

Global evidence linking development-driven urban actions with climate change mitigation and adaptation outcomes

Wenjia Cai

wcai@tsinghua.edu.cn

Tsinghua University <https://orcid.org/0000-0002-4436-512X>

Han Zhao

Tsinghua University

Alexander Baklanov

University of Copenhagen

Aliyu Barau

Bayero University Kano <https://orcid.org/0000-0002-1259-3929>

Frederic Bonou

National University of Science, Technology, Engineering and Mathematics

Sorin Cheval

Meteo Romania

Felix Creutzig

Bennett Institute for Innovation and Policy Acceleration, University of Sussex, UK

Congkai Hong

Tsinghua University

Victor Indasi

Clean Air Fund, London, UK

Rui Ito

Research Institute for Earth and Information Sciences, Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan <https://orcid.org/0000-0002-3170-0232>

Mingyu Lei

Tsinghua university

Ruiyao Li

Tsinghua university

Weiye Liao

Tsinghua university

Yihui Liu

Tsinghua university

Cameron T. McLean

Biodiversity Management Department, eThekweni Municipality, Durban, South Africa

Elinorata Mbuya

Ardhi University

Rita Nogherotto

Institute of Atmospheric sciences and Climate, CNR-ISAC, Italy

Shaurya Patel

Climate Institute, Ahmedabad University, Navrangpura, Ahmedabad, India

Minal Pathak

Ahmedabad University <https://orcid.org/0000-0002-9474-0485>

Géraldine Pflieger

Institute for Environmental Science and Department of Political Science and International Relations,
University of Geneva

Giulio Pistolesi

School of Environment, Tsinghua University, Beijing, China

Debra Roberts

School of Life Sciences, University of KwaZulu-Natal <https://orcid.org/0000-0002-9595-4792>

Samantha Sharpe

Institute for Sustainable Futures, University of Technology Sydney, Sydney, Australia

<https://orcid.org/0000-0001-8423-2519>

Andrew Sudmant

Edinburgh Climate Change Institute

Jinjie Sun

Tsinghua university

Yuhan Zhu

Tsinghua university

Article**Keywords:**

Posted Date: June 29th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9856126/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: There is **NO** Competing Interest.

1 ***Global evidence linking development-driven urban***
2 ***actions with climate change mitigation and***
3 ***adaptation outcomes***

4 Han Zhao^{1,2}, Alexander Baklanov³, Aliyu Barau⁴, Frederic Bonou⁵, Sorin Cheval⁶,
5 Felix Creutzig^{7,8}, Congkai Hong^{1,2}, Victor Indasi⁹, Rui Ito¹⁰, Mingyu Lei^{1,2}, Ruiyao Li^{1,2},
6 Weiyi Liao^{1,2}, Yihui Liu^{1,2}, Cameron T. McLean¹¹, Elinorata Mbuya¹², Rita
7 Nogherotto¹³, Shaurya Patel¹⁴, Minal Pathak¹⁴, Géraldine Pflieger¹⁵, Giulio Pistolesi¹⁶,
8 Debra C. Roberts^{17, 18}, Samantha Sharpe¹⁹, Andrew Sudmant²⁰, Jinjie Sun^{1,2}, Yuhan
9 Zhu^{1,2}, Wenjia Cai^{1,2}

- 10 1. *Department of Earth System Science, Institute for Global Change Studies, Ministry of*
11 *Education Key Laboratory for Earth System Modeling, Tsinghua University, Beijing, China*
12 2. *Tsinghua-Rio Tinto Joint Research Centre for Resources, Energy and Sustainable*
13 *Development, International Joint Laboratory on Low Carbon Clean Energy Innovation,*
14 *Laboratory for Low Carbon Energy, Tsinghua University, Beijing, China*
15 3. *Climate and Geophysics, Niels Bohr Institute, University of Copenhagen, Denmark*
16 4. *Department of Urban and Regional Planning, Bayero University Kano, Nigeria*
17 5. *National University of Science, Technology, Engineering and Mathematics, Benin*
18 6. *National Meteorological Administration, Bucharest, Romania*
19 7. *Bennett Institute for Innovation and Policy Acceleration, University of Sussex, UK*
20 8. *Potsdam Institute for Climate Impact Research, Berlin, Germany*
21 9. *Clean Air Fund, London, UK & Institute for Data Science, Curtin University, Perth,*
22 *Australia*
23 10. *Research Institute for Earth and Information Sciences, Japan Agency for Marine-Earth*
24 *Science and Technology, Yokohama, Japan*
25 11. *Biodiversity Management Department, eThekweni Municipality, Durban, South Africa*
26 12. *Institute of Building Research, Ardhi University, Dar es Salaam, Tanzania*
27 13. *Institute of Atmospheric sciences and Climate, CNR-ISAC, Italy*
28 14. *Climate Institute, Ahmedabad University, Navrangpura, Ahmedabad, India*
29 15. *Institute for Environmental Science and Department of Political Science and International*
30 *Relations, University of Geneva*
31 16. *School of Environment, Tsinghua University, Beijing, China*
32 17. *School of Life Sciences, University of KwaZulu-Natal, Durban, South Africa*
33 18. *Faculty of Geo-Information Science and Earth Observation, University of Twente,*
34 *Enschede, Netherlands*
35 19. *Institute for Sustainable Futures, University of Technology Sydney, Sydney, Australia*
36 20. *Edinburgh Climate Change Institute, University of Edinburgh, Edinburgh, United Kingdom*
37

Abstract :

Urban actions are central to achieving global climate goals, yet existing research prioritizes climate goals and overlooks the real-world motivations that drive decisions and shape mitigation and adaptation outcomes, potentially limiting synergies and slowing urban climate progress. Here we systematically evaluate 5,610 studies across over 750 cities using an AI-assisted knowledge extraction framework, shifting from climate-first to framing climate as a co-benefit of development-driven actions. We find that global evidence concentrates on nature-based, energy, and transport actions (54% of total). However, primary motivations vary from a green transition in Europe and Asia to urban resilience in Small Islands. Some actions (e.g., blue–green infrastructure) suggest potential broad applicability, while others appear in few cities, and some even show divergent climate outcomes depending on city type. We identify key barriers, such as economic-political conflicts, to aligning development and climate goals by examining underreported failure cases. Our study advocates for carefully-designed urban actions and leveraging local development agendas as entry points for climate co-benefits.

1 Introduction

Cities are widely recognized as central actors in global climate governance, and over the past two decades thousands have made climate-related commitments^{1,2}. A growing literature has examined urban climate actions in domains such as transport³, health⁴, land use and nature-based solutions⁵, adaptation^{6,7}, mitigation⁸, governance arrangements and policy instruments^{9,10,11}, while large-scale assessments by the IPCC have further strengthened the evidence of urban climate options^{12,13}. Most literature adopts a climate-first lens, treating development as a co-benefit. In practice, many urban actions that ultimately affect emissions, adaptive capacity or climate resilience are rarely designed for climate goals; instead, they are anchored in immediate development priorities, such as basic services supply, poverty alleviation, risk management¹⁴ and housing affordability^{15,16}, which vary by city type, development stage, history, geography, and institutional settings^{17,18}. It is therefore necessary to examine how local, development-oriented actions shape climate change mitigation and adaptation outcomes. Research in this area remains highly fragmented: findings are dispersed across isolated cases and lack comparative analytical frameworks, making it difficult to identify which actions are most likely to yield positive climate outcomes across cities. This gap limits practitioners' ability to leverage development agendas as strategic entry points for accelerating mitigation and adaptation, potentially limiting potential synergies and slowing urban climate progress¹⁹.

To address this gap, we developed a methodological framework (see 4. Method and *Figure 5*) that integrates an AI-assisted knowledge extraction pipeline to synthesize global evidence linking city types, context-specific development topics, urban actions, and their climate change mitigation and adaptation outcomes. While climate and development actions often overlap, this study begins from a development-oriented perspective identifies studies framed around urban development challenges (e.g., congestion) and then filter for those with documented climate impacts, thereby capturing climate-linked, development-driven urban actions. First, we conducted a systematic literature search in the Scopus and Web of Science databases, retrieving 58,047 peer-reviewed articles after deduplication. From this corpus, 5,610 urban studies were identified as eligible ([see Table S2 for detailed eligibility rules](#)), of which 2,419 could be directly linked to specific cities, while the remainder are generic urban studies

at city levels or urban areas that are not spatially specific. These studies document urban actions, policies, or solutions centered on specific development topics and examine their climate change mitigation and/or adaptation outcomes. Then, key information was extracted using a two-stage pipeline. In the first stage, three large language models (Gemini-2.5 Pro, Qwen-3, and DeepSeek-V3.2) independently extracted key phrases from each study across three rounds. The extracted phrases were clustered using BERTopic, with 11 local development-oriented topics finalized and consolidated through researcher alignment (see [Figure S1 & Table S5](#)). We identified 48 sub-categories of urban actions and aggregated them into 10 major categories (see [Table S6](#)). In the second stage, the same procedure was applied to consistently assign studies to the identified action categories and development topics, while simultaneously extracting city names, country names, and related climate outcomes of urban actions. Finally, all identified cities were mapped to the Global Human Settlement Urban Centre Database (GHS-UCDB) ²⁰ to obtain standardized city attributes, covering more than 750 cities in the world (see 4. Method for details).

Moving beyond the climate-centric view, this study establishes an evidence base that reveals the differentiated development priorities of urban practitioners, maps the heterogeneous climate outcomes of urban actions across regions, and documents the supporting evidence. In addition to identifying actions with cross-city evidence of climate co-benefits, we foreground the rationale behind examples of failure as lessons on implementation gaps. We also highlight the importance of enriching research on local actions and cross-city comparative research to expand this evidence foundation, ultimately helping to turn actions centered on local development topics into pathways for climate mitigation and adaptation. Our work aims to create the framework for leveraging development-driven actions, supported by scientific evidence, to be mobilized for achieving climate outcomes in urban practice.

2 Results

2.1 Urban actions reflect distinct local developmental profiles

Our results indicate evidence linking urban actions with climate outcomes continues to grow worldwide (*Figure 1a*). The evidence base is broad and diverse, yet its spatial distribution remains highly uneven, with relatively more cases reported in a small number of megacities, including Beijing, New York, and Shanghai (>30 cases

each) (*Figure 1a*). This distribution reflects research and reporting bias toward data-rich and global mega cities, as documented in previous research^{11,21}.

From a development perspective, global evidence primarily focuses on "Green Energy and Economic Transition" (19%), "Water Security and Reliability" (16%), and "Transport Accessibility and Efficiency" (15%), while topics like "Food Security and Sustainable Agriculture" and "Social Equity and Inclusive Services" constitute significantly smaller proportions (~2% each). This underrepresentation highlights critical evidence gaps, particularly in regions where food security and equity are central to urban resilience. Over time, studies related to "Green Energy and Economic Transition" have demonstrated substantial growth, whereas the proportions of resource efficiency and water security and reliability have declined (*Figure 1d*), a trend reflecting a growing urban emphasis on clean energy transitions worldwide. Regionally, evidence from Europe, Africa, and Asia predominantly emphasizes "Green Energy and Economic Transition" (26%, 23%, and 18%, respectively), reflecting the central role of energy transitions in their development. Australia and North America focus more on "Water security and reliability" (28% and 25%), followed by "Transport accessibility and efficiency" (15% and 13%), highlighting their infrastructure- and service-oriented concerns. South America exhibits a greater proportion of evidence related to "Resource Efficiency and Circularity" in contrast to North America (16% vs 6%), whereas Small Islands predominantly emphasize "Urban Resilience and Risk Reduction" (35%) (*Figure 1b*), consistent with their high climate exposure (see [Figure S2\(a\)](#)). Additional specific patterns emerge at the national level, for instance, Japan and some countries in Southeast Asia and focus more on urban resilience, whereas cities in India, Türkiye, and Colombia exhibit greater emphasis on transport accessibility and sustainable infrastructure (see [Figure S3](#)), reflecting the heterogeneity of their realities and challenges.

Urban actions are primarily categorized into three major categories: nature-based and ecosystem (19%), energy (19%), and transport and mobility (16%), collectively representing approximately ~54% of the total (*Figure 1e*). Over time, the number of studies in these three major categories of action has increased globally, while water management and waste and circular economy have declined. Meanwhile, land use & spatial planning and construction & buildings together account for 14% of actions, a

share that has remained relatively stable over time. This trend likely reflects a shift in research focus and the distribution of research funding. While these categories dominate globally, regional differences in action are reflected in the evidence. Africa and South America frequently focus on nature-based and ecosystem (22% and 23%) and energy solutions (26% and 16%), followed by water management actions (14% and 17%), while Europe, Asia, and North America by comparison exhibit a greater share of transport & mobility actions (19%, 14%, and 14%, respectively) (*Figure 1c*). In Asia, particularly in China, actions integrating knowledge and governance are more frequently reported, reflecting the central role of institutional coordination in action in these cities. Australia places a greater focus on nature-based and ecosystem actions (28%) and water management (20%), whereas Small Islands concentrate their actions in resilience enablers/tools and waste and circular economy, reflecting the climate vulnerabilities and resource constraints (see [Figure S2\(b\)](#)). In terms of evidence gaps, fewer than 100 studies are reported for each action category in Africa, South America, and Oceania, while small island contexts are particularly underrepresented, with no more than 4 cases per category (see [Figure S4](#)). Even when considering per capita case coverage, small islands and Africa remain the fewest (see [Figure S5](#)).

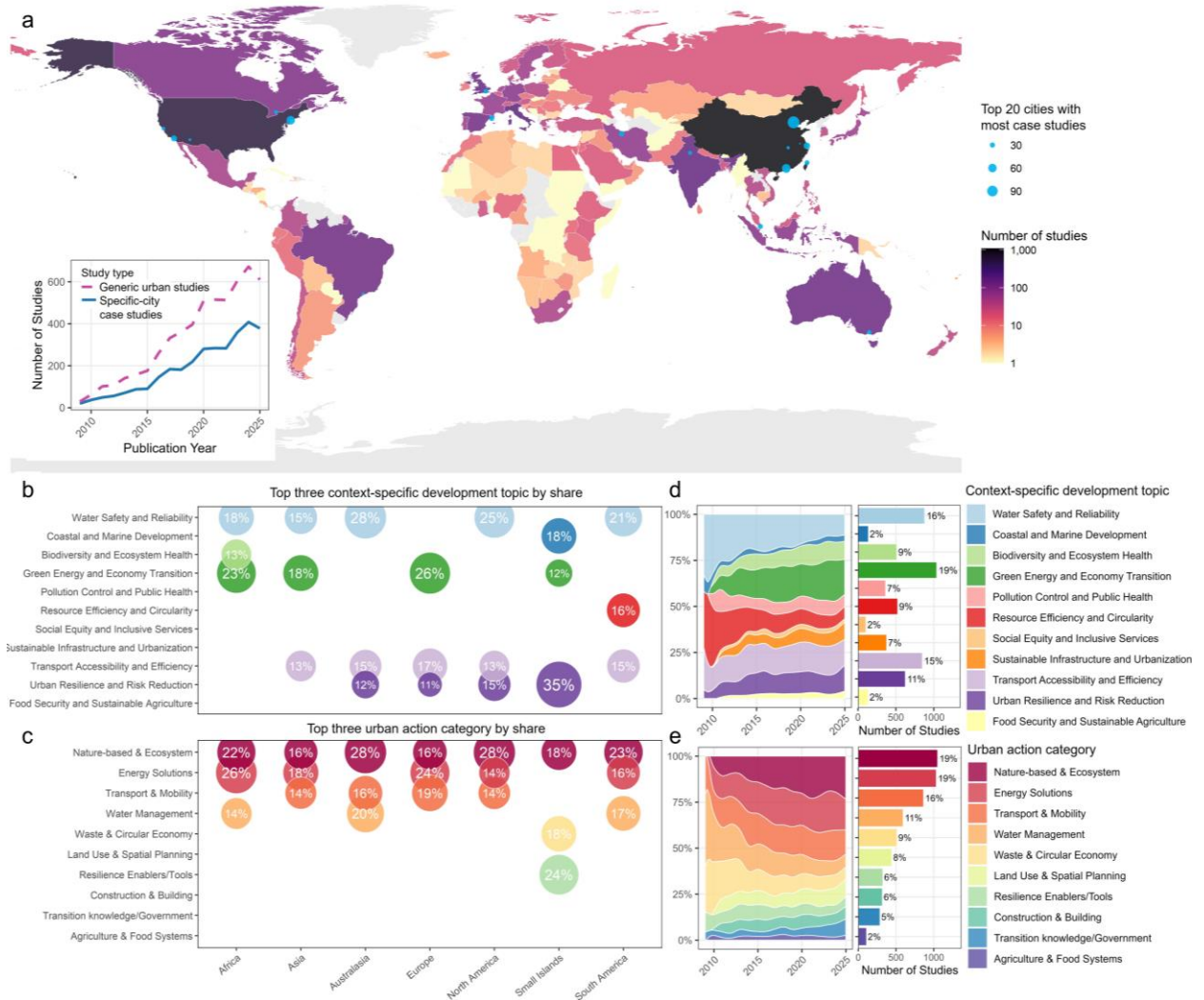


Figure 1 Spatio-temporal patterns of studies on development-oriented urban actions with evidence on climate outcomes. (a) Geographic distribution of evidence. Country-level case counts are shown by colour intensity (darker = more cases). Blue circles, sized by case count, mark the 20 cities with the most specific-city studies. The lower-left inset plots growth trends, split by specific-city versus generic urban studies. The top three (b) context-specific development topics and (c) urban action categories with most case studies by within-region share, bubble size and percentages indicate the share, only the top three highest-share per region are shown. Trends in proportional streamgraphs of studies and their share of the total number of studies by (d) context-specific development topics and (e) major category of urban actions.

Furthermore, to better support practical decision-making across cities under a consistent framework, we adopt the global city typology from Montfort, et al.¹⁷, build on the city types referred in IPCC AR6¹³ and Mahtta, et al.²². Cities are categorized into four types: Emerging, Rapid Growing, Established, and Megacities. We then examined how urban development topics and actions are associated with average city characteristics, identifying differences of cities in which each topic or action appears (see Section 4.3.2 for details).

In specific-city studies, established cities and megacities account for the largest share; while emerging and rapidly growing cities are represented by fewer studies and are more frequently linked to the development topics “Resource Efficiency and Circularity” and “Biodiversity and Ecosystem Health,” respectively (*Figure 2a*). Our results further show that differing environmental conditions, resource endowments, and capacity levels shape distinct preferences in development topics and urban actions by cities. For development topics, “Pollution Control and Public Health” and “Water Safety and Reliability” are associated with higher Subnational Human Development Index (SHDI) (~0.83), reflecting their stronger urban service delivery need. In contrast, “Resource Efficiency and Circularity” and “Food Security and Sustainable Agriculture” tend to occur in cities with the lowest SHDI (0.75 and 0.71) and smaller populations but high GDP growth, reflecting a primary concern with basic resources and food provision. “Social Equity and Inclusive Services” appears in cities with high population growth (1.9%) and low per-capita emissions (2.6 t CO₂e), whereas “Sustainable Infrastructure and Urbanization” and “Transport Accessibility and Efficiency” concentrate in cities with higher emissions (4.7 and 4.6 t CO₂e) and GDP above the global mean (~23,000 PPP), suggesting distinct motivations between earlier-stage cities and more established ones (*Figure 2a*).

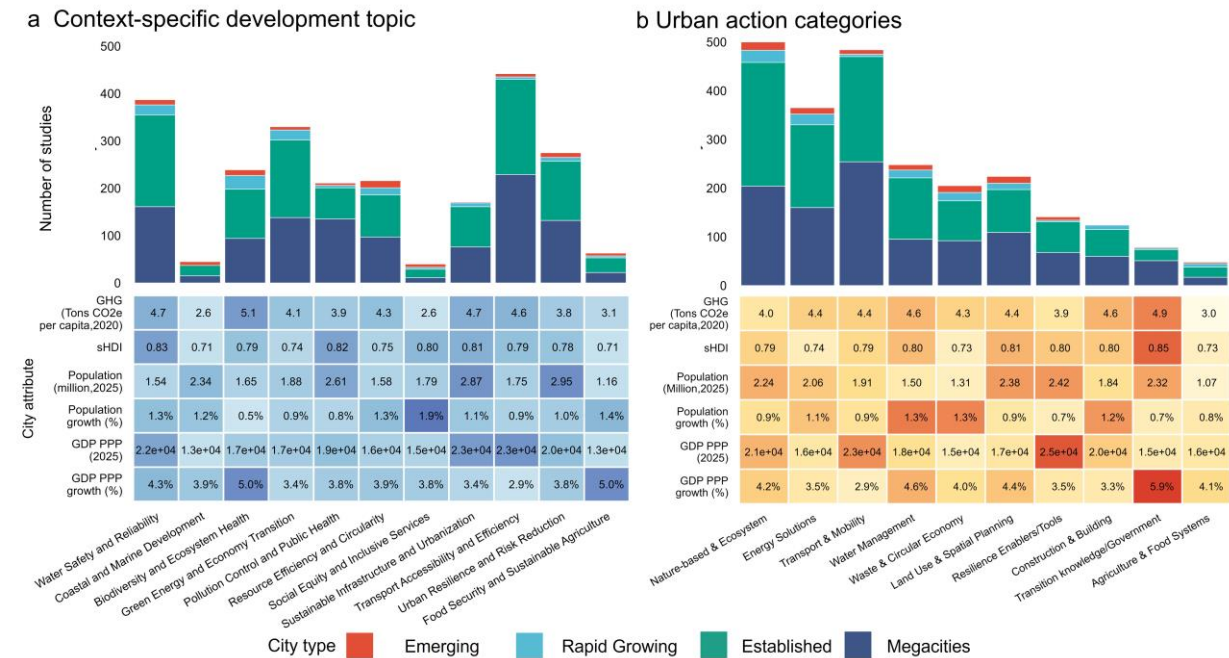


Figure 2 Characteristics of cities across urban actions categories and context-specific development topics. For each category, the upper panel shows the number of specific

city studies associated with four city types, by (a) context-specific development topics and (b) urban action categories. The lower panel summarizes the average characteristics of cities covered by the evidence, including population-weighted average CO₂ emissions and SHDI in 2020, total population and GDP in 2025, population growth and GDP growth from 2000-2025. Colors indicate differences from the overall mean (z-score).

The distribution of evidence across urban action categories follows broadly similar patterns across city types, with nature-based & ecosystem, transport & mobility, and energy solutions most frequently reported in all city types, although emerging cities report relatively fewer transport & mobility actions (*Figure 2b*). Core-sector actions (energy, transport, water, waste) display city characteristics similar to their corresponding development topics because these actions directly serve as operational instruments for addressing the same sectoral priorities. In contrast, “Transition Knowledge and Governance” actions appear more in larger populations (2.32 million), higher SHDI (0.85), higher emissions (4.9 t CO₂e per capita), and higher GDP growth (5.9%) cities, reflecting stronger institutional frameworks and greater capacity for knowledge interventions. Resilience tools are concentrated in cities with both higher GDP (~25,000 PPP) and larger populations (2.42 million), indicating both greater financial capacities to invest in urban resilience and higher population exposure to hazards.

Generally, the patterns of urban actions and underlying development topics in our results reflect not only the influence of local environmental conditions, resource endowments, and capacity levels by city types, but also the combined influence of scholarly incentives. Accordingly, the uneven distribution of urban actions is shaped by underlying differences in urban characteristics, which are linked to variation in investment capacity and implementation conditions, rather than by simple adherence to best practices. Expanding the scope of viable urban actions evident in less developed urban areas will require strengthening funding aid and capacity building²³.

2.2 Heterogeneity and evidence breadth of local development-driven actions with climate co-benefits

Urban types and their characters shape the development topics and actions as examined earlier. The top actions by city type, identified among the 48 sub-categories of urban action with the most abundant evidence (see [Table S6 for the hierarchy of](#)

action categories), further reveal how action choices and associated climate co-benefits differ systematically by city type (*Figure 3*).

The distribution of sub-category actions shows a different pattern from that of major action categories across city types. In emerging cities, documented actions are more concentrated in waste prevention, minimization and management, as well as land use and spatial planning (22% and 17%). Their top sub-category actions are primarily linked to “Resource Efficiency and Circularity” (26%) and “Biodiversity and Ecosystem Health” (13%). Actions of rapidly-growing cities show a more dispersed but emphasis on integrated water management (15%), land use and spatial planning (13%), and green-blue infrastructure (12%), actions are primarily in terms of “Biodiversity and Ecosystem Health” (26%), "Green Energy and Economy Transition" (21%), and "Water Safety and Reliability" (21%). In these two city types, top sub-category actions such as disaster management, coastal defense, and ecosystem connectivity directly strengthen vulnerable communities, making adaptation co-benefits the immediate outcome.

In constant, top sub-category actions in established cities are more concentrated in green-blue infrastructure (25%), integrated water management (13%), and land-use planning (11%), frequently associated with “Transport Accessibility and Efficiency” (29%) and "Water Safety and Reliability" (21%). Megacities have similar patterns to established cities, yet they show a uniquely high concern for "Pollution Control and Public Health" (12%), reflecting higher environmental health and well-being concerns in these cities. The top mentioned local development-driven actions in megacities, more often reveal evidence of mitigation co-benefits, namely renewable energy and transport technology, reflecting the technical and economic advantages that enable systematic pursuit of emissions reduction in these cities.

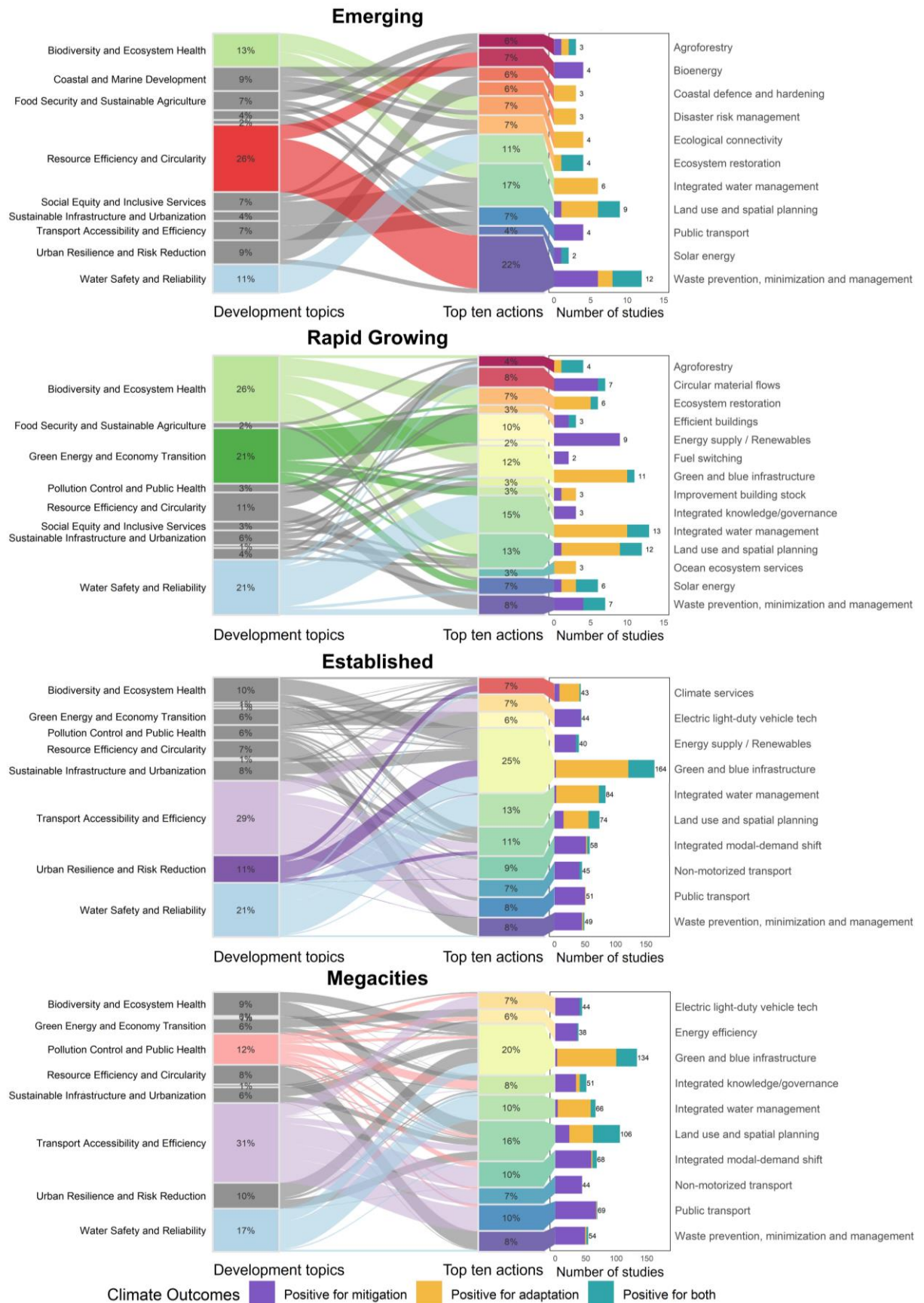


Figure 3 Evidence of local development-oriented urban actions and their climate change mitigation and/or adaptation co-benefits. Each panel represents a city type.

Flows indicate how different sub-categories of actions are linked to climate outcomes and their number of reported studies. The width of flow represents the share of peer-reviewed city specific studies reporting that action–climate impact linkage. Right-hand side, the urban actions are shown together with the number of reported studies of their climate change co-benefits. The figure shows the top ten actions with the largest evidence base for each city type, and tied actions are retained. Only the three development topics with the highest shares in the action evidence of each city type are colored to improve readability.

Looking across city types, action under Nature-based and ecosystem (i.e., Green-blue infrastructure, Ecosystem services) and Integrated water management are more aligned with adaptation co-benefits, whereas Energy solutions (i.e., Bioenergy, Solar energy) and Transport and Mobility category actions (i.e., Modal-demand shift, Electric vehicles) tend to align with mitigation co-benefits, consistent with previous research^{5,24,25}. Notably, even similar actions tend to be translated into different climate outcomes across cities, because local development conditions steer what is studied. For instance, in emerging and rapidly growing cities, where basic service gaps persist, waste management is examined largely through an adaptation lens - linked to sanitation, flood control, and informal settlements – so evidence frequently shows dual adaptation-mitigation synergies (e.g. promoting mangrove protection and carbon sequestration in Kundapura, India²⁶, enhancing urban humanitarian response and reducing methane in Port-au-Prince, Haiti²⁷). In established cities and megacities, where these gaps are already addressed, waste management is more examined from a mitigation perspective, discussing how it could help cut waste-related emissions (e.g., waste separation in Shenzhen²⁸ and reusable food containers in Seoul²⁹).

Furthermore, ranking urban sub-category actions with documented climate co-benefits by evidence volume and richness (the number of individual cities covered) across four city types, we distinguish action categories with broad documented evidence breadth from those concentrated in specific urban contexts (*Figure 4*).

In emerging cities, the most cross-city evidence is associated with waste prevention and management. Examples include Surabaya’s Takakura Home Composting³⁰ and the semi-mechanized trench in Villanueva³¹, both low-cost, decentralized approaches that have been adopted without heavy infrastructure investment. Land-use and spatial planning also span more than ten cities, while

bioenergy remains concentrated in only a few, indicating relatively higher financial or technical barriers. Rapidly growing cities show the strongest cross-city evidence for sub-category action of land-use and spatial planning, reflecting challenges in balancing rapid urbanization and environmental sustainability. By contrast, circular material flow related actions such as industrial symbiosis in Liuzhou³², show relatively higher per-city case numbers but less cross-city evidence, reflecting the specialized industrial structures and governance required for their application. In established cities, the evidence base is substantially broader, with sub-category action of green-blue infrastructure alone covering more than 100 cities, alongside a greater presence of actions such as climate services and electric light-duty vehicle technologies (e.g., well-designed integrated urban climate services (IUS) enable safe and resilient cities^{33,34}), showing a shift toward technology- and service-intensive solutions. Megacities display the widest diversity of development-oriented actions associated with climate co-benefits, the action portfolio diversifies toward technology-intensive and systemic interventions, with particularly strong evidence for public transport and knowledge- or governance-related actions, while some measures, such as shared automated electric mobility systems, are concentrated in specific cities (e.g., New York City and Austin).

Across city types, sub-category actions in green-blue infrastructure, land-use and spatial planning, and integrated water management, consistently demonstrate the most substantial evidence base and the broadest cross-city representation, with each comprising over 100 cities. The significance of these actions stems from their alignment with essential requirements for urban service provision, as also reflected across regions (see [Figure S6](#)). In contrast, practices like agroforestry and coastal zone management, while present in all urban types, the limited richness suggests they are specifically adapted to distinct geographic or socio-economic conditions.

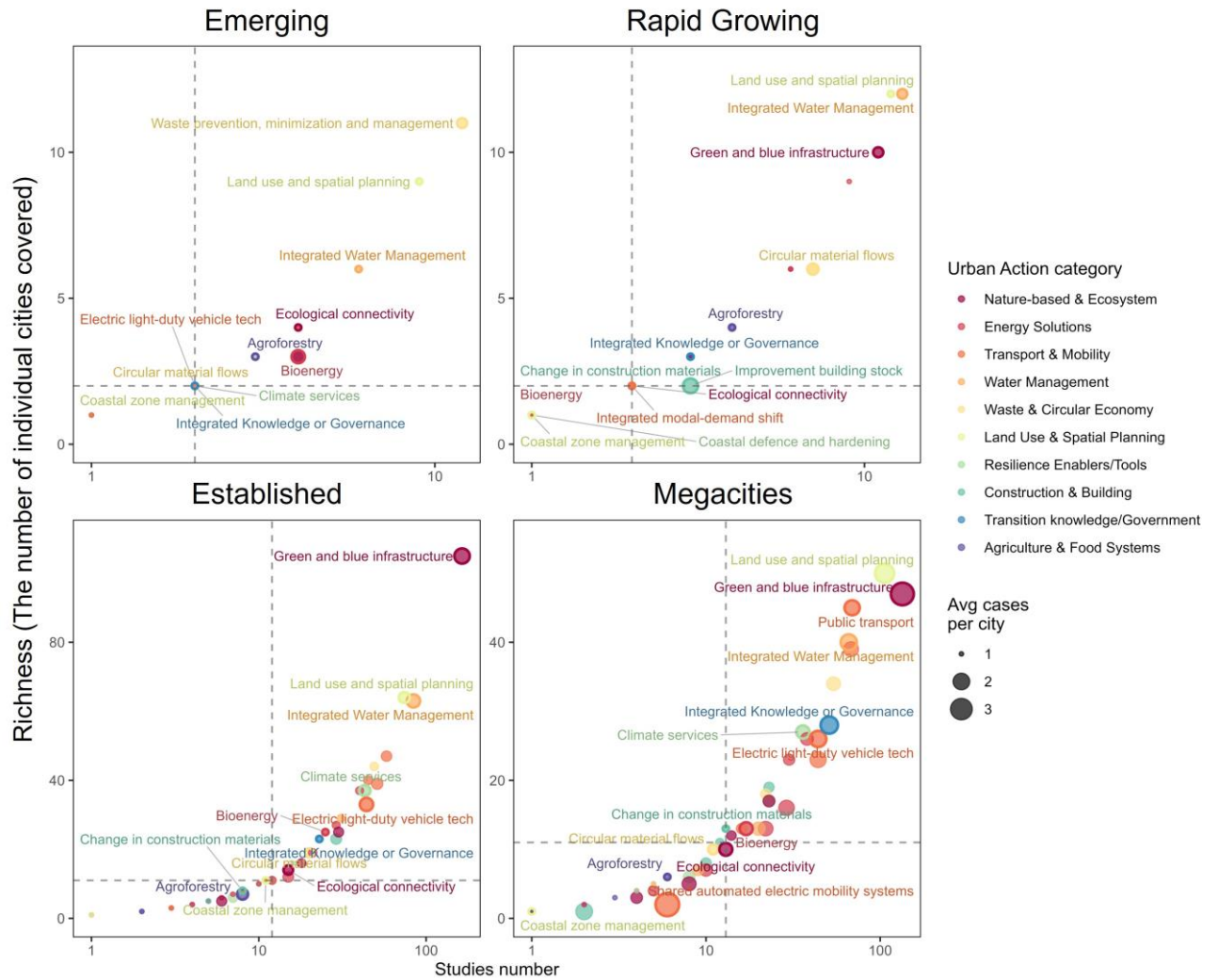


Figure 4 Cross-city-type richness of urban actions with documented climate co-benefits. Each panel shows results for one of four city types. The x-axis represents the total number of climate co-benefit cases within each city type, and the y-axis shows richness (number of individual cities covered). Each bubble represents a sub-action, with size indicating mean cases per city and color indicating urban action category. Dashed lines indicate the mean values of total cases and richness for each city type.

2.3 Insights from under-reported failure cases

Simply looking at success stories (see Section 2.2) limits our ability to truly understand the structural barriers faced by cities during action implementation; therefore, including actions associated with negative outcomes is essential. Our results show existing evidence is biased toward reported positive outcomes, with mitigation co-benefits accounting for approximately half of specific city studies, while failure or trade-offs are rarely reported (~3%, see Figure S7). Notably, these cases are most frequently reported in energy- and land-use-related actions, which together account for

44%. The causes of failure primarily stem from action barrier (57%), economic and political conflicts (53%), and technical trade-offs (39%) (*Table 1*) with weak institutional instruments and limited managerial capacity being the most frequently mentioned (48%) drivers. Among economic and political factors, prioritizing economic growth over environmental goals (62%) often leads to deviations from action objectives, such as urban sprawl converting peri-urban greenfield and agricultural land in Auckland³⁵. Technological factors primarily involve unresolved trade-offs (54%) between technology choice and local development.

These patterns reveal that the failure of many actions is not due to technical infeasibility, but rather to the reproduction or exacerbation of development conflicts. For instance, when sustainability is leveraged primarily for economic expansion without social safeguards, it risks causing environmental degradation and deepening urban inequality (such as green gentrification³⁶ or livelihood displacement³⁷, such cases even heighten local people's exposure to climatic events); these trade-offs are more often documented in large, complex cities. Treating these cases as essential learning evidence will be critical for ensuring that actions, and even broader development frameworks, are not implemented at the expense of vulnerable groups, thereby achieving inclusive and durable climate co-benefits.

Table 1 Reason for failure of urban actions.

Primary theme	Coverage (%)	Secondary theme	Proportion (%)
People	21%	Stakeholder conflict	73%
		Psychological reactions (fear, blame, mistrust, risk aversion)	27%
Action	57%	Management problems (lack of enforcement, failure to sustain project)	35%
		Implementation barriers (plans not realized, weak institutional tools)	48%
		Lack of capacity	10%
		Avoidance of difficult decisions	8%
Information	29%	Communication failures	30%
		Lack of feedback or reflection	45%

		Data related issues	25%
Funding	9%	Lack of funding	78%
		Misallocation or corruption	22%
Economic and political	53%	Economic growth overriding environmental goals	62%
		Lack of political support or unstable policy	8%
		Counterproductive government policy	30%
Technology	39%	Inappropriate technology choice (e.g., Mismatch with local, or requires excessive maintenance, cost, or expertise.)	26%
		Low efficiency or performance gap (e.g., Technology performs worse than expected)	22%
		Unintended environmental trade-offs (e.g., rebound effects increasing net emissions)	52%

3 Discussion

Our study conducted an AI-assisted knowledge extraction framework that analyses how urban actions reflect city-specific development priorities, and how those actions relate to climate outcomes, based on 5,610 studies. By offering a development-oriented perspective, our evidence base supplements the climate-first narrative, showing that local development agendas can serve as effective entry points for climate targets when local enabling conditions and equity safeguards are in place. This framework resonates with the operational language of municipal governance, not only for achieving global climate goals, but also for helping identify urban actions more likely to align with climate outcomes, thereby promoting synergies and boosting urban climate progress, while supporting sustainable urban development.

These findings, demonstrate how development stages and city typologies systematically shape both the choice of actions and their climate outcomes. While approximately 54% of the reviewed studies focus on major-category actions in nature-based, energy solutions, and transport, with similar proportional distributions across city types (*Figure 2*), we find different development-driven motivations. For instance, Asia and Europe are primarily focused on green energy transition (23–26%), while Small Islands focus on addressing urban resilience (35%), these disparities reflect both

scientific attention and the priorities of local practitioners responding to context-specific challenges. Diverse socio-economic conditions, resource endowments, and capacity levels constrain and shape cities' preferences for context-specific development topics and urban actions. Technology- or governance-intensive actions (such as those in the "Transformative Knowledge and Governance" category) are predominantly documented in established cities and megacities that are already well equipped, while the evidence base for resource- and capacity-building actions in emerging and rapidly growing cities remains comparatively thin. This imbalance highlights a gap in literature concerning cities with the greatest need for such interventions. Furthermore, our results indicate that land-use planning and green-blue infrastructure (GBI), with consistent evidence across over 100 cities, suggest that strategies under these sub-categories may have greater potential for transferability. However, such transferability is contingent on minimum institutional capacity, financing access, technology, and governance alignment. In addition, the climate outcome of an urban action is conditional upon local context, namely, such actions are context-dependent. Urban practitioners should assess the set of local enabling conditions before adopting a specific intervention and tailoring it to local capacities, to secure context-specific climate co-benefit, which is consistent with a climate-delivery-modes perspective³⁸. In this evidence base, such enabling conditions include land-governance authority, predictable finance, cross-agency coordination, technical and data capability, maintenance and operations arrangements, and distributional safeguards that prevent climate and development risks from being shifted onto already vulnerable groups.

This study reflects that the geographic distribution of current research is uneven (*Figure 1*). To boost confidence in pursuing development–climate synergies, help avoid repeating past failures, and, where conditions allow, pursue technological leapfrogging, future efforts should strengthen research in less developed regions, such as emerging and rapidly growing cities in South America and Africa, as well as small island and high-latitude regions (as shown in [Figure S3](#)). To provide a more practical and solution-based knowledge foundation for local decision-making, subsequent research might focus on enhancing the ability of evidence to reflect the enabling conditions, namely, institutional, fiscal, and structural, that govern whether an action delivers its intended co-benefits. The cumulative worth of the evidence base would be increased by

improving transparency and standardization in urban studies³⁷: through consistent reporting of city types, development topics, enable conditions, and cost-benefits. Furthermore, the available evidence is concentrated in certain action categories, and tends to emphasize positive outcomes, which may introduce a bias towards successful interventions. These failure cases of our evidence base suggest that well-intentioned development-oriented urban action can generate maladaptation, infrastructure or policy lock-in, green gentrification, and livelihood displacement when objectives are pursued through delivery arrangements that mobilise land, finance, governance support, and infrastructure faster than safeguards, accountability, and maintenance capacities . More efforts on increased awareness and better decision-making would result from systematic reporting and process tracing of failure, lock-in mechanisms, and related costs and benefits. Lastly, researchers can distill insights, while enhancing interpretability and reducing hallucinations, by utilizing the vast, coherent evidence produced by such works through multidisciplinary methodologies, particularly cutting-edge technology like artificial intelligence, thereby pointing to pathways that align context-specific development topics with maximum climate co-benefits.

It is crucial to clarify that this study seeks to provide urban decision-makers with a clearer pattern of local development-driven actions and their corresponding climate outcomes, supported by scientific consensus. That is, our analysis relies on peer-reviewed literature worldwide, and such evidence hotspots do not always align with the priorities expressed in top-down policy development needs, i.e., these patterns may be influenced by factors like publication incentives (e.g., research funding bias). Furthermore, our results reflect the strategy-level applicability of urban actions across cities; however, as heterogeneity in variables, methods, and levels of detail across studies constrains quantitative comparison, assessing the degree of mitigation or adaptation performance and implementation scale beyond the scope of this study. Nonetheless, the distribution of evidence in our study aligns with that reported by Montfort, et al.¹², Lamb, et al.²¹ and Sharifi, et al.³⁹, supporting the robustness of the observed patterns. Future studies could address the limitations by incorporating grey literature, such as official reports and government documents, and representative samples of actions in different contexts, to capture a broader spectrum of outcomes.

4 Method

4.1 Evidence base construction framework

The systematic mapping of this study follows PRISMA guideline⁴⁰, we employed an Artificial Intelligence (AI) assisted and human-in-the-loop information extraction pipeline framework to ensure both efficiency and reliability. *Figure 5* outlines the framework for this study, with details of the search strategy, screening procedure, and eligibility criteria provided in the [Supplementary Information](#).

First, we conducted a systematic literature search. To capture dimensions related to urban development, action types, and climate synergies or trade-offs, we constructed a series of Boolean search strings (see [Table S1](#)). Specifically, we reviewed titles, abstracts, and keywords from existing review articles and highly cited studies to identify synonymous and closely related terms. Employing these composite Boolean search strings, we executed searches via the Scopus and Web of Science. After deduplication, the initial literature base comprised 58,047 papers. Then, the AI-assisted and human-in-the-loop filtering and validation process ultimately yielded 5,610 urban-related studies (with a validated accuracy of 89–96%, see *Table 2*), of which 2,419 provided enough information to be directly connected to specific urban centers.

Second, we used a two-stage knowledge extraction pipeline to analyze the screened and eligible literature. In the first stage, we utilized Large Language Models (LLMs) to extract raw information phrases from each study that described urban actions and associated development topics. We extracted key information from the titles and abstracts of each study using three LLMs: Gemini-2.5 Pro, Qwen-3, and DeepSeek-V3.2. Each model was executed independently for three rounds. We encoded each phrase into semantic representations for urban development topics using BERTopic model. The output is then subjected to agglomerative hierarchical clustering. The preliminary clustering outputs were subsequently reviewed and aggregated by the research team, resulting in 11 development topics. To identify 48 distinct sub categories of urban actions, we used the IPCC AR6 framework and multi-source knowledge. These actions were then divided into ten major categories. In the second stage, we systematically mapped each study to the 48 urban action categories and 11 development topics identified in the first stage by applying the same methodology to each study. This guaranteed a systematic and comparable categorization, enabling the analysis of urban actions and the development requirements that go along with them within a uniform

framework.

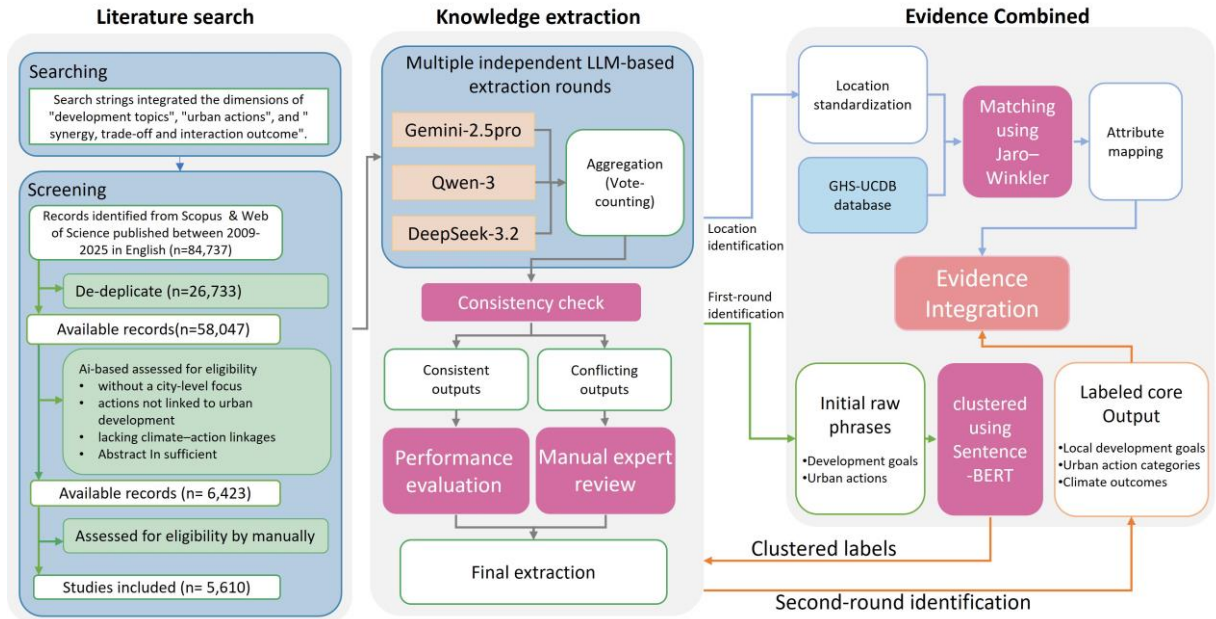


Figure 5 AI-assisted information extraction framework

Finally, we used a combination of exact matching and fuzzy matching based on the Jaro-Winkler distance to extract city and country names simultaneously. These were then harmonized across data sources by mapping to the GHS Urban Centre Database (GHS-UCDB)²⁰. The final database was then created by combining corresponding urban action types, context-specific development topics, and climate outcomes.

4.2 Literature search

We first created a series of search strings to capture important dimensions to find literature pertinent to the research topic (see Table S1). These dimensions included study objects (urban actions and underlying local urban development topics), climate outcomes (synergy or trade-off), and outcomes (socio-economic performance and cost/benefits). We created the search strings iteratively to guarantee sufficient coverage across development topics. Specifically, we reviewed authoritative review articles and studies to compile commonly used keywords. The keyword list was refined through multiple rounds of manual checking based on expert judgement. Using these keywords, we constructed Boolean search strings for systematic literature retrieval. Terms from different dimensions were combined using the “AND” operator, while related terms within the same dimension were linked using the “OR” operator, to maximize recall while maintaining relevance. The final search covered 18 urban development related

topics and was limited to the period from January 2009 to September 2025, documenting the advancement of research pertinent to the IPCC AR6 assessment cycle.

The initial search was carried out in September 2025 by two authors (ZH and SJJ) using the title and abstract fields in Web of Science and Scopus. Applying the 18 query strings returned 84,725 abstracts, which were reduced to 58,047 records after deduplication. The analysis was limited to peer-reviewed journal articles. While journal publication is not inherently indicative of case success, the peer-review process provides a verified threshold that maintains a superior standard for documented evidence⁴¹.

4.3 AI-assisted screening

4.3.1 Inclusion and exclusion

To screen the 58,047 records, we used an LLM-assisted inclusion and exclusion procedure that has been used in previous studies⁴². First, the LLM was used to quickly screen titles and abstracts to remove clearly irrelevant records (see [Table S2](#)). This step was a fast but low-precision way to narrow down the sample. To make the results more reliable, the LLM ran three times for each record. The final inclusion or exclusion decision was made by vote counting rule. Then, this resulted in 5,610 studies, of which 2,419 were linked to specific cities, while the remainder were non-city-specific literature on cities or urban areas. In addition, 70 were retrospective studies with failure outcomes reported.

4.3.2 Knowledge Extraction

1) Evidence processing and merging

Following the approach of Wu, et al. ⁴¹, the extraction was driven by structured prompts to get key knowledge from the urban studies. The knowledge extraction process is executed auto via Python and R scripts interacting with LLM APIs.

In the first stage, we took raw phrases from each study that described the urban actions and corresponding development topics based on multiple LLMs. For development topics, we first identified statements describing the actual intention of the city or implementing organization, rather than the research aim of the authors. Where such purposes were explicitly stated, we extracted raw phrases; otherwise, they were inferred by LLMs from contextual descriptions. Here, ‘context-specific development

topic' describes topics rooted in place-specific socio-economic needs, rather than the spatial scale. Only the most prominent and illuminating development topic was kept when an abstract mentioned several. For urban actions, we extracted the primary action, solution, intervention, or implementation pathway that people actually do to achieve the corresponding development topic; policies, mechanisms, tools or models were extracted only when they were the primary intervention by the implementer (see [Table S3](#)).

Next, we used the BERTopic model to create semantic vectors for every phrase pertaining to context-specific development topics⁴³. Agglomerative hierarchical clustering was then used to analyze these vectors. The author team examined the resulting 20 development topic clusters and aggregated them into 11 development topics (see [Figure S1 and Table S5](#)). For urban actions, given the wide range of technical approaches, implementation scales, and application contexts, we did not rely solely on LLMs. We first created specific urban action descriptions based on established literature, led by IPCC AR6. To identify overlapping or closely related actions, phrases extracted from the first 1,000 studies were encoded and analyzed using the same techniques applied to development topics. Newly identified actions that were not adequately covered by pre-existing categories were added through iterative review by the author team, ensuring that the final categories were concise and coherent. Following several rounds of refinement, a final list of 48 sub-categories of urban actions was established. These actions were subsequently aggregated into 10 major category actions for further analysis (see [Table S6](#)).

In the second stage, we applied the same procedure to each study and mapped to the aggregated urban action categories and development topics established in the first stage, to analyze urban actions and their corresponding development topics for each study within a consistent boundary (see [Table S4](#)). To minimize illusions and randomness, the two stages of the knowledge extraction process are carried out independently for each article's title and abstract using three distinct large language models (LLMs), each of which is carried out independently three times. To ensure intra-model and inter-model consistency and stability, the results from various models were combined using a vote-counting rule (i.e., a final label was assigned when at least two LLMs converged on the same category; instances in which all three LLMs produced

different labels or in which no category achieved two or more votes were classified as inconclusive and resolved through expert manual adjudication). The same process was used to simultaneously extract city names, country names, and related climate outcomes of urban actions. We looked at climate mitigation and adaptation as two types of climate outcomes, and the outputs were either positive impact, negative impact, or no evidence. To ensure overall robustness and reliability, cross-model validation and manual verification were applied to all critical stages.

2) Geographic Information

Every study was mapped to the GHS-UCDB. The city names of each specific-city case study were first cleaned and normalized to eliminate formatting noise to guarantee consistency and comparability of geographic information across data sources. Then, cities were matched using exact string matching. For cities that could not be matched exactly, we applied fuzzy matching, based on the Jaro–Winkler distance, to assess the similarity between cities reported in the literature and those listed in the GHS-UCDB. In this database, cities are defined as urban centers with a population exceeding 50,000.

After that, each study was given a geographic location that could be connected to its socioeconomic, environmental, and other characteristics. Finally, each study was assigned a geographical location, which could be linked to its socioeconomic, environmental, and other attributes. As a result, we linked each study to the relevant city types, context-specific development topics, urban actions, and climate change mitigation and adaptation outcomes.

3) City-level attribution aggregation

To characterize city profiles associated with each action and development topic, we computed aggregate indicators across all cities linked to a given group. For population and GDP in 2025, population growth and GDP growth rate from 2000-2025, we use the arithmetic mean. For per capita CO₂ emissions and SHDI in 2020⁴⁴, we additionally compute population-weighted means because they are population-relevant attributes (see [Figure S8](#) for more details).

The unweighted mean is defined as:

$$\bar{x} = \frac{1}{N} \sum_{i=1}^N x_i \quad (1)$$

589 The population-weighted mean is defined as:

$$\bar{x}_w = \frac{\sum_{i=1}^N x_i \cdot Pop_i}{\sum_{i=1}^N Pop_i} \quad (2)$$

590 where x_i denotes the indicator value for city i , and Pop_i is its population.

591 4) Failure Case Analysis

592 We then selected and analyzed failure cases. First, the study had to be based on
 593 empirical research. Second, it had to describe the logic linking actions to outcomes.
 594 Third, it had to report negative outcomes or failure cases. Here, “failure” refers to a
 595 project that did not achieve its stated socio-economic or environmental objectives, or
 596 that produced unintended negative impacts during implementation. Improving coding
 597 based on the previous study^{45,46}, identified six dimensions of the causes of failure:
 598 People, Action, Information, Technology, Economic and Political conditions, and
 599 Funding, which ensured that the analysis of failure causes was comprehensive and
 600 traceable.

601 4.3.3 Validation

602 We employed confusion matrices to compare model outputs with manual
 603 reference labels to assess extraction performance. The results of the sampled data
 604 (n=307) were independently examined by three researchers (ZH, SJJ, and LYH) in five
 605 dimensions: City names, Development topics, Urban actions, Climate mitigation
 606 impact, and Climate adaptation impact. Any discrepancies were then discussed until a
 607 consensus was reached. We categorized the results into four types, in which true
 608 negatives (TN) occurred when both the AI and manual review identified information as
 609 missing (NA). True positives (TP) represented cases where the AI’s extracted category
 610 exactly matched the manual label. false negatives (FN) were cases where the AI missed
 611 a category identified manually, and false positives (FP) were defined as mismatches
 612 between AI and manual classifications. These results are summarized in *Table 2* and
 613 *Figure 6*.

614 Overall, the AI-assisted extraction framework showed high agreement with full
 615 manual extraction. For the city info extraction part, accuracy reached 96.81% (n = 282),

with a false-positive rate of 1.46% (95% CI: 0.40%–5.17%). Accuracies for the information of development topics, urban Action, climate mitigation outcomes, and climate adaptation outcomes were 88.85%, 89.51%, 92.18%, and 90.88%, respectively, with false-positive rates between 7.82% and 11.15%. Precision stayed consistent with accuracy, and recall reached or approached 100% in all stages, indicating the AI captured nearly all manually identified information.

Table 2 Performance metrics of information extraction

Stage	Data points	Accuracy (%)	False-positive rate (%)	95% CI of false positive rate (%)	Precision (%)	Recall (%)	F1 score (%)	Consistency (%)
City names	282	96.81	1.46	[0.40, 5.17]	98.54	95.07	96.77	96.81
Development topics	269	88.85	11.15	[7.92, 15.47]	88.85	100.00	94.09	88.85
Urban actions	267	89.51	10.49	[7.36, 14.74]	89.51	100.00	94.47	89.51
Climate mitigation impact	307	92.18	7.82	[5.31, 11.37]	92.18	100.00	95.93	92.18
Climate adaptation impact	307	90.88	9.12	[6.39, 12.87]	90.88	100.00	95.22	90.88

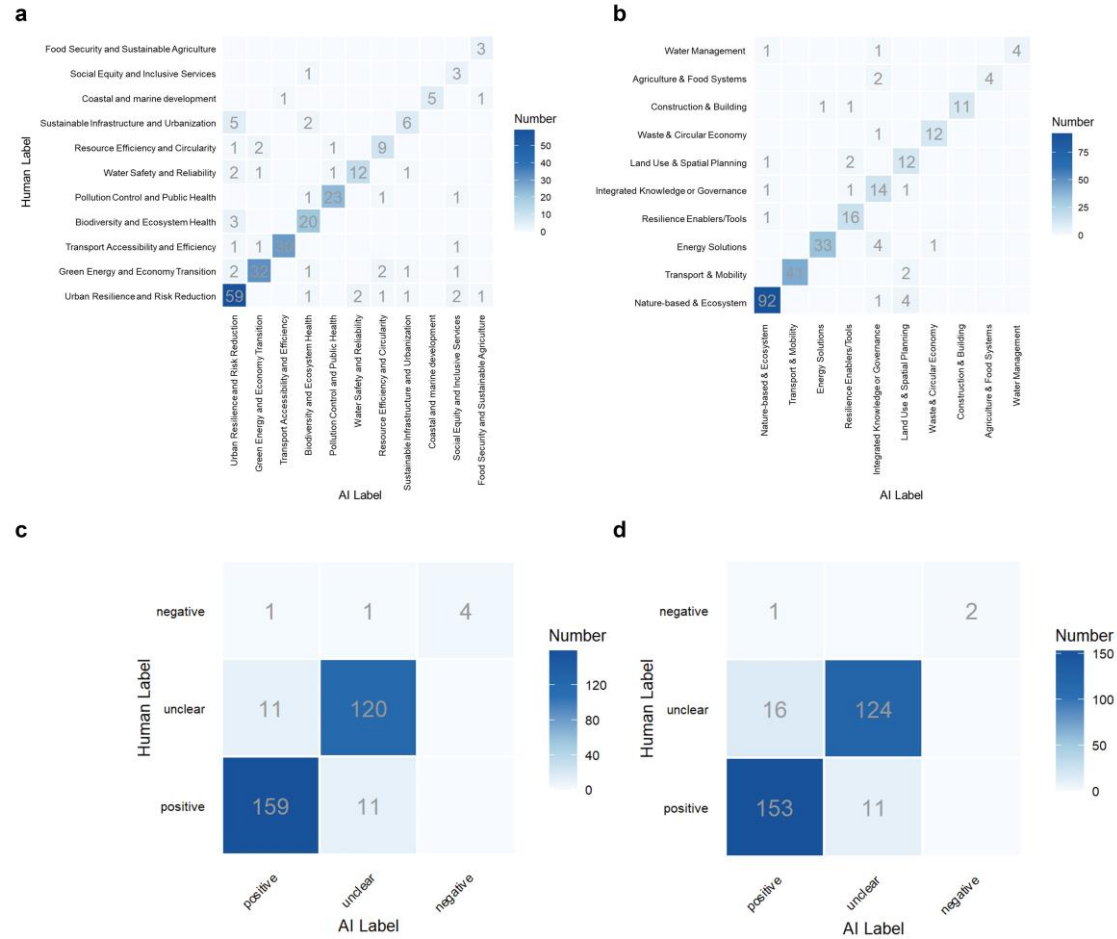


Figure 6 Confusion matrix comparing LLM labels with manual labels across evidence

categories. Panels represent the results for (a) context-specific development topics, (b) Urban action type, (c) Climate mitigation, and (d) Climate adaptation. The distribution shows high-frequency categories and their classification consistency.

Data availability

The evidence base and code will be made publicly available via a public repository.

Acknowledgements

This work was supported by the Leading Pilot Project for Discipline Breakthrough in Digital Ecological Civilization (JYB2025XDXM905), the Shuimu Tsinghua Scholar Program (2024SM137), and the Energy Foundation (Grant No. G-2409-35888), Tsinghua-Rio Tinto Joint Research Center for Resource Energy and Sustainable Development, Tsinghua University. We thank Simon Montfort for developing and sharing the global typology of cities, which greatly supported this study.

Contributions

H.Z. and W.C. designed the research. H.Z. developed the pipeline, quantitative analyses, and visualized the results. H.Z. and J.S. collected and prepared the datasets. H.Z., W.C., J.S., M.L., R.L., W.L., Y.L., G.P. and Y.Z. participated in expert judgement discussions and development topics and urban actions labelling. H.Z., J.S. and Y.L. performed manual validation and consistency checks. A.B., A.Ba., F.B., S.C., F.C., C.H., V.I., R.I., C.T.M., E.M., R.N., S.P., M.P., G.Pf., D.C.R., S.S. and A.S. contributed to the interpretation of results and improvement of the manuscript. H.Z. wrote the manuscript with contributions from W.C. and all co-authors.

Corresponding author

Correspondence to Wenjia Cai.

Competing Interests statement

The authors declare no competing interests.

Reference

- 1 Mi, Z. *et al.* Cities: The core of climate change mitigation. *Journal of Cleaner Production* **207**, 582-589, doi:<https://doi.org/10.1016/j.jclepro.2018.10.034> (2019).
- 2 Acuto, M. *et al.* What three decades of city networks tell us about city diplomacy's potential for climate action. *Nature Cities* **1**, 451-456, doi:10.1038/s44284-024-00081-1 (2024).
- 3 Creutzig, F. & He, D. Climate change mitigation and co-benefits of feasible

- transport demand policies in Beijing. *Transportation Research Part D: Transport and Environment* **14**, 120-131, doi:<https://doi.org/10.1016/j.trd.2008.11.007> (2009).
- 4 Giles-Corti, B. *et al.* Creating healthy and sustainable cities: what gets measured, gets done. *The Lancet Global Health* **10**, e782-e785, doi:10.1016/S2214-109X(22)00070-5 (2022).
 - 5 Goodwin, S., Olazabal, M., Castro, A. J. & Pascual, U. Global mapping of urban nature-based solutions for climate change adaptation. *Nature Sustainability* **6**, 458-469, doi:10.1038/s41893-022-01036-x (2023).
 - 6 Araos, M. *et al.* Climate change adaptation planning in large cities: A systematic global assessment. *Environmental Science & Policy* **66**, 375-382, doi:<https://doi.org/10.1016/j.envsci.2016.06.009> (2016).
 - 7 Chu, E., Anguelovski, I. & Roberts, D. Climate adaptation as strategic urbanism: assessing opportunities and uncertainties for equity and inclusive development in cities. *Cities* **60**, 378-387, doi:<https://doi.org/10.1016/j.cities.2016.10.016> (2017).
 - 8 Li, G. *et al.* Global urban greening and its implication for urban heat mitigation. *Proceedings of the National Academy of Sciences* **122**, e2417179122, doi:10.1073/pnas.2417179122 (2025).
 - 9 Ulpiani, G. *et al.* Are cities taking action against urban overheating? Insights from over 7,500 local climate actions. *One Earth* **7**, 848-866, doi:10.1016/j.oneear.2024.04.010 (2024).
 - 10 Ürge-Vorsatz, D. *et al.* Locking in positive climate responses in cities. *Nature Climate Change* **8**, 174-177, doi:10.1038/s41558-018-0100-6 (2018).
 - 11 Song, K., Burley Farr, K. & Hsu, A. Assessing subnational climate action in G20 cities and regions: Progress and ambition. *One Earth* **7**, 2189-2203, doi:10.1016/j.oneear.2024.10.001 (2024).
 - 12 Montfort, S. *et al.* Systematic global stocktake of over 50,000 urban climate change studies. *Nature Cities* **2**, 613-625, doi:10.1038/s44284-025-00260-8 (2025).
 - 13 Lwasa, S. *Urban Systems and Other Settlements in Climate Change 2022: Mitigation of Climate Change (eds Shukla, PR et al.)* 861–952. (Cambridge Univ. Press, 2022).
 - 14 Friesenecker, M. *et al.* Socially equitable climate risk management of urban heat. *npj Urban Sustainability* **5**, 8, doi:10.1038/s42949-025-00202-2 (2025).
 - 15 Young, D. & Essex, S. Climate change adaptation in the planning of England's coastal urban areas: priorities, barriers and future prospects. *Journal of Environmental Planning and Management* **63**, 912-934, doi:10.1080/09640568.2019.1617680 (2020).
 - 16 Mwenje, E. & Kumar, P. Challenges for mainstreaming climate adaptation in African cities. A case study of Kigali, Rwanda. *Landscape and Urban Planning* **245**, 105017, doi:<https://doi.org/10.1016/j.landurbplan.2024.105017> (2024).
 - 17 Montfort, S., Nachtigall, F., Repke, T., Binder, C. & Creutzig, F. A global typology of cities supporting coordinated climate action. (2026).
 - 18 Creutzig, F. *et al.* Bridging the scale between the local particular and the global universal in climate change assessments of cities. *Nature Cities* **2**, 369-378, doi:10.1038/s44284-025-00226-w (2025).
 - 19 Burley Farr, K., Song, K., Yeo, Z. Y., Johnson, E. & Hsu, A. Cities and

- regions tackle climate change mitigation but often focus on less effective solutions. *Communications Earth & Environment* **4**, 439, doi:10.1038/s43247-023-01108-6 (2023).
- 20 Melchiorri, M. *et al.* The Multi-temporal and Multi-dimensional Global Urban Centre Database to Delineate and Analyse World Cities. *Sci Data* **11**, 82, doi:10.1038/s41597-023-02691-1 (2024).
- 21 Lamb, W. F., Creutzig, F., Callaghan, M. W. & Minx, J. C. Learning about urban climate solutions from case studies. *Nature Climate Change* **9**, 279-287, doi:10.1038/s41558-019-0440-x (2019).
- 22 Mahtta, R., Mahendra, A. & Seto, K. C. Building up or spreading out? Typologies of urban growth across 478 cities of 1 million+. *Environmental Research Letters* **14**, 124077 (2019).
- 23 Bhattacharya, A., Songwe, V., Soubeyran, E. & Stern, N. Raising ambition and accelerating delivery of climate finance. *London: Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science* (2024).
- 24 Sharifi, A. Co-benefits and synergies between urban climate change mitigation and adaptation measures: A literature review. *Science of The Total Environment* **750**, 141642, doi:<https://doi.org/10.1016/j.scitotenv.2020.141642> (2021).
- 25 Sethi, M., Lamb, W., Minx, J. & Creutzig, F. Climate change mitigation in cities: a systematic scoping of case studies. *Environmental Research Letters* **15**, doi:10.1088/1748-9326/ab99ff (2020).
- 26 Vijaya Pandi, P. *et al.* Economic valuation of ecosystem services for application of circular economy approach in conservation of Kundapura mangroves of Karnataka, India. *Environmental Quality Management* **32**, 187-196, doi:<https://doi.org/10.1002/tqem.21919> (2022).
- 27 Patel, D., Brooks, N. & Bastable, A. Excreta disposal in emergencies: Bag and Peepoo trials with internally displaced people in Port-au-Prince. *Waterlines* **30**, 61-77 (2011).
- 28 Zhang, J., Qin, Q., Li, G., Tseng, C.-H. & Fang, G. Assessing the impact of waste separation on system transition and environmental performance through a city-scale life cycle assessment. *Ecological Economics* **211**, 107886, doi:<https://doi.org/10.1016/j.ecolecon.2023.107886> (2023).
- 29 Schuermann, H. & Woo, J. Estimating consumers' willingness to pay for reusable food containers when ordering delivery food: A contingent valuation approach. *Journal of Cleaner Production* **366**, 133012, doi:<https://doi.org/10.1016/j.jclepro.2022.133012> (2022).
- 30 Kurniawan, T. A., Puppim de Oliveira, J., Premakumara, D. G. J. & Nagaishi, M. City-to-city level cooperation for generating urban co-benefits: the case of technological cooperation in the waste sector between Surabaya (Indonesia) and Kitakyushu (Japan). *Journal of Cleaner Production* **58**, 43-50, doi:<https://doi.org/10.1016/j.jclepro.2013.08.002> (2013).
- 31 Oakley, S. M. & Jimenez, R. Sustainable sanitary landfills for neglected small cities in developing countries: The semi-mechanized trench method from Villanueva, Honduras. *Waste Management* **32**, 2535-2551, doi:<https://doi.org/10.1016/j.wasman.2012.07.030> (2012).
- 32 Dong, L. *et al.* Highlighting regional eco-industrial development: Life cycle benefits of an urban industrial symbiosis and implications in China.

757 *Ecological Modelling* **361**, 164-176,
758 doi:<https://doi.org/10.1016/j.ecolmodel.2017.07.032> (2017).

759 33 Baklanov, A. *et al.* Integrated urban services: Experience from four cities on
760 different continents. *Urban Climate* **32**, 100610,
761 doi:<https://doi.org/10.1016/j.uclim.2020.100610> (2020).

762 34 Grimmond, S. *et al.* Integrated urban hydrometeorological, climate and
763 environmental services: Concept, methodology and key messages. *Urban*
764 *Climate* **33**, 100623, doi:<https://doi.org/10.1016/j.uclim.2020.100623> (2020).

765 35 Richardson, B. F. Finance, food, and future urban zones: The failure of
766 flexible development in Auckland, New Zealand. *Land Use Policy* **119**,
767 106203, doi:<https://doi.org/10.1016/j.landusepol.2022.106203> (2022).

768 36 González Márquez, E. d. P. & García de Fuentes, A. Últimos paraísos.
769 Urbanización del espacio rural y resistencia social en el Pueblo Mágico de
770 Sisal, Yucatán. *Investigaciones geográficas* (2024).

771 37 Stock, R. & Sovacool, B. K. Left in the dark: Colonial racial capitalism and
772 solar energy transitions in India. *Energy Research & Social Science* **105**,
773 103285, doi:<https://doi.org/10.1016/j.erss.2023.103285> (2023).

774 38 Sudmant, A. *et al.* *From urban climate ambition to delivery: A framework of*
775 *climate delivery modes* (2026).

776 39 Sharifi, A., Seto, K. C. & Aboagye, P. D. The literature landscape on cities
777 and climate change. *Urban Climate* **66**, 102849,
778 doi:<https://doi.org/10.1016/j.uclim.2026.102849> (2026).

779 40 Page, M. J. *et al.* The PRISMA 2020 statement: an updated guideline for
780 reporting systematic reviews. *BMJ* **372**, n71, doi:10.1136/bmj.n71 (2021).

781 41 Wu, S. *et al.* Automated literature research and review-generation method
782 based on large language models. *National Science Review* **12**,
783 doi:10.1093/nsr/nwaf169 (2025).

784 42 Scherbakov, D., Hubig, N., Jansari, V., Bakumenko, A. & Lenert, L. A. The
785 emergence of large language models as tools in literature reviews: a large
786 language model-assisted systematic review. *Journal of the American Medical*
787 *Informatics Association* **32**, 1071-1086, doi:10.1093/jamia/ocaf063 (2025).

788 43 Chang, C. H. *et al.* Global evidence of human well-being and biodiversity
789 impacts of natural climate solutions. *Nature Sustainability* **8**, 75-85,
790 doi:10.1038/s41893-024-01454-z (2025).

791 44 Sherman, L., Proctor, J., Druckenmiller, H., Tapia, H. & Hsiang, S. Global
792 high-resolution estimates of the UN Human Development Index using satellite
793 imagery and machine learning. *Nature Communications* **17**, 1315,
794 doi:10.1038/s41467-026-68805-6 (2026).

795 45 Catalano, A. S., Lyons-White, J., Mills, M. M. & Knight, A. T. Learning from
796 published project failures in conservation. *Biological Conservation* **238**,
797 108223, doi:<https://doi.org/10.1016/j.biocon.2019.108223> (2019).

798 46 Dorst, H. *et al.* What's behind the barriers? Uncovering structural conditions
799 working against urban nature-based solutions. *Landscape and Urban Planning*
800 **220**, 104335, doi:<https://doi.org/10.1016/j.landurbplan.2021.104335> (2022).

801

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [AppendixGlobalevidencelinkinglocaldevelopmentorientedurbanactions0615.pdf](#)