IMPACT OF CITY GREEN ON SURROUNDING MICRO-CLIMATE CASE STUDY: WARRI - NARRINDA AREA, DHAKA

Rumana Rahman [1], Mohammad Moshfiqur Rahman [2]

[1] Architecture Department, Lecturer, Sonargaon University,

[2] Architecture Department, Lecturer, Sonargaon University, GP Ja-146, Wireless Gate,Mohakhali, Dhaka, Bangladesh

Email: [1] rumanaathik10@gmail.com, [2] explore.mrahman@gmail.com

Abstract

Dhaka, decades of rapid population influx has led to demands for rapid urbanization. With increase in housing across the cosmopolitan, there is a demand for urban open space across various peripheries in the city. This research documentation encompasses the heat island of a central region in Dhaka city, the Warri–Narinda Zone. Through satellite data and field survey, attention has been placed on the cooling effect of city's Green Areas, Temperature and Humidity measurements during the day and night time. This research was conducted in the surrounding green areas of Warri-Narinda, the Baldah Garden, The Christian Cemetery and the neighboring households, avenues, and the Primary Road with flyover, secondary roads with mutual shading of build form. The cooling effect and relative humidity was recorded across various locations and the results indicated the cooling effects of city greens are remarkable not only at vegetated areas but also the surrounding built environments. This research aimed to explore the role of the Green Area on moderating the Microclimate, and to determine the impact of City Green Area on its surrounding micro climate in context of high density; and to find out the cooling effect depending on the types of existing trees in the region. From the field survey, temperature and humidity measurements show significant fluxes in the temperature through urban neighborhood.

Keywords: impact,city green,micro-climate.

Introduction

Dhaka is the center of economic, social, cultural, educational development. These phenomenon poses Dhaka become the most populated megacity of Bangladesh. Contemporary Urbanization is at the peak in this tropical cites resulted in unplanned and uncontrolled development. To meet the rapid growing demand the city green are increasingly modifies into unplanned build area. The ignorance towards urban green area is significant in developing cities like Dhaka. Consequently, cities are mostly uncomfortable for its habitats comparing to its rural surroundings, known as 'Urban Heat Island Effect'. Such urban heat island intensity is proportional to population size and density (Oke, 1973, Gyr and Rys, 1995, Brazel et.al.2000).

UHI effect is worse in the summer of the tropics and it causes many negative effects such as it create uncomfortable warm environment within the city, mortality may result by heat stroke. City green plays a significant role in regulating the urban climate. Even a single tree can modify its microclimate. In cities minimum 25% forest area is mandatory for a healthy living (Mowla, 1984).

However, in Dhaka there is roughly 12% of open green area barely left. The existence of the green areas is one of the remedy against the temperature rising in urban environment and it acting as a cool island (Honjo, T., Narita, K.I., Sugawara, H., Mikami, T., Kimura, K. and Kuwata, N., 2003). The potential of city green influence environmental factors such as air temperature, relative humidity, airflow, solar radiation not only for its own but also its surrounding microclimate. Therefore, the aim of this paper is to reveal the impact of city green on its surrounding microclimate in terms of air temperature and relative humidity.

Statement of Problem

With the increasing demand of urbanization in Dhaka, importance of green area is a factor of ignorance. Large built area and use of extensive hard surface result in uncomfortable warm outdoor environment, which negatively influence human outdoor activities and comfort. To reduce the impact of urban heat Island effect and ensure human outdoor comfort cooling effect of city green is an important criterion in the high- density context. However, Dhaka is becoming very short in this significant matter of sustainability. To understand the cooling effect of city green area in terms of air temperature this paper focuses on two objectives;

- To determine the impact of city green area on its surrounding microclimate in high-density context.
- To find out the cooling effect depending on density and type of trees in the green area.

Literature Review

Cities have produced significant changes to the ambient climate (Landsberg, 1981), (Oke, 1982). The characteristics of the urban build form, surface material of build form and ground cover etc. affect the environmental factors that characterizing a climate (Ahmed, 1995). The replacement of urban green with the urban fabric results in significantly higher night time temperatures in built-up areas compared to the surrounding rural environment (Balling and Brazel 1987; Lowry 1967; Oke 1997). Urban heat island effect causes several negative effect to environment. The UHI effect creates uncomfortable warm environment that may result in heat stroke in residents of the cities, in addition UHI also worsen air pollution by trapping air pollutant within the city (Chang, C.R., Li, M.H. and Chang, S.D., 2007). Moreover, the energy consumption is at its peak in cities during the warm period due to uncomfortable high temperature at night.

Planting of vegetation in urban areas is one of the main strategies employed to mitigate the UHI effect, since greenery plays a significant role in regulating the urban climate. City green have cooling capacity to reduce air temperature and the effect is most profound in its surrounding area (Ahmed K. S. (1996). Trees and ground surface cover with vegetation in open space has low reflectance value that helps to reduce the air temperature in an urban surrounding. Vegetation does not radiate the long wave radiation, which helps to maintain lower air temperature. Evapotranspiration reduces air temperature and increases relative humidity

(Wardoyo, 2011). Tree shade also helps to reduce the air temperature (Zahoor (1997) a study in Pakistan found that urban green has significant influenced to local temperature and effective in reducing air temperature about 6 –7 °F.

A city in the forms of natural reserves, urban parks, neighborhood parks, rooftop gardens, and so forth, the energy balance of the whole city can be modified through adding more evaporating surfaces (Yu, C. and Hien, W.N., 2006). According to Wardoyo (2011), vegetation also influenced the pattern of air movementthrough guidance, filtration, obstruction and deflection. Air movement sometimes depends on green areas characteristic and configuration.

Evapotranspiration reduces air temperature that increases relative humidity. It is found that relative humidity is always higher in the green areas than any hard surfaces. Using outdoor comfort is an important part of urban context, where multidimensional activities are included. Urban open spaces are essential components of urban design in Tropics, where increasing built density is resulting in inadvertent environmental modifications (Ahmed, 1995). Visual and physical accessibility to open space is important to human welfare at the neighborhood scale as well as the individual parcel (Jackson, 2003). Insufficient greenery in urban area reduces the aspiration and opportunities for natural experiences of residents outside the build environment, which may result in several health hazards, behavioral problems, and social isolation (Lindheim and Syme, 1983). Lynch (2007) in her study in Canada, stated that public open space influences quality of life through physical, social and psychological health, and through economic and environmental quality.

The climate of Bangladesh, based on a wide range use of classification by Atkinson (Koenigsberger, 1973), and it is characterized as a composite monsoon climate. Generally, in Bangladesh has a short and dry winter and the summer is long and wet with heavy rainfall. Although a large part of land mass of Bangladesh is laid above the Tropic of Cancer.

The nature of the local climate being a tropical is attributed to the local geographical characters. The humidity is remaining high throughout the whole year in summer season and especially from the month of June to September and it is often over 80%. According to Hossain and Nooruddin meteorologically the climate of Bangladesh is categorized into four distinct seasons Winter (cool dry), Pre-Monsoon (hot dry), Monsoon (hot and wet), Post-Monsoon (hot and wet), where Winter months (December to February) temperature 21-26°C, Pre-Monsoon (March to May) temperature max 34°C, Monsoon (June to September) avg. 31°C, Post-Monsoon (October to November) temperature bellow 30°C (Ahmed, 1996). Average Relative Humidity is 60-80%. Radiation on a horizontal surface 5.00 kWh/ m2 and Air Flow 4.1 m/s (Ahmed, 1996). shown in Table 1.

Table 1. Classification of the seasons and weather condition of Bangladesh

Bangla Calendar Month	Traditional Seasons	Meteorological Seasons	Gregorian Calendar Months
Chaitra	Bashanta	Pre-monsoon (hot-dry)	March
Baishakh	Grisha	Pre-monsoon (hot-dry)	April
Jaishtha	Grisha	Pre-monsoon (hot-dry)	May
Ashaar	Barsha	Monsoon (hot-wet)	June
Srabon	Barsha	Monsoon (hot-wet)	July
Bhadra	Sharat	Monsoon (hot-wet)	August
Ashin	Sharat	Monsoon (hot-wet)	September
Kartik	Hemanta	Post monsoon (hot-wet)	October
Arahayon	Hemanta	Post monsoon (hot-wet)	November
Poush	Sheet	Winter (cool-dry)	December
Magh	Sheet	Winter (cool-dry)	January
Falgun	Bashanta	Winter (cool-dry)	February

Source: Ahmed, 1995

Dhaka experiences a hot, wet and humid tropical climate. Under the Köppen climate classification, Dhaka has a tropical wet and dry climate. The city has a distinct monsoonal season, with an annual average temperature of 25 °C (77°F) and monthly means varying between 18 °C (64 °F) in January and 29 °C (84°F) in August. In this monsoon period, torrential rainfall occurs and is recorded from 781 mm to 1499 mm in the Dhaka, with the average humidity above 80% and an average temperature of 31°C. The post-monsoon season remains between October and November month.

Types of vegetation and its impact on environmental factors

Herbs: Direct Solar penetration is high thus; air temperature is also higher than other open space. Herb can allow uninterrupted airflow and view. Generally, relative humidity is higher in vegetated area and it depends on the density of the herbs.

Shrubs: Shrubs provide small shading depending on its leaf area. It hinder the natural wind flow at human level. Relative humidity is higher at human level and depends on density. Sometimes create visual barrier and filter air. Air temperature is less in shaded area.

Trees: Trees provide great shading thus air temperature is much lower under the trees. Airflow is gentle at the human level thus provide instant comfort. Relative humidity is higher under the tree. Because of less direct penetration of solar radiation ground cover or herbs can nor grow in the soil.

Methodology

The methodology followed by this study can be divided in two steps:

Literature Review: To establish theoretical basis and identify knowledge gap, wide reading has been done for evaluating the cooling impact of green area on its surrounding environment from various recourses.

Field study: A field survey was done in the month of July in dense context of Warri-Narrinda area. This research is conducted based on this field study and the result we found is the present climatic data we describes in this study. Baldah Garden and Dhaka Christian cemetery are the two adjacent green area divided by a secondary road in Warri- Narrinda area selected for the field investigation. The environmental data were collected in Baldah garden and Christian cemetery at randomly selected spots in each direction with reference of boundary walls and the duration of data collection was 11:00 am- 3:00 pm. The spots or points of data collection were 1 meter above from the ground level by using Indoor/ outdoor thermometer with Hygrometer named Lutron LM 8102, accuracy of (±1). Air temperature and relative humidity measurements were the measuring parameters of this research.

Figure 1. Lutron LM 8102

Description of The Context

Warri –Narinda area is selected for conducting field survey. The area consists with chunk of green area in the high- density context. Which is also historically important place in Dhaka. Wari is a planned urban development from early 19th century. While Narinda is an establishment of pre-Mughal period. Both these areas are situated alongside the Narinda road. Although these two areas are now transformed with new and modern structures, some of the historical structures and natural artifacts still exist in these areas.

Figure 2: Study Area. Warri - Narrinda
Source: Author, 2017

Baldah Garden is one of the historical important natural infrastructure of Wari. Narendra Narayan Roy Chaudhury, property owner of the Estate of Baldah, established the garden on his own property in 1909.It acquires 3.15 acres of land. It is divided into two units. The larger unit is named Cybele after the Greek nature goddess of fertility. It is roughly rectangular, with the northern side slightly cutting a corner, and measures about 136 meters in length and 76 meters in width. The smaller unit, Psyche meaning ‘soul’, is approximately 100 meters long and 45 meter wide.

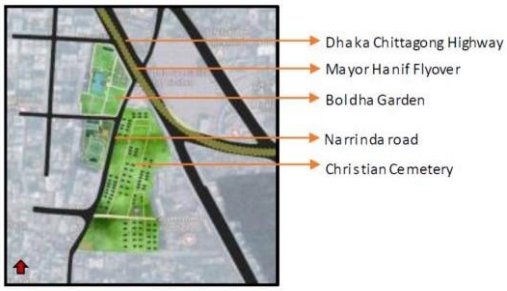


Figure 3. Study Area: Warri- Narrinda Source: Author, 2017

The garden is home to approximately eighteen thousand plants that are made up of more than eight hundred different species of exotic and indigenous plants. There are two sections to the garden, namely the Cybele and Psyche parts of the Baldah Garden. In the Psyche section, visitors will find the lily pond, the massive sundial and Sankandidhi amongst the varied selection of plants such as blue nympheas, climbing ivy, papyrus, aloes and Amajan lotus. Five hundred different trees can be seen in the garden, with four hundred creepers, over two thousand orchids, aquatic plants, cacti and beautiful ornamental trees. The plants that have been imported and collected from 50 countries.

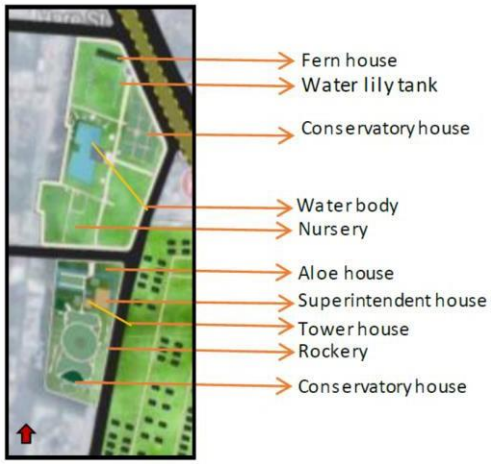


Figure 4. Baldha Garden
Source: Author,2017

Figure 5. Picture of Baldha Garden
Source: Author, 2017

The Christian Cemetery was developed mainly for the European traders and their families, thus most members of the East India Company lie buried there. Now Christian Cemetery is under the authority of Dhaka Archbishop and a restricted site. It acquires 7 acres of land surrounded by 8ft high wall. This old cemetery is full of colonial period graves; the oldest one is from 1725. The graves of many important figures from history are there.

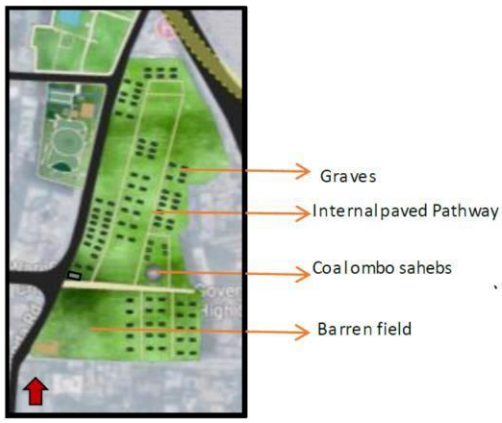


Figure 6. Dhaka Christian Cemetery
Source: Author, 2017

Figure 7. Picture of Dhaka Christian Cemetery
Source: Author, 2017

There is no church here or any other significant structure other than the tombs, one of them is ‘Colombo Saheb's’ tomb. Local Mahogany trees and some Rubber trees are the mostly planted beside the graves to provide shading. Ground of the cemetery is mainly covered grass and the unused landscape of the cemetery is an unplanned, for that reason the barren lands are occupied by creepers and ferns.

Data Analysis

Baldah Garden: Approximately 30 points are plotted with the reference of boundary wall to take the air temperature measurements, Fig: 5. The Highest temperature of Baldah Garden is measured at point 13(33.9°c) which is located near the nursery.

Figure 8. Top view of Baldah Garden Plotted points (1-30)
Source: Author, 2017

The lowest temperature of the garden is measured at point 16(30.4°c) which situated at the southwest edge of the garden. The average temperature is 31.83°c. Relative humidity was found highest (67%) near the water body (spot 8, 9 and 10) in the Baldah Garden.

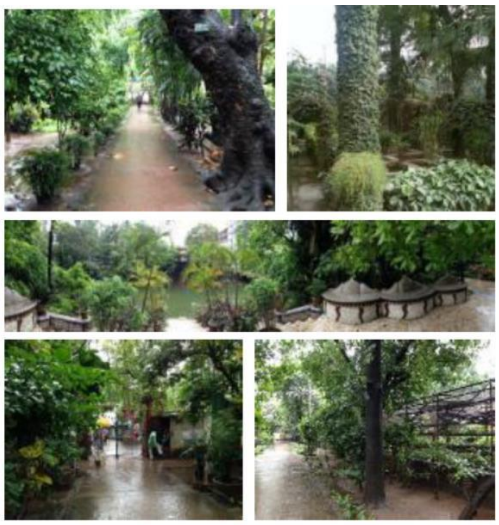
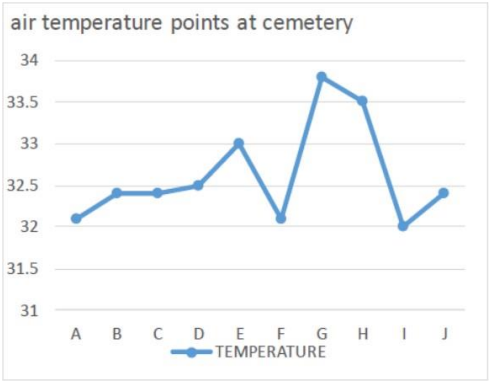
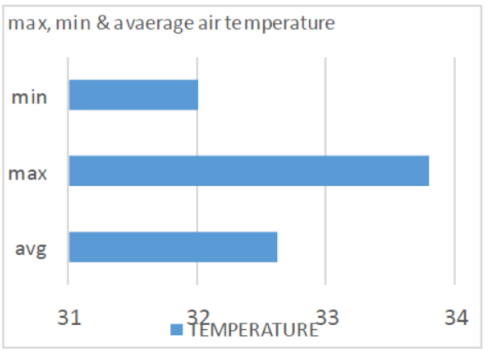


Figure 9. Image of Baldah Garden different Plotted points
Source: Author, 2017



Graph 01. Air temperature data diagram(Baldah Garden)
Source: Author, 2017



Graph 02. Maximum, minimum and average air temperature diagram(Baldah Garden)
Source: Author, 2017

The Roads: The primary road is adjacent to the site is 60 feet wide and the secondary road (Wari-Narinda) is nearly 20 feet wide. The connecting tertiary streets are very narrow, nearly 12 feet wide. The secondary road and the tertiary connecting streets don't have any pavement. The primary road have 3 feet wide pavement on both side. Highest temperature is measured at point 2(35.1°c) which is located at main road adjacent to the flyover .lowest temperature is measured at point 5(32.1°c) in Wari-Narinda road.

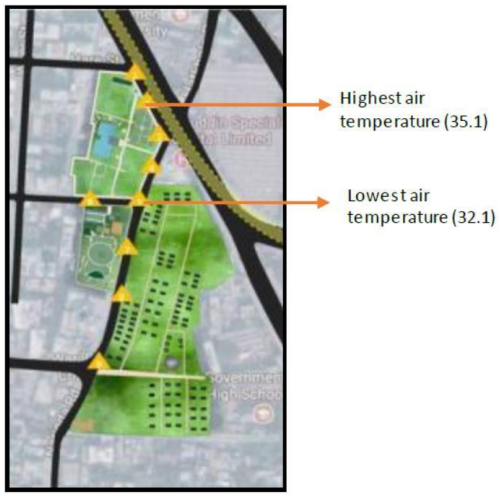
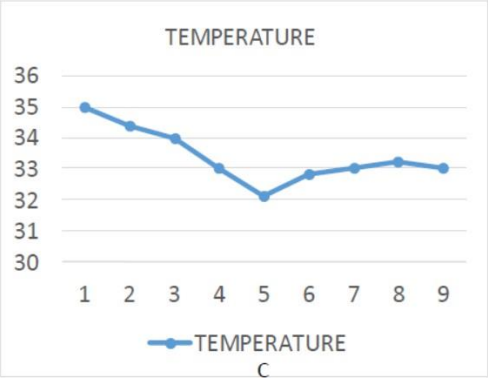
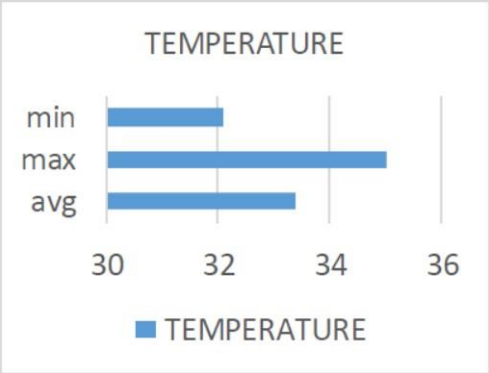


Figure 10. Top view of Cristian Cemetery, Plotted points (A-j)
Source: Author, 2017

Figure 11. Image of Cristian Cemetery different Plotted points
Source: Author, 2017



Graph 03. Air temperature data diagram (Cristian Cemetery)
Source: Author, 2017



Graph 04. Maximum, minimum and average air temperature diagram(Cristian Cemetery)
Source: Author, 2017

Results And Findings

City green has significant impact on its surrounding microclimate. Some finding from field survey can be described as;

1. The green chunk of dense Warri- Narrinda area showed significant temperature difference than surrounding build area. It can be address as Cool Island in middle of dense warm surroundings.
2. The Primary Road with flyover showed highest temperature, because of direct solar radiation penetration on hard surface. Secondary roads showed lower temperature than primary road because of the mutual shading of build form and cooling effect of Baldah Garden and Christian Cemetery. In addition tertiary roads shows lowest temperature difference due to mutual shading, cooling effect of both green area and road width. Relative humidity found lowest in the primary road because of direct solar radiation and vast use of hard surfaces.

Figure 12. Cool island effect of urban green
Source: Author, 2017

3. From field survey temperature and humidity measurements between Baldah Garden and Christian cemetery, Baldah Garden shows lower temperature and higher relative humidity; densely planted different types of Trees, Scrubs, and herbs and existence of water body are the main criteria of such findings. Wind flow is found minimal in the Baldha Garden.

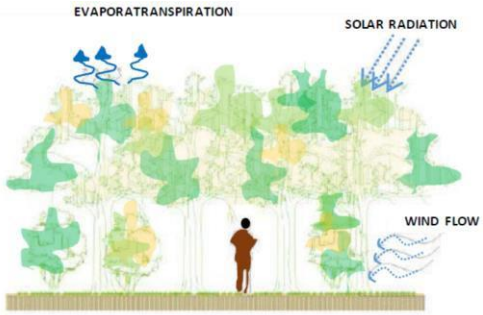


Figure 13. Impact of climatic parameter in Baldah Garden, Density of green
Source: Author, 2017

4. Types of trees (mostly local Mehegony and Rabar), less density of trees and existence of barren field are the reason temperature in the Christian cemetery found higher than Baldah Garden although the size of the Cemetery is larger than Baldah Garden. Relative Humidity is also found lower in the Cemetery because of density of the trees and direct solar radiation on barren ground. Wind Flow is better in the Cemetery than Baldha Garden.

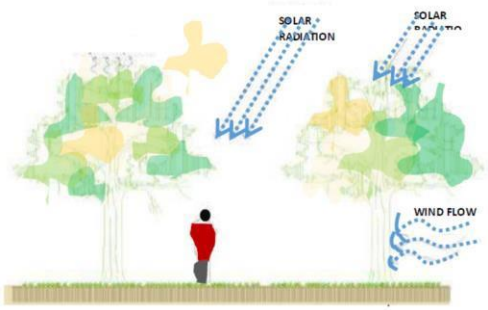


Figure 14. Impact of climatic parameter in Christian Cemetery, Density of green
Source: Author, 2017

Scope And Limitations

1. The study can be done in different parts of the city on various City Park, Garden landscape, etc. and it could conduct in different seasons and times of the day.
2. The field investigation is operated in the summer season (July). The results may be completely different in the other seasons of the year, as Bangladesh has wide variations of seasons. Therefore, the findings from the study would not be applicable for round the year.
3. The sky condition was a little cloudy sometimes while taking the temperature data from different points. Therefore, changing pattern of the temperature in different point is not static.

Conclusion

Urban green space plays a vital role to regulate urban climate. Creating urban green spaces is an effective temperature mitigation strategy for many tropical cities. In City like Dhaka, where the inhabitants face hot and humid climate for most part of the year; urban green plays a noticeable difference to ensure outdoor comfort. Moreover, urban green has great potential to reduce air temperature 3°C- 4°C and create cooling effect not only at the own green area but also on its surrounding build area. Types of green, configuration of the area, density of the green, context of the green are the key determining factors to get benefit from urban green in the urban landscape design. Importance of city green and its impact on regulating micro-climate is unavoidable for sustainable living.

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References

Ahmed K. S. (1995). Approaches to Bioclimatic Urban Design for the Tropics

with Special Reference to Dhaka Bangladesh, PhD Research

Ahmed, Z.N., 1994. Assessment of Residential Sites in Dhaka with respect to Solar Radiation Gains, unpublished Ph. D. De Montfort University, Leicester. p90.

Ahmed, Z.N., 2003. Natural ventilation

Chang, C.R., Li, M.H. and Chang, Chen, L. and Ng, E., 2012. Outdoor thermal comfort and outdoor activities: A review of research in the past decade. Cities, 29(2), pp.118-125.

Declet-Barreto, J., Brazel, A.J., Martin, C.A., Chow, W.T. and Harlan, S.L., 2013. Creating the park cool island in an inner-city neighborhood: heat mitigation strategy for Phoenix, AZ. Urban Ecosystems, 16(3), pp.617-635. ENGINEERING (BHRC), 17(3), pp.357-371.

Evaluation of urban heat islands mitigation strategies using 3dimentional urban micro-climate model ENVI-met. ASIAN JOURNAL OF CIVIL in dense residential areas: studying alternatives. Department of Architecture, Bangladesh University of Technology, Bangladesh.

Kleerekoper, L., van Esch, M. and Salcedo, T.B., 2012. How to make a city climate-proof, addressing the urban heat island effect. Resources, Conservation and Recycling, 64, pp.30-38.

Koenigsberger, O.H., Ingersoll, T.G., Mayhew, A. and Szokolay, S.Z. (1978). Manual of Tropical Housing and Building; Part One; Climatic Design. London: Longman.

Maleki, A. and Mahdavi, A., 2016.

S.D., 2007. A preliminary study on the local cool-island intensity of Taipei city parks. Landscape and Urban Planning, 80(4), pp.386-395.

SM Humayun Kabir (2012), "Baldah Museum", in Sirajul Islam and Ahmed A. Jamal, Banglapedia: National Encyclopedia of Bangladesh (Second ed.), Asiatic Society of Bangladesh.

Tariq, T. and Arch, M., An ENVI-met Simulation Study on Urban Open Spaces of Dhaka, Bangladesh.

Tuli, S.M. and Islam, N., 2014, December. Impact of vegetation in urban open spaces in Dhaka City; in terms of air temperature. In 30th International PLEA Conference.

Wardoyo J, (2011) “Vegetation Configuration as Microclimate Control Strategy in Hot Humid Tropic Urban Open Space”

Zahoor, A. (1997) Effect of Trees in Ameliorating Air Temperature in Urban Setting in Pakistan, Dissertation unpublished, University of Idaho.

Zia Uddin Ahmed (2012). "Baldah Garden". In Sirajul Islam and Ahmed A. Jamal. Banglapedia: National Encyclopedia of Bangladesh (Second ed.). Asiatic Society of Bangladesh.