Evaluating the Phenomenon of Urban Heat Island Effect of Suhrawardy Udyan, Dhaka

Sabrina Rahman, Soniha Nuzrat, Ashrafun Nahar liza, Nawrin Mahmud

Abstract— Dhaka City, like other large cities, is warmer than surrounding areas due to the urban heat island effect, which is defined as an increase in urban air temperature as compared to surrounding suburban and rural temperature. The development of a heat island has regional-scale impacts on energy demand, air quality, and public health. Artificial urban land uses such as public open spaces, commercial and residential buildings, roads, and parking lots covered by impervious surfaces can contribute to the formation of urban heat islands (UHIs). Considering the increasing paved area with little vegetation cover in Dhaka, Bangladesh, this study evaluated the phenomenon for UHI effect of Suhrawardy Udyan, Dhaka. The recent scenario after the construction of Liberation War Monument project will be evaluated through an observational study. With the help of Metrological department of Bangladesh, a comparative observational study will be evaluated with the previous scenario before construction of the project. This study will help us to observe the phenomenon of Urban Heat Island effect in a public open space.

Index Terms— Dhaka Public space, Impervious surface, Public open space, Temperature, Urban Heat Island, UHI effect of Suhrawardy Udyan.

1 Introduction

The term "urban heat islands" refers to the observed temperature difference between urban environments and the surrounding rural areas. Observations have shown that the temperatures of urban centers can be up to 12°C higher than neighboring regions (Fig. 1) [1].

Three types of urban heat islands are distinguished:

- Surface heat islands: by measuring the infrared radiation emitted and reflected by surfaces, it is possible to identify the locations in a city where the surfaces are hottest;
- Canopy layer heat islands: the canopy layer is the layer of air between the ground and treetops, or roofs of buildings, where most human activity takes place;
- Boundary layer heat islands: the boundary layer is located above the canopy layer. Canopy and boundary layer heat islands refer to air temperature [2], [1].

The intensity of heat islands changes daily and seasonally as a function of the various meteorological and anthropogenic parameters. In general, the intensity of canopy heat islands is greater at night than during the day [3], [4].

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An urban heat island is created when naturally vegetated surfaces – e.g., grass and trees – are replaced with non-reflective, water-resistant impervious surfaces that absorb a high percentage of incoming solar radiation [12]. The development of an urban heat island is a time-varying process involving the physical geography and built environment of a metropolitan region [14].

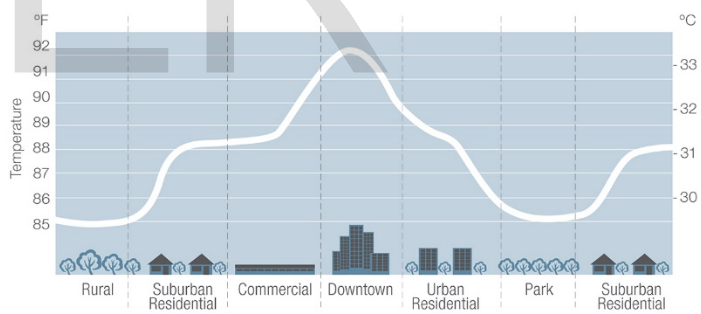

Fig. 1. Sketch of an Urban Heat Island Profile (Source: Lawrence Berkeley National Laboratory 2000)

In the presence of high moisture levels, vegetation plays a dominant role in surface cooling through evaporation and latent heat removed from soils and evaporation from plants (known as transpiration) [5]. In urban areas, where the fraction of the surface covered by vegetation is particularly low and surfaces tend to be water-resistant, potential surface cooling due to the loss of latent heat from vegetation and soil is reduced.

The rate at which solar energy is absorbed and reradiated depends not only on the physical properties of different surface types, but also on their configuration within the urban landscape, regional meteorology, and localized microclimate [3], [6]. This can lead to the formation of local 'hot spots', which may shift in space with diurnal and seasonal cycles, under particular meteorological conditions, and with land-use changes [11]. Thus, it could better be described as an 'urban heat island archipelago'.

Interactions between patterns of surface heating and regional meteorology determine the overall intensity of the heat island over space and time at each moment. In general, the intensity is greatest on calm, clear days in the pre-monsoon and monsoon.

On clear days, incoming short-wave radiation has a direct path to the surface. In this case, internal surface properties, such as heat capacity, play the dominant role in spatial surface heating differences. On cloudy days, a much larger percentage of incoming radiation is reflected, reducing surface heating. In this case, meteorological conditions tend to outweigh surface properties and the potential for urban heat island development will likely not be realized [7].

The addition of anthropogenic heat and pollutants from power plants, industrial processes, and vehicles into the urban atmosphere can further contribute to the intensity of the urban heat island effect [8]. Anthropogenic heat can directly raise near-surface air temperatures while air pollution increases absorption of radiation in the lower troposphere, often contributing to the creation of an inversion layer. The inversion layer not only prevents rising air from cooling at the normal rate, but also affects dispersion of pollutants that are produced in the urban area.

Although the heat island effect occurs throughout the year, its occurrence during the summer months is of particular public policy concern because of the association of higher temperatures with increases in air conditioning demand, enhanced air pollution [9] and heat-stress related mortality and illness [10], [12].

The urban heat island (UHI) phenomenon may cause air temperatures in cities to be 2–5 ^{0}C higher than those in surrounding rural areas [8]. Dhaka city is not different from this scenario. Particularly in the open public spaces while designing with impervious and reflective materials then the effect become worst. Suhrawardy Udyan, Dhaka, as a study area will be observer to understand the phenomenon before and after construction phase of the Liberation War Monument project. To evaluate the study last 15 years Temperature and Relative Humidity data has collected from Metrological Department, Bangladesh.

Findings of such studies can lead to formation of local standards of public open space surface material, which can result in mitigation of Urban Heat Island.

2 Methodology

2.1 Study Site

The study took place in Suhrawardy Udyan, which is located in Dhaka at 23.7329° N, 90.3983° E. This park consists of both paved & unpaved area which also includes a shallow water body. This kind of terrain diversity encouraged us to choose this place as our study site. It is one of the main green patches in the city. So, the temperature increase in this area can majorly affect the urban heat increase in Dhaka city.

Suhrawardy Udyan was formerly known as Ramna Race Course ground. Originally it served as the military club of the British soldiers stationed in Dhaka. It was then called the Ramna Race Course and later Ramna Gymkhana. After the end of colonial rule, the place – sometimes referred to as Dhaka Race Course was used for legal horse racing on Sundays. One can say that, the journey towards our independence as a nation started from here. There is a Mughal structure namely the Dhaka Gate and a centuries-old Hindu temple named Ramna Kali Mandir is in close proximity with the park. So historic and religious landmarks made this park more attractive to the urban citizens of Dhaka.

The park itself is 75 acre & we covered around 60 acres for our study purpose. Our study area contains "Museum of Independence, Dhaka" which is part of a 67-acre complex at Suhrawardy Udyan. There is a "Tower of Light" which is a 50-meter high tower composed of stacked glass panels. The museum is situated beneath the tower of light. A water body of the project reflects the whole tower but now is under potential threat as the local slum-dwellers use it for their daily needs. The museum's plaza area has a 5669 square meter of tiled floor.

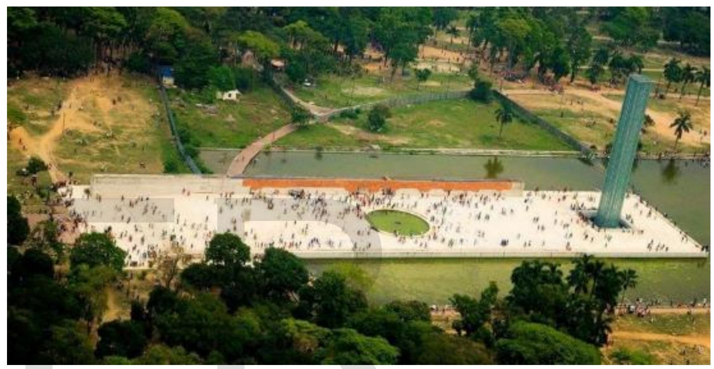

Fig. 2. Suhrawardy Udyan (Source: Real Bangladesh | The Carter Academy)

2.2 Methods

a. A systematic literature review was prepared on the impacts of Urban Heat Island (not presented here) and effectiveness of UHI mitigation measures, namely greening measures, urban infrastructure-related measures (architecture and land use planning), storm water management and soil permeability measures, and anthropogenic heat reduction measures.
b. The vegetation growth pattern in Suhrawardy Udyan changed its course over the years due to construction of the museum which will be discussed elaborately in the observation.
c. The design elements caused change in the landscape pattern. This created different temperature on different terrain which is observed during the study.
d. The major part of our study is to observe the temperature change over the years. We have collected this data from Bangladesh Meteorological Department.

3 Data Analysis

In this study, data from Bangladesh Metrological Department (BMD) has been collected to perceive the Urban Heat Island effect of Suhrawardy Udyan, Dhaka. The

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Metrological Department processed the data from their previous surveys. From the last 16 years of tremendous survey of BMD influenced this observation process very much. These data are collected for Sohrawardy Udyan from the climate division. The boundary of the study region is depicted in Figure 3.

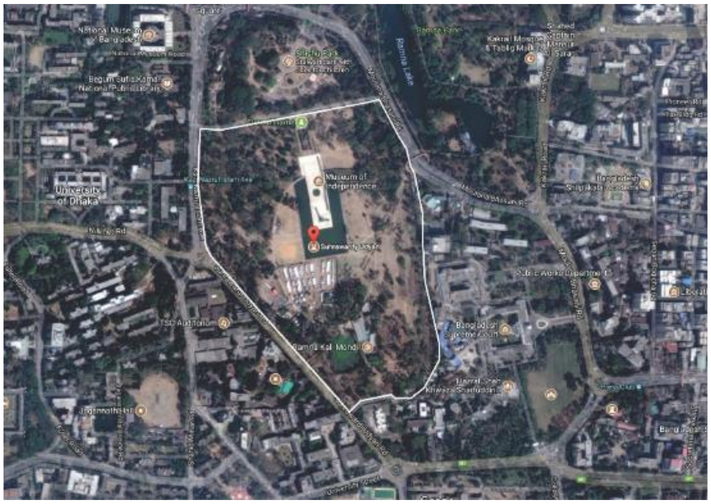
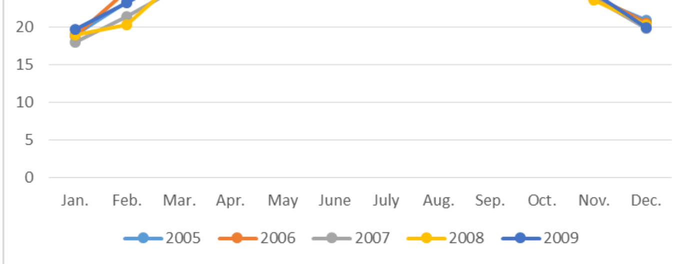


Fig. 3. Sohrawardy Uddan image (March 2014) of the study area. The white boundary line indicates the study area of the whole park premise. The study area is in the bustling city Dhaka. (Source: Google

Fig. 4. The Glass Tower of (a)Sohrawardy Udyan and (b) 'Shikha Chironton' (Source: Google)

The temperature data is collected from BMD of around 16 years. The thermal data of this area is observed by graph charts for different months in a year. Also, the data contains relative humidity along with the temperature to observe the whole scenario. Some measurement points were selected according to the climate division department to the exact geographic location for collecting data. The site is in the major location of the capital city Dhaka which is surrounded by so many busy traffic roads, the old high court building and the mausoleums of the three National leaders Sher-E-Bangla, Ak Fazlul Huq, Khwaza Nazimuddin And Huseyn Shaheed Suhrawardy to the south, Bangla academy, atomic energy commission, Bangladesh national museum, Public Library, and the Teachers Students Centre, Institute of Fine Arts and the main mosque of the university of Dhaka to the west, Birdem hospital, Dhaka club and Dhaka Tennis Complex to the north, and the Supreme Court, the institute of engineers, and the Ramna park to the east. Figure 4 shows the two important locations of the site. The temperature data is shown below in graphs along with the relative humidity table. The changes of the temperature in this area is small, and no significant difference is noted.

The average monthly and annual differences of all the points are calculated for each year. Base period for calculating temperature differences is 2001~2016. In the year of 2001~2004, From January to April the temperature is on increase which is up to 30deg Celsius and it continues in similar way up to October. After October in winter temperature decreases up to 19~20 deg Celsius. Focusing on the year 2005~2009, temperature increased in summer from April to October then it went down on winter season which is quite similar findings. Both increase and decrease of annual temperature of this area is significant in summer and winter season.



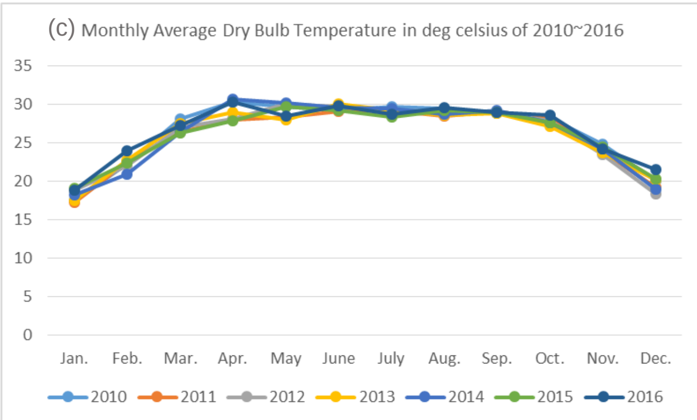


Fig. 5. Monthly Average Dry-bulb temperature in Degree-Celsius (a). 2001-2004, (b). 2005-2009, (c). 2010-2016

The monthly average dry-bulb temperature data of the year 2001-2016 is given below

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
2001	18.4	22.6	26.6	29.1	27.7	28	28.8	29.5	28.7	27.6	24.5	19.8
2002	19.7	22.6	26.2	27.6	27.8	28.3	28.5	28.6	28.9	27.4	24	20.3
2003	16.2	22.1	24.4	28.9	29.5	28.4	29.3	29.4	28.5	27.8	24	20.5
2004	18.2	21.8	27.1	27.8	30.4	28.5	28.6	29.1	27.7	26.9	23.4	21
2005	19	23.4	26.9	29	28.6	29.7	28.6	29	28.9	27	23.9	20.9
2006	18.9	24.9	27.4	28.6	29.1	29.1	29.2	29.1	28.5	27.9	24.3	20.6
2007	18	21.5	25.4	28.1	30	28.7	28.2	29.1	28.7	27.1	23.9	19.8
2008	19	20.3	26.6	29.2	29.3	28.7	28.5	28.8	28.9	27.1	23.7	20.4
2009	19.7	23.3	27	30.1	29.1	30.2	29	28.9	28.8	27.6	24.6	20
2010	17.6	22.3	28.2	30.4	29.7	29.3	29.7	29.5	28.9	28.3	24.9	20.1
2011	17.3	22.5	26.4	28	28.4	29.1	29.2	28.5	29.1	28.1	23.9	19.3
2012	18.9	22.1	27.1	28.1	30.1	29.7	29.1	29.2	29	27.9	23.5	18.4
2013	17.6	22.8	27.5	29	28	30.1	29.3	28.7	28.9	27.2	23.8	20.2
2014	18.3	21	26.5	30.7	30.2	29.6	29.5	28.8	29.2	27.7	24.3	19
2015	19.1	22.4	26.3	27.9	29.7	29.3	28.4	29.2	29	27.7	24.5	20.4
2016	18.9	24	27.3	30.4	28.5	29.9	28.8	29.6	29	28.6	24.2	21.6

Table 1: Temperature data used in the study

The relative humidity data is collected from the climatic division in %. The main period of the data collection is about 2001~2016. By comparing the collected data of these years of humidity the difference can be seen in this dense urban area. The information used for this study is given below.

2008	69	61	67	64	70	80	83	81	81	77	69	79
2009	72	55	53	66	72	74	80	82	81	73	66	69
2010	71	56	59	67	71	79	77	78	79	74	68	66
2011	69	54	57	64	76	80	79	82	77	73	67	73
2012	66	52	57	69	70	77	79	78	79	71	68	77
2013	65	55	55	63	78	76	77	80	81	78	66	72
2014	72	62	52	56	68	78	77	82	76	72	66	77
2015	70	63	52	68	71	77	81	79	78	73	69	68
2016	68	63	59	72	74	75	82	77	82	74	73	72

Table 2: Monthly Relative Humidity data of 2001-2016 in

The Relative Humidity is shown here in comparison of the year from 2001-2016. These graphs the showing the increase and decrease of R.H. in percentage %. From the year 2001~2005 significant humidity increases in the month of March in 20015 is noticeable. From 2006~2010 relative humidity increased from February to March. And in October month increased up to 80%. From year 2011 the Humidity decreased in the February month and gradually increased in July –September. In the year from 2001-2016 the change of the Relative Humidity is very low which varies in between 69-72% in average.

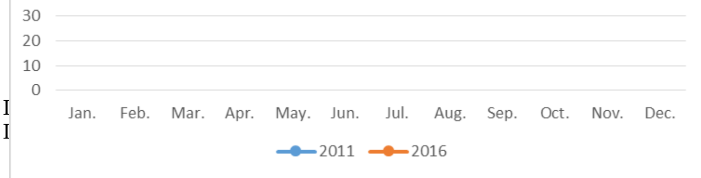


Fig. 6. The graph indicates the Relative Humidity in Percentage (%) (a) 2001-2004, (b). 2005-2009, (c). 2010-2016

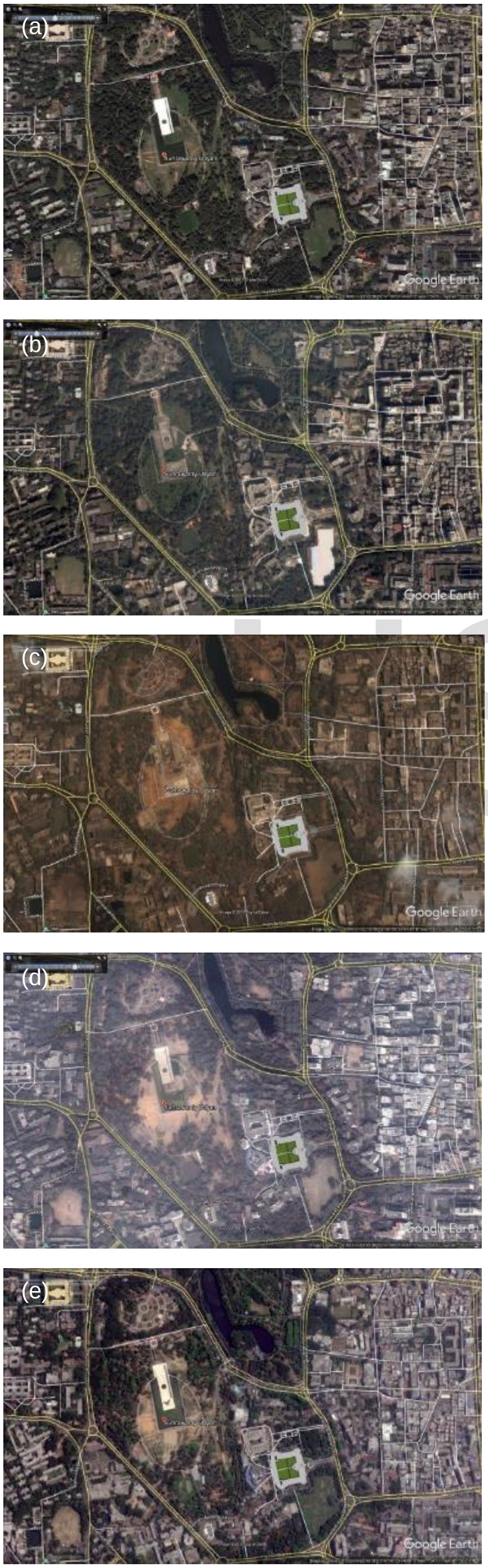


Fig. 7. a. 2001 (29.1°C), b. 2004 (27.8°C), c. 2008 (29.2°C), d. 2013 (29°C), e. 2016 (30.4°C) (Source: Google earth)

4 Observation

The temperature comparison is seen from the graph of figure 7 of year 2001-2004, which indicates that temperature differences are not much but its high in the end of year 2001. Temperature of that place in 2009 was on 20 degree Celsius where is was high on 2005. Also, the temperature was in kind of similar in 2010-2013. But in 2016 the temperature scale grew a little bit which is up to 21.6 degree Celsius. The Relative Humidity is shown here in comparison of the year from 2001-2016. These graphs the showing the increase and decrease of R.H. in percentage %. In the year from 2001-2005 there is no such significant variation which lies in between 70-72% around in the end. In the year of 2006-2010 the R.H. is almost same. Annually the R.H varies from 70-73% which is almost unnoticeable. In the year of 2011-2016 the R.H. is almost same. Annually the R.H varies from 69-73% which is almost unnoticeable.

Change in green coverage over time might explain the deviation of temperature through the year 2001 to 2016. All temperatures shown alongside the year of the pictures are Mean Dry bulb Temperature of the month of April of the respective years. It can be seen that whenever the green coverage is lost due to construction of the museum, the temperature reading is high. In 2001, 2013 and 2016 when the soil is exposed the temperature rose up to 2 degrees.

5 Conclusion

Suhrawardy Udyan is a part of Dhaka City, which Zareen A. Abedin (2013) identified to have UHI in her research [15]. This study has measured a maximum of 2^{0}C UHI (recorded on April 2016) by comparing the air temperature of the area in from 2001 to 2016.This paper evaluated the possibility of Urban Heat Island effect in Suhrawardy Udyan, Dhaka by analyzing the temperature and relative humidity variation over time with reference to its green coverage. The temperature has risen due to the lack of green coverage. So, the effect can be reduced by taking up greening measures surrounding the museum plaza. The cooling provided by vegetation may help ensure that some of these spaces will be used by the public [13].

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