Journal of Environmental Management 349 (2024) 119447

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Tactical urban pocket parks (TUPPs) for subjective and objective multi-domain comfort enhancement

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ARTICLE INFO

Handling Editor: Prof Raf Dewil

Keywords:
Tactical urban pocket parks
TUPP
Tactical urbanism
Urban heat island
Anthropogenic heat
Mitigation
Passive cooling
Urban resilience
Urban overheating
Multidomain outdoor comfort

ABSTRACT

Cities face growing anthropogenic overheating phenomena, such as Urban Heat Island Effect and more intense and frequent heatwaves, impacting livability and wellbeing of local citizens and tourists. To mitigate such effects, passive mitigation strategies have been widely studied in the past decades, to be integrated within the built environment. The insertion of green areas, i.e. parks, in urban areas is among the most common passive strategies, however it presents numerous challenges, as traditional parks are difficult to insert in an existing packed urban texture. Hence, in this study, we examine the significance of strategic small urban parks related to various construction types. These parks can be seamlessly integrated through tactical urbanism interventions to enhance both the objective and subjective perception of overall comfort. By coupling human-centric microclimate monitoring campaigns in the small parks and surrounding blocks (objective analysis) with questionnaire surveys to parks' users (subjective multidomain analysis) we aim at assessing their effectiveness. Results show that Tactical Urban Pocket Parks (TUPP) can slightly improve objective whole comfort and significantly enhance the improvement of subjective comfort (from neutral/bad to good/very good).

1. Introduction

Urban areas are subject to major stresses and pressures, due to the increase in urban population (United Nations, 2019) and the concentration of anthropogenic activities and their related overheating forcing. Among these challenges, Urban Heat Island (UHI) (Oke, 1982) and the increasingly frequent presence of heatwaves (Falasca et al., 2019; Founda and Santamouris, 2017), pose serious challenges to the safety and wellbeing of citizens. In fact, extreme high temperatures are nowadays common, frequent in time and exacerbated in cities during the hot season (Mayrhuber et al., 2018), and mortality rates increase has been associated to such extreme heat-stress conditions (Xu et al., 2016), leading to thousands excess deaths (Xu and Tong, 2017).

On the other side, while compromising microclimate quality and livability, the urban built environment itself, especially when integrated via nature based solutions and strategic greenery, could also contribute to mitigate UHI and improve urban resilience to heat stress (Akbari et al., 2015), (Nassary et al., 2022), (Douglas et al., 2021) even in the historical contexts (Pisello et al., 2013). In addition to mitigating such conditions, adapting to warmer urban climate is another way to cope with changing conditions in cities, especially sinche the human behavior role has shown to be strategic for affecting the performance of mitigation actions and the relative adaptation potential (Pisello et al., 2015). As by the European Environmental Agency (EEA) definition (European Environment Agency, 2022), adaptation is "the process of adjusting to the current and future effects of climate change", while mitigation means "making the impacts of climate change less severe". Both of these strategies could be employed towards urban resilience, which denotes the ability of a city to resist, continue functioning and recover from any stressor (Bautista-Puig et al., 2022). Considering that among the causes of UHI there are: (i) heat accumulation into the construction and urban components (e.g., building, streets); (ii) reduced evapotranspiration due to missing green and blue spaces; (iii) dense urban morphology, which causes wind path modification; (iv) anthropogenic heat accumulation, it is evident that specific strategies could be applied to the built environment to mitigate UHI and to adapt to increasingly hot conditions (Santamouris, 2019). Therefore, acting on those characteristics that are among the causes of UHI has proved effective for mitigation and

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https://doi.org/10.1016/j.jenvman.2023.119447
Received 4 April 2023; Received in revised form 13 October 2023; Accepted 20 October 2023
Available online 11 November 2023

adaptation purposes, as demonstrated in research related to the employment of high-albedo materials to cool down urban surfaces (Rosso et al., 2017a, 2017b; Santamouris and Yun, 2020), or those related to the use of greenery and water elements in cities (Schuch et al., 2017; Di Giuseppe et al., 2020; Chàfer et al., 2020) or enhanced evapotranspiration solutions (Park et al., 2021).

In this perspective, urban parks act as mitigation and adaptation oasis in the built environment (Lin et al., 2017; Rosso et al., 2022a). However, the insertion of big urban parks is difficult to spread in already dense urban areas, where there is not much space left for nature (Fischer et al., 2018). To surpass this limitation, tactical, diffuse small-sized urban parks can be implemented to provide a more just and spread benefit among the neighborhoods (Rosso et al., 2022a, 2022b; Bruce, 2017). Previous works investigated the specific typology of "pocket parks", verifying their ability to still provide ecosystem services (Delgado-Capel and Cariñanos, 2020) and improved whole comfort conditions (Rosso et al., 2022b). Pocket Parks have been studied with respect to their ability to provide improved comfort conditions thanks to wind, and designing greenery and shape according to urban wind (Zhong et al., 2022). Moreover, the importance of Pocket Parks in helping alleviate the COVID-19 pandemic has been highlighted in previous work, to improve accessibility to urban green space for everyone by turning vacant lots into pocket parks (Liu and Wang, 2021). A recent review evidences the increase of interest on the topic in the last years (Balai Kerishnan and Maruthaveeran, 2021), and other contributions explored the limitations to the diffusion of pocket parks, comprehending difficult management and maintenance and indicated possible solutions to surpass them (Rosso et al., 2022a; Yang and Hong, 2023).

In this context, we aim at expanding the concept and diffusion of pocket parks, by considering different typologies of small urban parks. Pocket parks possess specific architectural design features (Faraci, 1967) such as lot-size dimension, accessibility to pedestrians but detachment from the street, presence of furniture for users, presence of greenery (trees and vases) water displays and works of art. Being built in residual spaces, they usually have three closed sides and one size that is accessible from the street, in order to increase the sensation of being detached from the chaos of the city. However, we contend that, to further spread the diffusion of such small sized parks, even more temporary, simpler and less curated open spaces could be transformed into effective "pocket parks" to mitigate and adapt to increasing temperatures in cities. Therefore, we introduce the term "Tactical Urban Pocket Parks" (TUPPs), to define a broader sample of small urban parks, characterized by a variety of morphologies, design and architectural features, which can be tactically diffused within the urban texture due to their relatively small dimension, exploiting abandoned corners, infills or street extensions. The term "tactical" identifies pocket parks as one of the tactics (a pragmatic intervention immediately applicable (Knox, 1975)) to implement the more general strategy of obtaining resilient urban areas, which is a longer term, structural objective (Knox, 1975; Cappa et al., 2020), with improved comfort and safety against heat stress for citizens.

In previous research, we demonstrated that epitome pocket parks, with all of the above-mentioned features, are able to significantly but slightly mitigate thermal stress, but we assessed how they additionally benefit the perceived whole comfort of users (Rosso et al., 2022b; Cappa et al., 2019), both for tourists and frequent users. Building on this finding, we aim to investigate whether simpler and less curated, even temporary, small urban parks, synthesized by the TUPP typology that we introduced above, can provide objective mitigation of UHI and heat stress and also improve the whole comfort perception of users, i.e., the subjective perceived mitigation effect. Analyzing this potential role for small, residual urban outdoor spaces could have a far-reaching impact on the diffusion of small urban parks into urban areas, also by means of tactical urbanism actions (Silva, 2016), thus favoring the more equitable diffusion of mitigation and adaptation actions on the entire urban territory, and even in countries/neighborhoods with limited funds dedicated to such actions (Rosso et al., 2022a). This is the motivation for the use of the adjective "Tactical" in the definition of this small urban pocket park typology set, as the TUPPs could be introduced widely (and in close proximity for every citizen) within the urban texture, and their characteristics include a various range of small urban parks typologies subsets, including those requiring an easier construction and maintenance, for a more spread diffusion also in disadvantaged neighborhoods.

Therefore, in this work we assess the multi-domain microclimate variables in TUPPs, i.e., different small urban parks typologies, by means in field microclimate monitoring, to verify the potential mitigation of UHI and heatwave thanks to such parks.

Indeed, while pocket park typology is able to significantly, even if slightly, mitigate urban microclimate with respect to the generated heat stress (Rosso et al., 2022b), it has been overlooked whether and how other small urban parks typologies are also able to act on the same challenges. Moreover, while pocket park typology has also been demonstrated to be able to significantly improve subjective whole comfort sensation in its users during the hot season (Rosso et al., 2022b), again, other small urban parks typologies have been overlooked with respect to their potential in improving subjective whole comfort in pedestrians. Finally, in previous works the gap between objective and subjective comfort has been assessed for pocket parks, but this evidence is lacking with respect to other small urban park typologies, which could have a relevant role in urban resilience.

Thus, the research question we aim to respond to is the following: to what extent different typologies of small urban parks, gathered under the newly introduced Tactical Urban Pocket Parks (TUPPs) set of typologies, can be effective in mitigating intra-urban microclimate and subjective whole comfort perception, and are there any differences between the different typologies, considering both objective and subjective comfort?

In doing so, we employ an innovative portable and human-centered microclimate monitoring setup, in order to analyze the exact dynamic microclimate variables (Pigliautile et al., 2021) to which pedestrians and parks users are subject. The employed monitoring system allows to consider microclimate variations due to intra-urban granularity (Pioppi et al., 2020a), therefore it is particularly suitable for monitoring the investigated part of the city, comprising the small park and the surrounding streets.

Such assessment of intra-urban microclimate granular conditions, while allowing a human-centered perspective, does not consent to fully consider the subjective perception of users with respect to comfort conditions. In previous research, it was demonstrated that there is a gap between objective comfort assessment and subjective comfort perception (Rosso et al., 2022b; Castaldo et al., 2018), due to subjective preferences of users related to the pleasantness of the considered space. Therefore, to further disentangle this gap in the context of small urban parks, a parallel analysis focused on subjective whole comfort perception is carried out in this work, by means of questionnaire surveys to the users of the park, which are conducted at the same time of the monitoring campaign. This double experimental set-up allowed to directly compare the results of the microclimate monitoring (objective assessment) with that of the questionnaire surveys (subjective comfort assessment).

Thus, the originality and innovativeness of this work reside in it being the first extensive investigation of different small urban parks typologies, gathered under the novel small urban park typology set of the TUPPs. Here TUPPs are investigated for the first time for mitigation and human comfort purposes by means of a novel methodology able to assess and compare both microclimate mitigation (objective) and subjective comfort perception, quantitatively and qualitatively disentangling the difference between the two. Measurements by means of an innovative portable and human-centered microclimate monitoring provide for the objective assessment, while extensive survey campaigns to the users of the parks allow the subjective assessment. Resulting combined data are then investigated by means of statistical analyses to provide insights about objective-subjective assessment gaps, as well as

to consider the effect of architectural design variables on microclimate measurements for comfort. To further complement the subjective comfort evaluation of the parks, also google reviews from the users for the considered parks are taken into account.

Therefore, this research is relevant not only for researchers in the field of urban resilience and UHI and heatwaves mitigation, but also for professionals working in the field of urban outdoor spaces and for urban administrations and policy makers, as it could direct tailored tactical small-scale interventions to improve the livability of urban areas.

2. Methodology

The research is carried out by means of a combination of innovative experimental techniques carried out in the TUPP case studies and statistical analyses. In greater detail, in-field monitoring is conducted by means of portable, human-centered, microclimate stations, which measure the microclimate variables in the park and immediate surrounding streets (section 2.1). Parallel to the monitoring, questionnaire surveys are posed to the users of the spaces to assess their subjective whole comfort sensation (section 2.2). The results of both the analyses are then statistically analyzed, to check (i) whether there is a significant difference between the microclimate characteristics and the subjective perception inside and outside the small parks; and (ii) if there is a significant difference between the objective and subjective comfort (section 2.3).

To this aim, four relevant and significant case study TUPPs are selected, pertaining to different small urban parks typologies (section 2.4). All of the detailed aspects of each passage of the above-illustrated methodology are described in greater detail in the dedicated following subsections.

2.1. In field microclimate monitoring campaign

Microclimate monitoring campaigns are conducted in each investigated TUPP and their immediate surroundings (e.g., in the parks and surrounding streets), by means of an innovative portable weather station mounted on a walker-rollator (Fig. 1), which allows to assess the human-centered microclimate that characterizes the urban environment, thus monitoring the dynamic, intra-urban, hyper local variables in field. The portable weather station is equipped with various sensors placed at human height on a 1.8 m pole attached to the rollator. These sensors measured and mapped several environmental parameters in real time, including air temperature, relative humidity, wind speed and direction, solar radiation, georeferenced by a GPS. The frequency of the measurements is 1 Hz. The technical specifications of the above-mentioned sensors are illustrated in Table 1.

Data was gathered and analyzed in real-time using a portable computer, connected via cable to the station and a in-house graphical interface developed by the Authors.

The campaigns are carried out and repeated on different days, in each selected location (Table 2). During typical summer period, characterized by heat stress in the urban environment. The experiments were indeed performed on different days to measure the microclimate variables both during sunny and cloudy weather conditions, so as to

Table 1
Technical specifications of the sensors for assessing the measured environmental parameters.

Environmental parameters	Unit of Measure (U.o. M.)	Range, Accuracy and Resolution of the sensor
Air temperature	[°C]	Range −40 °C to +70 °C Accuracy ±0.3°C–20 °C Resolution 0.1 °C
Relative humidity	[%]	Range 0–100% Accuracy ±2% @20 °C (10%–90%) Resolution 1%
Wind Speed	[m/s]	Range 0.01–60 m/s Accuracy ±3% 0.01 m/s to 40 m/s ±5% above 40 and up to 60 m/s Resolution 0.01 m/s
Wind Direction	[°C]	Range 0–359° Accuracy ±3° 0.01 m/s to 40 m/s ±5° above 40 and up to 60 m/s Resolution 1°
Barometric Pressure	[hPa]	Range 300 to 1100 hPa Accuracy ±0.5 h Pa@ 25 °C Resolution 0.1 h Pa
Solar radiation	[W/m^2]	Spectral range 300–3000 nm Intensity Range 0–1600 W/m^2 Resolution 1 W/m^2
GPS	–	Horizontal accuracy: Less than 2.5 m Accuracy: longitude and latitude report to 6 decimal places

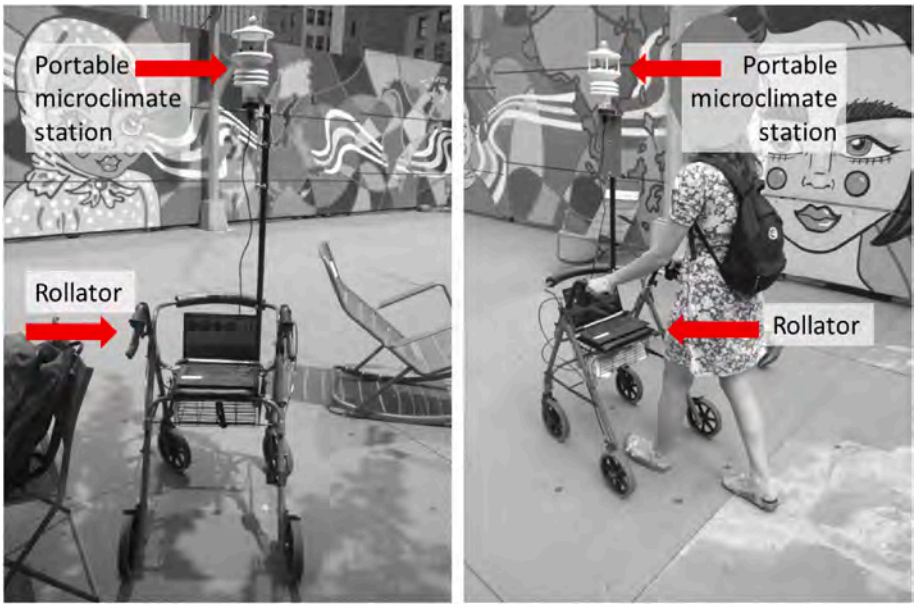

Fig. 1. The monitoring set-up, composed of the portable microclimate monitoring station mounted on the rollator. The images were taken during the monitoring campaign, and depict the monitoring in the POP.

Table 2
The data about the campaigns (both microclimate monitoring and surveys) with respect to TUPP typology, day time and weather conditions.

Tactical Urban Pocket Park (TUPP) Typology	Day	Weather conditions	Time
Pocket Park (PP)	July 26th August 1st	Cloudy Sunny	9 a.m. 1 p.m. 7 p.m.
Pocket Park (PP)	July 26th August 1st	Cloudy Sunny	9 a.m. 1 p.m. 7 p.m.
Interim Park (IP)	July 27th July 29th August 2nd	Cloudy Sunny Cloudy	9 a.m. 1 p.m. 7 p.m.
Privately Owned Public park (POP)	July 27th July 29th August 2nd	Cloudy Sunny Cloudy	9 a.m. 1 p.m. 7 p.m.

disentangle also the role of different weather conditions on the effectiveness of TUPPs, in summer 2019 (Table 2). Therefore, the monitoring campaigns are carried out during two consecutive days, given the impossibility of investigating all of the TUPPs the same day. Two parks each day are thus monitored. The monitoring session is conducted during the morning (at 9 a.m.), at midday (1 p.m.) and during the evening (7 p.m.), to have specific measurements in different times of the day.

Moreover, the measured data are synthesized into the apparent temperature (At), to more correctly compare the objective perception (obtained by the monitoring campaigns) with the subjective perception (obtained directly from pedestrians' opinion). In fact, *At* is defined as the corresponding temperature, at the given humidity level, that produce the same discomfort as in current temperature, humidity and solar radiation, and is also defined "heat index" (Steadman, 1984). *At* is evaluated starting from dry bulb temperature (T), wind speed (v) and relative humidity (from water vapor pressure (*vp*), as from Eq. (2)), as in the formula in Eq. (1) (Pioppi et al., 2020b; Australian Government Bureau of Meteorology):

$$\mathrm{At} = \mathrm{T} + 0,33 \cdot \mathrm{vp} - 0,7 \cdot \mathrm{v} - 4,0 \qquad \text{Eq 1}$$

$$vp = \frac{RH}{100} \bullet 6,105 \bullet \exp\left(17,27 \bullet \frac{T}{237,7 + T}\right) \qquad \text{Eq. 2}$$

2.2. In person surveys campaigns

Parallel to the infield microclimate monitoring campaigns, a subjective perception monitoring campaign is carried out, in the TUPPs and surrounding contexts. The daily timing is specified in Table 2, when questionnaire surveys are posed to the users of the small urban parks and passers-by on the streets. The time overlapping between objective and subjective comfort is a crucial aspect of the study, as it allows to precisely compare the two without any temporal bias. For the design of the survey, the needed characteristics are that the survey is rapid (it took 1–2 min to be completed), so as not to discourage completion; and at the same time able to disentangle the whole comfort perception of users as well as the individual perceptions related to the visual, acoustic and air quality-related spheres. To do so, we based the survey on previous studies (Rosso et al., 2022b; Castaldo et al., 2018), which adopted the ISO 10551 (International Organization for Standardization, 1995) survey about thermal sensation and adapted it to visual and acoustic perception. Therefore, the questionnaire survey investigates first whole comfort sensation, so that the interviewees are not biased for having already dissected their specific individual sensations. Then visual comfort; acoustic comfort; air quality; and finally, thermal comfort. The respondents had to indicate their perception on the above-illustrated perspective by using a Likert scale on 5 points, where "0" is neutral comfort, and the extremes are "-2" very bad, "-1" bad, "+1" good and "+2" very good comfort sensation.

At the end of the questionnaire, other brief questions related to personal characteristics (e.g., age, gender, reason for visiting) are asked, with the aim of better framing the whole and individual sensations of the respondents. The data are completely anonymous, and participation is voluntary. Interviewees are standing or sitting in the TUPPs and surrounding streets and are approached by the researchers, given a brief explanation of the general scope of the study, and then participate or not to the study.

In total, 348 surveys are collected, to conduct the desired statistical analyses, which require 10 observations for each variable (Rosso et al., 2022a).

To complement the subjective perception analyses about the TUPPs, the reviews on Google about the case study parks are analyzed. This analysis serves to report a more qualitative, vast, and discursive overview on the impressions of the users on the parks, to help disentangling the results of the subjective comfort assessment.

2.3. Statistical analyses

Data gathered from the microclimate monitoring campaigns and from questionnaire surveys are organized into convenient integrated databases and then analyzed by means of descriptive and statistical analyses. Linear regression analyses, to investigate the correlation between the considered variables, and *t*-test, to compare the means, are employed, with a confidence interval equal to 95%. For the regression analyses, the dependent variables (DVs) are the investigated ones, which are influenced by the independent variables (IVs): e.g., measured "air temperature" is a DV and being inside or outside the park is an IV; or declared "whole comfort" perception is a DV and being inside or outside the park is an IV.

Therefore, for investigating the effect of the TUPPs in mitigating overheated and/or over polluted urban conditions, the DVs are the monitored microclimate variables (air temperature, relative humidity, wind speed and direction, solar radiation), and IVs are being inside or outside the park, the day and the hour of the day, the typology of park.

Instead, for investigating the effect of the TUPPs on whole comfort and individual comfort perceptions, the DVs are the comfort perception (i.e., whole comfort, visual comfort, acoustic comfort, air quality and thermal comfort) and the IVs are being inside or outside the park, the day and the timing of the day, the typology of park (different TUPPs are considered), the personal characteristics and those for the visit (e.g., motivation, time).

Finally, to compare objective and subjective mitigation, the DVs are the comfort perceptions (whole comfort, visual comfort, acoustic comfort, air quality and thermal comfort) and the IVs are the monitored microclimate variables (air temperature, relative humidity, wind speed and direction, solar radiation), the park typologies within the TUPPs and the time and day of the monitoring campaign.

With respect to the t-tests, the means for the whole comfort and microclimate variables are compared, as well as those of the visual comfort and the solar radiation, those of the thermal comfort and the At.

The analyses are led considering different clusters (Fig. 2), from bigger and more general clusters (that of the TUPPs) to individual clusters identifying each park typology within the TUPPs, and then the individual parks, differentiated from all of the surrounding streets, down to the streets and the avenues, which are characterized by the same orientation.

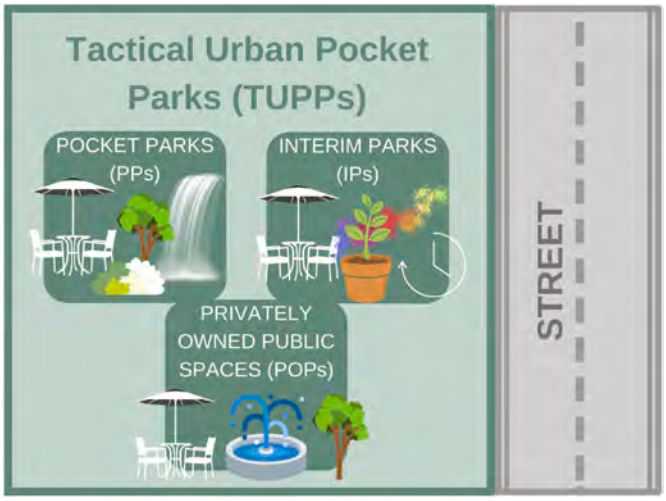

Fig. 2. Clusters for the analyses: Pocket Parks, Interim Parks, Privately Owned Public Spaces within Tactical Urban Pocket Parks bigger cluster; and Street.

2.4. Case study tactical urban pocket parks

The above-illustrated methodology is applied to TUPPs located in New York City, NYC, USA (Fig. 3). The climate for NYC is humid subtropical climate (Cfa) according to Köppen Geiger Classification (Peel et al., 2007), thus characterized by high summer temperatures with an average of 24.6 °C, a winter average temperature of 12.2 °C, and distributed precipitations during the year.

The city represents a densely populated urban area susceptible to the Urban Heat Island (UHI) effect, and it has limited space for traditional parks. Consequently, it offers a fertile ground for exploring alternative and experimental solutions, which makes it a significant and relevant context for studying the proposed approaches. The most famous pocket parks (PPs), which are the epitome of small urban park typology, were built here in the 60s′ and were the subject of a first study by the Authors (Rosso et al., 2022a, 2022b). Other small urban parks typologies, which we gather under the definition of TUPPs, were recently defined and implemented in NYC, and are described in this section. They are the temporary/interim street plazas (IPs), and the Privately Owned Public Spaces (POPs). These other small urban park typologies, still in the wider TUPP typology, are precisely regulated by NYC Dept. of Transportation (DOT), and correspond to different degrees of complexity, costs, flexibility with respect to PPs, which are here considered the eponymous small urban parks, due to their precise features aimed at improving pedestrians' comfort. While IP and POP are defined in the frame of NYC regulations, they possess general characteristics that can be applied and considered in other urban areas in other contexts, and a convenient variation of complexity and features that allow evaluating different small park typologies within the TUPP definition. These characteristics led to choosing the above-mentioned typologies to be selected for the purpose of this work.

2.4.1. Pocket parks (PPs) features

While the characteristics of PPs are described in great detail in previous articles by the Authors (Rosso et al., 2022a, 2022b), we recall them also here briefly, in order to compare them with the characteristics of the other small urban parks typologies, while all of the considered typologies (PPs, IPs, POPs) are gathered under the more inclusive set of TUPPs. The main features of PPs are the insertion of (i) greenery to increase evapotranspiration, contact with nature and biodiversity services, (ii) water bodies/fountains, which provide gray noise to cover traffic noise and further support the contact with nature, (iii) varied furniture to provide for individual or group accommodations for relaxing or eating, (iv) shade, provided by furniture or trees and (v) separation from the street, to convey the sensation of being in a green oasis detached from the chaos of the city (Rosso et al., 2022a).

Fig. 3. Manhattan (NYC, USA) and case studies location (left), zoom on the case study locations in Lower Manhattan and Midtown (right).

2.4.2. Interim plazas (IPs) features

The **temporary/interim plazas** (IPs) are part of the NYC plaza program (New York City Department of) and can be eventually transformed into permanent plazas. They are aimed at improving public space by intervening on underutilized portions of streets and transforming them into public plazas. The IP is the most simple and easy to obtain TUPP, composed by interim materials, and suitable also for tactical urbanism initiatives, in other countries and cities. IPs are built by NYC DOTs after a competitive evaluation of proposals, but they are proposed and, if successfully, managed, by community-based initiatives, as bottom-up approach to improving outdoor urban spaces (Rosso et al., 2022a). Surrounding neighborhood stakeholders must be involved and agree with the proposed plaza, according to DOT regulations. IPs should be located preferably in densely populated, close to public transportation and safe areas, and are encouraged in low-income or moderate-income neighborhoods. IPs design should "create environmentally friendly plazas that are appropriate to neighborhood context" and are implemented with continuous feedback and participation from local community stakeholders (New York City Department of Transportation, 2020). They do not have strict requirements with respect to minimum size or shape, but they are encouraged to have a surface area of no less than 2000 square feet (around 186 square meters). They are usually defined by a different pavement material or color than the street, from which they are separated either by railing or by planters, for security reasons. They should provide a clear path with minimum clutter, and furniture to accommodate people. They could be designed with tables and seating, lighting, public artworks and drinking fountains. They should incorporate trees and green covers. Trees and plantings provide shading, which could be enhanced by means of furniture (e.g., umbrellas). Greenery and trees are also encouraged to reduce stormwater runoff and should be placed so as to maintain a sense of openness and visibility in and throughout the IP. Moreover, plantings are designed to define edges, provide shadings and provide other protection (e.g., from the traffic) to plaza users.

2.4.3. Privately Owned Public Spaces (POPs) features

The **Privately Owned Public Spaces** (POPs) are instead "outdoor and indoor spaces provided for public enjoyment by private owners in exchange for bonus floor area or waivers" (NYC Planning, 2021). In this work, as we are investigating small outdoor urban parks, the focus is on outdoor POPs. As of now, there are more of 500 POPs in NYC, the majority located in lower and midtown Manhattan. POPs are parks where people can relax, sit, eat, and meet, to "enjoy urban life", and are aimed at ensuring that even the densest areas of NYC offer a good amount of open public space and greenery. All the POPs of NYC provide for a public space that is equal, as a sum in terms of surface, to 9*x* Bryant Park (NYC Planning, 2021). These TUPPs have much strict requirements than the IPs, and are based on private initiative, to benefit the broad public. POPs have to commit to very precise standards, with respect to their features and characteristics (NYC Planning, 2021). They should be located no closer than 175 feet (around 53 m) from other POPs or parks, to avoid a redundancy of parks that could be less used if too close to each other. Their minimum surface area is 2000 square feet (around 186 square meters, as for IPs) to accommodate the required amenities (e.g., seating, plantings). They should generally be regular in shape, with only small portion (less than 25% of the total surface) of their surface allowed to niches or alcoves, and with an average width and depth of 40 feet (around 12 m). Moreover, they should provide both shaded and sunny areas, thus South facing orientation is preferred (when possible). If not possible, they could be facing West or East, but they can never have a sole North-facing orientation: this requirement is also aimed at favoring the success of greenery and plantings. Visibility into and throughout the POP is another fundamental requirement to achieve a sense of openness and safety, therefore, within a certain design flexibility, they should be completely visible from one street frontage, and at least 50% visibility from the other street frontage. Through-block POPs are located on a midblock connecting two streets, and in addition to the previous indications, they should contain at least one circulation path. The connection to the sidewalk is of particular importance, as the success and amount of use of the POP depends on it: thus, the sidewalk frontage of the POP should be open and inviting. Moreover, POPs could have higher elevations than the sidewalk: as this could negatively affect the sense of openness and safety, such an elevation should be less than 2 feet (60 cm). At the same time, POPs cannot be sunken below street level.

With respect to amenities, seating should be abundant, well designed, and comfortable, to favor social interactions and resting. They should also be suitable to accommodate small groups or individuals that want to perform solitary activities. To this aim, also an amount of movable seating is provided.

Trees and greenery are key components of the POPs and are aimed at providing contact with nature and comfort to pedestrians. There is a balance between abundant planting and solar availability of the POP. At least 20% of the POP is composed by planted areas, and a minimum equivalent to four trees is required inside each smaller POP (more in bigger POPs). Appropriate soil depth must be provided, and irrigation is required for each green area.

As POPs are open generally 24/7 (contrary to IP and PP), lighting is crucial to maintain a sense of safety and to encourage the use of the POP. Light level is uniform and adequate to the use and dimension of the POP, and not direct or to strong, to avoid glare or impair visibility. Lights operate from 1 h before sunset to 1 h after sunrise.

Finally, POPs bigger than 5000 square feet (around 465 square meters) provide additional features, such as artworks, tables, water installations, kids' playgrounds or other amenities, which are not mandatory but recommended for smaller POPs.

2.4.4. Selected case study tactical urban pocket parks (TUPPs)

Four significant and relevant case studies of TUPPs pertaining to the above-described small urban parks typologies subsets are selected in Manhattan, NYC, USA, to study the effectiveness of different typologies of parks in improving microclimate and subjective comfort: two PPs located in Midtown Manhattan, one IP and one POP located in Lower Manhattan (Fig. 4). The case studies are selected in two areas of NYC that are characterized by the highest building density, i.e., lower Manhattan and Midtown, as visible from Figs. 3 and 4, in order to have homogeneous parameters with respect to height/width of the urban canyons and open spaces close to the parks.

PPs are the famous Greenacre Park and Paley Park (Rosso et al., 2022b) (Fig. 5). They are closed over three sides by surrounding buildings and have one open frontage to the sidewalk; they both host trees, greenery and waterfalls providing gray noise; they both provide varied and abundant seating areas and furniture, and they are separated from the street, but still visible and inviting.

As for the IP, Albany Street Plaza is considered, which is built with temporary materials, with minimal but curated intervention (Fig. 6). Trees and greenery are positioned into big vases, and provide for shading. A railing separates the IP from the street. Albany Street Plaza hosts tables and chairs. The considered IP has a trapezoidal shape and is open on three sides towards streets (Greenwich Street, Albany Street and Washington Street), and presents a wall completely covered with a colorful installation (Fig. 6).

With respect to the POP case study, 99 Church Street Plaza, a through-block POP, is located between Barclay Street and Park Place, Lower Manhattan (Fig. 6). A fountain, two water installations also providing water background gray noise, many plantings and a varied and abundant selection of seating, comprising movable seating and tables are here installed. In addition to planting, there are nine trees inside the POP. It is rectangular and closed over two sides (the longest sides) and open on two sides (the shortest ones).

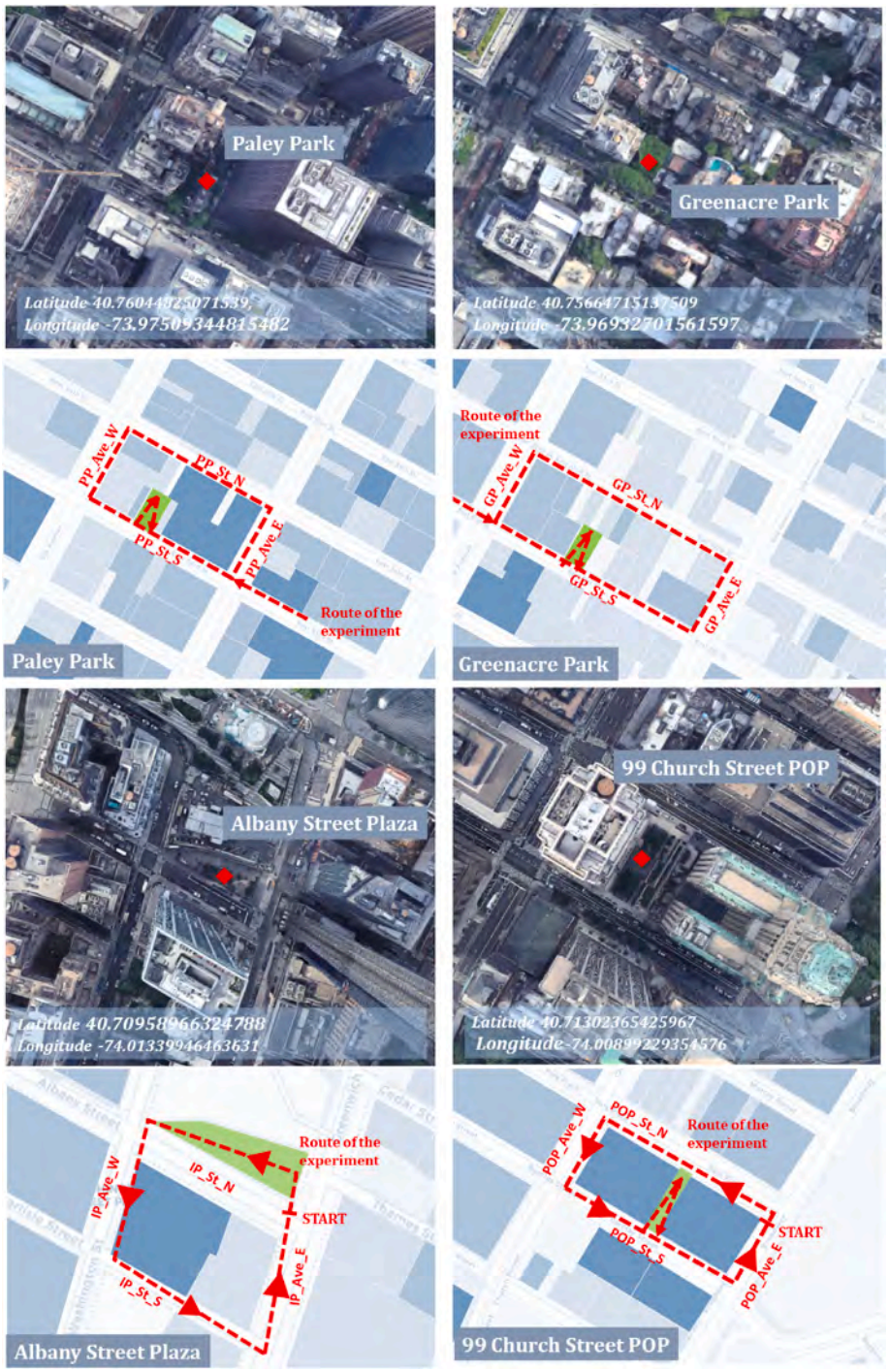

Fig. 4. Routes for the case studies small urban parks, and corresponding view from above.

3. Results

3.1. Objective comfort assessment

Regression analyses are carried out to verify the statistical significance of the microclimate mitigation via monitoring inside and outside the park, as well as with respect to the different parks typologies (Table 3). A 95% confidence interval is selected. The considered dependent variables are the microclimate variables measured during the monitoring sessions, while the independent variables are those related to the position (e.g., in the park, on the street) or the timing of the day when the monitoring campaign is carried out.

Scale clusters are considered, with increasing dimension. First, the single parks and surrounding streets and avenues are considered. Then, bigger clusters including all of the parks, all of the streets are accounted for (Fig. 7).

3.1.1. Air temperature

Air temperature (Tair) is lower in parks, considering all of them (the bigger cluster) by −0.07 °C on average. During the morning, the mitigation in the parks is equal to −0.1 °C, while at lunch there are generally +0.27 °C in the parks, and +0.22 °C during the evening with respect to surroundings.

However, considering the different weather conditions, the effect of

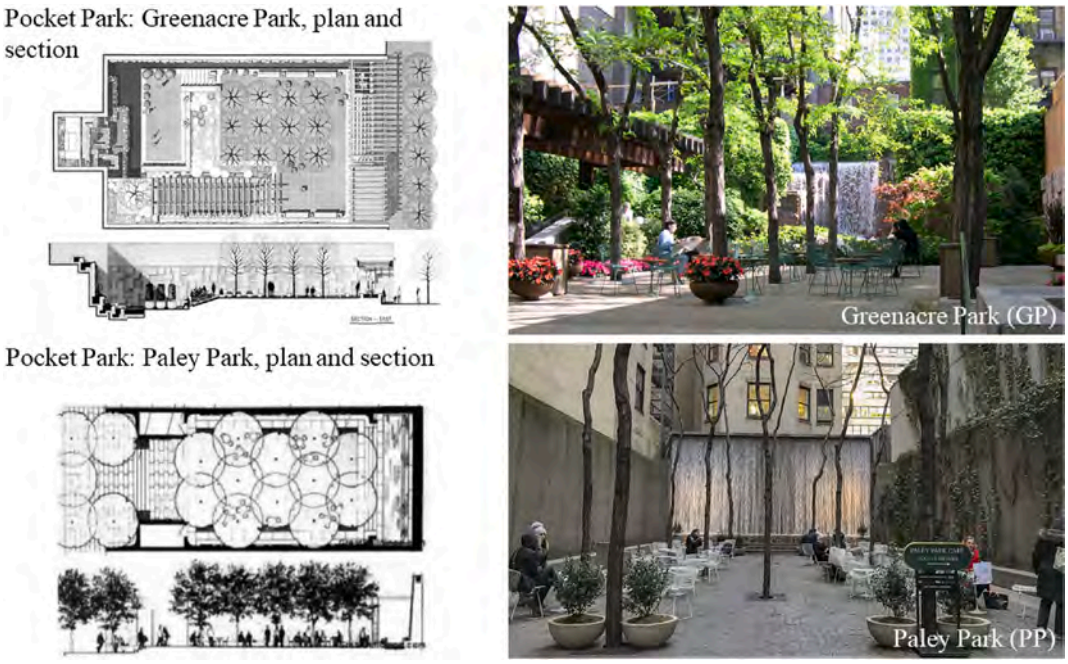

Fig. 5. The pocket parks (PP) case studies: Greenacre Park and Paley Park: plan and sections on the left, image on the right.

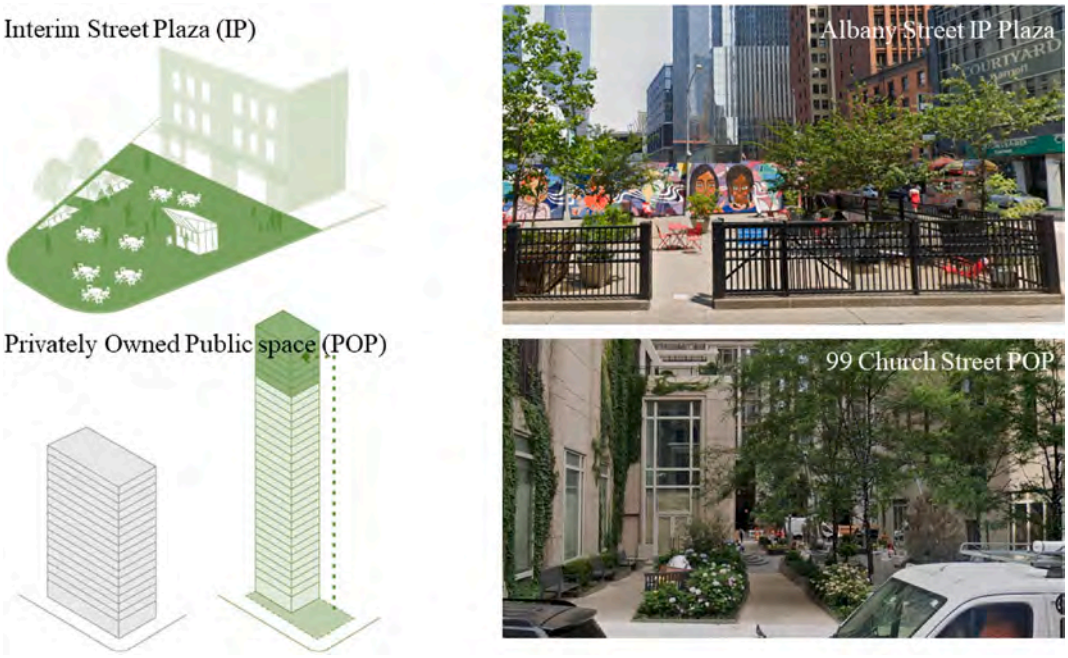

Fig. 6. The Interim Street Plaza (IP) and the Privately Owned Public Space (POP) case studies: schemes on the left, images on the right.

Table 3
Synthesis of the results of the regression analyses for the TUPPs and the individual typologies.

Microclimate variable	Tair	RH	SR	At
u.o.m	°C	%	W/m^2	°C
TUPPs	−0.07	+3.67	−56.73	+0.35
PPs typology	−0.37	+4.20	−93.22	−0.15
POP typology	−0.26	+1.25	−120.70	−0.20
IP tipology	+0.30	−0.90	57.39	+0.28

parks on temperature reduction is not significant during the cloudy days, while during the sunny days, the parks are +0.28 °C warmer. During the morning, in cloudy days, Tair is −0.21 °C colder in the parks, while during sunny days a minor overheating by +0.09 °C is measured. Tair is even higher on a sunny day at lunchtime, with +1.32 °C, against an increase by +0.32 °C in a cloudy day at lunchtime. The evening monitoring shows a negligible variation in temperatures on a cloudy day in the parks, while an increase equal to +1.1 °C during sunny days is experienced.

The mitigation is higher in **PPs**, Tair mitigation of −0.37 °C are experienced in the park with respect to the streets. The **POP** (Privately Owned Public Space, Barclay and Place POP) is able to provide a

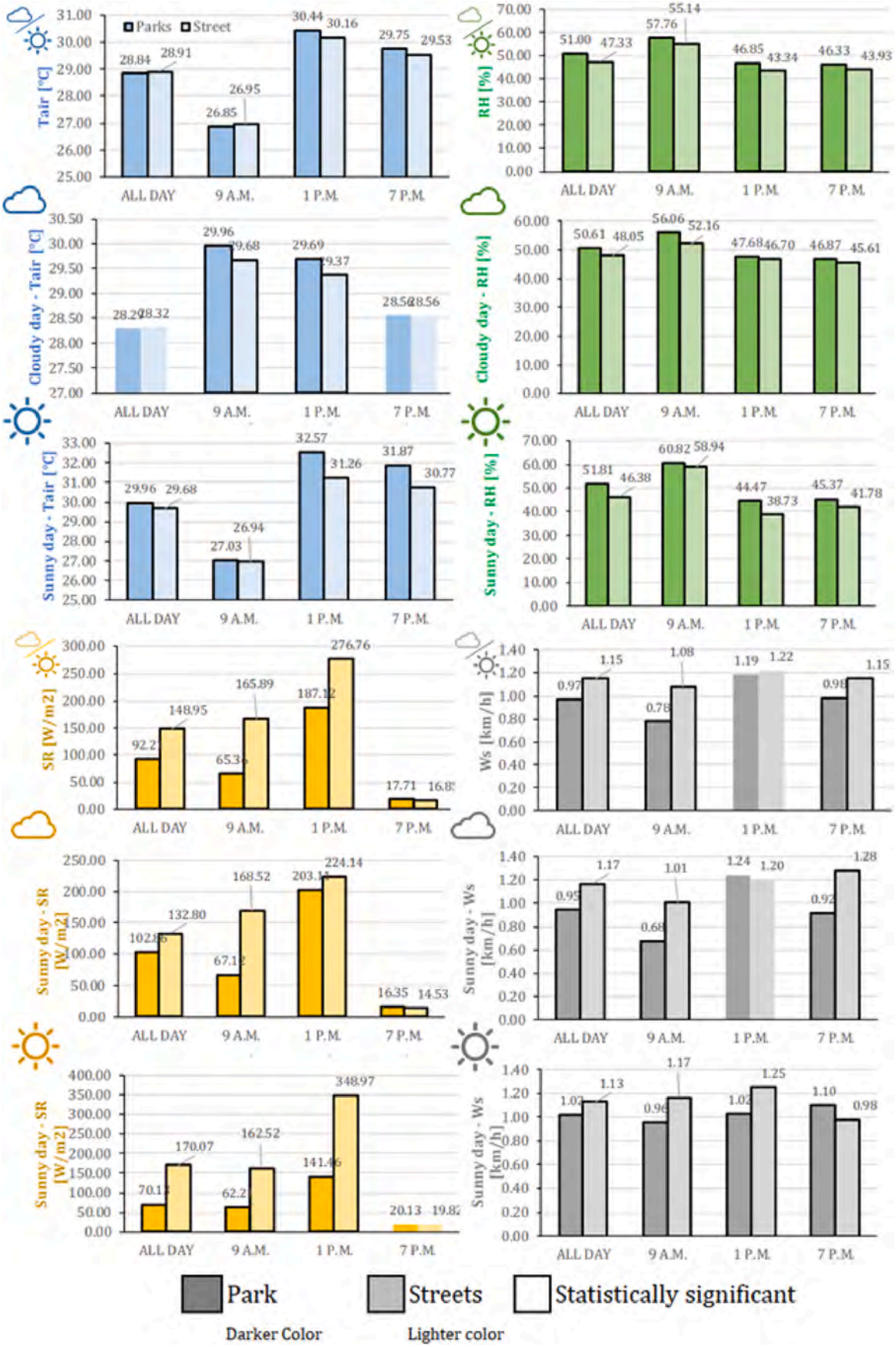

Fig. 7. Results of the regression analyses for the bigger cluster: parks compared to streets, during the different weather conditions and different times of the day for Tair, RH, SR, Ws (standard error respectively lower than 0.05 °C, 0.3 %, 10 W/m^2, 0.05 m/s).

−0.26 °C decrease in Tair. Finally, the **IP** (interim park, Albany Street Plaza) instead experiences higher temperatures (+0.30 °C) than the surrounding streets, in general (Fig. 8).

During the morning, PPs and POP show no significant Tair change, nor at lunchtime, nor during the evening. Instead, IPs display significant increases in Tair at midday (+0.63 °C) and evening (+0.30 °C), while no changes are observed during the morning.

By looking into greater detail into the different weather conditions, temperature during cloudy days and sunny days is analyzed within the clusters. During cloudy days, PPs do not significantly modify Tair, while they are able to mitigate temperatures during sunny days, up to −1.26 °C. Instead, IPs in sunny days display no significant change in Tair with respect to streets, while +0.40 °C Tair increase is found on cloudy days. POPs are able to mitigate Tair also during cloudy days, by −0.15 °C, while during sunny days not significantly modifications in Tair are observed.

3.1.2. *Relative humidity*

Relative Humidity (RH) is generally higher in the parks (bigger cluster), +3.67% with respect to surrounding streets (Fig. 7). In greater detail, during cloudy days, RH increase in parks is equal to +2.56%, while during sunny days it is +5.42%. During the morning, parks are +2.63% more humid than streets, at lunch 3.51% and during the evening +2.40% RH is measured. By also considering weather conditions and hours, on cloudy days during the morning, +3.90% increase in RH is measured, +0.98% at lunch, and +1.26% during the evening. Instead, on a sunny day, during the morning RH increase is lower, +1.88%, while it is much higher at lunchtime +5.74%, and equal to 3.59% during the evening.

When analyzing the individual TUPPs typologies (Fig. 9), PPs have generally higher (+4.2%) RH than surrounding streets and avenues. POP presents slightly higher RH than the streets (+1.25%), while IP have generally a lower RH thank streets, −0.90%.

During the morning, PPs show +2.63% RH increase with respect to streets, +3.28% at lunchtime and +1.29% in the evening. IP instead shows no significant change in RH during the morning with respect to streets, while at lunchtime it is drier than streets by −1.72% RH, and at evening by −1.05%. With respect to POP, they are generally drier (−0.65% RH) during the morning, wetter at lunch (+1.45%), and no significant change is measured during the evening.

During cloudy days, PPs in general display +2.60% increase in RH. In greater detail, in PP during the morning, RH increase is +5.09%, at

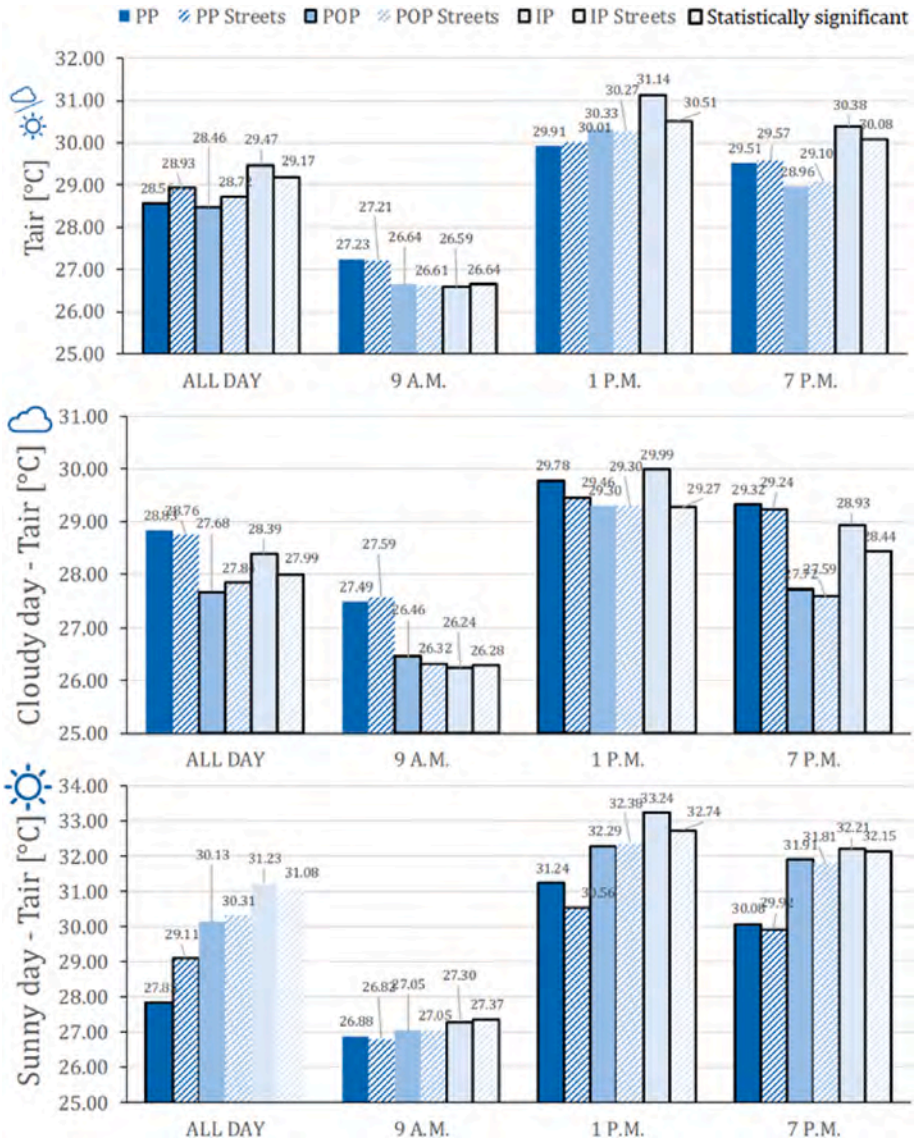

Fig. 8. Results of the regression analyses for the individual park typologies and close-by streets clusters for Tair (standard error lower than 0.05 °C): parks compared to streets, during the different weather conditions and different times of the day.

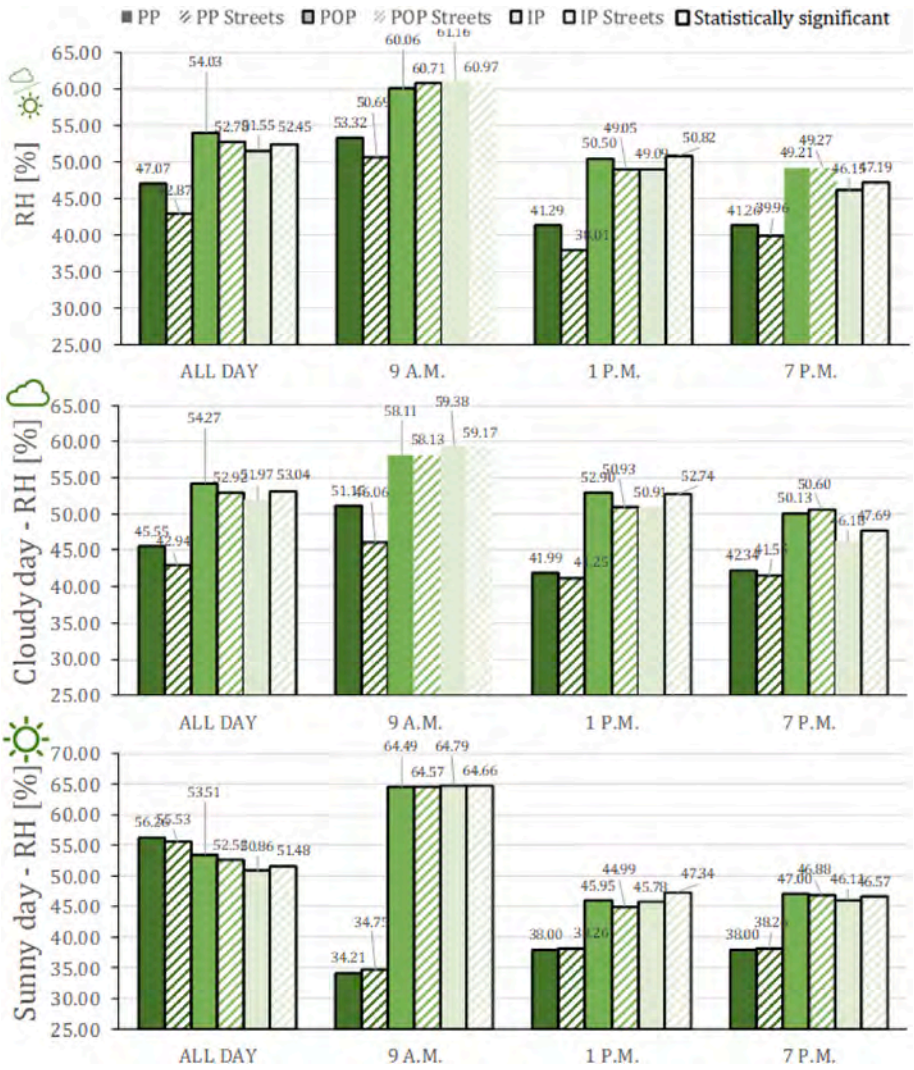

Fig. 9. Results of the regression analyses for the individual park typologies and close-by streets clusters, for RH (standard error lower than 0.3%): parks compared to streets, during the different weather conditions and different times of the day.

lunch +0.74%, and +0.80% during the evening. Instead, on sunny days, RH change in PPs is significant only during the morning, +0.74% increase. During cloudy days, IP in general has lower RH than surrounding streets (−1.07%); in greater detail, while during the morning this change is not significant, at lunchtime the decrease is equal to −1.83% and during the evening −1.51%. During sunny days, in general IP has no significant change in RH, even if when considering the different time of the day separately, while during the morning RH change is not significant, at lunch RH increases by −1.56% and during the evening −0.46%. In POP, RH during cloudy days is higher by +1.35% generally, while not showing significant change during the sunny day. In greater detail, POP in cloudy days during the morning has no significant RH change, while at lunch it is wetter (+1.98% RH) and during the evening drier (−0.47% RH). POP during sunny days instead generally shows no significant difference in RH with respect to surroundings, while by looking in greater on the different hours, while no change is demonstrated for the morning or the evening, at lunchtime the POP is wetter (+0.96% RH) than the surroundings.

3.1.3. Solar radiation

Solar Radiation (SR) is lower in the **parks** than on streets and avenues, −56.74 generally (Fig. 7). During the morning, parks are shaded in terms of SR by 100.52 W/m^2, +89.65 at midday and +0.86 in the evening. In greater detail, during cloudy days SR in parks is −29.94 than in surrounding streets, while during sunny days the mitigation of SR is much higher, −99.94. By looking at the SR during the different parts of the cloudy and sunny days (Fig. 10), in cloudy days parks reduce SR by −101.40 W/m^2, -21.03 at midday and higher SR is present during the evening, +1.82. During sunny days, the solar shading at midday is much higher, up to −207.51, while similar in the morning (−100.31) to the change observed during the cloudy days. During the evening of sunny days, parks experience no significant change than surrounding streets with respect to SR.

PPs experience a significant decrease in SR, equal to −93.22. SR mitigation in the POP is even higher, with −120.70. The IP instead has an opposite trend, as SR is +57.30 there with respect to streets and avenues. These results are supposedly linked to the height of the surroundings, as PPs and POP are located in very small residual spaces between high buildings, while the considered IP has three open sides, and the one that is not bordering a street or an avenue is an under-construction lot, which does not provide shadow. Moreover, trees are smaller and less densely positioned in the IP. While the PPs have three sides bordering buildings, the POP has two sides bordering buildings, which are the longer sides.

By considering the hours of the day, PPs modify SR by −132.2 in the morning, −181.4 at midday and −6.61 in the evening; SR decrease in POPs is equal to −120.9 in the morning, −240.7 at midday and −8.91 in the evening. IPs instead, as above-motivated, show the opposite trend,

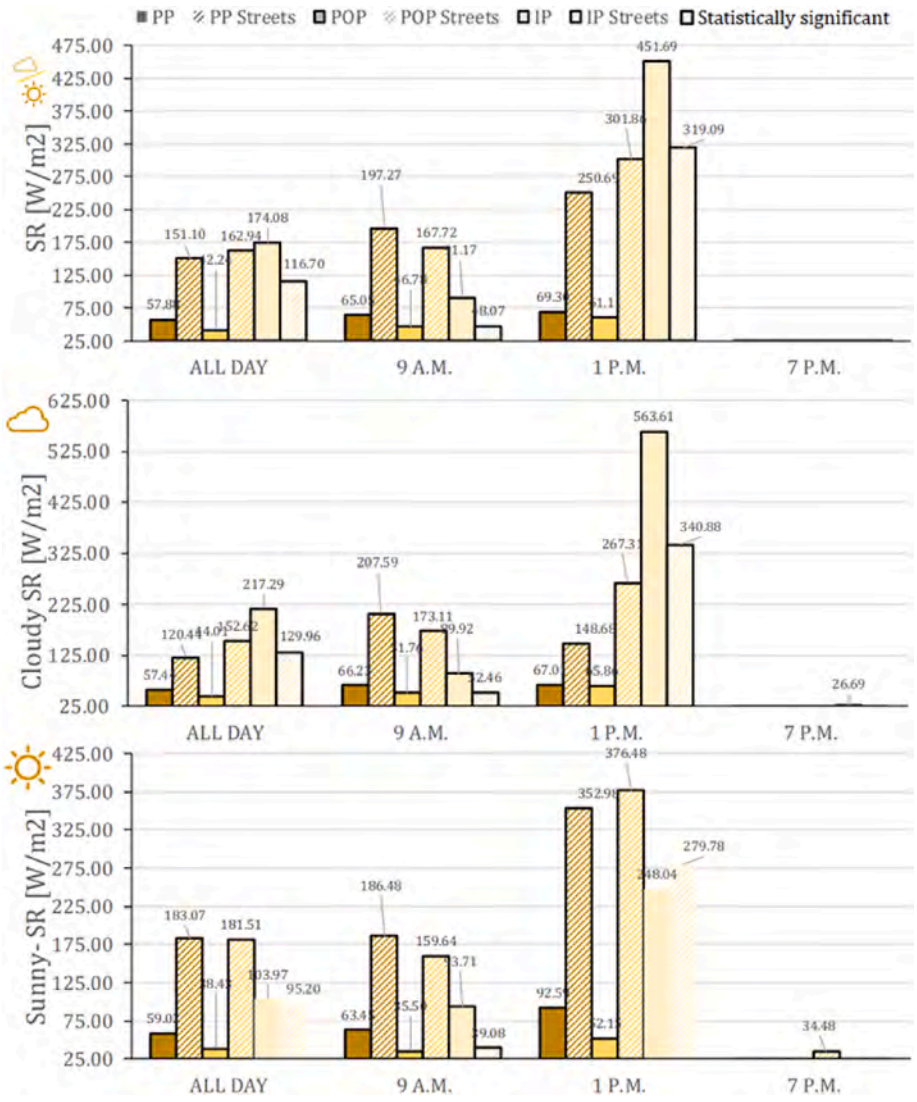

Fig. 10. Results of the regression analyses for the individual park typologies and close-by streets clusters, for SR (standard error lower than 10 [W/m2]): parks compared to streets, during the different weather conditions and different times of the day.

and SR increases in IPs than in surrounding streets: +43.10 in the morning, +132.6 at midday and +9.92 in the evening. When taking into account the weather conditions, PPs in cloudy days decrease SR by −62.99, the half of their mitigation in sunny days (−124.1). POP has even higher SR mitigation, −108.6 during cloudy days and −143.1 in sunny days; IPs show no significant change during sunny days with respect to surrounding streets, while during cloudy days they display higher SR than the surroundings, +87.33. In order to further disentangle SR with different weather condition and times of the day, PPs in cloudy days show a −141.4 reduction in the morning, −81.67 at lunch and −5.04 in the evening, while in sunny days −123.00 in the morning, −260.4 at midday and −9.17 the evening. The IP shows again the opposite trend, i.e., increasing SR, both during the cloudy and sunny days, at the different hours: +43.10 in the morning, +132.6 at midday and+9.9 in the evening for the cloudy day; +37.46 in the morning, +222.73 at midday and +11.42 in the evening for the sunny weather.

3.1.4. Wind speed

With respect to **Wind Speed (Ws)**, it generally decreases in parks (−0.18 km/h) with respect to streets, due to the enclosed space of the park and the presence of trees (Fig. 7). During the morning, generally mitigation is higher, equal to −0.30 km/h and −0.17 km/h in the evening, while negligible at midday. During the cloudy day mitigation is equal to −0.22 km/h, and in the sunny days −0.10 km/h. By looking into the different times of the day, for the cloudy day Ws reduction in the park is −0.33 km/h in the morning and −0.37 km/h in the evening, while negligible at lunch. Lower reductions are experienced during the sunny day, when in the morning reductions are up to −0.21 km/h, −0.22 km/h at lunch, and during the evening Ws is instead higher (+0.11 km/h).

By looking at the individual park typologies (Fig. 11), PPs reduce Ws by −0.24 km/h generally; −0.35 km/h in the morning, −0.21 km/h at lunch and changes are not significant in the evening. More precisely, for PP mitigation is higher during the cloudy day, equal to −0.27 km/h than during the sunny day, −0.20 km/h. During the morning mitigation is higher, equal to −0.37 in the cloudy day and −0.28 in the sunny day, at lunch −0.15 (cloudy) and −0.26 (sunny day), while negligible in the evening for the cloudy day and equal to – 0.31 in the sunny weather conditions. POP performance with respect to Ws is similar to the PP performance: it generally reduces Ws by −0.47 km/h. During the morning, −0.34 km/h are measured, −0.42 km/h in the evening. This mitigation is higher in the cloudy day, with −0.47 km/h in general, −0.36 km/h in the morning, −0.39 km/h at midday and −0.69 km/h in the evening. Very similar results are measured for the sunny day: 0.43 km/h in general, −0.24 km/h in the morning, −0.48 at midday and −0.62 in the evening.

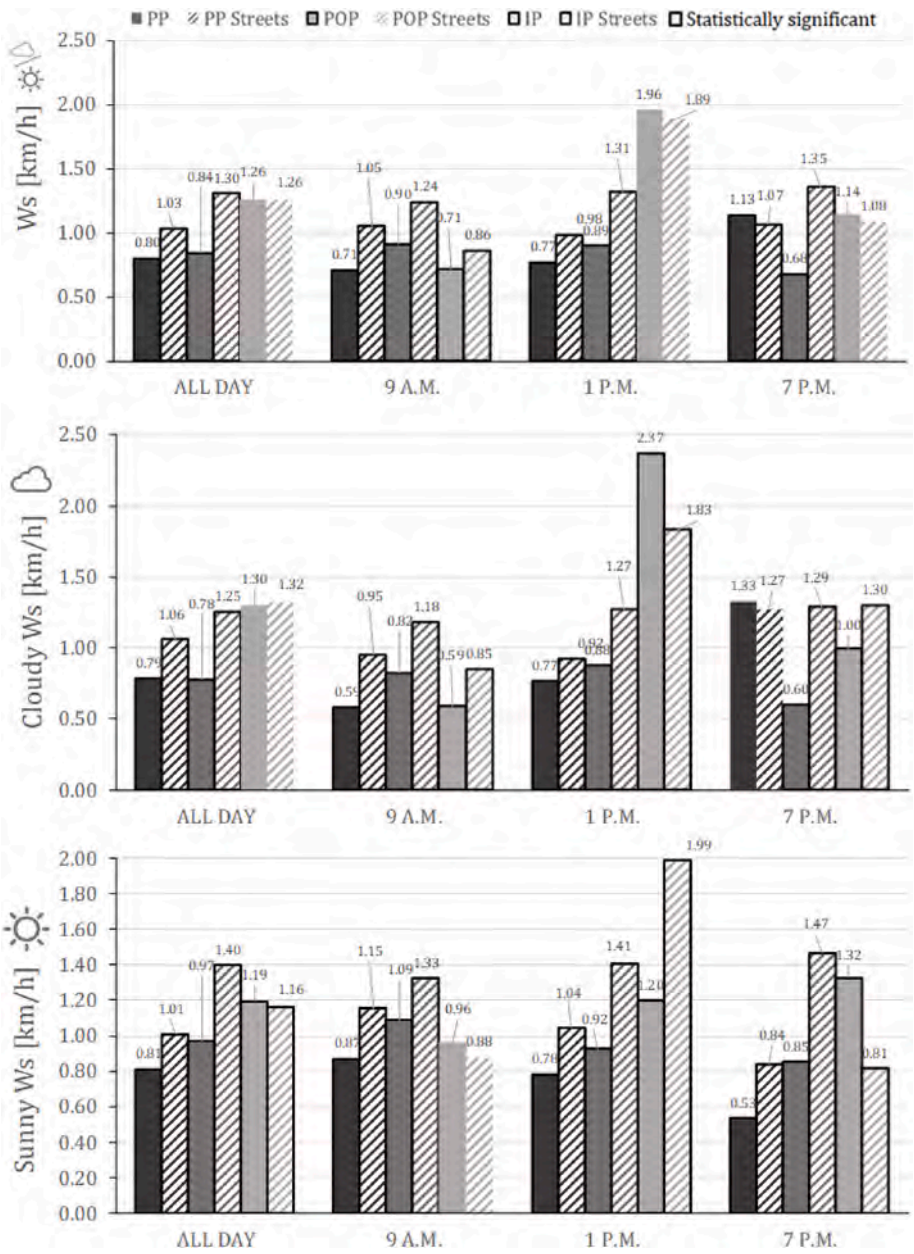

Fig. 11. Results of the regression analyses for the individual park typologies and close-by streets clusters, for Ws (standard error lower than 0.05 [m/s]): parks compared to streets, during the different weather conditions and different times of the day.

The IP behaves differently, as for SR, also for Ws: indeed, its morphology configuration is more open and this makes the slight difference with the surrounding streets, often non-significant, and highly variable depending to the moment of the day. For the cloudy day, reductions are experienced during the morning (−0.26 km/h) and the evening (−0.30 km/h), while at midday Ws in higher in the park (+0.54 km/h). During the sunny day, at midday Ws is reduced by −0.79 km/h, and increased in the evening by +0.51 km/h.

3.1.5. *Apparent temperature*

As a comfort indicator, **apparent temperature** (At) is considered. At is higher inside the parks (+0.35 °C), considering all of them (Fig. 12). In greater detail during the morning +0.08 °C are experienced, +0.89 °C at midday and +0.63 °C in the evening. During the cloudy day At variation is +0.21 in general, with a non-significant variation in the morning, +0.55 °C at midday and +0.12 °C in the evening. During the sunny day, increases in At in the parks are higher, equal to +1.14 °C. +0.25 °C are experienced during the morning, +2.85 °C at lunch, and +2.10 in the evening.

When considering separately each TUPP (Fig. 13), PPs do not significantly modify At (−0.01 °C) in general. POP is able to provide a higher mitigation of At, equal to −0.20 °C. Lastly, IP (interim parks, such as Albany Street Plaza) instead cause an increase in At equal to +0.28 °C. When considering also the time of the day, increases in PP are equal to +0.21 °C in the morning, +0.27 at midday and +0.06 in the evening. IPs show significant changes (+0.67 °C) at lunch, while At increases in the POP is equal to +0.31 °C. By taking into account also the weather conditions, PPs increase in At is equal to +0.30 °C in cloudy days, while in sunny days the PPs mitigate At by −0.63 °C. More precisely, PPs in the morning in cloudy days displays +0.25 °C, +0.13 °C in sunny conditions; at lunch increase is higher for the cloudy day, with +0.46 °C and even higher in sunny days, +0.70 °C. POPs do not generally show At changes in cloudy or sunny days: in sunny days, only during the evening there is a significant change in At, equal to +0.20 °C, while during the

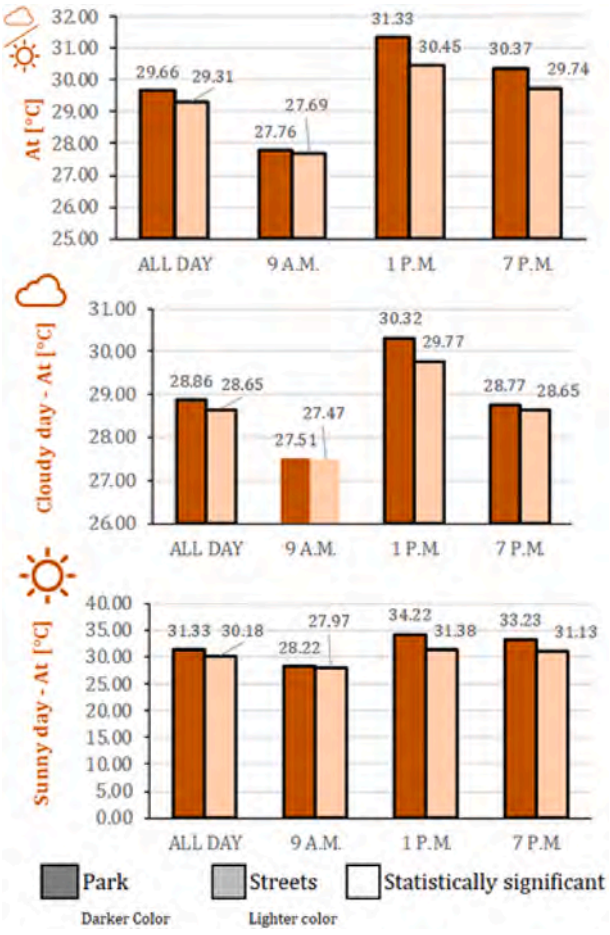

Fig. 12. Results of the regression analyses for the bigger cluster: parks compared to streets, during the different weather conditions and different times of the day for At (standard error lower than 0.05 [°C]).

cloudy days POP At changes are +0.15 °C in the morning, +0.27 °C at midday and +0.09 °C in the evening. Finally, the IP during the cloudy day increase is equal to 0.38 °C, while negligible during the sunny day. During the morning, the IP reduces At by −0.04 in the cloudy day and −0.09 in the sunny day. At lunch, +0.78 °C (cloudy day) and +0.51 °C (sunny day) are measured. During the evening, changes are significant only for the cloudy day (+0.40 °C).

3.2. Subjective comfort assessment

With respect to **personal characteristics**, whole comfort in the park is influenced by the time spent in the park by their users (+0.17). The longer the time, the better the beneficial effect on comfort is perceived. Also the reason to visit (+0.26), is significantly affecting whole comfort, with activities such as eating or work meeting showing higher overall comfort than relaxing, visiting, reading or just being outside. Older users appreciate more the whole comfort that parks are able to offer than younger participants (+0.15), while nor gender nor being usual users of the parks influence whole comfort perception.

Visual comfort is influenced by time spent in the park (+0.18), similarly to whole comfort: the longer the time, the better the beneficial effect on visual comfort. Again older users appreciate more the visual comfort offered by the parks (+0.18) than younger users. Same happens with acoustic comfort (age +0.32), where also gender is significant in affecting acoustic comfort. Indeed, male users assign higher grades to acoustic comfort in the park (−0.26) than female participants, who appeared more sensitive about this domain. Air-quality-related comfort is influenced solely by age (+0.23), again with older users declaring higher comfort evaluations. Finally, with respect to thermal comfort and personal characteristics, the more time is spent into the park, the higher the thermal comfort (+0.23) is perceived. Also visiting the park for active reasons, e.g., eating or work meeting, is significant in improving thermal comfort evaluations (as for whole comfort) (+0.19). Gender is also influencing thermal comfort, as female users are more comfortable with the warm temperatures than males, and thus they confirm to better evaluate the thermal environment of the parks (+0.27) in summer, with respect to males.

By **comparing the means of comfort perception inside parks against that one of surrounding streets**, for the various clusters, by means of t-tests, the difference between the means is always significant (Table 4). Therefore, the comfort perception inside the parks with respect to that one on the streets is always significantly different, as illustrated in Table 4 and Fig. 14.

Fig. 14 shows that, while almost all of the evaluation related to parks are above neutral (neutral to very good), the corresponding street evaluation is usually below the zero (representing neutrality), thus meaning neutral to bad comfort evaluation. Another interesting information is related to park typology (Fig. 14), where PPs achieve the highest evaluations in all of the comfort sensations, due to their peculiar morphology and curated space. POPs are just below PPs, and IPs come last among the parks, as hypothesized: however, even being last among parks, also IPs are able to provide a significantly increased comfort in users.

3.2.1. Users' reviews on Google

In order to complement the questionnaire surveys with more extended comments, Google reviews related to the parks were considered as a further qualitative indication of subjective perception on the large scale. The spontaneous reviews released directly by the users of the parks online allowed to motivate and further explain the synthetic evaluations given in the questionnaire surveys. All the reviews on Google related to each park were considered and read, disregard the time of the reviews.

While all of the most relevant comments are reported in the Appendix, in this section the findings and main synthesis are illustrated. The comments were analyzed by clustering them with respect to the domains of comfort perception, when identifiable: whole comfort perception (when the evaluation given in the comment is general) or visual, acoustic, air-quality-related and thermal comfort (when the evaluation given in the comment pertains to a specific domain).

For the PPs, Paley Park obtained an overall evaluation equal to 4.5 on 5 stars, based on 518 reviews (dated 2011–2022, most frequent are dated 4-3 years ago to today), and similarly Greenacre obtained 4.8 stars on 5, based on 756 reviews (dated 2013–2022, most frequent are dated 4-3 years ago to today). The PPs are described in most of the comments as an "*oasis*" a "*paradise*" detached from the "*chaos of the city*". For both the PPs, the focus of the comments is related to the waterfall, which is by far the most recurring word (Fig. 15). The term "*waterfall*" was employed, in addition to the whole perception domain, also for acoustic and visual perception, as the most striking element to capture users' attention and appreciation. With this respect, comments it appears that the more articulated, detached and natural-resembling waterfall in Greenacre attracted even more enthusiastic reviews, and its effect could thus be higher. The more recurring words related to visual comfort in the PPs, in addition to "*waterfall*", were "*beautiful*" "*oasis*" "*park*", "*small*", "*hidden*", "*gem*", "*clean*", "*park*", "*water*", "*little*", "*serene*" words for visual comfort, indicating that the small dimension, the curated and clean space and the presence of natural elements contributed to providing a positive experience with respect to visual comfort. For acoustic comfort, in addition to "*waterfall*", "*noise*", "*sound*", "*relaxing*", "*nice*", "*water*", "*loud*", "*hear*", "*soothing*", "*oasis*" were employed with a positive meaning. Waterfall, in addition to "*shade*", is also primary in the comments related to thermal comfort, and other recurring words in the thermal domain are "*refreshing*", "*cool*", "*relaxing*", and less frequent are

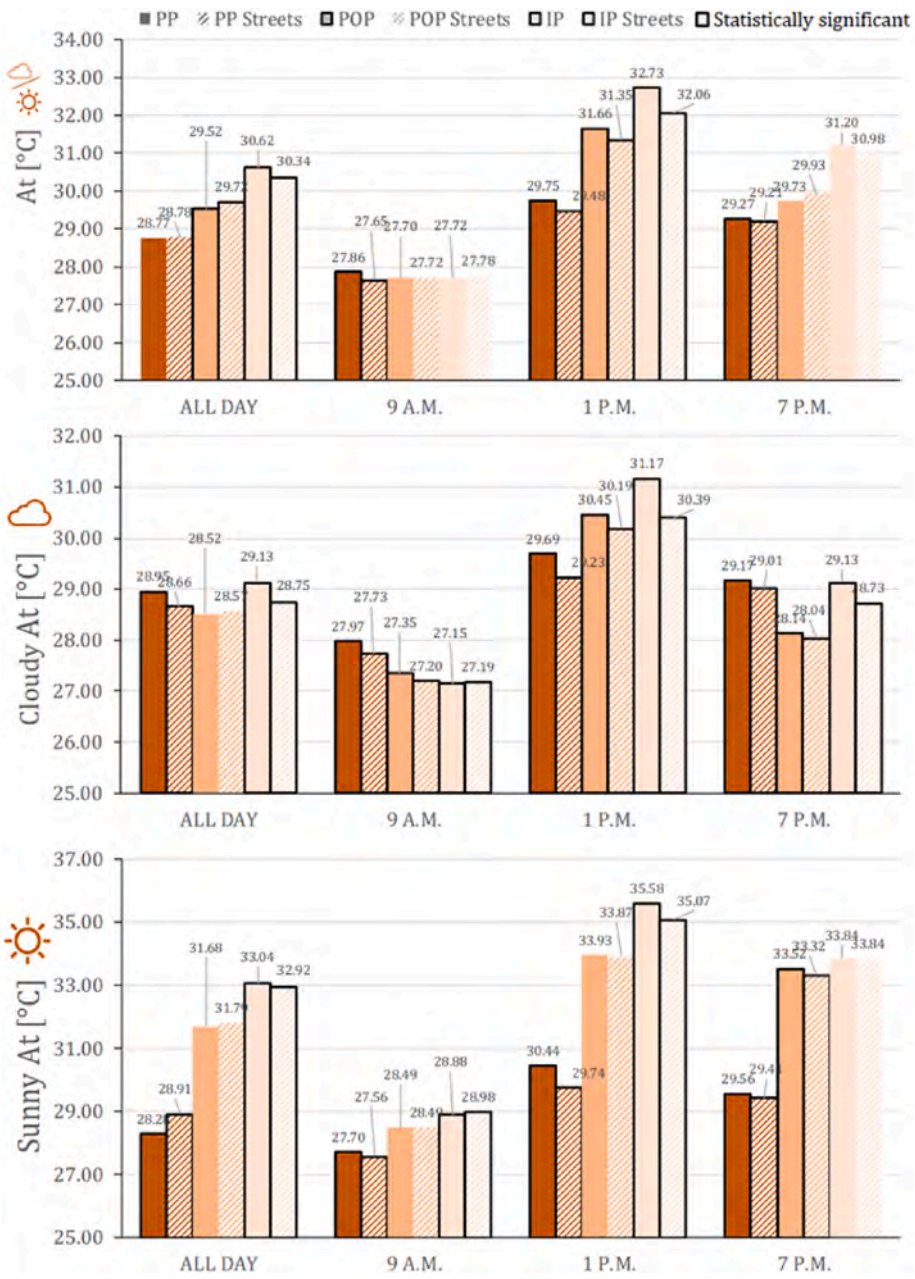

Fig. 13. Results of the regression analyses for the individual park typologies and close-by streets clusters, for At (standard error lower than 0.05 [°C]): parks compared to streets, during the different weather conditions and different times of the day.

Table 4
Subjective comfort evaluation: comparison of the means, for parks and streets, for the various clusters and corresponding assigned evaluation.

	Parks	Streets	PP park	PP streets	POP park	POP streets	IP park	IP streets
Whole comfort	1.31	0.01	1.50	0.23	1.26	0.06	1.10	−0.47
	good to very good	neutral	good to very good	neutral to good	good to very good	neutral	good	neutral to bad
Visual comfort	1.36	−0.10	1.62	0.10	1.31	−0.17	1.06	−0.42
	good to very good	neutral to bad	good to very good	neutral	good to very good	neutral to bad	good	neutral to bad
Acoustic comfort	0.50	−0.73	0.85	−0.42	0.41	−1.06	0.14	−1.05
	good to neutral	bad to neutral	good to neutral	neutral to bad	neutral to good	bad	neutral	bad
Air-quality	0.67	−0.63	0.91	−0.37	0.51	−0.78	0.51	−1.00
	good to neutral	bad to neutral	good	neutral to bad	good to neutral	bad to neutral	bad to neutral	bad
Thermal comfort	1.01	−0.17	1.13	0.16	0.97	−0.28	0.88	−0.74
	good	neutral to bad	good	neutral	good	neutral to bad	good	bad

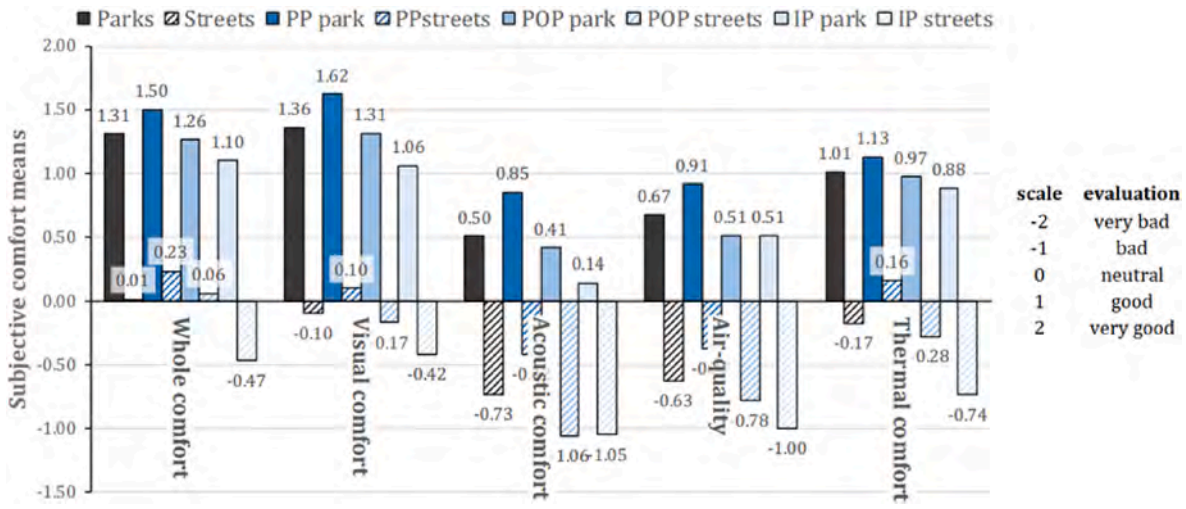

Fig. 14. Subjective comfort evaluation: comparison of the means, for parks and streets, for the various clusters.

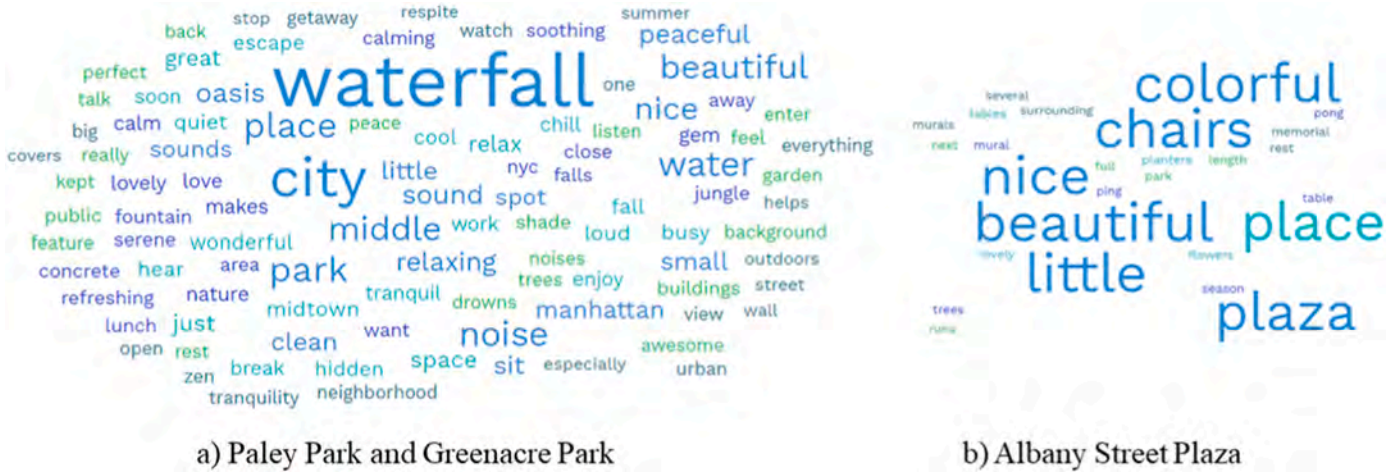

Fig. 15. Word Cloud from the Google reviews a) for both the PPs, Paley Park and Greenacre Park; and b) Word Cloud from the Google reviews for the IP.

"*chill*", "*respite*", "*tranquil*", "*oasis*", "*sun*" and "*semi-shaded*" for Paley Park. For Greenacre the waterfall is the most recurring word, in addition to "*shade*" and "*cool*", while other words are "*refreshing*", "*warm*", "*fresh*", "*greenery*", "*oasis*", "*humid*", "*pleasant*", "*tree*", "*water*".

Comments such as "Such a peaceful, quiet place to step off the busy midtown streets" or ""It may be small, it may be surrounded by buildings but somehow this place has everything you want from a public space. Have a seat while moving the furniture as you need, have a rest under the shade" well synthesize the tone for the whole comfort domain, with almost none negatively commenting the park. Only one "negative" comment was referred to the whole comfort, reading "Very nice, but I wish it was bigger", referring to the small dimension of the pocket park, which was however praised by the majority of the commenters. Other comments on the loud waterfall noise, which is however seen almost always as positive, are as follows "The waterfall is loud, so it's bad for phone calls, which is actually great! It also really helps block the car noise on 53rd", or "If you do want to talk with someone, do not sit too close to the waterfall" or also "The waterfall can be a tad loud but that is relaxing to me, you will know as soon as you get there whether it is something you will like or not" or "It has a huge water feature, so it's a bit loud but honestly, after a while it's just white noise". Even in this case, only one comment related to thermal and acoustic perception is negative "Nice getaway during work but gets humid and loud because of the waterfall". Air quality was commented specifically only for Paley Park, where a peculiar situation for smoking users was registered years ago, but it is no more relevant today.

The relevance and prominence of the waterfall, which is the most astonishing natural feature in both parks, demonstrates that such a strong visual and acoustic natural element is the main feature of the park allowing to disconnect from the city and connect with nature, thus being the protagonist of the calm, peace and relaxation that come from nature in the middle of the city.

As such, it is evident that, as this element is missing from the other two considered park typologies, the disconnection from the city and connection with nature is lower, further motivating the higher comfort perception votes declared in the surveys for the PPs when compared to the other park typologies, POPs and IPs. The POP actually displays water elements, under the form of two fountains, which provide art and noise, and which could partially take on the role of the waterfall, both with respect to noise and visual domain. However, it was not possible to retrieve comments on the POP from Google, as the park was not indicated in the map. With respect to the IP, only 9 comments were retrieved, with a mean score of 4.3, thus slightly lower than that of the PPs, dating from two years ago to today. The main comments evidenced the words "*beautiful*" "*little*" "*plaza*" "*colorful*" "*chairs*" "*nice*" (Fig. 15), evidencing that the most appreciated aspects are related to the visual domain. Planters, trees, flowers were also recognized as elements elevating the quality of the plaza, while "*colorful*" is related to the big

mural, which, as it happened for the waterfall for the PPs, is the most mentioned and appreciated feature of the IP: "*Nice little place to rest. There are several chairs and colorful murals surrounding the place*" and "*Beautiful colorful mural that runs the full length of the plaza*" are the comments dedicated to it.

3.3. Comparison between objective and subjective comfort assessment

By looking into the correlation of measured microclimate variables (objective assessment) and declared comfort evaluations (subjective assessment), a gap between the two is visible in some cases.

Regression analyses are conducted to see the variation of the dependent variables (individual comfort sensations) due to the considered independent variables (the measured microclimate variables) (Table 5). Indeed, the most interesting finding is that visual comfort is not affected by solar radiation, which we would have expected to be influencing it, e.g., due to glare. This finding also explains how the subjective perception is influenced by intangible and un-measurable variables, such as the contact with nature and the pleasantness to the eye of an urban environment. Also Google reviews further consolidate this result, as for PPs and the IP visual perception was related to the presence of natural elements, the cleanliness of the parks and the art displays (such as the "colorful mural"). Whole comfort is influenced by air temperature and relative humidity, which are also the same variables affecting air-quality perception and thermal comfort. Thermal comfort is also significantly affected by At, as a synthetic indicator of comfort. In all of these cases, when Tair and RH grow, the comfort sensations decrease.

We further investigate the interdependencies between whole comfort (considered as a dependent variable) and the other comfort sensations (considered as independent variables) and we find that whole comfort is influenced by all the other comfort sensations, except acoustic comfort. The most influencing variable (with a coefficient equal to +0.28) is visual comfort evaluation, while the coefficients for air-quality and thermal comfort are +0.18 and + 0.12 respectively: therefore, as visual comfort increases, so does whole comfort. Also this finding is supported by the Google reviews, as the same elements that most characterized visual comfort are also usually the protagonists of the whole comfort positive comments.

4. Discussions and limitations

Based on the above presented results, different considerations can be discussed on the specific perspectives of this study.

With respect to **microclimate mitigation,** findings demonstrate that TUPPs are not particularly effective in mitigating microclimate variables, such as T_{air}, RH, while they reduce the amount of SR reaching their users, as well as reduce the W_s due to the peculiar, enclosed morphology. These findings confirm those of previous studies related to PPs (Rosso et al., 2022b). However, by looking at different small urban park typologies within the TUPPs, we find that the effective mitigation is higher in PPs and POPs, while IPs on the contrary display higher temperatures than the surrounding streets.

By considering instead **subjective perception,** while not particularly effective in mitigating physically microclimate, when considering subjective comfort sensations (i.e., whole and individual comfort perceptions), TUPPs are all effective in providing a significantly more comfortable perception for their users, when compared to surrounding streets, most often leading from a "bad to neutral" evaluation of the urban environment outside the park to "good to very good" evaluation in the parks. Also in this case, results related to PPs confirm previous results (Rosso et al., 2022b), while the insights can be extended to POPs and IPs, thus to TUPPs in general.

Therefore, it is evident a **gap between objective and subjective comfort:** Even if the performance of PPs is better than that of POPs and IPs, also POPs and IPs are very effective in improving the observed perception. When investigating the correlation between the TUPPs and the measured microclimate variables, they are not often significantly correlated, meaning that other factors, such as pleasantness to the eye and contact with nature, or even simply personal reasons, are responsible for the good subjective evaluation. These considerations, while confirming the effectiveness of TUPPs in improving the urban built environment, also indicate that there is the need to consider the comfort conditions physically detected in such parks, because TUPPs do not correspond most of the times to an actual improvement in the thermal conditions. The performance gap between perception and actual microclimate conditions is in any case important to be considered, while TUPPs have demonstrated to be beneficial for the livability and enjoyment of the parks, as they provide a more pleasant environment, thus supporting the psychological wellbeing and reconnection with nature of urban citizens. Therefore, the implementation of TUPPs in the urban texture would have this undenied advantage. On the other side, a tailored overheating mitigation action, while designing TUPPs, is expected to optimize their performance as effective passive cooling solution in the urban context. These findings hold important practical implications for the urban resilience and livability of dense cities, for public and cities' administrations especially, by means of providing useful information on the design choices and effects (both subjective and objective) of small areas in cities that can be developed as TUPPs.

In discussing the above remarks, it is useful to evidence some limitations of this study, in order to support and delineate possible future research on the same topic. While considering significant examples of TUPPs, a wider sample of case studies for each TUPP type could further reinforce the analyses. Additionally, morphological parameters of the urban fabric were only indirectly considered: indeed, while considering the parks in homogeneous areas with respect to height-width ratio of surrounding open spaces, height-width parameters, and also other porosity and morphology characteristics could further add to this study.

Table 5
Variables affecting subjective comfort evaluations.

Dependent variable/Independent variables	T_{air}	RH	SR	W_s
Whole comfort	✓	✓	×	×
Visual comfort	–	–	×	×
Acoustic comfort	–	–	–	×
Air-quality	✓	✓	×	×
Thermal comfort	✓		×	×

Dependent variable/Independent variables	**At**
Thermal comfort	✓

Dependent variable/ Independent variables	**Visual comfort**	**Acoustic comfort**	**Air-quality**	**Thermal comfort**
Whole comfort	✓	×	✓	✓

LEGENDA
✓ Significantly affecting
× Not affecting
– Not considered

5. Conclusions

This work investigates to what extent different typologies of Tactical Small Urban Parks, gathered under the definition of TUPPs, can be effective in mitigating intra-urban microclimate and subjective whole comfort perception in the outdoors during the hot season. Moreover, different TUPPs typologies subsets are analyzed, considering both objective and subjective comfort. The research question was:

To what extent different typologies of small urban parks, gathered under the newly introduced Tactical Urban Pocket Parks (TUPPs) set of typologies, can be effective in mitigating intra-urban microclimate and subjective whole comfort perception, and are there any differences between the different typologies, considering both objective and subjective

comfort?

Responding to this question, reduced microclimate mitigation effects are demonstrated linked to TUPPs, and mainly related to PPs and POPs. On the other side, subjective perception in the TUPPs is significantly better than on surrounding streets, disregard the low objective mitigation of thermal discomfort, showing a perception gap that could be further addressed.

It is therefore evident how the implications of these findings are relevant for different stakeholders. In fact, the advancement of knowledge about mitigation and adaptation strategies by means of the employment of the innovative experimental method here presented is relevant for researchers in the field of urban mitigation and adaptation strategies, which could use the same method for analyzing micro-granular urban spaces, as well as for further considering the performance gap between objective and subjective comfort conditions. Policymakers and urban administrations could also use these findings for better planning suitable, diffuse and more equitable adaptation and mitigation strategies in increasingly dense, extended and warmer cities, as we presented a variety of suitable TUPPs typologies. Finally, also citizens and active citizenship associations, i.e., civil society, are interested in the results of this work, as tactical urbanism interventions and grass-root initiatives can be carried out to develop bottom-up initiatives aimed at designing effective TUPPs, thus favoring the resilience of neighborhoods to warmer climate.

Credit author statement

F.R.: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Resources, Funding acquisition, Writing - Original draft. B.P.: Methodology, Validation, Formal analysis, Investigation, Writing - Review & editing. A.L.P.: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Writing - Review & editing, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgements

Federica Rosso gratefully acknowledges Ermenegildo Zegna that supported her research thanks to the EZ Founder's Scholarship 2018–2019, 2019–2020 and 2020–2021. The authors thank UNESCO Chair on "Water Resources Management and Culture" at University for Foreigners of Perugia and Honors Centre of Italian Universities (H2CU) at Sapienza Università di Roma for supporting their studies and the international cooperation between NYC institutions and Italian Universities.

Anna Laura Pisello Thanks the European Commission for funding the ERC Grant, HELIOS (G.A. n. 101041255) and the MSCA DN MuSIC (G.A. n. 101073357). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Council Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

Moreover, the three Authors would like to thank their sons for being patient, as during the writing of the paper all the three Authors have been pregnant with Paolo, Ascanio Maria, and Michelangelo. They hope this research will contribute to create a more just, equitable and sustainable urban environment for them and for this and future generations.

Appendix

Google reviews comments for the parks, clustered according to perception domains

Whole comfort.

PPs.

Paley Park: [Not Available in CrossRef][Not Available in Internal Pubmed][Not Available in External Pubmed].

"We spent much longer than expected here, as it was just so relaxing" "Awesome, chill place in crowded city" "Very peaceful" "Such a peaceful, quiet place to step off the busy midtown streets" "Great public space to escape the busyness of the city (…) The waterfall makes the space so peaceful and ideal for taking a break or meeting up" "Sit down on the numerous available seats with tables and take in the serenity from the waterfall (…) It's a private park, but open to the public with security to make you feel safe" "Clean and safe" "A simple slice of serenity amidst the hustle of midtown" "Relaxing waterfall on the middle of the busy Manhattan!" "Pristine, well-kept public space with a waterfall in the middle of NYC. There are small rubbish bins and a water cooler too. What a way to unwind in the city (…)" "Very nice, but I wish it was bigger" "isolation from the city" "very relaxing mini park" "Relaxing and clean … felt like a hidden gem" "The waterfall here offers an escape thats truly uncanny. This place is great if you want some respite from the hustle and bustle of the city" "Oasis in the middle of hectic and noise" "It may be small, it may be surrounded by buildings but somehow this place has everything you want from a public space. Have a seat while moving the furniture as you need, have a rest under the shade" "Chill little hangout spot to catch a break from the city".

Greenacre Park:

"An oasis in the city" "Wonderful to hear the sound of the waterfall in the middle of the city and relax in this corner of nature" "It fills you with relax, in the middle of the city but far from chaos and frantic city life of this big city" "You forget you are in one of the most traffic-intense cities in the world" "Great park! Awesome waterfall!" "offers a zen escape during the weekday lunch-hour rush—and on top of that, it even features its very own 25-foot-high waterfall. Go alone to absorb the quiet" "In a neighborhood short on green spaces, this one delivers tranquility and beauty in a very small space" "Nice quiet place for a quick break" "It is beautiful" "Calm outdoors" "I love running around New York City but sometimes in the middle of all the crazy you need a moment to reset and collect yourself before getting back out into the intense rhythm that can be Midtown Manhattan" "Love that waterfall" "A slice of tranquility" "The tranquility in the heart of Manhattan was soothing and comfortable" "A quiet place to quiet your mind in the middle of a busy world" "It's exactly what I needed on such a busy workday. Wanted to stay all day! Went back to work, feeling 1000*x* better" "super peaceful spot to hang out during work breaks or just on a summer day out" "Really nice park with a waterfall, small quiet park in the neighborhood to sit and relax, read, have lunch or even take a nap. Nice getaway within the city" "Lovely and peaceful little park in the middle of Manhattan" "Cozy little tranquil spot." "This is a beautiful and tranquil place. 5 min will relax you" "A peaceful haven in the middle of Manhattan." "Peaceful place to rest your feet and soul in middle of bustling mid-town." "Beautiful nature area in the city. Small but very peaceful" "Wonderful, incredibly peaceful place. Hard to believe oasis in Manhattan." "I felt like I'd snuck into a secret garden when we stopped in this little hidden gem. Everything about this park tucked away between buildings and under a canopy of trees is absolutely perfection" "A wonderful urban oasis" "Unique place for NYC. You feel no huge city around you. Enjoy the waterfall and peace!" "My backyard! This is the perfect combination of big enough for the locals and quite cozy".

POP:none.

IP:

"Nice little plaza with tables, chairs, planters with lovely flowers and trees in season. Also a ping pong table and BEAUTIFUL COLORFUL MURAL THAT RUNS THE FULL LENGTH OF THE PLAZA." "Beautiful park next to the 9/11 memorial" "Nice little place to rest. There are several chairs and colorful murals surrounding the place".

Visual comfort:

PPs.

Paley Park:

"enjoy (…) watching the waterfall feature" "Nice water falls at the end of park." "It's thoughtfully designed down to the smallest detail and is kept clean and orderly" "Very well maintain park" "Like the sound of water, but in general it's not inviting. Don't like the floor tiles at all." "So serene! Such well kept and clean little rest area loved it alot!" "Beautiful, and clean" "A beautiful oasis right in the middle of a concrete jungle. Serene waterfall, trees and seating nestled in between two tall buildings makes this an almost magical secret garden of wonders" "Very well maintained place" "A tranquil place with beautiful water fall" "It was very nice. Clean not crowded at all and a very calming environment! Glad I went! The waterfall is beautiful!!" "A Great Thinking Space And A Beautiful Sight" "Nice and clean and birds want visit w you" "It's a very serene place to sit and get some peace in the middle of the busy city. The architect has put in beautiful elements that soothes our mind" "Neat little pocket park. Just where it's needed" "Beautiful waterfall fountain" "the attendants are kind and make sure the area stays clean and visitors respect the park" "Needs more lighting but real calm, nice, different Park to eat n sit and talk".

Greenacre Park:

"Beautiful place! Hidden gem. And kudos to the people who keep it so clean and pretty" "The two stage water falls is beautiful" "Beautiful view" "the park is very clean" "A beautiful, tranquil space." "Beautiful green oasis in the concrete jungle" "Very beautiful waterfall" "Beautiful small urban park in Manhattan" "A small good looking space to enjoy the nature" "magnificent waterfall" "nice lush place to relax and take a break from the urban landscape" "Beautifully maintained island of calm in the middle of midtown" "Perfect spot to sit and watch the lovely waterfall" "Amazing view of the waterfall makes everything better" "Buitifull well designed park. Reminds Japanese gardens. The waterfall is magnificent. You will be in disbelief that such kind of garden possible in the middle of city buildings" "A lovely and well appointed outdoor space that is always kept tidy. A welcome oasis in the area!" "Such a hidden gem in Midtown Manhattan!!! It's so peaceful here with all the trees and fall. I love the flowers as well" "breathtaking artificial waterfall" "One of my favorite parks in NY. It's small, but a wonderful oasis that seems much bigger than it is through the wonderful design and landscaping. Has a great waterfall too" "Beautiful park with a waterfall" "It's so peaceful to sit and watch and hear the water fall" "It was such a calming oasis in the middle of a busy city. We must have spent a half hour there just watching the waterfall".

POP: none.

IP:

"Nice little plaza with tables, chairs, planters with lovely flowers and trees in season. Also a ping pong table and beautiful colorful mural that runs the full length of the plaza." "Beautiful park" "Nice little place to rest. There are several chairs and colorful murals surrounding the place".

Acoustic comfort:

PPs.

Paley Park:

"The large wall waterfall here silences the constant NYC street noise" "Chill place to sit down and hear the water fall!" "As soon as you enter, the noise of the waterfall covers the noise of the city, perfect for relaxing (…)" "A beautiful place to escape the city noise" "The waterfall is loud, so it's bad for phone calls, which is actually great! It also really helps block the car noise on 53rd" "The waterfall sounds are soothing during a lunch break from work especially" "water dropping relaxing sounds" "If you do want to talk with someone, do not sit too close to the waterfall" "Nice spot to stop off for a little lunch or just to hear the waterfall drown out some of the background noise" "quiet escape from the city noises" "As soon as you walk in it drowns out the city sounds" "enjoy the sound of water" "relaxing sound" "Get your lunch here and eat it while listening to the sound of a fountain away from all the noise of the city" "The waterfall is a nice way to relax in the middle of a busy city" "The waterfall can be a tad loud but that is relaxing to me, you will know as soon as you get there whether it is something you will like or not" "The waterfall drowns out all the city noises" "just chill on my own with the waterfall in the background" "The crashing water is a tad loud to talk over but still a nice spot." "Nice place to relax and listen to the sound of the water fall." "small park. The infernal noise of the city disappeared. Only water flows" "the sound of the fountain cancels out the street noise" "There's a waterfall towards the back that blocks off the noise of the city, which creates a really nice ambience" "Waterfall sound has a calming effect on you" "Relaxing waterfall sound in the middle of city" "The waterfall blends out the city noise".

Greenacre Park:

"The waterfall is the best part and makes it so that you can barely hear any city noise which is cool." "Very serene place just to sit and listen too the waterfall." "love the sound of the waterfall, very loud and cancels out the city noise - makes you feel close to nature" "The water flow is calming" "Just fantastic when the water fall is running … sunny or cloudy" "The water feature masks the sounds of the city providing a lovely oasis" "Little oasis in the city. The waterfall noise drowns out the sounds of the city (honking, jackhammering, motorcycles)" "It has a huge water feature, so it's a bit loud but honestly, after a while it's just white noise" "**Close your eyes, listen to the roar of the man made waterfall, and it can be easy to escape NYC**" "as soon as you enter the park, the disruptive, chaotic sounds of Manhattan are literally drowned out by the cascading waterfall" "relax with the view and sound of the big and nice artificial waterfall" "enjoy sounds of waterfall in the middle of concrete jungle" "you get lost in the sounds of the waterfall" "As soon as you enter the are the giant waterfall gives you the feeling of being miles away from the bustle of the city" "A lovely little pocket park in midtown. The waterfall is more interesting than the usual "wall of water" and provides soothing background noise to bring a moment of peace in the heart of the city" "It's so peaceful to sit and watch and hear the water fall" "The falling water helps to minimize traffic noise, and bring nature into the city." "You will hear the roar of the waterfall from the sidewalk which is not common in the city) You can close your eyes and forget" ""Nice getaway during work but gets humid and loud because of the waterfall" "Oasis in the city. The white noise of the waterfall covers over any city noise." "The waterfall creates such ambience" "I love the sound of the waterfall" "This is a piece of paradise in the middle of midtown. All city noises are blocked out by the sound of the waterfall. This park has saved me some days due to its zen like atmosphere" "The falling water is soothing, though can be noisy." "This place is a hidden gem in the concrete jungle of Manhattan. Absolutely amazing! Great spot for chilling out to waterfall sounds" "The park design is very zen and the waterfall takes you away from the craziness of the city noise and traffic. I spend lunches here at times and feel rejuvenated" "Waterfall adds to the calm".

POP: none.

IP:none.

Air quality:

PPs.

Paley Park:

"those of us who smoked had one last place where we could relax with a cigar" "It's a tranquil place. But people smoking mess up the atmosphere" "Why can men in groups smoke in such a delightful little oasis here! It is supposed to give us, citi ppl, a refreshment, but now has become another polluted spot" "Pretty and very peaceful, except I was told it's privately owned and smoking is allowed" "It would be an

enjoyable place except for the smokers" "Too many people smoking cigars. At least five people smoking in that little space."

Greenacre Park: none.

POP: none.

IP: none.

Thermal comfort:

PPs.

Paley Park:

"In the hot season the fountain lower temperature" "Beautiful place for relaxing and drinking outdoors, semi-shaded by the direct sun. A tranquil oasis in the middle of the city" "It was awesome. Nice and cool especially in this heat" "It's a great place to sit and chill in the summer" "Was there on a muggy Sunday afternoon and the falls provided a cool respite" "relaxing and refreshing waterfall" "it's a refreshing little stop".

Greenacre Park:

"Refreshing atmosphere" "Drop by for a breath of fresh air at this relaxing spot as you unwind" "Wonderful small park open on warm months only, with tree shade" "Lots of greenery and good shade" "A hidden cool waterfall" "A special oasis right in our immediate neighborhood! Refreshing waterfall with plenty of chairs and tables" "Clean cool calm flowing water falls, surrounded by plants a fresh shrubs" "Cool" "This tiny park with a waterfall is nicely landscaped with plenty of shade, a small overhang that is ideal when it rains" "Nice getaway during work but gets humid and loud because of the waterfall" "Charming little spot with a waterfall. It isn't open in the winter, but when it is warm out, sitting here and reading a book is a wonderfully pleasant way to pass the time".

POP: none.

IP: none.

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