



Learning from Africa's urban climate innovations: A new framework and comparative analysis to foster transformative climate action

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ABSTRACT

African cities face intensifying climate risks shaped by rapid urbanisation, informality, unequal access to services, and exclusionary governance, yet these urban centres are also important sites of experimentation and innovation. This paper examines how climate innovations in African cities have emerged across technological, social, governance, and livelihood domains, and it assesses their potential to support equitable and transformative urban climate action. We seek to fill several gaps in existing innovation scholarship, which is often biased towards isolated sectors and Global North contexts, by offering a cross-sectoral and justice-oriented analysis of African urban examples. The paper will develop an analytical framework that considers multiple dimensions of climate innovation: domains of action; types of innovation; and levels of equity, institutionalisation, and scale. This framework is applied to case studies from East and Southern Africa (Kampala, Durban, Nairobi, Embu, and Dar es Salaam), including pay-as-you-go solar energy, community-based flood early warning systems, nature-based solutions, and psychosocial resilience initiatives.

Rather than consisting of technological change alone, climate innovations in African cities often involve hybrid combinations of social, technical, governance, and livelihood innovations that respond simultaneously to climate risks and wider development challenges. Equitable innovations will require cross-cutting strategies including social mobilisation and enabling governance frameworks, appropriate technologies, and inclusive livelihood support. Moreover, we argue that their transformative potential depends largely on whether innovations become institutionally embedded, linked across scales, and oriented towards justice. Our findings and framework may offer lessons for promoting inclusive, scalable pathways towards climate resilience in cities of the Global South.

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1. Introduction

African cities face compounding climate risks and extreme weather events (including floods, droughts, and heatwaves) that disproportionately affect marginalised residents, whose vulnerabilities are often rooted in structural inequality and exclusionary governance (Finn and Cobbinah, 2023). Rapid urbanisation rates, precarious informal livelihoods, and unequal access to vital services compound these challenges while also increasing the need for innovative, scaled-up climate action in African cities (Simon et al., 2021; UN-Habitat, 2020). Over half of African city-dwellers live in informal settlements ('slums'), typically with low-quality housing that has inadequate access to risk-reducing infrastructure, and these areas can be highly vulnerable to climate change (UN-Habitat, 2024). At the same time, African cities are critical sites of experimentation, innovation, and learning. For instance, informal settlements and informal service providers often fill gaps left by formal institutions, which may enable the creation of bottom-up climate innovations (Satterthwaite et al., 2020).

Despite rising interest in urban innovations – and specifically in climate innovations – few studies examine the range of novel strategies in African cities that seek to address climate change alongside other development challenges. As compared to innovations more generally, 'climate innovations' involve the creation and implementation of new or significantly improved products, organisational forms, or governance systems that specifically support climate adaptation or mitigation actions (Schot and Steinmueller, 2018; UN-Habitat, 2024). Research on climate innovation must grapple with issues of equity, inclusivity, and the unjust distribution of benefits and risks within urban areas (Ziervogel and Hamann, 2024). Although there is burgeoning scholarship on urban climate innovation globally, empirical studies remain fragmented with a focus upon isolated sectors and biased towards the 'Global North' (Castán Broto and Bulkeley, 2013; van der Heijden, 2019; Aboagye and Sharifi, 2026; Evans et al., 2025; Mokhles et al., 2025; Sharifi et al., 2026). We argue for cross-city comparisons that can reveal opportunities and challenges in scaling equitable innovation, including often-overlooked climate initiatives in African cities.

This paper seeks to enrich interdisciplinary literature on climate innovation by offering a cross-sectoral synthesis and framework to analyse African urban examples, drawing on case studies in five Southern and Eastern African cities: Kampala, Durban, Nairobi, Embu, and Dar es Salaam. Based upon these emerging and well-established climate innovations, we interrogate how to foster equitable, scaled-up strategies alongside how to promote inclusive state/community relations in generating such interventions. The paper contributes to the literature on urban climate innovation in three key ways. First, it develops a justice-oriented analytical framework for understanding climate innovation in African cities (including community-led initiatives in informal settlements), emphasising the interplay between technological, social, governance, and livelihood innovations. Second, the paper demonstrates how climate innovations often seek to generate multiple social, economic, and governance-related benefits (not merely technological gains) and thereby can help respond to African city-dwellers' complex array of needs. We foreground bottom-up initiatives and co-produced strategies that can tackle the socio-political marginalisation that underpins urban climate vulnerabilities. Third, the paper highlights the importance of institutionalisation and cross-scale governance in shaping whether locally grounded innovations can evolve from small-scale experimentation into more equitable or potentially transformative climate action.

Rather than offering a comprehensive account of innovation in African urban areas, the illustrative examples presented in this paper may spur further comparative investigations with newfound attention to equity, scale, and institutional aspects of urban climate innovations. Our findings indicate that climate innovation in African cities has emerged through hybrid constellations of social, technological, governance, and livelihood innovations, with transformative outcomes most likely when these domains become institutionally embedded and justice-oriented. 'Hybrid' innovations combine elements from more than one type (e.g. technological and livelihood, or social and governance), and these blended approaches reflect the relational, negotiated character of many African urban climate innovations (Bandaiko and Finn, 2025). Meanwhile, 'transformative' adaptation entails addressing the underlying social, economic, and political systems that drive disparate experiences of climate vulnerability (Pasquini et al., 2024). It focuses on power structures and their influence on socio-ecological systems, in order to promote more equitable, justice-driven climate resilience outcomes (Roberts and Pelling, 2021). While recognising the agency and ingenuity of African urban innovators, we also acknowledge the profound constraints within which they operate and emphasise the need for far-reaching institutional and political transformation (thus rejecting facile techno-optimism or merely short-term solutions).

After synthesising recent literature on climate innovations, we develop a framework and typology of climate innovation in African cities that highlights the centrality of equity, scale, and institutional embeddedness. Empirical findings from five African cities are then presented to demonstrate our framework's utility, with a focus upon social and governance innovations. We explain the implications for climate justice and discuss the remaining socio-political obstacles facing transformative innovations in African cities. The paper concludes with a proposed research agenda and identifies key lessons for practice to promote just, climate-resilient futures in African cities.

2. The politics of climate innovation: towards a multidimensional understanding in African cities

Prior studies of innovation (including in organisational theory, economics, and science and technology studies) have highlighted its ability to advance social and technological change, but with limited attention to the multifaceted climate innovations in African cities. Urban climate literature has increasingly adopted the language of innovation, often framed around experimentation, rapid prototyping, and entrepreneurial action (Ziervogel and Hamann, 2024). Across many cities (including in Africa), climate experiments and living labs have proliferated that position cities as testbeds for novel adaptation and mitigation strategies; relatedly, urban innovation is considered a key mode of fostering climate action (Castán Broto and Bulkeley, 2013; Bulkeley et al., 2016; Frantzeskaki et al., 2017). Yet to date, there are few empirical analyses of climate innovations in the Global South (including social, livelihoods, and governance

initiatives), many of which seek to address urgent community needs, but are hamstrung by limited access to technology or capital (Huang et al., 2025). These strategies can emerge organically from community-driven interventions, while also sometimes shifting towards a marketized approach and technical complexity (ibid.). We next synthesise recent studies of climate innovation (with particular attention to its social dimensions), emphasising the need for an equity and justice lens as well as the importance of building upon innovations in African informal economies or informal settlements.

A focus upon social innovation can support inclusive participation and safeguards for low-income groups in African cities, who are disproportionately affected by climate injustices and longstanding socio-political exclusions. Despite their diversity, African cities often share challenges including entrenched informality and precarious livelihoods, fragmented institutional mandates and constrained public finance, and an array of ‘everyday’ risks as well as climate-related threats (Pieterse and Parnell, 2014; Dodman et al., 2019). These conditions often produce “soft limits” to climate adaptation and innovation that are social and institutional, rather than purely biophysical (Thomas et al., 2021; Berkhout et al., 2024; Ziervogel and Hamann, 2024). In such contexts, social innovation becomes particularly salient, as it helpfully foregrounds the institutional and political dimensions of adaptation. Ziervogel and Hamann (2024) define ‘social innovation’ in climate adaptation as a novel process or product that seeks to generate more effective and just responses to complex social problems for collective benefit. They emphasise interrelated dimensions of social innovation: 1) mapping and strengthening diverse actors’ complementary roles, 2) linking micro–meso–macro scales, and 3) balancing democratic considerations with instrumental goals, as scaling-up financial and technological innovations without participatory processes or equitable decision-making may only reinforce existing inequities, particularly in starkly divided African cities (ibid.). More positively, informal systems can perform critical economic, environmental, and social roles (e.g., waste management and employment creation), and climate innovations need to complement these productive functions of informality (Azunre et al., 2021).

Instead of an uncritical use of ‘innovation,’ it is important to adopt justice-oriented analyses with attention to local contexts, such as consideration of how innovations can address multiple socioeconomic inequalities and build upon inclusive, bottom-up transformations in African cities (Ziervogel and Hamann, 2024; Huang et al., 2025). The latter framing resonates strongly with scholarship on urban informality, where innovation often involves renegotiating power relations, supporting political recognition, and amplifying marginalised citizens’ agency in decision-making processes, including in relation to climate change (Eakin et al., 2025). Relatedly, we draw upon recent literature on supported self-provisioning (SSP), which has explored grassroots-led relationships with formal governance structures, highlighting a form of bottom-up “city-making” that is neither completely autonomous nor wholly dependent on state institutions (Bandauko and Finn, 2025). It positions SSP as negotiated relations amongst diverse state and non-state actors, which can produce generative possibilities (e.g. social cohesion and service innovation) to address context-specific structural constraints. In other words, SSP helps to analyse informality as a leading site of alternative forms of governance and a key potential source of inclusive climate innovations (ibid., also below).

‘Innovation’ has often been applied too broadly in past literature, obscuring important distinctions in intent, mechanisms, and political orientation (Marques et al., 2018); moving forward, there is a need to understand the politics of climate innovation with attention to its transformative as well as regressive possibilities. Marques et al. (2018) distinguish between *structural social innovation* (i.e., transformative institutional change), *targeted radical social innovation* (initiatives that explicitly challenge dominant power relations), *targeted complementary social innovation* (working within existing institutional frameworks), and *instrumental social innovation* (largely a rebranding of established practices). Relatedly, Beckman et al. (2023) describe a “social innovation trap,” in which fragmented and managerial disciplinary approaches privilege instrumental considerations such as efficiency, replication and financial viability. The existing literature has thus often under-theorised questions of democratic governance, sectoral roles, and the significance of place and scale (ibid.). This imbalance is particularly consequential in African cities, where climate-related innovations frequently emerge under conditions of institutional fragmentation, low-quality shelter and precarious informal livelihoods, and unaccountable or exclusionary forms of governance (often rooted in colonial legacies) (Robin and Castán Broto, 2021).

We thus conceptualise innovation not as a neutral descriptor of novelty, but as a political process that may either reinforce prevailing institutional logics or may seek to catalyse transformative adaptation pathways. Drawing upon several African city examples, below we seek to spur further cross-country, empirical analyses of how to promote climate-resilient strategies in cities facing stark political and socio-economic exclusions. Our findings illustrate how informal settlements and livelihoods can help to generate multifaceted climate innovations and potential benefits, while also underscoring the importance of critically analysing their institutional and political contexts.

3. Towards transformative adaptation and innovation in African cities: An analytical framework to understand equitable, scaled-up and institutional change

Synthesising recent literature on social innovation and transformative adaptation, we next create a framework to deepen understanding of climate innovations in African cities with an emphasis upon scale, equity, and institutional change. Social innovation aligns closely with calls for transformative adaptation, aiming to address the structural and systemic drivers of vulnerability, rather than merely alleviating immediate risks. Such literature has argued for incorporating justice considerations, as these are central to both adaptation and social innovation processes (Ziervogel and Hamann, 2024; Eakin et al., 2025). Underscoring the pivotal role of politics and the need to combat longstanding exclusions, Pel et al. (2020) propose that transformative social innovation is a process of challenging dominant institutions within specific socio-material contexts. They argue that transformative innovation should be contextually embedded, actively drawing upon the resources and institutional structures that are present even in ‘institutional voids’. In a complementary discussion of transformative adaptation in informal settlements, Howard et al. (2025) advocate recognising these areas’ legitimacy; ensuring equitable, fit-for-purpose governance frameworks; and addressing the drivers of complex risks.

Transformative adaptation and equitable resilience will also depend upon transforming knowledge systems, and climate scholars have argued for embracing multiple forms of knowledge (including ‘citizen science’ and community-led data collection) rather than privileging conventional forms of ‘expertise’ (Orlove et al., 2023; Garcia et al., 2022).

Nevertheless, we acknowledge the tensions regarding key values, approaches, and timescales utilised in innovative practices vs. climate adaptation and resilience interventions. Innovations are often framed in the language of entrepreneurship, which centres upon experimentation and rapid prototyping (Ziervogel and Hamann, 2024). Innovation culture thus often prioritises efficiency and the ability to swiftly redirect in the face of change, as seen in climate innovation labs where prototypes are trialled and adapted in near-real time. By contrast, climate adaptation and resilience interventions often emphasise more systematic, lengthy assessments of vulnerability, risk, and governance transformations over longer-term timescales. Innovation's emphasis on agility may foster novel solutions but can entail superficiality or insufficient contextual grounding; adaptation's rigour can help ensure robust decision-making, but may hinder timely action in rapidly evolving climate contexts (Ford and King, 2015; Pelling et al., 2015; Olazabal and Castán Broto, 2022; Grönholm, 2022).

While there are potential synergies between climate innovation and transformative adaptation, it is important to note that equitable outcomes cannot be assumed, and cities will need to address the profound political and institutional obstacles to inclusive climate action. Not only is there a complex relationship between climate innovation and resilience, it is also contingent upon local circumstances. Innovations can enhance urban resilience including by reducing exposure, improving early warning systems, or creating buffers against climate shocks (Adegun et al., 2026; Meerow et al., 2016). But not all innovations lead to resilience, and they may instead generate dependencies or exclude vulnerable populations. Urban climate innovations need to be understood within the wider context of systemic urban vulnerabilities since “innovative action [will depend] not only on agency within cities, but also on many factors beyond the city scale” (Patterson and Huitema, 2019, p376). Municipal climate strategies often struggle to work across scales,

Table 1
Case Study Summaries and Methods.

Case	Innovation domain	Key actors	Scale	Justice dimensions	Methods
M-KOPA	Technological/ livelihood	Private sector, households	Multi-country	Access to energy but limited governance transformation	Document review of corporate literature and solar market brief insights from M- KOPA and Africa Mini grid Developers Association. Semi-structured interviews with official policymakers and M-KOPA consumers across Kampala (in Makindye Division and Kawempe Division)
CBFEWS Durban with a focus on the area of Quarry Road West (QRW)	Social/ governance	Community leaders, university, municipality	Settlement—with pilot upscaling to other settlements	Strong procedural justice and knowledge co-production	Focus groups, semi- structured interviews and workshops with community members from QRW, Learning Labs using arts- based methods (e.g. playdough modelling) with community members and local government officials, document review.
DARAJA	Hybrid technological/ governance	Meteorological services, NGOs, communities	Multi-city	Inclusive climate information, cross- scale integration	Field observation, as well as desktop research to analyse the project's activities and engagements, including: information ecosystem mapping, focus groups, household surveys, key informant interviews, and multi-stakeholder workshops.
NbS in Kenyan Informal Settlements (Nairobi and Embu)	Social	Community groups (in Nairobi and Embu's informal settlements), NGOs with strong community participation in informal settlements (led by Kounkuey Design Initiative or KDI), local leaders from city and county governments	Local	Livelihoods, community-led adaptation, environmental justice	Focus groups with community leaders and residents in Mathare (Nairobi); reflections with KDI on experiences in Nairobi and Embu; narrative reports and other document review.
‘Race to Resilience’ (R2R) Psycho- social Resilience Initiative in Nairobi	Social	Grassroots networks, NGOs	Local but with strong potential to scale-up	Recognition of climate trauma and seeking to tackle stigma around mental health	Reflections and interviews with ‘Race to Resilience’ participants; document review

sectors, and jurisdictions, which may hamper socio-spatial inclusion and climate justice, especially in cities of the Global South where low-income residents already face entrenched exclusions (Chu et al., 2016; Hageer, 2025). Furthermore, urban climate interventions may face shortfalls in resources, political will, and cross-departmental cooperation; rising levels of participation fatigue; and reliance upon short-term projects (Schmidt et al., 2024).

Given the complex and interrelated challenges in African cities, it will be insufficient to pursue short-term, standalone climate innovations but instead will need to address several objectives simultaneously. For instance, innovative approaches will need to reduce climate risk and longstanding vulnerabilities, strengthen service delivery and livelihoods, with such changes enabled and sustained by inclusive local governance processes. Multifaceted strategies are therefore needed that foster *equity* (including in data-collection, targeting, and design of interventions); respond to local assets and priorities while also acting *across scales*; and create *institutional innovations* that can together tackle the drivers of climate injustices. Embedding climate innovations in progressive, longer-term institutional change processes can also help to avoid “pilotitis” and to shift limits, rather than merely demonstrating feasibility (Ziervogel and Hamann, 2024).

Based on the above, our conceptual framework has positioned climate innovation in African cities at the intersection of three dimensions, as follows:

1. Domains of action: key urban sectors where innovations are emerging such as energy, water/flood management, and nature-based solutions.
2. Types of innovation: technological, social, governance, and livelihoods, as well as a combination thereof, including top-down, bottom-up, and hybrid initiatives.
3. Levels of equity, institutionalisation, and scale: innovations are located along a continuum between more/less inclusive, more/less institutionalised, and smaller/larger in scale.

These dimensions provide an analytical framework that identifies where innovation occurs, how it takes shape, and what kinds of resilience outcomes it enables or constrains. An initiative's sectoral domain is analytically distinct from the type of innovation it represents: for example, flood management may rely on technological devices, social mobilisation, governance reform, local knowledge practices, or hybrid combinations of these. Although our framework can help to uncover pathways towards equitable resilience, these interventions also have the potential to (inadvertently or otherwise) deepen exclusions and vulnerabilities. To operationalise this framework in African cities, co-authors assessed each case against the three dimensions, starting with the dominant domain(s) of action and type(s) of innovation, followed by each case's relative position in terms of scale, institutionalisation, and equity. The process

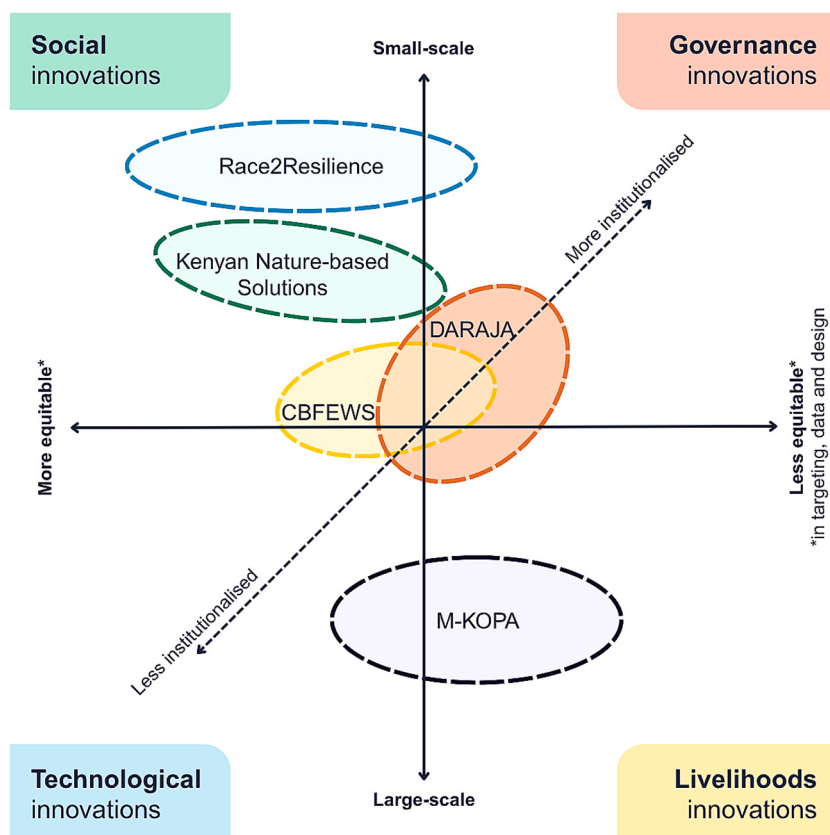


Fig. 1. Mapping Climate Innovations in African Cities: Domains of action, scale and justice dimensions.

is intended to generate analytically useful comparisons, rather than quantitative assessments, and we next detail our cases and methods more fully.

4. Methodology and case selection

The paper draws on five illustrative case studies in African cities to anchor the analysis. Each study has employed qualitative methods, including documentary analysis of relevant plans, reports, and other project documents, as well as field observations, learning labs, semi-structured interviews and focus group discussions (see Table 1). Co-authors developed the specific cases, followed by an iterative cross-case analysis to identify key themes and divergences in relation to climate innovation. The selected case studies represent diverse domains of climate innovation across African cities: technological innovation (M-KOPA's pay-as-you-go solar energy system); hybrid governance and knowledge innovations (community-based flood early warning system in Durban, as well as Dar es Salaam, Nairobi, and Kampala); and bottom-up innovations centred on nature-based solutions (Nairobi and Embu in Kenya) and efforts to promote psychosocial resilience in Nairobi's informal settlements ('Race to Resilience' or R2R). Together, these cases explore how different forms of innovation emerge, interact, and scale across urban contexts. Each of the five cases have operated beyond an initial pilot phase – ranging from the decade-long CBFWS (since 2014) and M-KOPA (since 2010) to the more recent R2R initiative (since October 2024) – affirming them as established interventions rather than untested pilots.

The cases are used as analytically revealing vignettes through which to examine how different domains of action, types of innovation, and resilience pathways intersect in practice. Together, they allow comparison across sectors and African cities, while also showing that transformative potential often depends upon how technical, social, and institutional elements are assembled, embedded, and contested. More generally, this paper seeks to inform equitable, scalable climate strategies that can overcome siloed programmes and better address complex development issues in African cities.

Analytically, we map climate innovations across the diverse African cities using a multi-dimensional framework that considers scale, levels of institutionalisation, and equity (from less to more equitable in terms of the interventions' targeting, data practices, and design) (Fig. 1). Our framework seeks to assess their potential for transformative climate action – understood as shifts that help address the structural drivers of vulnerability, rather than merely managing climate risk, with justice considerations as central (See et al., 2025; Fisher et al., 2025). This analytical heuristic enables the identification of recurring patterns and constellations of innovation, but avoids the privileging of decontextualised 'best practice' examples (Montero and Baiocchi, 2022). While the cases illustrate some configurations of urban climate innovations, further research can test and deepen our framework (see Conclusion). Many initiatives cut across multiple domains and may change over time to incorporate additional dimensions. Although the four quadrants' domains represent the dominant entry points, innovations may subsequently shift in their focus and there can be overlaps or blurring across domains.

The analytical distinction between social and governance innovations is important in African cities, where socially driven, bottom-up innovations frequently precede or exist in tension with formal governance processes; social innovations may also struggle to scale-up and institutionalise effectively. Social innovations often emerge from within communities and civil society, reshaping norms, relationships, collective action, and the production of knowledge—often from within informal contexts (Huang et al., 2025). Governance innovations, by contrast, involve changes to formal rules, policies, institutional arrangements, and decision-making processes that shape how authority, resources, and accountability are enacted across scales (Bellinson and Chu, 2019). In turn, our framework helps to reveal how misalignment between social and governance innovations; limited levels of institutionalisation; and inability to work across scales can constrain transformative climate outcomes. Moreover, the framing is a direct response to Beckman et al.'s (2023) core argument that scale and place are foundational yet under-analysed in the innovations field, and that equitable forms of participation have rarely been considered.

5. Case study analysis: understanding multi-dimensional climate innovations in practice

We next apply our framework and explore detailed findings from African cities, followed by a discussion of lessons across the case studies.

6. Case Study 1: M-KOPA solar micro-grids in Kampala

Strengthening Access to Clean Energy and Inclusive Financial Services.

Although limited access to formal energy and finance has constrained socio-economic development in African cities, solar energy provision has rapidly scaled-up in several African nations, including amongst low-income urban residents. To promote widespread uptake of clean energy, M-KOPA has developed an innovative Pay-As-You-GO (PAYGO) solar model that targets low-income households and informal micro-enterprises (Labari, 2025; MasterCard Foundation, 2018). M-KOPA is currently active in 5 African nations: Kenya, Uganda, Nigeria, Ghana and South Africa. Since 2010, M-KOPA has provided over one million solar home systems across its markets, with Uganda being a major hub for off-grid homes (M-KOPA, 2025).

M-KOPA is a privately led model that replaces kerosene with solar power at half its cost, without government subsidies or tariffs (Karjalainen et al., 2018). The key innovation of M-KOPA is its flexible, accessible financing model. In Uganda, customers can acquire a M-KOPA III off-grid solar kit on a rent-to-own basis after paying a deposit of UGX 90,000 (US\$28) plus daily mobile payments of UGX1,700 (~US\$0.5) for up to a year. With no formal qualification requirements (besides the initial deposit), M-KOPA's PAYGO model has expanded to encompass access not only to solar power but also to smartphones, water-tanks, and refrigerators, cash loans and

health insurance. Within Fig. 1, M-KOPA spans the technological and livelihood domains, characterised by large scale, low levels of institutionalisation, and uneven equity gains, as explained below.

Integrating Flexible Payments and Solar Systems for Livelihood Resilience.

M-KOPA is a top-down, private sector-driven model catering for low-income households' needs via large-scale distribution networks, accessible financing models, and customer support. It combines a low upfront deposit with flexible daily repayments, integrated through mobile money and managed via a GSM-enabled platform that allows users to access energy, monitor usage, and track repayments without relying on traditional banking (Rastogi, 2018; Baker et al., 2025). The system's integrated nature enables real-time monitoring and credit management, providing reliable energy access with minimal upfront risk. Moreover, M-KOPA facilitates access to low-carbon solutions across multiple domains, including solar PV and LED energy; energy-efficient stoves; and digital financial platforms. In turn, the model can create pathways towards robust livelihoods and potentially help to buffer households from economic or climate-related shocks.

M-KOPA has generated substantial improvements not only for livelihoods, but also for health and well-being. For instance, households in Kampala using M-KOPA technologies reported spending 90% less on kerosene lamps and batteries, which also minimises exposure to air pollutants and fire hazards like candles (M-KOPA, 2025). Half of these customers reported using their product for income generation, with 86% reporting improved quality of life – illustrating the far-reaching benefits of this innovation (ibid.). For instance, a female M-KOPA consumer in Kampala's informal settlements explained how replacing kerosene with solar has substantially enhanced her children's education and improved air quality, while also bolstering her livelihood as a shopkeeper:

Before getting the solar system, my kids were studying using poor tadoobas (tin lamps), and the smoke was choking us every night. Now the lights from the M-KOPA system are brighter, and my children can do their homework safely. My phone is always charged, which keeps my small retail shop running. I don't have to buy expensive kerosene or walk long distances to pay for phone charging anymore; the power is right here in my house (Shopkeeper in Makindye Division, Kampala).

Commercial Scalability and the Pressures of Asset Financing in African Cities.

M-KOPA's commercially scalable model demonstrates how private-sector innovation can extend energy and water, micro-finance and technology to low-income urban households. By 2023, as many as 1 million customers had accessed solar home systems (across the M-KOPA network in 5 nations) (M-KOPA, 2019). Customers reportedly save \$650 annually on average, while refurbished phone and e-mobility activities have mitigated 55,000 tCO₂e (M-KOPA, 2024). However, there are still equity-related concerns, such as rising indebtedness amongst marginalised customers, and we also highlight the lack of institutionalisation and public oversight.

M-KOPA's daily repayment structures closely mirror the cash flow of informal work, but can also impose constant pressure due to the erratic, unreliable nature of earnings in the informal economy (Nzekwe, 2025). A boda boda (motorcycle) rider in Kampala described how M-KOPA's algorithm-controlled payment systems clash with fluctuating daily incomes, resulting in chronic stress and anxiety. The threat of household disconnections and lowered credit ratings due to nonpayment can lead to ongoing cycles of debt, as he explained:

The challenge with M-KOPA is that it doesn't understand our rhythms of work. Sometimes it pours rain all morning, and as a boda boda rider, I make almost nothing. I am always in debt because of the rigid payment system. If I miss the daily mobile money payment by just a few days (or sometimes hours), the algorithm would automatically cut off my power, leaving my family in pitch darkness. You find yourself trapped in a loop of constant anxiety, taking micro-loans from other people to feed the M-KOPA meter so that they don't lock your system or report your name to the credit bureau. (Boda boda rider, Kampala's Bwaise III parish).

While M-KOPA ostensibly has prioritised small-scale entrepreneurs, these findings suggest that innovative climate mechanisms may only reinforce structural inequalities, especially if approaches to informal livelihoods are insufficiently inclusive or even at loggerheads with capitalist imperatives (Finn, 2025). Therefore, M-KOPA's trajectory highlights both the promise and the shortcomings of asset financing in Africa's informal economy. Solar kits and other M-KOPA products may provide a chance to own livelihood assets, but they also tether the customers to daily repayments. Relatedly, there is a risk of indebtedness and potential for heightened inequalities, as PAYGO models may disproportionately benefit more established entrepreneurs or better-off households, while heightening pressures upon more precarious users (Collings and Munyehirwe, 2016; Ojong, 2022).

Moreover, there is a fundamental challenge due to M-KOPA's limited institutionalisation, which reflects the tension between decentralised, private infrastructure and centralized, government-led development agendas. Uganda's national energy strategies still prioritize centralized grid densification, correspondingly sidelining standalone solar as a temporary, rural fix without considering its role in urban areas (Baker et al., 2025). In turn, M-KOPA has operated in a regulatory grey zone straddling energy, telecom, and micro-finance sectors without a single, harmonized consumer protection framework. According to a Ugandan government analyst, “For true institutionalization to occur, digital providers [such as M-KOPA] must have submitted to the same public accountability, consumer protection guidelines, and grid-interoperability standards that govern standard public infrastructure” (senior policy analyst, Ministry of Energy and Mineral Development). In the absence of such institutionalisation, M-KOPA has largely avoided public oversight and remained largely unregulated (e.g., in setting tariffs and disconnection policies), and it may thus only reproduce the socioeconomic and climate vulnerabilities facing highly marginalised households.

Conclusions: Reflecting on the Integration of Technological and Livelihood Innovations.

The M-KOPA model has strong potential to address climate mitigation goals and energy poverty, alongside enhanced quality of life, health outcomes, and access to opportunity. But given the profound equity and governance concerns, there is a need for stronger regulatory oversight (and related institutionalisation processes).

While M-KOPA illustrates how market-driven models can rapidly scale and expand access to energy, climate innovation in African cities also emerges through smaller scale, bottom-up collaborative governance arrangements that integrate technical systems with locally grounded knowledge. The following case studies will examine more hybrid constellations of innovation that bridge the

technological, social, governance, and to a lesser extent livelihoods, quadrants of innovation.

7. Case Study 2: empowering informal settlements through community-based flood early warning systems in Durban, South Africa

7.1. Knowledge co-production and participatory governance for flood resilience in informal settlements

Informal settlements often face disproportionate flood risk (Adegun et al., 2026), but these challenges have motivated innovative efforts to co-produce early warning systems. In Durban, South Africa, informal settlements were amongst the hardest hit by the April 2022 floods, which claimed over 450 lives and displaced 40,000 people (Sutherland, 2025). During these floods, Palmiet Catchment's community-based flood early warning system (CBFEWS) saved an estimated 250 to 400 lives in the Quarry Road West (QRW) informal settlement (Sutherland, 2025). Functioning since 2016, this locally grounded intervention seeks to strengthen inclusive, gender-responsive flood resilience in QRW. The CBFEWS has evolved into a social-technological innovation integrating governance reform, livelihood protection, and justice-centred adaptation. Its significance lies not only in reducing flood risk, but in challenging the failures of planning and exclusionary risk governance that undergird urban climate injustices. Within our framework (Fig. 1), the CBFEWS is positioned primarily in the social/governance domains, operating at settlement scale with strong procedural equity, significant recognition for local knowledge, the centrality of ecological infrastructure and growing levels of institutionalisation (O'Donoghue et al., 2025).

7.2. Delivering epistemic justice through social innovation

As a “targeted radical social innovation,” this initiative has transformed knowledge production and power relations through recognising the valuable local expertise of informal settlement residents (Sutherland, 2025). The CBFEWS emerged through the Palmiet Catchment Rehabilitation Project, a coalition of academics from the University of KwaZulu-Natal (UKZN), community leaders, eThekweni Municipality representatives, and civil society organisations, who together formed a Community of Innovators (ibid.). The system combines real-time community observations with scientific and technical information, such as data from the South African Weather Service (SAWS), the municipal Forecast Early Warning System (FEWS), municipal rain and stream gauges, and radar. By translating and integrating these different forms of data, the CBFEWS communicates more accurate flood warnings and updates via WhatsApp groups across the catchment, particularly to the most vulnerable households (O'Donoghue et al., 2025). Through lived experience, Learning Labs, PhotoVoice, and other participatory methods, the CBFEWS has been refined and further co-produced using local, place-based knowledge and government's technical forecasting information, with warnings translated into trusted, actionable messages (ibid.). As a female CBFEWS representative interviewee noted: “We always knew how the river behaves, we watch it, we know how it works and when it will flood, but before this system, nobody treated that knowledge as important.” This prior dynamic reflects a broader pattern of recognitional injustice in flood early warning systems, whereby the knowledge, needs, and capacities of marginalised residents are frequently overlooked in formal governance arrangements, reinforcing pre-existing inequities during flood events (Aboagye and Nakamura, 2026). By contrast, we argue that the CBFEWS' respect for and validation of community insights has promoted epistemic justice and co-production of knowledge, with potential to overturn the socio-economic, spatial, and political marginalisation of informal settlements (cf. Mitlin et al., 2020).

7.3. Participatory protocol design and hybrid governance

The CBFEWS is an example of self-supported provisioning (SSP), as it is neither a completely independent nor fully embedded institutional structure (Bandaiko and Finn, 2025). Governance innovation is evident in the CBFEWS' underpinning hybrid model that aligns formal institutional protocols with local priorities. Through processes of institutionalisation, including becoming a standing agenda item in the municipal Joint Operations Centre, the CBFEWS has moved towards more inclusive and embedded forms of adaptation governance (O'Donoghue et al., 2025). Additionally, its WhatsApp communication networks ensure that information circulates rapidly and in locally meaningful ways. Nevertheless, the system remains somewhat fragile due to considerable dependence on maintaining trust, municipal buy-in, and the continued presence of institutional and community champions. Its sustainability over time is thus contingent upon long-term collaborations between government actors, academic researchers, and (perhaps most importantly) marginalised residents. In sum, the CBFEWS case indicates that hybrid governance is an ongoing process that can bring together novel constellations of actors, but such connections may remain tenuous and vulnerable to political, institutional and other changes.

7.4. Integrating technical forecasting with local observations

Melding citizen observations with “augmented intelligence” is central to the CBFEWS, resulting in several socio-technical innovations and inclusive gains for affected residents. Municipal hydraulic modelling and radar data are combined with citizen science and real-time community observations to refine locally specific flood thresholds. Such findings can markedly improve the reliability and utility of flood data, and advanced flood warnings can substantially promote safety and enable community-wide mobilisation. As a female Quarry Road representative explained during an interview, “Even thirty minutes makes a difference. We can communicate back what is happening here with the river, and it gives time to quickly spread the word and move, and start to get children out.” During the 2022

floods, despite electricity load-shedding and blocked bridges, early SAWS alerts combined with the municipality's FEWS and community messaging networks enabled evacuation before floodwaters destroyed homes. As a female CBFWEWS monitor explained during a focus group discussion, such findings are locally credible and rapidly acted upon during emergencies: *“the warning comes through our WhatsApp group with people we know and we can trust, we understand that when they message it is serious and time to act.”*

In complementary social innovations, residents use low-cost tools (such as whistles, pots and pans) for communicating flood alerts to the wider community in coordinating evacuation, although challenges persist in dissemination across heterogeneous residents (O'Donoghue et al., 2025). This illustrates that innovation lies not in forecasting sophistication alone, but in supporting translation, trust, and local interpretive capacity. At the same time, receiving a warning does not guarantee residents' ability to respond, since age, gender, disability, caregiving roles, and asset ownership jointly shape who can act on risk information and how effectively. As a Quarry Road young male noted during an interview, there are limits to inclusion even in this bottom-up, socially embedded model: *“We try to include everybody, but some are new to the settlement, or speak different languages and are difficult to reach so not everyone can be reached each time.”*

7.5. Livelihood co-benefits but limited ability to address structural drivers of vulnerability

The CBFWEWS' associated livelihood improvements centre on reducing losses of material assets, household goods, and land. Improved warning accuracy allows residents to move belongings to higher ground and clear drainage channels before floodwaters peak. This is important in informal settlements, where the loss of documents, tools, and building materials can deepen long-term precarity. The system is also linked to catchment-wide river rehabilitation and ecosystem-based adaptation initiatives that create local employment while reducing flood risk (Sutherland, 2025).

The CBFWEWS reflects a combination of social, governance, technological, and, to a lesser extent, livelihood dimensions of innovation. By embedding community knowledge in formal institutional processes and governing implementation in more inclusive ways, it has shifted the social limits of adaptation and opened space for more just forms of resilience. Nevertheless, it has left intact the underlying drivers of vulnerability including insecure tenure, unsafe land occupation, inadequate infrastructure, and poverty (Adegun et al., 2026; Howard et al., 2025). The CBFWEWS has developed inclusive social learning processes, but its transformative potential remains constrained.

7.6. The scalable potential of climate information systems

Scalability in the context of African urban innovation is fundamentally a political undertaking, rooted in questions of authority, institutional embedding, and access to resources. To move beyond isolated success stories, adaptations must be sufficiently embedded in institutional change processes (Amorim-Maia and Olazabal, 2025).

In Durban, the CBFWEWS model has been adapted and piloted in three additional settlements under the CLARE INACCT Resilience project and Research for Impact Opportunities Fund, supported by an extensive body of empirical research and practical tools developed over a decade (e.g. co-developed community trainers' manual and flood emergency response toolkits). Importantly, the scaling process does not involve replicating a fixed model, but adapting core principles of co-production, hybrid governance, and contextualised applications of technology.

Meanwhile, the DARAJA initiative (Developing Risk Awareness through Joint Action)¹ is an important regional example of scaling people-centred climate information systems. Operating across Dar es Salaam, Nairobi, and Kampala (as well as operating in Ethiopia, Rwanda and Sudan), DARAJA connects national meteorological agencies with informal settlements through co-produced, locally tailored warnings. The initiative maps local “information ecosystems” to understand how weather information is received and understood in different contexts (RESURGENCE, 2025). Based on these insights, technical jargon is translated into accessible messages in local languages and disseminated through SMS, community radio, and trusted “weather champions,” with feedback loops to improve responsiveness and accuracy (Kounkuey Design Initiative (KDI), 2025). Similar to CBFWEWS, DARAJA's approach has bridged formal and informal systems to enhance dissemination of warnings to those most at risk (RESURGENCE, 2025). During the 2018–2023 pilot phase, DARAJA provided over 980,000 people across the three cities with improved access to actionable forecast information, contributing to a 300% increase in household repairs (in response to forecasts) in Nairobi and a 122% increase in Dar es Salaam (World Habitat, 2024).

DARAJA's expansion across East Africa shows that people-centred climate information systems can be reproduced in diverse contexts when equitable institutional partnerships, financing, and community intermediaries are in place. However, scaling may potentially dilute the relational qualities that make such systems effective. Scaling-up such innovations will rely less upon developing tools and protocols, but rather on supporting iterative, continuous institutional learning and strengthening community capacities. Like the CBFWEWS, DARAJA shows that impactful climate information systems strongly depend on cultivating inclusive co-production and ensuring contextually appropriate modes of communication.

¹ DARAJA was primarily funded by the UK Foreign, Commonwealth & Development Office (FCDO) via the Met Office-led Weather and Climate Information Services for Africa (WISER) program.

7.7. Reflecting on multi-dimensional innovation: recognising informal residents as vital co-producers of resilience

The CBFWS and DARAJA cases demonstrate that inclusive approaches can contribute simultaneously to multiple dimensions of innovation including livelihoods, social, governance, and technological. Both cases underscore the need to build upon local institutions and networks, which will require long-term finance, establishing trust across diverse actors as well as within low-income areas, and the ability to embed community knowledge in formal systems. To transform the drivers of climate vulnerability, such measures will need to recognise the interdependence amongst the facets of innovation. Social mobilisation alone is insufficient if not institutionally embedded; state-led systems remain limited when they fail to incorporate local knowledge; and technology cannot foster resilience without trust, translation, and local legitimacy. The benefits of knowledge integration and co-production illustrated in the above case studies can extend to more physical manifestations of adaptation. While early warning systems focus on improving preparedness and risk information, complementary climate innovation in African cities have taken the form of spatial and environmental interventions that address flood risks while generating broader social and livelihood benefits. We next turn to bottom-up innovations in Nairobi's informal settlements, where residents and civil society organisations have developed nature-based solutions (NbS) to transform degraded urban spaces into sites of climate adaptation, livelihood generation, and community wellbeing.

8. Case Study 3: innovations in inclusive public spaces and nature-based solutions (NbS): lessons from Kenyan informal settlements

8.1. Bottom-up efforts to enhance flood resilience and create multiple co-benefits

Within our framework, the following Kenyan NbS initiatives sit primarily in the social domain, while also demonstrating emerging governance innovations (Fig. 1). The cases offer multifaceted socio-economic, health, and climate benefits, and we explore their potential to foster more transformative modes of adaptation. Although they are generally small-scale and informally organised, the Embu case shows an emerging shift towards institutionalisation.

In a set of community-led innovations, residents of Nairobi's informal settlements have self-organised to improve green spaces, as well as to strengthen livelihoods, enhance quality of life, and promote flood resilience. For example, in Korogocho settlement, residents cleared a dumpsite to create a People's Park and cultivated vegetable gardens to generate incomes for local youth (Muchiri and Opiyo, 2022). Led by a community-based organisation called Komb Green Solutions, this inclusive approach to Korogocho's public spaces began in 2017 and has spurred similar initiatives across Nairobi (Wairimu, 2020). In a 2022 study, the Kenyan affiliates of Slum Dwellers International (SDI) called *Muungano wa Wanavijiji* and Shack Dwellers International-Kenya (SDI-Kenya) profiled over 425 climate action groups across Nairobi's informal settlements. Key activities include planting trees, regular clean-ups, and creating community parks, alongside income-generating activities (Mburu, 2022). These groups usually prioritize livelihood opportunities (e.g., poultry-rearing, urban agriculture, and recycling/waste collection), which typically benefit low-income young men, as such livelihood activities are rarely framed as jobs for women. Moreover, the groups' community-led climate initiatives became increasingly crucial following Kenya's devastating 2024 floods (and concomitant forced evictions) by helping to tackle flood-related vulnerabilities and support economic recovery (see Case Study 4 below). As a community leader in another settlement called Mathare explained, "After people were evicted, groups (including ours) decided not to leave the space bare... There is a lot of urban farming going on, tree planting, and building parks with gabions, which helps control waters during the rainy season" (FGD, December 2025).

Indeed, Mathare residents emphasised the multiple co-benefits of improved public spaces, which not only reduce the environmental and socioeconomic impacts of flooding but also can foster health and community pride. Community leaders noted that tree-planting and parks have improved control of floodwaters (while also limiting soil erosion); generated employment for youth who sell vegetables; and prevented floodwaters from entering houses or destroying other local assets (FGD, December 2025). Moreover, grassroots leaders noted proudly that Mathare has several community parks that create "a nice environment where you can go and relax" (FGD, December 2025). There is strong potential for community parks and related climate actions to enhance mental health, promote confidence in community-led solutions, and contribute to lasting reductions in flood vulnerabilities (McPhearson et al., 2025). As Mathare community leaders reflected, "We all know the benefits of planting trees and proper disposal of waste. When we plant trees, we expect the floods not to affect us the same way that they affected us previously" (FGD, December 2025). Residents thus recognised that bottom-up NbS and related livelihood activities may generate a virtuous circle with longer-term improvements in health and climate resilience, complemented by increased self-efficacy and social cohesion.

Yet these predominantly self-funded efforts remain constrained by limited resources, insecure tenure and weak state recognition. Their transformative potential depends not only on community initiative, but also on supportive governance arrangements and integration with wider infrastructure systems. The next section explores a contrasting approach to green infrastructure in Kenyan informal settlements, followed by a reflection on associated challenges and the need for further governance innovations.

8.2. Participatory designs for NbS and innovations in hybrid infrastructure

Kounkuey Design Initiative (KDI), a nonprofit design and community development organisation, has utilised participatory processes to support NbS, improve livelihoods, and enhance conventional ('grey') infrastructure in Nairobi's informal settlements. Working closely with residents of Kibera and other informal settlements to co-design such interventions since 2006, KDI has developed green infrastructure strategies that promote flood resilience while creating multi-functional, inclusive spaces (Diep et al., 2022; Hernandez-Montilla, 2026). For instance, the first Kibera Public Space Project (KPSP 01) has generated community

gardens, a pavilion and footbridge, and multiple livelihood opportunities (e.g., composting projects, brick production) (Dessie et al., 2025). Other KDI-supported projects have developed innovative hybrid infrastructures and collaborations with utility providers: for instance, KPSP 07 created play-spaces and a flood-resilient bridge, connected with trunk sewer lines, and provided reinforced gabions to withstand the impacts of floods (Mulligan et al., 2020). In a similarly integrated approach to drainage provision, KPSP 08 incorporated rainwater harvesting, pervious paving, and underground water detention alongside sewer connections (i.e., combining green, grey, and blue infrastructure) (Mulligan et al., 2020). Although KDI's model relies primarily upon donor funding, Kibera residents contribute about 5% of costs through labour, and the use of incremental learning processes can result in appropriate, low-cost technical solutions implemented by residents (Hernandez-Montilla, 2026; Dessie et al., 2025).

KDI works closely with resident groups in informal settlements to manage and maintain these initiatives, which may face governance challenges but can still enhance living standards, flood resilience, and community capacities. For example, residents have learnt how to maintain drainage channels and harvest rainwater, while also improving recreation spaces and living conditions in flood-prone areas (Diep et al., 2022). Many of KDI's projects promote gender equality, such as through combining playgrounds, childcare centres, WASH and laundry facilities, and spaces for women-led savings groups to meet and enhance their livelihoods (Dessie et al., 2025). However, community management of NbS can be highly challenging without government support or sufficient funding for maintenance (Mulligan et al., 2020). Residents of informal settlements may prefer conventional sewers or drains, especially given the complexity of managing unfamiliar green infrastructure (ibid.). Although KDI and its grassroots partners have demonstrated that grey infrastructure can successfully be combined with NbS, such hybrid approaches can be difficult to implement, especially as government officials in Nairobi have rarely expressed interest in NbS (ibid.; Hernandez-Montilla, 2026).

However, in an important shift towards co-produced and institutionalised NbS, KDI worked with local officials and informal settlement residents in Embu (a town of 75,000 near Mount Kenya) to develop Kenya's first County Government-adopted green infrastructure plan, which was incorporated into the county's spatial plan and integrated development plan. Launched in 2025, a pilot NbS project in an informal settlement called Dallas has integrated riverbank restoration with improved public space, enhancing ecological resilience and local livelihoods, and it forms part of a planned network of resilient, multifunctional public spaces in informal settlements (Realising Urban Nature Based Solutions (ruNbS), 2025; Covenant of Mayors in Sub-Saharan Africa (CoM SSA), 2019). Although small-scale, this initiative represents an important step towards institutionalising and legitimising the use of participatory NbS amongst Kenyan decisionmakers.

8.3. Reflecting on governance barriers and addressing key constraints to NbS in informal settlements

The above NbS innovations often face hurdles to scaling-up and realising their potential due to limited resources, insecure land tenure, and lack of state recognition, exacerbated by histories of social and environmental injustices. Many of Nairobi's informal settlements are in ecologically fragile, flood-prone areas with poor-quality soils, and these precarious locations are rooted in colonial-era planning decisions (Owuor and Mbatia, 2012). Although access to land has been highly politicised, Kenyan land law has usually relied upon technical solutions and ignored the entrenched political interests in an inequitable status quo (Manji, 2020). Green spaces in Kibera and other informal settlements may garner the attention of politically connected land-grabbers and, in further challenges, some community parks were destroyed during the 2024 flash floods (Dessie et al., 2025; Ndung'u, 2024). Meanwhile, residents of informal settlements may lack the funds and capacities to maintain parks, manage multiple forms of pollution, and address other socio-ecological challenges facing NbS (Diep et al., 2022). To promote longer-term flood resilience and tackle such underlying vulnerabilities, community-led NbS may benefit from melding with conventional 'grey' infrastructure and inclusive city-wide governance measures (Mulligan et al., 2020). But tenure insecurity and legacies of exclusion frequently hamper these collaborations; such challenges are often exacerbated by limited knowledge of NbS amongst decisionmakers and low-income residents alike.

Although varying in their levels of technical complexity and external support, the above NbS can generate wide-ranging social and economic benefits for informal settlements; they also highlight the need to develop complementary governance innovations. Bottom-up NbS strategies in Nairobi's informal settlements typically remain precarious and poorly coordinated, given their decentralised approach and exigent need to focus upon daily survival (Mburu, 2022). Nevertheless, climate action groups have combined their short-term livelihood imperatives with efforts to foster collective benefits, generating significant possibilities for longer-term improvements in flood resilience and community efficacy. KDI and its partners have helped to unlock an array of co-benefits (e.g., socioeconomic gains, gender-equitable strategies, and enhanced grassroots capacities) and set important precedents for how to combine grey-green-blue infrastructure in informal settlements (Mulligan et al., 2020; Dessie et al., 2025). With additional governmental support for grassroots and civil society groups, as in Embu County, it may be possible to develop more meaningful NbS partnerships and to help realise the transformative potential of these community-led innovations.

The final case study below illustrates a complementary community-led innovation, in which residents of Nairobi's informal settlements seek to foster psychological resilience. These efforts are an example of a 'targeted radical social innovation,' as they have challenged traditional power relations and the stigma surrounding mental health (Marques et al., 2018). Low-income residents have designed inclusive, locally embedded strategies as well as creating incipient partnerships with local media, service providers, and government officials.

9. Case Study 4: promoting mental health and climate resilience in Nairobi's informal settlements

9.1. Grassroots first responders: addressing climate trauma

The trauma and psychological toll of Kenya's April 2024 devastating floods, which claimed hundreds of lives and displaced thousands, were compounded by the government's unlawful evictions and demolitions that uprooted thousands more households in Nairobi's informal settlements (Ouma, 2024). Evictions in the riparian reserve especially affected households in the most precarious dwellings, while flood-related losses of shelter, livelihoods, and sense of safety afflicted residents in informal settlements more generally. In response, community leaders offered essential assistance and psychosocial support to their fellow residents. First responder groups including youth leaders and community health promoters (CHPs) helped to rescue vulnerable groups like the elderly or people with disabilities, while also spearheading relief efforts and mutual assistance (Koyaro et al., 2025). The following case study will discuss Muungano/SDI-Kenya's efforts to enhance psychosocial resilience following the floods, representing an example of hybrid social-governance innovation, wherein the actors' complementary roles can address complex social challenges for collective benefit (Ziervogel and Hamann, 2024). Within our framework (Fig. 1), this initiative represents a social innovation operating at local scale, exhibiting limited but rising levels of institutionalisation and strong recognitional equity. We explore below how these interventions may facilitate recognitional justice, in addition to enhanced solidarity, mutual support, and newfound understanding of the psychological dimensions of resilience.

With mental health impacts of Kenya's 2024 flood event being poorly acknowledged, many grassroots leaders and residents faced insomnia or PTSD for months afterwards. CHPs and youth leaders often had to recover bodies and lost their relatives, but they had few opportunities to process the grief and trauma (Koyaro et al., 2025). As a youth leader in Nairobi's informal settlement of Mathare recalled, *"We lost a lot of friends and family members [in the 2024 floods] either through death or relocation... Some of us are still facing the effects of flooding, including [being] affected by mental illness"* (FGD, December 2025). Similarly, a CHP in Mathare noted that these volunteers responded promptly to support others, but their own well-being was overlooked: *"We helped move residents to safer ground... Some people became sick, others were traumatized. We had to be there to help them... One challenge we face is when the community expects us to be okay when we are not okay"* (FGD, December 2025). Although a few CHPs in Nairobi's informal settlements had already been trained as lay counsellors, there was usually limited attention to such concerns due to longstanding taboos around mental health.

9.2. Social innovation and strategic partnerships for scaling mental health outreach in informal settlements

To address unmet needs in informal settlements, while also raising public awareness of the links between mental health and climate change, a campaign was launched under the 'Race to Resilience' (R2R) initiative in October 2024. This intervention in Nairobi is led by the Kenyan slum-dweller federation *Muungano*, SDI-Kenya, and other civil society organisations (with funds from the L'Oreal Foundation). Building upon previous mental health outreach and reflections with Kenyan adolescents led by the Tabasamu Café project (another project partner), R2R created cafes exploring climate resilience, while extending the focus beyond adolescents. Beginning with three Nairobi informal settlements that were hard-hit during the 2024 floods, R2R has enabled community leaders to reflect on their experiences and offered additional training. In turn, these participants have trained further participants using a readily scalable model of 'Trainers of Trainees (TOTs)'. Over the past 18 months, 10 Climate Resilient Cafes have been established in Nairobi's informal settlements. Between 20 and 30 residents participate in each session, and the initiative has reached approximately 1200 community members (personal communication, SDI-Kenya). One trainer from Mukuru explained how the cafes enabled parents to voice their anxieties about their children's safety and to reflect on the links between mental health and extreme weather events more generally, as follows:

Our Cafe [has] been educational, especially in understanding how climate change and mental health are connected... Through the shared experiences, it was easy to see how we are affected by climate change and our mental state during and after a disaster... We would share the worries [and] parents talked [about] their family safety, and how children will get to school (personal communication, SDI-Kenya).

The initiative also benefits from strong media engagement and a partnership with a local health organisation (LVCT Health) that freely provides telehealth services, including a hotline and SMS service offering mental health support. To foster wider uptake, R2R has engaged in extensive outreach to local TV talk shows and community radio stations in informal settlements to raise awareness about mental health, challenge stigmas, and share relevant resources (SDI-Kenya, 2025). Listeners call-in seeking information about mental health, and the show facilitates access to referrals when additional support mechanisms are required. Men, who rarely engage in conversations about mental health due to social stigma, have notably called-in and shared their personal struggles (Shack Dwellers International Kenya (SDI-Kenya), 2025).

9.3. Reflecting on psychosocial resilience pathways

Key innovations include a locally embedded training model that capacitates existing grassroots leaders; responds to pressing community priorities after the floods; and has scaled-up rapidly. Partnering with a local health organisation (LVCT Health) and engaging community media outlets further expands the programme's reach, with related benefits in changing discourses around mental health and raising awareness more broadly. R2R is complemented by the federation's grassroots savings groups, partnerships with government actors to upgrade shelter and infrastructure, and bottom-up NbS strategies (see Case 3 above), which can help to reduce climate vulnerabilities over the longer term (Corburn et al., 2022). Since the model builds upon well-established local networks and taps into SDI-Kenya/Muungano's ongoing advocacy for climate justice, there is a strong potential to replicate and expand across

other Kenyan cities through incorporating mental health and climate resilience within community institutions. Although government support is still in its early stages, R2R has engaged officials working on health and youth affairs in Nairobi's County Government to help garner support. There are plans to partner with additional agencies such as Nairobi County's mental health team, youth department, and first responders like the fire department and disaster management teams. In sum, R2R has equitably and rapidly addressed an unmet grassroots need with substantial potential to advance mental health, community cohesion, and solidarity in informal settlements, while also promoting wider social and governance innovations on a formerly taboo topic.

10. Concluding reflections: implications for theory and practice

Taken together, the above case studies help to reveal the genesis, emerging trajectories, and transformative potential of climate innovations in African cities. First, climate innovations rarely operate within a single domain; instead, they often combine technological, social, governance, and livelihood dimensions. Even apparently technical interventions depend heavily upon their ability to meet multiple social and economic needs, while also relying upon trusted intermediaries and governance alignment. Second, innovations often emerge at small scales through bottom-up experimentation, but their durability is contingent upon whether local governments can enable institutionalisation without erasing grassroots agency. Third, the extent to which innovations can contribute to equitable climate resilience and transformation is ultimately a question of justice, including who participates, whose knowledge counts, and who benefits.

Climate innovations vary substantially in their potential to foster climate justice or merely deliver incremental reductions in vulnerability. Across the cases, M-KOPA improves energy access and livelihood resilience through rapid technological and financial diffusion, but to date has limited scope to influence underlying governance processes or political exclusions. DARAJA shows how climate information can travel effectively across cities through institutionalised partnerships, while the Durban CBFWS demonstrates how a socially rooted initiative can become more impactful and equitable as community knowledge, technical systems and municipal engagement are brought together. In Nairobi, nature-based solutions and mental health initiatives illustrate how locally grounded action can challenge exclusionary assumptions about climate knowledge, while also combating stigma and fostering multifaceted gains in informal settlements.

These examples show that movement across domains is not automatically progressive: hybridity can extend technical reach without redistributing power. Of central importance is whether interactions between social, governance, technological and livelihood dimensions can reconfigure decision-making, strengthen participation and legitimacy in marginalised areas, and recognise the value of local knowledge. Market-led initiatives such as M-KOPA are often framed as primarily instrumental and technical innovations, while DARAJA and CBFWS more closely resemble complementary innovations that work through existing institutions to improve the accessibility and inclusiveness of climate information systems. The Nairobi cases reflect elements of radical social innovation, as they challenge assumptions about who produces knowledge, governs climate risk and participates in decision-making. Yet these more radical initiatives may struggle to gain official traction, which underscores the importance of co-producing equitable interventions and institutionalising community-led solutions (but without undermining their autonomy and agency).

Theoretically, the paper advances climate innovation scholarship by showing that African urban innovations are often hybrid, combining technological, livelihood, social and governance dimensions in complex configurations. Extending prior literature (e.g. Marques et al., 2018; Zervogel and Hamann, 2024), our framework provides a heuristic for tracing the trajectories through which locally grounded initiatives do—or do not—gain institutional support, connect across scales, and redistribute recognition, resources and decision-making power (Beckman et al., 2023). It therefore enables climate scholars to distinguish innovations that challenge inequitable governance arrangements from those that primarily optimise or reproduce existing systems. Future research can deepen our comparative understanding of climate innovations in African and other Global South cities, including (A) their changing trajectories over time; (B) alternative strategies to foster scale, equity, and institutionalisation (alongside the associated barriers); and (C) roles of diverse actors including social enterprises and financial agencies, academic institutions and civil society groups. Subsequent research can also offer conceptual and theoretical analyses of how urban climate innovations navigate their competing priorities or tensions, with related consideration of the implications for climate justice and transformative adaptation.

Regarding lessons for practice, our findings caution against equating transformation with merely scaling-up, wider replication, or technical diffusion. We suggest that cities should invest not only in implementing equitable climate solutions, but also in the enabling social, governance, and institutional conditions that shape their trajectories. For instance, we have highlighted the pivotal role of trusted intermediaries, who can help to promote meaningful grassroots participation; official recognition for local knowledge; and sustained public support, alongside accountability to marginalised groups. Scaling-up should focus on transferring the inclusive governance principles underlying the above cases—such as co-production, local translation, and cross-scale linkages—rather than reproducing rigid, decontextualised models. These enabling conditions are essential if locally grounded innovations are to help reshape urban climate governance, reduce entrenched inequalities, and support more just and resilient futures.

CRediT authorship contribution statement

Hayley Leck: Writing – original draft, Methodology, Investigation, Conceptualization. **Clara Marais:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Paul Isolo Mukwaya:** Writing – original draft, Methodology, Investigation, Conceptualization. **Michelle Koyaro:** Writing – original draft, Investigation. **Vera Bukachi:** Writing – review & editing, Investigation. **Alice Sverdlik:** Writing – original draft, Visualization, Methodology, Investigation, Conceptualization.

Declaration of competing interest

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

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Data availability

Data will be made available on request.

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