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Assessing public attitudes towards urban green spaces as a heat adaptation strategy: Insights from Germany

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HIGHLIGHTS

- Surveyed 2253 German residents after the 2022 summer of record-breaking heat.
- High perceived availability of neighbourhood green spaces.
- Majority find green spaces accessible, but few use them for heat relief.
- Residents may not recognize the cooling potential of green space during heat events.
- Strong support for more parks and street trees as a heat mitigation strategy.

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ABSTRACT

Urban green spaces are recognized as essential elements of cities. They offer multiple benefits, including mitigating the urban heat island effect and its negative impact on public health. They also present opportunities for people to interact, recreate, and connect with nature. To explore attitudes towards urban green spaces, we surveyed 2253 German adults after the hot summer of 2022 to identify their preferences, frequency of use, and perceived benefits of green spaces. We were particularly interested in their perceptions and views of urban green spaces as an adaptation measure against heat stress. Our findings reveal that most respondents have a green space within a 15-minute walk from their home, with over 80% indicating there is plenty of nearby green space that is easy to access and well-maintained. Health and well-being emerged as primary motivators for visits, with many prioritizing relaxation over physical activity or social interaction. Despite their positive attitudes toward green spaces, fewer than 20% of respondents frequented them on very warm days, suggesting that many residents may not recognize the cooling potential of green spaces during heat events. However, over 70% of respondents supported prioritizing efforts towards establishing more parks and shaded green spaces, and over 80% supported planting more trees along streets as a heat mitigation and adaptation strategy. As climate change intensifies, it is vital for planners, policymakers, and emergency managers to understand and incorporate perceptions about green spaces in the decision-making process, ensuring that they are effectively promoted and utilized as urban heat mitigation measures.

1. Introduction

As climate change continues to reshape our world, cities are already bearing the brunt of more frequent and extreme weather events (Estrada et al., 2017; Hunt & Watkiss, 2011). Heat waves, in particular, are becoming increasingly frequent, hotter, and longer, posing significant threats to society and the environment (IPCC, 2021; Russo et al., 2015; Thompson et al., 2022). This was starkly evident during the 2022 summer heat wave in Europe (Ballester et al., 2023). The summer of 2022 was the continent's hottest on record (Copernicus, 2022), and more than 61,600 people died from heat-related illness during the months of June, July, August and September (Ballester et al., 2023).

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These tragic events underscore the urgent need for societies to confront the realities of a changing climate and implement effective strategies for mitigation and adaptation in their cities. One approach gaining traction is the investment in green spaces (Wong et al., 2021). Examples of greenery projects include the green makeover of the Champs Élysées in Paris and London's movement to become a 'national park city.' Such initiatives not only underscore a commitment to expand urban green spaces but also recognize their role in enhancing city resilience against a myriad of challenges posed by climate change, including extreme heat.

Green spaces as a cooling solution to urban heat. Urban green spaces can be broadly defined as open spaces predominantly covered with vegetation found in the urban environment, ranging from public and private gardens and parks to green walls and green roofs, greenways, and woodlands (Taylor & Hochuli, 2017). Prominent among these are urban public parks, which act as crucial components in mitigating urban heat (Aram et al., 2019; Bowler et al., 2010). Parks serve as cool islands, as their vegetation shades surfaces and absorbs the radiation energy by photosynthesis and transpiration, which leads to a maintained cooler microclimate (Bowler et al., 2010; Du et al., 2017). Furthermore, the cooling effect of an urban park can extend beyond the park's border through air convection and heat exchanges (Aram et al., 2019; Yan et al., 2018).

Previous research has shown that the cooling effect depends strongly on features such as the size, shape, and type of the green space, the amount of tree and grass cover, as well as on the land cover characterizing the immediate environment surrounding the site (Aram et al., 2019; Bowler et al., 2010; Yan et al., 2018; Ziter et al., 2019). Parks (and streets) with trees are also cooler during the day as trees significantly reduce local temperatures through transpiration and by providing shade (Bowler et al., 2010; Shashua-Bar & Hoffman, 2000; Ziter et al., 2019). In this regard, a recent study by Barboza et al. (2021) suggested that doubling the tree cover in European cities could cut the number of heat-related deaths during summer months by nearly 40 %. This assertion emphasizes the pivotal role that trees and green spaces can play in improving public health, especially under the backdrop of intensifying heat waves. Moreover, green spaces are multifunctional and produce wide-ranging social and environmental benefits (Roberts et al., 2022). Beyond cooling, parks provide recreational spaces (Bertram et al., 2017; Fischer et al., 2018), mitigate air and noise pollution (Nowak et al., 2006; Vieira et al., 2018), support biodiversity (Nielsen et al., 2014; Qiu et al., 2013), reduce runoff into storm drains (Feldman et al., 2019; Zölch et al., 2017), and contribute to the mental well-being of urban residents (Bratman et al., 2019; Fong et al., 2018; Larson et al., 2016).

The German context. Germany presents a compelling case for studying urban green spaces and their role in mitigating heat stress. Historically, German cities have consistently prioritized the integration of nature within urban settings. For example, the Eilenriede forest in Hannover, located in the heart of the city and dubbed the city's "green lung," stands as one of Europe's largest urban forests, nearly twice the size of New York's Central Park. This is also evident in transformative projects like the Emscher Landscape Park, which reimagined a former industrial zone into a regional network of urban parks and vast green spaces (Shaw, 2002). Moreover, forward-thinking policies like Berlin's *Biotopflächenfaktor* ("Biotope Area Ratio"), developed in the late 1980s and early 1990s, mandate the inclusion of green spaces in new developments, ensuring that as the cities grow, nature remains intertwined within the urban fabric (Lakes & Kim, 2012).

While Germany has long championed the role of green spaces in its cities, recent research paints a more nuanced picture. Wüstemann et al. (2017) noted that, compared to the investigation of urban green space coverage across European cities by Fuller and Gaston (2009), the *per capita* urban green provision in major German cities is relatively low. Furthermore, they highlighted substantial disparities in green space distribution and accessibility related to income, education, age and household composition. Although Germany's case is far from unique – evidence from Europe, North America, Latin America, China and elsewhere suggests that strong inequalities in green space supply characterize cities and communities across countries and regions (Chen et al., 2022; Rigolon et al., 2018; Schüle et al., 2019; Song et al., 2021) – such findings gain further significance in the broader context of heat adaptation strategies. Germany was among the countries worst affected by extreme heat in 2022, but research on heat risk perception and vulnerability in Germany remains scarce (Beckmann & Hiete, 2020). Moreover, while countries like France (Pascal et al., 2006) and England (Lo et al., 2022) have established heat action plans, Germany is still developing a comprehensive adaptation strategy on climate change and heat health action plans at the national level (Bundesregierung, 2023; Mücke & Litvinovitch, 2020). This backdrop underscores the importance of exploring how German residents use and perceive green spaces, especially during periods of extreme heat. At a time when global calls and initiatives to increase canopy cover in cities are gaining momentum (Barboza et al., 2021; Sousa-Silva et al., 2023), in our paper, we explore the extent to which public perception of green spaces as a heat mitigation solution corresponds to the actual behaviour of the public during heat events. Drawing on survey data from Germany, we seek to address two related and overarching research questions: (1) How do people perceive and use green spaces?; and (2) To what extent do people use green spaces as an adaptive measure against extreme heat events? We further formalize our research inquiry developing hypotheses guided by insights from prior literature (Arnberger et al., 2017, 2021; Barbosa et al., 2007; Giles-Corti et al., 2005; Kabisch et al., 2021; Lafortezza et al., 2009; Lin et al., 2014; Oh et al., 2021; Schindler et al., 2022):

H1a: Individuals who live in closer proximity to green spaces are more likely to visit them.

H1b: Individuals who more frequently visit green spaces will have a stronger orientation to nature.

H2a: Individuals who more frequently visit green spaces during non-extreme heat events are also more likely to visit them during extreme heat events as a heat-coping behaviour.

H2b: Individuals with higher levels of perceived heat impact severity are more likely to utilize green spaces during extreme heat events.

2. Methods

2.1. Survey and data collection

We conducted our study in Germany, a country with an estimated human population of 83 million residents, approximately 18.6 % of the EU-27 total (Eurostat, 2020). In major German cities, nearly the entire population have access to a green space within 500 m around their place of residence, but green space provision differs between major cities (Wüstemann et al., 2017).

Data was collected between November 29 – December 19, 2022 via an online survey conducted by YouGov, an international market and public opinion research company. YouGov recruits participants from an opt-in internet panel comprised of pre-registered panellists. Participants are invited to complete surveys using quota sampling that matches the general adult population or other target population (YouGov, 2023). In total, we surveyed 2253 German residents who were 18 years of age or older and asked them about a range of topics including perceptions and use of urban green spaces, recent experience with extreme weather, and support for government policies. As part of this survey, participants also provided information about their sociodemographic and household characteristics (Table A1 in the Online Appendix). Overall, the survey sample was within ± seven percentage points of German national population statistics for gender, age, and educational attainment measures (Table A1). In this study, we focused on responses to survey questions related to participants' perceptions and use and of green spaces during *normal days* (i.e., on a daily basis) and during *very warm days* in the summer of 2022, as well as support for local government policies related to heat adaptation. The period referred to as "very warm days" was defined in the survey as "days with high air temperatures exceeding

30 °C," in line with the definition provided by Germany's National Meteorological Service, which categorizes a 'hot day' as any day on which the maximum air temperature exceeds 30 degrees Celsius (UBA, 2023). The survey used both a nationally representative sample of 915 adult Germans and an additional sample of 1338 urban residents in five representative cities in Germany, with the sample size of each city generally corresponding with its relative population level: Berlin (n = 515), Munich (n = 257), Hamburg (n = 261), Mannheim (n = 153), and Kiel (n = 152). We selected these five city-cases based on variation in available green space and population size (see Fig. A1 in the Online Appendix). As a proxy for level of urban green space, we used NDVI and percent green area available through data retrieved from Barboza et al. (2021). The survey questionnaire was first written in English, then translated in German, and administered in German to survey participants. Survey question text reproduced in this article are from the English language questionnaire.

2.2. Measures

Perceptions and use of urban green spaces. To ensure that all respondents had a shared understanding of urban green spaces, a definition was provided at the start of the survey, which described green spaces as areas of vegetation in public and private areas, including parks, gardens, lawns, tree alleys, green roofs, and cemeteries. Respondents were asked how often they visited an urban green space, specifying their frequency of use (never, once or several times a year, several times a month, once a week, several times a week, daily). We also asked respondents to rate their reasons for visiting green spaces (convenience of the location; aesthetic appreciation; accessibility, safety, and quality of green space; health and well-being benefits; personal connection to green space), distance travelled and effort required to reach the green space, what activities do they engage in when they visit them, and whether there were barriers preventing them from utilizing green spaces. To understand whether people with access to a private garden use green spaces differently, we also asked respondents if they had access to a backyard in their place of residence. In the second part of the questionnaire, as respondents were prompted to recall their experiences from the past summer, we asked them about visiting green spaces in periods of intense heat: "…during very warm days, how often did you go to a park?" with frequency of use measured on a five-point scale (never, rarely, sometimes, often, always).

Neighbourhood green space. To assess respondents' perception of neighbourhood greenness, we asked them to indicate their level of agreement with a series of statements related to the availability and accessibility of urban green spaces on a four-point scale ranging from 1 (strongly disagree) to 4 (strongly agree). These included: "…the nearest green space is easy for me to access" (mean = 3.41), "…the green spaces are well-maintained" (mean = 2.97), "…there are a lot of green spaces" (mean = 3.14). Internal consistency of the statements was evaluated using Cronbach's alpha (α = 0.77), indicating good internal consistency. For the models, responses were coded as dichotomous items such that 1 refers to agree or strongly agree and 0 disagree or strongly disagree.

Nature relatedness. To measure respondents' levels of connectedness with nature we used the short-form of the nature relatedness scale developed by Nisbet and Zelenski (2013). This validated scale consists of six items (from the original 21 items) representing the "self" (as a sense of identification with nature) and "experience" (as a measure of comfort with and desire to be out in nature) dimensions of a person's connection to nature (Nisbet et al., 2009; Nisbet & Zelenski, 2013). Respondents used a 5-point scale to rate their level of agreement from 1 (strongly disagree) to 5 (strongly agree). Responses to all six statements were averaged to create an overall measure of nature relatedness (mean = 3.21; Cronbach's alpha = 0.83), with higher values representing a stronger connection to nature.

Experience with heat and support for heat adaptation-related policies. The emphasis on heat-related experiences and behaviours was introduced in the second part of the questionnaire when participants were prompted to recall their experiences from the past summer. We asked respondents about their experience with heat "during the past summer" using two indicators. These included: "… how often did you experience uncomfortably warm weather?" (number of days too warm; mean = 4.98) with responses on an eight-point scale from 1 (never) to 8 (for more than a month) and "…how often have you experienced personal discomfort from the heat?" (thermal discomfort; mean = 2.55) with responses on a five-point scale from 1 (never) to 5 (more than once a week). For support of heat adaptation-related policies, we asked respondents to provide their level of agreement ("Do you agree or disagree that your local government should…") with various heat-related policies, situated on a four-point scale from 1 (strongly disagree) to 4 (strongly agree). These included: "… create more parks and shaded green spaces to address the impacts from very warm weather?" (mean = 3.41) and "… plant more trees along streets to address the impacts from very warm weather" (mean = 3.52).

Covariates. The control variables included in this study were the city of residence, gender (male = 46.8 %, female = 53.2 %), age (population 65 years or older = 19.9 %), education level (university education = 34.4 %), and average household income (up to 3,000€ = 49.3 %).

2.3. Statistical analysis

We used linear regression models to investigate the association between the frequency of green space use and seven explanatory variables (gender, age, household income, nature-relatedness score, perceived neighbourhood greenness, distance to green space, and backyard access). We were also interested in how urban green space use may have changed during very warm days. We thus also predicted park visit frequency during very warm days using the following explanatory variables in our modelling: urban green space visit frequency (during normal days) and heat experience (number of days too warm). In the second stage of our analysis, we explored factors that shaped support for heat adaptation-related policies. Using linear regression, we predicted each policy using the same individual and household characteristics as covariates, while also including park visit frequency during very warm days and heat experience (number of days too warm).

Prior to running the models, we tested for correlations between explanatory variables using Spearman's rank correlations. Since green space availability and the nearest green space accessibility were correlated ($r = 0.56$), we tested each of these in separate models. The variables that emerged as significant predictors and had their associated models highly ranked based on delta-AIC values were selected for further analyses. These included 'perceived neighbourhood greenness' for the models predicting urban green space visit frequency and 'perceived neighbourhood urban green space accessibility' for the models predicting each policy. Additionally, we conducted alternative modelling using ordinal logistic regression rather than linear regression to predict these measures. We found no substantive differences compared to the results presented in the main text (Tables A2 and A3 in the Online Appendix). We have opted to present the results from linear regression models in the main text for ease of interpretation. We also tested whether geographical differences influenced the survey results and their interpretation by including each city as a dummy variable in alternative regression modelling. As the inclusion of these city variables were not statistically significant and did not substantively change other model estimates in terms of magnitude or significance (Table A4 in the Online Appendix), we opted to present the results for the combined sample. Differences between groups were assessed using independent samples t-tests. All statistical analyses were conducted using R version 4.3.0.

3. Results

3.1. Perceptions and use of urban green spaces

The results of our survey show that neighbourhood green spaces are easily accessible for a majority of respondents. Over 60 % reported living within a 15-minute walk of the nearest green space. Moreover, over 80 % of respondents also agreed that there is plenty of green space near them, and 90 % found them easy to access (Fig. 1). Additionally, three-quarters of respondents agreed that the green spaces in their neighbourhoods are well-kept.

Among the reasons for visiting green spaces presented to respondents, we found the primary motivation to be the positive outcomes anticipated for health and well-being (Fig. 2). This holds for those respondents who self-reported spending "a lot of time in green spaces" and those who did not. Convenience of the location, beauty, and accessibility, safety, or the quality of the green space were the next most frequent reason for visiting, while personal connection was the least frequent (Fig. 2).

Going for a walk was the main driver for our survey respondents' visits to green spaces, rather than more intense physical activity or social interactions (Fig. 3). Over half reported going for a walk in a green space at least once a week (56 %), with another 28 % doing so at least once a month. Relaxing in green spaces was also a frequent activity, with almost half of the respondents doing this at least once a week and 30 % at least once a month. Differences in activity preference influenced the frequency of green space use. For example, while 17 % of respondents reported walking their dogs in green spaces a more than once a week, over two-thirds reported never doing so, a difference that is likely related to dog-ownership. In comparison, visiting green spaces to meet friends was broadly popular among respondents: only 21 % reported never meeting friends there, and almost half of our sample met friends there at least once a week, though less than 10 % did so as regularly as several times a week.

3.2. Heat-related impacts

Our survey revealed that over 30 % of respondents experienced discomfort from heat at least once a week during the summer of 2022. Yet, the majority (66 %) expressed minor to no concerns about the adverse impacts of warm weather. Reflecting on that summer, when asked about their typical actions during very warm days, 61 % indicated that they chose to stay home and avoid going outside. A closer examination of the responses among those who self-reported experiencing personal discomfort from heat at least once a week revealed that park visitation was less frequent compared to those who felt discomfort less often, with an approximate 10 % point difference (Fig. 4). However, even among those who felt more discomfort, visiting urban parks was still preferred over cooled buildings or the use of air conditioning.

For park visitors during warm days, when asked about their reasons for visitation, these included the park's proximity to their home (77 % agreement), easy access (76 %), and the opportunity to enjoy nature (75 %). Seventy percent also cited the availability of shaded areas as a reason for their visit. More than half of the respondents (52 %) disagreed with the statement that they visited parks because they were cooler than their homes.

3.3. Predictors of green space use on normal and very warm days

To further explore the factors influencing urban green space usage during 'normal days,' we developed a model associating visitation frequency with personal household characteristics, perceived neighbourhood greenness, and nature-relatedness scores (Fig. 5a). In this model, the addition of gender and age did not change the effect size of the model predictors significantly, but higher income and having access to a backyard both increased the likelihood of visiting a green space more often (see Table A5 in the Online Appendix for full regression outputs). Those living farther away from green spaces were more likely to visit, a result that was statistically significant. Agreement with the statement "there is a lot of green spaces in my neighbourhood" was also associated with increased visitations. Furthermore, a higher nature-relatedness score was a predictor of more frequent visits.

As is observed from Fig. 5b, in the model investigating the use of green spaces during 'very warm days,' age became a relevant factor, with older individuals being less likely to visit. Those who travelled farther to reach a green space still visited more frequently. Those with a private garden visited less, possibly reflecting decreased necessity. Regular visitors during normal days continued to visit frequently, even on very warm days. Unlike the results during normal days, the perceived greenness of one's neighbourhood did not significantly impact visitation during very warm days. Similar to the 'normal days' model, a stronger connection to nature (higher nature-relatedness scores) significantly predicted more frequent visits. Additionally, respondents who reported fewer days of experiencing uncomfortably warm weather (number of days too warm) were more likely to visit green spaces.

3.4. Support for heat adaptation-related policies

We explored support for local government policies intended to mitigate the effects of heat using two proposed policies: creating more parks and planting more trees along streets. We found that the majority of respondents favourably viewed both policies. Over 70 % supported the creation of more urban parks and shaded green spaces as a means to mitigate the impacts of very warm weather. Furthermore, support for planting more trees along streets surpassed even that, with over 80 % of the sample either somewhat or strongly agreeing with this policy.

We next investigated models separately for each policy (Fig. 6). These models showed that personal and household characteristics were not predictive of policy support. On the other hand, those who perceived their nearest green space as easily accessible were more likely to report higher policy support, even though this factor was not a significant predictor in the models explaining green space use. Respondents with a higher nature-relatedness score and individuals more impacted by heat were more likely to show support for the two policies. There was also a positive association between frequent park visitation and increased policy support, suggesting that visiting green spaces during very warm days may influence the support for more parks (statistically significant at the $p < 0.05$ level) as a heat-related adaptation strategy. More

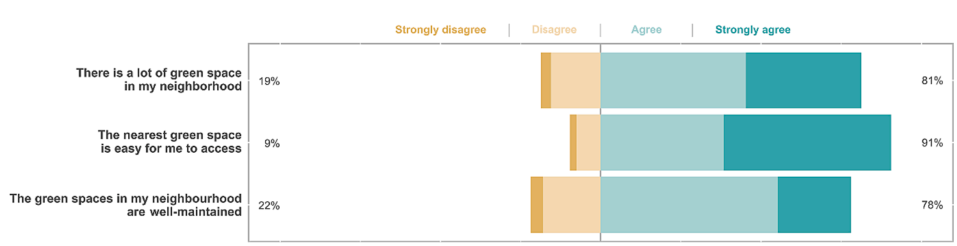

Fig. 1. Distribution of responses to statements about neighbourhood green spaces (n = 2253).

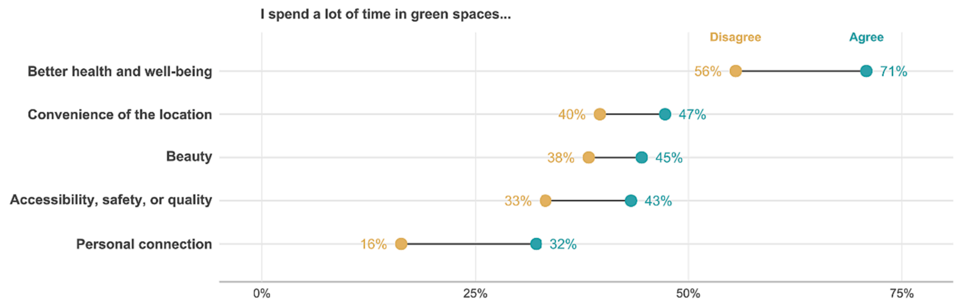

Fig. 2. Reasons for visiting urban green spaces, comparing individuals who agreed with the statement "I spend a lot of time in green spaces" (green; n = 1361) to those who disagreed (brown; n = 892). Each point represents the mean percentage agreement for the stated reason, and the lines show the difference between the two groups. The differences in responses between the groups were statistically significant for all reasons (*t*-test, $p < 0.01$). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

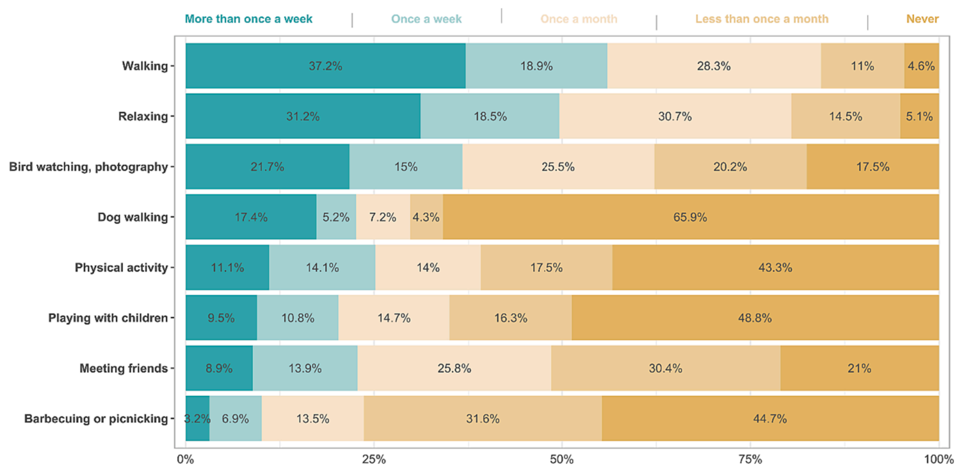

Fig. 3. Comparison of frequency of activities undertaken by our survey respondents visiting green spaces. Each bar represents the percentage of respondents participating in a specific activity, with frequencies ranging from 'more than once a week' to 'never.' Sample includes only those respondents who reported visiting a green space at least once a year (n = 2121). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

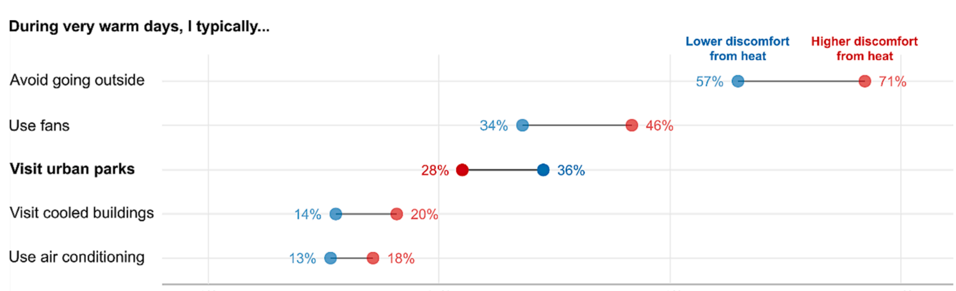

Fig. 4. Attitudes during very warm days. Comparison between individuals who reported experiencing personal discomfort from heat at least once a week (red; n = 661) and those who did not (blue; n = 1592). Each point represents the mean percentage agreement for the stated reason, and the lines show the difference between the two groups. The differences in responses between the groups were statistically significant for all statements (t-test, $p < 0.01$).

frequent park visitation was not associated with the policy of more street trees (not statistically significant at the $p < 0.05$ level).

4. Discussion

In this study, we examined how German residents relate to their urban green spaces and whether they utilize these areas to mitigate the impacts of extreme heat. Our findings reveal that a majority of respondents view these spaces as accessible, abundant, and well-maintained areas that provide opportunities for relaxation and improved well-being. These perceptions appear to influence when, why, and how people use them. However, while parks and green spaces are highly valued and frequently visited, this regular usage does not necessarily translate into their utilization as an adaptation strategy during extreme heat events.

4.1. *Use of green spaces during 'normal days' versus 'very warm days'*

In reflecting upon the accessibility of green spaces, as we hypothesized in **1a**, previous studies have shown that people are more likely to use green spaces if they are easily accessible and within walking distance from their residences (Barbosa et al., 2007; Konijnendijk, 2023;

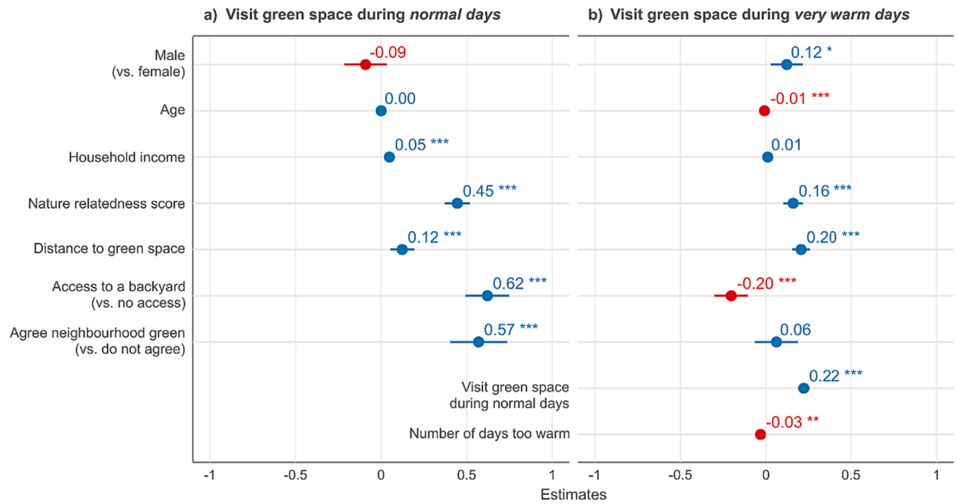

Fig. 5. Linear regressions predicting frequency of use of urban green spaces during normal days (**a**) and very warm days (**b**). Solid dots represent the effect sizes and bars represent 95% confidence intervals. Asterisks denote statistical significance (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$) and the p-values are provided at the top of each graph. See Table A5 in the Online Appendix for full regression outputs.

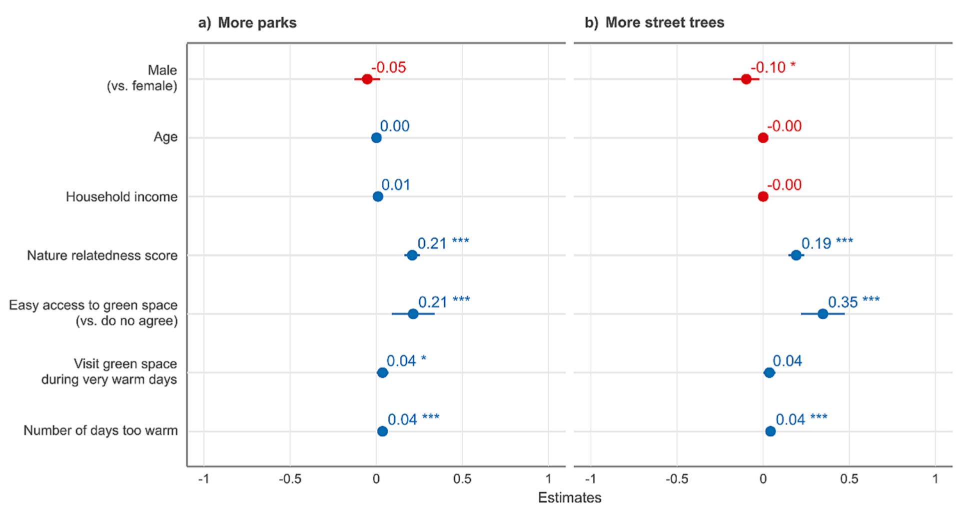

Fig. 6. Linear regressions predicting support for heat-related adaptation policies: creating more parks (**a**) and planting more trees along streets (**b**). Solid dots represent the effect sizes and bars represent 95% confidence intervals. Asterisks denote statistical significance (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$) and the p-values are provided at the top of each graph. See Table A6 in the Online Appendix for full regression outputs.

Wüstemann et al., 2017). Across Europe, national recommendations for urban green provision vary. In Germany, the target has been set for every household to have access to urban green within "walking distance," though this term is not clearly defined. In our study, 77.1 % of survey respondents said they live within a 15-minute walk of a green space. This figure closely aligns with the World Health Organization recommendation for urban green accessibility and the European Environment Agency recommendation that people should have access to urban green within a 15 min walking distance (300 m straight-line distance, approx. 500 m path distance, around 10–15 min by foot) (Grunewald et al., 2017; WHO, 2017). These findings align with those of Wüstemann et al. (2017), who estimated that 93 % of German households have access to green spaces within 500 m and 74.1 % within 300 m of their home. In the context of the city of Berlin, Kabisch et al. (2016), using municipal land-use data, found that 58.7 % of the city's population lives within a 300 m distance of a green space and 81.9 % within 500 m, while Grunewald et al. (2017) reported that 61.4 % of Berlin's residents have access to urban green spaces within a 300 m distance. From our own survey, 72.8 % of respondents living in Berlin (n = 515) indicated they reside within a 15-minute walk of green spaces. This positive proximity is further echoed in a high perception of green space availability in their neighbourhoods, which, though high at 76 %, is still below the average for the whole sample at 81 % (data now shown).

Interestingly, our models showed that respondents willing to travel longer distances tend to visit green spaces more frequently, which is inconsistent with our first hypothesis. This suggests that proximity might not be the sole determinant in their choice of green spaces. It could be hypothesized that these respondents may have specific preferences or needs that are met by certain parks or green areas, even if they are farther away. They might also have established routines or habits that revolve around particular spaces, leading to more intentional visits. This observation aligns with the findings of Schindler et al. (2022), who found that people often travelled considerable distances, well beyond the typical accessibility metrics (green cover in buffers ranging from 300 to 500 m), to reach their most frequented urban green spaces. While our data showed that a personal connection to a specific space was the least reported reason for visitation (Fig. 2) – with factors like convenience of the location, accessibility, safety, and quality of the green space ranking higher – it is plausible that visits that require more travel may still be driven by other factors not captured in our survey.

More expectedly, and in line with our **hypothesis 1b**, we found that individuals with a stronger orientation to nature visited urban green spaces more frequently than those less connected to nature. Our model results underscored this, with higher nature-relatedness scores of participants consistently predicting more frequent visits. This also aligns with findings from studies such as by Lin et al. (2014), which emphasized that a psychological orientation toward nature is more important than the actual physical proximity.

While the overwhelming appreciation for and regular use of green spaces is evident, it does not necessarily translate into increased visitation during periods of extreme heat. We hypothesized in **hypothesis 2a** that individuals who frequently visit green spaces on typical days, being more attuned to their benefits, would also be more likely to seek refuge in these spaces during extreme heat. This assumption was confirmed by our findings. However, we found that it was the individuals less impacted by heat who opted to visit urban parks more, thus refuting our **hypothesis 2b**. Our data also indicated that individuals with access to backyards were more likely to visit public green spaces on normal days but were less inclined to do so during very warm days. These observations highlight a potential disconnect between the general perception of green spaces as a heat adaptation solution and the actual user behaviour during heat waves. Among those who opted to go outside, the main motivators to go to a green space were proximity, accessibility, and the opportunity to connect with nature. Notably, more respondents preferred visiting a green space over opting for cooled indoor spaces like museums or movie theatres.

As summers become hotter and heat waves become more frequent and intense (IPCC, 2021; Russo et al., 2015), adaptation strategies to limit the health impacts of extreme heat become paramount. Prior studies have highlighted the risk of high temperatures and heat waves for public health, including heat-related illness and mortality (Campbell et al., 2018; Gu et al., 2016; Kovats & Kristie, 2006; Watts et al., 2021). Heat-related illness is a set of preventable conditions ranging from mild forms to more severe types, including heat exhaustion and heat stroke. Particularly vulnerable groups include the very young or elderly, those with disabilities or pre-existing medical conditions, those with a low socioeconomic status, those who have to work outdoors, those who are socially isolated, and those who do not have access to air conditioning (Campbell et al., 2018; Gu et al., 2016; Kovats & Kristie, 2006; Watts et al., 2021). Moreover, in the German context recent scholarship has demonstrated that higher levels of reported negative heat impacts occurred more frequently for vulnerable groups and those residing in areas experiencing a higher frequency of high-temperature days (Zanocco & Sousa-Silva, 2023). Because personal heat exposure depends upon an individual's location, planting trees and laying out green spaces can reduce the heat stress to which an individual is exposed in a city and, by doing so, mitigate at least some of the health impacts of such extreme temperature events.

Green space is increasingly recognized as an effective – and one of the most popular – approaches to mitigate the health impacts of extreme heat (Barboza et al., 2021; Gaffin et al., 2012; Wong et al., 2021). This is corroborated by studies showing a decrease in heat-related mortality risks as the level of vegetation increases (Laaidi et al., 2012; Madrigano et al., 2015), which has prompted further research emphasizing the health benefits of increasing tree coverage to cool the urban environment (Barboza et al., 2021; Iungman et al., 2023). In general, green spaces, particularly with a high number of trees, cool the urban environment through shade provision (blocking incoming radiation from the sun so less heat is absorbed) and evapotranspiration (where trees release water vapour into the atmosphere through their leaves, providing evaporative cooling and reducing the amount of sensible heat in the environment), thus reducing human heat stress during summer days. Combining shading and evapotranspiration, these spaces (such as urban parks) have been predicted to reduce peak surface temperature by 2–9 °C (Wong et al., 2021). However, our findings indicate that although urban green spaces are widely accessible to most survey residents, they are not the primary refuge for coping with heat. This underscores a potential gap between the availability of these spaces and the public's awareness or inclination to use them for relief from the heat. Previous studies also pointed out this, stressing that increases in tree coverage should be combined with other interventions to produce more significant temperature reductions, thereby having greater beneficial effects on health. For instance, Pascal et al. (2021) suggested that adaptations to reduce heat-related health impacts should focus on limiting exposure to heat, reducing individual vulnerability to heat, and implementing targeted measures to limit the health outcome after exposure. Of note, in line with these previous findings, authorities often advise people to stay indoors during the hottest hours of the day, discourage outdoor activities, or, if at all possible, seek refuge in a public place with air conditioning, especially vulnerable groups such as the elderly (Koppe et al., 2004; Sampson et al., 2013; Zuo et al., 2015). Such recommendations may inadvertently dissuade individuals from visiting parks even outside the peak heat hours. Addressing the general population and vulnerable groups with well-targeted recommendations, including encouraging going to a shaded park earlier or later in the day when conditions are less extreme, could result in increased understanding and use of green spaces as a cooling behaviour, which in turn could, to some extent, alleviate symptoms of thermal discomfort during heat waves (Lafortezza et al., 2009; Sampson et al., 2013).

4.2. *Implications for policy and practice*

Our findings underscore strong public support for urban greening policies as a heat adaptation strategy. Over 70 % of our survey respondents endorsed the creation of more urban parks and shaded green spaces, and more than 80 % were in favour of planting more trees along streets. This widespread support remained consistent across personal and household characteristics, suggesting a broad-based recognition of the value of green spaces in urban environments. While the German public is overwhelmingly supportive of greening to combat the effects of heat, current policy does not reflect this sentiment. For example, Germany is in the process of developing their first nationwide 'heat health action plan,' yet urban greening policies have not been featured prominently in it. The challenge, however, lies not only in providing (more of) these spaces but in ensuring residents are aware of their cooling benefits during heat waves. In this regard, we emphasize the distinction between heat adaptation strategies at federal, state and local levels – such as the creation of more green spaces within regional and urban planning – and the use of these spaces, which we view as an individual-level choice. As our findings demonstrated, even when green spaces are accessible, many German residents do not always view them as cooler alternatives. This highlights the importance of communication strategies – in Germany, as elsewhere – that convey both the heat-related health risks and the key role green spaces can play in thermal comfort and reducing heat stress (Mücke & Litvinovitch, 2020; Sampson et al., 2013; Sanchez Martinez et al., 2019). It also underscores the need for a more comprehensive approach to the planning and management of urban green spaces in the context of urban climate resilience, such as how to increase human thermal comfort and reduce the negative impacts of heat waves. To address this, revamping existing parks with features like installing water stations and misting systems or adding more trees can substantially enhance cooling and further enhance their appeal during heat waves (Livesley et al., 2021; Wong et al., 2021).

Moreover, the design of urban green spaces can be strategically altered by landscape designers and planners to create larger cooling areas to ameliorate heat stress (for a critical review, see (Graça et al., 2022). For example, trees with large, dense canopies are the most effective for improving thermal comfort in the summer due to the canopy shading (and evapotranspiration) (Kong et al., 2017). Yet, the cooling effect of evaporation only works when the trees receive enough water, so city managers and landscape professionals also need to consider management issues such as irrigation water supply (Cheung et al., 2022). Irrigation may help urban trees to retain their leaves during heat waves thus enhancing their shade and evapotranspiration cooling effects. Besides variables such as optimal types, amounts and distribution of vegetation that affect the ability of trees and other natural elements to alter microclimates (Bowler et al., 2010; Morakinyo et al., 2020; Rahman et al., 2020), urban green spaces may also include built elements that affect their cooling effect. For example, shading structures intercept solar radiation, reducing surface and air temperatures, while pavements made of light-coloured, permeable materials with low thermal resistance and high porosity can reduce surface temperature and modify the local microclimate (Shooshtarian et al., 2018).

The observations from our research further suggest that individuals who frequent parks during warmer days are more inclined to support the creation of additional green spaces, and those severely affected by the heat demonstrate even stronger advocacy for such initiatives. Knowing that the development and management of green spaces are often underfunded in comparison to needs (Smith et al., 2023; Vogt et al., 2015), we wish to emphasize the opportunity to harness this support not only for the establishment of more green spaces but also for maintaining and enhancing existing spaces. As cities worldwide grapple with the escalating impacts of hotter summers, tapping into the cooling potential of urban green spaces – and optimizing their use by the public – could serve as an effective, sustainable, and widely supported heat adaptation strategy. Building on our findings, we encourage more research on the interplay between public perceptions of green spaces as a heat mitigation solution, their actual usage during periods of heat stress, and public support of urban greening policies, which has been absent or insufficiently in most studies to date. Our study addresses this gap and provides insights with broader implications beyond the German context. Public support for green space-related policies means that it is more likely to be salient in current public discussions and will likely continue to have salience over longer time horizons (Drews & van den Bergh, 2016). This persistent public attention is a crucial step for developing new green spaces in neighbourhoods where there is little and for safeguarding the quality and continuity of maintenance of green spaces.

4.3. Study limitations and further research

While our study provides valuable insights, there are limitations to consider. First, our purposive sampling approach means the results might not fully represent the German population, possibly overlooking certain demographics or regional nuances. Second, the reliance on self-reported data can introduce biases related to recall errors and subjective interpretations (Althubaiti, 2016). Given our survey was administered between November and December, there is a risk of recall bias, with participants potentially have less accurate recollections of the frequency of visits or their discomfort levels during peak summer heat. Moreover, the particularly hot summer preceding our survey could have influenced the results. Though we deliberately timed the survey post-summer to minimize recency bias (Weber, 2010), questions targeting self-reported experiences might have been affected by potential challenges in recalling precise summer occurrences. Recall bias occurs when differences in the accuracy or completeness of the memories retrieved ('recalled') by survey participants regarding events or experiences from the past influence their responses to survey questions (Althubaiti, 2016). Memory biases can be bi-directional: one can underestimate or overestimate positive or negative past experiences, likely due to underlying mechanisms such as motivational and contextual variables (Colombo et al., 2020; Zhao & Luo, 2021). Therefore, the associated memory might have been remembered less intensely (i.e., underestimation) or more intensely (i.e., overestimation). If we had surveyed Germans during the heat waves, we might have received different responses, most likely greater in effect than what we report here. Another constraint relates to the method of collecting information about green space availability and accessibility. We relied on participants' self-reports rather than objective measurements of distances to the nearest green spaces. This means that the perceived accessibility might not correspond with actual distances. Additionally, as we did not have data on indoor and green space outdoor temperatures, we could not form a direct link between objective temperature measurements and personal experiences. Future research could benefit from combining qualitative and quantitative approaches to examine the relationship between exposure, vulnerability, adaptive capacity, and behaviour. Detailed spatial analyses and longitudinal studies could also offer insights into these dynamics over time.

4.4. Conclusions

Green spaces play a crucial role in Germany's urban areas, serving both recreational needs and mitigating the impacts of increasing temperatures. Our findings highlight the public's recognition of their importance. Yet, awareness concerning their cooling benefits during heat events remains a challenge. As the impacts of climate change intensify, there is an increasing need to understand and address urban residents' perceptions and behaviours related to green spaces, ensuring they are promoted as an effective mitigation strategy for urban heat. Such understanding can shape strategies to address heat-health risks, steering urban planning towards further development and improvements of green spaces that build capacities for adapting to climate change.

CRediT authorship contribution statement

Rita Sousa-Silva: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Chad Zanocco:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.landurbplan.2024.105013.

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