating. The park is mainly divided into three zones known as Zone 01 (Place A, Place B, Place C), Zone 02 (Place D, Place E), and Zone 03 (Place F, Place G). Considering the surface cover and surrounding environment, the places are selected to collect the data in each zone. As shown in figure 1;

Figure 1, Three zones and data collected places called A, B, C, D, E, F, and G.

6.1. ENVIRONMENT OF ZONE 01, 02 AND 03

Front area of the park is named as a zone 01 (Figure 1). Different surface materials such as rubble, interlock paving, lawn, concrete and cement surfaces can be found. Place A (Rubble and interlock paving area), B (Concrete and cement surface area, water fountain area), and C (Lawn area) were selected according to above surfaces. The water fountain is in operation only within the hours of 1800H – 2000H daily. Middle part of the park is named as zone 02 (Figure 1). Water body acts as an immediate surrounding and the ground surface is compacted sand mix soil. The middle area of the jogging track is selected as Place D and junction which is located in end of the zone 02 is selected as Place E. Zone 03 is the end portion of the park. This area is mainly covered from vegetation, concrete sleepers and rubble are used as a surface cover in northern end of the park. In this zone, places are selected according to the surface material. Place F is covered with compacted sand mix soil area and Place G is covered with concrete sleepers and rubble area.

7.2. DATA MEASUREMENT PROTOCOL

The climatic data are taken from those sites along with 15-hour duration on 15th of July 2018, since 6 am to 9 pm. HOBO data logger (Temperature, humidity), Anemometer (Wind speed) are used to collect data. Data that are to be collected under outside data management are used as the input of the "RayMan Pro 2.1" software for thermal comfort calculations and Microsoft excel was used for data analyzing and forming graphs.

7. Field study at Urban wetland park, Nugegoda

7.1 VARIATION OF MICRO-CLIMATIC PARAMETERS IN ZONE 01

7.1.1 Directly proportional correlation among air temperature and wind velocity in zone 01

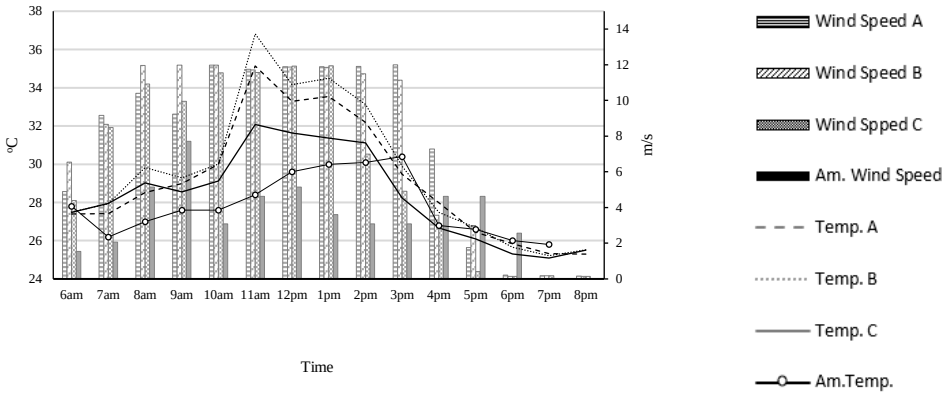

Figure 2, Temperature and Wind Velocity variation with ambient temperature and ambient Wind Velocity of Zone 01. Highest temperature is recorded as 36.81 ^{o}C in Place B

In Zone 01, wind speed is higher than the ambient wind speed. The graph indicates that from 6am to 10am, temperature of A, B, C places are rising up. The highest temperature is recorded at 11am. From 10am to 1pm, wind speeds of all three places are were recorded to be at their highest and the same scenario with temperature as well. After 3pm, the temperature and wind speed gradually begin to decrease. After 6pm, the wind speed is lower than 1m/s and the temperature has gone lower than the ambient temperature. This shows a correlation between temperature and wind speed in Zone 01.

7.1.2. Zone 01 records higher wind velocity values than the ambient

Figure 3 indicates that, there is lesser variation of wind direction. The wind directions are limited in between south-west and west-north-west. According to the ambient wind speed, highest wind speed is recorded as 7.72 m/s. But it was recorded 11.9 m/s as highest wind speed in zone 01. There is a 4.18 m/s difference among ambient and zone 01 wind speed values. In this situation, the local climatic effects are dominated than the global climate conditions. The pressure fields are created around the park. As a result, wind velocity is higher than the ambient wind velocity, around the park area.

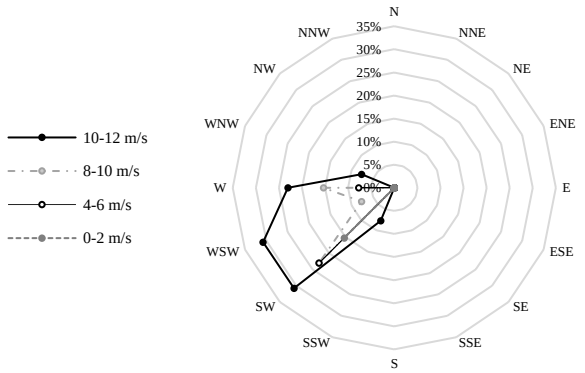

Figure 3, Windrose analysis of zone 01. Wind direction is south-west and 11.9ms^{-1} is the highest wind speed.

7.1.3. Impact of the ground surface cover on increasing air temperature in zone 01

The temperature values of places in zone 01 can be arranged as C < A < B (Lawn area < Rubble paved area < Water fountain area) according to the ascending order. Area is covered by rubble and interlock paving, near the main road and build mass, place B area is located in close proximity with the water fountain area and it is fully covered with hardscape materials such as concrete and cement surfaces and also, place B area is covered by lawn. Pattern of the temperature variation of place A and B are equal unlike place C, because, the materials of that places are equal unlike place C.

7.2 VARIATION OF MICRO-CLIMATIC PARAMETERS IN ZONE 02

8.2.1. Correlation among air temperature and wind velocity in zone 02

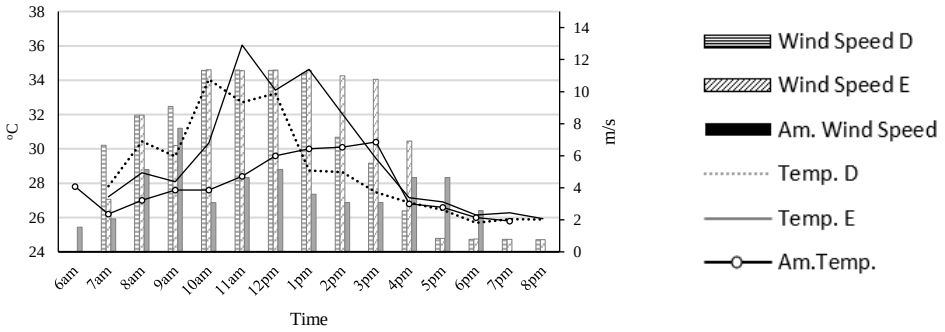

Figure 4, Temperature and Wind Velocity variation with ambient temperature and ambient Wind Velocity of Zone 02. Highest temperature is recorded as 36.05 °C in Place E.

Figure 4 indicates that from 7am to 10am, the wind velocity was raised up and the temperature also behaves according to the wind speed. At 9am, place E records 6.63 m/s and place D records 9.07 m/s as their wind speeds. Place D is higher than place E from 2.44 m/s. At that time, the air temperature records place E as 28.08 oC and place D as 29.56 oC. Place D is higher than place E from 1.48 oC. It shows that when the wind speed is high, the temperature also rises up in two places in same zone. After 1pm, place D wind speed shows a significant downturn until 5pm. The temperature of place D also began to decrease. The temperature is decreased by 6.77 oC. There is a directly proportional correlation among the temperature and wind speed after 1pm. After 4pm, all the temperatures are coming to a same value, but there is an extensive deviation among ambient and zone 02 wind speed values. Ambient wind speed is higher than the zone 02 wind speed. But there is an inversely proportional correlation among ambient temperature and wind velocity, and directly proportional correlation among zone 02 temperature and wind velocity.

7.2.2. Impact of wind direction to the air temperature in zone 02

Temperature in the Zone 02 is higher than the ambient. The wind has come from a direction in between west-south-west and west directions by crossing the build mass, water body area, and traffic struck area (Figure 4). Because of that, heat came attached to the air flow and it caused a rise in temperature of Zone 02. Thus, the rise of wind speed has no significant use over the park.

7.3. VARIATION OF MICRO-CLIMATIC PARAMETERS IN ZONE 03

7.3.1. Directly proportional co-relation with wind velocity and temperature of place G

The figure 5 indicates that there is an extensive difference between place F and place G wind velocity values. The figure 5 shows that the temperature pattern of both places are equal, but the levels of temperature values are different from each other. But after 10am, the pattern is changed. Wind velocity of place F was decrease by 5.88 m/s, but the temperature value of place F does not show any change in its pattern. But place G records highest temperature at 11am. At that time, the wind velocity of place G was also higher. It was recorded as 11.37 m/s.

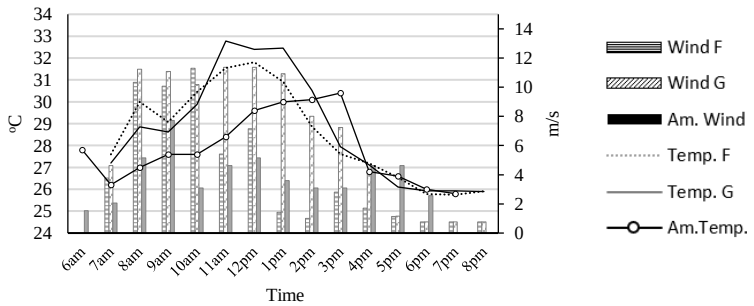

Figure 5, Temperature and Wind Speed variation with ambient temperature and ambient Wind Velocity of Zone 03. Highest temperature is recorded as 32.78 °C in Place G at 11am.

Within 11am to 1pm time period, the wind velocity and the temperature did not show any extensive variation in place G. The temperature of place G varied in between 32.78 oC and 32.39 oC. Wind speed varied in between 11.37 m/s and 10.93 m/s. After 1pm, wind speed of place G has begun to decrease gradually and be equal to place F wind speed at 5pm. Accordingly, wind velocity does not affect the temperature of place F. There is a co-relation with wind velocity and temperature of place G.

7.3.2. Impact of wind direction to the air temperature in zone 03

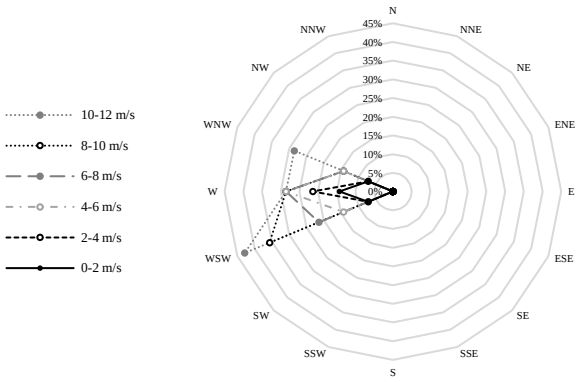

Figure 6, Windrose analysis of zone 03. Wind direction is west and 10.77 ms^{-1} recorded as the highest

Temperature of the zone 03 is higher than the ambient temperature (Figure 6). The figure 6, wind rose analysis indicates that the wind came from a direction in between west-south-west and west-north-west directions by crossing the build mass, water body area, and traffic struck area. Because of that, heat came attached to the air flow and it caused a rise in temperature of zone 03. The rise of wind speed has no significant use for the park. But when place F is considered, the wind velocity does not affect to the temperature. Most prominently, surrounding and surface cover affects it.

7.4. PATTERN OF THE TEMPERATURE VARIATION IN BETWEEN ALL ZONES IN THE PARK AND AMBIENT VALUES

There is an extensive difference in between zones in the park and ambient temperature patterns, but the zones show a slightly similar pattern. The levels of the temperatures are different from each other. The highest temperatures are recorded at 11am in all zones. Zone 01 and zone 02 has a low difference as 0.3 oC, but zone 01 and zone 03 has extensive deviation. It shows a difference of 2.52 oC. According to above statements, there is a significant temperature difference in between zone 01 and zone 03. The ambient highest temperature is recorded at 3pm, but the three zones of park has recorded the highest at 11am.

7.5. IMPACT OF SURROUNDING ENVIRONMENT, WIND SPEED AND DIRECTION TO THE UPSURGE OF RELATIVE HUMIDITY

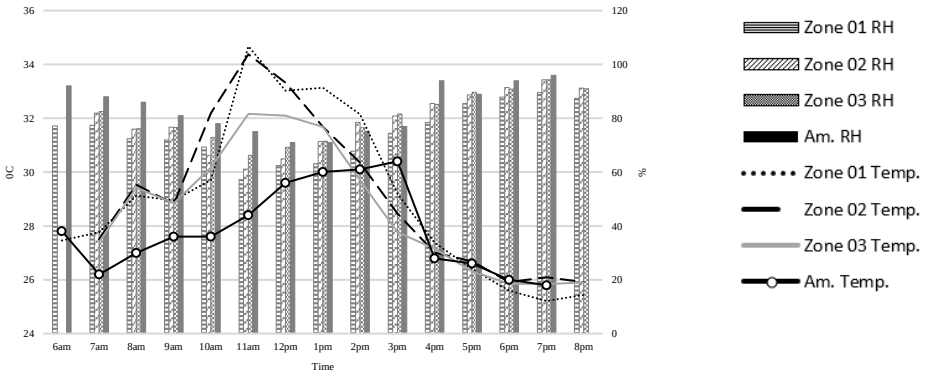

Figure 7, Temperature and RH variation of all zones in the park.

7.5.1. Behavior of temperatures

Results indicate that, the temperature of place F is independent from wind direction and wind velocity. The surrounding environment and ground surface cover are mainly affecting it. Marsh area, water body, trees and water plants act as the immediate environment. This has a negative effect on the wind flow. Because of that it caused to increase the RH level. The ground surface cover is the main cause to the temperature of place F. The pathway surface is covered with compacted sand mix soil. The place G surface is made by concrete sleepers and rubble. Generally, the specific heat capacity of concrete is higher than soil. (Johansson et al., 2004)

The Figure 7 indicates that the temperature of place G is beginning from a lower point than place F. But after 11am, place G temperature is higher than place F. It shows that, the place G is getting time to absorb heat than place F. According to above arguments, surrounding area and surface cover has a high influence over the variation of the temperature pattern of zone 03.

7.6. CORRELATION BETWEEN AIR TEMPERATURE AND WIND VELOCITY OF ALL ZONES

The wind velocities of all zones are different from each other. Zone 03 is recorded to have lowest wind velocity values. Wind speed of Zone 01 is higher than wind speed of zone 02. Then consider about wind speed values and temperature pattern of zone 02, a directly proportional co-relation can be identified. Within 8am to 10am time period, a subsidence of wind velocity values in all zones is seen. The temperature values also behave according to that variation. There is a directly proportional co-relation among the temperature pattern and wind pattern of the park.

According to the study, the wind is directed to the park from south-west direction. The wind came by crossing the build mass, and traffic struck area. Because of that, heat came attached to the air flow and it caused a rise in temperature of park, but zone 03 indicates lower temperatures than other two zones. There is vegetation in between build mass and zone 03. The wind came to the zone 03, after crossing that vegetated land. It can be suggested that, the vegetated land has acted as a buffer zone to the zone 03 (Figure 8).

Figure 8, Wind direction is coming to the park by crossing heat dense area.

7.7. THERMAL COMFORT OF THE PARK ACCORDING TO THE PET

Highest temperature is recorded at 11am and minimum temperature is recorded at 7pm of the park. Because of that, PET value is calculated to find the thermal comfort of the park, relative to the ambient. According to table 01 and figure 9, both ambient PET values are in between 230C and 290C. According to that, it has “Slight heat stress”

The park shows extensive difference from the ambient temperature. In the day time, all the zones are above 290C as a PET value. According to ranges of the PET values, it shows “Warm” as thermal perception and “Moderate heat stress” as grade of physiological stress. At the night time also, it is the same in zone 02 and 03, but zone 01 indicates “Slightly warm” and “Slight heat stress” level.

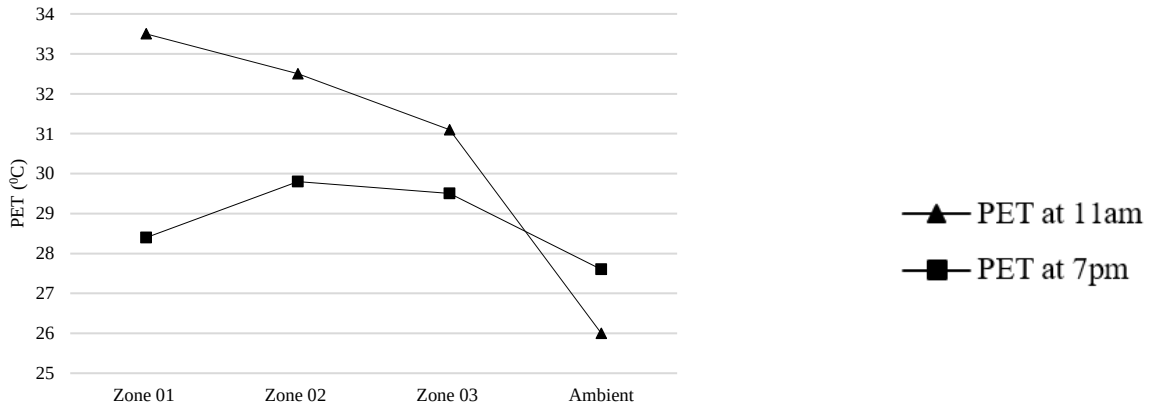

Figure 9, PET value of the park and PET value of the ambient

8. Conclusion

The analysis concludes that there are different temperatures recorded in different ground surfaces. All the temperatures of zone 01 are higher than the ambient. There is an inversely proportional correlation between ambient temperature and wind velocity, but temperature of all zones and wind velocity has a directly proportional correlation. Zone 02 has the same ground surface. But temperature pattern differs from each other. Also, humidity level of zone 02 is higher than zone 01 and place D is more humid than place E. It is because place D is surrounded by water than place E. It proves that though the ground surface cover is equal, temperature and relative humidity are influenced by surrounding area. Zone 03 is showing a different pattern of temperature variation than the two other zones and it records the lowest temperature in the park, however that is also higher than the ambient. When considering the surface temperature of the selected places, an inequality formula can be formed as below.

Lawn < Concrete sleeper paved area < Rubble paved area < Soil and sand mixed< pathway < Water fountain

Temperature

Wind is directed from south-west and wind came by crossing the build mass, and traffic struck area. Because of that, heat comes with the air flow. That is the cause to increase the temperature of park, but different surface covers are reacting against the increase of temperature. Zone 01 and 02 are directly influenced by surrounding build mass to increase the temperature, but average temperature of zone 01 is little bit higher than zone 02, becausesurface cover is different than zone 01. Temperature of Zone 03 shows an extensive drop down when compared with the two others. It can be suggested that, wind which came crossing the vegetated area is the cause to the reduction of air temperature of zone 03. That vegetated land act as a buffer zone to zone 03. According to the thermal comfort level of the park, it is in Moderate heat stress level in the day time. In all three zones, zone 03 shows the least stress level when compared with other zones.

The study shows that, surrounding area and surface cover are more important to micro-climate of a wetland park, which is located in an urban context. Ground surface cover has an effect over the increase of air temperature of the park. Surface cover is a factor that has affected the heat coming from the surroundings. A vegetated surface cover can give a positive impact to heat coming from surrounding. For future design proposals, it can be suggested that, if there is any park in an urban area, a buffer zone in between built mass and park and vegetated surface covers will be helpful to mitigate the heat coming from surrounding. Apart from this case study, there is a possibility for future researches to be conducted with the aim of finding whether other public parks of the country are within this comfortability level or not.

9. Acknowledgements

Dr. D.P. Chandrasekara, Archt. Janaka Dharmasena, Mrs.Umeshika Fernando of Arthur C. Clarke institute of modern technology, Prof. Shiranee Balasooriya, and Landscape Archt. Kowshika Gunasena

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