

Ecological Urban Parks for Climate Resilience: A Systematic Review of Design, Equity, and Sustainability

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ABSTRACT

Cities are facing rising heat stress, flooding pressure, ecological fragmentation, and uneven access to green space, yet the literature on ecological urban parks often treats environmental performance, social equity, and governance as separate concerns. This systematic review addresses that fragmentation by examining how park design can simultaneously support climate resilience, distributive justice, and urban sustainability. Following PRISMA 2020 guidance, we reviewed peer-reviewed journal articles indexed in Scopus and published between 2020 and 2025. From 464 records identified through keyword searches and subsequent screening, 39 studies were selected for detailed thematic synthesis. The review shows that ecological urban parks can reduce urban heat, improve stormwater retention, enhance air quality, and support biodiversity, but their effectiveness depends strongly on park size, vegetation structure, water elements, and local urban context. The evidence also reveals persistent inequalities in access, quality, and participation, especially for lower-income, peripheral, migrant, and elderly groups. Participatory design approaches, including digital monitoring, big-data analytics, and community-based planning, can improve responsiveness and stewardship, although they remain constrained by institutional capacity, cost, and technical complexity. Across the reviewed studies, park typologies that integrate ecological, cultural, educational, and recreational functions appear more robust than single-purpose models. The literature remains geographically uneven and heavily reliant on modelling and simulation. Overall, the review argues that climate-resilient urban parks require context-specific design, explicit equity commitments, and stronger empirical validation in future research.

INTRODUCTION

Climate change is intensifying extreme heat, hydrological stress, ecological fragmentation, and environmental-health burdens in cities, making urban green infrastructure a central concern in planning and design (Park and Jo 2021; An *et al.* 2020; Suhardono *et al.* 2024). In this context, urban parks can no longer be understood only as recreational amenities. They increasingly function as ecological infrastructures that regulate microclimates, store carbon, absorb runoff, support biodiversity, and provide restorative public space. As urban areas continue to densify, the quality, distribution, and design of parks are becoming decisive for resilience, sustainability, and public wellbeing.

Recent studies show that the contribution of urban parks to climate resilience is substantial but highly design-dependent. Urban green spaces can sequester carbon at meaningful rates when ecological design is embedded from planning through management (Park and Jo 2021). Parks also reduce urban heat island intensity, improve air quality, and create habitat for native and migratory species, thereby stabilising urban ecological processes (An *et al.* 2020; Suhardono *et al.* 2024). Since 2015, park design has shifted from ornamental and mono-functional layouts toward

multifunctional systems such as pocket parks, urban wetlands, and biodiversity corridors that combine ecological performance with social value (Lee 2021; Hui and Keai 2024). This shift has been accompanied by growing emphasis on local ecological conditions, adaptable materials, flexible programming, and participatory planning as core elements of climate-responsive design (Zhang *et al.* 2021; Song 2022; Bai and Sadia 2023; Rahmatika 2025).

At the same time, the benefits of green infrastructure are not distributed evenly. Access to high-quality urban parks is increasingly framed as an environmental-justice issue rather than a purely spatial question. Studies using spatial accessibility tools such as Spatial Design Network Analysis show that residents in dense, marginal, and poorly connected neighbourhoods often face systematic disadvantages in reaching and using parks. Evidence from Wuhan, for example, demonstrates how biased urban development patterns can restrict access for vulnerable groups and reinforce pre-existing inequalities (Jiao *et al.* 2020; Li *et al.* 2021).

Assessing the sustainability of urban parks therefore requires more than biophysical measurement alone. Recent frameworks combine ecological indicators with spatial performance, aesthetic quality, and social utility so that both tangible and intangible benefits can be evaluated together

(González *et al.* 2023). Within this broader ecosystem-services perspective, parks are expected to regulate microclimates, manage stormwater, and improve environmental quality through design devices such as bioswales, constructed wetlands, and other nature-based solutions (Taylor *et al.* 2020; Yarnvudhi *et al.* 2021; Zhang *et al.* 2024).

Urban parks also matter because they mediate everyday relations between people and urban nature. Community gardens, informal recreation spaces, and educational programs can strengthen mental health, environmental awareness, local identity, and social interaction, while also creating opportunities for more adaptive and inclusive governance (Daniels *et al.* 2020; Kabisch *et al.* 2021; Addas 2022).

Despite this growing literature, the evidence base remains fragmented. Environmental performance, equity, participation, and design typology are often discussed in parallel rather than in an integrated way, making it difficult to understand how ecological urban parks actually function as climate-resilience instruments across different urban contexts. This fragmentation limits the usefulness of the literature for designers, planners, and policymakers who must make trade-offs among environmental effectiveness, social inclusion, and implementation feasibility.

This systematic literature review addresses that gap by synthesizing interdisciplinary research on ecological urban parks published between 2020 and 2025. The review asks: How do ecological urban parks function as instruments of climate resilience, and which design and equity principles strengthen their sustainability outcomes? To answer this question, the paper first explains the review method, then outlines the theoretical framework, presents thematic findings, and concludes with implications for research and practice.

METHODS

This review was conducted between August and October 2025 using a qualitative systematic literature review approach. The analysis focused on how design strategies and spatial-equity principles shape the capacity of ecological urban parks to deliver resilient, inclusive, and sustainable urban outcomes.

Search Strategy

The review followed PRISMA 2020 guidance to improve transparency and reproducibility (Dobrinic *et al.* 2025). Scopus was selected as the main database because of its broad international coverage and its strong representation of design, planning, and environmental journals. The initial search prioritised terms related to urban or city parks and design rather than relying only on the phrase climate change, because many climate-relevant park studies are indexed through outcome terms such as cooling, runoff control, biodiversity, resilience, or ecosystem services. Climate relevance was therefore assessed during screening and eligibility review, not only through the first keyword string. Using this logic, the search retrieved 464 records, which were then narrowed to 39 journal articles published in English between 2020 and 2025 and directly relevant to ecological urban parks, design, and climate-resilience outcomes. Conference papers, review articles, books, non-peer-reviewed sources, rural green-space studies, and publications outside the language and date criteria were excluded (Monteiro *et al.* 2020).

Screening, Eligibility, and Thematic Coding

Screening proceeded in three steps (Mirzoev *et al.* 2021). First, titles and abstracts were examined to remove clearly irrelevant records. Second, full texts were assessed against the inclusion and exclusion criteria. Third, backward snowballing from reference lists was used to identify additional studies that were strongly aligned with the review question but had not

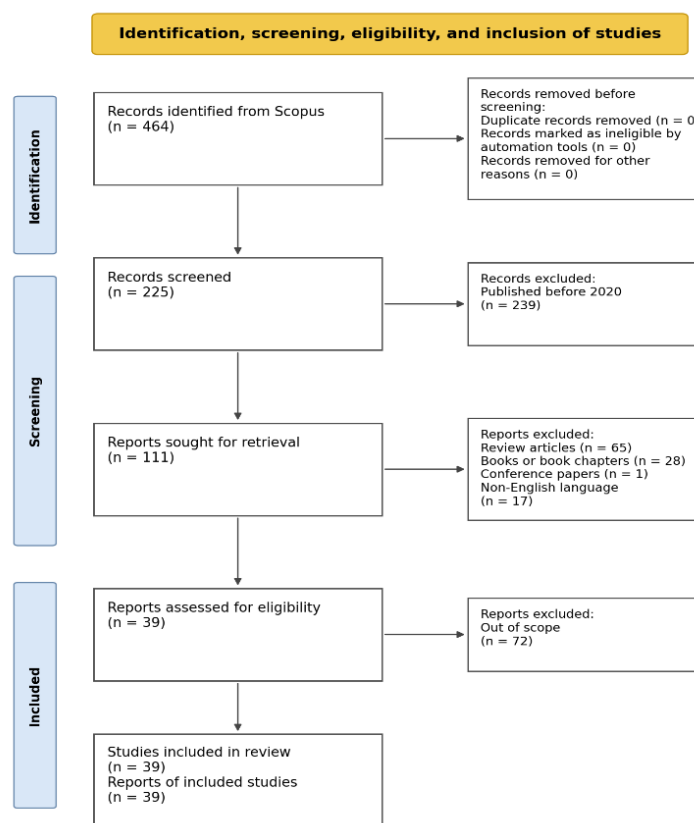


Figure 1. PRISMA flow diagram of the literature identification, screening, eligibility, and inclusion process used in this review
Source: synthesized from Dobrinic *et al.* (2025), Monteiro *et al.* (2020), Mirzoev *et al.* (2021), Hartt *et al.* (2023), and Saraswat *et al.* (2024)

been captured in the initial search (Saraswat *et al.* 2024; Hartt *et al.* 2023). Zotero was used to document and manage sources throughout the process. After selection, the final articles were coded thematically into four analytical clusters: environmental performance and cooling effects; equity and accessibility; participatory design and user engagement; and park typologies and integrated design models. Figure 1 summarises the identification, screening, eligibility, and inclusion pathway.

THEORETICAL FRAMEWORK

Resilience Theory in Urban Ecology

Resilience theory provides a useful foundation for interpreting ecological urban parks because it focuses on the capacity of socio-ecological systems to absorb disturbance, adapt to change, and continue functioning under pressure (Su *et al.* 2022; Myalkovsky *et al.* 2023). In urban contexts, this perspective shifts attention away from static green-space provision and toward adaptive infrastructures that can respond to climate risk, land-use change, and demographic pressure.

From this viewpoint, urban parks are not peripheral amenities but operational ecological infrastructures. Through biodiversity support, stormwater regulation, and climate moderation, they contribute directly to the adaptive capacity of cities and help stabilise ecological processes that are otherwise disrupted by urbanisation (Kong *et al.* 2022; Myalkovsky *et al.* 2023; Wijaksono *et al.* 2025a).

Several analytical tools translate resilience into planning practice. Coupling-coordination models examine the relationship between urbanisation and ecological resilience, while DPSIR frameworks trace how environmental pressures, system states, impacts, and policy responses interact across urban systems (Xiao *et al.* 2023; Kan and Lv 2024).

More integrative socio-ecological frameworks extend this logic by combining ecological, social, and economic indicators within mixed-method assessment models. These approaches are particularly useful for park research because they help explain not only whether a park performs ecologically, but also how that performance is shaped by governance, land-use dynamics, and everyday social use (Li and Li 2023; Deng and Liu 2023; Man *et al.* 2021; Wang *et al.* 2023).

Urban Political Ecology and Spatial Justice

Urban political ecology complements resilience thinking by asking who benefits from green infrastructure and under what conditions. It draws attention to the political, institutional, and cultural processes through which urban nature is produced, managed, and contested, and it highlights the structural inequalities that shape access to parks and other public environmental goods (Sykes 2025; Jabbar *et al.* 2021). In this perspective, equity involves not only physical proximity, but also cultural relevance, meaningful participation, and fair governance (Sykes 2025).

The idea of "Just Green Enough" is especially relevant here because it recognises that greener cities are not automatically more just cities. Park improvement can enhance urban environments while also contributing to displacement, green gentrification, or selective investment unless distributional safeguards are built into planning decisions (Sykes 2025). Empirical studies continue to show that affluent neighbourhoods are more likely to receive high-quality green infrastructure, whereas economically marginalised areas remain underserved (Facundes *et al.* 2024; Chang 2024).

GIS-based analysis has been central to exposing these spatial inequalities. By mapping service areas, entry conditions, and socio-demographic patterns, researchers have shown that disparities in park access are often systematic rather than incidental, reinforcing the need for explicit spatial-justice criteria in urban planning and policy (Eshetu *et al.* 2021; Huang *et al.* 2020; Ayala-Azcárraga *et al.* 2023).

Landscape Architecture and Participatory Design

Landscape architecture provides the design lens through which these socio-ecological concerns are materialised. Contemporary practice has moved away from purely top-down park production toward participatory models that treat communities as active contributors to spatial design, management, and adaptation. This shift reflects the recognition that resilient parks must respond to local needs, values, and lived experience rather than only to abstract planning standards (Daneshyar *et al.* 2023; Reaver 2023).

Participatory tools now extend from workshops and participatory video to digitally mediated forms of engagement, including augmented reality and other interactive platforms. These methods can strengthen user satisfaction, social cohesion, and contextual fit by allowing local knowledge to shape design priorities and by translating technical plans into more accessible forms of discussion (Jia *et al.* 2020; Ihle *et al.* 2024; Wijaksono *et al.* 2025b; Puig-Ribera *et al.* 2022).

The theoretical basis for this shift also comes from human-nature frameworks. Biophilic thinking emphasises the psychological and health value of everyday contact with nature, while ecological design principles encourage mimicry of ecological processes, habitat integration, and low-impact material strategies. The close-to-nature heuristic brings these strands together by linking ecological performance with human wellbeing in a shared design logic (Mosler and Hobson 2021; Mistry and Shaw 2021; Bi *et al.* 2024).

Taken together, these ideas position ecological urban parks as multifunctional landscapes where climate regulation, habitat support, recreation, and community use must be coordinated within limited urban space. In this sense, participatory landscape architecture provides the practical bridge between resilience theory and spatial justice, helping translate broad sustainability ambitions into site-specific design decisions (Park *et al.* 2020; Ngome and Yeom 2024).

REVIEW OF THEMES

Environmental Performance and Cooling Effects

Across the reviewed literature, environmental performance emerges as one of the clearest pathways through which ecological urban parks support climate resilience. The evidence consistently shows that green infrastructure can moderate urban heat, manage runoff, improve air quality, and sustain ecological functions when park form and planting are carefully designed (Widyanti 2025). Figure 2 synthesises these interrelated ecological processes.

Vegetation planning is repeatedly identified as a first-order design variable. In Chittagong, Hasan and Haider (2023) show that green belts and peripheral green wedges reduce surface temperature while also contributing to broader disaster-mitigation strategies. Comparable logic appears in sponge-city planning in the Yangtze River Delta, where multifunctional green infrastructure improved runoff control and water quality as part of wider climate-adaptation design (Ji and Rao 2023).

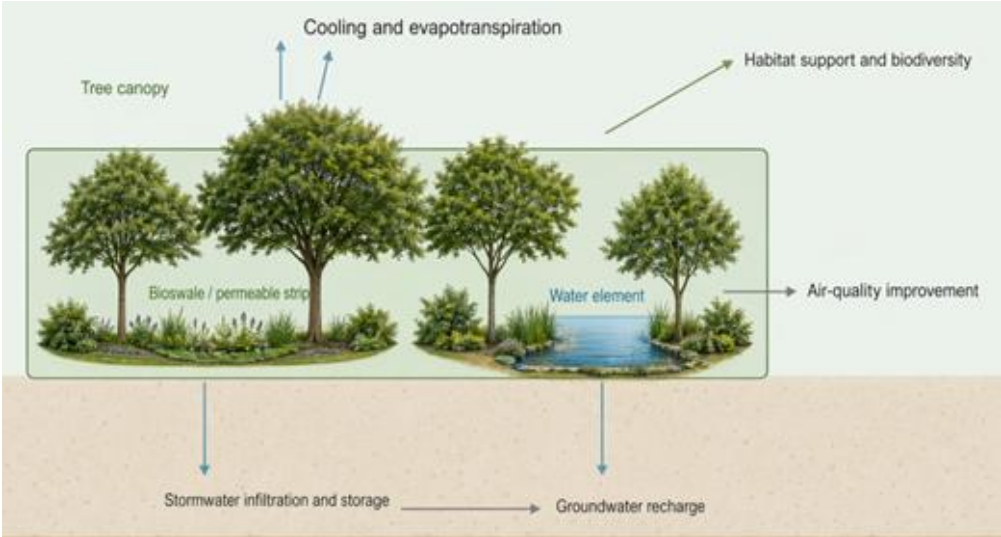


Figure 2. Ecological functions of urban parks for climate resilience. Source: synthesized from Hasan and Haider (2023); Ji and Rao (2023); Abdallah *et al.* (2025); Zhou Z. *et al.* (2023); and Penteado (2021)

Table 1. Climate-resilience functions and cooling mechanisms of urban parks

No.	Author (Year)	City/Region	Resilience Function	Metric / Model	Key Outcome
1	Hasan and Haider (2023)	Chittagong, Bangladesh	Greenbelt and GI planning	Master-plan review	Peripheral green wedges for heat & disaster mitigation
2	Ji and Rao (2023)	Yangtze R. Delta, China	Sponge-city flood control	Comparative case analysis	Sponge designs improve runoff & water quality
3	Yao X. <i>et al.</i> (2022)	Fuzhou, China	UHI cooling	Landsat + PCI, PCG indices	1.08 ha optimal size for thermal comfort
4	Paolinelli <i>et al.</i> (2022)	Pistoia, Italy	Flash/river-flood basin park	Design integration	Combines hydraulic safety & recreation
5	Liu J. <i>et al.</i> (2021)	Jiangmen, China	Sponge facilities and WQ	Volumetric capture calculation	Meets sponge city targets
6	Jiao and Han (2022)	China (multi-city)	Sponge green-space mix	ANN + landscape indices	Optimal park mix for infiltration & biodiversity
7	Abdallah <i>et al.</i> (2025)	Riyadh, Saudi Arabia	Outdoor thermal comfort	UTCI + parametric optimization	Trees (10-15 m) reduce UTCI by 11K
8	Yao Y. <i>et al.</i> (2022)	Guangzhou, China	Air-quality improvement	i-Tree Eco + LCZ	Efficient PM reduction via roadside GI
9	Hong L. <i>et al.</i> (2022)	Jiaozuo, China	Ecological restoration	GIS suitability mapping	Rehab of quarry areas diversifies landscape
10	Zhou Z. <i>et al.</i> (2023)	Anhui, China	Wetlandpark sustainability	Landscape ecology evaluation	Supports SDGs; high eco-social-economic grade
11	Penteado (2021)	Portland, USA (scenarios)	Wildlife viability	HexSim dispersal model	GI networks sustain biodiversity (frogs, meadowlarks)

Remote-sensing and microclimate studies further demonstrate that cooling is not produced by greenery in the abstract, but by specific spatial and biophysical configurations. Research in Chinese cities suggests that well-vegetated parks can reduce surrounding temperatures by as much as 2°C, with optimal cooling associated in some cases with parks of around one hectare, depending on context and configuration (Yao X. *et al.* 2022; Aram *et al.* 2020; Yang *et al.* 2022).

Hydrological performance is equally important. Multifunctional ecological parks can combine flood mitigation, public use, and landscape restoration, as seen in Italian flood-basin parks and Chinese sponge-city facilities. These studies show that bioretention systems, permeable green-space mixes, and water-sensitive design can improve infiltration and water quality while maintaining public

amenity value (Paolinelli *et al.* 2022; Liu J. *et al.* 2021; Jiao and Han 2022).

Vegetation structure also shapes human thermal experience at the micro scale. Parametric simulations in Riyadh indicate that tree canopies between 10 and 15 m in height can substantially reduce thermal stress, lowering UTCI values by around 11 K. Other work shows that urban vegetation can also reduce particulate matter and noise, demonstrating that climate-resilient park design often delivers multiple environmental co-benefits simultaneously (Abdallah *et al.* 2025; Yao *et al.* 2022; Suciyani 2023).

The ecological role of parks extends beyond temperature regulation. GIS-based restoration studies show how degraded urban land can be converted into biodiverse habitat, while wetland parks provide strong cooling performance through evapotranspiration and also generate

ecological, social, and economic benefits aligned with sustainability agendas (Hong *et al.* 2022; Zhou *et al.* 2023).

At larger scales, connectivity matters as much as site performance. Modelling work from Portland suggests that networks of linked open spaces are better able to sustain wildlife movement and ecological function than isolated green patches, indicating that climate resilience should be considered across park systems rather than only within individual sites (Penteado 2021).

Taken together, these studies show that ecological urban parks make their strongest environmental contribution when cooling, hydrology, air quality, and habitat support are designed as mutually reinforcing functions rather than as separate objectives.

The evidence also shows that there is no single best model. Park size, vegetation composition, water features, and surrounding urban form interact differently across contexts. Climate-resilient design therefore depends on locally grounded ecological knowledge and on the ability to adapt general principles to place-specific conditions.

Table 1 consolidates the main resilience functions reported in the reviewed studies and highlights the design variables most frequently associated with strong environmental performance.

Equity and Accessibility of Urban Parks

Equity and accessibility form the second major theme in the literature. Here, urban parks are evaluated not only by ecological effectiveness but by who can reach them, use them safely, and participate in their production and governance. This broader framing aligns park planning with distributive, procedural, and recognition justice.

Evidence from multiple cities shows that inequality in park provision remains persistent. In Shanghai, Wang *et al.* (2022) demonstrate that foreign residents and blue-collar workers experience distinctive forms of park injustice, while research from Taiyuan shows strong urban-rural disparities in community park access. These patterns support wider

spatial-justice arguments that environmental amenities remain unevenly distributed along socio-economic lines (He *et al.* 2024; Facundes *et al.* 2024; Chang 2024).

Methodologically, GIS and accessibility modelling have been especially important in making these disparities visible. Studies in Surrey, Sofia, and Guangzhou show that park access depends on more than Euclidean distance: entrances, walkability, safety, attractiveness, and service quality all influence whether nearby parks are actually usable, especially in peripheral or disadvantaged areas (Sharma *et al.* 2025; Petrova-Antonova *et al.* 2025; Zhang *et al.* 2023).

Equity is also shaped by mobility and life stage. Work on elderly residents indicates that non-motorised movement and district-scale provision can improve functional access, yet global reviews also warn that new park investment and nature-based solutions may accelerate green gentrification unless anti-displacement safeguards are put in place (Guo *et al.* 2020; Cucca *et al.* 2023).

Some typologies show how environmental and social goals can be aligned more deliberately. Edible landscapes, multifunctional green spaces, and park systems coordinated with transport and pedestrian-safety planning can enhance thermal comfort, food value, connectivity, and everyday usability, particularly for groups that are often overlooked in conventional park provision (Coban and Demiroglu 2020; Paslawski and Rudnicki 2021; Perera *et al.* 2021; Ghomi and Hussein 2023; Muhammad 2025; Faradilla 2018).

Overall, Table 2 shows that equity in ecological urban parks is a multidimensional question. Fair provision requires attention to distribution, mobility, safety, cultural relevance, and governance, not simply to the number of parks on a map.

Participatory Design and User Engagement

The third theme concerns participatory design and user engagement. The literature suggests that ecological urban parks are increasingly shaped through combinations of community participation, digital monitoring, and data-driven planning. These approaches seek to improve design responsiveness,

Table 2. Equity metrics used to assess access to urban parks

No	Study	City / Region	Demographics / Focus	Equity Tool / Method	Key Implication
1	Wang <i>et al.</i> (2022)	Shanghai, China	Socio-economic strata & citizenship	Pluralistic EJ framework	Foreign & blue-collar groups face park injustice
2	He <i>et al.</i> (2024)	Taiyuan, China	Vulnerable groups	Gini, Lorentz, Ridge regression	Community parks most inequitable – urban-rural gaps
3	Sharma <i>et al.</i> (2025)	Surrey, Canada	Equity-deserving residents	Focus groups + GIS	52% in 15-min areas; infrastructure & safety crucial
4	Petrova Antonova <i>et al.</i> (2025)	Sofia, Bulgaria	15-min city walkability	Accessibility Index + Shannon, Simpson	Large intra-district gaps; grades POI richness
5	Zhang <i>et al.</i> (2023)	Guangzhou, China	General population	Improved 2SFCA (multi-entrance)	Fringe zones low access; entrances crucial
6	Guo <i>et al.</i> (2020)	Harbin, China	Elderly residents	ISEE framework	Non-motor trips equitable; district parks optimal
7	Cucca <i>et al.</i> (2023)	Global meta-analysis	Economically vulnerable	Quantitative + qualitative meta-review	Green gentrification linked to parks & NBS
8	Coban and Demiroglu (2020)	Kilis, Turkey	Urban residents	Edible-landscape survey	Edible landscapes reduce heat, enhance community
9	Paslawski and Rudnicki (2021)	Polish city centre	Car commuters	Flexible P&R design study	Phased P&R enhances comfort & modal shift
10	Perera <i>et al.</i> (2021)	Colombo, Sri Lanka	Private-vehicle users	Discrete-choice experiment	Walking distance critical for P&R uptake
11	Ghomi and Hussein (2023)	Hamilton, Canada	Collision hotspots	Bayesian SEM	Amenities predict pedestrian safety inequities

Table 3. Participatory and smart-planning approaches in urban park design

No	Technology / Approach	Case Study (Locale)	Scale	Reported Benefit	Implementation Barrier
1	Big-data-assisted park-city planning	Jinzhai County, China (Hong <i>et al.</i> 2022)	City	Data-driven height & landscape control	Data integration, governance complexity
2	IoT sensor-based spatial system	Qingdao ecological parks (Luo 2022)	City-wide	Smart detection guides layout	Standardizing sensor management
3	Improved GoogLeNet vegetation recognition	Sci-innovation park, China (Xie 2024)	Park	92.9% image accuracy	Compute demand at large scale
4	Ecological strategy in smart-city space	Multiple Chinese cities (Che 2021)	City	Integrates ICT with ecological layout	Bridging planning, ecological data
5	Coupled transit & P&R network model	Barcelona, Spain (Pallarès, 2025)	Metro region	Reduces general costs by 4.6%	Geographic constraints, ring siting
6	Transdisciplinary rewilding Garden City	Global conceptual (Langenheim and Yu 2023)	Conceptual	Refines garden-city vision via ecology	Complexity of large-scale rewilding
7	Urban-axis spatial shaping	Bistrița-Beclean, Romania (Tătar 2023)	Corridor	Promotes sustainability transitions	Diverse socio-economic contexts
8	Eco- Park component prioritization (Delphi + TOPSIS)	Alborz, Iran (Noorzadeh 2023)	Eco- Park	Clear criteria for sustainable design	Biodiversity management, funding

Table 4. Integrated typologies of resilient urban parks

No	Author (Year)	Engagement Method	Cultural / Health Benefit	Measurement Approach	Design Insight
1	Puddle (2023)	Play advocate & POpTED case study	Risky play → child well-being	Practitioner narrative	Enable play beyond playgrounds
2	Soares <i>et al.</i> (2022)	Practitioner interviews	Creative campus spaces	Thematic analysis	Address research-practice gaps
3	Morabito (2020)	Reflective landscape analysis	Democratic urban landscapes	Comparative project review	Perceived areas shape eco-aesthetics
4	Tahroodi and Ujang (2022)	Space-syntax + GIS + observations	↑ Passive social interaction	Correlation & combo-charts	Path accessibility predicts contact
5	Petryshyn <i>et al.</i> (2022)	Case studies historic cities	Local identity & image	Graphic attractiveness index	Geoplastics & heritage fusion
6	Gavrilidis <i>et al.</i> (2024)	Surveys (Iran vs Romania)	Tailored cultural ES	Cluster & stats analysis	No one-size-fits-all green space
7	McCarthy & Russo (2023)	UK citizen survey + interviews	Stewardship ↑ ecosystem services	Mixed methods	Multifunctional NBS + civic care
8	Liu X. <i>et al.</i> (2023)	Multi-source data (space-psych-behav)	Landscape aesthetic & satisfaction	Coupling-coordination model	Address 'high coupling-low coord.' Gaps
9	Wan <i>et al.</i> (2024)	PPGIS + regression (Dujiangyan)	Health restoration in blue-green space	Macro-micro analysis	Park-community structure optimization

operational efficiency, and long-term stewardship by linking ecological data with user experience and local knowledge (Hong *et al.* 2022; Luo 2022; Xie 2024).

Smart technologies can support this shift, but they do not replace governance. Big-data analytics, IoT-based monitoring, and AI-assisted vegetation recognition provide new tools for spatial optimisation and adaptive management, yet inclusive planning still depends on institutions that can interpret data, coordinate stakeholders, and translate evidence into action. Studies using Delphi techniques, participatory modelling, and integrated transport-park planning show that participatory processes remain essential for building legitimacy and contextual fit, even when implementation is challenged by funding limits, institutional fragmentation, and uneven local capacity (Noorzadeh 2023; Pallarès 2025; Langenheim and Yu 2023).

Table 3 therefore suggests a consistent lesson: participatory design is most effective when technological systems and community engagement are treated as

complementary rather than competing modes of park governance.

Park Typologies and Integrated Design Models

The final thematic cluster examines park typologies and integrated design models. Rather than asking only whether parks perform well environmentally, these studies consider how different spatial formats bring together ecological, cultural, educational, recreational, and health-related functions within a coherent design strategy.

Several studies emphasise flexibility and user-centredness. Research on risky or unstructured play, creative campus landscapes, and democratic urban space shows that park design can support wellbeing and social learning when it accommodates exploratory use, stakeholder diversity, and evolving patterns of occupation rather than prescribing a single model of behaviour (Puddle 2023; Soares *et al.* 2022; Morabito 2020).

Spatial configuration and cultural integration are equally important. Studies using space syntax, GIS, observation, and heritage-based analysis show that path structure, visual coherence, and culturally meaningful landscape elements strongly influence social interaction, attachment, and everyday use (Tahroodi and Ujang 2022; Petryshyn *et al.* 2022).

Comparative work also demonstrates that context matters. Cultural ecosystem services are valued differently across social and regional settings, and multifunctional nature-based solutions gain traction when they resonate with local expectations of stewardship, identity, and public benefit. This means that imported park models may perform poorly if they are not translated into local socio-cultural terms (Gavrilidis *et al.* 2024; McCarthy and Russo 2023).

Integrated analytical frameworks strengthen this point by showing how aesthetics, behaviour, and ecological performance are linked. Coupling-coordination models and participatory GIS analyses indicate that public acceptance and restorative value are higher when ecological functionality is matched by spatial legibility, comfort, and perceived safety (Liu X. *et al.* 2023; Wan *et al.* 2024).

Table 4 synthesises these findings and suggests that resilient park typologies are rarely single-purpose. Their strength lies in the deliberate integration of environmental performance with cultural meaning, user experience, and social inclusion.

DISCUSSION

The discussion brings these themes together by asking not only what ecological urban parks can do, but under what design and governance conditions they perform most effectively. Across the reviewed studies, parks emerge as critical infrastructures for reducing heat stress, managing stormwater, improving air quality, and supporting biodiversity, confirming their central role in climate-resilient urban systems (Hasan and Haider 2023; Yao X. *et al.* 2022). At the same time, the literature shows that ecological effectiveness alone is insufficient: parks must also be spatially just, culturally legible, and institutionally governable. This broader reading is consistent with resilience theory, which views adaptive capacity as the product of environmental, social, and institutional relations rather than of technical performance alone (Su *et al.* 2022; Myalkovsky *et al.* 2023).

Climate Resilience and Design Sensitivity

One of the clearest insights concerns design sensitivity. Cooling and hydrological benefits vary markedly according to park size, canopy structure, ground permeability, and the presence of water. The oft-cited finding that parks of approximately 1.08 ha can produce strong thermal benefits is useful, but it should not be mistaken for a universal threshold. Likewise, the thermal value of trees between 10 and 15 metres in height illustrates the importance of vegetation structure, not a one-size-fits-all specification. Read together, the evidence suggests that climate-resilient parks must be designed through local ecological diagnosis, iterative evaluation, and adaptation to urban morphology rather than through generic templates (Yao X. *et al.* 2022; Abdallah *et al.* 2025).

Spatial Equity and Environmental Justice

A second major insight is that climate resilience and environmental justice are inseparable. Studies from Shanghai, Taiyuan, Surrey, and other cities show that accessibility is patterned by income, citizenship, age, mobility, and urban location. Groups that are already socially or spatially marginalised are often the least well served by high-quality green space, even where aggregate park provision appears adequate (Wang *et al.* 2022; He *et al.* 2024; Sharma *et al.* 2025).

These findings reinforce the claims of urban political ecology and spatial justice: environmental amenities are shaped by power, investment, and planning priorities, not distributed neutrally through the city. They also show that equity cannot be reduced to physical distance. Entrance design, safety, infrastructure quality, and displacement risk all influence whether parks function as public goods. Without explicit equity safeguards, climate adaptation projects may reproduce exclusion or contribute to green gentrification (Facundes *et al.* 2024; Sykes 2025; Cucca *et al.* 2023).

Participatory Design, Smart Technologies, and Governance

The review also highlights the promise and limits of smart and participatory park governance. Big data, IoT systems, and AI-based ecological monitoring can improve observation, diagnosis, and adaptive management, especially when cities need timely information about vegetation, use patterns, or environmental conditions (Hong *et al.* 2022; Luo

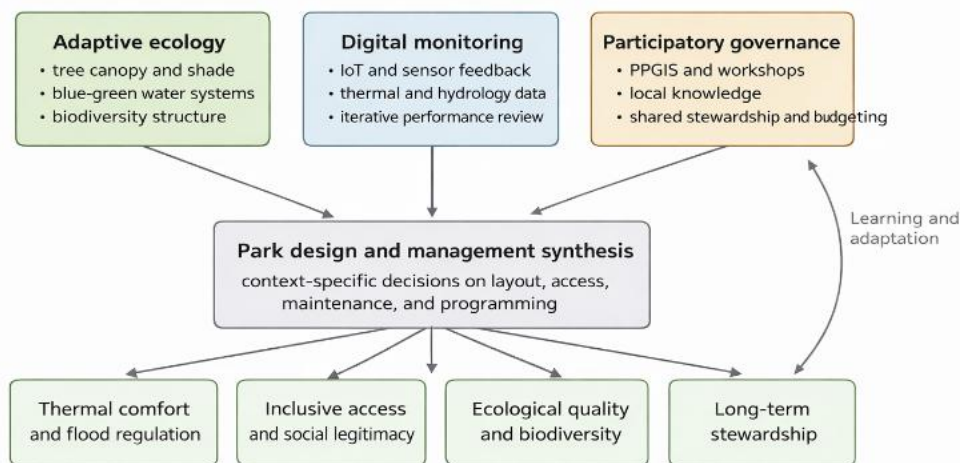


Figure 3. Integrated framework linking adaptive ecology, participatory governance, and digital monitoring in future urban parks. Source: synthesized from Hong *et al.* (2022), Luo (2022), Xie (2024), Mohammadi Tahroodi and Ujang (2022), McCarthy and Russo (2023), and Noorzadeh (2023)

2022; Xie 2024). Figure 3 summarises this convergence of adaptive ecology, participatory governance, and digital monitoring. Yet the literature makes clear that technological sophistication alone does not guarantee better parks. The value of these tools depends on governance capacity, long-term maintenance, interpretive expertise, and the extent to which communities are meaningfully involved in decision-making (Kong *et al.* 2022).

Implementation barriers are therefore substantial. Data integration across platforms, high operating costs, sensor standardisation problems, and uneven municipal capacity can all restrict the practical use of digital systems. These challenges matter because they introduce a new layer of inequality: better-resourced municipalities are more able to adopt advanced tools, while resource-constrained cities may struggle to sustain them over time.

Participatory methods partly address this problem by grounding design in local knowledge and everyday experience. Approaches such as PPGIS, stakeholder workshops, and Delphi-based prioritisation help translate user preferences into spatial decisions and strengthen procedural justice, although they also require time, facilitation, and institutional commitment to avoid becoming symbolic rather than substantive (Tahroodi and Ujang 2022; McCarthy and Russo 2023; Noorzadeh 2023).

Park Typologies, Cultural Values, and Multifunctionality

Park typologies provide another important lesson. Designs that combine cultural ecosystem services, educational functions, flexible recreation, and habitat value tend to support higher user satisfaction and stronger stewardship than narrowly programmed or purely ornamental spaces. In this sense, multifunctionality is not only an ecological principle but also a governance and social-use principle (Gavrilidis *et al.* 2024; McCarthy and Russo 2023).

Equally important, the literature rejects universal solutions. Cross-cultural work shows that meanings attached to green space vary across communities, while analytical studies demonstrate that public acceptance depends on aesthetics, accessibility, and perceived safety as much as on ecological performance. This supports landscape-architecture arguments for close-to-nature design that is context-sensitive rather than formulaic (Gavrilidis *et al.* 2024; Liu X. *et al.* 2023; Wan *et al.* 2024; Mosler and Hobson 2021).

Methodological and Geographic Limitations

Methodologically, however, the evidence base remains uneven. Many studies rely on remote sensing, simulation, or scenario modelling, which are valuable for comparison but less able to demonstrate long-term social and ecological outcomes on the ground. This limitation is especially visible in studies of cooling, flood control, and sponge-city performance, where modelled potential often exceeds observed post-implementation evaluation (Ji and Rao 2023; Liu J. *et al.* 2021).

The geography of the literature is also narrow. East Asia, parts of Europe, and North America dominate the evidence base, while rapidly urbanising regions in the Global South remain underrepresented. This imbalance matters because climate risk, governance arrangements, and informal urban conditions vary widely across world regions, limiting the global transferability of current design guidance.

Integrating Climate Resilience and Equity Agendas

Future research should therefore move beyond parallel treatment of resilience and equity. More explicit analysis is

needed on how design strategies, governance instruments, and investment models can advance both ecological performance and environmental justice at the same time. Longitudinal and mixed-method studies would be especially useful for tracing how parks perform after implementation and how benefits are distributed over time.

Overall, this review reinforces the value of combining resilience theory, urban political ecology, and participatory landscape architecture. Ecological urban parks are most effective when they are simultaneously biophysically functional, socially inclusive, culturally resonant, and institutionally maintainable.

In practical terms, this means that climate-resilient park planning should prioritise context-sensitive ecological design, explicit equity criteria, participatory governance, and stronger post-occupancy evaluation. These conditions determine whether urban parks operate as durable climate infrastructures or remain isolated green amenities.

CONCLUSION

This review set out to examine how ecological urban parks function as instruments of climate resilience and which design and equity principles strengthen their sustainability outcomes. The synthesis shows that ecological urban parks can substantially moderate urban heat, improve stormwater management, enhance environmental quality, and support biodiversity, but that these benefits are strongly conditioned by local design variables such as vegetation structure, park size, water integration, and spatial configuration. The review also shows that resilience outcomes are weakened when access, safety, cultural relevance, and participation are unevenly distributed. In other words, parks contribute most effectively to urban sustainability when ecological performance is coupled with spatial justice and inclusive governance. Participatory and digitally supported management approaches can strengthen this coupling, although their success depends on institutional capacity and long-term resources. The evidence therefore supports an integrated design agenda in which ecological urban parks are planned as multifunctional infrastructures rather than as isolated recreational spaces. Future research should expand empirical work in underrepresented regions, test modelled claims through longitudinal evaluation, and examine more directly how climate adaptation and equity goals can be advanced together.

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