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RESEARCH ARTICLE

Effect of outdoor thermal comfort condition on visit of tourists in historical urban plazas of Sevilla and Madrid

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Abstract
The tourism plays a significant role in economics and development of any country through revenue generation from multiple sources. Spain has been tourist place and host million foreign tourist. The tourism is highly depended on climate and thermal comfortness of the visiting place. This present research aimed to analyze the outdoor thermal comfort conditions in microclimates of the urban ancient plazas of the two important cities of Spain, namely Sevilla and Madrid on a hot humid stress day of the year. The microclimatic measurement, questionnaire survey, and simulation results were examined to evaluate the thermal comfort condition of six different urban plazas in Sevilla and Madrid to distinguish the supreme time to visit each ancient site. The results have suggested that the outdoor thermal comfort range for the tourist in the historical plazas of Sevilla and Madrid varies from 28.42 to 30.87 °C and 24.5 to 29.82 °C in the hot summer. Despite the high heat stress condition, the result of questionnaires survey shows that about 38.11% and 28.09% of tourists in Sevilla and Madrid, respectively, were satisfied with the thermal conditions. As witnessed from the result of the Envi-met simulation, Plaza de Santa Ana of Madrid and Plaza Nueva of Sevilla is the best place for visitors in the early morning hours. Additionally, during the peak hours, the thermal comfort of Alameda de Hercules of Sevilla and Plaza de Santa Ana of Madrid is the most suitable historical places for visitors, whereas in the evening hours, Plaza Nueva of Sevilla and Plaza de Mayor of Madrid with wider semi-open spaces and relatively suitable vegetation bring more favorable conditions for visitors. The comparison of the simulation result with the questionnaire reveals that the urban plazas with relatively high thermal stresses have a higher rate of thermal dissatisfaction.

Keywords Microclimatic measurement · Questionnaire survey · Simulation results · Urban Plazas · Tourist places · Mediterranean cities

Introduction

The tourism industry is one of the largest industries in the world and has always affected the economies of many tourist-friendly countries (Jover and Díaz-Parra 2020). The industry can improve relations between countries, cultural exchanges (Yu 2021), and various occupations and help countries to generate more revenue by creating opportunities for entertainment and recreation for tourists (Alipour et al. 2012; Matthew et al. 2021). The latest published statistics show that after France, with an annual attraction of about 89 million foreign tourists, Spain has hosted 82 million foreign tourists annually, which this volume of foreign tourists has set a clear vision for the tourism industry of this country (Argandoña 2010; Manganelli et al. 2016). However, industrial tourism is highly dependent on climate and its changes (Saarinen and Tervo 2006; Wall and Badke 1994). So that, one of the most crucial information needed by tourists is the weather conditions of tourist destinations (Hopkins 2014; Saarinen and Tervo 2006) and proper thermal comfort as the desirability and acceptability of the climate play an important role in deciding for tourist destinations

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(Lin and Matzarakis 2008). Indeed, it is an undeniable fact that urban areas are growing on a global scale (Afsharzadeh et al. 2021; He 2018), which has affected climate change (increasing levels of hardship) (Gachkar et al. 2021; Mohammad et al. 2021). These led to disruption in urban environments (increased heat waves and heat stress conditions) and the presence of tourists in cities (Bigano et al. 2008; Lopes et al. 2021; Mohammad and Goswami 2019).

Numerous studies have been conducted on thermal comfort in urban microclimates, all of which point to a direct relationship between climatic conditions and the use of outdoor environments (Chen et al. 2020; Deng and Wong 2020; Karimi et al. 2021; Knaus and Haase 2020; Mohammad et al. 2019; Mohammad and Goswami 2021a, 2021b). Thermal comfort in open metropolitan spaces is of extensive significance because of its huge effect on human wellbeing (Falah et al. 2020; Xiong et al. 2015), urban vitality (Afsharzadeh et al. 2021) and the energy consumption of buildings (Ibrahim et al. 2021). It is better to identify the indexes that influence thermal comfort to create the proper conditions (Gachkar et al. 2021; Ng and Cheng 2012). Various factors are influencing the promotion of thermal situation in open urban spaces, which can be mentioned to plants (Shafiee et al. 2020; Simon 2016), the albedo of material (Gachkar et al. 2021; Mohammad et al. 2019, 2021; Zhou et al. 2018), the urban form including direction (Abaas 2020; Athamena 2022; Karimimoshaver and Shahrak 2022), sky view factor (SVF) (Jamei and Rajagopalan 2017; Song and Jeong 2016), and aspect ratio (Vassiliades et al. 2022; Xiaomin et al. 2006), which affects small urban microclimates and the role of water (Chan et al. 2017). For example, the role of the percentage of urban trees on thermal comfort in hot and humid climates of Roorkee taluk in Uttarakhand state of India has been investigated by (Mohammad et al. 2021). Their result shows that when the urban canyon is cover with 50% of the proper trees, the air temperature decreases by 0.97 °C during the day and by 0.71 °C during the night. Another study by Fahed et al. (2020) reveals that the ambient temperature of the roof top decreases with an increasing albedo of the material and reaches a maximum value of 2.5 °C during mid-noon. Also, Ali-Toudert and Mayer (2006) investigated the effect of various orientations of urban forms in summer and winter seasons in a tropical city of Ghardaia and found that the N-S orientation has less exposure to solar radiation in winter than in summer and leads to making better thermal comfort. Another research is conducted by Gachkar et al. (2021) regarding the effects of water on thermal comfort in Urmia and the results illustrated that a proper arrangement of the water pond creates a significant cooling effect for the thermal comfort of pedestrians.

Understanding the relationship between outdoor thermal comfort impact and tourism has been one of the most important research indicators among scientists since the late eighteenth century. So that, Mieczkowski provided a tourism climate comfort index (TCCI) to assess tourist climate relations (Mieczkowski 1985). A few years later, in 2003, Freitas estimated the tourism climate in light of three essential perspectives of aesthetic, physical, and thermal (de Freitas 2003). In connection with the relationship between climate parameters and tourism, various research have been done. Nasrollahi et al. (2017) assessed several climatic variables in the hot and dry district of Iran examined and its relationship with the thermal comfort of tourists and finally set on the appropriate time for visitors in this historical city of Isfahan. In a similar research, Matzarakis et al. (2013) conducted studies on meteorological indicators and their impact on tourism. Zare et al. (2018) have used ISO 7730 to analyze thermal comfort in Kerman based on both subjective and objective procedures. As well, different research have been reported in other parts of planet earth, including the city of Taiwan (Lin and Matzarakis 2008), Italy (Salata et al. 2017), China (Ma et al. 2019), Canada (Scott et al. 2007), and Portugal (Lopes et al. 2011). A survey of studies led on various environments showed that the majority of these studies have been done on an enormous scale and utilizing the information given by different meteorological stations to assess the significant pointers and decide the scope of thermal comfort reasonably for sightseers. However, unlike other previous studies, which focuses the impact of thermal comfort on historical sites, this study considered the range of thermal comfort and comparing them in different urban plazas of Seville and Madrid. This study tries to identify the most appropriate time for tourists to visit each of the historical sites of Seville and Madrid during the day and night.

Method

Selected area

The aim of this study is to investigate the thermal comfort conditions of various cultural sites that were compared during the day and night hours to distinguish the reasonable time to visit each cultural site in Sevilla and Madrid.

Sevilla is situated in the southwest of the Iberian Peninsula (37° 21′ 55″ N, 6° 0′ 30″ W) and as the capital of the Independent People Community of Andalusia (Castaño-Rosa et al. 2018) has had encountered a huge development in recent 20 years (Herrera-Gomez et al. 2017; Jover and Díaz-Parra 2020). It has a total urban area of about 140 km^2 with a population of around 700,000 inhabitants and a population density of 5000 citizens/km^2. The city experiences Mediterranean climate (Csa) as per Köppen-Geiger climatic classification (Kottek et al. 2006), with mild winters and blazing hot summers. The warmest month of the year was recorded in July in the city of Seville, with maximum and minimum temperatures of 34 °C and 18.9 °C. On the other hand, January is considered as the coolest month with average maximum temperatures of 16 °C and average minimum temperatures of 5.7 °C (Galán et al. 2003), and due to the short distance from the Atlantic Ocean (60 km), sometimes the temperature is changed by the gentle breeze of the sea (Rodrigo 2019). It receives an average total annual rainfall of about 554 mm, mainly within the month of October to April.

The city of Madrid as one of the tourism hubs is also examined in this study. Madrid (40° 25′ 0.3900″ N and 3° 42′ 13.6440″ W), the capital of Spain, with a population of over 16.642 million people and 604 square kilometers area is one of the most important tourist cities in Europe (Gómez-Villarino et al. 2021), like other cities (Barcelona and Sevilla), and is belong to CSA zone (Soutullo et al. 2020). CSA (climate-smart agriculture) is an approach related to agricultural systems and its climate change consequence that help people to increase their productivity and incomes with minimum greenhouse gas emissions wherever possible. Rainfall is concentrated in spring and autumn, while cloudless days are more common in summer. Regionally, its climate is slightly influenced by the presence of the central mountain range, which divides the inner plateau of the Iberian Peninsula into two parts and affects the wind direction (mainly NE-SW). The condition of the Manzanares River, which flows from north to south of the city, further contributes to this impact, directing cold air from the mountains into the city (Garcla and Gómez 1996).

The study areas are among the hot spots in Europe that have high summer temperature, making the area prone to heat islands and sometimes heat wave and heat stress conditions (Follos et al. 2020). High humidity and low wind speed conditions are other features of these cities (Peña et al. 2018), and when such conditions match with high temperatures, the recurrence of fatalities because of hotness stress increments drastically (Kalkstein 1991). This in turn highlights the significance of understanding the consequences of planning decisions and the topic of mitigating risk through developed urban planning. Research conducted in each of the surveyed cities has covered three of the most important historical plazas. One of the most important factors in selecting these urban plazas was a distance between the selected places because the probability of visiting different ancient monuments and places with short distances at a certain time increases. A brief description of each of these urban plazas (three in Sevilla (Fig. 1b) and three in Madrid (Fig. 1c)) is given below:

Plaza de España: This urban plaza is the most admirable building in Seville, Spain, after the cathedral of this city, and the reason is the large and extreme scale along with the grandeur and beauty that can be seen in this structure. It is a landmark example of Regionalism Architecture, mixing elements of the Baroque Revival, Renaissance Revival, and Moorish Revival (Neo-Mudéjar) styles of Spanish architecture (Nsang 2012).

Alameda de Hercules: This is the most established public garden in Europe since the 1992 World's Fair and has since formed into one of the most well-known social spots for local people and vacationers (Muñoz 1998).

Plaza Nueva: This is a public square in the city center of Seville which was established in 1856. The land in this part of the San Fernando Monastery, which was previously built from 1270 to 1840, was later taken over by the local government and turned into a public square (Navarro De Pablos 2017).

Plaza de Colón: This famous square in the city center of Madrid, dedicated to the man who discovered America. It is one of most important open spaces and a strategic location in the city, leading out to prominent streets such as El Paseo de Recoletos, El Paseo de la Castellana, Calle Génova, Calle Serrano, and Calle Goya. It is also home to eminent buildings such as the Torres de Colón, a monument to Christopher Columbus presides over the square from the center of the fountain around which the traffic flows. The square is also home to the Jardines del Descubrimiento, a park that first opened back in 1970, where you can admire various sculptures as well as a monument dedicated to the discovery of America. Underground to this plaza, Fernán Gómez Cultural Centre is situated.

Plaza Mayor: Plaza Mayor is a square with arched passages in the city of Madrid, which is equally popular with tourists and locals, and its symmetrical rectangular buildings have a uniform architectural system. In medieval times, the landscape of the plaza mayor was the only space for a market outside the city walls. In the 1560s, King Philip II asked Juan de Herrera, the architect of Escorial, to turn the market into a real square, and this lasted until 1617 and the reign of King Philip III. The result was a large field measuring about 120 by 90 m with wooden buildings around it. All the buildings around the square were completely burnt down by fire three times in 1631, 1672, and 1790, and this is the last reconstruction we are witnessing today (Basterra et al. 2009).

Plaza de Santa Ana: Santa Ana Square is one of the sights of Spain, located in the center of Madrid. Santa Ana Square dates to the seventeenth century, but its appearance was very different from the current shape of the square. Construction of the current shape of Santa Ana Square was completed in 1880. The square is famous for its monument to Pedro Calderón de la Barca, the famous writer, and Federico García Lorca, the Granadian poet (Del Corral 2008).

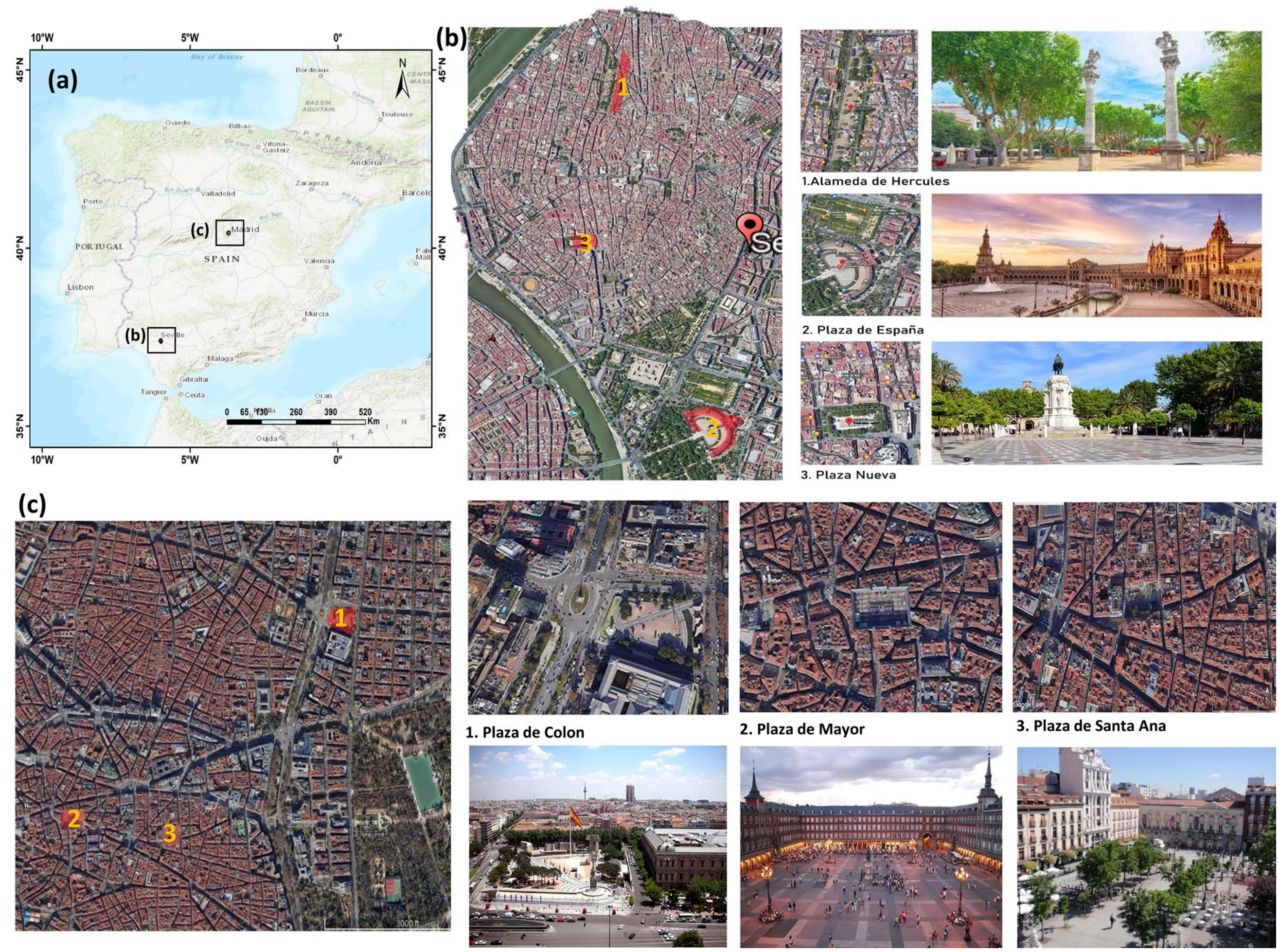


Fig. 1 **a** Location of Sevilla and Madrid in Spain, **b** locations of the three plaza's places in Sevilla, and **c** locations of the three plaza's places in Madrid

Research period

This study was conducted to find the most appropriate time for tourists to visit each urban plaza along with the importance of their thermal comfort in hot a summer month (Karimi et al. 2020; Mohammad et al. 2021). Meteorological data of Seville and Madrid station were collected for the last ten years (from 2010 to 2020). The average monthly air temperature (Ta) and wind speed (Ws) over Sevilla (Fig. 2a) and Madrid (Fig. 2b) were plotted to select the suitable hottest month for our simulation. From this, we selected July as the suitable month for simulation as it is showing maximum air temperature and minimum wind speed over the last 10 year. Also, the Barajas and Sevilla airport station's meteorological data near the study areas, situated at 12–14 km and 17–20 km, respectively, was used as climatic indicators during the last 10 years (2010 – 2020).

For finding the suitable day in July month for the simulation, we compared the meteorological data in July 2021 and find that 13th–14th July 2021 in Sevilla (Fig. 2c) and 10th–11th July 2021 in Madrid (Fig. 2d) would be possible day for evaluating the tourist's thermal comfort in the hottest day of the year with minimum wind speed.

Thermal comfort index

Based on the assessments from previous literatures, it is seen that more than 165 thermal comfort indicators have been designed; however, four common indicators of thermal comfort, including standard effective temperature (SET*), physiological equivalent temperature (PET), predicted mean vote (PMV), and universal thermal climate index (UTCI), have been more commonly used (Mohammad et al. 2021). Among these four indexes, PET is more frequently used as it is produced by taking into account the influence of short- and long-wave radiation in outdoor environments on human energy levels (Matzarakis et al. 2007, 2021). It is widely used in urban textures with intricate shadow patterns

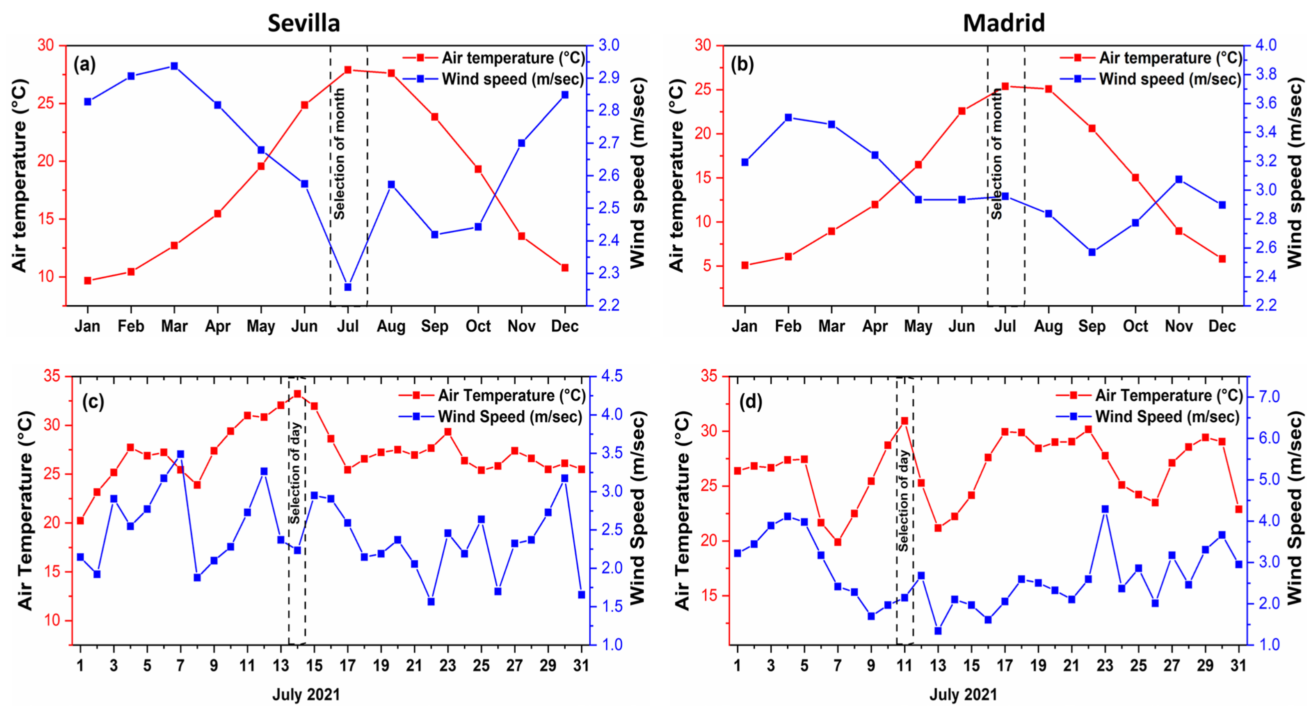


Fig. 2 Dispensation of change of monthly meteorological data averaged from 2010 to 2020 (for selecting suitable month), for Sevilla (**a**) and Madrid (**b**); dispensation in July 2020 (for choosing the suitable day for simulation) for Sevilla (**c**) and Madrid (**d**)

(Middel et al. 2017; Mohammad et al. 2021). Moreover, as seen from the many previous researches that have been done in hot and humid climates (Binarti et al. 2021; Hegazy and Qurnfulah, 2020; Lian et al. 2020), it is supposed to use the PET index in the present study with hot and humid climatic condition. It is easily calculated by Ray-Man software advanced at the Meteorological Institute of the University of Freiburg based on the instructions of the German Engineering Association (Gachkar et al. 2021).

Simulation

In this research, like most previous studies of outdoor thermal comfort (Gachkar et al. 2021; Karimi et al. 2020; Mohammad et al. 2021; Nasrollahi et al. 2017), Envi-met was used as a reliable software to investigate climatic conditions in open urban spaces (Wai et al. 2020; Xiong et al. 2020). This software is a non-hydrostatic three-dimensional model designed according to the fundamental of thermodynamics, fluid dynamics, and the laws of atmospheric physics and is able to calculate all influential indexes of outdoor thermal comfort (Forouzandeh 2021; Liu et al. 2021; Yilmaz et al. 2021). Six important historical plazas of Sevilla and Madrid along with their urban areas are simulated in this present study (Fig. 3). Since none of them had a time limit for visitors, the thermal comfort conditions of historic sites were evaluated over a 24-h period for finding the best suitable time for vising tourist. Also, given that in the first 2 h, the simulations lack the necessary credits, so the simulations have been started before the hottest day of July, consider for simulation. In addition, the default values of all other indexes in the Envi-met model were considered in the simulations. The details of the simulations for the Sevilla and Madrid are given in Table 1 and Table 2, respectively.

To calculate the physiological equivalent temperature (PET), Rayman software that made by Matzarakis et al. 2007 has been used and needs different indexes included of air temperature, humidity, wind speed, mean radiant temperature, human activity, and type of cover. Heat transfer resistance of 0.5 Clo (suitable for summer dressing habits) and 80 W activity (walking outdoors) was considered (Taleghani and Berardi 2018; Wang et al. 2016). In addition, as shown in Table 3, the default values of the other model parameters are used in the simulations.

Field study

Measurement

To accredit the simulation results performed by Envi-met software, field studies were performed with the metrological device on the same day of measurement at a suitable

Fig. 3 The location of receptors in each case study

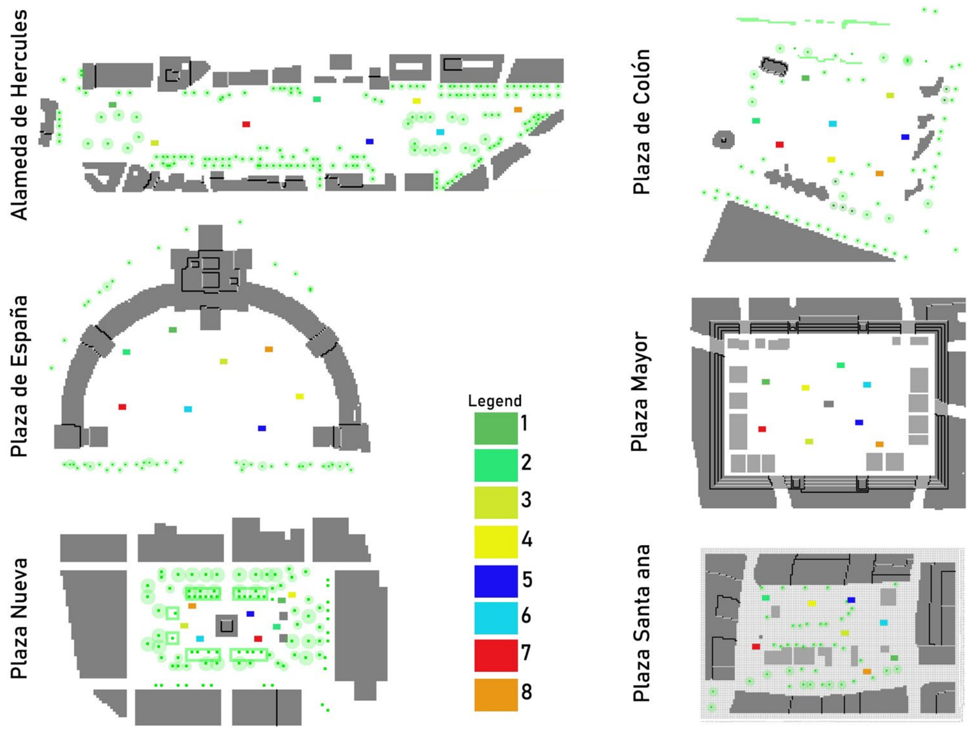


Table 1 ENVI-met input data for simulations in each case study in Sevilla

Simulation days			13th–14th July 2021		
Starting time			22:00 h		
Simulation period			26 h		
Air temperature in 2 m	Max		315.93 K at 5:00 PM		
	Min		297.04 K at 7:00 AM		
Relative humidity in 2 m	Max		38% at 7:00 AM		
	Min		11% at 5:00 PM		
Wind speed in 10 m			2.22 m-sec		
Wind direction			135° (NW–SE)		
Specific Humidity in 2500 m			8.93 g/kg		
Solar adjust factor			0.65		
Soil temperature	Upper layer (0–20 cm)		298 K		
	Middle layer (20–50 cm)		295 K		
	Deep layer (50–200 cm)		293 K		
Thermal transmittance of walls			0.5 W m^{-2} K^{-1} (default value)		
Thermal transmittance of roofs			0.5 W m^{-2} K^{-1} (default value)		
Albedo of walls			0.5 (default value)		
Albedo of roofs			0.5 (default value)		
Plazas evaluated	Number of grids (x, y, z)	Size of x grid cells	Size of y grid cells	Size of z grid cells	Number of nesting grids
Alameda de Hercules	(65,240,25)	2.00	2.00	2.00	2
Plaza de España	(140,183,25)	2.00	2.00	2.00	2
Plaza Nueva	(125,77,20)	2.00	2.00	0.50	2

Table 2 ENVI-met input data for simulations in each case study in Madrid

Simulation days			10th–11th July 2021		
Starting time			22:00 h		
Simulation period			26 h		
Air temperature in 2 m	Max		314.26 K at 4:00 PM		
	Min		292.04 K at 6:00 AM		
Relative humidity in 2 m	Max		49% at 6:00 AM		
	Min		12% at 4:00 PM		
Wind speed in 10 m			2.00 m-sec		
Wind direction			90° (W-E)		
Specific Humidity in 2500 m			8.93 g/kg		
Solar adjust factor			0.9		
Soil temperature	Upper layer (0–20 cm)		298 K		
	Middle layer (20–50 cm)		295 K		
	Deep layer (50–200 cm)		293 K		
Thermal transmittance of walls			0.5 W m^{-2} K^{-1} (default value)		
Thermal transmittance of roofs			0.5 W m^{-2} K^{-1} (default value)		
Albedo of walls			0.5 (default value)		
Albedo of roofs			0.5 (default value)		
Plazas evaluated	Number of grids (x, y, z)	Size of x grid cells	Size of y grid cells	Size of z grid cells	Number of nesting grids
Plaza de Colón	(165,140,30)	2.00	2.00	1.00	2
Plaza Mayor	(172,133,30)	2.00	2.00	2.00	2
Plaza de Santa Ana	(158,98,17)	2.00	2.00	2.00	2

Table 3 RayMan input data for calculating thermal comfort

Clothing insulation		0.9 clo (summer clothes)
Activity		80 W (walking)
Personal data	Height	1.75 m
	Weight	75 kg
	Age	35 years old
	Sex	Male

height from the ground as seen in priors studies (Nasrollahi et al. 2017, 2021). The thermal sensing votes (TSV) were examined on a 7-point semantic differential scale (cold, cool, slightly cool, neutral, slightly warm, warm, hot) and, to satisfy tourists, along with questionnaires. Different climatic variables collected during the field measurement includes air temperature (Ta), relative humidity (Rh), wind speed (Ws), and global temperature (T_{Globe}). This collected parameter helps in the calculation of mean radiant temperature (MRT). Certainly, based on different studies (Chen et al. 2014; Gál and Kántor 2020; Lee et al. 2019), MRT is obtained from Eq. 1, where D is global diameter (Tg) and ε is global emissivity. The obtained results are compared with the simulation outputs, which determine the amount of thermal comfort of each classical plazas of Seville and Madrid. Table 4 illustrates the features of the instruments used in this research.

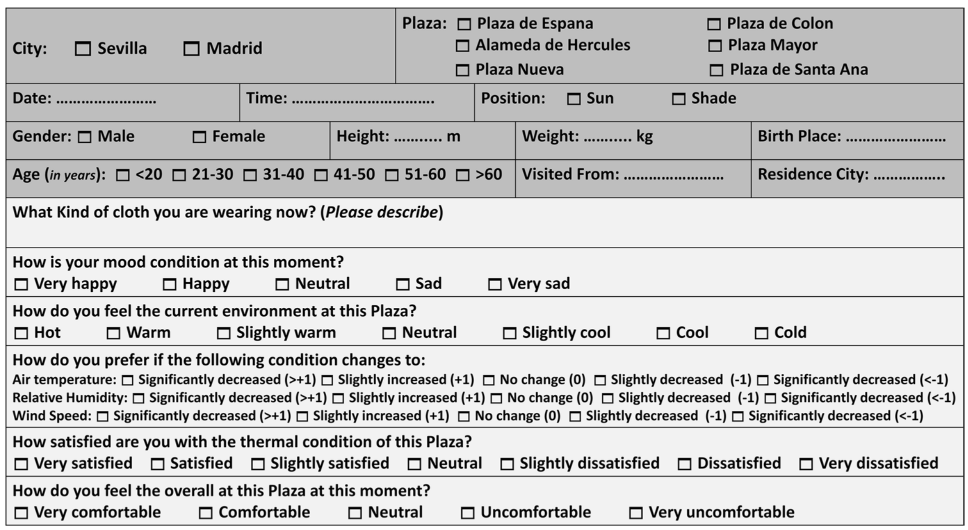
$$T_{MRT} = \left[\left(T_{GLOBE} + 273.15\right)^4 + \frac{1.1 * 10^8 * Ws^{0.6}}{\varepsilon * D^{0.4}} * \left(T_{GLOBE} - T_A\right) \right]^{0.25} - 273.15 \quad (1)$$

Questionnaire

This questionnaire has been prepared in accordance with previous studies (Mohammad et al. 2021; Sharmin et al. 2015) and ASHRAE-55 (Heating et al. 2004). It is mainly divided into two parts. The first part is related to the individual characteristics of tourists such as gender, height, their resident, weight, and age of people, whereas the second part is expressed to the feeling of warmth, thermal preference, thermal satisfaction, and length of stay in plazas. The questionnaires were distributed and completed among tourists in the morning (8 a.m. to 1 p.m.) and in the afternoon (4 p.m. to 9 p.m.) time, with maintaining the conditions of health protocols arising due to COVID-19 situation. Each questionnaire took between 5 and 7 min to complete and was designed for both visitors in English and Spanish. An example of a questionnaire is shown in Fig. 4.

Table 4 Features of the instrument used in this research

Instrument		Measured parameter	Accuracy	Range
Globe-thermometer		Tg	≤0.1 °C at 0 °C	0.1
Weather data logger		Ta, Ws	±0.9 °C from 40 °C to 60 °C; ±0.5 °C from 5 °C to 40 °C; ±1.1 °C from −20 °C to 5 °C ±3%	−40 °C to 70 °C
		Rh	±3%	0 to 90%



City: ☐ Sevilla ☐ Madrid	Plaza: ☐ Plaza de Espana ☐ Alameda de Hercules ☐ Plaza Nueva	☐ Plaza de Colon ☐ Plaza Mayor ☐ Plaza de Santa Ana

Date: .... Time: .... Position: ☐ Sun ☐ Shade

Gender: ☐ Male ☐ Female Height: .... m Weight: .... kg Birth Place: ....

Age (*in years*): ☐ <20 ☐ 21-30 ☐ 31-40 ☐ 41-50 ☐ 51-60 ☐ >60 Visited From: .... Residence City: ....

What Kind of cloth you are wearing now? (*Please describe*)

How is your mood condition at this moment?
☐ Very happy ☐ Happy ☐ Neutral ☐ Sad ☐ Very sad

How do you feel the current environment at this Plaza?
☐ Hot ☐ Warm ☐ Slightly warm ☐ Neutral ☐ Slightly cool ☐ Cool ☐ Cold

How do you prefer if the following condition changes to:
Air temperature: ☐ Significantly decreased (>+1) ☐ Slightly increased (+1) ☐ No change (0) ☐ Slightly decreased (-1) ☐ Significantly decreased (<-1)
Relative Humidity: ☐ Significantly decreased (>+1) ☐ Slightly increased (+1) ☐ No change (0) ☐ Slightly decreased (-1) ☐ Significantly decreased (<-1)
Wind Speed: ☐ Significantly decreased (>+1) ☐ Slightly increased (+1) ☐ No change (0) ☐ Slightly decreased (-1) ☐ Significantly decreased (<-1)

How satisfied are you with the thermal condition of this Plaza?
☐ Very satisfied ☐ Satisfied ☐ Slightly satisfied ☐ Neutral ☐ Slightly dissatisfied ☐ Dissatisfied ☐ Very dissatisfied

How do you feel the overall at this Plaza at this moment?
☐ Very comfortable ☐ Comfortable ☐ Neutral ☐ Uncomfortable ☐ Very uncomfortable

Fig. 4 Sample questionnaire used in the research

Validation

In this research, to evaluate the efficiency of ENVI-met software, the criteria coefficient of determination (R^2) and the Willmott agreement index (d) have been used like other research (Gachkar et al. 2021; Salata et al. 2016). The Willmott agreement index (d) is calculated using Eq. (2), where Pi and Oi are the predicted and observed values, respectively, n is the total number of observations, and $\overline{Q_i}$ is the mean of the observed values. The performance evaluation of three parameters, namely Ta, T_{MRT}, and Ws, which have a significant effect on heat perception of individuals, has been considered in this study. Table 5 reports the mean values of R^2 and d using the evaluation performed for each case study.

$$d = 1 - \frac{\sum_{i-1}^{n} \left(P_i - Q_i\right)^2}{\sum \left(\left|P_i - \overline{Q_i}\right|\right) + \left(\left|P_i - \overline{Q_i}\right|\right)^2} \quad (2)$$

According to conducted results in the plazas of Seville, the correlation ratio (R^2) for Ta was between 0.82 and 0.89, MRT was between 0.79 and 0.84, and Ws was between 0.77 and 0.81, while d varies from 0.67 to 0.81 for the different plazas of Seville. As well, in the Madrid case studies good correlation were observed in the different plazas. The correlation ratio (R^2) of Ta, MRT, and Ws was between 0.8 and 0.9 in the three selected plazas, whereas d is from 0.68 to 0.79. The gained results is comparable with the outcome of the prior reported studies (Gachkar et al. 2021; Karimi et al. 2020; Lee et al. 2016). It can be accounted for obtaining results are advised satisfactory, and the extent of this difference can be related to elements like limited simulation accuracy in the ENVI-met model (Acero and Herranz-Pascual 2015), incompatibility of native plant profiles with software plants, and variation in MRT (Krüger et al. 2011).

Table 5 Quantitative assessment of the ENVI-met efficiency based on the evaluation of R^2 and d in Sevilla and Madrid

Sevilla				Madrid			
Location	Index	*d*	R^2	Location	Index	*d*	R^2
Plaza de España	T_A	0.74	0.82	Plaza de Colón	T_A	0.71	0.8
	T_{MRT}	0.79	0.79		T_{MRT}	0.76	0.82
	Ws	0.72	0.77		Ws	0.73	0.84
Alameda de Hercules	T_A	0.68	0.86	Plaza de Mayor	T_A	0.73	0.82
	T_{MRT}	0.8	0.84		T_{MRT}	0.77	0.86
	Ws	0.69	0.79		Ws	0.79	0.81
Plaza Nueva	T_A	0.76	0.89	Plaza de Santa Ana	T_A	0.68	0.81
	T_{MRT}	0.81	0.82		T_{MRT}	0.75	0.83
	Ws	0.67	0.81		Ws	0.68	0.9

Results

Questionnaire results

Questionnaires were distributed in different sections as shown in Fig. 4 in the selected plazas of Seville and Madrid to assess the feeling of thermal comfort. An overall of 180 questionnaires were collected in 7 days in two shifts in the morning and evening, and each questionnaire lasted about 5 to 7 min to ensure the stability of outside weather conditions. The highest number of forms was entered in Plaza de Espana (92) and the lowest in Plaza Nueva (42). While, in Madrid the completed questionnaires were the lowest and highest in Plaza de Santa Ana (36) and Plaza de Colón (87), respectively. Overall, participants completing the questionnaire in the city of Seville were 55.36% male and 44.64% female. While in the plazas of Madrid, women (58.35%) participated more than men (41.65%) in completing the questionnaire. Domestic tourists were 9.06% from Seville, 8.33% from Malaga, and 7.97% from Cadiz. Most foreign tourists included 5.07% from France, 2.75% from Switzerland, 3.5% from Morocco, 8.05% from Netherland, and 4.5% from Italy. While polls in plazas of Madrid showed that domestic tourists were less than foreign tourists and more than 80% of those polled were from France, Switzerland, Italy, Netherlands, Morocco, and Turkey. In terms of age, the highest frequency is related to tourists between 41 and 50 years and then to the age range of 31 to 40 years in the city of Seville, while the highest frequency in Madrid was related to tourists between 51 to 60 and 41 to 50 years. About 67.86% and 54.86% of tourists in Seville and Madrid surveyed the weather conditions to determine their travel destination, and about 60.85% and 42.65% of them were informed of the reasonable weather situation to visit the ancient sites of Seville and Madrid, respectively.

Thermal comfort sensation of tourists

Given that the questionnaires were evaluated and completed in one of the warm months of the year, the thermal comfort sensation of travelers was more disposed to the hotness range. The explanation of the thermal comfort sensation of the interviewees is illustrated in Fig. 5. With increasing attendance time at each of the assessed plazas in Madrid and Seville, the increase in the feeling of warmth led to a decrease in the level of comfort of tourists and their dissatisfaction with the thermal situation and their priority for

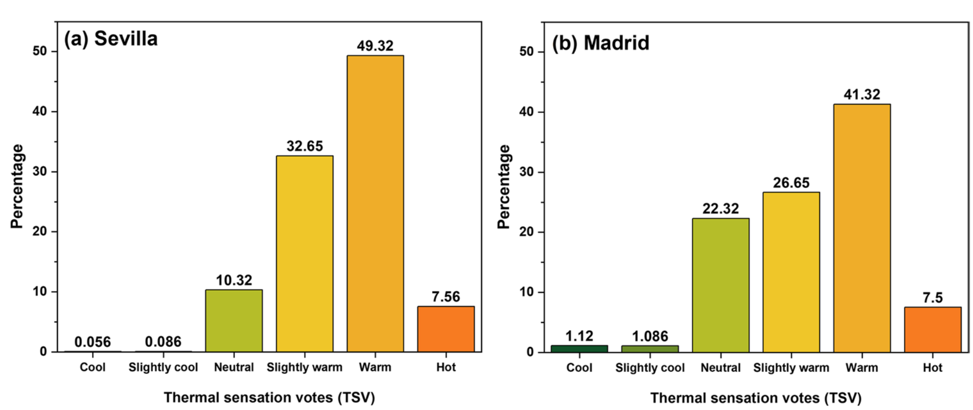


Fig. 5 Percentage distributions of thermal sensation votes (TSV) in all the six sites of Sevilla and Madrid

Table 6 Gamma correlation for thermal sensation and other parameters in the plazas of the city of Sevilla

Parameters		Value coefficient	Approx. Sig	Description
Thermal sensation	Exposure time	−0.312	0.002	✓
	Thermal preference	−0.343	0.000	–
	Mental condition of tourists	0.260	0.647	✓
	Thermal comfort	−0.126	0.002	–
	Thermal Satisfaction	−0.195	0.001	✓

Table 7 Gamma correlation for thermal sensation and other parameters in the plazas of the city of Madrid

Parameters		Value coefficient	Approx. Sig	Description
Thermal sensation	Exposure time	−0.512	0.018	✓
	Thermal preference	−0.212	0.001	–
	Mental condition of tourists	0.342	0.346	✓
	Thermal comfort	−0.175	0.004	–
	Thermal Satisfaction	−0.234	0.002	✓

cooler conditions developed. While when the visitors are in shady places, their thermal sensation has been increased. In addition, it is necessary to mention that there is no relation between tourist's emotional states (happiness and sadness) and their thermal comfort sensation. The importance of the relationship between tourist's sense of thermal comfort and various factors is shown in Tables 6 and 7 for Sevilla and Madrid, respectively.

Thermal comfort satisfaction of tourists

Based on the assessment of the results of the questionnaire conducted in the city of Seville, about 38.11% was satisfied, 21.09% were slightly satisfied, and 9.09% were very satisfied with the thermal conditions as most of whom were elderly. While surveys conducted in Madrid showed that about 28.19% were satisfied, 21.09% were slightly satisfied, and 9.31% were very satisfied with the thermal conditions. This is due to high heat stress, and tourists' satisfaction may be in line with their expectations of this hot season. Figure 6 shows the percentages of satisfaction of tourists in each of the selected plazas of Seville and Madrid.

Percentage distributions of satisfaction at each plaza of Sevilla and Madrid

Evaluations in the city of Seville show that visitors to the Plaza Nueva and Plaza de Espana were more satisfied than Alameda de Hercules (Fig. 7). Plaza Nueva has an almost smaller outdoor space than other squares, and, the shaded trees, also the semi-open porch of Plaza de Espana, got the highest level of tourist satisfaction. However, Alameda de Hercules got the least unlevel of thermal satisfaction among every one of the plazas regardless of having many shade trees. On the other hand, the vegetation cover of Plaza de Colón plays a similar role in overall thermal comfort satisfaction.

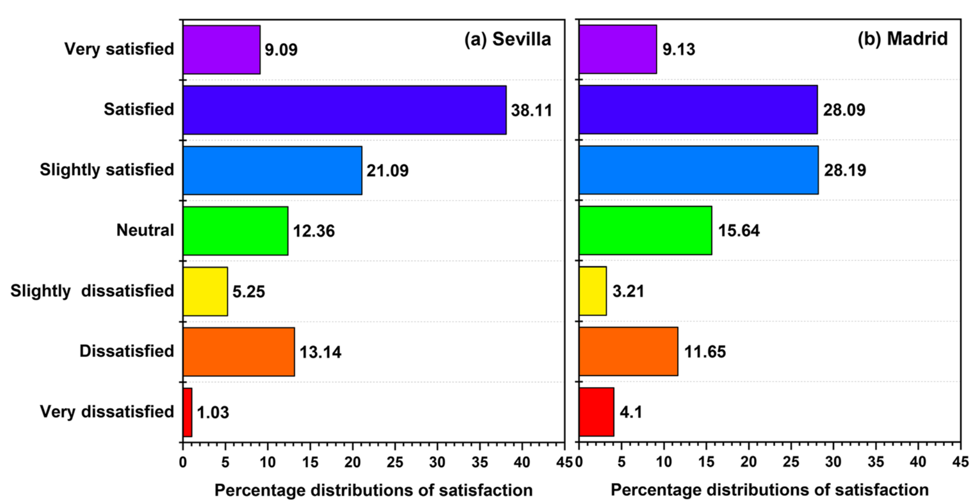


Fig. 6 Percentage distributions of satisfaction in the plazas of the city of Sevilla and Madrid

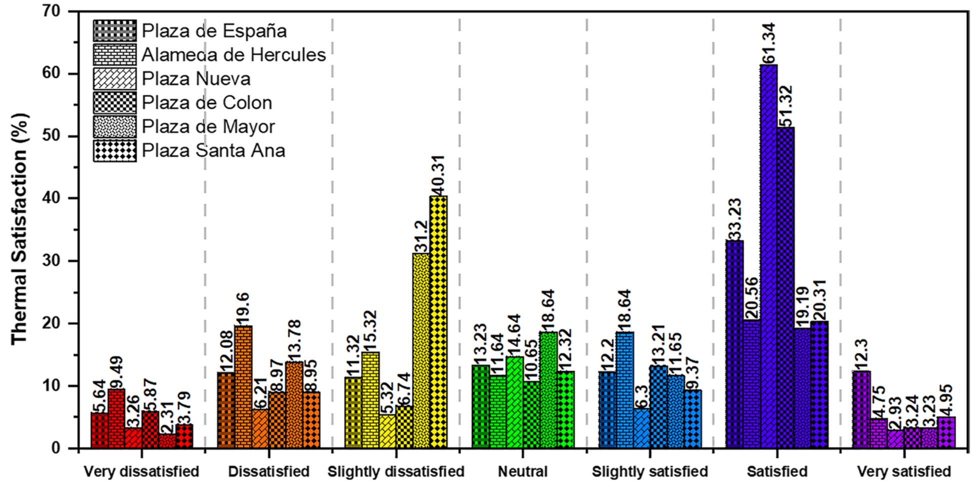


Fig. 7 The percentage of satisfaction distribution in each urban plaza in Sevilla and Madrid

The visitors to the Plaza de Santa Ana and Plaza de Mayor were less satisfied than the Plaza de Colón. At the same time, the Plaza de Mayor and Plaza de Santa Ana have the lowest thermal satisfaction among all urban plazas in Madrid and Seville due to the lack of shade trees and suitable porches or the vast open space. The psychological effects of tourists expecting from the capital's squares play a considerable role in terms of thermal comfort. In general, shadings of trees and buildings, radiations, and site morphology in these plazas can affect the perceived satisfaction of tourists.

Thermal comfort zone of tourists in Sevilla and Madrid

Climatic indicators required to calculate PET were measured when completing the questionnaires and as input parameters in Rayman have been considered. In addition to climatic indicators, the 80-W metabolic rate for a 35-year-old man with a height of 1.75 cm and a weight of 75 was added to the climatic data, and the PET value was calculated for each of the designated points (Höppe 1999). A metabolic rate of 80 watts is a normal rate for someone walking at 1.2 m per second (Mayer and Höppe 1987). According to previous research (Kántor et al. 2012; Mohammad et al. 2021) which stated that metabolism, clothing insulation, height, weight, and age of individuals do not have a significant influence on the calculation of PET. To make an autonomous index of individual conduct, the amount of clothing and activity in PET calculations are kept constant (Höppe 1999). It is fundamental to compute the mean thermal sensation votes (MTSV) for every 1 °C PET interval to comprehend the connection among PET and TSV (De Dear and Brager 2002). In this research, the relevance between PET and MTSV with Eq. 4 (for Seville) and Eq. 5 (for Madrid) is defined in accordance with prior researches (ASHRAE 2001; Gachkar et al. 2021; Nakano and Tanabe 2004; Nasrollahi et al. 2021), with thermal comfort domain between −0.5 and + 0.5 is acceptable. In this climate, the neutral PET of Sevilla was 28.44 °C when MTSV was equal to zero (Eq. (4)). While in Madrid, substituting 0 in Eq. (5), the neutral PET was 27.18 °C, and finally, the outdoor thermal comfort in Sevilla ranged 28.42 °C to 30.87 °C PET, while the PET range is between 24.5 and 29.82 °C in Madrid (Fig. 8).

$$MTSV = 0.203PET - 5.794 \quad (4)$$

$$MTSV = 0.188PET - 5.113 \quad (5)$$

Simulation results

Figure 9 shows the average Ta, Rh, Ws, and MRT changes at Z = 1.7 m, and the map of Ta, Rh, Ws, and MRT at

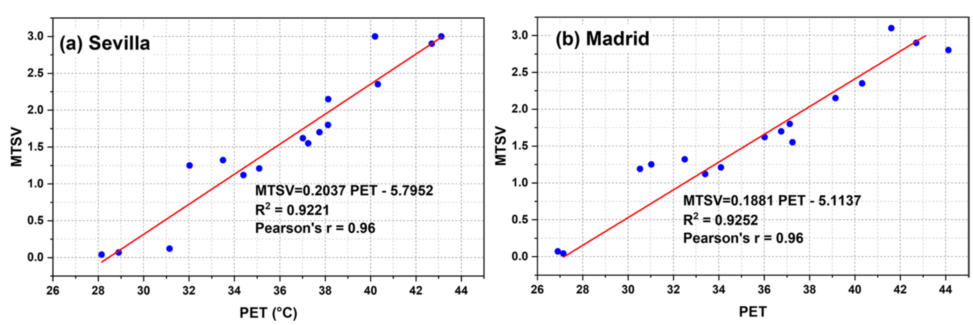


Fig. 8 Correlation between the mean thermal sensations votes (MTSVs) and PET in Sevilla and Madrid

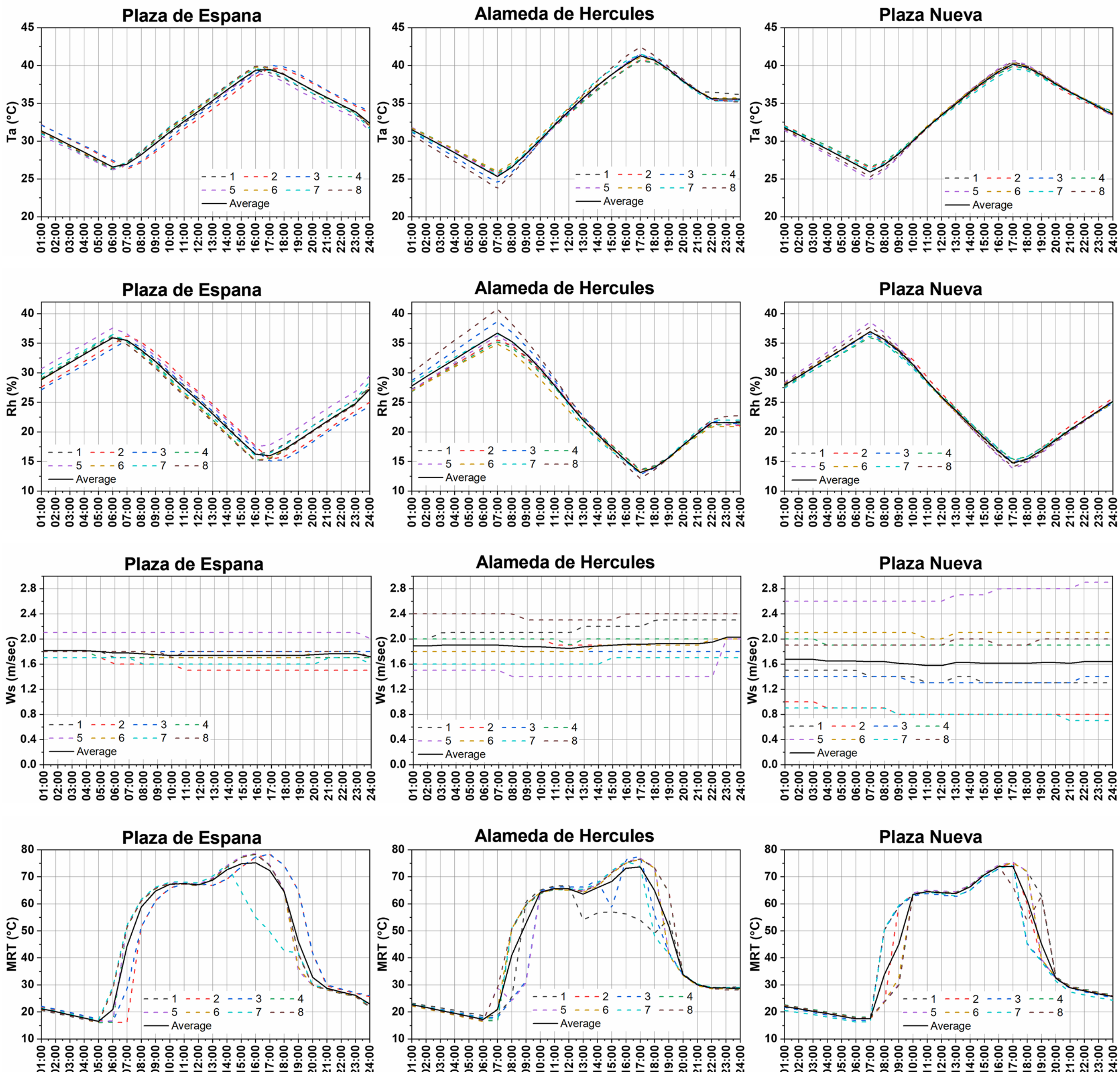


Fig. 9 Variation of Ta, Rh, Ws, and MRT in each receptor of the three selected plazas of Seville

12:00 p.m. is shown in Fig. 10 for the different plazas of Seville. The evaluation results of Sevilla plazas showed that the difference of Ta in several sites was less than the various other factors, so that the maximum difference between the lowest temperature in Plaza de España and Alameda de Hercules was 0.37 °C that is due to its subsidence in comparison with other plazas. On the other hand, Rh shows another trend from the Ta. Alameda de Hercules and Plaza Nueva because of high vaporization have the most elevated measure of Rh than Plaza de España. The MRT index depends on the shade of trees (both the tree canopy and height), subsidence of some plazas, and their walls, which in some hours of the day due to lack of suitable vegetation covers and some of them have experienced temperatures up to 75.2 °C. The shadow of the trees played a more important role in reducing the MRT than the shadows of the walls. So that, due to the presence of suitable vegetation in Plaza Nueva (both tree canopy and height) compared to Alameda de Hercules and Plaza de España, MRT was lower than the other two plazas, while the average MRT difference between Plaza de España and Alameda de Hercules has reached 2.32 °C due to lack of proper coverage. In connection with the effect of Ws on each case study, it can be stated that due to the considerable size of Plaza de España and Alameda de Hercules in comparison with Plaza Nueva, the Ws values have recorded higher than Plaza Nueva. However, the relatively taller walls and shallower depths of the Plaza de España have a lower Ws than the Alameda de Hercules. The most suitable OTC was obtained in Plaza Nueva, where relatively good vegetation and small space compared to other fields were the most important factors of superiority over other plazas. Generally none of the plazas were within the PET range and only some of them were in the thermal comfort zone during some hours of the night.

The average Ta, Rh, Ws, and MRT changes at Z = 1.7 m and the map of Ta, Rh, Ws, and MRT at 12:00 p.m. is illustrated in Figs. 11 and 12, respectively, for the different plazas of Madrid. Analysis of Madrid squares showed that the difference of Ta in different places due to being at the same level (no difference in height) is even less than the temperature difference in Sevilla plazas, so that the maximum difference reaches up to 0.23 °C. On the other hand, Plaza de colon has the highest Rh content compared to Plaza de Santa Ana and Plaza de Mayor (32.36%), due to its relatively good vegetation compared to other plazas and high evaporation. The least daytime MRT was seen under the plane trees in Plaza de Colón due to more shading coverage (48.46 °C). In addition, the maximum values in MRT (28.17 °C) during the night occurred in this scenario because of forestalling the active radiation to the sky. Conversely, Plaza de Mayor had the biggest degree of radiation during the daytime among all plazas because of the less shadow power, where the MRT was 5.42 °C and 7.22 °C higher than in the Plaza de colon and Plaza de Santa Ana individually. Nonetheless, the greatest decrease in MRT during the night occurred in Plaza de Mayor because of diminished measure of seen long-wave radiation. The most suitable ventilation in Plaza de Colon has been recorded due to its location in an open space compared to other options, while the placement of other plazas in a closed space has led to a decrease in wind speed. The most suitable ventilation among the surveyed plazas is assigned to Plaza de Colón, where due to its location in a more open space than the other two plazas even despite having vegetation cover, the wind speed has increased significantly compared to other plazas. Lack of proper ventilation, small space and limited, and having the most intense thermal stress during sunny hours among other plazas are the most reasons of creating the worst thermal comfort condition in Madrid (Figs. 13 and 14).

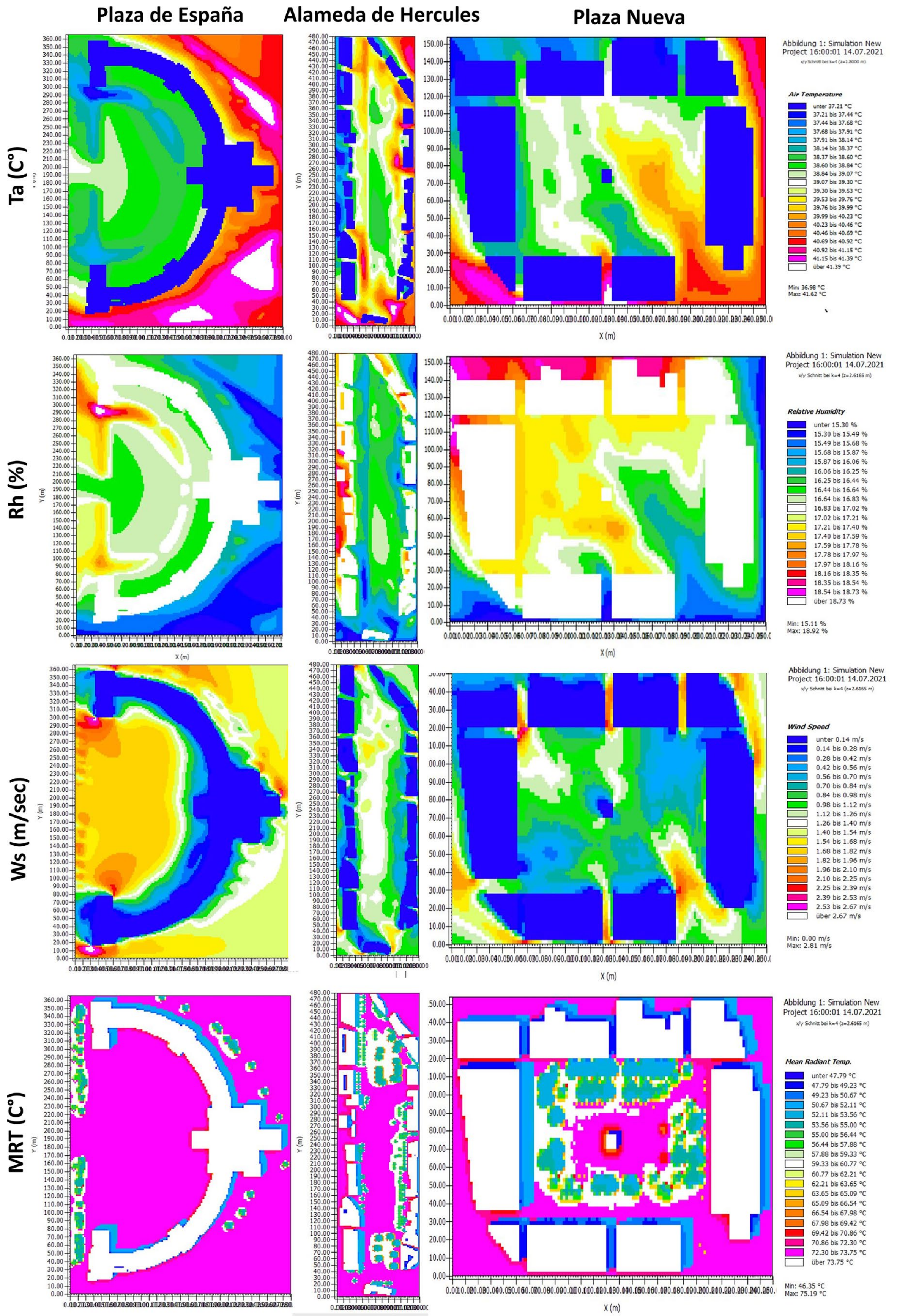
Comparison of thermal conditions in different urban sites

To compare the thermal comfort situations in various urban areas, climatic indicators including Ta, Ws, Rh, and MRT were determined in the planned places of each urban plazas, and their information was utilized to estimate PET's thermal comfort index in Rayman software. The thermal comfort situation in the simulated microclimates of each urban plaza was not quite the same as different destinations during the hours of the day. For example, according to estimates made in the city of Seville, the amount of PET is less than in Madrid, so the difference between the highest value in Sevilla plazas (Plaza de Espana) and the highest amount of pet in Madrid plazas (Plaza de Colón) reaches 4.61 °C.

The thermal comfort schedule has outlined the most reasonable opportunity to visit each popular urban plaza in a day with the mean hottest month of the year (Table 8). The thermal situation of the considered urban plazas was divided into 2-h intervals between 1 a.m. and 12 noon. Each color addresses a 3 °C scope of PET's thermal index. Albeit, none of the urban plazas is consistent with the PET adequate thermal ranges from 8 a.m. to 9 p.m.; however, these types of decisions are considerably comparative, and destinations with better thermal comfort conditions are positioned appropriately to visit. For example, thermal comfort conditions in the periods 9–11 a.m. show that in the surveyed plazas in Madrid, Plaza de Santa Ana is in the priority of visitors, while Plaza de Mayor and Colon are in the next priorities. On the other hand, in the surveyed plazas in the city of Seville, Plaza Nueva provides the most suitable conditions for thermal comfort for visitors during this period. Alameda de Hercules of Sevilla and Plaza de Santa Ana of Madrid were a better option to visit during the peak hours (11 a.m. to 3 p.m.) of heat than other sites. Semi-open spaces and having suitable trees in Plaza Nueva and Plaza de Mayor created more favorable thermal comfort conditions than other urban plazas and considered of the most important reasons for choosing visitors in the evening.

Comparison of simulation and questionnaire results

In the simulation models, two popular urban plazas with higher thermal comfort conditions (Plaza Nueva and Plaza de Colon) reported higher satisfaction levels in the questionnaires (Table 9). However, three local urban areas with lower thermal comfort conditions (Plaza de Mayor, Plaza de Santa Ana, and Alameda Hercules) got lower fulfillment levels. On the other hand, based on the output of the simulation, Plaza de Espana had the most exceedingly terrible thermal comfort conditions during the day in contrast with other popular destinations, and after Plaza de Mayor and Alameda de Hercules, Plaza de Espana had a higher level of dissatisfaction than different locales. This may be because of individuals' assumptions from Plaza de Espana Palace. Thus, their satisfaction level with thermal comfort in this urban square diminished. In several investigations, it is obvious that the mental assumptions for individuals influence their understanding (Nasrollahi et al. 2017, 2021; Zeng and



Plaza de España
Alameda de Hercules
Plaza Nueva
Ta (C°)
Rh (%)
Ws (m/sec)
MRT (C°)
X (m)
Y (m)
Abbildung 1: Simulation New Project 16:00:01 14.07.2021
Air Temperature
unter 37.21 °C
37.21 bis 37.44 °C
37.44 bis 37.68 °C
37.68 bis 37.91 °C
37.91 bis 38.14 °C
38.14 bis 38.37 °C
38.37 bis 38.60 °C
38.60 bis 38.84 °C
38.84 bis 39.07 °C
39.07 bis 39.30 °C
39.30 bis 39.53 °C
39.53 bis 39.76 °C
39.76 bis 39.99 °C
39.99 bis 40.23 °C
40.23 bis 40.46 °C
40.46 bis 40.69 °C
40.69 bis 40.92 °C
40.92 bis 41.15 °C
41.15 bis 41.39 °C
über 41.39 °C
Min: 36.98 °C
Max: 41.62 °C
Abbildung 1: Simulation New Project 16:00:01 14.07.2021
Relative Humidity
unter 15.30 %
15.30 bis 15.49 %
15.49 bis 15.68 %
15.68 bis 15.87 %
15.87 bis 16.06 %
16.06 bis 16.25 %
16.25 bis 16.44 %
16.44 bis 16.64 %
16.64 bis 16.83 %
16.83 bis 17.02 %
17.02 bis 17.21 %
17.21 bis 17.40 %
17.40 bis 17.59 %
17.59 bis 17.78 %
17.78 bis 17.97 %
17.97 bis 18.16 %
18.16 bis 18.35 %
18.35 bis 18.54 %
18.54 bis 18.73 %
über 18.73 %
Min: 15.11 %
Max: 18.92 %
Abbildung 1: Simulation New Project 16:00:01 14.07.2021
Wind Speed
unter 0.14 m/s
0.14 bis 0.28 m/s
0.28 bis 0.42 m/s
0.42 bis 0.56 m/s
0.56 bis 0.70 m/s
0.70 bis 0.84 m/s
0.84 bis 0.98 m/s
0.98 bis 1.12 m/s
1.12 bis 1.26 m/s
1.26 bis 1.40 m/s
1.40 bis 1.54 m/s
1.54 bis 1.68 m/s
1.68 bis 1.82 m/s
1.82 bis 1.96 m/s
1.96 bis 2.10 m/s
2.10 bis 2.25 m/s
2.25 bis 2.39 m/s
2.39 bis 2.53 m/s
2.53 bis 2.67 m/s
über 2.67 m/s
Min: 0.00 m/s
Max: 2.81 m/s
Abbildung 1: Simulation New Project 16:00:01 14.07.2021
Mean Radiant Temp.
unter 47.79 °C
47.79 bis 49.23 °C
49.23 bis 50.67 °C
50.67 bis 52.11 °C
52.11 bis 53.56 °C
53.56 bis 55.00 °C
55.00 bis 56.44 °C
56.44 bis 57.88 °C
57.88 bis 59.33 °C
59.33 bis 60.77 °C
60.77 bis 62.21 °C
62.21 bis 63.65 °C
63.65 bis 65.09 °C
65.09 bis 66.54 °C
66.54 bis 67.98 °C
67.98 bis 69.42 °C
69.42 bis 70.86 °C
70.86 bis 72.30 °C
72.30 bis 73.75 °C
über 73.75 °C
Min: 46.35 °C
Max: 75.19 °C

◂**Fig. 10** Ta, Rh, Ws, and MRT maps at 12:00 for each selected plazas of Seville

Dong 2015). Similarly, Cohen et al. (2013) and Gachkar et al. (2021) researched the expectation of thermal comfort of people in paths, stations, and squares in historical garden, respectively. In both research, psychological effects were observed on their perception of thermal comfort, although with the experience of better thermal comfort in the urban plazas, they anticipated other thermal conditions.

Discussion

Tourism is so important in the economic and social development of any country, and nowadays economists have called it as invisible exports, because tourism goods and services are offered without the cost of transporting goods for export by attracting foreign tourists inside. Nature tourism is one of the branches of tourism based on the preservation and sustainability of the environment and guarantees the sustainable development of the tourism industry in relation to the needs of tourists and the host community. However, it is highly

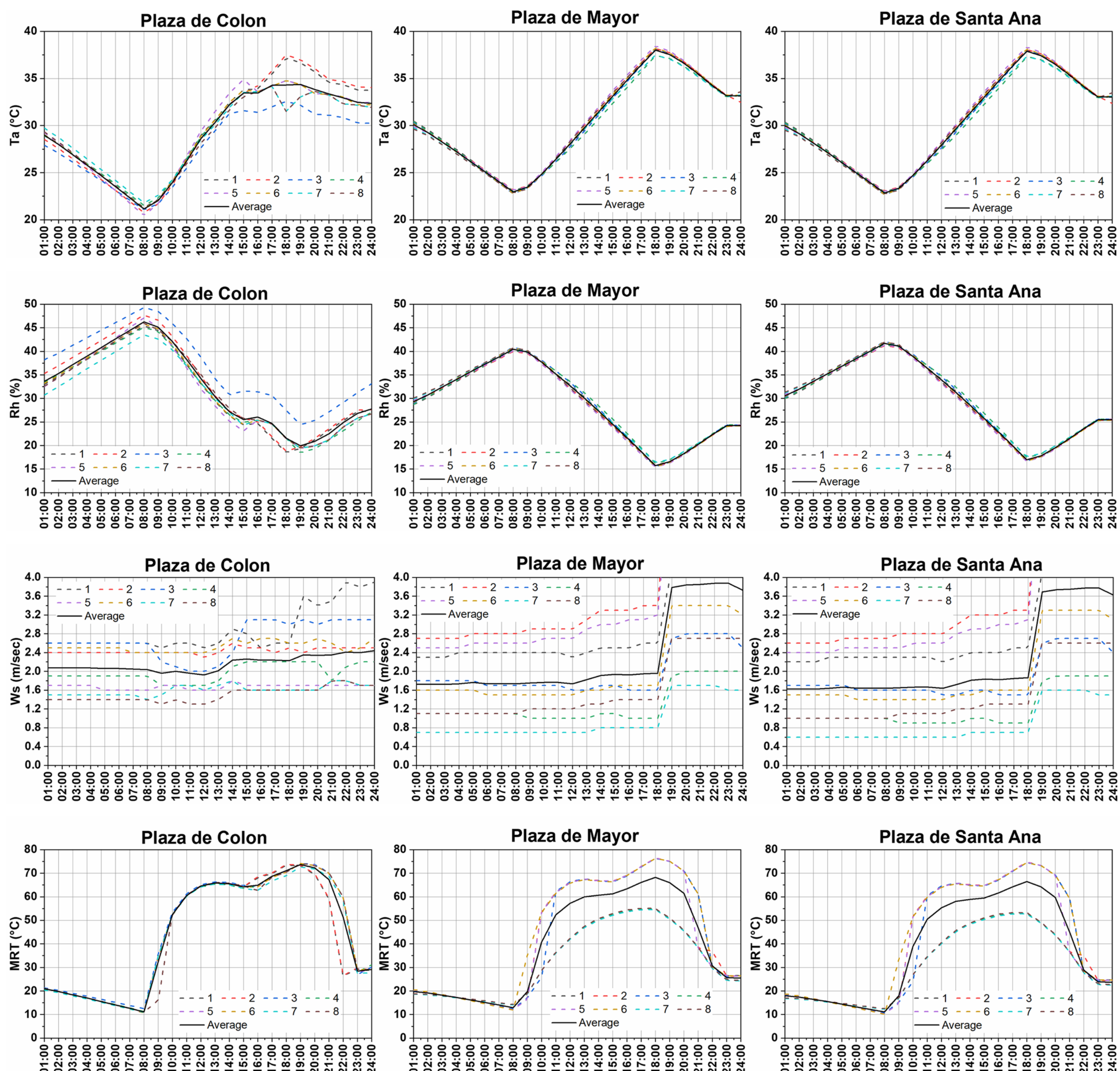


Fig. 11 Variation of Ta, Rh, Ws, and MRT in each receptor of the three selected plazas of Madrid

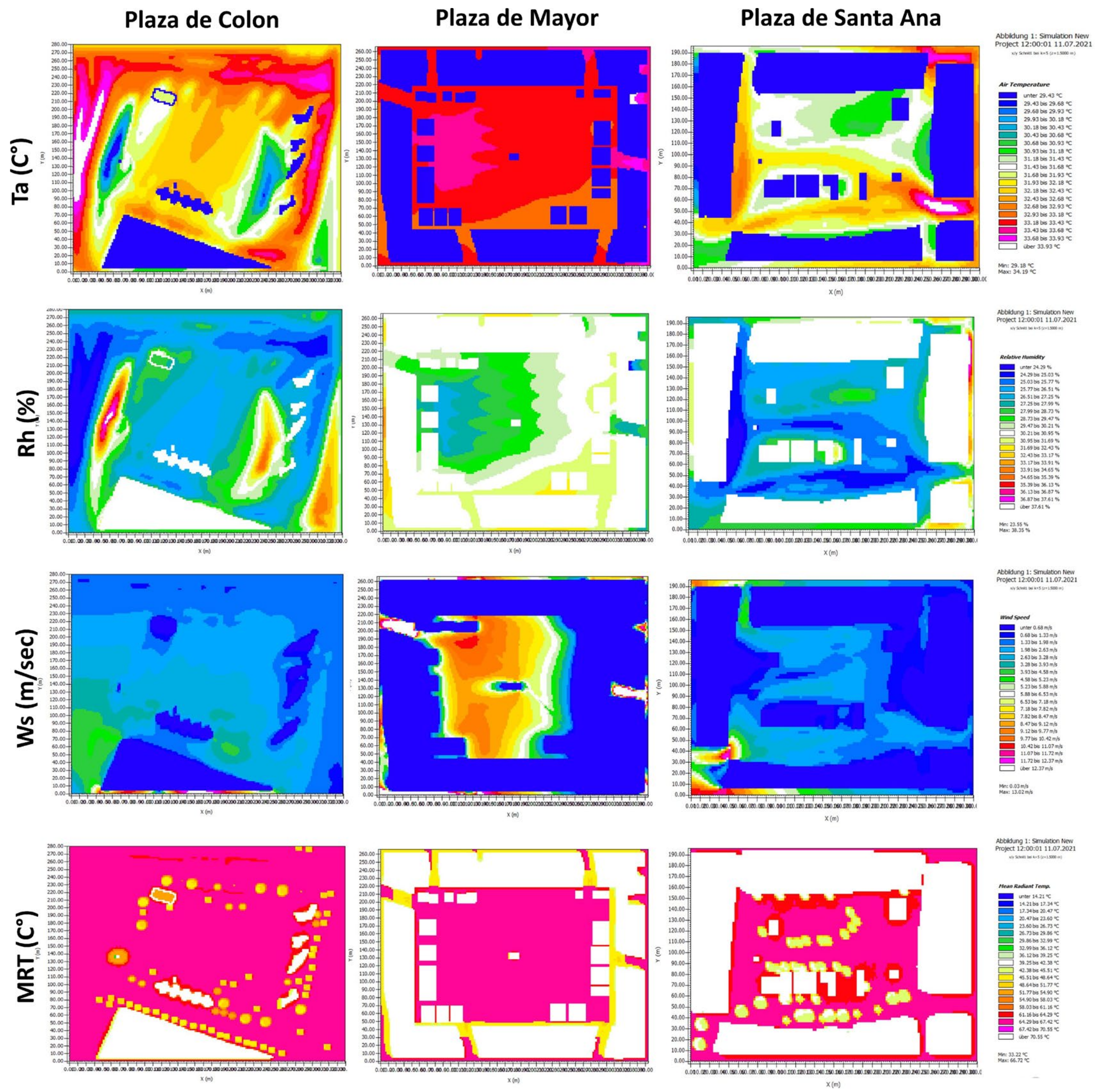
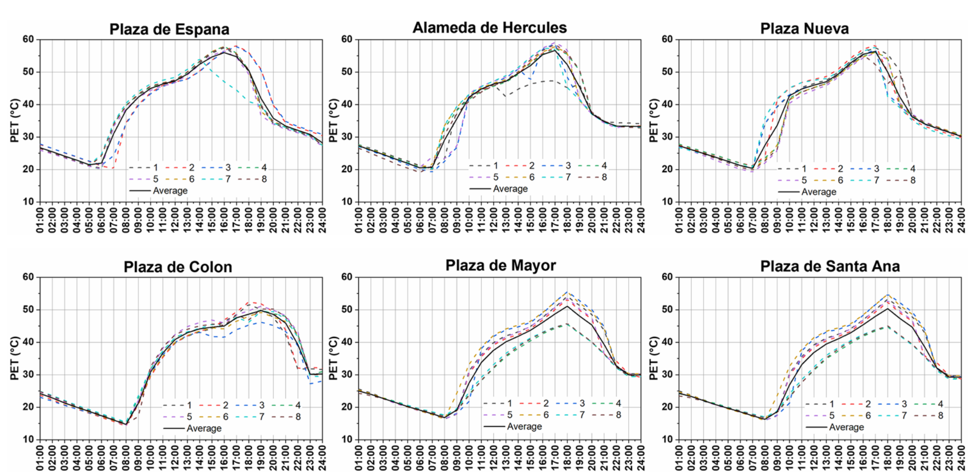


Fig. 12 Ta, Rh, Ws, and MRT maps at 12:00 for each selected plazas of Madrid

Fig. 13 Variation PET between selected plazas of Seville and Madrid in different times



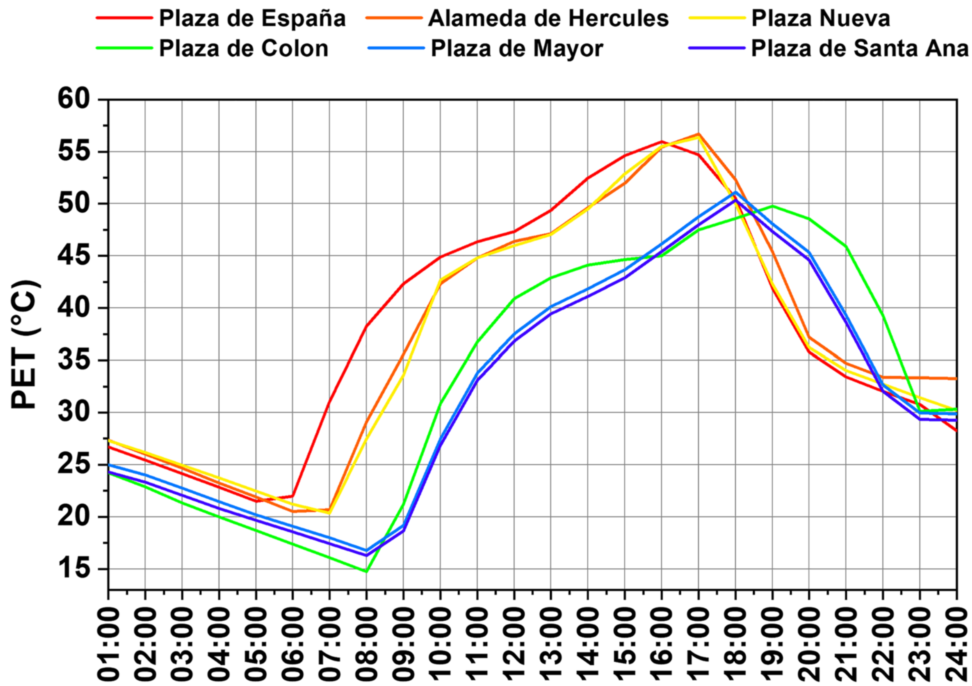


Fig. 14 A comparison of thermal comfort (i.e., PET) between selected plazas of Seville and Madrid in different times

Table 8 Thermal comfort calendar of the historical sites in average during the hottest month

Time	Plaza de Mayor	Plaza de Colón	Plaza de Santa Ana	Alameda de Hercules	Plaza de España	Plaza Nueva	Legend
1-3	24.49	23.55	23.81	26.68	26.08	26.74	20.1-23°C
3-5	22.09	20.66	21.44	23.96	23.49	24.34	23.1-26°C
5-7	19.65	18.04	19.13	21.21	21.74	21.84	26.1-29°C
7-9	17.39	15.41	16.86	24.9	34.66	23.91	29.1-32°C
9-11	23.33	26.03	22.76	38.94	43.61	38.14	32.1-35°C
11-13	35.65	38.82	34.98	45.2	46.84	45.41	35.1-38°C
13-15	40.97	43.51	40.28	48.31	50.91	48.28	38.1-41°C
15-17	44.91	44.84	44.16	53.69	55.3	54.19	41.1-44°C
17-19	49.94	48.06	49.16	54.48	52.61	53.16	44.1-47°C
19-21	46.7	49.16	45.98	41.3	38.82	39.26	47.1-50°C
21-23	35.99	42.59	35.33	34.04	32.73	33.38	50.1-54°C

dependent on climate change and always as one of the most important indices necessary by tourists and desirable thermal comfort conditions and plays an important role in increasing the presence of tourists in urban spaces. Current research analyzed the thermal comfort conditions by using meteorological data irregardless of microclimates created in urban plazas. The current research is conducted to assess thermal comfort conditions in the microclimates of the metropolitan squares of Sevilla and Madrid in a constantly with extreme hotness stress. The thermal comfort sensation of tourists at the urban plazas of Sevilla ranges from 28.42 to 30.87 °C of PET, while the pet range in urban plazas of Madrid is varied between 24.5 and 29.82 °C. Notwithstanding the extreme heat stress, about 38.11% and 28.09% of tourists in Sevilla

Table 9 Thermal satisfaction of tourist in historical place in hottest month

Historical place	Satisfaction (%)	Neutral (%)	Dissatisfaction (%)
Alameda de Hercules	20.56	11.64	19.6
Plaza de España	61.34	14.64	6.21
Plaza Nueva	33.23	13.23	12.08
Plaza de Colón	51.32	10.65	8.97
Plaza de Mayor	19.19	18.64	13.78
Plaza de Santa Ana	20.31	12.32	8.95

and Madrid, respectively, were satisfied with the thermal conditions, while 13.14% and 11.65% were dissatisfied. This shows the mental adaptability of travelers with the current situation in spite of the great hotness stress. Albeit, the respondents are from various environments and nations, yet their thermal comfort inclination is near the comfort zones of warm climates (subtropical, hot, humid, and tropical). Based on the simulation results, approximately none of the historic urban areas are in their comfort zone during the day, except from 9 to 11 am in Plaza Colon. These well-known urban plazas don't have a period impediment to visit and can be visited during the night hours. The thermal comfort situation analogation of each urban plazas is the most important factor regarding choosing the suitable visiting time range.

The overall satisfaction of the tourists with the thermal comfort conditions due to the psychological effects is evaluated in this present study in hottest heat stress month of July. The best time to visit the Plaza de Santa Ana is the early morning hours, while Plaza de Mayor and Plaza de Colon are in the next priorities. On the other hand, in the surveyed plazas in the city of Seville, Plaza Nueva provides the most suitable conditions for thermal comfort for visitors during this period. In the peak hours of heat (11 a.m. to 3 p.m.), the priority goes Alameda de Hercules of Sevilla and Plaza Santa de Ana of Madrid in terms of thermal comfort. Semi-open spaces and having suitable trees in Plaza Nueva and Plaza de mayor provided more favorable thermal comfort conditions than other urban plazas and considered of the most important reasons for choosing visitors in the evening.

It is deduced in this research that urban plazas with higher thermal pressure in the simulation cycle have a higher amount of thermal dissatisfaction in the survey. Albeit both results have a bit different from each other, there are similarities in outcomes. The thermal comfort conditions are predicted through simulation. Indeed, the differences in simulation and field study results, which accounts for the psychological effects, could not be simulated.

Conclusion

This study examined the factors related to the thermal comfort in open space, considering that the tourists can choose the most appropriate time to visit each of the historic sites of Seville and Madrid during the day and night. According to field measurements, questionnaires, and analyses managed in this study, the acceptable range of outdoor thermal comfort for visitors in the well-known urban plazas of Sevilla varies from 28.42 to 30.87 °C in the hot summer, while the PET range in Madrid is between 24.5 and 29.82 °C. Despite the high heat stress condition, about 38.11% and 28.09% of tourists in Sevilla and Madrid, respectively, were satisfied with the thermal conditions, while around 13.14% and 11.65% were dissatisfied. This indicates the psychological compatibility of tourists with the conditions despite the high heat stress. According to the Envi-met different scenario evaluated results, almost none of the surveyed sites were in the range of thermal comfort. However, Plaza de Santa Ana is the best place for visitors in the early morning hours in Madrid and Plaza Nueva in Sevilla at the same time. In addition, during the peak heat hours, Alameda de Hercules of Sevilla and Plaza de Santa Ana of Madrid in terms of thermal comfort are the most suitable historical places for visitors. Concerning semi-open spaces and relatively suitable vegetation, Plaza Nueva and Plaza de Mayor bring more favorable conditions in terms of thermal comfort for visitors in the evening. The result of the present study witnessed that the urban plazas with relatively high thermal stresses in the simulation process have a higher rate of thermal dissatisfaction in the questionnaire. However, there are effective psychological aspects that differentiate the results of simulation and questionnaires because the effects of psychology could not be simulated.

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Author contribution Conceptualization; methodology; software; writing, original draft preparation; data curation; investigation: A.K. Conceptualization, methodology, software, visualization, data curation, original draft preparation, reviewing, and editing: P.M. All authors have read and agreed to the published version of the manuscript.

Data availability The data that support the findings of this study are available from the corresponding author on request**.**

Declarations

Ethics approval The authors acknowledge that the current research has been conducted ethically. He declares that this manuscript does not involve research about humans or animals.

Consent to participate The author consented to participate in this research study.

Consent for publication The authors consent to publish the current research in the *Environmental Science and Pollution Research* journal.

Competing interests The authors declare no competing interests.

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