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A microclimatic study of urban neighbourhood parks

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A microclimatic study of urban neighbourhood parks

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Abstract. Green spaces are considered important natural and human-centric spaces in a city. They are considered essential to allow the proper functioning of the natural ecosystem in an urban environment. The study aims to determine the thermal impact of a neighbourhood park upon its residential surroundings in a rapidly urbanising city. The city of Gurugram, India, was chosen for a study as it has seen unprecedented growth, increasing the need to develop green spaces. A traverse survey is conducted in some chosen neighbourhood parks of Gurugram, and microclimatic variables are recorded. Three sites in different wards are surveyed multiple times to record on-site climatic data, building typology, building heights, survey points, and characteristics. These are then denoted graphically, and specific trends are generated and explained. The study also provides a path towards the study's future scope, further enhancing the research topic's overall understanding.

1 Introduction

Green spaces in an urban environment are vital due to their various economic, social and environmental benefits [1]. Green spaces aim to be essential recreational spaces that provide a much significant break in a dense concrete jungle. Chalking out land to be designated as green space cannot be a viable solution. Without a larger picture in mind, it creates a loose and non-cohesive green infrastructure where there is no flow or interconnectivity between these services to maintain the "natural flow" of the ecological services.

Everyone has rights to their land and property, but they have a collective responsibility on a community level. Individual residential units join to form a neighbourhood, and urban neighbourhood green spaces are formed within them as they are considered an important area for improved quality of life. With ongoing research and public awareness, a green area within an urbanised neighbourhood becomes a scientifically-backed necessity and a demand by the residents.

Applying assessments of green space values and benefits to planning and management have been identified as an area in need of further research [2]. The ability to assess and regulate the natural environments' sustainability performance, based upon measurable criteria at various scales, is critical for sustainable urban development.

Therefore, the study aims to determine the thermal impact of a neighbourhood park upon its residential surroundings in a rapidly urbanising city. The city of Gurugram, India, was chosen for such a study as it has seen unprecedented growth, which increases the need to develop green spaces. The study introduces its need and the various terms and phenomena associated with urban neighbourhood green areas. The literature case studies help understand the practical usage and challenges while applying specific tools, techniques and methodologies associated with the study. Traverse surveys are conducted across the three sites, and the data is studied to understand the importance of various design parameters of an open neighbourhood park.

2 Literature Review

Urbanisation is an essential component of global land transformation and directly correlated with increased production and consumption of goods, resulting in increased land use, greenhouse gas emissions, urban heat islands, loss of biodiversity, and the destruction of sensitive ecosystems. The results are, amongst other negative impacts on society with and affected by climate change, a decrease in human health and well-being [3]

The Census of India in 2011 revealed that 31.16% of the total Indian population is now residing in the urban areas, which in total accounts for 37 crore people. The percentage of the set number of urban populations is expected to swell up to 40% by 2026. It is also predicted that the number of towns and cities, which was 7933 according to Census data in 2011, would surpass 10,000 in the next decade [4].

Urbanisation is the result of increasing population in the cities, which requires more land for dwelling, which causes natural land to be changed into urban areas. The constant use of concrete and other building materials, especially with low reflectance and non-pervious properties, has been a primary source of the urban environment's changing conditions. It is also observed that the region's temperature is more in the area where there is more human intervention to the natural counterpart setting.

Urban Heat Island (UHI) is generally described as the urban areas with higher temperatures than their neighbouring non-urbanised areas [5]. This is due to the fact that the urban areas use materials which have higher solar absorption, lower solar reflectivity and greater thermal capacity than their surrounding areas due to darker and less vegetated surfaces. Apart from that, reduced sky view, evapotranspiration and wind speed are also significant causes for such phenomemnon [6][7]. The urban heat island has been described as an 'unintended consequence of urbanisation'. Various factors are attributed to the UHI's cause in cities, but lack of vegetation in cities is a significant contributor to this phenomenon. Reduced tree cover leads to a reduction in both shading of surfaces and transpiration cooling by tree canopies, compared with rural areas [8].

Climate modification benefits are direct tools to understand the performance of an urban neighbourhood green space. There have been researches on climatic benefits of green spaces in urban areas that contribute to mitigating the urban heat island effects, reduced energy use and emission, air pollution interception and mitigation. Global climate change issues have further highlighted the need to address a range of environmental issues, including making better use of green spaces in the public realm.

Though being an essential metric of measurement, the climatic temperature is not an accurate representation of humans' temperature. Various other climatic variables lead to the micro-climatic condition with which an average human body interacts. Hence, a thermal index comfort is a better scale of measurement in such scenarios. A thermal index comfort is based on different variables like air temperature, radiation, air humidity, wind speed, and personal factors like clothing and metabolism. [9]. Such variables provide various indices divided under three categories: direct, empirical, and Rational.

Empirical indices were selected for measurements due to their relatively simple calculations and their independence towards personal factors, varying the readings as per sample size or survey time. The effective temperature is one of the empirical indices of thermal comfort. It is a simple experimental estimation index that represents thermal sensation via the combination of air temperature, relative humidity and wind speed. It is the most commonly used environmental index due to its wide range of application. [10]. The formula proposed for calculating effective temperature is [11]:

$$ET = 37 - \frac{37 - T}{0.68 - 0.0014 \, . RH + \frac{1}{1.76 + 1.4 \, . V^{0.75}}} - 0.9 \, . T \, . (1 - 0.01 \, . RH) \quad (1)$$

Where ET = Effective Temperature (in °C), T = Air Temperature (in °C), RH = Relative Humidity (in %), V = Wind Speed (in m/s).

A few literature case studies were also referred to understand the procedure for designing a traverse survey. These case studies summarise the research done in different parts of the world to understand the various parks' thermal performance. The sample sizes may vary from the author's research, but it provides the tools and techniques for carrying out such instrumentation surveys in practice. The selection of the following case studies was made to understand the practical studies done on various sites worldwide to understand the parks' thermal performance.

Table 1: Summary of Literature Case Studies

Sl No.	Title	Author (s)	Country	Study Objectives
1	Thermal performance of tropical urban parks [12]	Y. Hwang Q. Lum Y. Chan	Singapore	Investigate the range of micro-scale thermal performance of existing parks in Singapore through on-site measurements
2	Effects of urban parks on the local urban thermal environment [13]	C. Chang M. Li	Taiwan	To explore details related to the planning and design of city parks, and To understand the temperature trend in and around the urban parks

The significant findings in the literature study have been the need to optimising green space planning. As urbanisation is spreading at an unprecedented rate, the cities' physical planning is not taking cognisance to its adverse environmental effects. Hence, the importance of green parks has not been exploited to its maximum capacity. The case studies help in identifying a general trend of a park's thermal performance. The primary lessons learnt from these case studies have been about identifying various variables required for the study of outdoor thermal performance, understanding the process of site sampling and selection, and the tools and techniques required to map the variables.

3 Methodology

As discussed in the previous sections, the study requires a lot of knowledge, procedure and preparedness to understand the impact of green space. Also, in a climatic study, the survey's time and date are crucial to acquire the correct data set while surveying. The literature study provided the knowledge required for the preparation of the survey.

A well-laid protocol is required to facilitate the study's advancement to implement and analyse the survey procedure and its subsequent data. The city of Gurugram provides the basis for a case of rapid growth rate and gives the potential of studying the overall urban heat island effect on a neighbourhood level scale. In the current urban scenario, a framework is required to understand how and to what extent the green spaces contribute to the urban environment.

The survey methodology begins with a statistical database of the city for the study area identification process by acquiring data from government sources and GIS. Based on the data obtained, a detailed study of the various identified sites was done. A pilot study was conducted via a traverse survey to gauge the general trends in and around the sites. Dates for the peak stress studies were done by determining the months' hottest days, and then similar surveys were conducted on those days to generate peak stress results. The data is then put into a graph and studied to understand general trends and patterns. The conclusion provides an overall encapsulation of all the knowledge gained through the survey data and the impact of the design parameters of the park upon its microclimate.

3.1 City Profile

Gurugram is a satellite town of the National Capital Region of Delhi situated at the 28° 27' 27.0828" N Latitude and 77° 1' 34.8384" E Longitude. It is an important centre of trade and commerce for Haryana, and the town hosts several Multi-National Corporations and industries that deal with mechanical, electrical, textile, electroplating, and chemical products. The city has experienced a phenomenal rate of growth in the last decade demographically. Various master plans have been devised to regulate the city's development while maintaining the city's high-income flow. This growth rate is very high and rare, which leads to enormous and unprecedented stress on the infrastructure and the city's natural ecology. Hence, the city of Gurugram was chosen for study as the trends of the thermal performance of neighbourhood parks for such a city will be of great learning.

The city of Gurugram is divided into four development zones with 35 municipal wards, and these areas have seen an unprecedented amount of growth in recent time. As per Census Data of 2011, the city has more than six times the population in only five years since 2006 (Figure 1). The municipal wards are further subdivided into sectors. The sectors mostly follow the ward boundary, and hence it can be seen that each ward comprises multiple sectors.

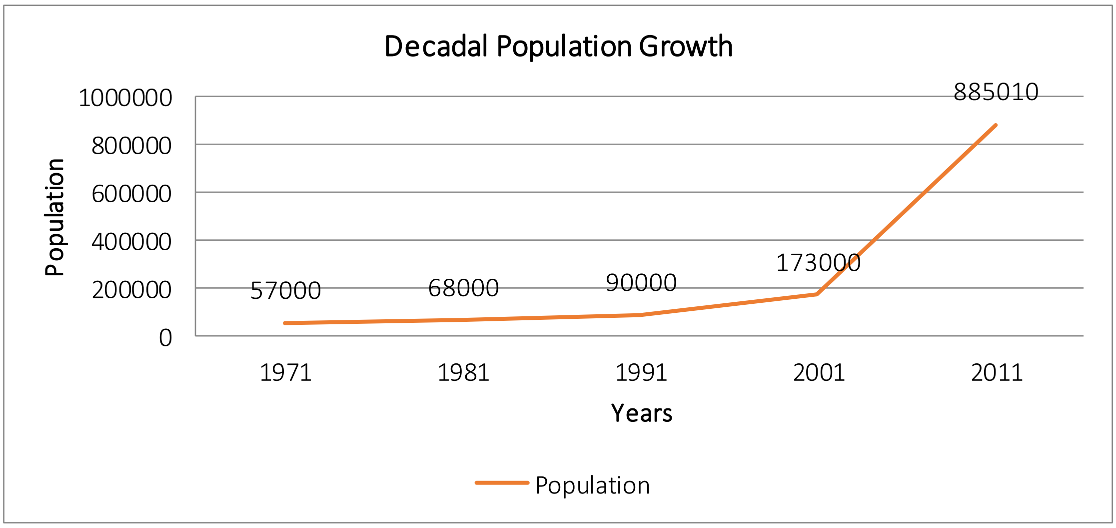

Figure 1: Population data of Gurugram. *Source: Census Data, Govt. of India.*

Using GIS and NDVI, the green cover of the whole city was mapped to determine the site for the traverse survey. NDVI stands for "Normalised Difference Vegetation Index". It is a simple graphical indicator used for remote sensing measurements. These are generated through satellite images, and it captures various radiations, which evolves into spectral bands (Figure 2). NDVI is majorly used in identifying and differentiation lives green vegetation in an area.

The principal rationale behind it is that live green plants absorb solar radiation in the photosynthetically active radiation (PAR) spectral region, which is the source of energy during photosynthesis. The leaves re-emit infrared radiation, which is captured via the satellite. The use of NDVI in the study was directed towards identifying the green areas in the city. Various researchers have used Normalized Difference Vegetation Index (NDVI) in the study of temporal growth of

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urbanisation resulting in depletion of vegetation cover and variation in Land Surface Temperatures (LST) [14].

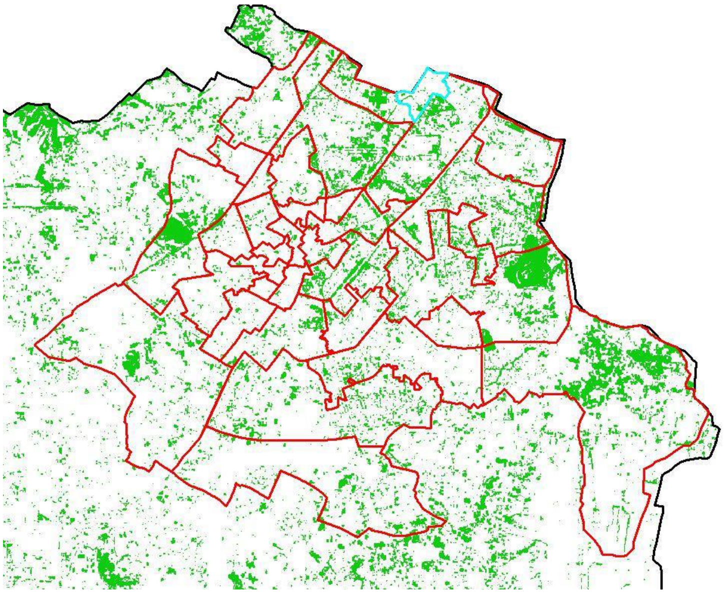


Figure 2: NDVI Data for Gurugram. *Source: Extracted from OSM Files by Author*.

3.2 Site Profile

Ward 19 is chosen as a case study of the neighbourhood parks, as per the following factors:

- situated in the middle of the city.
- the only ward that is under three development zones.
- the closest correlation to the average data of the city (apart from one parameter).
- the highest green space per capita among the wards which are situated in the middle of the city.

In the three sectors, we have three parks that are more or less equal in size but have minor differences in surroundings and orientation.

3.2.1 Site A situated in Sector 31, 32 A. It is the smallest of the three surveyed sites and is surrounded by a 10m wide road on all sides (Figure 3). The park's shape is peculiar as two residences are also inside the park area, preventing it from having a rectangular shape. With low rise houses in its immediate surroundings and an 18 m wide commercial road towards the north-western side, high gusts of wind are expected inside the park.

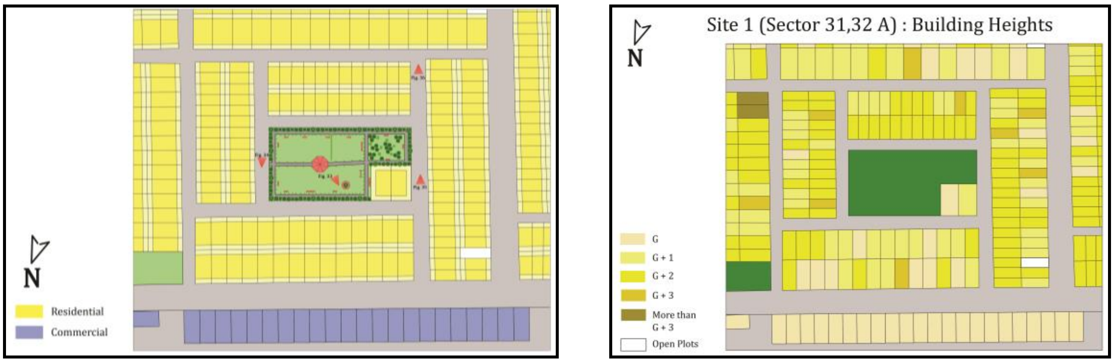


Figure 3: Site A (Sector 31, 32A)

3.2.2 Site B situated in Sector 15-2. The site is surrounded by a 10 m wide road on all sides (Figure 4). There is a green belt present on the north-western side of the park after a couple of rows of low rise residences. Presently, there are many empty plots on the site. The site has a 24 m wide road towards the south-western side after a residential belt; this road is a sub-arterial road adjacent to a large public school, a significant landmark in the sector.

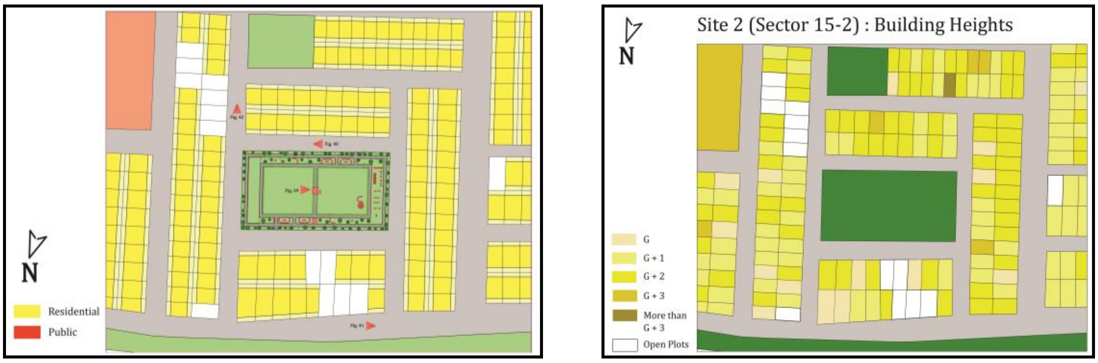


Figure 4: Site B (Sector 15-2)

3.2.3 Site C situated in Sector 15-1. The site surrounded by a 10 m wide road on three sides. The south-western edge is adjacent to a low-rise public community centre (Figure 5). The site has a North-West to South-East orientation, which is different to that of the other sites (namely A and B's North-East to South-West orientation). There is a 24 m wide road towards the south-eastern part of the site across a row of low-rise residences.

Figure 5: Site C (Sector 15-1)

3.3 Data Collection

The weather data for New Delhi (ISHRAE) was used to calculate the effective temperature (ET) on an hourly basis for three months (January, February and March) to understand the days with maximum ET per month. The month of March shows the highest amount of days having a high ET throughout the month. Hence, the Pilot study was chosen from March 1st and 2nd, 2019. The Peak Stress days were calculated as the end of March (30th and 31st, March 2019) and towards April (27th and 28th, April 2019).

The pilot study was done to understand the fundamental trends which are prevalent in the site. The pilot study was instrumental in generating a basic understanding of the general happenings around the park. The peak stress study was done for March and April. As the general trends were already mapped, the peak stress study shows the number of extremes recorded during that time.

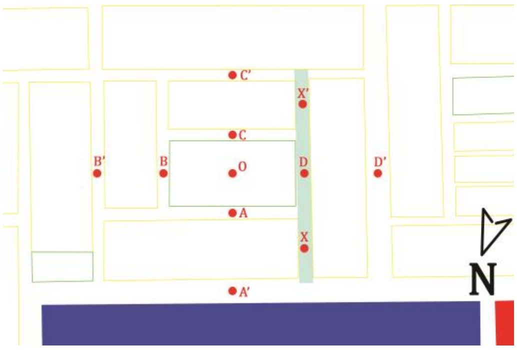
Date:	2nd and 3rd March, 2019	(Pilot Study)
	29th, 30th, 31st March, 2019	(Peak Stress Study - March)
	26th, 27th and 28th April, 2019	(Peak Stress Study - April)
Time:	8:00 am to 6:00 pm	

Instruments Used: *HT200 Heat Stress WBGT Meter* for measuring Air Temperature and Mean Radiant Temperature and *Kaindl Windtronic 2* to measure Wind Velocity.

3.4 Traverse Survey

The traverse survey's path and points were chosen according to a pre-planned procedure, which began with identifying a long street near the park to determine if there are any canyon drafts there. Secondly, place the origin point of the traverse survey, which will be the park's centre. The next survey point would be just outside the park and will be in the northern direction. The surveyor will then take a round around the park from north to the east, then south, and west; the same path will be followed for the path beyond one row of buildings. The data (measurements and photographs) will be taken at every point, and the surveyor will shift its data point after every 10 minutes to the next location. There can be a maximum of eleven survey stations per site so that the traverse survey can restart after every two hours.

For nomenclature, the origin point (or the point at the centre of the park) will be denoted as O. This is the station that gives us the park's base thermal data. The stations placed in the northern direction outside the park will be dented as A. Similarly, the stations situated at the Eastern, Southern and the Western direction of the park will be B, C and D, respectively. The stations situated parallel to these after a row of houses would be denoted with an apostrophe. Hence, they would be A', B', C' and D'. The extra stations present to understand the canyon draft will be denoted by X (Figure 6, 7 & 8).



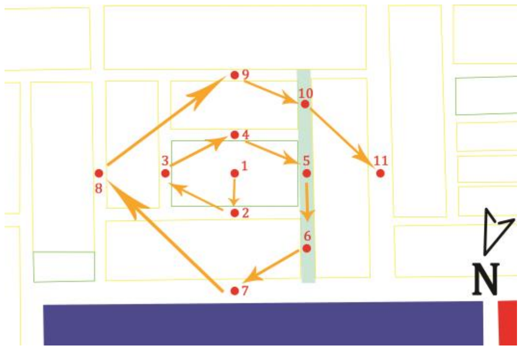


Figure 6: Traverse Survey Path and Stations for Site A

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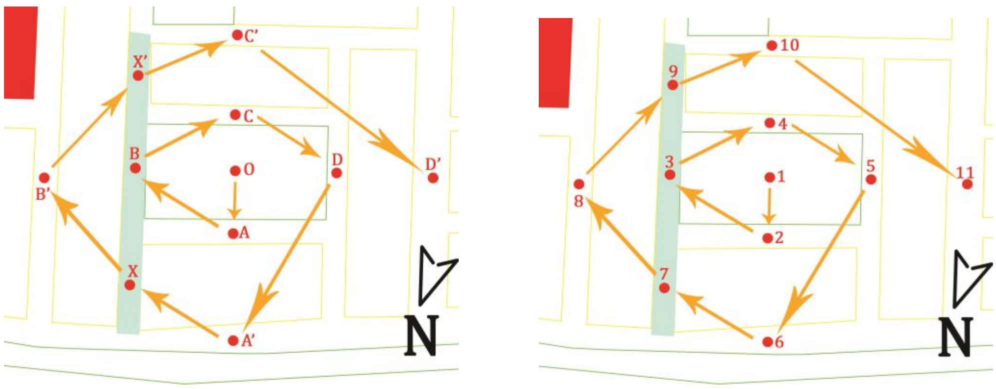


Figure 7: Traverse Survey Path and Stations for Site B

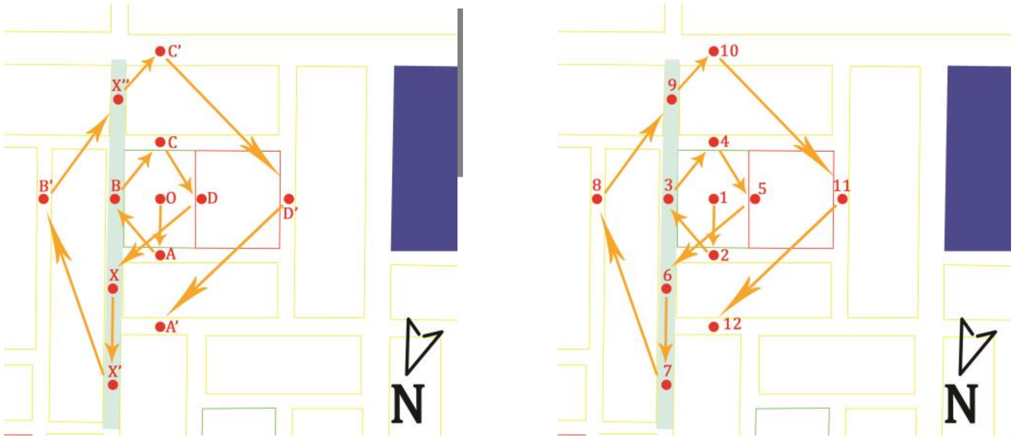


Figure 8: Traverse Survey Path and Stations for Site C

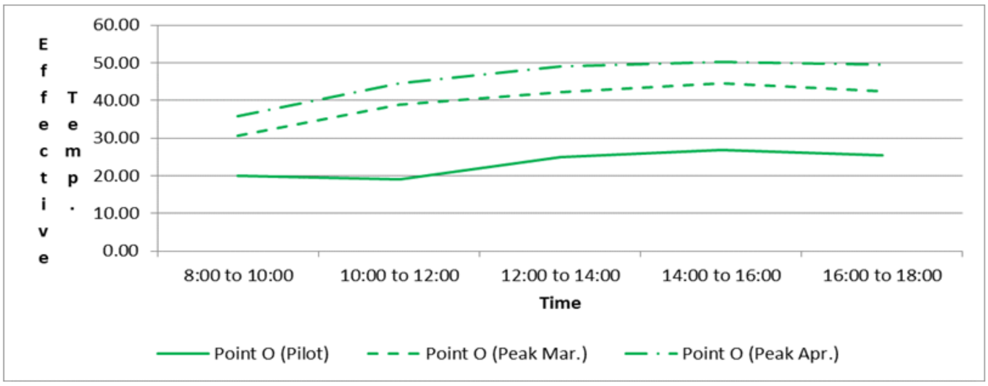
4 Results and Discussion

After the traverse survey is completed, all the data is recorded, and then the Effective Temperature (ET) is calculated in each case. The results are then plotted onto the graphs to understand the correlation between the various points and see how much the thermal comfort varies at different areas of the park.

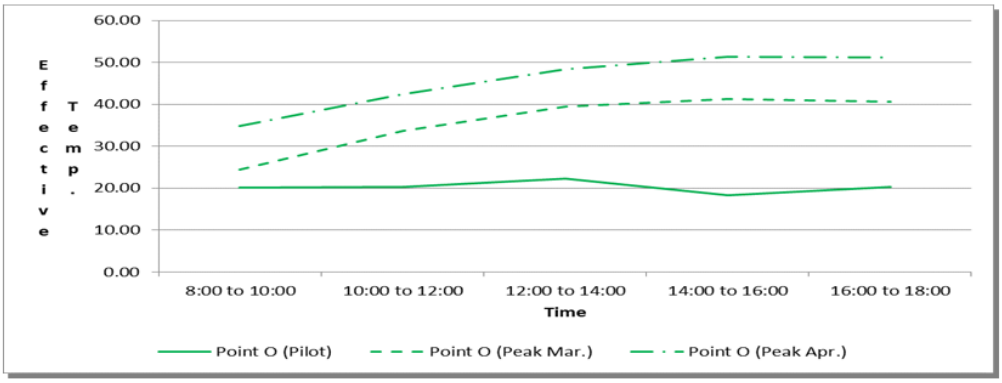
4.1 Park Centre (O)

The data recorded during the peak stress has shown many similarities in the overall trend. The morning hours show a higher reading than its adjacent counterparts due to its high sky view factor and shade provided by the peripheral trees. Site A shows a gradual increase in temperature that nearly plateaued towards the evening. Site B has the highest temperature difference between the two peak stress data, signifying the rapid rise of heat between March and April. Site C had a similar peak trend with a closer temperature difference (Figure 9).

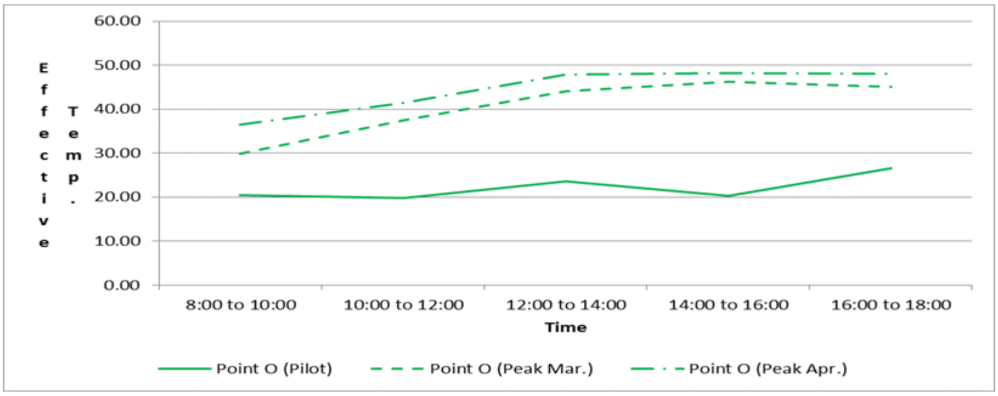
The pilot study's pattern was markedly different from that of its peers. It does, however, display a noticeable difference in the increase of about 10-15 degrees Celsius in the overall effective temperature during peak stress days. There is a noticeable temperature difference of around 2-5 degrees Celsius in March and April, which is more noticeable in the morning. This leads one to conclude that during these months, these areas are usually much cooler in the morning and have a relatively similar thermal stress when it is past noon.



Site A



Site B



Site C

Figure 9: Temperature variations in the Park Center (O).

4.2 Northern Side (A, A')

The configuration of the northern side is quite similar in site A and B. Hence, they both have a very similar graph. The common trend here is that the point farther away from the park is much hotter during the whole day. Site B was much warmer than A due to the park's larger size (Figure 10). The fall on Site C's Point A' from 14:00 to 16:00 is an anomaly since the temperature ranges have remained constant. However, there was a substantial increase in wind velocity, which resulted in an overall cooling of the temperature. The temperature graph for Site C in Peak stress surveys is very similar in the two surveys.

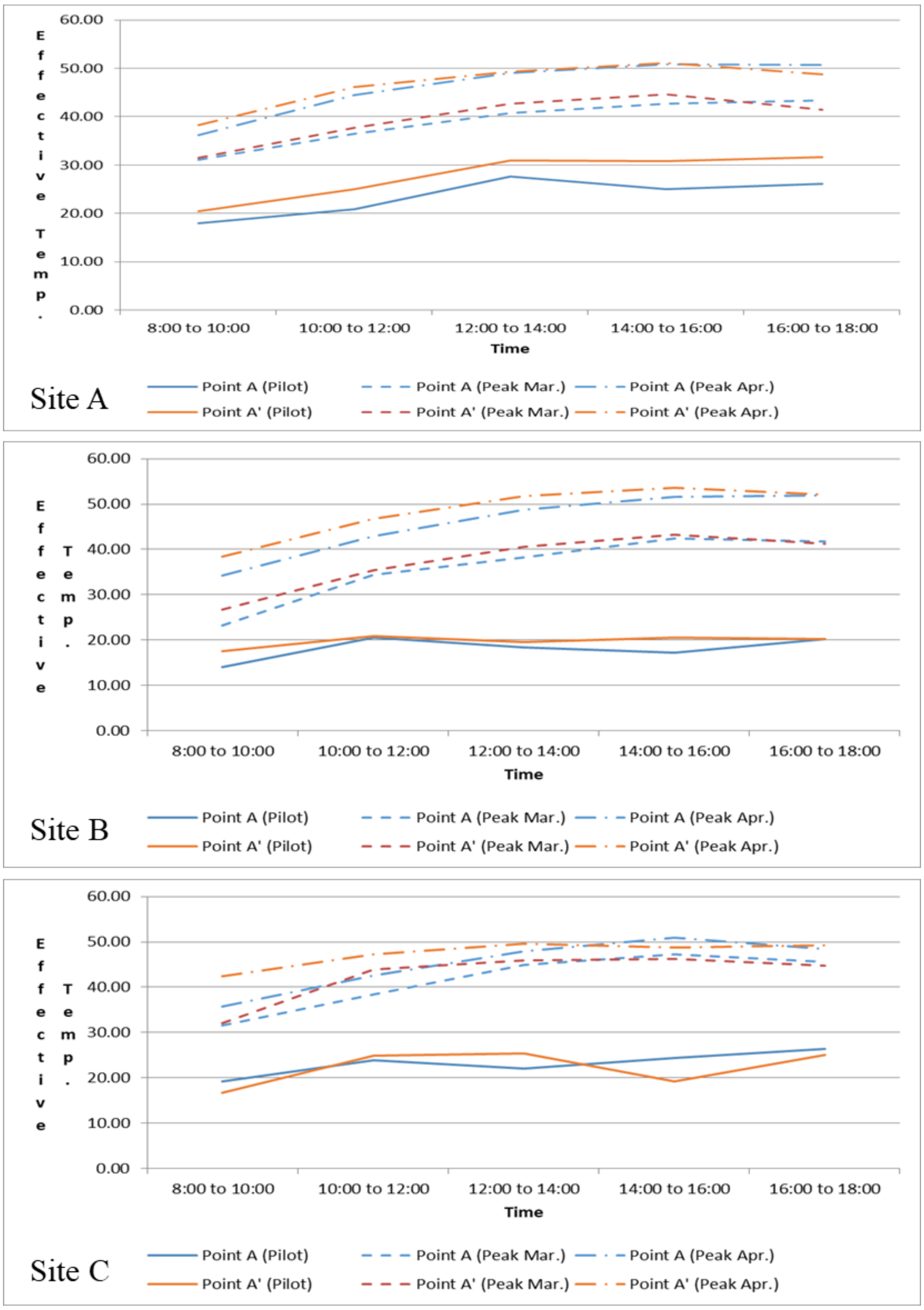


Figure 10: Temperature variations at Northern side (A, A').

4.3 Eastern Side (B, B')

The temperature graph of the eastern side is very similar in all three sites. The lack of peak stress temperature difference in Site C is also similar to that of its Northern counterparts. The previous trend at Site A about the point farther away from the park being much hotter during the whole day is still prevalent in this case. Site B is relatively much cooler than the park itself (Figure 11). Hence it can be seen as the vegetation used nearby the park also impacts the overall temperature. The morning temperatures at Site B are lower than other sites towards the eastern side during the peak stress study.

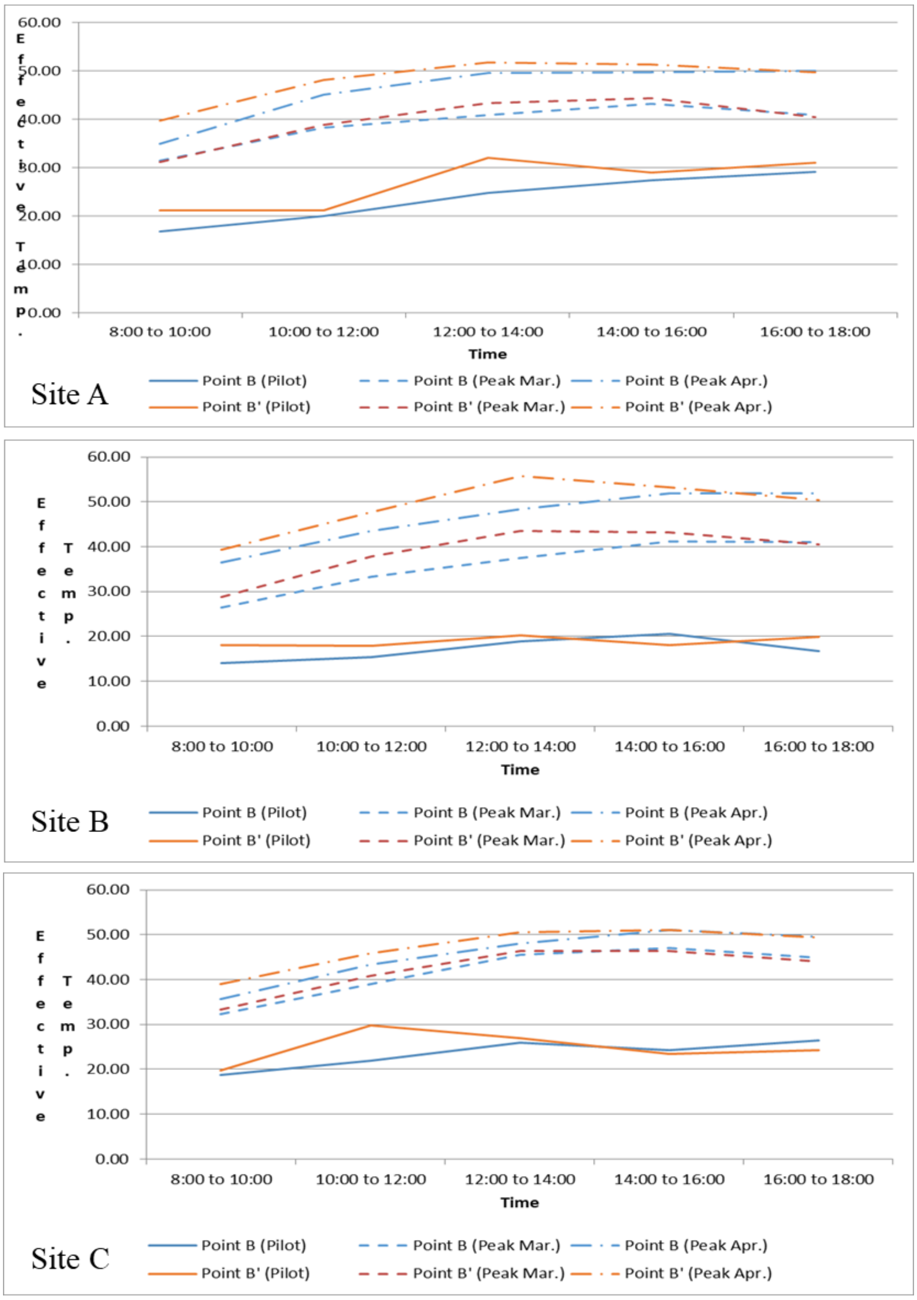


Figure 11: Temperature variations at Eastern side (B, B').

4.4 Southern Side (C, C')

The southern side has a similar trend, with the temperature capping at noon. The southern areas near the park reached temperatures below 50 degrees Celsius, while most of the areas away from the park were hotter. The temperature difference has a higher variance in the morning as they peak during the afternoon and then slow in the evening. The pilot study of site B showed an anomaly as it had a lower effective temperature graph for the points away from the park throughout the whole day than the station adjacent to the park (Figure 12).

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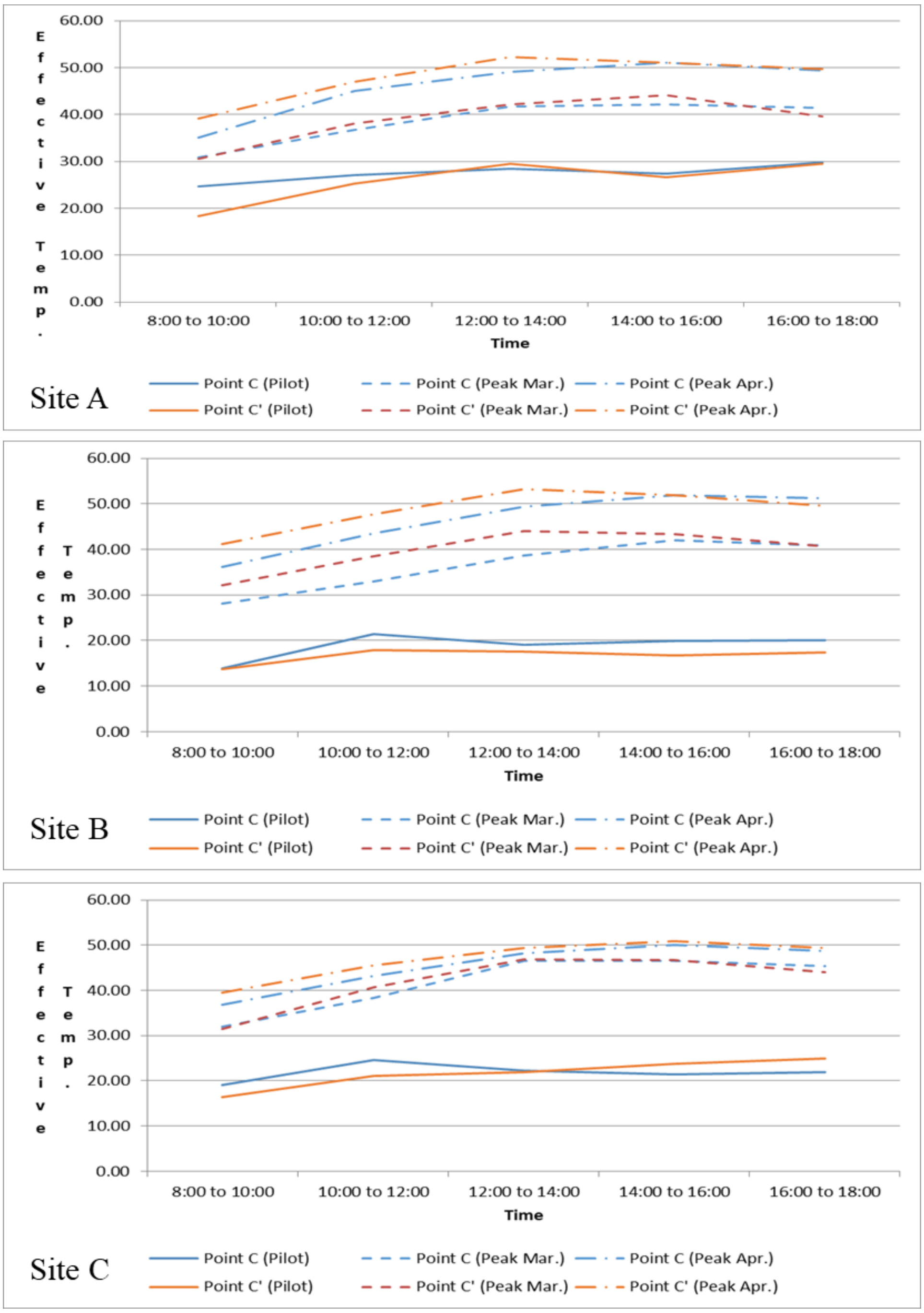

Figure 12: Temperature variations at Southern side (C, C').

4.5 Western Side (D, D')

The western side has a bit of anomaly during the peak stress study. The readings at Site A and B show a similar trend but have a higher average than other parts of the park, with readings at Site B being the highest among all. Site C's readings provide a different scenario, probably due to different orientation of the park or green areas at or around the survey stations (Figure 13).

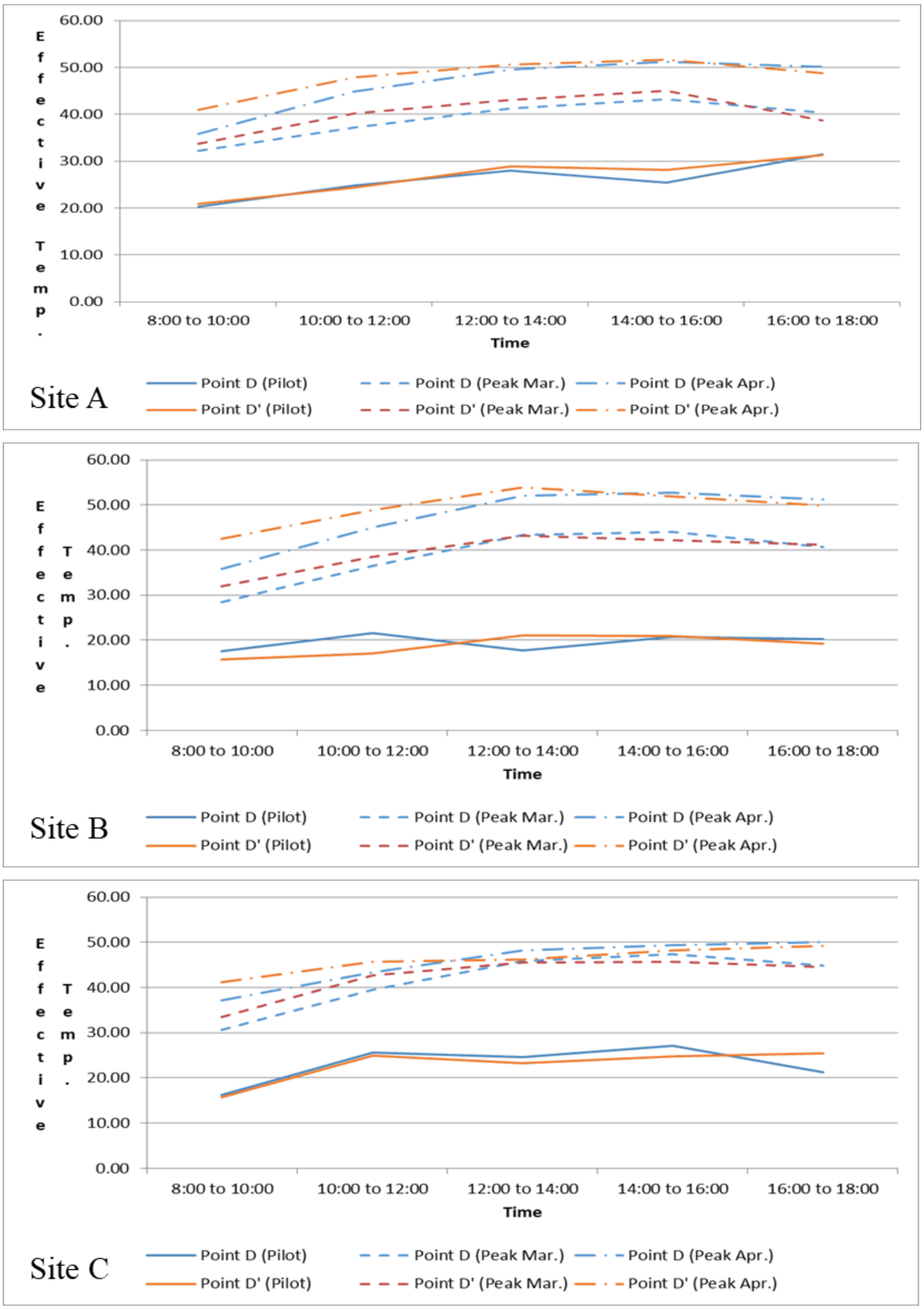

Figure 13: Temperature variations at Western side (D, D').

4.6 Corridors

A corridor was marked at each site to understand a wind draft's presence and create a difference in the overall thermal performance. The fundamental trends show (more clearly on peak stress surveys) that the more away from the park generally have a higher effective temperature, even high wind speed does not help the overall cause (Figure 14). These readings even out towards the end of the day.

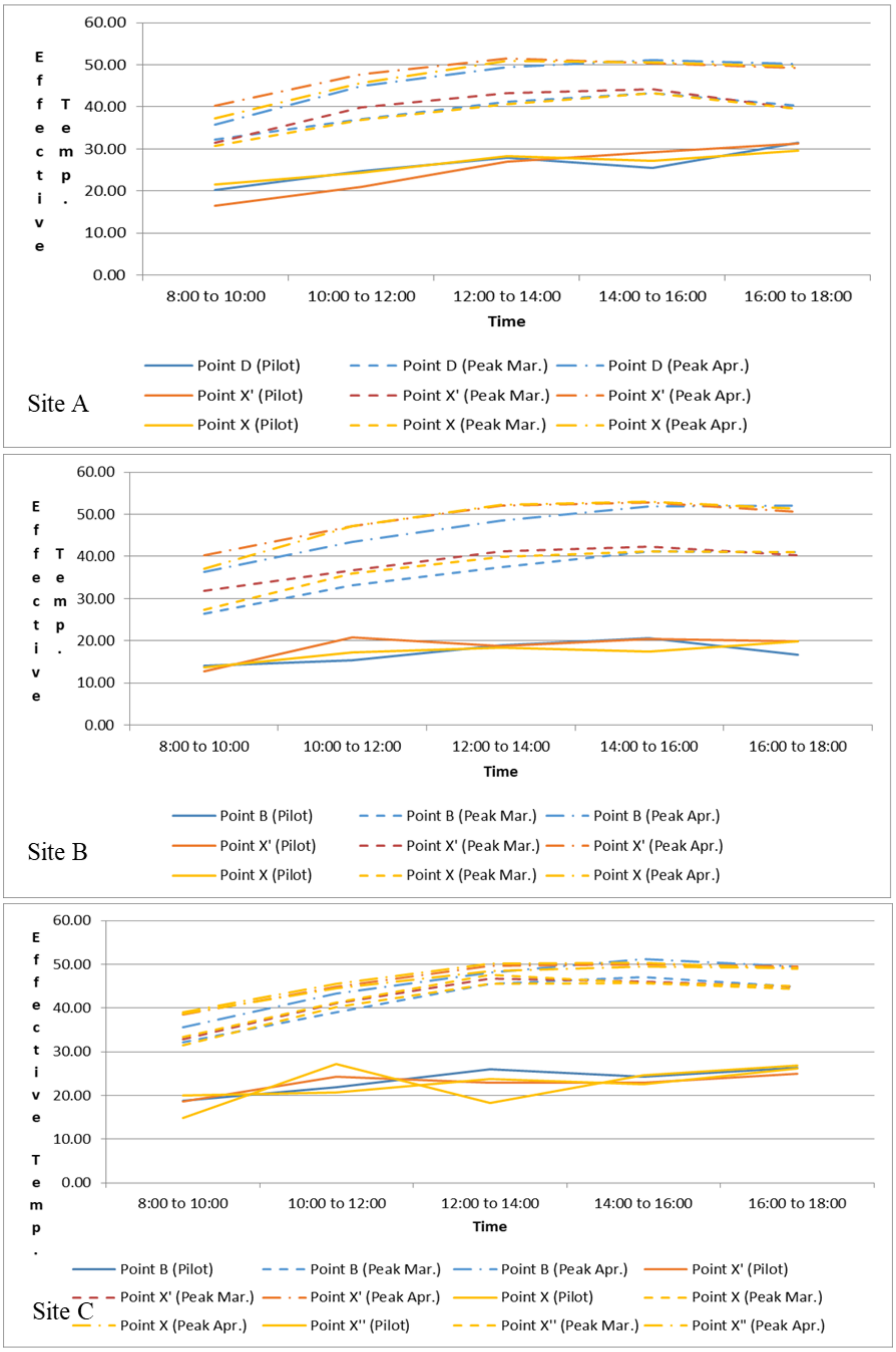

Figure 14: Temperature variations at Corridors.

4.7 Impact of Park Parameters

The impact of specific design features on such a level of scale is mentioned as follows:

Orientation: The park's orientation has given different results, with Sites A and B showing similar trends and Site C with a relatively different thermal graph throughout the day.

Relative Distance to the Park: The thermal performance of the stations adjacent to the park were generally better than those which were farther away from it. This difference is more apparent on peak stress days as the difference in temperature is significantly higher. With the surface remaining similar in most cases, such comparisons increase the importance of park adjacencies in an urban neighbourhood.

Wind Corridors: Surprisingly, the stations placed within the selected wind corridors had a very similar thermal trend to those placed generally around the site. This shows that in a low rise urban neighbourhood, long wind corridors have little to no effect on the overall microclimate.

Foliage: The presence of dense foliage over certain areas have shown better thermal performance; these mainly were present near the site and coupled with the overall benefit of providing a dense green space.

5 Recommendations and Conclusion

Following the lessons learnt from the various literature, case studies, study area analysis, and personal experience throughout the study. Some conclusions drawn are that the factors that impact the overall climate on various scales (like mesoscale or local-scale) are vastly different. The urban climate has its own set of variables that define a specific area's microclimate. The neighbourhood parks have a critical thermal effect on their immediate surroundings but require careful design strategies to maximise their impact. The park's size, orientation, and vegetation density all play a significant role in deciding the overall temperature inside and around the park. Implementing Urban Green Space Redesigning Strategies is more than just a policy intervention because local neighbourhood parks need community input to carry out different strategies.

Various other parameters can be included in this study which remained unexplored in this study, like a more informed and analytical approach can be made upon the study areas through the usage of modern climatic simulation tools. These can also be used to quantify the thermal mitigation of the recommended strategies. A much more detailed analysis can be made upon the thermal impact of neighbourhood green areas by increasing the study time for a year or more to understand better a yearlong trend with a particular emphasis on the peak stress months. The analysis of private green spaces opens the door to various mitigation measures such as green walls and terraces.

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References

[1] Hunter A, and Luck G 2015 Defining and measuring the social-ecological quality of urban green space: a semi-systematic review *Urban Ecosystem* **18(4)** 1139–1163.
[2] Luederitz C, Brink E, Gralla F, Hermelingmeier V, Meyer M, and Niven L et al 2015 A review of urban ecosystem services: six key challenges for future research *Ecosystem Services* **14** 98–112.
[3] Tzoulas K, Korpela K, Venn S, Yli-Pelkonen V, Kaźmierczak A, and Niemela J et al 2007 Promoting ecosystem and human health in urban areas using green infrastructure: A literature review *Landscape and Urban Planning* **81(3)** 167-178.
[4] Urban Greening Guidelines, 2014. New Delhi, India: Town and Country Planning Organisation, Ministry of Urban Development, Government of India, 2014.

[5] Arifwidodo S and Chandrasiri O 2015 Urban heat island and household energy consumption in Bangkok, Thailand *Enrg. Proc.* **79** 189-194.
[6] Martin P, Baudouin Y and Gachon P 2014 An alternative method to characterize the surface urban heat island *International Journal of Biometeorology* **59(7)** 849-861.
[7] Oke T 1982 The energetic basis of the urban heat island *Quarterly Journal of the Royal Meteorological Society* **108(455)** 1 24.
[8] Federer C 1976 Trees modify the urban microclimate *J. of Arb* **2** 121-127.
[9] De B and Mukherjee M 2018 Optimisation of canyon orientation and aspect ratio in warm-humid climate: Case of Rajarhat Newtown, India *Urban Climate* **24** 887-920.
[10] ASHRAE Handbook 2001 Atlanta Ga.: American Society of Heating Refrigerating and Air-Conditioning Engineers
[11] Wu J, Gao X, Giorgi F and Chen D 2017 Changes of effective temperature and cold/hot days in late decades over China based on a high-resolution gridded observation dataset *Intl. J. Of Climo.* **37** 788-800.
[12] Hwang Y, Lum Q and Chan Y 2015 Micro-scale thermal performance of tropical urban parks in Singapore. *Building. and Environment* **94** 467-476.
[13] Chang C and Li M 2014 Effects of urban parks on the local urban thermal environment. *Urban Forestry & Urban Greening.* **13(4)** 672-681.
[14] Subarao Pawar A, Sahu S, Mukherjee M 2015 Assessing Thermal Behaviour of LULC from Micro-Meteorological Measurements ACE 2015.