

1 **Review article: Re-viewing Berlin’s Urban Parks from the Perspectives of Socio-Economic**
2 **Inequality, Climate Resilience, and Sustainable Management**

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19
20 **Short summary**

21 *Berlin’s parks are vital for recreation, biodiversity, and climate resilience, yet they face growing*
22 *challenges from socio-economic inequalities and climate change. Our review examines how factors like*
23 *gentrification and extreme weather impact access to and sustainability of these parks. By analysing*
24 *over 200 studies, we highlight the need for inclusive policies, community engagement, and climate-*
25 *adaptive park designs to ensure that Berlin’s parks remain accessible, resilient, and socially just.*

26
27 **Abstract:**

28 Berlin, renowned for its rich history and vibrant cultural tapestry, possesses an extensive network of
29 urban parks that function as vital lungs for the city, providing recreation, ecological services, and respite
30 from urban life. Yet, these green spaces confront mounting pressures from shifting socio-economic
31 dynamics and escalating climate-related impacts. This review investigates the intricate interplay
32 between socio-economic conditions and climate change in shaping the resilience, accessibility, and
33 sustainability of Berlin’s parks. Drawing on more than 200 research articles, reports, and policy papers,
34 it synthesises insights on park management, biodiversity, governance, and socio-economic disparities,
35 with particular attention to their intersectionality. The findings highlight that socio-economic
36 inequalities strongly influence patterns of access, quality, and affordability of green spaces, exposing
37 disadvantaged communities to uneven benefits and environmental burdens. Processes of gentrification,
38 often intensified by the appeal of green neighbourhoods, exacerbate displacement and exclusion,
39 underscoring the need to integrate social justice into green space planning. Simultaneously, climate
40 change introduces new threats, including rising temperatures, extreme weather events, and biodiversity
41 loss, which compound urban vulnerabilities. Case studies from Berlin illustrate innovative strategies—
42 ranging from community-driven initiatives to climate-resilient park design—that demonstrate pathways
43 towards inclusive, adaptive, and sustainable management of urban parks in the face of complex socio-
44 environmental challenges.

45
46 **Keywords:** *Urban Green Spaces, Climate Resilience, Biodiversity, Environmental Justice, Community*
47 *Engagement*

50 **1. Introduction:**

51 Urban parks and greens are crucial elements of city life, contributing significantly to live-ability,
52 environmental quality, and residents' well-being (Panagopoulos et al., 2016; Parker and Simpson, 2018).
53 In Berlin, a city with dynamic urban development, these green spaces characterize cityscape and hold
54 large importance (Lachmund, 2013; Kronenberg et al., 2020). This study investigates how climate
55 change and climate extreme events impact *urban parks* in Berlin, considering varying socio-economic
56 conditions, and, thus, aims to foster sustainable urban ecosystems. The review paper explores how
57 socio-economic factors, climate change highlighting extreme weather impact Berlin's urban parks,
58 emphasizing the growing challenges posed by more frequent and intense climate-driven events. The
59 primary objective is to comprehensively understand the intricate socio-environmental dynamics at play
60 within urban parks, more specifically, which are public spaces, as opposed to other types of greenery
61 such as private gardens or roadside trees. These other types of greenery will also be considered when
62 discussing general bio-physical and social interactions. This in-depth analysis, based on a systematic
63 review of literature either as peer-reviewed journal articles or government documents, endeavors not
64 merely to mitigate impacts, but to elucidate the complex interplay of ecological, social, and economic
65 factors. Through this nuanced understanding, we seek to develop informed recommendations that will
66 foster the creation and maintenance of sustainable urban ecosystems.

67 Berlin, known for its history, culture, and urban life, has a strong connection to greenery (Brantz and
68 Dümpelmann, 2011). Understanding Berlin's urban parks, thus, requires a historical perspective
69 (Angelo, 2021). In contemporary Berlin, urban parks serve purposes beyond just aesthetics and leisure
70 (Li, 2023). Ongoing urbanization demands a re-evaluation of their role (Lehmann, 2012). For example,
71 the transformation of Tempelhofer Feld from an airport into a community park and then (partly) a
72 refugee-shelter exemplifies this shift (Owens, 2018).

73 Re-viewing sustainability for Berlin's urban parks from an intersecting society-ecosystem-policy
74 perspective is a response to evolving climate and society. It emphasizes the interplay between ecological
75 integrity, social equity, and economic viability within Berlin's green spaces (Ricci, 2022; Kotsila et al.,
76 2023). This re-viewed sustainability encompasses unique ecosystem services (Fontaine, 2013),
77 emphasizes inclusivity (Anguelovski et al., 2020), acknowledges economic benefits (Edwards, 2005),
78 addresses climate resilience (Abbass et al., 2022), and calls for flexible and adaptive governance models
79 (Renn and Klinke, 2013; Green et al., 2016). Despite challenges, such as in its traffic policies, Berlin's
80 aspirations for sustainability and efforts to balance environmental responsibility, social equity, and
81 economic goals offer valuable insights for advancing global green city initiatives (Alibašić, 2018; Ricci,
82 2022).

83 The concept of urban sustainability revolves around the capacity of cities to maintain or enhance the
84 well-being of current and future urban residents while minimizing environmental impacts
85 (Spiliotopoulou and Roseland, 2020; Sheikh and van Ameijde, 2022). This concept of
86 multidimensionality serves as a central theme within the context of intersectionality, which is the
87 primary focus of our paper. Intersectionality recognizes that individuals and communities possess
88 multiple intersecting identities based on factors such as race, gender, class, age, and sexuality, which
89 shape their experiences and access to resources (Davis, 2014; Lindley et al., 2021). Applying
90 intersectionality to urban sustainability means acknowledging that sustainability challenges and
91 benefits are not evenly distributed among all urban residents (Castán Broto and Neves Alves, 2018;
92 Anguelovski et al., 2020). By critically assessing the literature, it becomes evident that this framework
93 is essential for understanding the complexities of urban sustainability in a diverse city like Berlin.

94 The aim of this review is to examine how socio-economic conditions and climate-related extreme events
95 shape the resilience and sustainable management of Berlin's urban parks. Specifically, it seeks to answer
96 the following research question: ***What scientific recommendations exist for maintaining and
97 developing Berlin's urban parks in ways that safeguard their social functions and enhance their
98 resilience to climate extremes, while accounting for the interlinkages between ecological, social, and
99 economic dimensions?*** Additionally, the review investigates whether these recommendations are
100 reflected in the City of Berlin's current strategies and planning frameworks.

101 The review begins with a description of the methodology, detailing the systematic review process; it
102 then presents an analysis of how socio-economic factors and climate change affect the ecological,
103 social, and economic roles of urban parks. To ground these analyses in a concrete setting, Berlin is
104 examined as a detailed case study. The city's historically layered and socially diverse park system—

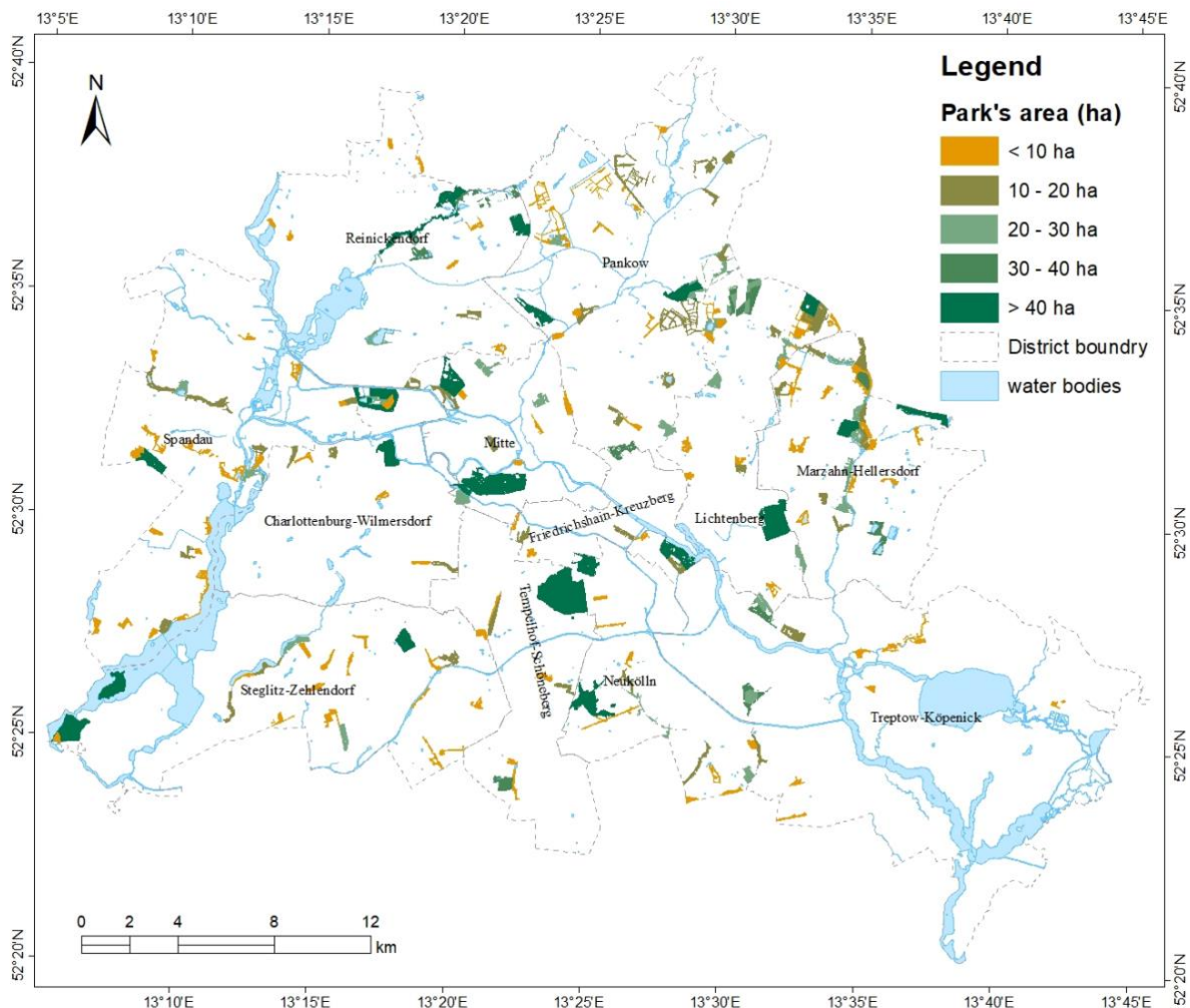
105 ranging from iconic spaces such as Tiergarten and Volkspark Friedrichshain to more recent
 106 transformations like Tempelhofer Feld and Mauerpark—offers valuable insights into resilience,
 107 inequality, and sustainable management. Finally, the discussion synthesizes these findings to propose
 108 recommendations for enhancing the sustainability and resilience of Berlin's green spaces in response to
 109 present and future challenges.

110 **2. Study area: Berlin**

111 Berlin, Germany's capital, presents a detailed case study for the development of its extensive urban
 112 green network amidst a rapidly growing population (Figure 1). Spanning a city area of more than 89,000
 113 hectares, Berlin's population is projected to grow significantly, with forecasts predicting approximately
 114 4 million residents by 2040; this growth trend is expected to continue (Statistical Office Berlin-
 115 Brandenburg, 2024). Additionally, Berlin hosts a substantial immigrant community, with over half a
 116 million residents contributing to the city's demographic composition (Amt für Statistik Berlin-
 117 Brandenburg, 2024).

118 Despite the notable population growth, Berlin maintains a substantial portion of its area as green spaces.
 119 Over 30% of the city is covered by green spaces, including public parks, forests, private gardens,
 120 allotment gardens, cemeteries, recreational areas, sports grounds, and street greenery (Kabisch and
 121 Hasse, 2014). Specifically, public green spaces **excluding the forest areas** around 5246 hectares of the
 122 city, which is part of the total area designated as green (Kabisch and Hasse, 2014). However, while
 123 residential areas have seen an 18% increase over the past decade, the expansion of green spaces has not
 124 kept pace, highlighting the need for innovative integration of green spaces within the growing city (Amt
 125 für Statistik Berlin-Brandenburg, 2024).

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128 Figure 1. Map depicting the study area: Berlin city and its parks categorized by area, including water
 129 bodies such as the River Spree (adopted from FIS Broker, <https://fbinter.stadt-berlin.de/fb/index.jsp>).

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The evolution of Berlin's urban green spaces is deeply intertwined with the city's historical narrative, reflecting its cultural, political, and social transformations. In the 19th century, landscape architects such as Peter Joseph Lenné played a pivotal role in converting royal estates into public parks like Tiergarten and Volkspark Friedrichshain. This transformation marked a shift towards recognizing the importance of greenery in urban life, making these spaces accessible for public leisure and recreation (Brantz and Dümpelmann, 2011; Wolschke-Bulmahn and Clark, 2021). In the 20th century, Berlin's parks became arenas of political significance, mirroring Berlin's turbulent socio-political landscape. Iconic spaces such as Tempelhofer Feld and Mauerpark today symbolize the city's division during the Cold War and its later reunification, illustrating the complex role of green spaces in reflecting and shaping societal changes (Angelo, 2021). Representative views of Berlin's historic urban parks, such as Volkspark Wilmersdorf and Rudolph-Wilde-Park, demonstrate how these landscapes combine heritage, ecological functionality, and everyday recreation within the city's green network (Figure 2).



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Figure 2. Volkspark Wilmersdorf and Rudolph-Wilde-Park as a representative historic urban park in Berlin: Developed in the early 20th century and later extended to form a continuous green corridor, Volkspark Wilmersdorf and Rudolph-Wilde-Park exemplifies Berlin's tradition of multifunctional park

150 design. Its expansive lawns, tree-lined avenues, and integrated play and sports areas support recreation,
151 biodiversity, and climate regulation, illustrating the city's longstanding commitment to accessible and
152 ecologically valuable public green spaces. (Photo courtesy: Kei Namba)

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154 Concurrently, Berlin's urban parks are integral to the city's ecological, social, and economic fabric. They
155 contribute to biodiversity, mitigate the impacts of climate change, and serve as vital cultural and social
156 hubs, enhancing the well-being of its residents (Gandy, 2014; Kowarik, 2023). Economically, these
157 green spaces boost property values, attract tourism, and stimulate local economies, though this growth
158 can lead to challenges such as gentrification, which necessitates a careful balance between economic
159 development and social equity (Collins et al., 2022; Vargas-Hernández et al., 2023). Additionally, parks,
160 in general, have been crucial for public health, offering essential spaces for relaxation and physical
161 activity, particularly during the COVID-19 pandemic, underscoring their role in mental health and
162 community resilience (Collins et al., 2022).

163 However, Berlin's green spaces face significant challenges in ensuring ecological sustainability, social
164 inclusivity, and economic balance. The city's efforts to adapt to climate change, ensure equitable access
165 for all residents and manage economic disparities are critical to the future of these spaces (Stoetzer,
166 2018 and 2022; Amorim-Maia et al., 2023). The repurposing of former industrial sites, such as the
167 transformation of Görlitzer Bahnhof into Görlitzer Park (Figure 3) in the late 1980ies or Berlin-
168 Tempelhof Airport into a vast urban park in the 2010s, exemplify the city's ongoing innovative approach
169 to integrate green spaces into its urban landscape (Draus et al., 2021). These efforts highlight Berlin's
170 commitment to use its green network as a tool to navigate the complex challenges posed by socio-
171 economic shifts and climate change (Kabisch and Hasse, 2014; Lachmund, 2013).

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Figure 3. Görlitzer Park: Located in Kreuzberg, representing the social complexity of Berlin’s green transformation—balancing everyday recreation, community informality, and contested governance. (Photo courtesy: Subham Mukherjee)

179 **3. Review approach:**

180 This review employs a systematic approach to identify, analyse, and synthesize relevant academic
181 literature on urban parks in Berlin. The focus is on understanding the intersectionality between Berlin's
182 evolving socio-economic conditions, climate change impacts, and the role of urban parks in fostering
183 sustainability. By adhering to established systematic review protocols, the methodology involves a
184 thorough, predefined search strategy, selection criteria, and critical evaluation process. This ensures a
185 robust and unbiased examination of literature that spans socio-environmental studies, historical
186 overviews, and case-specific investigations relevant to Berlin’s urban parks.

187 The following key components are included:

188 **Socio-environmental Studies:** To understand the contemporary significance of urban parks in Berlin,
189 an analysis of existing research on socio-environmental studies have been conducted. These studies
190 involve the collection of academic literatures related to the ecological impact of these green spaces,
191 their cultural and social relevance, economic implications, and their role in enhancing residents' well-
192 being.

193 **Case-specific Investigations:** Further, case-specific literature survey on selected urban parks in Berlin
194 is included, that offer detailed insights into how those urban parks in Berlin have been shaped by the
195 city's history and continue to evolve in response to contemporary challenges. We investigated the
196 transformations and adaptations of these spaces through localized data collection and analysis.

197 Applying a systematic analytical approach includes a including a representative sample of research
198 articles were that address the intersectionality between Berlin's changing socio-economic conditions,
199 climate change impacts, and their influence on urban parks, with a focus on achieving sustainability.

200 An exhaustive keyword search was conducted across academic databases to across academic databases
201 to identify relevant articles, utilizing platforms such as PubMed, Scopus, Web of Science, and Google
202 Scholar. The following keywords and combinations were used:

- 203 - Berlin
- 204 - Urban parks
- 205 - Greenspaces
- 206 - Socio-economic conditions
- 207 - Climate change
- 208 - Sustainability

209 To be included in the review, academic papers had to meet the following criteria:

- 210 1) **Relevance:** Papers had to directly address the intersectionality of socio-economic conditions,
211 climate change impacts, and urban parks and greens, in general, and urban parks, in particular,
212 within the context of Berlin.
- 213 2) **Publication Type:** Only peer-reviewed journal articles and conference papers published in
214 English were considered.
- 215 3) **Publication Date:** A comprehensive literature review was conducted to encompass the
216 historical and contemporary understanding of urban green spaces and extreme weather
217 events. Scholarly articles and reports were included from across the entire available publication
218 spectrum, except for those specifically listed in the Appendix, till May 2024. This inclusive
219 approach ensures the analysis considers the full range of relevant research, providing a robust
220 foundation for understanding these critical issues.

221 Papers were excluded from consideration if they fell into any of the following categories:

- 222 1) **Non-English Language:** Papers published in languages other than English were generally
223 excluded due to limited translation resources. However, the study did include websites, reports,
224 and articles in German, as well as other non-academic materials from both governmental and
225 non-governmental organizations (after verification), to provide relevant examples. References
226 to these non-academic articles and reports are typically provided in the footnotes.
- 227 2) **Irrelevance:** Papers that did not directly address the intersectionality of socio-economic
228 conditions, climate change impacts, and urban parks and greens, in general, in Berlin were
229 excluded.
- 230 3) **Publication Type:** Books, theses, reports, and non-peer-reviewed articles were excluded to
231 maintain the academic rigor of the selection.

232 The initial search yielded a total of 634 academic papers. These papers underwent screening based on
233 title and abstract to exclude those not meeting the inclusion criteria. Following this screening, 308
234 papers remained for full-text review. Each of these papers underwent a critical assessment to evaluate
235 its relevance to the research topic.

236 After the full-text review, a final selection of around 200 academic publications was made based on
237 their direct relevance to the intersecting subject areas of Berlin's changing socio-economic conditions,
238 impacts of climate change, and urban parks within the context of sustainability. These selected papers
239 formed the foundation for the analysis and synthesis presented in this review article.

240 The final selection of papers covered a wide range of topics, methodologies, and findings, facilitating a
241 comprehensive and multifaceted exploration of the research area. Incorporating these papers ensures
242 that the review offers a well-rounded and informed perspective on the subject matter, integrating various
243 research approaches and insights to inform the discussion and conclusions of the article.

244 By amalgamating background analysis, socio-environmental studies, and case-specific investigations,
245 this review approach enables a comprehensive exploration of the complex relationships between
246 Berlin's urban parks, socio-economic conditions, and climate change. Moreover, it provides a robust

247 empirical foundation for the subsequent sections of this article, which delve into the multifaceted
248 challenges and opportunities faced by these green spaces in Berlin.

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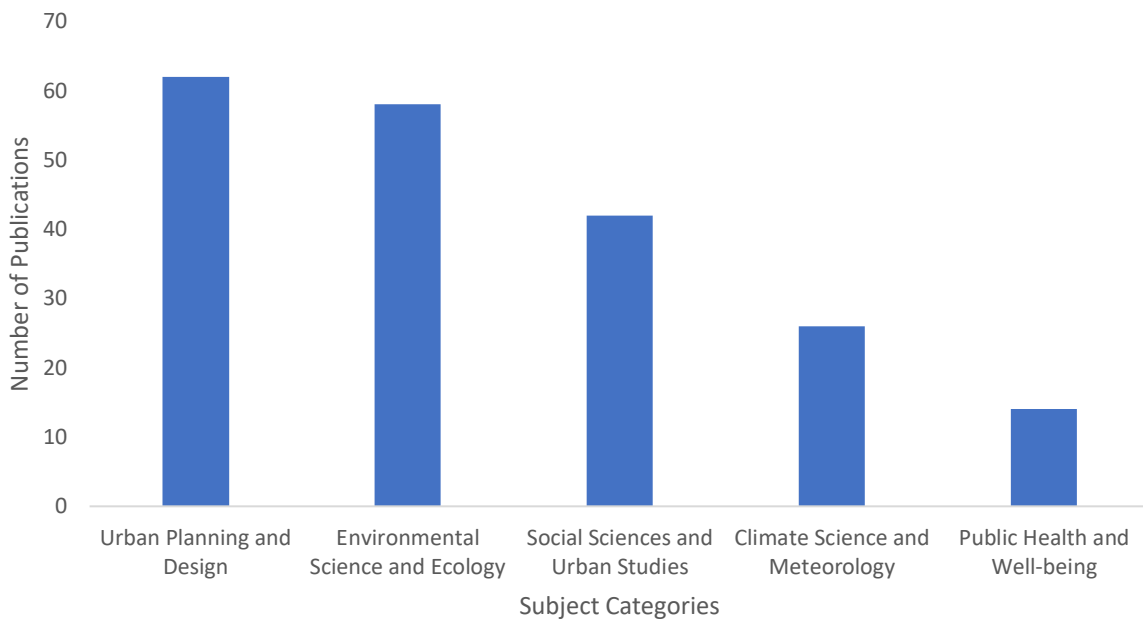
250 4. Synthesizing key Insights from Reviewed Literature

251 The extensive literature search on Berlin’s parks as sustainability infrastructure in the face of climate
252 change yielded a diverse array of academic papers. These papers (more than 200, altogether listed in
253 the *Reference* section) span multiple disciplines, time periods, and geographical focuses, offering a
254 comprehensive understanding of how urban green spaces in Berlin contribute to the city's resilience and
255 sustainability. This section provides a critical analysis of the selected papers, categorized by discipline,
256 year of publication, and focal study area, to contextualize their relevance within the broader discourse
257 on urban sustainability and climate adaptation.

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259 A. Disciplinary Breakdown

260 The selected papers can be assigned to five primary disciplines (Figure 4): Urban Planning and Design,
261 Environmental Science and Ecology, Social Sciences and Urban Studies, Climate Science and
262 Meteorology, and Public Health and Well-being.



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Figure 4. Disciplinary breakdown of the selected papers in the literature review.

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266 a) **Urban Planning and Design:** This category comprises about 30.7% of the selected papers. The
267 focus here is on the planning, design, and implementation of green spaces in urban settings,
268 specifically how these spaces function as critical infrastructure within the urban fabric of Berlin.
269 Key contributions from this discipline include discussions on the integration of green spaces into
270 urban planning frameworks, the challenges of densification, and the role of parks in enhancing
271 urban liveability (e.g., Lachmund, 2013).

272 b) **Environmental Science and Ecology:** Approximately 28.7% of the publications reviewed fall
273 under this category. These studies primarily explore the ecological functions of urban green spaces,
274 including biodiversity conservation, ecosystem services, and the role of green infrastructure in
275 mitigating urban heat islands and managing stormwater. Berlin's parks are frequently examined as
276 case studies for understanding urban biodiversity and the ecological benefits of green spaces in
277 densely populated areas (e.g., Kowarik, 2023).

278 c) **Social Sciences and Urban Studies:** This category accounts for roughly 20.8% of the papers. The
279 focus is on the socio-cultural implications of urban green spaces, such as their role in fostering
280 social inclusion, mitigating gentrification, and promoting community well-being. The intersection
281 of urban green space development with issues of social equity and justice is a recurring theme,

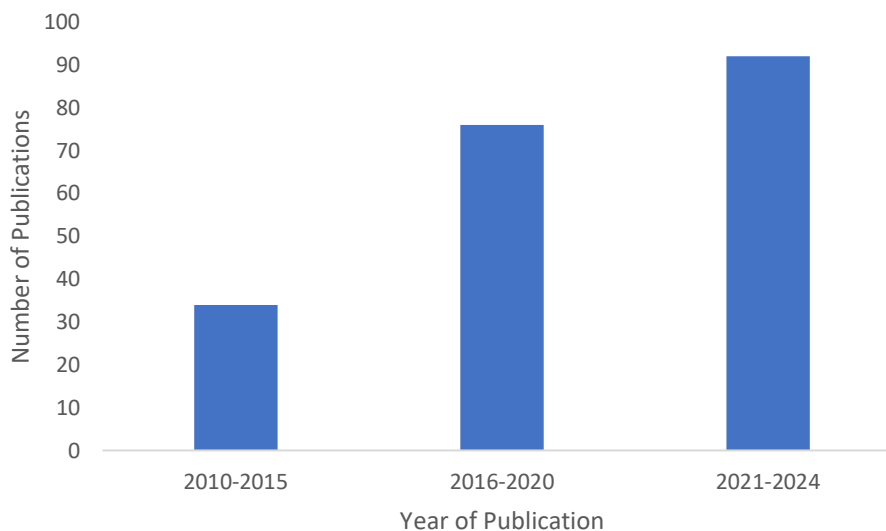
282 particularly in studies examining the impacts of green gentrification in Berlin (e.g., Anguelovski et
283 al., 2020).

284 d) **Climate Science and Meteorology:** Around 12.9% of the selected papers are from these
285 disciplines. These studies are crucial in understanding the direct and indirect impacts of climate
286 change on urban areas, with a specific focus on Berlin. Topics include the increasing frequency and
287 intensity of extreme weather events, such as heatwaves and heavy rainfall, and the role of green
288 spaces in mitigating these effects. The papers highlight how Berlin's green infrastructure can help
289 the city adapt to changing climatic conditions (e.g., Fenner et al., 2019).

290 e) **Public Health and Well-being:** The remaining 6.9% of the papers focus on the health-related
291 benefits of urban green spaces. These studies examine how access to parks and green areas
292 contribute to physical and mental health, especially in the context of urban environments. In Berlin,
293 the relationship between green space availability and public health outcomes is a key area of
294 investigation, with several studies linking park accessibility to improved well-being during periods
295 of extreme heat and other climate-related stressors (e.g., Kabisch et al., 2021).

296 B. Year of Publication

297 The papers reviewed span over a decade, with an increase in publications over the last five years (Figure
298 5). This temporal distribution reflects the growing importance of urban green spaces in climate
299 adaptation strategies and the rising academic interest in Berlin's response to climate change.



300 Figure 5. Temporal distribution of the reviewed papers where the bars show the total number of
301 publications during the time-interval mentioned.
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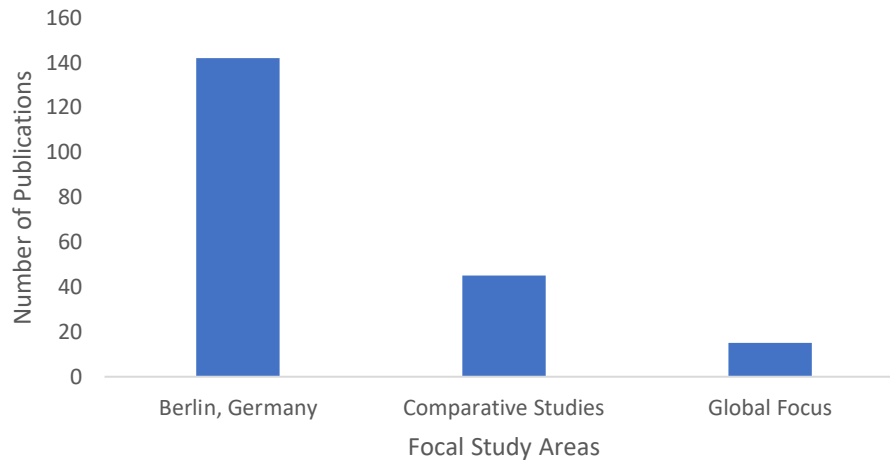
304 a) **2010-2015:** During this period, about 16.8% of the reviewed papers were published. These early
305 studies primarily laid the groundwork for understanding the role of green spaces in urban planning
306 and environmental management in Berlin. Topics included initial explorations into green
307 infrastructure and its potential to enhance urban resilience (e.g., Wolch et al., 2014).

308 b) **2016-2020:** This period saw a significant increase in publications on the city's urban greens,
309 accounting for 37.6% of the publications, considered for review in this study. The focus shifted
310 towards the integration of green spaces into broader urban sustainability frameworks and addressing
311 the socio-political challenges associated with urban green space development, such as gentrification
312 and social equity (e.g., Bernt, 2016).

313 c) **2021-2024:** The most recent period accounts for 45.5% of the publications reviewed, reflecting the
314 heightened urgency in addressing climate change impacts on urban areas. The studies from this
315 period are particularly relevant to the current discourse on climate adaptation, exploring how
316 Berlin's parks are leveraged as key infrastructure to mitigate the impacts of extreme weather events,
317 such as heatwaves and heavy rainfall (e.g., Baganz and Baganz, 2023).

318 C. Focal Study Area

319 The focal study area of the selected papers primarily centres on Berlin, Germany, with some studies
 320 including comparative analyses with other global cities (Figure 6). Berlin is a unique case study due to
 321 its historical, political, and social context, making it an ideal subject for examining the intersection of
 322 urban green spaces and sustainability.



323 Figure 6. Geographical focus of the selected papers.

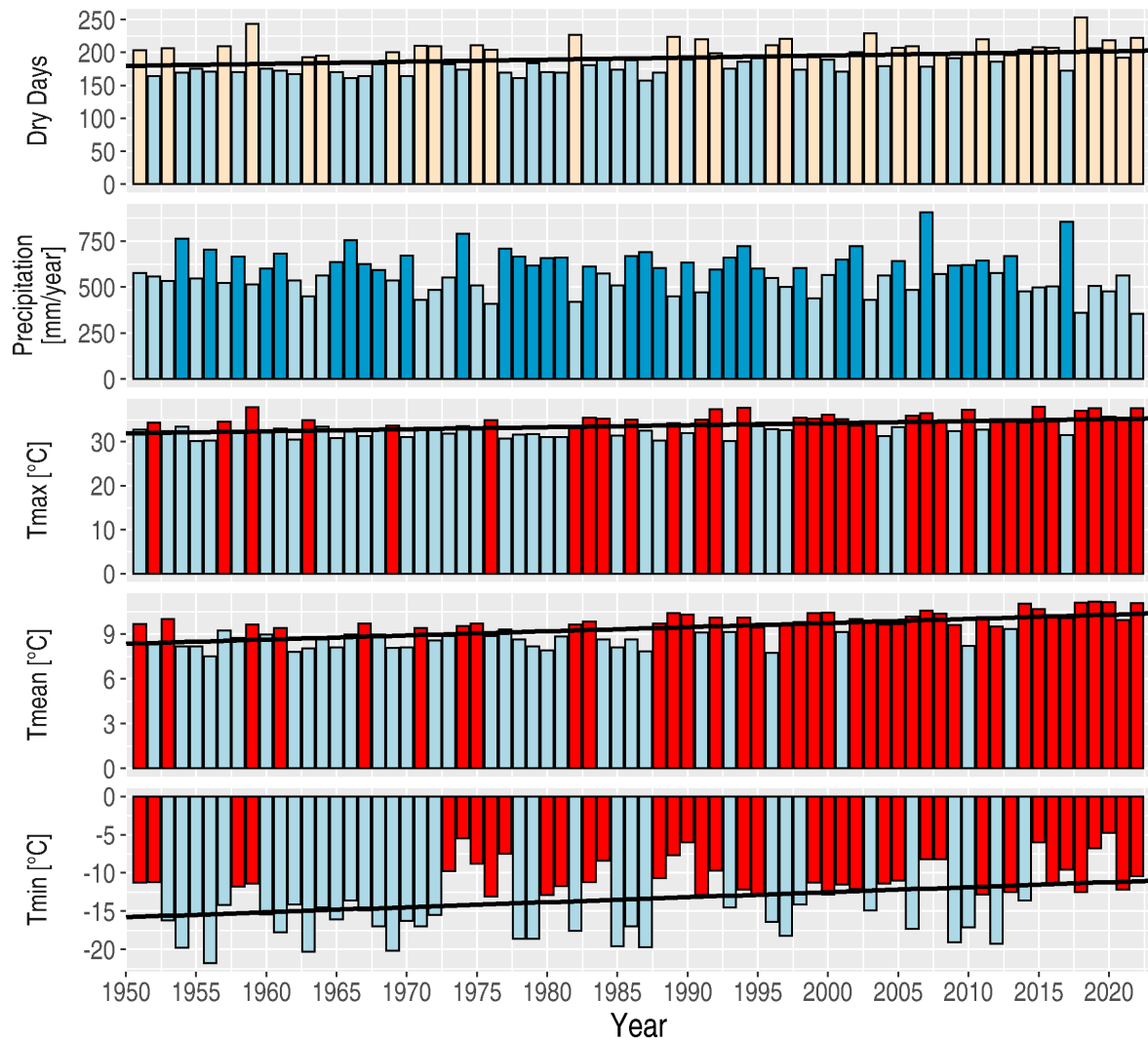
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- 326 a) **Berlin, Germany:** Approximately 70.3% of the papers included in the review focus exclusively on
 327 Berlin. These studies explore a wide range of topics, from the ecological functions of parks to their
 328 role in social cohesion and climate adaptation. The emphasis on Berlin highlights the city's
 329 innovative approaches to urban green space management and its challenges in balancing
 330 development with environmental sustainability (e.g., Breuste and Breuste, 2022).
- 331 b) **Comparative Studies:** About 22.3% of the papers include Berlin as part of a comparative study
 332 with other cities, such as Leipzig, London, and New York. These studies provide valuable insights
 333 into how Berlin's green space strategies compare with those of other cities, offering lessons in good
 334 practices and highlighting areas where Berlin's approach can be improved (e.g., Ali et al., 2020).
- 335 c) **Global Focus:** 7.4% of the papers included in the review have a broad, global focus, but still
 336 reference Berlin as a case study within a wider context. These studies often discuss global trends in
 337 urban sustainability and climate resilience, positioning Berlin within the global discourse on how
 338 cities can adapt to and mitigate the effects of climate change (e.g., Gill et al., 2007).

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340 5. Climate Change and Urban Parks: Impacts on Berlin's Biophysical Systems

341 Urban parks in Berlin, like their counterparts around the world, face a growing threat from climate
 342 change (Fryd et al., 2012; Jansson, 2013; Shade et al., 2020; Angelo, 2021). In Berlin a statistically
 343 significant temperature increase can be observed since 1950; the linear trend implies a rise of the annual
 344 mean temperature of 2.1°C (0.028 K/yr; adj. R²:0.39) as well as of the annual minimum (4.8°C; trend:
 345 0.07 K/yr; adj. R²: 0.11) and maximum temperature (3.4°C; trend:0.046K/yr; adj. R²: 0.21) (Figure 7).
 346 The data stems from a weather station located in the Botanical Garden within the green district of
 347 Dahlem. A comparison to the Berlin-Brandenburg area-mean time series (DWD, 2025) suggest that the
 348 temperature trend in Figure 7 can be attributed to climate change and does not reflect the effects of
 349 increasing urbanization. While annual mean precipitation does not show any statistically significant
 350 trends, the number of dry days has increased (23.4 d, trend:0.316 d/yr; adj. R²: 0.09), indicating a shift
 351 towards lesser but extremer rainfall events. This shift is predicted to increase with rising greenhouse
 352 gas concentrations (e.g., Nissen et al. 2017). The following subsections examine the impact of climate
 353 change on urban parks in Berlin exploring the implications of rising temperatures and extreme weather
 354 events.



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 356 Figure 7: Climate Trends in Berlin (1950-2023): Precipitation and Temperature Variations with
 357 Statistical Significance. From top to bottom: The number of days without precipitation per year
 358 (beige/blue more/less than the long-term mean), Annual precipitation (light/dark blue less/more than
 359 the long-term mean), absolute temperature maximum of the year (blue/red lower/higher than the long-
 360 term mean), average temperature of the year (blue/red lower/higher than the long-term mean), and
 361 absolute temperature minimum of the year (blue/red lower/higher than the long-term mean). The long-
 362 term mean is based on the period 1950-2023. Black lines denote statistically significant linear trends
 363 (5% level) (Data source: the weather station Berlin-Dahlem, Germany).

364 *5.1. Rising Temperatures: Urban Heat Islands effects*

365 Rising annual temperatures are a global phenomenon driven by climate change, and Berlin reflects this
 366 broader trend (Abbass et al., 2022; Sander and Weißermel, 2023). At the same time, the urban heat
 367 island (UHI) effect, which occurs independently of climate change, significantly elevates local
 368 temperatures and aggravates the perceived impacts of warming. UHI arises from urban structures such
 369 as concrete, asphalt, and dense building forms that absorb and radiate heat, making cities—including
 370 their parks and green spaces—warmer than surrounding rural areas (Marando et al., 2022). While
 371 climate change amplifies this effect, UHI would persist even in the absence of global warming, as it is
 372 inherently linked to urban morphology and density (Tsoka et al., 2020; Marando et al., 2022; Irfeey et
 373 al., 2023). The interaction of these drivers means that urban parks in Berlin are increasingly exposed to
 374 heightened heat stress during summer months, with consequences for both ecological functioning and
 375 human well-being (Kabisch et al., 2021; Xu et al., 2022).
 376 Climate Analytics (2024) conducted a study on heat stress and adaptation measures in Berlin and
 377 Brandenburg, commissioned by the Climate Change Centre Berlin Brandenburg. Their project report

378 highlights the critical role of green spaces and sustainable urban planning in mitigating the combined
379 impacts of climate change and urban heat, with a particular emphasis on reducing exposure to heat
380 stress in densely built-up environments (Climate Analytics, 2024). Using the example of Greifswalder
381 Strasse in Berlin, the authors analysed a range of development scenarios to evaluate resilience options
382 for addressing heat stress. The study concludes that the most effective strategy involves a combination
383 of reduced ground surface sealing and the establishment of large, contiguous biotope networks with tree
384 cover, which together can substantially lower urban heat loads and strengthen ecological connectivity.

385 386 5.2. *Current State and Significance:*

387 **Implications for Park Functionality:** Thermal stress in Berlin during hot spells is lower in parks and
388 other green spaces compared to built-up areas, making them important cooling refuges (Langer et al.,
389 2020). However, while excessive heat primarily discourages people from leaving their homes, those
390 who do venture outside may still experience discomfort in parks, particularly if shade and water access
391 are limited (Kabisch et al., 2021; Lo et al., 2022; Xu et al., 2022). For vulnerable populations, such as
392 the elderly and young children, prolonged exposure to high temperatures—even in green spaces—can
393 pose health risks (Kabisch et al., 2021). This underscores the need for urban parks to be designed with
394 climate resilience in mind, ensuring they remain accessible, comfortable, and inclusive spaces for
395 recreation and well-being (Reyes-Riveros et al., 2021).

396 **Ecological Consequences:** Rising temperatures, both from climate change and the urban heat island
397 effect, have significant ecological implications for Berlin's urban parks and green spaces (Kraemer and
398 Kabisch, 2022; Kowarik, 2023). Some plant species may struggle to adapt to the warmer conditions,
399 leading to shifts in biodiversity, where certain species thrive while others dwindle (Lehmann, 2021).
400 However, such shifts are not inherently negative; urban biodiversity has historically been dynamic,
401 particularly in cities where alien species have contributed to increased species richness, a unique feature
402 of urban ecosystems (Kowarik and Ranger, 1994; Kowarik, 2019, 2023). Wildlife inhabiting the urban
403 spaces also faces challenges due to rising temperatures as changes in temperature can disrupt seasonal
404 behaviors, affecting breeding, migration, and feeding patterns of birds, insects, and mammals (Hsiung
405 et al., 2018; Kubelka et al., 2022). These disruptions may contribute to further shifts in biodiversity
406 (Koleček et al., 2020), but as with plants, urban wildlife has shown resilience, with new and non-native
407 species sometimes enriching the ecological fabric of cities (Kowarik, 2023; Stoetzer, 2022).

408 409 5.3. *Extreme Weather Events:*

410 Climate change brings a heightened risk of extreme weather events, including droughts, heavy rainfall,
411 storms, and flooding (Hettiarachchi et al., 2018, Caldas-Alvarez et al. 2022). Berlin's urban parks (and
412 greens, in general) are not exempt from these impacts (Fenner et al., 2019; Eckstein et al., 2021).

413 **Flooding:** Intense rainfall events can lead to pluvial flooding in urban parks, causing damage to
414 infrastructure (Alexander et al., 2019), eroding soil (Hazelton and Murphy, 2021), and potentially
415 affecting plant life (Czaja et al., 2020; Zipperer et al., 2020). Parks situated in low-lying areas are
416 particularly susceptible (Mehtab and Kamal, 2023). Flooding not only disrupts park activities but also
417 necessitates costly repairs and can pose safety hazards to visitors (Southon and van der Merwe, 2018).

418 **Damage to Park Infrastructure due to Natural Hazards:** According to the IPCC (2012), a hazard is
419 defined as the potential occurrence of a natural or human-induced physical event that may cause loss of
420 life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods,
421 service provision, and environmental resources. In the context of urban parks, the specific hazard is
422 damage from extreme weather events, such as storms (Miller, 2020). Trees, pathways, recreational
423 facilities, and infrastructure within parks are particularly vulnerable to such damage. This vulnerability
424 can lead to temporary closures of parks, necessitate costly rehabilitation efforts, and pose safety risks
425 (Yildirim et al., 2021). The functional capacity of these spaces and the services they provide to the
426 community can be severely disrupted by storm-related damage (Karaye et al., 2019; Miller, 2020).

427 428 5.4. *Biodiversity Loss:*

429 Biodiversity is a fundamental component of urban park ecosystems, contributing to their resilience and
430 sustainability (Gonçalves et al., 2021; Lehmann, 2021). It includes the variety of plant species, the
431 presence of wildlife, and the intricate web of ecological relationships that develop in these green spaces
432 (Aerts et al., 2018; Heydari et al., 2020). In Berlin, biodiversity loss emerges from the combined

433 pressures of urbanisation and climate extremes. Habitat fragmentation, pollution, and the spread of
434 invasive species are intensified by weather-related events such as heatwaves, droughts, and flash floods
435 that overwhelm insufficient infrastructure like sewage systems. These processes interact to degrade
436 habitats, reduce species populations, and disrupt ecological balance, further accelerating biodiversity
437 decline (Lehmann, 2021). While biodiversity loss is driven by multiple causes, its significance in the
438 climate crisis is amplified because reduced biodiversity diminishes urban parks' ability to mitigate and
439 recover from extreme events (Heydari et al., 2020). Therefore, addressing biodiversity loss requires
440 recognising the compounded role of both urban development and climate-driven stressors to understand
441 the broader impacts on biophysical systems in urban parks.

442 **Species Migration:** Climate change influences the distribution of plant and animal species (Mashwani,
443 2020). As temperatures rise, some species may need to migrate to more suitable habitats, both within
444 and outside the city (Keeffe and Han, 2019). In the context of Berlin's urban parks, this migration can
445 disrupt established ecological relationships (Stoetzer, 2018; Kowarik, 2023). The composition of
446 species in these green spaces may shift, impacting the balance and dynamics of these ecosystems
447 (Breuste et al., 2020; Baganz and Baganz, 2023).

448 **Vulnerability of Native Species:** Native plant and animal species within urban parks may face
449 increased competition from invasive species that are better adapted to warmer or more disturbed
450 conditions (Alizadeh and Hitchmough, 2019). This competition for resources and habitat can lead to
451 shifts in species composition and a potential decline in the richness of native flora and fauna (Storch et
452 al., 2022). The loss of native species can have cascading effects on the overall functioning of the urban
453 park ecosystem (Carboni et al., 2021; Park and Razafindratsima, 2019). Ecosystem services are a vital
454 aspect of urban park functionality (Mexia et al., 2018). These services encompass a range of benefits
455 provided by ecosystems, including urban parks, that contribute to the well-being and quality of life of
456 the city's residents (Pukowiec-Kurda, 2022).

457 **Pollination:** Urban parks play a crucial role in supporting pollinators, such as bees and butterflies
458 (Ayers and Rehan, 2021; Dylewski et al., 2019). These insects are essential for the pollination of plants,
459 including many food crops (Requier et al., 2023). Climate change can disrupt the timing and availability
460 of flowering plants, impacting pollinators' foraging patterns (Bhatnagar et al., 2019; Gérard et al.,
461 2020). This disruption can ultimately affect the pollination of food crops within and beyond the city,
462 potentially leading to reduced agricultural yields and increased food prices (Marshman et al., 2019;
463 Requier et al., 2023).

464 **Pest Control:** Ecosystem services provided by urban parks include natural pest control (Qiu, 2019;
465 Sikorski et al., 2021). Predatory insects and birds that inhabit these green spaces help regulate pest
466 populations in nearby agricultural areas (Rocha and Fellowes, 2020). Climate change can alter the
467 distribution and behaviour of these species, potentially leading to increased pest problems in both urban
468 and rural environments (Qiu, 2019; Skendžić et al., 2021).

469

470 *5.5. Other Effects of Climate Change on Ecosystem:*

471 **Air Quality and Water Regulation:** Urban parks contribute to air and water purification by absorbing
472 pollutants and filtering water. They act as green lungs in the city, helping to improve air quality and
473 maintain water quality. Studies show that green spaces significantly reduce air pollution through
474 deposition on leaf surfaces and improve water management by promoting infiltration and reducing
475 surface runoff (Vieira et al., 2018). In Berlin, however, the effectiveness of these services is shaped
476 more by local urban conditions than by long-term climatic trends. Elevated ozone levels, for instance,
477 are largely linked to transportation emissions and the urban heat island (UHI) effect, which intensifies
478 pollutant concentrations during warm periods (Xing and Brimblecombe, 2019). Climate change can
479 exacerbate these stresses by prolonging heatwaves, but it is not the primary cause. Likewise, while
480 Figure 5 does not indicate a significant long-term reduction in precipitation, localised heavy rainfall
481 events combined with extensive surface sealing can overwhelm park infrastructure, affecting infiltration
482 and water purification capacity (Kuhleemann et al., 2020).

483 **Climate Regulation:** Urban parks play a role in local climate regulation by providing shade, reducing
484 heat, and mitigating the urban heat island effect (Langer et al. 2020). However, climate change can
485 challenge the parks' capacities to provide these services effectively. Increased heatwaves can test the
486 parks' ability to offer cooling and relief to visitors, especially to vulnerable population groups. Without

487 proper adaptation measures, urban parks may become less effective in mitigating extreme temperatures,
488 leading to heat-related health issues (Gabriel and Endlicher, 2011; Scherer et al. 2013).

489 **Overall Ecological Stability:** The ecosystem services provided by urban parks contribute to the overall
490 ecological stability of the city. They support biodiversity, enhance resilience to environmental changes,
491 and foster a healthier urban environment. Parks in Berlin have been shown to host a variety of plant and
492 animal species, contributing to urban biodiversity (Palliwoda et al., 2017). However, climate change-
493 induced disruptions to these services can undermine the ecological stability of these green spaces,
494 affecting both wildlife and human residents. Changes in temperature and precipitation patterns can alter
495 the habitat conditions within parks, making them less suitable for certain species and reducing the
496 overall biodiversity (Battisti et al., 2019).

497

498 **6. Green Spaces, Governance, and Socio-economic Dynamics in Urban Park Management in** 499 **Berlin**

500 The interplay between urban green spaces and park management provides a foundational understanding
501 of how Berlin's urban infrastructure and planning strategies intersect with broader socio-economic
502 dynamics. By contextualising these dimensions, this section establishes the relevance of green
503 infrastructure policies and initiatives as critical enablers of equitable access and social inclusivity in the
504 governance of urban nature. This approach bridges the gap between governance frameworks and socio-
505 economic disparities, offering a comprehensive lens through which to examine Berlin's green
506 infrastructure, with particular emphasis on public parks as the most multifunctional and socially
507 significant spaces. The concept of urban green space covers multiple dimensions ranging from parks,
508 community gardens, allotment colonies, cemeteries, and urban forests to buildings with green roofs and
509 facades. Accordingly, policies must be analysed at different levels of governance (EU, federal, state,
510 municipal) that influence the development and management of local green spaces in Berlin. At the
511 global level, the Berlin Senate adopted the Berlin Urban Nature Pact in September 2024, an international
512 initiative that aims to mobilise cities around the world to protect and restore nature in urban areas.¹

513 Urban green spaces could also offer effective nature-based solutions for sustainable urban drainage
514 systems (SUD) in reducing stormwater flows and combined sewer overflows (CSOs) for urban water
515 management in Berlin (Wild et al. 2024). Implementing the Sponge City Concept especially in urban
516 areas and using rainwater from private roofs to water public green spaces are also promoted in
517 Germany's National Water Strategy (2023).² At the municipal level, Berlin has introduced various
518 policy incentives to promote water-sensitive or climate proof infrastructure. For example, the city's
519 strategy to reduce flood risk is through decentralized rainwater harvesting.³ Berliner
520 Regenwasseragentur (Berlin's Rainwater Agency), an initiative of Berliner Wasser Betriebe (BWB) and
521 of Senatsverwaltung für Mobilität, Verkehr, Klimaschutz und Umwelt (SenUVK) promotes
522 decentralized rainwater harvesting projects by installing green rooftops on buildings, unsealed parking
523 places for storm water management etc. Berlin also provides incentives for those who use rainwater for
524 private houses and gardens (Wild et al. 2024)⁴. Berlin's vision to develop climate friendly urban green
525 spaces are reflected in StEP Klima (2011) and the StEP Klima KONKRET (2016), a strategic spatial
526 concept followed by the city's Urban Development Plan Climate 2.0, StEP Klima 2.0 (2022).

527 Berlin's urban landscape strategy (*Strategie Stadtlandschaft*), adopted by the Senate in 2011, focuses
528 on the development and enhancement of the city's diverse green spaces. The focus of the strategy is on
529 climate change and resource-efficient cities, demographic change and cultural diversity. The strategy
530 supported programs such as urban tree campaign and the mixed forest program.⁵

531 In 2020, the Berlin's Senate established the Charter for Berlin's Urban Green "Charta für das Berliner
532 Stadtgrün" in order to ensure that urban development is also green development and adapted the action

¹ <https://www.berlin.de/rbmskzl/aktuelles/pressemitteilungen/2024/pressemitteilung.1481549.php>

² <https://www.bmu.de/download/nationale-wasserstrategie-2023>

³ <https://www.bwb.de/de/schwammstadt-berlin.php>

⁴ <https://regenwasseragentur.berlin/massnahmen/regenwasser-sammeln-und-nutzen/>

⁵ <https://www.berlin.de/sen/uvk/natur-und-gruen/landschaftsplanung/strategie-stadtlandschaft/>

533 program for Berlin's Urban Green 2030 "Handlungsprogramm für das Berliner Stadtgrün 2030" with
534 concrete projects, measures and instruments.⁶⁷

535 Although Berlin's legal and strategic frameworks—such as the Public Parks Law (1997), the Charter
536 for Urban Green (2020), and the Urban Green 2030 Programme—apply to the city's entire green
537 infrastructure, parks remain their principal focus. These policies highlight the dual challenge of
538 safeguarding ecological functions and ensuring equitable access, underscoring the centrality of parks in
539 shaping Berlin's green future.

540 **Landschaftsprogramm:** The landscape program, including the species protection program (LaPro), is
541 a strategic, city-wide planning instrument for integrative environmental precautions. It pursues the goal
542 of integrating ecological concerns into urban development at a city-wide level.⁸ Moreover, the Berlin's
543 administration has been engaged with the issues of environmental justice in its districts since 2008, not
544 only due to population growth in the city but also because of growing concerns for climate related
545 challenges (SenStadt and SenMVKU, 2023).

546 Furthermore, the initiative called "Volksentscheid Baum" has drafted the "BäumePlus-Gesetz" (Trees
547 Plus Act) for Berlin, which is intended to enshrine measures to make Berlin "weather-proof and heat-
548 proof" by 2035. According to the drafted law, Berliners would be allowed to plant trees and shrubs
549 themselves on streets.⁹

550 There are diverse forms of how urban spaces are managed. For example, GrünBerlin is a state-owned
551 public enterprise that implements Berlin's political guidelines, and which are accompanied by
552 corresponding public supervisory bodies (Grün Berlin: [https://gruen-berlin.de/en/company/about-
553 gruen-berlin](https://gruen-berlin.de/en/company/about-gruen-berlin)). GrünBerlin runs several of the major parks in Berlin and represents a case of private
554 organization and territorial governance of land (Colding et al., 2013).

555 Kabisch (2015) identifies key challenges in Berlin's urban green governance, including (a) increasing
556 development pressure due to population growth and financial constraints on the municipal budget, (b)
557 loss of expertise, and (c) low awareness of green space benefits among various stakeholders due to
558 insufficient communication. Climate change is expected to further intensify these challenges. In
559 addition to these issues, Berlin's urban green spaces are often shaped by informal practices, such as
560 community-led initiatives, temporary land use, and adaptive greening efforts (Draus et al., 2020).

561 Berlin's urban green spaces, including community gardens, have been at the center of struggles between
562 local governments, which were often skeptical of civic engagement, and social movements advocating
563 for public access to green areas. These tensions became particularly visible in the early 1980s when the
564 first community gardens emerged in West Berlin (Rosol, 2010; Colding et al., 2013).

565 After reunification, the city had an abundance of unused urban spaces (*Brachen*). However, financial
566 constraints on the municipal budget limited green space development (Kabisch, 2015). The lack of
567 public funds also led to various forms of temporary land use (*Zwischennutzung*), where former
568 industrial areas were repurposed into cultural centers and informal green spaces. In response to these
569 budgetary challenges, local politicians began advocating for increased civic engagement in managing
570 green spaces (Rosol, 2010; Colding et al., 2013).

571

572 6.1. Social Disparities

573 Social disparities are a defining feature of urban life, including Berlin's urban life, and they have a direct
574 influence on the utilization of urban parks, in particular, and greenspaces, in general.

575 **Access to Green Space:** Income disparities can lead to unequal access to green spaces. Wealthier
576 neighbourhoods often have more well-maintained parks, whereas low-income areas may lack such
577 amenities. As a result, residents of economically disadvantaged areas may have limited access to these
578 essential recreational and restorative spaces, exacerbating social inequalities. In terms of accessibility,
579 there are strong disparities in green space provisions at household and individual levels in major German
580 cities (Wüstemann et al., 2017). Also, in the context of European urban areas, vulnerable and
581 unprivileged groups of residents receive below-average green cooling, while upper-income residents,

⁶ <https://www.berlin.de/sen/uvk/natur-und-gruen/charta-stadtgruen/>

⁷ https://www.berlin.de/sen/uvk/_assets/natur-gruen/charta-stadtgruen/charta.pdf?ts=1683531724

⁸ <https://www.berlin.de/sen/uvk/natur-und-gruen/landschaftsplanung/landschaftsprogramm/>

⁹ <https://www.baumentscheid.de/klimaanpassungsgesetz>

582 nationals and homeowners experience above-average cooling provision (Rocha et al., 2024),
 583 corresponding to the findings for Berlin.
 584 Berlin's *Umweltgerechtigkeitsatlas* (Environmental Justice Atlas) 2021/2022 identifies neighbourhoods
 585 most affected by environmental stressors such as air pollution, noise, and limited access to green spaces.
 586 In 2023, a guideline for promoting environmental justice in Berlin's neighbourhoods was developed
 587 through a participatory process involving local representatives and experts from the Senate (SenStadt,
 588 SenMVKU). Regarding green space provision, the neighbourhoods most negatively affected are
 589 highlighted in the map shown in Figure 8¹⁰.

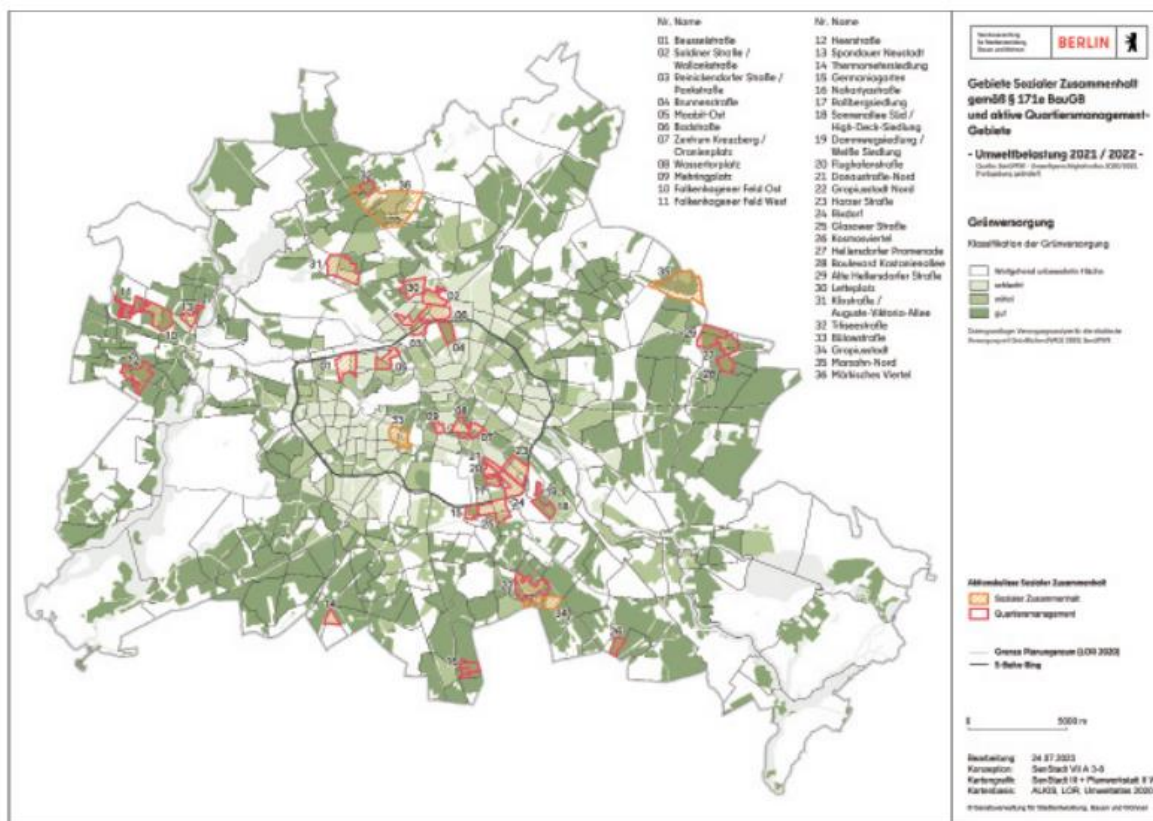


Figure 8: Provision of green spaces within the framework of social cohesion. (Source: Praxisleitfaden Umweltgerechtigkeit in Berliner Quartieren (SenMVKU, 2023))

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 593
 594 Residents who suffer from multiple environmental burdens earn less money than the average income in
 595 Berlin. The Senate classifies the social status of the neighbourhoods such as Glasower Straße listed as
 596 “very low”: around twelve percentage of people who live there are unemployed, and around 24 percent
 597 of the total population receive social security. 56% of children grow up in families that receive social
 598 security.¹¹¹²

599 **Affordability of Leisure Activities:** The ability to engage in recreational activities within Berlin's
 600 parks can be limited for individuals and families with low financial means due to costs associated with
 601 certain amenities and activities (Blokland and Vief, 2021). This economic barrier further reinforces the
 602 exclusion of low-income communities from the benefits of urban green spaces, particularly parks
 603 (Blokland and Vief, 2021). Research has shown that low-income families often face challenges such as
 604 a lack of well-maintained facilities, limited free recreational programs, and fewer organized activities
 605 in parks (Rigolon, 2016; Cohen et al., 2019). Additionally, economic disparities play a significant role

¹⁰ <https://climateanalytics.org/publications/hitzestress-und-anpassungsma%C3%9Fnahmen-in-der-metropolregion-berlin-brandenburg>

¹¹ <https://climateanalytics.org/publications/hitzestress-und-anpassungsma%C3%9Fnahmen-in-der-metropolregion-berlin-brandenburg>

¹² <https://www.rbb24.de/politik/beitrag/2022/08/berlin-umwelt-gerechtigkeit-karte-kieze-laerm-hitze-luftverschmutzung.html>

606 in determining access to community recreation resources, which are essential for promoting physical
607 activity and overall well-being (McKenzie et al., 2013; Blokland and Vief, 2021).

608

609 6.2. *Gentrification and Displacement*

610 Gentrification is a significant socio-economic phenomenon in Berlin, particularly in areas near urban
611 parks. This process carries both opportunities and challenges for urban greens.

612 **Investment and Improvement:** Gentrification often brings increased investment in the
613 neighbourhood, which can lead to park improvements, enhanced safety, and overall revitalization. This
614 can make these spaces more attractive and accessible, thereby increasing their relevance in the urban
615 fabric (Kabisch and Haase, 2014).

616 **Displacement and Social Exclusion:** On the flip side, gentrification can lead to the displacement of
617 long-standing, low-income residents. As high-income individuals and families move in, property values
618 and rents rise. Consequently, the communities that so far relied on these green spaces for social and
619 cultural activities may be pushed out, altering the socio-demographic makeup of neighbourhoods. This
620 displacement disrupts the social bonds that parks facilitate and can lead to social exclusion (Ali et al.,
621 2020). Moreover, the phenomenon of "green gentrification" highlights how improvements in green
622 spaces can inadvertently contribute to these processes of exclusion (Triguero-Mas et al., 2022).

623 **Informality and illicit activities:** In addition to the transformation of the abandoned railroad site into
624 Naturpark Südgelände, Berlin is also known for its green space, informality and illicit activities such as
625 criminalities (drug dealing or prostitution) in parks (e.g., Görlitzer Park) (Draus et al., 2020). A tension
626 emerged when former *Brachen* or wasteland spaces transferred from informal social gathering areas
627 into residential landscapes or public parks (Lachmund, 2003; Draus et al., 2020). The Berlin's city
628 administration selectively promotes some activities, such as those of 'urban pioneers' in Tempelhof and
629 turns a blind eye to others. For Tempelhof, this was a deliberate strategy, as those urban 'pioneers' were
630 mobilized by the city government to occupy the space with 'informal' activities such as urban
631 gardening. However, once the territory was 'settled', the net of control began to be extended. In this
632 context, the categories of formality and informality become confused (Draus et al., 2020).

633

634 6.3. *Access and Equity*

635 The concept of access and equity in relation to urban parks is central to understand their intersectionality
636 with socio-economic conditions.

637 **Inequitable Distribution:** The uneven distribution of parks, often favouring more affluent
638 neighbourhoods, results in an inequitable urban landscape. Low-income communities may have to
639 travel relatively long distances to access green spaces or contend with overcrowded parks, limiting their
640 ability to reap the associated physical, mental, and social benefits. Studies indicate significant disparities
641 in green space provision across German cities, with income being a major factor influencing access to
642 urban green spaces (Wüstemann et al., 2017). Additionally, the distribution of urban green spaces in
643 Berlin shows considerable dissimilarity by immigrant status and age, highlighting the need for equitable
644 planning (Kabisch and Haase, 2014).

645 **Social Inclusion:** Urban parks play a crucial role in fostering social inclusion, yet access varies
646 significantly among socio-economic groups. Wealthier communities often enjoy several opportunities
647 for social interaction, leisure activities, and cultural engagement within these spaces. In contrast,
648 socially vulnerable groups, including those with migration backgrounds and low-income levels, may
649 encounter social barriers that limit their participation and integration within urban park settings. This
650 disparity underscores the need for equitable access strategies to ensure that all residents can benefit
651 from the social advantages offered by urban greenspaces. The accessibility of urban green spaces can
652 significantly impact social inclusion, with disparities evident in who benefits from these spaces
653 (Wüstemann et al., 2017).

654 **Economic Resilience:** Socio-economic conditions directly affect the economic resilience of
655 communities living near urban parks. Gentrification can bring economic benefits, but it can also lead to
656 housing and social instability for displaced populations. Low-income communities may experience
657 gentrification as a threat rather than an opportunity, further accentuating income disparities. The
658 phenomenon of green gentrification, where park improvements lead to increased property values and
659 displacement of low-income residents, has been documented in various contexts, including Berlin (Ali
660 et al., 2020).

661 In sum, while Berlin's governance frameworks and policies address the entire spectrum of urban green
662 infrastructure, this review foregrounds public parks as a key entry point for analysis. Parks remain the
663 most multifunctional and socially significant spaces, making them particularly well suited for
664 examining the intersections of socio-economic dynamics, governance challenges, and climate
665 resilience.

667 7. Examples of Sustainability Strategies Unveiled in Berlin's Parks

668 This section critically explores strategies and approaches aimed at achieving sustainability within
669 Berlin's urban parks, considering the intersectionality of socio-economic conditions and climate change
670 impacts. It delves into innovative solutions and case studies that provide insights into how these
671 essential green spaces can evolve to meet the challenges of the 21st century.

672 7.1. Equitable Access and Inclusion

674 **Redistributive Green Space Planning:** Equitable access to urban parks requires a redistributive
675 approach to green space planning. It involves identifying areas with limited access to green spaces,
676 particularly in low-income neighbourhoods, and strategically locating or expanding parks to ensure
677 proximity and inclusivity. Additionally, considering residents' needs and preferences in the park design
678 process can foster a sense of ownership and inclusivity.

679 **Community Engagement:** Community engagement is a vital aspect of achieving equity and inclusion.
680 Involving local communities in park design and decision-making processes can lead to more tailored
681 and community-responsive green spaces. This approach enhances the sense of belonging and
682 encourages active participation in park activities (Kurth, 2022).

683 **Example 1- The "Tempelhofer Freiheit":** Tempelhofer Freiheit, the former Tempelhof Airport turned
684 urban park – **Tempelhofer Feld (Figure 9)**, exemplifies the potential of inclusive green space planning.
685 Its adaptive reuse was guided by community input and ensured that the park remains accessible to a
686 diverse range of Berliners. The park now hosts various recreational and cultural events, providing a
687 model of community involvement and inclusive design (Bartoli and Heyden, 2017; van Ham and
688 Klimmek, 2017; Pegorer, 2023; Ranzato and Broggin, 2023; Chen et al., 2021). Tempelhof also plays
689 a crucial role as intersection between formal and informal space (Draus et al. 2020). The Helmholtz
690 Center of Environmental Research (UFZ) conducted a study which concludes that the Tempelhofer Feld
691 was a unique place for society and nature (Brenck et al. 2021). Maintaining the Tempelhofer Feld is
692 also contested. One perspective favour preserving the parkland, while other political entities in Berlin
693 advocate for developing at least some portions of the area of the park¹³ for housing.

694

¹³ <https://leute.tagesspiegel.de/neukoelln/macher/2021/08/04/181017/was-die-parteien-mit-dem-tempelhofer-feld-vorhaben/>



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697 Figure 9. Tempelhofer Feld: Converted from Berlin’s former airport into a vast open parkland,
698 illustrating adaptive reuse and community-driven urban greening, the site now accommodates diverse
699 informal uses, from urban gardening to sports and cultural events (Photo courtesy: Kei Namba and
700 Asutosh Banerjee)

701

702 *7.2. Resilience and Climate Adaptation*

703 **Resilient Park Design:** To address the impact of climate change, parks need to be designed keeping
704 resilience in mind. This involves implementing climate-adaptive features such as green infrastructure,
705 tree planting, and water management systems (Pancewicz, 2021). Creating shaded areas, installing
706 fountains, and incorporating natural elements can help to mitigate heat stress. In Berlin, parks can be
707 envisioned as interconnected green corridors but also facilitate wildlife movement and enhance
708 ecological resilience, even amidst the challenges of an already densely built-up city facing increasing
709 population pressures. Figure 10 illustrates these principles through Gleisdreieck Park, where climate-
710 adaptive design transforms a former railway site into a multifunctional landscape resilient to heavy
711 rainfall and urban stressors.

712 **Example 2- Gleisdreieck Park:** Gleisdreieck Park in Berlin is a key example of resilient park design.
713 It connects several neighbourhoods, addressing inequities in green space distribution and offering
714 accessible green areas for diverse communities. The park's landscape is specifically designed to absorb

715 heavy rainfall, reducing the risk of flash flooding in the area by enhancing local water management
716 systems. In addition to its climate-adaptive features, it serves as an urban oasis that supports recreational
717 activities and promotes biodiversity, while acting as an integral part of the city's green infrastructure
718 network (Csizmadia et al., 2017; Naumann et al., 2018; Zaykova, 2021; Ferrari, 2023).
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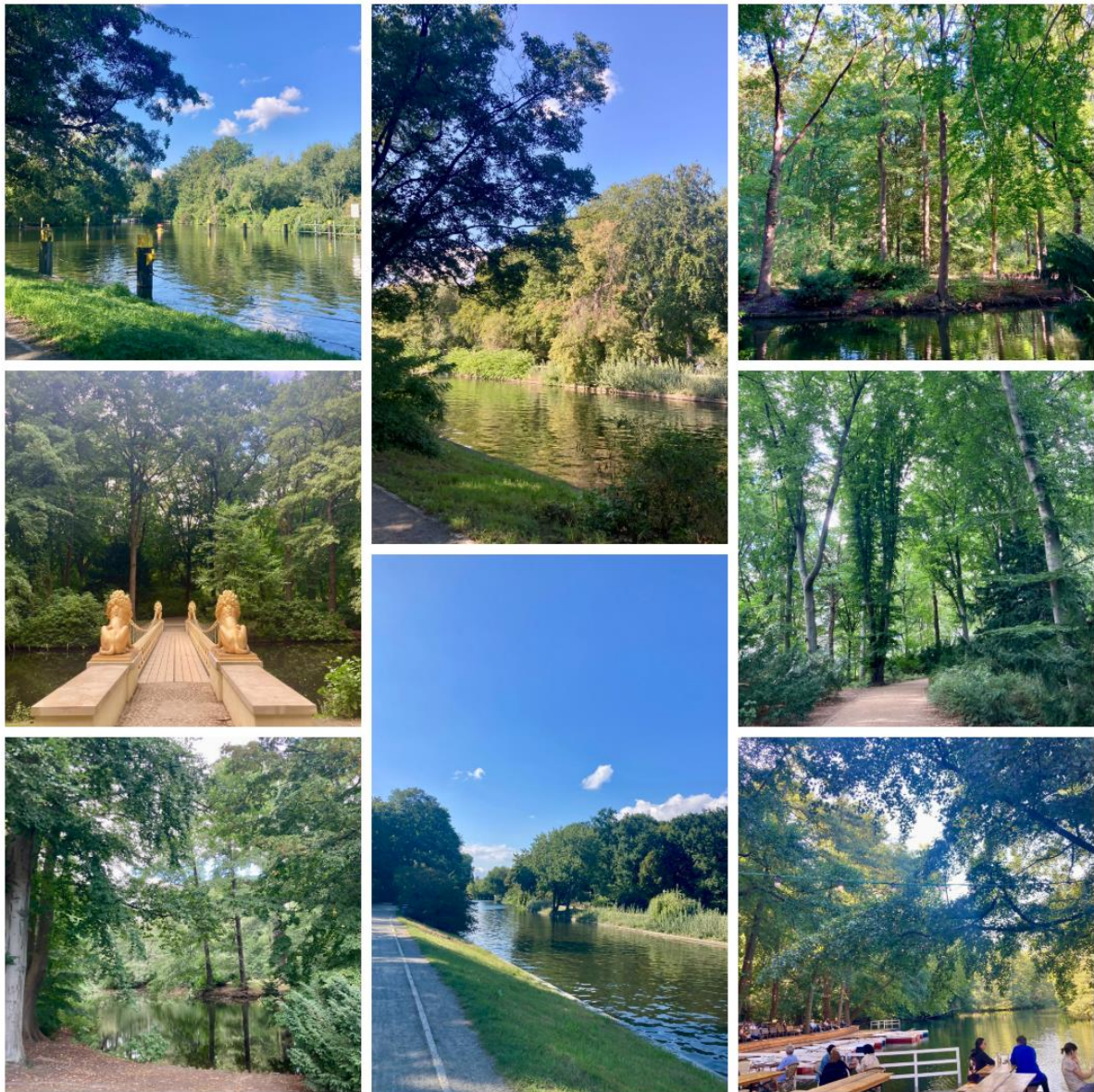


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722 Figure 10. Gleisdreieck Park as a model of resilient urban design in Berlin: Created on a former railway
723 junction, Gleisdreieck Park exemplifies how post-industrial landscapes can be transformed into
724 multifunctional green spaces that absorb heavy rainfall, reduce runoff, and enhance biodiversity. The
725 park's adaptive design—featuring rainwater retention basins, native vegetation, and shaded recreation
726 zones—illustrates how ecological resilience and social inclusivity can be integrated within Berlin's
727 dense urban fabric. (Photo courtesy: Kei Namba)

728
729 *7.3. Promoting Sustainability Through Community Engagement*
730 **Environmental Education:** Community-based sustainability programmes within urban parks involve
731 the offer of environmental education and of awareness initiatives. These programs can educate residents
732 about the importance of urban biodiversity, sustainable land management, and climate change
733 resilience. Teaching people how they can contribute to park sustainability, such as through responsible
734 waste management or wildlife protection, fosters a sense of stewardship.

735 **Eco-friendly Events:** Parks can host eco-friendly events that promote sustainable practices, such as
736 zero-waste festivals or environmental workshops. Encouraging event organizers to adopt sustainable
737 policies, reduce resource consumption, and minimize waste generation aligns these spaces with broader
738 sustainability goals.

739 **Example 3 - Tiergarten Park:** The Tiergarten Park exemplifies sustainable community programming.
740 It offers educational opportunities for residents and visitors, including wildlife observation and
741 environmental education activities. The Park also hosts eco-friendly events that promote sustainability
742 and responsible resource management, aligning with the city's commitment to a greener future (Zefkili,
743 2011; Lachmund, 2013; Skandrani and Prévot, 2015; Feld, 2017). **Figure 11 illustrates the Tiergarten
744 Park as a space where environmental education, eco-friendly events, and everyday recreation converge,
745 highlighting its role in fostering public awareness and community participation in sustainability.**
746



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749 **Figure 11. The Tiergarten Park as a site of community engagement and environmental learning in**
750 **Berlin: As Berlin’s largest and oldest park, the Tiergarten serves as both a biodiversity-rich urban forest**
751 **and a civic landscape that hosts environmental education programs, cultural festivals, and eco-friendly**
752 **public events. Its extensive green corridors, monuments, and open spaces provide opportunities for**
753 **experiential learning and collective stewardship, exemplifying how heritage parks can support**
754 **sustainability goals through community participation. (Photo courtesy: Kei Namba)**

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7.4. Inclusivity in Gentrification Strategies:

Affordable Housing Provisions: To ensure inclusivity in gentrifying areas near urban parks, city planners can implement affordable housing provisions (Sainburg, 2023). These policies aim to maintain socio-economic diversity in neighbourhoods experiencing gentrification, ensuring that low-income residents can remain in these communities.

Community Benefits Agreements: Collaborative agreements between developers, the city, and local communities can stipulate those investments in gentrified areas, including park improvements, come with community benefits (Rosen, 2023). These agreements can include the allocation of resources for affordable housing, job opportunities, and accessible green spaces that prioritize the needs of existing residents (Michels and Hindin, 2022).

Example 4 - Hasenheide Park: Hasenheide Park in Berlin's Neukölln district highlights the importance of affordable housing provisions and community benefits agreements (CBAs) in addressing gentrification (Skandrani and Prévot, 2015; Hardinghaus et al., 2021; Collins et al., 2022). As shown in Figure 12, Hasenheide Park serves as a socially vibrant green space where inclusive planning and equitable access help mitigate the socio-economic pressures of neighbourhood change. Affordable housing policies can maintain socio-economic diversity by enabling long-term residents to stay in gentrifying neighborhoods near urban parks (Kabisch and Haase, 2014). CBAs between developers, the city, and communities ensure investments in parks, like Hasenheide, also fund affordable housing, job opportunities, and accessible green spaces, prioritizing the needs of existing residents (Rigolon et al., 2020; Rigolon and Nemeth, 2020; Martens et al., 2022).



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779 Figure 12. Hasenheide Park as a socially inclusive urban green space in Berlin: Located in the diverse
780 district of Neukölln, Hasenheide Park embodies the intersection of environmental quality and social
781 equity. As surrounding areas experience rapid gentrification, the park remains a key recreational and
782 cultural space that supports local diversity through community use and accessible public amenities. Its
783 role in the neighbourhood highlights how urban green spaces, when supported by affordable housing
784 and community benefit frameworks, can foster resilience against socio-spatial displacement. (Photo
785 courtesy: Fabian Becker)

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787 **8. Discussion of Findings: Urban Parks as Essential 'Third Places' in Berlin Amidst Socio-**
788 **Environmental Challenges from Heavy Rainfall Events**

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Figure 13. Mauerpark as a vibrant ‘third place’ in Berlin’s socio-ecological landscape: The park exemplifies how public green spaces function as informal arenas of leisure, cultural exchange, and collective identity in a diverse metropolis. Its open lawns and amphitheatre attract residents and visitors for music, markets, and social interaction, reflecting the park’s strong community character. Yet, as with many of Berlin’s parks, Mauerpark’s role as an inclusive third place is increasingly tested by climate-induced stresses such as heavy rainfall, soil compaction, and maintenance challenges, underscoring the need for adaptive and equitable management strategies. (Photo courtesy: Kei Namba)

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Urban parks serve as quintessential “third places,” offering informal public spaces where individuals gather for leisure, social interaction, and respite from urban life (Oldenburg, 1989). In Berlin, these parks hold particular significance, as they not only contribute to the city’s ecological and cultural fabric but also serve as social hubs that bridge the divides between its diverse populations (Jeffres et al., 2009; Purnell, 2015). Figure 13 illustrates these dynamics through Mauerpark, where vibrant community life coexists with increasing environmental pressures, epitomising the dual social and climatic challenges faced by Berlin’s parks. However, the function of parks as third places is increasingly compromised by the intensifying impacts of climate change, especially extreme rainfall events. This discussion comprehensively examines the challenges facing Berlin’s urban parks, analysing both the environmental and social dimensions of climate change, financial constraints, and inequality in green

810 space access. By integrating these perspectives, the following sections explore potential strategies to
811 enhance the resilience and inclusivity of urban parks in Berlin.

812 While considering a range of meteorological phenomena, including heat waves and droughts, which are
813 well-documented in literature, this review prioritizes heavy rainfall events due to their unique and
814 significant challenges specific to Berlin's parks. While urban parks provide vital ecosystem services
815 such as climate regulation, flood mitigation, and social well-being, studies like Pasternack et al. (2020)
816 show that extreme rainfall events can overwhelm urban infrastructure, including parks, leading to
817 significant disruptions. Caldas-Alvarez et al. (2022) demonstrate that heavy precipitation in Berlin, such
818 as the June 2017 event, caused substantial economic damage and strained local resources. Unlike other
819 meteorological events, heavy rainfall leads to immediate runoff issues, soil erosion, and infrastructure
820 degradation in parks, as highlighted by Lorenz et al. (2019), who observed storm intensification in
821 urbanized areas of Berlin. The unique interaction between urban environments and precipitation
822 patterns, leading to increased risks from flash floods (heavy rainfall that cannot be *managed* by surface
823 and sewage system), makes it imperative to prioritize research on rainfall impacts over other weather
824 phenomena, which have already been extensively studied in Berlin's parks (Haase and Kabisch, 2014;
825 Lorenz et al., 2019; Pasternack et al., 2020; Kabisch et al., 2021; Caldas-Alvarez et al., 2022).

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827 *8.1. Heavy Rainfall and Biophysical Disruptions in Parks*

828 Berlin's parks are not immune to the escalating frequency and magnitude of heavy rainfall events due
829 to climate change, which imposes significant stress on their biophysical environments. Intense rainfall
830 leads to soil erosion, waterlogging, and increased surface runoff, all of which deteriorate the parks'
831 ecological functions. Soil erosion, in particular, severely impacts the ability of parks to support
832 vegetation, retain water, and provide natural habitats for urban biodiversity (Sarah et al., 2015). As
833 erosion strips away topsoil, the ability of parks to absorb water and facilitate groundwater recharge is
834 compromised, resulting in worsened flood risks and the degradation of green space quality (Kowarik,
835 2023).

836 Compaction from frequent foot traffic in popular parks, combined with insufficient vegetation cover,
837 exacerbates these effects by reducing infiltration rates, which intensifies the volume of surface water
838 runoff. This, in turn, not only threatens the ecological integrity of the affected parks but also limits their
839 ability to function as refuges during extreme weather events, such as acting as cooling zones during
840 heatwaves or spaces for respite during periods of heavy rain (Pancewicz, 2021). These disruptions
841 underscore the pressing need for sustainable park design that incorporates climate-adaptive features,
842 particularly in managing water flow and preventing soil degradation (Gill et al., 2007). As shown in
843 Figure 14, signs of soil erosion, surface runoff, and vegetation loss are evident in several of Berlin's
844 parks, such as, Stadtpark Steglitz, Fischtalpark and Volkspark Friedrichshain, reflecting the cumulative
845 impacts of heavy rainfall events and intensive public use on park soils and vegetation cover.

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Figure 14. Evidence of soil erosion and surface degradation in Berlin’s urban parks: Photographs from a) Stadtpark Steglitz, b) Fischtalpark and c) Volkspark Friedrichshain, illustrate the biophysical stresses caused by recurrent heavy rainfall and high visitor pressure. Erosion of topsoil, waterlogging, and compaction reduce infiltration capacity and vegetation resilience, exemplifying the challenges faced by Berlin’s parks in maintaining ecological functionality under changing climatic conditions. ((Photo courtesy: Ehsan Razipoor and Subham Mukherjee)

856 *8.2. Social Implications of Heavy Rainfall in Third Places*

857 Beyond the biophysical impacts, heavy rainfall events also undermine the social functions of parks as
 858 third places. Waterlogged fields, flooded pathways, and damaged infrastructure render parks unusable
 859 for extended periods, limiting access to spaces crucial for community engagement, physical activity,
 860 and social interaction (Tomeczyk et al., 2016). This problem is compounded for vulnerable
 861 populations—such as the elderly, low-income residents, and migrant communities—who rely heavily
 862 on public parks for recreation and as gathering places, especially in dense urban areas where private
 863 green spaces are limited (Kabisch and Haase, 2014).
 864 Various studies document that climate-induced disruptions to park accessibility disproportionately
 865 affect these communities, exacerbating social inequalities in cities (Anguelovski et al., 2020). For
 866 instance, marginalized groups are more likely to live in areas with fewer high-quality parks, and when

867 heavy rain renders these spaces unusable, their options for outdoor leisure become further restricted
868 (Wüstemann et al., 2017). In this sense, climate change exacerbates not only environmental
869 vulnerabilities but also entrenched social inequities, reinforcing the need for inclusive urban green space
870 planning that addresses both environmental and social dimensions.

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872 *8.3. The Ecological and Social Instability: A New Reality for Urban Parks*

873 Heavy rainfall directly challenges the ecological stability of Berlin's parks, which are essential for urban
874 biodiversity and ecosystem services. Climate-driven shifts in precipitation patterns have been shown to
875 alter species composition, with some plant species thriving while others decline due to water saturation
876 or soil nutrient loss (Kowarik, 2023). Such shifts impact the broader urban ecosystem, leading to a
877 reduction in biodiversity and the degradation of ecosystem services, including pollination and natural
878 pest control, which are vital for maintaining healthy park environments (Reynaert et al., 2020).

879 This ecological instability also diminishes the parks' ability to function as social spaces, which is critical
880 to their role as third places. Flooded and poorly maintained parks discourage their use for social
881 gatherings, thereby weakening community ties. Studies on urban sociology emphasize that parks, as
882 third places, are particularly important in fostering informal social interactions that contribute to social
883 cohesion (Oldenburg, 1989; Purnell, 2019). The more parks are subjected to environmental degradation,
884 the less they can fulfill this role, especially for socio-economically disadvantaged groups who have
885 fewer alternatives for outdoor recreation (Byrne, 2017).

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887 *8.4. Redefining Urban Parks as Resilient Third Places: The Role of Adaptive Strategies*

888 The compounded effects of climate change and social inequities necessitate a rethinking of how Berlin's
889 parks can continue to function as third places under increasingly unpredictable environmental
890 conditions. One critical approach is the integration of adaptive water management systems, such as
891 Sustainable Urban Drainage Systems (SUDS), which mitigate the impacts of heavy rainfall by
892 controlling runoff and preventing soil erosion (Gill et al., 2007). These systems not only enhance the
893 ecological resilience of parks but also ensure that they remain accessible during extreme weather events,
894 safeguarding their role as social spaces (Masson-Delmotte et al., 2021).

895 In addition to biophysical solutions, there is a growing need for participatory planning processes that
896 involve local communities in park management and adaptation efforts. Community engagement fosters
897 a sense of ownership and ensures that park designs reflect the needs of diverse user groups, particularly
898 those most affected by climate change (Kurth, 2022). Inclusive Park planning that prioritizes climate
899 resilience can help sustain the multifunctionality of parks as both ecological assets and social hubs,
900 thereby enhancing their ability to act as third places even in the face of environmental challenges
901 (Haaland and van den Bosch, 2015).

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903 *8.5. Equity in Access: Addressing the Social Dimension of Climate Resilience*

904 The uneven distribution of green spaces across Berlin's neighborhoods underscores the importance of
905 redistributive green space planning as a strategy for fostering equity in access to parks. Ensuring that
906 all residents—especially those from marginalized communities—have equal access to climate-resilient
907 parks is essential for promoting social equity in the city (Kabisch and Haase, 2014). This can be
908 achieved by targeting investments in green infrastructure toward underserved areas, which often
909 experience the highest climate vulnerabilities (Jeffres et al., 2009; Purnell, 2019).

910 Equity in access must also be considered when designing adaptive features, such as shaded areas and
911 rain shelters, which can help parks serve as refuges during extreme weather events (Pancewicz, 2021).
912 Without intentional planning that addresses these disparities, the benefits of climate-resilient parks may
913 disproportionately accrue to wealthier neighborhoods, further entrenching social divides.

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915 *8.6. Toward Sustainable and Inclusive Third Places*

916 Berlin's urban parks are at a critical juncture, where their continued function as third places is threatened
917 by the dual pressures of climate change and social inequities. Heavy rainfall events, in particular, pose
918 significant risks to both the ecological health of these parks and their ability to serve as inclusive social
919 spaces. Addressing these challenges requires a holistic approach that integrates climate-adaptive
920 infrastructure with socially inclusive planning processes. By rethinking the design and management of
921 parks to prioritize resilience and equity, Berlin can ensure that its green spaces remain accessible and

922 functional as third places for all residents, even in an era of increasing environmental unpredictability.
923 Körnerpark illustrates how historical garden landscapes in Berlin can be reinterpreted as accessible
924 cultural and community-oriented public spaces, functioning in many respects as a modern ‘third
925 place’—that is, a venue beyond home and work where social interaction, cultural expression and shared
926 leisure converge (Figure 15).
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930 Figure 15. Körnerpark as a reinterpreted heritage ‘third place’ in Berlin: Originally created between
931 1912 and 1916 in a neo-baroque style on the site of a former gravel pit, Körnerpark in Neukölln
932 exemplifies how historical garden design can be adapted to contemporary public needs. Its terraced
933 lawns, fountains, and the Orangerie—now hosting an art gallery and café—create a lively civic space
934 that merges cultural heritage with community interaction. As a reimagined *third place*, Körnerpark
935 demonstrates how historic landscapes can foster social resilience and inclusivity while preserving
936 ecological and aesthetic value in a dense urban environment. (Photo courtesy: Kei Namba)

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938 **9. Conclusions:**

939 This review article critically examines the state of Berlin’s urban parks, situating them within the city’s
940 wider green infrastructure but treating parks as the primary lens of analysis. The deliberate focus on
941 parks reflects their prominence as the most multifunctional, accessible, and socially significant form of

942 urban greenery in Berlin. While community gardens, allotments, green roofs, and other green spaces
943 contribute to the city's resilience, this article analyses parks in particular to understand how socio-
944 economic dynamics, governance challenges, and climate-related stressors converge.
945 Our findings highlight the interplay between socio-economic conditions and climate change in shaping
946 the accessibility, functionality, and resilience of Berlin's parks. Strategies and policy incentives exist—
947 such as the Sponge City Initiative, the Urban Development Plan Climate 2.0, and the Charter for Urban
948 Green—but gaps remain in implementation. More systematic integration of resilience measures and
949 stronger community involvement are needed to translate these frameworks into practice. Equity
950 challenges are also persistent: income and social status influence access and quality, with disadvantaged
951 groups disproportionately exposed to environmental burdens. These disparities underscore the urgency
952 of embedding environmental justice principles into urban park governance.
953 By systematically synthesising literature across urban planning, environmental science, climate
954 research, social sciences, and public health, this review provides a comprehensive interdisciplinary
955 analysis. While ecological and planning perspectives remain foundational, emerging insights from
956 social sciences and public health demonstrate the importance of equity, health, and well-being in
957 resilience planning. Berlin's case illustrates both opportunities and tensions in managing parks to
958 balance biodiversity conservation, climate adaptation, and social justice
959 Several research projects confirm the multifunctionality of Berlin's parks for climate mitigation,
960 adaptation, and community well-being. Yet they also demonstrate that parks can reflect and exacerbate
961 socio-economic disparities, particularly through processes of gentrification and uneven access. This
962 synthesis highlights three interlinked priorities for sustainable management: enhancing resilience
963 through climate-adaptive design, reducing socio-spatial inequalities in access and quality, and
964 strengthening civic engagement in planning and stewardship.
965 Finally, the review points to a forward-looking research agenda. Quantifying the economic and
966 ecological value of ecosystem services remains a complex challenge, requiring advanced
967 interdisciplinary methods. Longitudinal studies are needed to trace biodiversity change, ecosystem
968 services, and park utilisation over time. Partnerships with communities, supported by citizen science
969 and co-produced knowledge, can enrich data collection while fostering stewardship. Future research
970 should therefore integrate robust empirical evidence, inclusive governance, and adaptive design to
971 ensure that Berlin's urban parks remain resilient, equitable, and vibrant in the face of escalating climate
972 and social pressures.

973

974 **Author contribution**

975 SM conceptualized the study and developed the initial framework of the manuscript, with support from
976 KN and KMN. Together, SM, KN, and KMN conducted the systematic review, synthesizing key
977 findings and drafting the manuscript. ER contributed to the visualization of results by creating maps
978 and providing analytical insights. SH and BS critically reviewed and refined the manuscript, ensuring
979 coherence and academic rigor.

980

981 **Competing interests**

982 KMN is one of the members of the editorial board of the journal – NHESS.

983

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