Effect of open space surface treatment and built form on thermal profile: A case of Mumbai, India

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ABSTRACT

The thermal environment ~~in~~of Recreational Open Spaces (ROS) is primarily a result of the surrounding built form which includes buildings, trees, and surface treatment materials. To study the impact of land surface treatment choice and urban form on the thermal characteristics of open spaces, a case study assessment was undertaken in the dense urban context of Mumbai, India. To study ROS and its thermal profile, we selected three open spaces adjoining a school in Mumbai exhibiting different surface material treatments and built form. A comparative analysis was completed using ENVI-met based modelling. The model outcomes were validated using heat stress meters and thermal infrared camera readings.

The results highlighted the significant impact of the land surface choice and vegetation on the ambient air temperature and surface temperature of ROS. Open spaces with concrete paving and open mud surface showed the air temperature about 3°C and 1.5°C higher than the surfaces covered with natural materials during day hours. During the evening, concrete surfaces showed comparatively high maximum surface temperatures (Ts) compared to other, i.e. by 4.1 °C. The inferences from this study would assist in appropriate policy formation and design guidelines that render thermally suitable ROS and mitigate the urban heat island effect.

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Keywords

Recreational Open Spaces; Urban Heat Island; Surface Treatment; Thermal Comfort; Developing Nations

Nomenclature

ROS	Recreational Open Space
T _a	Ambient Air Temperature
T _s	Surface Temperature
V	Wind speed
hrs	Hours

1.0 Introduction

Recreational amenities like parks and playgrounds are essential natural spaces in the dense urban context that help to improve the urban quality of life (Tian et al., 2014). ROS help in mitigating various urbanization ills by providing many ecosystem services like improving and sustaining varied biodiversity, aiding stormwater management, improving air quality, and carbon sequestration (Konijnendijk et al., 2013). Various studies have investigated the cooling effects of open space entities like vegetation and natural surface treatment through processes like evapotranspiration (Bolund and Hunhammar, 1999; Bowler et al., 2010; Zhang et al., 2014), cooling of air from shading provided by trees, etc. (Chang and Li, 2014; Georgi and Zafiriadis, 2006; Lin et al., 2015; Mcpherson et al., 1997). Dense urban areas are experiencing increased air temperatures owing to climate change that negatively impacts human comfort and health (Spronken-Smith and Oke, 1998). With the increasing trends of land surface temperature in urban areas, the thermal profile in ROS are worst affected (Liu et al., 2017; Sodoudi et al., 2018). The thermal profile of ROS is primarily a result of the surrounding built form that includes buildings, trees, and the surface treatment material. Inappropriately planned ROS could

adversely affect their thermal profile, resulting in underperforming or underutilized civic amenities.

Studies that investigate thermal profile in open spaces, usually consider air temperature, solar radiation, and wind speed (Givoni et al., 2003). Certain studies look at the design of the open space or the built environment surrounding the open space to evaluate the thermal comfort for the ROS (Martinelli et al., 2014). The study by Cohen et.al. (Cohen et al., 2014) further investigated the environment quality associated with open spaces emphasizing on the in-situ measurements of pertinent indices of noise and air pollution along with certain climatic variables. Furthermore, land surface treatment and surrounding form for open spaces was investigated to be major influencers affecting the experienced thermal comfort (Chatzidimitriou and Yannas, 2015).

Past studies have used existing thermal indices like Physiological Equivalent Temperature (PET), Universal Thermal Climate Index (UTCI) for investigating the thermal profile of open spaces (Golasi et al., 2018; Höppe, 1999; Mehrotra et al., 2020). However, given the number of indices, the selection of appropriate indices and its validation is difficult. Also, a particular Index does not capture the actual ground condition completely. To analyse thermal comfort in open spaces, microscale studies have been conducted using computational models that model various scenarios. Once validated, results of computation models provide basis for proposing implementing strategies for heat mitigation (Crank et al., 2018). Outdoor thermal profile studies are needed to suggest mitigation strategies like cool roof, green cover, cool pavements in open spaces (Akbari and Kolokotsa, 2016; Errell and Pearlmutter, 2012; Taleghani, 2018). Numerical models like ENVI-met and SOLWEIG are widely in modelling thermal variables for various regions (Acero and Herranz-Pascual, 2015; Emmanuel et al., 2007; Lindberg et al., 2016; Mehrotra et al., 2019).

Few studies have assessed the linkage between built form, open spaces, and the resultant thermal profile, specifically for the context of a developing nation. The current study is an attempt to corroborate the effect of varied surface treatments and surrounding built forms on the thermal profile of open spaces specific to the urban context of Mumbai, India. Due to robust and

accurate capability to model complex outdoor environment (Salata et al., 2016; Wu and Chen, 2017), ENVI-met is used to carry out this study.

Mumbai is a densely populated tropical megacity of India. This coastal city has a high level of humidity with moderately hot temperatures throughout the year. The city experiences three seasons of summer, monsoon, and winter. The city experiences three seasons of summers (March to May), winter (October to February) and monsoon (June to September). Past weather data of Mumbai (year 1981–2010) from the India Meteorological Department (IMD) archives for santacruz station, show that city's average maximum temperature as 37.6oC in summers with average minimum of 14.3oC in Winters. Highest temperature of 42.2 is recorded in the month of April. Average precipitation is 2,184. mm and average humidity as 74%. The available green open spaces in Mumbai is about 0.8 sq.m. per capita, much lower than the WHO recommended standard of 9 sq.m. per capita (MMR-EIS, 2012). There is a scarcity of available and usable open spaces in Mumbai for the vast population. To ensure better comfort for open space users, the ROS must be planned to optimize their thermal profile. To understand the impact of land surface treatment choice and urban form, on the ambient air temperature and the resultant thermal comfort, a case study assessment was undertaken. To study ROS and its thermal profile, a selection of three open spaces adjoining a school in Mumbai within the IIT Bombay campus was made. IIT Bombay is an educational institution and campus located in the 'S' ward jurisdiction of Mumbai metropolitan area. The selected ROS surfaces were treated with different materials and were around different built forms. The surrounding included the presence of trees and built forms of different heights and types. Figure 1 represents the location of three case study sites within the IIT Bombay campus and depicts the varied built form and land surface treatments of the respective sites. The land surface materials were earth/mud, concrete, paver tiles, and asphalt. ENVI-met modelling was used with further validation methods to quantify and validate the variation in the thermal profile of open spaces as explained in the following section.

105 **Table 1: Site locations**

Sr. No.	Monitoring Location	Nomenclature	Land surface Material	Vegetation Layout	Surrounding built form / Level of enclosure
1	KV Playground	ROS 1	Barren soil	Trees on the outer periphery	Open
2	KV Assembly Court	ROS 2	Concrete paved floor	Interspersed trees	Built on three sides , open on one end
3	Academic block ground	ROS 3	Earth with leaves on the ground	Dense tree cover	Built on one side, Semi open

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107 Figure 1 Case study location within the IIT Bombay campus with reference images of the context

2. Methodology

A model of three ROS including built, vegetation and surface materials is prepared as an input to the ENVI-met software to simulate thermal variables like air temperature and land surface temperature. ENVI-met is a three-dimensional microclimate model that can simulate thermal variables in urban areas with a high resolution. The ENVI-met generated output is further used for comparatively analyzing the impact of land surface treatment on the ambient air temperature, surface temperature, and relative thermal comfort. The results were validated using ambient air temperature and surface temperature, recorded over three intervals in morning, afternoon and evening, over three days. Along with the ambient air temperature readings, infrared thermal imaging data of the various surface treatments were also recorded and the results validated.

The study has three components:

1. Simulation of three different ROS in ENVI-met
2. Monitoring of surface temperature using Infrared Camera for three different periods.
3. Monitoring of ambient air temperature using LSI heat stress meter for three different periods.

Based on the above study components, the thermal profile of open spaces could be assessed and further to it heat mitigation measures could be suggested.

2.1 Thermal profile simulation in ENVI-met

The simulation of the study area that included three ROS and built form elements like buildings, trees, ground surface and roads were carried out in ENVI-met 4.4 winter release version. The area was simulated for 12 hours for March month and validated for the same days. The input to S/W includes- building footprint with height information, material finish information and its insulating properties. Trees were chosen from the available library of ENVI-met as dense and medium in foliage and 15m to 25m in height. Mumbai meteorological station data was used to

force ENVI-met simulations. Hourly data on Air temperature and humidity was considered while wind speed and direction were kept constant. The thermal conditions were simulated from 9:00 am to 21:00 hours, i.e. for 12 hours for 24th March 2017. Figure 2 shows three ROS in the study area and weather profile input for ENVI-met simulations.

Figure 2: Input area and meteorological data files in ENVI-met for simulations

2.2 Monitoring Surface Temperature (Ts)

The study area simulated for air temperature (T_a), wind flow (v) and surface temperature (T_s). The results from ENVI-met simulations are verified on the ground on for three times in a day for a week duration. The verification is carried out using FLIR E60 Thermal Imaging camera, that captures the radiated heat from the surfaces. The difference in T_s of three ROS is captured by the camera. The emissivity ranges between 0.92 to 0.95 (Chatzidimitriou and Yannas, 2015), and here it is considered as 0.95.

2.3 Ambient Air temperature monitoring

The simulated air temperature is verified on the field using thermal sensors – LASTEM LSI heat stress meter. The instrument is commonly used to monitor outdoor thermal variables and

calculate heat stress (Noro et al., 2015). Figure 3 shows the use of LSI meter for monitoring T_a and Handheld FLIR Infrared camera for monitoring.

Figure 3 (a) and (b) LSI LASTEM heat stress meter, (c) and (d) Handheld FLIR thermal camera

3.0 Results

The study results are discussed stepwise for thermal comfort variables T_s and T_a . ENVI-met model is evaluated using field measurements carried out at three selected ROS sites, during three time periods of a day i.e., 11:00, 14:00 hours and 18:00 hours. Surface Temperature results for three time periods for three ROS are shown in Figure 4. The apparent surface temperature was accurately captured in FLIR than ENVI-met model, but results are correlated with the model. Results show highest surface temperatures were found on ROS 2 ($T_s = 42^\circ\text{C}$) during the afternoon, which could be due to direct and high solar radiation on the paved surface that emitted radioactive heat. ROS 1 also found to have high T_s i.e. above 37°C in the afternoon (Refer Figure 5)

Figure 4 FLIR images of three sites showing surface temperature with the varied surface treatment a) mud cover, b) cement concrete paved and c) leaves, taken at three time of day i.e. in morning, afternoon and evening.

The field results of air temperatures correlated with the output received from ENVI-met model. However, during the afternoon period, the modelled data showed higher T_a values (1.5°C) than observed T_a on-site and during evening average difference was 0.5°C (refer Figure 5). The mean error between simulations and real monitoring data was tested using the statistical method Coefficient of Variance in Root mean Square Error (CVRMSE) and found to be under acceptable limits i.e. $CV(RMSE)$ is below 10%, as per ASHRAE².

²ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers publishes a set of standards and guidelines relating to thermal environmental conditions for human occupancy

Figure 5 Ta is modelled for three period as a, b, and c and Ts is modelled as d, e and f for three time periods, i.e. 11 hrs, 14 hrs and 18 hrs respectively, using ENVI-met for 3 ROS in the study area.

Figure 6 Variation in Ta in three ROS at three time periods

4. Discussion

The study results indicate that built form and surface material are major parameters that determine the outdoor thermal comfort of open spaces. This has implications on walkability, use of open spaces as well as indoor energy usage.

The results show that ROS 1 and ROS 2, both have high Ta in the afternoon, but ROS 2 has maximum Ta when compared to other ROS during the evening, i.e at 18:00 hours. This is the time when the land surface starts cooling. The probable reason for high Ta at ROS 2 could be because of the concrete paved surface that radiates heat and the surrounding built form that further confines the radiant heat, raising the air temperature. The enclosure of the open space should be such that it shades the ground during day time but allows heat to escape. Airflow to the open space also plays an important role in dissipating the heat away.

ROS 1 experiences high Ta in the afternoon due to direct solar radiation that heats the exposed surface. But interestingly, due to openness and airflow, the surface cools down fast, as shown in Figure 6. Compared to other ROS, ROS 3 shows lower Ta and well as Ts, due to natural surface cover and tree shade that lowered the surface temperature and its air temperature throughout the day.

When surface temperature is high, its adjoining air also gets heated up due to convection. Further, the built environment plays an important role in shading the surfaces as well as allowing air movement to reduce heat retention – that leads to the formation of heat islands.

The results highlighted the significant impact of the land surface choice on the ambient air temperature of recreational open spaces. Open spaces which were treated with only earth/mud showed the highest air temperature (~34°C) and about 3°C higher than other areas. The air temperature and surface temperature calculated using ENVI-met vary between morning, afternoon and evening, where afternoon temperatures were beyond the comfortable temperature range. The ground (ROS 3) enclosed with walls and trees had the most suitable thermal comfort throughout the day compared to other areas. The study shows how built areas with vegetation and suitable surface treatment can regulate thermal comfort in open spaces that in turn reduces

the formation of urban heat islands. ENVI-met can be an effective tool in generating scenarios for modulating air and surface temperatures.

The study indicates ENVI-met has been able to model the outdoor thermal environment with acceptable accuracy. However, It has limited capability to model exact surfaces present in the real-world situation. During the afternoon, the error in the model was highest and showed higher values than the observed values. This could be because of not considering the shadow of buildings and air flows at local levels. Another limitation of ENVI-met is that the approximation of building as blocks which could affect the accuracy in estimating thermal variations. Overall, the model is useful in estimating thermal parameters at different periods at a fair resolution of building blocks, which is not available in other models.

Thus, the study brings into light how surface temperature, surrounding trees and its built environment are both important to determine the thermal comfort of ROS. **We can hereby confirm our hypothesis based on the survey results as follows:**

$$\text{Outdoor Thermal profile} = f(\text{surface treatment, built environment, tree cover})$$

Policy decisions should be made considering the above parameters to provide a thermally conducive open space for enhancing public usage of open spaces. The study would assist in decision making pertaining to the design of building forms that render thermally suitable ROS and mitigate the urban heat island effect. Using the inferences from this study, design guidelines regarding the appropriate land surface treatment of ROS could also be recommended to achieve thermally comfortable urban amenities of recreation. Heat mitigation measures like cool paving and increasing shading devices, vegetation cover etc. Cool paving in open spaces could be achieved by using high-albedo materials. Local agencies and researchers should further test these materials and proposed guidelines for usage in open spaces as a mitigation measure to control heat and ensure thermal comfort of users.

Further scope of the study includes investigation of seasonal variations in ROS types and sensitivity analysis of build form parameters.

5. Conclusions

The results of investigations of three different ROS confirms that the significant variation in thermal performance of ROS is dependable on built form, surface treatment and tree cover. The three open spaces behaved differently during the different time of the day. The difference was maximum during the afternoon period given the influence of solar radiation on the ground. The study showed the effectiveness of tree cover in regulating surface temperature and air temperatures in any area. It is an effective, easily applicable and cost-effective solution to reduce afternoon heat gain. Tree cover should be encouraged in all public open spaces and roads as a mandatory feature, specifically in a tropical city like Mumbai that has high pedestrian movement. The study also brings out the importance of built geometry in enclosing an open space. Varying openness and height of buildings have a high impact on the thermal profile of the enclosed open spaces. With the help of built form, tree cover and surface treatment, the radiant heat and ambient air temperature could be modulated.

Numerical models like ENVI-met could be helpful to develop various scenarios to select appropriate built form and surface material for achieving overall desired thermal performance at a different time of the day and year. This study was limited to explore temperature variation in three different ROS. Further, the research scope could be extended to study various other factors that influence thermal comfort in ROS, as well as carry out a sensitivity analysis of each factor.

The study successfully brings out key issues that need attention and need to be incorporated in urban planning and design of public spaces, to reduce thermal discomfort in tropical cities and overall urban heat island effect of urban areas.

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274 **References**

- 275 Acero, J.A., Herranz-Pascual, K., 2015. A comparison of thermal comfort conditions in four
276 urban spaces by means of measurements and modelling techniques. *Build. Environ.* 93,
277 245–257. <https://doi.org/10.1016/j.buildenv.2015.06.028>
- 278 Akbari, H., Kolokotsa, D., 2016. Three decades of urban heat islands and mitigation technologies
279 research. *Energy Build.* 133, 834–852. <https://doi.org/10.1016/j.enbuild.2016.09.067>
- 280 Bolund, P., Hunhammar, S., 1999. Ecosystem services in urban areas. *Ecol. Econ.* 29, 293–301.
281 [https://doi.org/10.1016/S0921-8009\(99\)00013-0](https://doi.org/10.1016/S0921-8009(99)00013-0)
- 282 Bowler, D.E., Buyung-ali, L., Knight, T.M., Pullin, A.S., 2010. Landscape and Urban Planning
283 Urban greening to cool towns and cities : A systematic review of the empirical evidence.
284 *Landsc. Urban Plan.* 97, 147–155. <https://doi.org/10.1016/j.landurbplan.2010.05.006>
- 285 Chang, C.-R., Li, M.-H., 2014. Effects of urban parks on the local urban thermal environment.
286 *Urban For. Urban Green.* 13, 672–681. <https://doi.org/10.1016/j.ufug.2014.08.001>
- 287 Chatzidimitriou, A., Yannas, S., 2015. Microclimate development in open urban spaces: The
288 influence of form and materials. *Energy Build.* 108, 156–174.
289 <https://doi.org/10.1016/j.enbuild.2015.08.048>
- 290 Cohen, P., Potchter, O., Schnell, I., 2014. A methodological approach to the environmental
291 quantitative assessment of urban parks. *Appl. Geogr.* 48, 87–101.
292 <https://doi.org/10.1016/j.apgeog.2014.01.006>
- 293 Crank, P.J., Sailor, D.J., Ban-Weiss, G., Taleghani, M., 2018. Evaluating the ENVI-met
294 microscale model for suitability in analysis of targeted urban heat mitigation strategies.
295 *Urban Clim.* 26, 188–197. <https://doi.org/10.1016/j.uclim.2018.09.002>
- 296 Emmanuel, R., Johansson, H., E., R., 2007. Urban shading – a design option for the tropics? A
297 study in Colombo, Sri Lanka. *Int. J. Climatol.* 27, 3–11. <https://doi.org/10.1002/joc.1609>
- 298 Erell, E., Pearlmutter, D., 2012. Effect of high-albedo materials on pedestrian thermal comfort in
299 urban canyons. 8 th Int. Conf. Urban Clim. Dublin ... 8–11.
300 <https://doi.org/10.1016/j.uclim.2013.10.005>

- Georgi, N.J., Zafiriadis, K., 2006. The impact of park trees on microclimate in urban areas. *Urban Ecosyst.* 9, 195–209. <https://doi.org/10.1007/s11252-006-8590-9>
- Givoni, B., Noguchi, M., Saaroni, H., Pochter, O., Yaakov, Y., Feller, N., Becker, S., 2003. Outdoor comfort research issues. *Energy Build.* 35, 77–86. [https://doi.org/10.1016/S0378-7788\(02\)00082-8](https://doi.org/10.1016/S0378-7788(02)00082-8)
- Golasi, I., Salata, F., de Lieto Vollaro, E., Coppi, M., 2018. Complying with the demand of standardization in outdoor thermal comfort: a first approach to the Global Outdoor Comfort Index (GOCI). *Build. Environ.* 130, 104–119. <https://doi.org/10.1016/j.buildenv.2017.12.021>
- Höppe, P., 1999. The physiological equivalent temperature - a universal index for the biometeorological assessment of the thermal environment. *Int. J. Biometeorol.* 43, 71–75. <https://doi.org/10.1007/s004840050118>
- Konijnendijk, C.C., Annerstedt, M., Nielsen, A.B., Maruthaveeran, S., 2013. Benefits of Urban Parks - A systematic review, International Federation of Parks and Recreation Administration. Copenhagen and Alnarp.
- Lin, W., Yu, T., Chang, X., Wu, W., Zhang, Y., 2015. Calculating cooling extents of green parks using remote sensing: Method and test. *Landsc. Urban Plan.* 134, 66–75. <https://doi.org/10.1016/j.landurbplan.2014.10.012>
- Lindberg, F., Onomura, S., Grimmond, C.S.B., 2016. Influence of ground surface characteristics on the mean radiant temperature in urban areas. *Int. J. Biometeorol.* 60, 1439–1452. <https://doi.org/10.1007/s00484-016-1135-x>
- Liu, Y., Li, J., Li, S., 2017. An Evaluation on Urban Green Space System Planning Based on Thermal Environmental Impact. *Curr. Urban Stud.* 05, 68–81. <https://doi.org/10.4236/cus.2017.51005>
- Martinelli, L., Battisti, A., Matzarakis, A., 2014. Multicriteria analysis model for urban open space renovation: An application for Rome. *Sustain. Cities Soc.* 14, e10–e20. <https://doi.org/10.1016/j.scs.2014.07.002>
- Mcpherson, E.G., Grimmond, S.U.E., Souch, C., 1997. Quantifying urban forest structure , function , and value : the Chicago Urban Forest Climate Project. *Urban Ecosyst.* 49–61.

- Mehrotra, S., Bardhan, R., Ramamritham, K., 2020. Diurnal thermal diversity in heterogeneous built area: Mumbai, India. *Urban Clim.* 32, 100627. <https://doi.org/10.1016/j.uclim.2020.100627>
- Mehrotra, S., Bardhan, R., Ramamritham, K., 2019. Outdoor thermal performance of heterogeneous urban environment: An indicator-based approach for climate-sensitive planning. *Sci. Total Environ.* <https://doi.org/10.1016/j.scitotenv.2019.03.152>
- MMR-EIS, 2012. Inventorisation of Open Spaces and Water Bodies in Greater Mumbai.
- Noro, M., Busato, F., Lazzarin, R.M., 2015. Urban heat island in Padua, Italy: Experimental and theoretical analysis. *Indoor Built Environ.* 24, 514–533. <https://doi.org/10.1177/1420326X13517404>
- Salata, F., Golasi, I., de Lieto Vollaro, R., de Lieto Vollaro, A., 2016. Urban microclimate and outdoor thermal comfort. A proper procedure to fit ENVI-met simulation outputs to experimental data. *Sustain. Cities Soc.* 26, 318–343. <https://doi.org/10.1016/j.scs.2016.07.005>
- Sodoudi, S., Zhang, H., Chi, X., Müller, F., Li, H., 2018. The influence of spatial configuration of green areas on microclimate and thermal comfort *Urban Forestry & Urban Greening* The influence of spatial configuration of green areas on microclimate and thermal comfort. *Urban For. Urban Green.* 34, 85–96. <https://doi.org/10.1016/j.ufug.2018.06.002>
- Spronken-Smith, R.A., Oke, T.R., 1998. The thermal regime of urban parks in two cities with different summer climates. *Int. J. Remote Sens.* 19, 2085–2104. <https://doi.org/10.1080/014311698214884>
- Taleghani, M., 2018. The impact of increasing urban surface albedo on outdoor summer thermal comfort within a university campus. *Urban Clim.* 24, 175–184. <https://doi.org/10.1016/j.uclim.2018.03.001>
- Tian, Y., Jim, C.Y., Wang, H., 2014. Assessing the landscape and ecological quality of urban green spaces in a compact city. *Landsc. Urban Plan.* 121, 97–108. <https://doi.org/10.1016/j.landurbplan.2013.10.001>
- Wu, Z., Chen, L., 2017. Optimizing the spatial arrangement of trees in residential neighborhoods for better cooling effects : Integrating modeling with in-situ measurements *Landscape and*

359 Urban Planning Optimizing the spatial arrangement of trees in residential neighborhoods for
360 . Landsc. Urban Plan. 167, 463–472. <https://doi.org/10.1016/j.landurbplan.2017.07.015>
361 Zhang, B., Xie, G., Gao, J., Yang, Y., 2014. The cooling effect of urban green spaces as a
362 contribution to energy-saving and emission-reduction : A case study in Beijing , China.
363 Build. Environ. 76, 37–43. <https://doi.org/10.1016/j.buildenv.2014.03.003>
364