

# Thermal comfort evaluation of green space geometries in different Local Climate Zone

## The case of hot-arid climate

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CAP LTER Twenty-fifth  
All Scientists Meeting  
and Poster Symposium

Friday, January 13, 2023

## INTRODUCTION

The significant effects of urbanization on local climate are well-known and documented information. It is a serious issue in both developing and developed countries because the increasing of three-dimensional (3D) urban structures change the physical and geometric characteristics of land surface (Guo et al., 2020; Singh et al., 2017). To create a cooler urban surface, urban green infrastructure are important in addition to urban 3D morphology, geometry, and surface characteristics.

Especially, urban green spaces (UGS) in public spaces have been the main topic in urban climate studies to achieve sustainable urban development (Kántor et al., 2018; Taleghani & Berardi, 2018). Different indicators have been used by many researchers to examine the effects of urban green spaces on the urban ecosystem (Crnk et al., 2018; Makropoulou & Gospodini, 2016). However, previous studies did not suggest a standardisation about UGS location, aspect ratio, orientation, and area size in different urban landscapes to decrease LST. It is necessary to examine the spatial adequacy of UGS characteristics quantitatively and qualitatively to evaluate their outdoor thermal comfort in different building types with mathematical models. More information and detailed investigations are needed to determine suitable green space characteristics in terms of thermal comfort within different building types. Therefore, the relationship between 3D urban morphology, green space characteristics and land surface characteristics needs further investigation to eliminate this gap.

## BACKGROUND

In recent years, models contribute to analyses in different detail resolutions, from the local to regional scales, to determine the climatic differences arising from the urban morphology (Acero & Herranz-Pascual, 2015; Alchapar & Correa, 2016). In the literature, there are many different subjects of study, mainly in hot-arid and hot-humid urban areas. Some studies focus on the influences of planting scenarios on different urban local spaces such as the pedestrian zone, squares, urban canyon and morphology, and green areas (Morakinyo et al., 2018; Unal Cilek et al., 2021; Unal et al., 2018). Many studies have considered the effects of different design elements such as material albedo, the ratio of water, the green area and impervious surface on urban public spaces to improve outdoor thermal comfort (Chatzidimitriou & Yannas, 2016; Kántor et al., 2018; Perera, 2015; Unal et al., 2018; Zhu et al., 2021). Most of the studies investigate the elimination of micro-scale urban heat island effects on urban geometry and urban morphology combined with LCZ (Karakounos et al., 2017; Unal Cilek & Ushu, 2021; Zhao & Fong, 2017). It is essential to improve the cooling performance through proper design. Previous studies have demonstrated that the determination of the urban thermal condition is a complex process, including climate, environment, and building index combination. In recent years, the strategies about the urban heat stress mitigation has developed with 3D climate model. To create a cooler urban surface, urban green infrastructure are important in addition to urban 3D morphology, geometry, and surface characteristics. eliminate this gap.

## RESEARCH QUESTIONS

The main research questions are as follow:

- Which geometric characteristics is suitable/unsuitable for LCZ?
- How orientation and tree canopy was affected the UGS thermal comfort?
- How tree canopy change the thermal condition of the UGS?

## STUDY AIM

This study aimed to statistically determine the suitable urban green space (UGS) geometry in different local climate zone (LCZ) for hot-arid climate. It combined the LCZ, 3D model results and statistical analysis. This study presents the preliminary results of the post-doc project which title is "Determination of Optimum Green Space Characteristics in terms of Thermal Comfort for the Building Types in Local Climate Zone". Study's results will be guide for future researchers and decision makers to standardize UGS characteristics in different urban morphologies and to develop climatically comfortable UGS designs and plan strategies that can be implemented in future cities.

## METHODOLOGY

Study methodology comprises four stages.

- **Determination of 2D and 3D characteristics:** The geometric characteristics of green spaces (area size, aspect ratio, and orientation) and building type of LCZ (LCZ 1-6) were determined (Fig. 1).

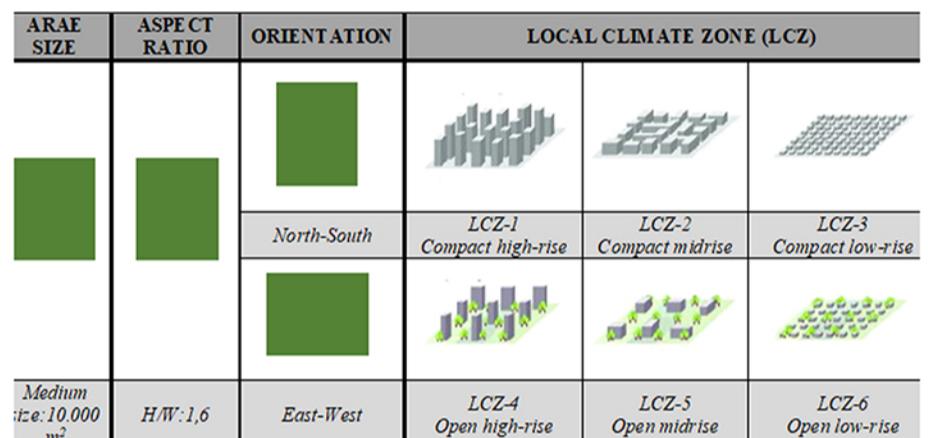


Fig 1. The 2D and 3D characteristics of green spaces

- **Determination of canopy cover:** There are three canopy cover were determined. These are 0% full grass cover, 50% canopy cover, and 100% canopy cover (Fig. 2).

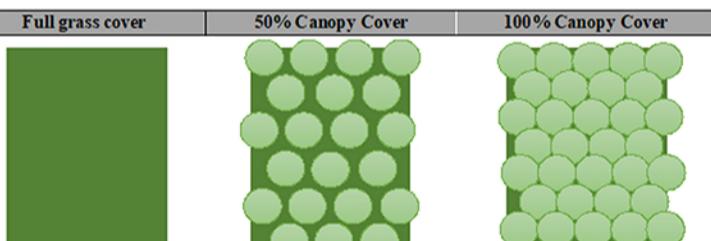


Fig 2. The canopy cover ratio of scenario

- **ENVI-met analysis:** As a result of the combination of green space characteristics and canopy cover, 36 scenarios were determined to analyze in ENVI-met (Fig. 3). Mean Physiological Equivalent Temperature (PET) for each green spaces and LCZ classes were obtained from ENVI-met for three canopy cover (0%, 50%, 100%) scenario. ENVI-met requires three basic types of data to start a simulation including spatial, simulation and climate data. Firstly, spatial data, including land uses and their characteristics, were digitised in Sketchup software with ENVI-met plugin. Simulation data including simulation date, start-finish, and simulation period. In this study, the spatial resolution was determined as 5 x 5 m, and the simulation period was determined as 8 hours. The simulation date was defined as 20 June 2017 according to hottest day of the last 20 years (2000-2020). The start-finish time of the simulation were identified according to the hottest period of the day, from 10:00 to 18:00 (<https://ag.arizona.edu/azmet/az-data.htm>).

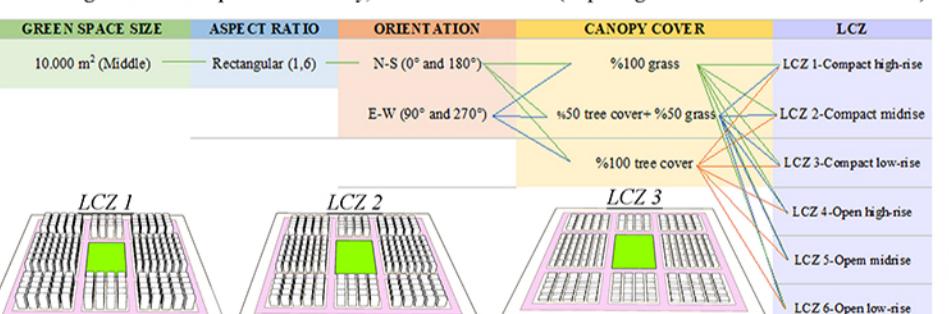


Fig 3. The number of scenario with the combination of The 2D and 3D green spaces characteristics the example of 3D model

- **Statistical analysis:** Finally, suitable and least suitable UGS characteristics were determined according to the statistical significance of PET differences ( $p > 0.05$ ) using the one-way ANOVA with post-hoc Tukey-HSD test analyses of pairwise comparisons.

## RESULTS

Fig. 4: Tukey-HSD comparison matrix for all scenarios, where the blue and red grids show the significantly different ( $p < 0.05$ ) mean PET.

		FULL GRASS COVER						50% CANOPY COVER						100% CANOPY COVER												
		LCZ 1		LCZ 2		LCZ 3		LCZ 4		LCZ 5		LCZ 6		LCZ 1		LCZ 2		LCZ 3		LCZ 4		LCZ 5		LCZ 6		
LCZ 1	LCZ 2	LCZ 3	LCZ 4	LCZ 5	LCZ 6	LCZ 1	LCZ 2	LCZ 3	LCZ 4	LCZ 5	LCZ 6	LCZ 1	LCZ 2	LCZ 3	LCZ 4	LCZ 5	LCZ 6	LCZ 1	LCZ 2	LCZ 3	LCZ 4	LCZ 5	LCZ 6	LCZ 1	LCZ 2	
E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	
-0.40	1.09	0.95	1.66	1.59	0.81	0.56	1.48	1.39	2.19	2.04	-2.36	-2.58	-1.52	-1.60	-0.78	-0.77	-1.60	-1.72	-1.05	-1.04	-0.43	-0.38	-2.66	-2.84	-1.90	-1.96
1.49	1.36	2.06	1.99	1.21	0.97	1.88	1.79	2.59	2.44	-1.96	-2.18	-1.12	-1.20	-0.37	-0.37	-1.20	-1.32	-0.65	-0.64	-0.03	-0.02	-2.25	-2.43	-1.50	-1.56	
-0.13	0.58	0.50	-0.28	-0.52	0.39	0.31	1.10	0.96	-3.45	-3.67	-2.60	-2.69	-1.86	-2.69	-2.81	-2.14	-2.13	-1.52	-1.47	-3.74	-3.92	-2.99	-3.05	-2.22	-2.16	
0.71	0.63	-0.15	-0.39	0.52	0.44	1.23	1.09	-3.31	-3.54	-2.47	-2.55	-1.73	-2.56	-2.67	-2.00	-1.99	-1.38	-1.34	-3.61	-3.79	-2.86	-2.92	-2.09	-2.02	-2.87	-2.93
-0.08	-0.86	-1.10	-0.18	-0.27	0.52	0.38	-4.02	-4.25	-3.18	-3.26	-2.44	-3.27	-3.38	-2.71	-2.70	-2.09	-2.05	-4.32	-4.50	-3.57	-3.63	-2.80	-2.73	-3.58	-3.64	
-0.78	-1.02	-0.11	-0.19	0.60	0.45	-3.95	-4.17	-3.11	-3.19	-2.36	-3.31	-2.64	-2.63	-2.02	-1.97	-4.24	-4.42	-3.49	-3.55	-2.72	-2.66	-3.51	-3.57	-3.02	-2.98	
0.24	0.67	0.59	1.38	1.24	-3.17	-3.39	-2.32	-2.41	-1.58	-2.12	-1.86	-1.84	-2.12	-1.94	-1.97	-1.87	-1.87	-3.46	-3.64	-2.71	-2.77	-2.9	-2.24	-2.19	-1.60	
0.91	0.83	1.62	1.48	-2.92	-3.15	-2.08	-2.16	-1.34	-1.33	-2.17	-2.28	-1.61	-1.60	-0.99	-0.95	-2.32	-2.40	-2.47	-2.53	-1.70	-1.63	-2.04	-2.15	-1.36	-1.25	
-0.09	0.71	0.56	-3.84	-4.06	-3.00	-3.08	-2.25	-2.25	-3.08	-3.20	-2.53	-2.52	-1.91	-1.86	-4.13	-4.31	-3.38	-3.44	-2.61	-2.55	-3.40	-3.46	-2.91	-2.87	-2.27	-2.17
0.80	0.65	-3.75	-3.98	-2.91	-2.99	-2.17	-2.16	-2.99	-3.11	-2.44	-2.43	-1.82	-1.78	-4.05	-4.23	-3.29	-3.36	-2.53	-2.46	-3.31	-3.37	-2.83	-2.78	-2.19	-2.08	
-0.15	-4.40	-4.63	-3.56	-3.64	-2.82	-3.64	-3.64	-3.64	-3.76	-3.76	-3.08	-3.08	-4.27	-4.23	-4.70	-4.88	-3.94	-4.01	-3.18	-3.11	-3.96	-4.02	-3.48	-3.43	-2.84	-2.88
0.00	-0.84	-0.94	-0.27	-0.26	0.34	0.39	-1.88	-2.06	-1.03	-1.03	-0.37	-0.37	-1.13	-1.13	-0.94	-0.94	-0.36	-0.36	-0.37	-0.37	-1.15	-1.21	-0.66	-0.62	-0.03	-0.03
0.83	0.83	0.00	-0.12	0.55	0.56	1.17	1.																			