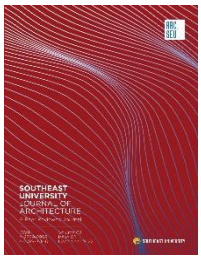

SEUJA,VOL. 2, NO. 2, DECEMBER. 2022, PP. 36-46

ARC. SEU

Southeast University Journal of Architecture

Journal homepage: www.seu.edu.bd/seuja

Study on the Energy Consumption Pattern in Reference to Local Climatic Zone (LCZ) and Urban Microclimate of Dhaka City

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ARTICLE INFORMATION

Received: November 11, 2022
Revised: Fabruary 26, 2023
Accepted: March 03, 2023
Published online: May 16, 2023

Keywords:

LCZ of Dhaka city,
electric consumption pattern,
urban microclimate

ABSTRACT

More than half of the world people resides in urban areas and consumes three fourth of the global energy. This erratic pace of urbanization and high population growth is the key issues to global energy crisis. This paper aims to inspect energy consumption patterns referencing LCZ areas of Dhaka city by conducting several steps. It uses area wise energy consumption for two consecutive years, land use pattern of the selected area, Qgis simulation to identify different LCZ and population density and microclimatic analysis of selected area using EnviMet software. The study is carried out in Tejgaon, a mixed use zone of Dhaka city which is commercial, institutional and industrial use dominated. The findings showing that high population density, high buildup area and land use pattern have direct impact on increasing energy consumption of any particular urban area. They also impact on outdoor microclimate parameters. The radiation balance, energy budget and water balance also remains unsuitable in dense, highly populated urban area like Tejgaon. Through this study it is evident that urban planning has a significant impact on transforming built environment pattern as well as population concentration of a particular area which leads to high energy consumption of that particular area and might lead to uncomfortable microclimatic situation outdoor.

1. Introduction

Only 40% of the 160 million people of Bangladesh have access to electricity [1].World's 55% population lives in urban areas today [2] and 75 percent of global primary energy is devoted to run urban areas [3]. Bangladesh is having 38.18% urban area by 2020 and capital Dhaka has faced rapid urbanization for last two decades [4, 5]. About 40 to 45 percent of the nation's total electrical production is used in Dhaka [1]. With the rapid population growth and urbanization, land use pattern of Dhaka city has got diversified variations [6]. Land use pattern has very close relation to the energy consumption pattern [7]. Because the land-covered character and land-use patterns inside the city produce an urban heat island. Many researchers have been carried out to look at the variables affecting energy consumptions and some of them [8-18] found out urban heat island effect increases energy consumption. Urban heat island effect and global warming, is rising urban temperatures. According to the report, almost 75% of Dhaka city's electricity use is dependent on temperature. As stated by the study, Dhaka city may reduce its power consumption by 81 MV with a 1°C drop in air temperature. For cooling purposes, it uses a considerable quantity of electricity [1]. Another fact is, within 415.16 km2 area of Dhaka city, sixteen million people dwell [1]. Yet, a sizable portion of its population is growing every day. Study has found that population growth is the main cause of the rise in temperature and, thus, the need for more power for cooling [1]. Land use pattern guides the built up area of a particular urban space. The built structures and landscape characterize the local Climatic Zones (LCZ) [19]. Hence the electricity consumption patterns are co-related the LCZ of a city [20].

Here the research question is do the changes in the built environment that characterizes Local Climatic Zone (LCZ) create any impact on the local microclimate therefore on the

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ISSN No.: 2789-2999 (Print), ISSN No.: 2789-3006 (Online)

energy consumption pattern of that zone. This particular research intends to search the correlation of energy consumption pattern with reference to population density and LCZ that comes from land use pattern and creates outdoor microclimate. For the growing energy crisis worldwide as well as in Bangladesh it is crucial to analyze the factors enhance energy consumption.

The study is conducted in Tejgaon area that is settled in the central part of Dhaka city [Fig 1, 2]. As outlined in the 1959 Dhaka city master plan, Tejgaon moved from a peripheral location to become the center of enormous industrial activity in order to meet the demands of the expanding population. The physical qualities of the area have changed from the state as it was intended by Dhaka Improvement Trust (DIT) in 1968 due to ongoing changes in land uses. The People's Republic of Bangladesh's administration recently decided to develop the area as a commercial and residential hub [21]. Tejgaon industrial area for its central location, continuous changes in its land use pattern with the growing population and for its growing demand of energy has been chosen as the research ground.

2. Literature Riview

The LCZ scheme is a tested classification method that has been used in the comprehension and assessment of thermal environments [22-25].The LCZ system's rational design directs modifications to urban planning, or the built environment, which impacts the urban microclimate outside due to radiation balancing and local heat rejection from neighboring buildings. By doing this, the prospect of many LCZs exhibiting diverse patterns of energy use is created. Therefore, based on microclimatic guidelines, it is crucial to assess the energy consumption patterns of buildings throughout different zones of a city [26].

A limited number of studies have also evaluated building energy usage patterns using the LCZ technique [27, 28]. Thus, it is imperative to investigate and is of considerable interest to the scientific community how building energy consumption changes in response to intra-urban temperature variation at the city level. The goal of the current study is to examine the summertime energy consumption patterns in established LCZs throughout a normal working day (daytime) in Tejgaon, Dhaka, and a tropical South Asian city. The energy consumption pattern was evaluated with land use mapping, population, built structures and urban microclimatic study at outdoor level [29].

A key issue for city development is the rise in energy demand. According to several assessments, a sizeable portion of the world's energy resources are utilized to regulate the indoor conditions of buildings. Energy consumption is controlled by urban microclimate, and urban microclimate is influenced by urban settings or urban morphology, which is a factor that is frequently overlooked [30]. Urban design has the potential to reduce the amount of energy used in a tropical city like Dhaka by modifying the built environment and microclimate.

Fig 1: Master plan of Tejgaon area

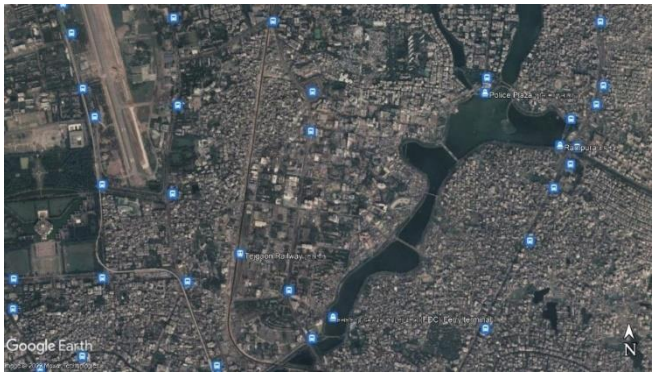


Fig 2: Google map of Tejgaon area

Energy needs space to be produced and distributed, according to recent studies. Therefore, if energy data is specialized and examined in relation to other geographical and environmental aspects, the chance for novel insights and the understanding of new causal relationships are increased. There are very few studies that link these spatial patterns to energy usage.

Urban microclimate: The local climate found in urban areas, which can differ greatly from the climate of the nearby rural areas, is known as the urban microclimate. [31].

Thermal comfort: The contentment with the thermal environment is expressed by that mental state. Outside of comfortable conditions, discomfort exists and is determined by the intensity and duration of thermal stress. [31].

There are four environmental factors that determine comfort. They are:

i. Air Temperature (T_a)
ii. The Mean Radiant Temperature
iii. Air Velocity
iv. The Relative Humidity (R_h)

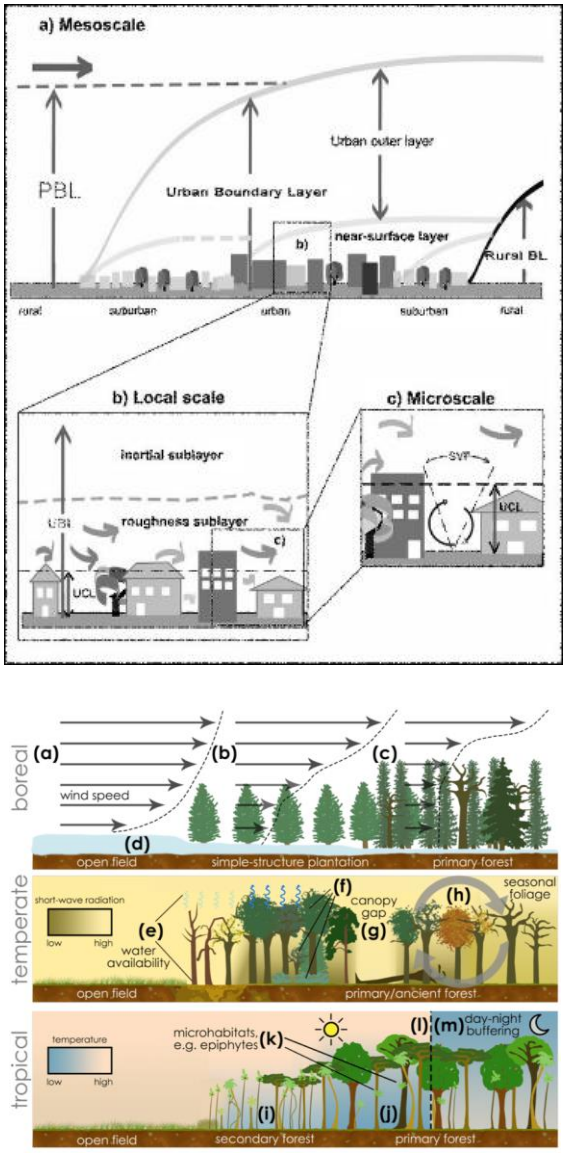


Fig 3: urban boundary layer and multiple vegetation drivers

Outdoor thermal comfort: The heat perception of pedestrians on streets is significantly impacted by the urban microclimate. Numerous factors, including respondents' individual characteristics, psychological and behavioral traits, and cultural backgrounds, may affect how much of an impact something has [32]. The microclimate of high-density cities in the tropics is quickly deteriorating as a result of global warming, the heat island effect, air pollution, and dwindling green areas.

In the high-density, tropical metropolis of Dhaka, Sharmin et al. (2019) have conducted a study on outdoor thermal comfort through field surveys, combining detailed microclimatic monitoring with pedestrians' subjective reports. This study began with an examination of the urban form's influence on the microclimate before determining how physiologically equivalent temperature, or PET, affects thermal perception and other factors including acceptability. Air temperature, globe temperature, and mean radiant temperature are the most crucial variables (correlation coefficients of r = 0.47, 0.45 and 0.44 respectively) [33] in the microclimatic conditions, which are influenced by urban geometry, and are found to statistically connect with Thermal Sensation Votes (TSV). For the tropical climate of Dhaka city, this study also created a summer PET (Physiologically Equivalent Temperature) scale.

Thermal sensation	Acceptable PET range for Dhaka (^{0}C PET)	Acceptable air-temperature range for Dhaka (^{0}C)
Cool	23.5 – 26.5	24 – 27
Slightly cool	26.5- 29.5	27 – 30
Neutral	29.5 – 32.5	30 – 33
Slightly warm	32.5 – 35.5	33 – 36
Warm	35.5 – 38.5	36 - 39
Hot	> 38.5	> 39

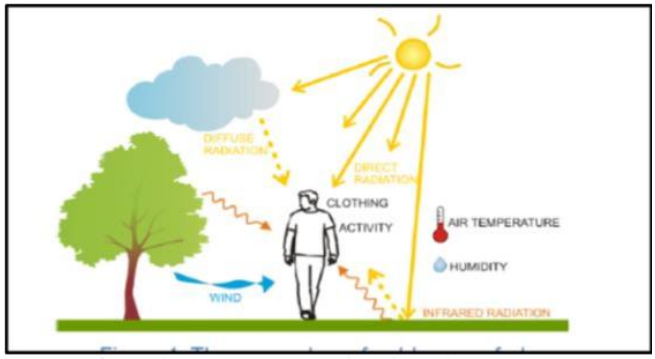


Fig 4: Summer PET classification for Dhaka (Sharmin et al., 2019) and the parameters of outdoor thermal comfort

According to research, roadways with a high percentage of trees are much more comfortable and have physiological equivalent temperatures (PET) that are lower than those with fewer or no trees. The frequency of strong heat stress ($PET > 35$ °C) was 64%, 11%, and 0%, respectively, for streets with low, medium, and high tree cover [34].

Outdoor thermal comfort (OTC) in tropical cities:

Tropical cities are distinguished by consistently high temperatures, a narrow range of daytime temperatures, and high nighttime humidity [35]. This compromise between a drop in temperature and a rise in humidity required proper evaluation to get the advantages of urban greenery generally. With a comprehensive thermal comfort index that is sensitive to changes in humidity, such as the Universal Thermal Climate Index (UTCI) or the Modified Physiologically Equivalent Temperature, OTC should be assessed throughout the diurnal cycle and under various climatic circumstances [35].

A tropical monsoon climate, such as in Southeast Asia regions, is typically characterized by high temperature and humidity throughout the year [36]. The deterioration of

the urban thermal environment is a serious issue. In minimizing solar radiation from the sun, landscape can really modify the microclimate. The most important landscape elements, that can have the greatest influence on solar radiation in landscape, are woody plants and solid structures.

According to Schimdt (1979), a single layer of leaves, when exposed to solar light, will typically absorb 80% of incoming visual radiation, while reflecting 10% and transmitting 10%. According to Kotzen (2003), a tree's canopy casts shadows, and these shadows signify a decrease in the downward flow of energy, particularly of visible light and solar infrared radiation.

In tropical country, wind is one microclimate indicators that is highly influenced by landscape elements and has an impact on both human thermal comfort and building energy use and many other things in the landscape. It is a crucial factor to take into account while designing a landscape for microclimate. Heat might be carried away from people and buildings by the wind [36].

According to Brown (1995), landscape features and design often have little impact on air temperature and atmospheric humidity. The dense shade of trees and large amount source of water plays an important role to give a good design impact throughout the whole tropical urban microclimate. For some reason, both landscape elements are basics entity in giving a good tropical microclimate environment. In general, any modification in terms of humidity will be very quickly dissipated by air movement (wind). In an area of already high humidity such as our tropical country, it would be difficult and inadvisable to increase humidity. However, it can increase by having a source of water, such as a pond, or through transpiration from plants. As the water evaporates, it utilizes heat from the air and therefore cools the surrounding air.

In figure 05, outdoor conform zone in Dhaka during summer season has been shown [37].

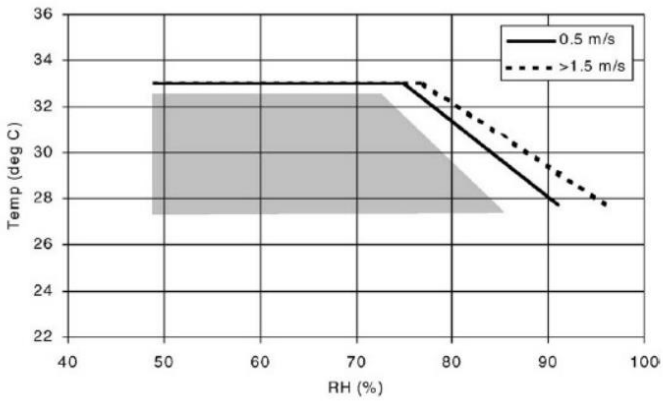


Fig 5: Outdoor conform zone in Dhaka Bangladesh (Source: Ahmed, 2003)

3. Aim and objectives

- The aim of this study is to explore the possible co-relation between local energy consumption data of Tejgaon area with its land use pattern and urban morphology considering LCZ of Dhaka city.
- The objective of this research is to search for the relation between the microclimatic factors within the particular LCZ with thermal comfort and energy consumption data.

4. Methodology

For this research, the energy consumption data of different areas of Dhaka city has been collected from DPDC (Dhaka Power Distribution Company). The field survey map of DPDC including the electricity feeder zones also has been collected from DPDC website. Then the feeder zones have been identified on Dhaka city Google map by juxtaposing the DPDC survey map. After that, the feeder zone area of Tejgaon area and its energy consumption data has been extracted for further analysis of this research. The land use map of the study area has been also collected from DAP (Detail Area Plan) of Dhaka city. The Qgis software along with Urban Multi scale Environmental Predictor (UMEP) plug-in has been used to generate the LCZ of Dhaka, population density, radiation balance, energy budget and water balance.

Surface Urban Energy and Water Balance Scheme (SUEWS), a land-surface model, has been used in Qgis to simulate energy exchanges in the city. SUEWS allows the energy and water balance exchanges for urban areas to be modeled [38-40]. SUEWS has been used within UMEP to the model and simulation process. Model output from SUEWS (simple) is radiation balance, energy budget and water balance. Within UMEP Processor, Urban Energy Balance (SUEWS/BLUEWS, Advanced) has been used to generate Morphometric Parameters for vegetation. UMEP Pre-processor with SUEWS Prepare has been used with Polygon grid frames to generate population density. In Urban Energy Balance, SUEWS and WUDAPT has been used for vector grid generation. After vector grid generation, UMEP Pre-Processer within Spatial data under LCZ converter has been used with LCZ raster image. These LCZ output generate the buildup condition, population density mapping and open street mapping of Dhaka city.

The microclimatic parameters such as the air temperature and the relative humidity of the study area have been generated from field survey and EnviMet simulation. Finally, the analysis and findings have been done considering the relations among energy consumption, land use pattern, LCZ and thermal comfort.

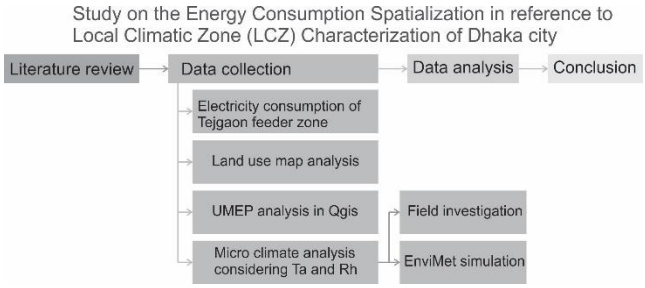


Fig 6: step by step methodology

Data Accumulation and Observations:

Land use of Tejgon:

Thirty percent of the Dhaka city area is mixed use development [Fig 7]. The land use map indicating a large amount of mixed use development in the study area [Fig 8] which is mostly commercial with some residential area revealed from the field survey data.

সারণি ২.১.৪৫: ঢাকা উপ-অঞ্চল ১১ এর বিদ্যমান ভূমি ব্যবহার

উপ-অঞ্চল	ভূমি ব্যবহার শ্রেণিবিভাগ	এলাকা (একর)	এলাকা (হেক্টর)	শতাংশ (%)
ঢাকা উপ-অঞ্চল-১১	মিশ্র ব্যবহার	৫৫৩.১১	২২৩.৯৩	৩০.৩৯
	আবাসিক	৪৭৪.১৪	১৯১.৯৬	২৬.০৫
	পরিবহন ও যোগাযোগ	২৮১.১৩	১১৩.৮২	১৫.৪৫
	জলাধার	১৩১.৪৯	৫৩.২৩	৭.২২
	প্রাতিষ্ঠানিক/প্রশাসনিক	৯৯.৪৬	৪০.২৭	৫.৪৬
	স্বাস্থ্যসুবিধাসমূহ	৬৭.৮৭	২৭.৪৮	৩.৭৩
	শিক্ষা ও গবেষণা	৬২.১৬	২৫.১৭	৩.৪২
	বাণিজ্যিক	৫০.০০	২০.২৪	২.৭৫
	শিল্পকারখানা	৩৪.৯৬	১৪.১৫	১.৯২
	সংরক্ষিত	৩২.৩১	১৩.০৮	১.৭৮
	উন্মুক্ত স্থান	২২.৬৭	৯.১৮	১.২৫
	সামাজিক সুবিধাসমূহ	১০.৬৮	৪.৩২	০.৫৯
	অব্যবহৃত জমি	০.০৯	০.০৪	০.০০
	সর্বমোট	১৮২০.০৭	৭৩৬.৮৭	১০০.০০

উৎস: পরামর্শক প্রতিষ্ঠান কর্তৃক পরিচালিত ফিজিক্যাল ফিচার জরীপ, ২০১৬-১৭ থেকে প্রাপ্ত।

Fig 7: Land use of Dhaka city (source: DAP)

Energy consumption Pattern of Tejgaon area:

DPDC (Dhaka Power Distribution Company) has divided Dhaka city into some feeder zone for it operation suitability [Fig 6]. From these feeder zones the study area Tejgaon is identified [Fig 7] and electricity consumption data has been collected.

This particular study looked into the energy consumption pattern of the study area in relation to its population density. In the table 1, electricity consumption pattern of the area has been shown for the last six financial year basis.

Population of Tejgaon area:

According to detail area plan (DAP) the population of Tejgaon area is 3lakh 69 thousand and the population density is 203 people per Acre [Fig 9].Therefore it is highly dense area and with the changing urban morphology of added commercial high-rise buildings the population of the site will further increase. It can increase the energy demand accordingly.

- During FY 19-20 electricity consumption dropped significantly during covid lockdown period.
- During Covid and 'locked-down' situation, mixed use commercial buildings consumed less electricity.
- It is also observed that the consumption rate in last three years (FY 20-22) has gone far beyond the previous rate (FY 17-19) [Table 2, Fig 12] due to over commercial use after lockdown. This situation might be aggravated with increased population and added commercial high-rise along with cooling load.

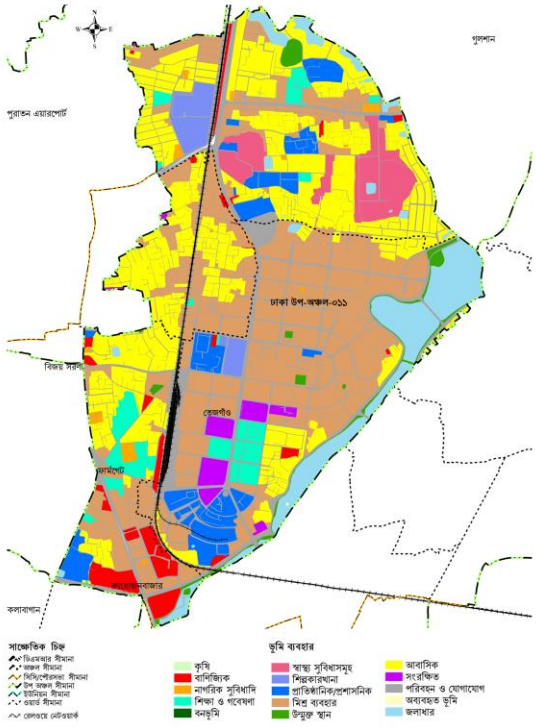
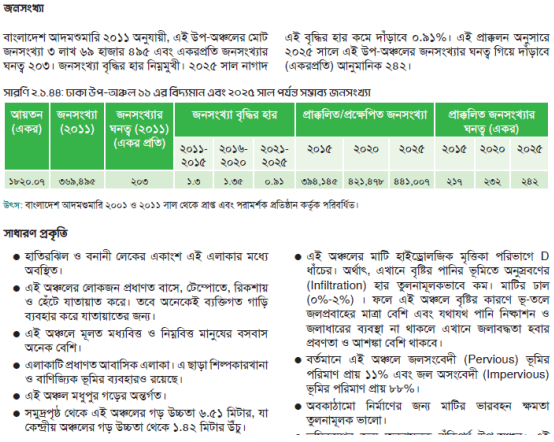


Fig 8: Land use map of Tejgaon (source: DAP)



জনসংখ্যা

বাংলাদেশ আদমশুমারি ২০১১ অনুযায়ী, এই উপ-অঞ্চলের মোট জনসংখ্যা ৩ লাখ ৬৯ হাজার ৪৯৫ এবং একরপ্রতি জনসংখ্যার ঘনত্ব ২০৩। জনসংখ্যা বৃদ্ধির হার নিম্নমুখী। ২০২৫ সাল নাগাদ এই বৃদ্ধির হার কমে দাঁড়াবে ০.৯১%। এই প্রাক্কলন অনুসারে ২০২৫ সালে এই উপ-অঞ্চলের জনসংখ্যার ঘনত্ব গিয়ে দাঁড়াবে (একরপ্রতি) আনুমানিক ২৪২।

সারণি ২.১.৪৪: ঢাকা উপ-অঞ্চল ১১ এর বিদ্যমান এবং ২০২৫ সাল পর্যন্ত সম্ভাব্য জনসংখ্যা

আয়তন (একর)	জনসংখ্যা (২০১১)	জনসংখ্যার ঘনত্ব (২০১১) (একর প্রতি)	জনসংখ্যা বৃদ্ধির হার			প্রাক্কলিত/প্রক্ষেপিত জনসংখ্যা			প্রাক্কলিত জনসংখ্যার ঘনত্ব (একর)		
			২০১১-২০১৫	২০১৬-২০২০	২০২১-২০২৫	২০১৫	২০২০	২০২৫	২০১৫	২০২০	২০২৫
১৮২০.০৭	৩৬৯,৪৯৫	২০৩	১.৩	১.৩৫	০.৯১	৩৯৪,১৪৫	৪২১,৪৭৮	৪৪১,০০৭	২১৭	২৩২	২৪২

উৎস: বাংলাদেশ আদমশুমারি ২০০১ ও ২০১১ সাল থেকে প্রাপ্ত এবং পরামর্শক প্রতিষ্ঠান কর্তৃক পরিবর্ধিত।

সাধারণ প্রকৃতি

- হাতিরঝিল ও বনানী লেকের একাংশ এই এলাকার মধ্যে অবস্থিত।
- এই অঞ্চলের লোকজন প্রধাণত বাসে, টেম্পোতে, রিকশায় ও হেঁটে যাতায়াত করে। তবে অনেকেই ব্যক্তিগত গাড়ি ব্যবহার করে যাতায়াতের জন্য।
- এই অঞ্চলে মূলত মধ্যবিত্ত ও নিম্নবিত্ত মানুষের বসবাস অনেক বেশি।
- এলাকাটি প্রধাণত আবাসিক এলাকা। এ ছাড়া শিল্পকারখানা ও বাণিজ্যিক ভূমির ব্যবহারও রয়েছে।
- এই অঞ্চল মধুপুর গড়ের অন্তর্গত।
- সমুদ্রপৃষ্ঠ থেকে এই অঞ্চলের গড় উচ্চতা ৬.৫১ মিটার, যা কেন্দ্রীয় অঞ্চলের গড় উচ্চতা থেকে ১.৪২ মিটার উঁচু।
- এই অঞ্চলের মাটি হাইড্রোলজিক মুক্তিকা পরিমাণে D ধাঁচের। অর্থাৎ, এখানে বৃষ্টির পানির ভূমিতে অনুস্রবণের (Infiltration) হার তুলনামূলকভাবে কম। মাটির ঢাল (০%-২%)। ফলে এই অঞ্চলে বৃষ্টির কারণে ভূ-তলে জলপ্রবাহের মাত্রা বেশি এবং যথাযথ পানি নিষ্কাশন ও জলাধারের ব্যবস্থা না থাকলে এখানে জলাবদ্ধতা হবার প্রবণতা ও আশঙ্কা বেশি থাকবে।
- বর্তমানে এই অঞ্চলে জলসংবেদী (Pervious) ভূমির পরিমাণ প্রায় ১১% এবং জল অসংবেদী (Impervious) ভূমির পরিমাণ প্রায় ৮৮%।
- অবকাঠামো নির্মাণের জন্য মাটির ভারবহন ক্ষমতা তুলনামূলক ভালো।

Fig 9: Population density of the study area (source: DAP)

Table 1: Electricity consumption of Tejgaon Area (source: DPDC)

Analyzing electricity consumption (MkWh) of FY 17-22, the following observations have been made.

NOCS	FY 17-18	FY 18-19	% Change (17-18 to 18-19)	FY 19-20	% Change (18-19 to 19-20)	Share% 19-20	FY 20-21	% Change (19-20 to 20-21)	Share% 20-21	FY 21-22	% Increase	Share% 21-22
Tejgaon	315786589	304602329	-3.54	290597807	-4.60	3.22	316199945	8.81	8.81	331178266	4.74	3.36

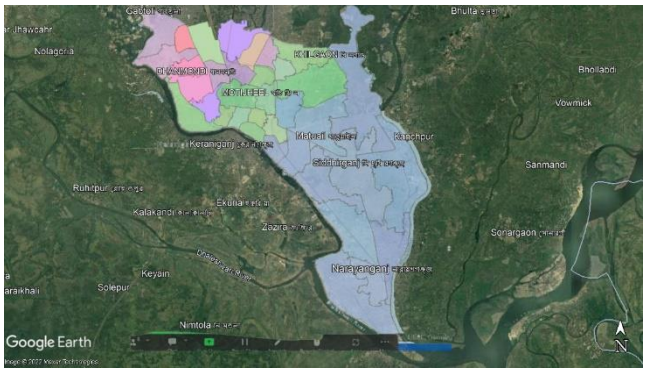


Fig10: Electricity supply feeder zones of Dhaka city (source: DPDC)

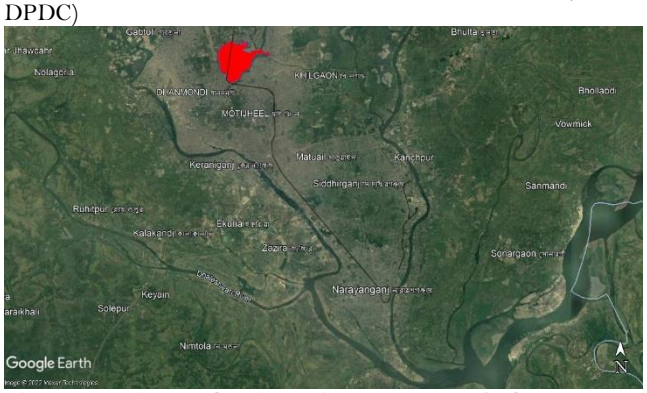


Fig 11: Google map showing Tejgaon as DPDC feeder zone

Table 2: Energy consumption pattern of Tejgaon Area (source: DPDC)

NOCS	FY 17-18	FY 18-19	FY 19-20	FY 20-21	FY 21-22
Tejgaon area electricity consumption (MkWh)	315786589	304602329	290597807	316199945	331178266

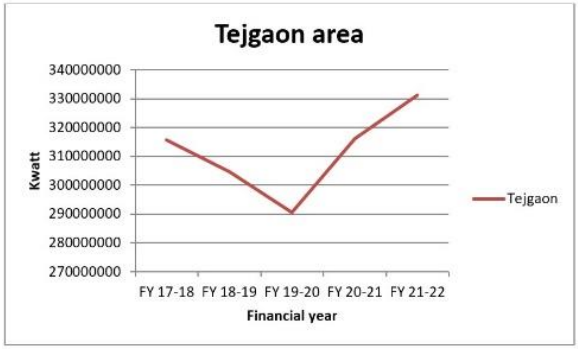


Fig 12: Energy consumption pattern of study Area

Another analysis in Fig 13, showing the energy consumption (Financial Year, FY 21-22) comparison among the different areas of Dhaka city. From this figure it is evident that energy use is high in Tejgaon. The land use pattern and population density is correlated with high energy consumption of this area. A study was carried out in India. Where it was revealed that the LCZ which is dominated by residential buildings consumes maximum energy for its longest period of use time and the LCZ dominated by commercial areas has high energy uses during mid of the day when cooling load is high. The study also identified that LCZ with green and vegetation had least cooling load [41].

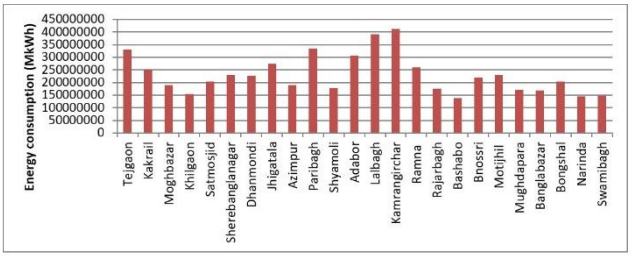


Fig13: Comparative analysis of energy consumption among different zones of Dhaka city

LCZ generation and Qgis outcome analysis:

Using Qgis software along with Urban Multiscale Environmental Predictor (UMEP) LCZ of Dhaka, population density, radiation balance, energy budget and water balance has been generated.

At first, the population density mapping and open street mapping of whole Dhaka city has been generated using Qgis and UMEP [Fig 14, 15]. From the figure 19 it is evident that the study area is having high population density compared to other area. Similarly figure 15 shows the dense road network along the site. Detailed and closed mapping is shown in fig 17 and in fig 18. Figure 18 shows population density 26867per hector. Figure 15 displays closed grid iron road network pattern. Another important finding of Qgis is LCZ generation of Dhaka city [Fig16]. From the LCZ pattern it is seen that Dhaka is highly built

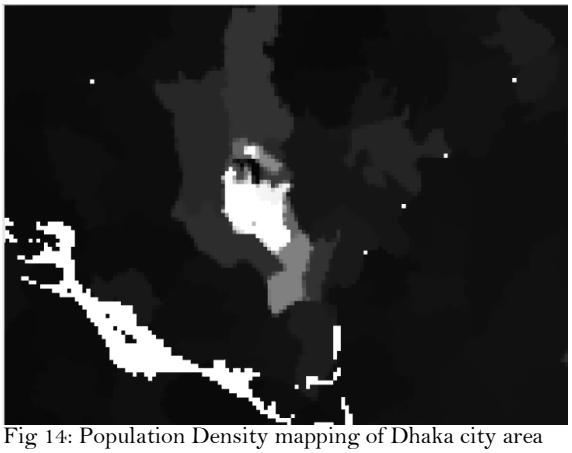


Fig 14: Population Density mapping of Dhaka city area

up area with limited blue green infrastructure. From this the LCZ of the study area is extracted [Fig 16]. The LCZ mapping of the study area indicates that almost 80% of the area is covered by building and hard surface. Minimal green patches are seen which may has little or no impact on urban microclimate. Though a prominent green patch (Hatirjheel) is seen in the map but that is out of the site boundary.

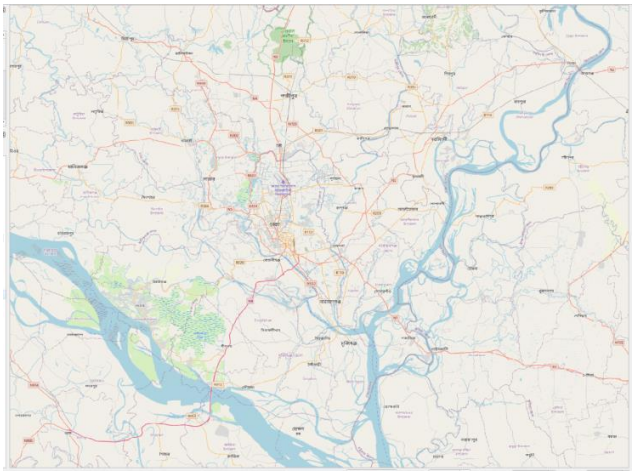


Fig 15: Open street mapping of Dhaka city area

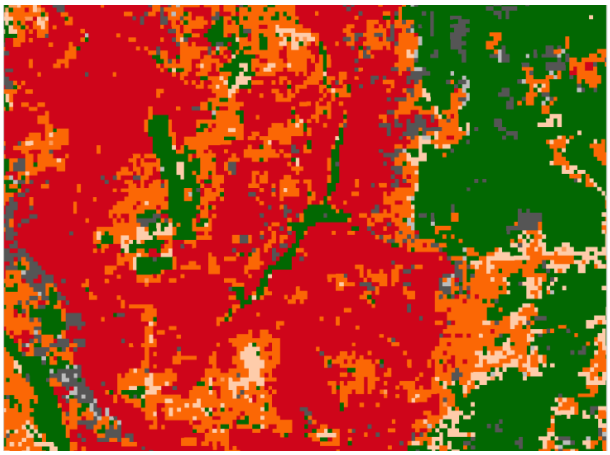


Fig 16: LCZ showing build up condition of Dhaka city

Fig 17: Population Density mapping of Tejgaon area

Fig 18 Open Street mapping of Tejgaon area

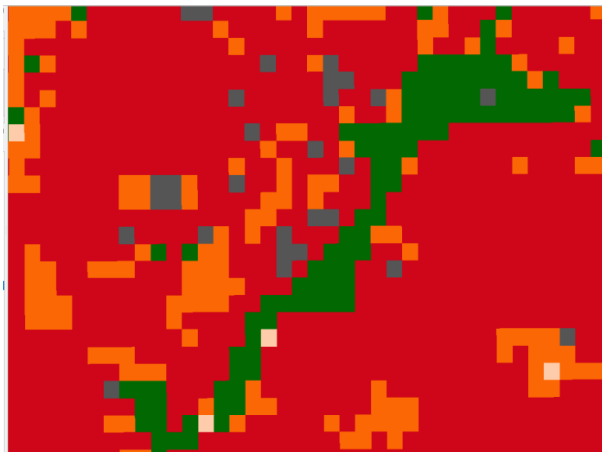
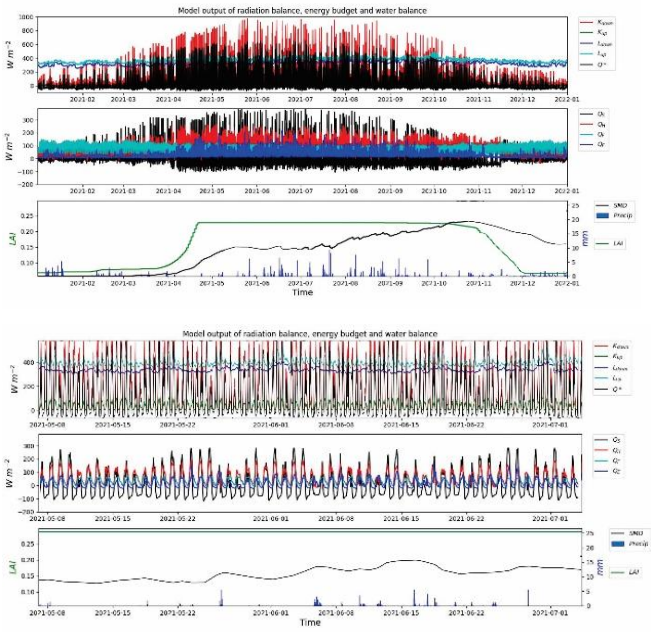


Fig 19: LCZ showing build up condition of Tejgaon Area



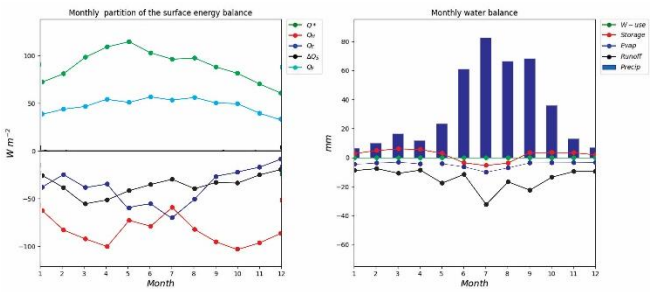


Fig 20: Model output of radiation balance, energy budget and water balance

Here, in fig 20, the Qgis model output of radiation balance, energy budget and water balance is indicating that energy consumption is higher during summer season than winter in the study area. The results also showing that water storage is not very high in the area and runoff water increase during rainy season.

Envimet Simulation And Urban Microclimatic Analysis:

A busy and dense area has been selected from Tejgaon area for micro climate analysis. Both field survey and EnviMet simulation have been conducted and data have been collected. Collected data have been compared considering two thermal comfort parameters, Air Temperature (T_a) and Relative Humidity (R_h).

Table 3: micro climate outdoor parameters analysis

Time : 1.00pm	Field survey data 13th November, 2022	Simulation result 13th November, 2022	Simulation result 19th June, 2022	Comments
Air Temperature (T_a) °C	30.9°C	23.96°C	36°C	November : Neutral, within comfort range June: Warm, comfort range exceeds
Relative Humidity (R_h) %	34.5%	51.74%	87%	November: within comfort range June: comfort range exceeds

Fig 21: 3D view from EnviMet and image of the EnviMet simulated area

Fig 22: google image showing simulated raea

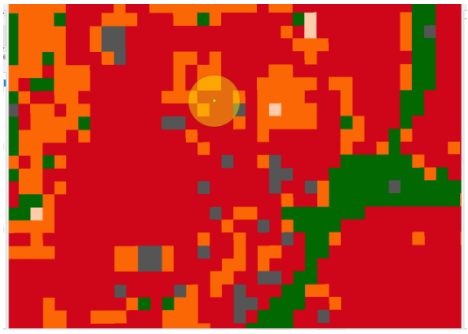
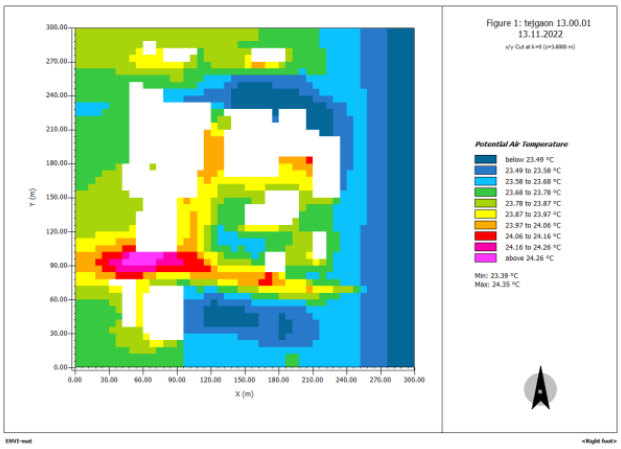


Fig 23: The circle locating the EnviMet simulated zone on LCZ generated image



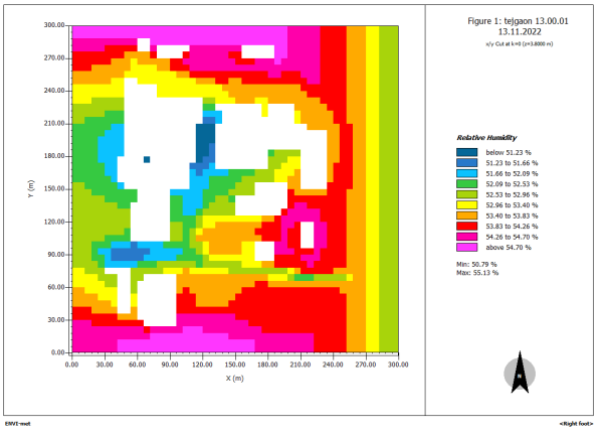


Fig 24: Results from EnviMet simulation

5. Analysis and Findings

- From the analysis it is observed that the land use pattern of Tejgaon area is mixed use zone with mostly commercial zones.
- The study area having high population density 203 people per acre (source: DAP), therefore high energy consumption pattern331178266MkWh per yr.
- During Covid and 'locked-down' situation, mixed use commercial buildings consumed less electricity.
- Therefore the consumption rate in last three years (FY 20-22) has gone far beyond the previous rate (FY 17-19) due to accelerated use after lockdown and indicates continuation of this trend for added commercial high-rise building in near future along with conceived cooling load.
- From the LCZ analysis, it has been observed that 80% of the study area is built up with buildings and road surfaces which is affecting the outdoor microclimate as well as thermal comfort.
- Qgis analysis shows that the study area has high population density and huge built up area. The electricity consumption is also high. The results also showing that water storage is not very high in the area and runoff water increase during rainy season.
  Microclimatic analysis shows that Air Temperature and Relative humidity during summer season (June) is beyond outdoor comfort range but November (nearly winter season) is within outdoor comfortable range of Dhaka city.
- As per different researches, some approach might be taken to improve outdoor comfort range during summer season. Such as selection of non-reflective building outer material that does not store energy inside and building material having less thermal mass. Another measure is to plant more trees and increasing of blue and green infrastructures than grey. Proper building orientation and energy efficient technologies reduce energy consumption significantly. Finally, limiting the population density during day time by controlling the percentage of commercial land use might reduce the cooling load as well as the energy consumption during day time.

6. Conclusion

In the Study area per capita energy consumption is 897MkWhonly during daytime which is higher compared to other LCZ of Dhaka city. This is for the commercial and mixed use pattern of the site. 80% of the site is built up of buildings and roads which has deteriorated urban microclimate at outdoor area. Microclimatic analysis shows that Air Temperature and Relative humidity during summer season (June) is beyond outdoor comfort range but November (nearly winter season) is within outdoor comfortable range of Dhaka city. The Qgis simulation results also showing that water storage is not very high in the area and runoff water increase during rainy season.

From this study it is evident that urban planning has direct impact on urban landscape and LCZ which defines urban morphology and demography. With the land use pattern and increased population the energy consumption gets accelerated and highly built up area impose direct impact on urban outdoor microclimate.

This research particularly looked into Tejgaon area only. No comparison was derived here among the other LCZ. It has a great possibility to carry on with similar kind of research with the other LCZ of Dhaka city and comparison can be derived. The energy consumption pattern with the diurnal temperature variation could be further analyzed.

7. Reference

[1] Istiaque A, Khan SI (2018) Impact of ambient temperature on electricity demand of Dhaka city of Bangladesh. Energy and Power Engineering 10 (07):319

[2] https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

[3] https://unhabitat.org/topic/urban-energy#:~:text=To%20run%20their%20activities%2C%20cities, the%20world's%20total%20greenhouse%20gases.

[4] https://www.statista.com/statistics/761021/share-of-urban-population-bangladesh/

[5] Asaduzzaman and Rob, Environmental Control over Urbanization of Dhaka City (Dhaka: The Mappa, 1997).

[6] Ferdous, Jannatul & Rahman, M Tauhid Ur.(2018).

Temporal Dynamics And Relationship Of Land Use Land Cover And Land Surface Temperature In Dhaka, Bangladesh.

[7] Zhang, C.; Lin, Y. Panel estimation for urbanization, energy consumption and CO2 emissions: A regionalanalysis in China. Energy Policy 2012, 49, 488–498. [CrossRef]

[8] Statistical Yearbook of Bangladesh, 32nd Edition, Bangladesh Bureau of Statistics, Statistics and Informatics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh, August 2013.

[9] Parkpoom, S. and Harrison, G.P. (2008) Analyzing the Impact of Climate Change on Future Electric Demand in Thailand. IEEE Transactions on Power Systems, 23, 1441-1448.

https://doi.org/10.1109/TPWRS.2008.922254

[10] Engle, R.F., Granger, C.W.J., Rice, J. and Weiss, A. (1986) Semiparametric Estimates of the Relation between Weather and Electricity Sales. Journal of the American Statistical Association, 81, 310-320.

https://doi.org/10.1080/01621459.1986.10478274

[11] Hor, C.-L., Watson, S.J. and Majithia, S. (2005) Analyzing the Impact of Weather Variables on Monthly Electricity Demand. IEEE Transactions on Power Systems, 20, 2078-2085.

https://doi.org/10.1109/TPWRS.2005.857397

[12] Hyndman, R.J. and Fan, S. (2010) Density Forecasting for Long-Term Peak Electricity Demand. IEEE Transactions on Power Systems, 25, 1142-1153.

https://doi.org/10.1109/TPWRS.2009.2036017

[13] Henley, A. and Peirson, J. (1997) Non-Linearities in Electricity Demand and Temperature: Parametric versus Non-Parametric Methods. Oxford Bulletin of Economics and Statistics, 59, 149-162.

https://doi.org/10.1111/1468-0084.00054

[14] Terasvirta, T. and Anderson, H.M. (1992) Characterising Nonlinearities in Business Cycles Using Smooth Transition Autoregressive Models. Journal of Applied Econometrics, 7, 119-136.

https://doi.org/10.1002/jae.3950070509

[15] Akbari, H., Davis, S., Dorsano, S., Huang, J. and Winert, S. (1992) Cooling Our Communities—A Guidebook on Tree Planting and Light Color Surfacing. US Environmental Protection Agency, Office of Policy Analysis: Climate change Division.

[16] Santamouris, M., Papanikolaou, N., Livada, I., Koronakis, I., Georgakis, C., Argirous, A., et al. (2001) On the Impact of Urban Climate on the Energy Consumption of Buildings. Solar Energy, 70, 201-216.

https://doi.org/10.1016/S0038-092X(00)00095-5

[17] Badr, E.A. and Nasr, G.E. (2001) On the Relationship between Electrical Energy Consumption and Climate Factors in Lebanon: On-Integration and Error-Correction Models. International Journal of Energy Research, 25, 1033-1042.

https://doi.org/10.1002/er.735

[18] Parkpoom, S., Harrison, G.P. and Bialek, J.W. (2004) Climate Change Impacts on Electricity Demand. In: Nouri, H., Ed., Proceedings of the 39th International Universities Power Engineering Conference, Bristol, Section T14.2.

[19] Alexander, Paul & Mills, Gerald. (2014). Local Climate Classification and Dublin's Urban Heat Island.Atmosphere. 2014. 755-774. 10.3390/atmos5040755.

[20] Hankey, S.; Marshall, J.D. Impacts of urban form on future US passenger-vehicle greenhouse gas emissions.Energy Policy 2010, 38, 4880–4887. [CrossRef]

[21] Das, Anutosh & Haque, Afsana & Taher, Sk & Salam, Md. (2016). A Study on Development Trend of Tejgaon Industrial Area. Bangladesh Planning Research Conference (BPRC), 5-6 February 2016, Paper ID: 719

[22] K. Villadiego, M.A. Velay-Dabat, Outdoor thermal comfort in a hot and humidclimate of Colombia: A field study in Barranquilla, Build. Environ. 75 (2014)142–152, https://doi.org/10.1016/j.buildenv.2014.01.017.

[23] Z. Wu, F. Kong, Y. Wang, R. Sun, L. Chen, The Impact of Greenspace on Thermal Comfort in a Residential Quarter of Beijing, China, Int. J. Environ. Res.Public Health 13 (12) (2016) 1217, https://doi.org/10.3390/ijerph13121217.

[24] D.D. Miloševic´, S. Savic´, V. Markovic´, D. Arsenovic´, I. Šec´erov, Outdoor human thermal comfort in local climate zones of Novi Sad (Serbia) during heat wave period, Hungarian Geographical Bulletin 65 (2) (2016) 129–137, https://doi. org/10.15201/hungeobull.65.2.4.

[25] R. Kotharkar, A. Bagade, Local Climate Zone classification for Indian cities: A case study of Nagpur, Urban Clim. 24 (2017) 369–439, https://doi.org/ 10.1016/j.uclim.2017.03.003.

[26] X. Yang, T. Jin, L. Yao, C. Zhu, L.L. Peng, Assessing the Impact of Urban Heat Island Effect on Building Cooling Load based on the Local Climate Zone Scheme, Procedia Eng. 205 (2017) 2839–2846, https://doi.org/10.1016/j. proeng.2017.09.904.

[27] X. Yang, L.L.H. Peng, Z. Jiang, Y. Chen, L. Yao, Y. He, T. Xu, Impact of urban heat island on energy demand in buildings: Local climate zones in Nanjing, Appl. Energy 260 (2019), https://doi.org/10.1016/j.apenergy.2019.114279 114279.

[28] G. Yang, Y. Fu, M. Yan, J. Zhang, Exploring the distribution of energy consumption in a northeast Chinese city based on local climate zone scheme: Shenyang city as a case study, Energy Explor. Exploit. 38 (5) (2020) 2079–2094, https://doi.org/10.1177/0144598720950465.

[29] R Kotharkar, A Ghosh, S Kapoor, D Reddy, Approach to local climate zone based energy consumption assessment in an Indian city, Energy and Buildings,Volume 259,2022,111835,ISSN 0378-7788,https://doi.org/10.1016/j.enbuild.2022.111835.

[30] Tuli, S. M. (2015). Study on the impact of microclimate on energy spatialization in urban areas of Dhaka. Central Library, Bangladesh University of Engineering and Technology, BUET, August.

[31] Toparlar, Y., Blocken, B., Maiheu, B., & van Heijst, G. J. F. (2018). Impact of urban microclimate on

summertime building cooling demand: A parametric analysis for Antwerp, Belgium. Applied Energy, 228(April), 852–872. https://doi.org/10.1016/j.apenergy.2018.06.110

[32] Toparlar, Y., Blocken, B., Maiheu, B., & van Heijst, G. J. F. (2018). Impact of urban microclimate on summertime building cooling demand: A parametric analysis for Antwerp, Belgium. Applied Energy, 228(April), 852–872. https://doi.org/10.1016/j.apenergy.2018.06.110

[33] Sharmin, T., Steemers, K., & Humphreys, M. (2019). Outdoor thermal comfort and summer PET range: A field study in tropical city Dhaka. Energy and Buildings, 198, 149–159. https://doi.org/10.1016/j.enbuild.2019.05.064

[34] Ren, Z., Zhao, H., Fu, Y., Xiao, L., & Dong, Y. (2022). Effects of urban street trees on human thermal comfort and physiological indices: a case study in Changchun city, China. Journal of Forestry Research, 33(3), 911–922. https://doi.org/10.1007/s11676-021-01361-5

[35] Meili, N., Acero, J. A., Peleg, N., Manoli, G., Burlando, P., & Fatichi, S. (2021). Vegetation cover and plant-trait effects on outdoor thermal comfort in a tropical city. Building and Environment, 195(February), 107733. https://doi.org/10.1016/j.buildenv.2021.107733

[36] Fairuz Shahidan, M. (n.d.). Tropical Microclimate Indicators for The Malaysian Urban Landscape Developing Tree Canopy Density Model for Malaysian Native Plant Species View project Green Facade Cooling Effect View project. https://www.researchgate.net/publication/224054097

[37] Ahmed KS. 2003. Comfort in urban spaces: defining the boundaries of outdoor thermal comfort for the tropical urban environments, Ener. Build. 35, pp. 103-110Bowler et al., (2010)

[38] Järvi L, Grimmond CSB & Christen A 2011: The Surface Urban Energy and Water Balance Scheme

(SUEWS): Evaluation in Los Angeles and Vancouver J. Hydrol. 411, 219-237

[39] Järvi L, Grimmond CSB, Taka M, Nordbo A, Setälä H &Strachan IB 2014: Development of the Surface

Urban Energy and Water balance Scheme (SUEWS) for cold climate cities, , Geosci. Model Dev. 7, 1691-

1711

[40] Ward HC, L Järvi, S Onomura, F Lindberg, A Gabey, CSB Grimmond 2016 SUEWS Manual V2016a, http:

//urban-climate.net/umep/SUEWS Department of Meteorology, University of Reading, Reading, UK

[41] Kotharkar R, Ghosh A, Kapoor S, Reddy D, Approach to local climate zone based energy consumption assessment in an Indian city,Energy and Buildings,Volume 259,2022,111835,ISSN 0378-7788,https://doi.org/10.1016/j.enbuild.2022.111835.