Strengthening informal urban functions for climate-resilient cities

Author

Allen Glen Cumaya Gil
Yale School of the Environment, Yale University
New Haven, Connecticut, United States
Email: allen.gil@aya.yale.edu
ORCID: 0000-0003-2347-296X

Preprint Statement

This manuscript is a non-peer-reviewed preprint submitted to EarthArXiv and is currently under consideration for peer review at *npj Urban Sustainability*. It has not yet been certified by peer review. The author welcomes constructive feedback, comments, and suggestions that may help improve the manuscript.

Correspondence
Correspondence concerning this manuscript should be addressed to Allen Gil at allen.gil@aya.yale.edu.

Suggested Citation

Gil, A.G.C. (2026). *Strengthening informal urban functions for climate-resilient cities.* EarthArXiv preprint. [DOI]

Perspective

Strengthening informal urban functions for climate-resilient cities

Allen Glen C. Gil[1]
[1]Yale School of the Environment, Yale University, New Haven, CT, USA
Correspondence: allen.gil@yale.edu

Abstract

Informal workers provide essential urban functions, yet climate hazards can disrupt the conditions that sustain them. We propose the informal urban function as an analytical unit linking worker conditions, functional performance, and sustainability outcomes. The framework identifies structural conditions shaping capacity, climate pathways leading to continuity, erosion, disruption, or reconfiguration, and intervention points for strengthening worker well-being, functional performance, and resilience.

Keywords: informal sectors; informal urban functions; climate-resilient cities; urban sustainability

Informal urban functions connect work to urban sustainability

Many cities depend on functions performed substantially through informal work. Waste pickers recover recyclable materials, street vendors connect food suppliers with consumers, informal water vendors extend water provision where piped systems are absent or unreliable, and home-based workers use residences as sites of production [1–5]. These activities can generate environmental and social value even when providers have limited recognition, resources, rights and institutional support [6,7]. Climate change raises the stakes because heat, flooding, drought and storms add pressure to workers and operating systems with limited capacity to absorb disruption [8,9].

Existing scholarship establishes important parts of this problem but rarely traces the full connection between them. Research on informality centers workers, livelihoods, rights and institutions, whereas urban sustainability research more often examines services, infrastructure and system outcomes [6,7]. Climate research increasingly documents exposure, health risks and livelihood disruption among informal

workers [8–11]. Evidence becomes thinner as analysis moves from worker and operating impacts to changes in service volume and coverage, reliability and affordability, and recovery. Worker vulnerability becomes an urban sustainability problem when it changes functions on which urban populations or systems depend.

We define an informal urban function as a recurring service, flow or system role performed substantially through informal workers, enterprises or organized networks. The concept separates four analytical levels:

Informal activity → informal urban function → functional performance → urban sustainability outcome

Waste recovery, street vending, and informal water provision serve as recurring empirical anchors that illustrate the framework across distinct urban functions. They span material, food and water systems and illuminate different parts of the causal sequence. Waste picking performs material recovery, whose volume and effectiveness can influence landfill diversion, circularity and greenhouse-gas mitigation [1,12,13]. Street vending performs decentralized food provisioning, whose availability, affordability and reach can influence food access [2,14]. Informal water provision can extend water access where piped systems provide incomplete or unreliable service, with performance expressed through coverage, reliability, affordability and quality [3,4].

Functional performance determines whether an activity produces beneficial, harmful or mixed outcomes. Material recovery can support circular flows and also expose workers and nearby communities to environmental and health hazards [15]. Street vending can improve food access, yet its performance depends on public-space access, infrastructure and tolerable thermal conditions [2,11,16]. Informal water markets can extend access while variations in affordability, reliability and quality generate unequal outcomes [3]. Sustainability therefore requires empirical evaluation of what function is provided, how well it performs and how benefits and harms are distributed.

Proposition 1. Informal actors contribute to urban sustainability through identifiable functions whose performance and outcomes can be evaluated.

Structural conditions shape functional capacity

Functional capacity reflects the ability of informal workers and networks to sustain provision, adapt operations and recover performance after disruption. Research across informality and urban resilience identifies unequal access to resources, infrastructure, protection, political influence and urban opportunities [6,7,17]. We

organize the conditions shaping functional capacity into five dimensions: recognition; resources and infrastructure; rights and regulation; institutions and organization; and socioeconomic security. These dimensions translate broad patterns of marginalization into conditions that can be diagnosed across functions and places.

Recognition determines whether functions and providers are visible to institutions and considered in planning, investment and adaptation [2,7]. Resources and infrastructure determine the material and financial capacity to sustain provision and recover after disruption. Relevant resources include shade, workspaces, storage, transport, finance and social protection [3,4,8,16].

Rights and regulation shape access to the spaces, assets and resources needed for provision. Recycling cooperatives in Santiago illustrate direct functional effects: repressive policy reduced collection and worker outcomes, whereas supportive policy and capital improved environmental, economic and social performance [18]. Institutions and organizations shape coordination, bargaining and access to support. Waste-picker organizations can strengthen institutional access [19], and informal water provision depends on relationships among vendors, consumers, utilities and public authorities [3,4].

Socioeconomic security determines how much disruption workers can absorb before illness, asset loss or interrupted income produces prolonged effects [8,9,20]. The five dimensions can operate independently or reinforce one another, producing different functional capacities even among workers exposed to similar hazards.

Climate pressure propagates through informal urban functions

Climate hazards become urban sustainability risks when their effects propagate from workers and operating conditions into the performance of functions on which urban populations or systems depend. This propagation can begin with direct impacts on providers or with disruption elsewhere in the urban system. Heat can reduce safe working time and productivity, flooding can interrupt workplaces and routes, and recurrent hazards can damage health, livelihoods and assets [8–11,21]. Informal traders in Windhoek, for example, report changes in productivity, income, trading hours, customer flows and infrastructure access under extreme heat and flash flooding [11]. In Lodwar, drought and flooding disrupt piped water provision and change demand for water vendors, their sales patterns and their relationships with government and utilities [4]. Climate pressure therefore reaches informal functions through both provider-level impacts and system-mediated changes in the conditions under which provision occurs.

Four interacting channels organize this propagation. Human capacity includes health, fatigue and safe working time. Assets and resources include equipment, inventory, finance and material inputs. Space and infrastructure include workplaces, routes, utilities and distribution systems. Networks and institutions include suppliers, customers, worker organizations, utilities, government and information [4,8–11,21]. These channels interact with one another. Reduced working time can lower income and limit workers' ability to replace damaged assets. Infrastructure damage can lengthen travel and restrict access to markets. Disruptions to suppliers, customers or utilities can also shift demand and make continued provision more difficult. Climate pressure can therefore cascade across several dimensions of functional capacity even when the initial impact enters through only one.

Structural conditions determine how strongly these pressures translate into functional change. Recognition can influence access to emergency support; infrastructure and financial resources can buffer operational losses; secure rights can preserve access to workspaces and resources; organization can facilitate coordination and collective adaptation; and socioeconomic security can give workers greater room to reduce exposure without immediately losing their livelihoods [6–9,17]. The same hazard can therefore produce different functional responses across places or sectors because baseline capacity differs. These conditions also affect whether repeated shocks are absorbed, accumulate into declining performance or push provision beyond a threshold at which normal operations can no longer be sustained.

Functional responses can take four broad forms: continuity, erosion, disruption and reconfiguration. Continuity occurs when provision is maintained despite pressure. Erosion describes cumulative deterioration in volume, coverage, reliability, affordability or quality. Disruption occurs when losses become large enough to produce substantial temporary failure. Reconfiguration occurs when the scale, location, timing, organization or mode of provision changes. These responses are not necessarily discrete states. Recurrent hazards can shift a function from continuity to erosion and eventually disruption, while adaptation, changing demand or institutional intervention can produce reconfiguration during or after that process.

Continuity and reconfiguration can signal resilience, but they can also conceal rising costs or deeper system failure. Workers may maintain provision by accepting unsafe exposure, sacrificing income, reducing consumption or depleting assets [8,9,20]. In Lodwar, flood damage shifted households away from piped service, and drought increased reliance on vendors and led county authorities to contract tanker operators for emergency supply [4]. The expansion of informal water provision occurred because the wider water system lost capacity, illustrating how climate pressure can drive functional reconfiguration.

Whether a functional response becomes a wider urban sustainability problem is shaped by dependence, substitutability, redundancy and distribution. Dependence determines how strongly people or systems rely on the function. Substitutability determines whether equivalent alternatives are accessible when performance changes. Redundancy determines whether other providers or systems can absorb lost capacity. Distribution determines who bears the costs or receives the benefits of continuity, decline or reconfiguration. These conditions explain why identical changes in functional performance can have very different urban consequences. A modest decline may have limited effects where alternatives are abundant, yet the same decline can severely affect populations with few substitutes. Conversely, greater reliance on an informal function can maintain service while transferring costs or risks toward workers or disadvantaged users.

Informal water provision illustrates this downstream propagation. Failure of piped supply can reduce substitutability and increase dependence on vendors, making informal provision more important to continuity of water access. Yet greater vendor activity does not itself imply improved sustainability because affordability, reliability and water quality may deteriorate as dependence rises [3,4]. Similar distinctions apply across informal functions: the sustainability outcome is shaped by how functional performance changes, how essential the function is, what alternatives exist and how resulting benefits and burdens are distributed.

Figure 1 summarizes this causal sequence. Structural conditions establish baseline functional capacity and condition how climate hazards propagate through human capacity, assets and resources, space and infrastructure, and networks and institutions. These interacting pressures generate continuity, erosion, disruption or reconfiguration, whose downstream sustainability outcomes are shaped by dependence, substitutability, redundancy and distribution. The framework therefore shifts the analytical question from whether informal workers are vulnerable to when, how and under what conditions climate pressure on workers and operating systems becomes functional change and, in turn, shapes urban sustainability outcomes.

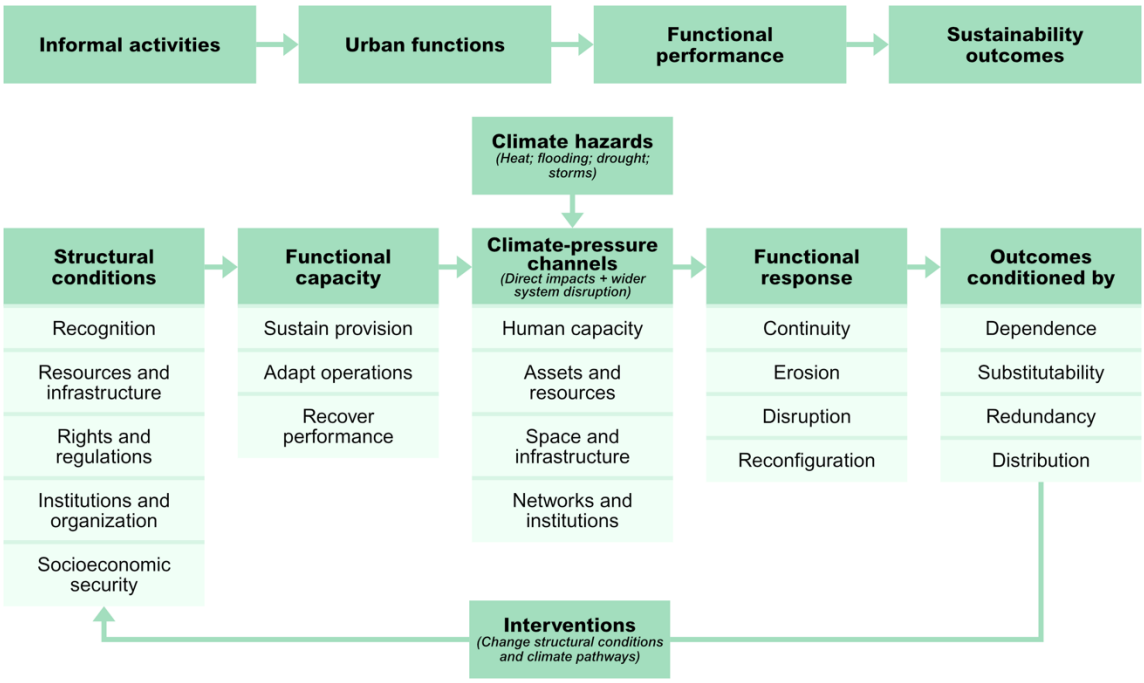

Figure 1 | Structural conditions and climate pathways shaping informal urban functions. *Informal activities generate urban functions whose performance contributes to sustainability outcomes. Structural conditions shape functional capacity, including the ability to sustain provision, adapt operations, and recover performance. Climate hazards affect these functions through human capacity, assets and resources, space and infrastructure, and networks and institutions, including effects mediated by disruption elsewhere in the urban system. These pressures can produce continuity, erosion, disruption or reconfiguration. Sustainability outcomes are conditioned by dependence, substitutability, redundancy and distribution. Interventions can strengthen resilience by changing structural conditions and climate pathways.*

Proposition 2. Structural conditions shape baseline functional capacity, and climate hazards can alter capacity and system relations in ways that change functional performance and downstream urban sustainability outcomes.

Structural diagnosis identifies intervention points

A function-centered diagnosis identifies what is limiting a function and which interventions can strengthen its performance. Limited recognition can exclude informal providers from planning, data systems and emergency support, creating a case for institutional inclusion. Resource and infrastructure deficits can constrain provision and recovery, pointing to investments in workspaces, equipment, finance and basic services. Insecure rights can destabilize access to spaces and resources,

while weak organization and socioeconomic insecurity can limit bargaining power and force workers to continue operating under unsafe conditions [7,8,18,19].

Effective adaptation also requires matching interventions to the climate pathway affecting a function. Shade can reduce thermal exposure and help sustain safe working time among street-based workers [11,16]. Investments in assets, infrastructure and finance can improve the ability to absorb losses and restore operations. Stronger coordination among workers, utilities and public authorities can reduce disruption across networks and institutions, as evidence from recycling systems and informal water provision suggests [3,4,18]. Social protection can further expand workers' capacity to respond to climate shocks without sacrificing health or livelihoods [8].

Intervention portfolios should therefore address the structural constraints and climate pathways that most directly shape functional performance. Street vending affected by heat may require shade, secure access to public space, and income protection; waste recovery exposed to flooding may require protected facilities, equipment, and organizational support; and informal water provision during drought may depend on storage, transport capacity, and coordination with utilities and government. The diagnostic value of the framework lies in identifying where capacity is constrained and which combination of interventions can strengthen it.

Policies can also alter functions in unintended ways. Redevelopment can reduce vendors' access to public space, and exclusionary formalization can displace workers or weaken the services and environmental value they provide [7,16]. Informal water markets can extend access during service gaps while raising concerns over affordability, reliability, quality and equity [3]. Evaluation should therefore track worker outcomes, functional performance and urban sustainability outcomes together to determine whether an intervention strengthens the function and improves conditions for the people who provide and depend on it.

Proposition 3. Strengthening beneficial informal urban functions requires interventions that improve structural conditions, reduce climate pressure, and protect worker well-being.

Operationalizing the framework

The framework can be operationalized through five questions that move from identifying the function to diagnosing capacity, tracing climate pressure, evaluating outcomes and locating intervention points.

Box 1 | Informal Urban Functions Climate Resilience Checklist

1. What function is being provided?
Identify the activity and focal urban function, the providers and populations that depend on it, and the indicators needed to measure functional performance and potential sustainability outcomes.

2. What shapes functional capacity?
Assess recognition; resources and infrastructure; rights and regulation; institutions and organization; and socioeconomic security. Identify which conditions most strongly enable or constrain the ability to sustain provision, adapt operations and recover performance.

3. How does climate pressure alter functional capacity and operating conditions?
Trace direct and system-mediated effects through human capacity, assets and resources, space and infrastructure, and networks and institutions, including changes in demand, access and coordination.

4. What is the functional response and how does it shape urban sustainability outcomes?
Identify continuity, erosion, disruption or reconfiguration and measure the resulting change in functional performance. Assess how dependence, substitutability and redundancy shape urban sustainability outcomes and how benefits and burdens are distributed across workers, users and places. Track worker conditions even when provision is maintained or reconfigured.

5. Where can intervention change the pathway?
Match interventions to the diagnosed structural constraints and climate pathways, then assess intended and unintended effects on workers, functional performance and urban sustainability outcomes.

Applying the framework across sectors

Waste recovery, street vending and informal water provision provide complementary tests of the framework. Waste recovery provides comparatively strong evidence connecting functional performance to environmental outcomes [12,13]. Street-vending research provides substantial evidence on climate exposure and operating conditions [2,11,14,16]. The smaller literature on informal water provision provides a particularly clear example of climate-driven functional reconfiguration [3,4]. Table 1 compares the three sectors through common analytical dimensions.

Table 1 | Cross-sector application of the informal urban functions framework

Dimension	Waste recovery	Street vending	Informal water provision
Function	Material recovery	Food provisioning	Decentralized water provision
Sustainability relevance	Circularity, landfill diversion, mitigation	Food access, affordability	Water access, reliability, affordability, equity
Structural concerns	Recognition, facilities, organization, regulation	Public-space access, shade, infrastructure, recognition	Source access, storage and transport capacity, infrastructure, regulation, utility relations
Climate evidence	Worker health, operating conditions and livelihoods affected	Productivity, income, operating hours and customer flows affected	Drought and flooding alter demand, vendor activity, distribution patterns and emergency provision
Functional performance to assess	Recovery volume, coverage, interruption, recovery	Availability, hours, coverage, affordability	Volume, coverage, reliability, affordability, quality, response during disruption
Illustrative intervention points	Facilities, rights, protection, finance, organization	Secure space, shade, services, protection, representation	Secure sources, storage, resilient distribution, regulation, finance, utility and emergency coordination

Evidence summarized from refs. 1–4, 10–14 and 18–19.

Table 1 also shows why evidence should not be generalized across sectors. Waste recovery has quantified links between recycling performance and greenhouse-gas mitigation [12,13]. Street-vending studies connect heat and flooding to productivity, income, operating hours and customer flows [11]. In Lodwar, climate disruption alters demand for water vendors and their role in emergency supply [4]; in Nairobi, informal water markets extend access while producing trade-offs involving affordability, reliability, quality and equity [3].

Informal water provision also shows that formal and informal systems can overlap. Provider networks may include unregistered operators, small enterprises, registered vendors, utility relationships and public contracts [3,4]. The relevant analytical

question is how substantially informal workers, enterprises or networks perform an urban function and how those arrangements shape their performance.

Three empirical tests for a research agenda

The framework generates three empirical tests. First, studies should determine whether changes in worker conditions, operating environments and system relationships produce measurable changes in functional performance. This requires pairing exposure and worker outcomes with measures of volume, coverage, reliability, affordability, spatial redistribution and recovery [4,8,11].

Second, comparative research should test whether the five structural dimensions explain differences in baseline performance, functional responses and recovery across functions and places. Comparisons should also examine whether relationships between formal and informal systems strengthen functional capacity or reproduce insecurity and unequal outcomes.

Third, intervention studies should test which combinations of structural reform and hazard-specific adaptation improve worker outcomes, functional performance and sustainability outcomes together.

These tests would move research from documenting vulnerability toward explaining when climate pressure changes urban functions, which mechanisms produce different responses, and which interventions improve outcomes across workers and cities.

Informal urban functions are a missing dimension of urban resilience

Urban resilience depends on the ability to sustain essential functions under stress, including functions provided through informal work. A city can lose functional capacity even when physical infrastructure remains intact if workers and networks can no longer operate effectively. The reverse can also occur when infrastructure fails and informal providers take on unmet demand. Urban resilience therefore depends on how infrastructure, institutions, workers and provider networks work together to sustain urban functions.

Cities often rely on informal functions without providing the conditions needed to support them. Climate change can increase pressure on workers and operating systems, and failures elsewhere in the city can increase reliance on informal provision. As a result, functional continuity or reconfiguration can occur alongside

worker insecurity, unequal service and declining conditions in other parts of the urban system.

The informal urban function provides a common analytical unit for tracing how activity, capacity and performance connect to urban sustainability outcomes. It helps identify where climate pressure enters the system, why functions respond differently and where intervention can strengthen resilience. Building urban climate resilience therefore requires protecting beneficial functions and improving the well-being and security of the people who provide them.

Data availability

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Use of large language models

OpenAI ChatGPT was used during manuscript development to assist with literature organization, conceptual refinement, and language editing. The author reviewed and verified the cited sources, interpretations, and final manuscript and assumes responsibility for its content.

Author contributions

A.G.C.G. conceived the Perspective, developed the conceptual framework, reviewed and synthesized the literature, and wrote and revised the manuscript.

Competing interests

The author declares no competing interests.

References

1. Dias, S. M. Waste pickers and cities. *Environment and Urbanization* **28**, 375–390 (2016). doi:10.1177/0956247816657302.
2. Giroux, S., Blekking, J., Waldman, K., Resnick, D. & Fobi, D. Informal vendors and food systems planning in an emerging African city. *Food Policy* **103**, 101997 (2021). doi:10.1016/j.foodpol.2020.101997.
3. Chumo, I., Mberu, B. & Kabaria, C. How informal water markets serve the urban population: Dynamics of invisible hand in Nairobi's water sector. *PLOS Water* **4**, e0000379 (2025). doi:10.1371/journal.pwat.0000379.
4. Zhao, J. *et al.* The structure of informal water markets: Insights from spatial monitoring in Lodwar, Kenya. *PLOS Water* **4**, e0000279 (2025). doi:10.1371/journal.pwat.0000279.

5. Chen, M. A. & Sinha, S. Home-based workers and cities. *Environment and Urbanization* **28**, 343–358 (2016). doi:10.1177/0956247816649865.
6. Banks, N., Lombard, M. & Mitlin, D. Urban informality as a site of critical analysis. *The Journal of Development Studies* **56**, 223–238 (2020). doi:10.1080/00220388.2019.1577384.
7. Tucker, J. L. & Anantharaman, M. Informal work and sustainable cities: From formalization to reparation. *One Earth* **3**, 290–299 (2020). doi:10.1016/j.oneear.2020.08.012.
8. Dodman, D. *et al.* Climate change and informal workers: Towards an agenda for research and practice. *Urban Climate* **48**, 101401 (2023). doi:10.1016/j.uclim.2022.101401.
9. Sverdlik, A. *et al.* Understanding the interplay of occupational, public health, and climate-related risks for informal workers: A new framework with findings from Zimbabwe and India. *Social Science & Medicine* **348**, 116750 (2024). doi:10.1016/j.socscimed.2024.116750.
10. Dias, S. M., Castán Broto, V., Cypriano, B., Ogando, A. C. & Gonçalves, J. The case for a climate bonus: Waste pickers' perceptions of climate change in Minas Gerais. *Environment and Urbanization* **36**, 93–111 (2024). doi:10.1177/09562478241230813.
11. Thorn, J. P. R., Maruza, T. C. G. & Stoffberg, M. Climate justice and informal trader's access to urban green spaces. *Cities* **159**, 105725 (2025). doi:10.1016/j.cities.2025.105725.
12. Mesquita, J. L. C., Gutberlet, J., de Araujo, K. P., Cruvinel, V. R. N. & Duarte, F. H. Greenhouse gas emission reduction based on social recycling: A case study with waste picker cooperatives in Brasília, Brazil. *Sustainability***15**, 9185 (2023). doi:10.3390/su15129185.
13. Reis-Filho, J. A., Gutberlet, J. & Giarrizzo, T. Invisible Green Guardians: A long-term study on informal waste pickers' contributions to recycling and the mitigation of greenhouse gas emissions. *Cleaner Waste Systems* **10**, 100217 (2025). doi:10.1016/j.clwas.2025.100217.
14. Guibrunet, L., Ortega-Avila, A. G., Valerino-Perea, S., Correa Campos, J. M. & Pozos Espinosa, V. I. Street vendors as actors of a sustainable food system: The case of Mexico City. *Geo: Geography and Environment* **11**, e00152 (2024). doi:10.1002/geo2.152.
15. Finn, B. M., Cobbinah, P. B. & Gounaridis, D. The informal paradox: Electronic waste and the toxic circular economy in Ghana. *npj Urban Sustainability* **5**, 101 (2025). doi:10.1038/s42949-025-00299-5.
16. Basu, S. & Nagendra, H. The street as workspace: Assessing street vendors' rights to trees in Hyderabad, India. *Landscape and Urban Planning* **199**, 103818 (2020). doi:10.1016/j.landurbplan.2020.103818.
17. Eakin, H. *et al.* Negotiating informality and urban resilience: Implications for equity. *Ecology and Society* **30**, 20 (2025). doi:10.5751/ES-16059-300220.

18. Navarrete-Hernandez, P. & Navarrete-Hernandez, N. Unleashing waste-pickers' potential: Supporting recycling cooperatives in Santiago de Chile. *World Development* **101**, 293–310 (2018). doi:10.1016/j.worlddev.2017.08.016.
19. Gutberlet, J., Carenzo, S., Kain, J.-H. & Mantovani Martiniano de Azevedo, A. Waste picker organizations and their contribution to the circular economy: Two case studies from a Global South perspective. *Resources* **6**, 52 (2017). doi:10.3390/resources6040052.
20. Kadungure, A., Machemedze, R., Malaya, W., Banda, N., Loewenson, R. & Sverdlik, A. Towards climate change resilience and informal workers' health in Zimbabwe: An action-research case study. *Cities & Health* **7**, 1055–1071 (2023). doi:10.1080/23748834.2023.2261755.
21. Amankwaa, E. F. & Gough, K. V. 'We are at the mercy of the floods!': Extreme weather events, disrupted mobilities, and everyday navigation in urban Ghana. *Singapore Journal of Tropical Geography* **44**, 235–254 (2023). doi:10.1111/sjtg.12482.