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Buyana Kareem^{1,2,3} , Shuaib Lwasa^{1,2,3} , Denis Tugume^{1,2,3}, Paul Mukwaya^{1,2,3}, Jacqueline Walubwa⁴, Samuel Owuor⁴, Peter Kasaija^{1,2,3}, Hakim Sseviiri^{1,2,3}, Gloria Nsangi^{1,2,3} and Disan Byarugaba^{1,2,3}

¹ Urban Action Lab, Makerere University, Uganda

² Department of Geography, Geo-informatics and Climatic Sciences, College of Agricultural and Environmental Sciences, PO Box 7062 Kampala, Uganda

³ University Road, CUHSS Building, South Wing Ground Floor, Kampala, Uganda

⁴ Department of Geography and Environmental Studies, University of Nairobi, Kenya

E-mail: kbuyana@gmail.com

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Supplementary material for this article is available [online](#)

Abstract

African cities are largely less-built with agile informal settlements and multiple ecologies that harbor different pathways for resilience to climate change. We undertook a qualitative systematic review of academic and policy evidence, to address the question of what interventions are emerging at neighbourhood to city scale to enhance resilience to climate change in Africa. Resilience at neighbourhood scale often stems from harnessing the local resource base and technologies for urban agriculture and forestry; alternative energy from wastes; grassed drainages for protection against erosion; recreation along dry riverbeds; fog-water harvesting; and adjustments in irrigation schedules. At city scale, planning is targeted at buildings, mobility and energy service delivery as the objects to be made resilient. The review established that evidence on comparisons across regions is mainly on East, West and South African cities, and much less on cities in Northern and Central Africa. Ecological comparisons are majorly on coastal and inland cities, with minimal representation of semi-arid and mountainous cities. Resilience efforts in capital cities are the most dominant in the literature, with less emphasis on secondary cities and towns, which is necessary for a deeper understanding of the role played by inter-municipal and inter-metropolitan collaborations. African cities can bring context-sensitivity to global debates on climate resilience, if theoretical perspectives are generated from emerging interventions across case studies. We conclude with suggestions on what future research needs to take on, if evidence on resilience to climate change in African cities is to be strengthened.

Climate change in African cities

Climate change and rapid urbanization are twin global challenges as articulated by Agenda 2030 of the 17 Sustainable Development Goals (SDGs). Climatic threats, including floods, drought, water stress, sea level rise, heat waves and storms, are highest on the list of exposure to economic and social risks in cities (World Bank 2019). Although a weaker intensified rainfall trend has been projected for Africa (Kendon *et al* 2019), slum settlements in cities like Dhaka and Maputo are some of the most vulnerable during cyclones and heavy rainfall (Zehra *et al* 2019). Cyclone Kenneth, which landed in the Cabo Delgado province in northern Mozambique on 25 April 2019, led to 45 fatalities and left 374 000

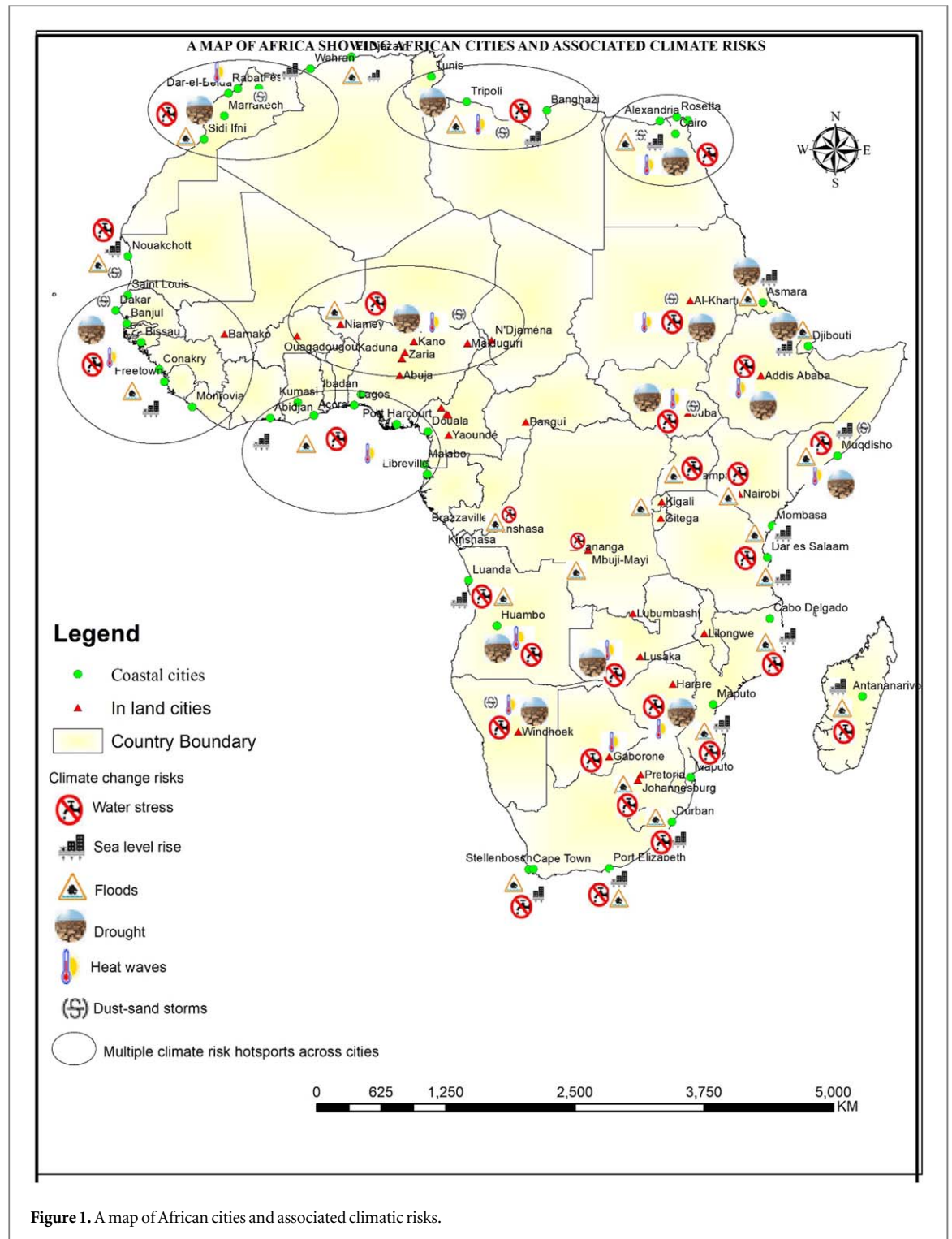
people at risk of waterborne diseases (Cambaza *et al* 2019). Cholera, diarrheal and rodent-borne diseases may increase as a result of more frequent and severe floods and drought, thus affecting urban populations in high-risk areas (World Health Organization WHO (2018), Fombe 2019, Siegel 2020). For the inland mountainous cities like Addis Ababa, extreme rainfall and droughts have intensified hazards disease outbreaks and food insecurity. In August 2006, for example, floods killed more than 100 people in the Ethiopian capital. In Kampala (Uganda), an inland city, flash floods usually destroy backyard gardens, make roads impassable, accelerate contamination of air and water sources and contribute to the intensive spread of diseases like cholera and malaria (Lwasa *et al* 2018).

In terms of regional differences in exposure, projections show increased precipitation in areas of Western Africa and Eastern Africa (Endris *et al* 2019, Odoulami *et al* 2019), and this has been linked to changes in the characteristics of the El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) for the case of northern and equatorial part of East Africa. Coastal areas are especially subject to flooding as a result of both precipitation events and sea level rise. An estimated 54 million Africans live in vulnerable Low Elevation Coastal Zones (LECZ)—defined as areas 10 meters or less above sea level—and this figure is projected to rise to over 100 million by 2030 (Becker *et al* 2019). As shown in figure 1, cities around rivers and creeks are susceptible to riverine flooding, though localized flooding occurs outside these areas as well, especially in more heavily developed settings (Abiodun *et al* 2019, Ponte *et al* 2019, Soares *et al* 2019, Ziervogel 2019). In Bamenda (Cameroon), approximately 20% of the 250 000 residents live on floodplains and roughly 7% live in informal settlements on steep slopes. Land clearance for settlement and for quarrying and sand mining, along with other land-use changes caused by urban expansion, have further created serious problems of soil erosion. Soil that is washed down the hills blocks drainage channels and changes peak water flows. Degradation of the land has exacerbated problems with floods (Tume *et al* 2019). An estimated 17% of Mombasa's area (4600 hectares) could be submerged by a sea-level rise of 0.3 meters, with a larger area rendered uninhabitable or unusable for agriculture because of waterlogging and salt stress. Sandy beaches, historic and cultural monuments, and several hotels, industries and port facilities would also be negatively affected. Mombasa already has a history of disasters related to climate extremes, including floods that have caused serious damage and loss of life nearly every year (Okaka and Odhiambo 2019).

An assessment of the vulnerability in the cities of Alexandria, Rosetta and Port Said (Egypt), suggests that with a sea-level rise of 50 cm, more than 2 million people would have to abandon their homes, 214 000 jobs would be lost, and the cost in lost property value and tourism income would be over US \$35 billion, which does not include the immeasurable loss of world famous historic, cultural and archaeological sites (Elshazly *et al* 2019). In Banjul (Gambia), the city is less than 1 meter above sea level and flooding is common after heavy rains in settlements established on reclaimed land in dried-up valleys, and in settlements close to mangrove swamps and wetlands. Problems with flooding are likely to intensify under a warmer climate with an increase in the strength and frequency of tropical storms, coupled with a negative influence on fish assemblage in the Central River Region (CRR) (Gomez *et al* 2020). Although some important areas of Abidjan (Côte d'Ivoire) lie on a plateau and may escape the direct effects of sea-level rise,

major economic centers, including the nation's largest port and much of the international airport, are on land less than 1 meter above sea level. A sea-level rise in Abidjan is likely to inundate 562 square kilometers along the coastline of the Abidjan region, as lowland Marshes and lagoons dominate the coastal zone. Average retreat will vary from 36 to 62 m (Anouman *et al* 2019).

Given the location in hot regions, African cities are likely to face increased exposure to excessive heat over the coming decades. Projections show that aggregate exposure in African cities will increase by a multiple of 20–52, reaching 86–217 billion persons per day by 2090, depending on the scenario. The most exposed cities are located in Western and Central Africa, although several East African cities indicate an increase of more than 2000 times the current level by 2090 (Rohat *et al* 2019). Average temperatures in North African cities are expected to rise between 1.5° and 3° Celsius by 2060, with a risk of increased desertification. The ElNiño-Southern Oscillation (ENSO) events that ran from October 2014 to June 2016, followed by a La Niña from July 2016 to January 2017, are responsible for heightening the drought conditions in the cities of Djibouti, Mogadishu and Addis Ababa, since the year 2017 (Qu *et al* (2019)). Coral reefs that have the potential of protecting human and marine life in Djibouti, are also vulnerable to rising sea surface temperatures (SSTs), wind and heat waves along the Gulf of Aden, which leads to coral bleaching and anthropogenic impacts (Cowburn *et al* 2019). High rates of urbanization coupled to drought and high demand for water in Tripoli-Libya, has made groundwater levels decline and exceed 12 m in the Southern area while in the Northern area near the coastal line, depletion is continuous and more than 70 wells will be confronted by saline water intrusion by the year 2100. The salinity levels in these wells will make the groundwater unfit for human consumption (Aswad *et al* 2019). An almost similar situation has occurred in Niamey-Niger, where ponds have exhibited a change in groundwater discharge behavior due to consecutive dry days and changes in the spatial pattern of rainfall (Boko *et al* 2020). Drought impacts on water availability and security have also been witnessed in Harare-Zimbabwe, where severe drought episodes have been observed in 1991–1992, 1994–1995, 2002–2003, 2015–2016, and 2018–2019 (Frischen *et al* 2020, Tanyanyiwa 2020). The studies presented indicate that although rapid onset disasters like cyclones often have devastating effects on informal settlement and African urban ecologies, slow onset climate events, such as drought and flush floods are also negatively impacting lives and infrastructures, which warrants responses from different disciplines and communities of policy and practice.



The framing and operationalization of resilience to address climatic change in cities

Building resilience to climatic change in cities is closely linked to how the world will resolve the twin challenges of rapid urbanization and accelerated change in global temperature (Parnell 2016, Simon et al 2016, Holmstedt et al 2017, Patel et al 2017, Rybski et al 2017). The unpacking of pathways to climate resilience in cities, however, is usually dualistic in

nature, viewing the resourcefulness of local community actors as a downstream approach that is parallel to, and sometimes conflicting with upstream interventions, which are influenced by municipal regulations, economic trends, technological advancements, geopolitics, and other global forces. The upstream lays emphasis on the role of multi-lateral and government agencies in brokering and facilitating leadership coalitions, through reforming urban policies across sectors, to enhance collaboration amongst municipalities, and deliver on sector-wide plans for recovery from

hazardous weather events. For instance a number of city global alliances have been created to confront the specter of a warming planet, and lead the transformative path to limiting the global mean temperature to 1.5 degrees (McGushin *et al* 2018, Pelling *et al* 2018). The World Mayors Council on Climate Change (WMCCC) was founded by Kyoto's mayor in December 2005, following the entry into force of the Kyoto Protocol. The C40 Cities Climate Leadership Group of large cities, launched in October 2005, now has 40 participating and 19 affiliate city government agencies (Rosenzweig *et al* 2010, Vigié and Hallegatte 2012). Of recent, the European Commission launched the 'Covenant of Mayors in Sub-Saharan Africa' (CoM SSA) to work with African cities on the climate challenge.

Conversely, the downstream approach usually centers on actions and networks that pervade the realm of government and municipal interventions. Such actors operate through neighborhood groups, citizen coalitions, associations of informal urban service delivery operators, and federations of city traders, who seek to coalesce their efforts towards re-building local communities in face of flooding and other consequences of extreme weather events. Examples include green roofing and rain water harvesting movements in urban informal settlements of cities in the global south, which are targeted at improved storm-water management, better regulation of building temperatures, reduced urban heat-island effects, while promoting the conservation of green spaces for reduced pollution and intensity of surface run-off (Oberndorfer *et al* 2007). The downstream approach has also been researched widely in the global north with concepts such as a 'first-responder city', which stem from studies that illuminate the opportunities associated with increasing the capacity of local communities to avoid, prepare for, and effectively respond to extreme weather events (Ebi 2011, Schmeltz *et al* 2013, Rosenzweig and Solecki 2014). The other component of studies on the downstream approach are on-ground volunteers and local nonprofits that influence urban development dynamics for enhanced community resilience, by for example disseminating early warning information to low-income urban residents, which is framed as the 'civic infrastructure' for resilient neighbourhoods by Graham *et al* (2016) and Elkin and Keenan (2018). Quantitative studies on downstream interventions have provided metrics for measuring the effectiveness of community-led efforts, by factoring in the extent of community engagement, emergency supplies, communication with neighbors, civic engagement, and collective efficacy (Eisenman *et al* 2016, Kwok *et al* 2018).

What is common across the framing and operationalization of downstream and upstream approaches, is the notion that climate resilience in cities is an incremental, multi-actor and cross-scalar process. The incrementalists like Abdoumalik (2016) and Dovey

(2016), argue that resilience starts in what is gradual and integral for people with regard to the natural and built landscapes in which they live, the talents and skills of stakeholders chosen to represent them, rather than emphasis on what is lacking in terms of opportunities and resources. The interdependence amongst actors and their multiple decisions for climate resilience is key from a multi-actor perspective, where for example communities and inter-municipal collaborations take lead to build networks that catalyze efforts towards confronting extreme weather events (Giest and Howlett 2013, Fünfgeld 2015, Bansard *et al* (2017)). Both incremental and multi-actor processes are characterized by interlocking and dynamic political, social, economic and spatial factors, which means that the hindrances to and enablers for climate resilience are cross-scalar in nature (Bahadur *et al* 2013, Bahadur and Tanner 2014, Tanner *et al* 2015). But advances in framing climate resilience in cities have not taken on a broader perspective when it comes to the contextual diversity and local priorities of urban regions in Africa. Cities of Africa are not only shaped by informality, which is the opposite of centralized planning systems in China and much of the global north (Bai *et al* 2014, Shatkin 2016), but are also characterized by multiple ecologies and infrastructures that perhaps require unique pathways to resilience in the face of climatic hazards (Schäffler and Swilling 2012, Fraser *et al* 2017). However, our understanding of African urban pathways to climate resilience has remained patchy and minimally represented, even in global assessments such as those by the Intergovernmental Panel on Climate Change (IPCC). This paper addressed this gap through a systematic review of evidence, from both science and policy, on the interventions that are emerging at neighbourhood to city scale, to enhance resilience to climate change in Africa.

Methods and Materials

Approach

The search for academic literature was done qualitatively, as one of the methodological approaches deemed appropriate in understanding institutional, ecological and social dimensions of climate resilience in cities (Ford *et al* 2011, Berrang-Ford *et al* 2015). Academic material was generated from Scopus, using the keyword search strategy and in line with the review question. The review question is what interventions are emerging at neighbourhood to city scale to enhance resilience to climate change in Africa? The key words used are: Climate Change (CC), Climate Resilience (CR) and African Cities (AC). Literature published in languages other than English was not considered and therefore the material selected may not be representative of Anglophone and Francophone cities of Africa.

Inclusion and exclusion criteria

The key terms used in the search for material were: Climate Change (CC), Climate Resilience (CR) and African Cities (AC) (see supplementary file 1 available online at stacks.iop.org/ERL/15/073002/mmedia for String of Search Terms). The initial search result was 1051, covering the period of 2006–2019. But when subjected to the inclusion and exclusion criteria (figure 2), 95 academic articles appeared from Scopus for selection, 72 were excluded and 25 articles were included, based on their titles, abstracts, texts, methodology and results. Papers were also included if they contained climate-related terms such as: flooding, storm surges, drought, landslides, heat waves, wind storms and wild fires. We also considered papers with abstracts, texts and results on West, East, South, Central, and North Africa, as a way of representing different geographical locations in the continent. The search further considered papers with ecological terms namely; in-land, coastal, semi-arid or arid and mountainous cities. For pathways to CR, we included papers with abstracts, texts and results on: (i) local community interventions; (ii) interfaces amongst different actors, (iii) climate change policies and climate change plans; and (iv) local and technological innovations. Papers with terms such as adaptation, mitigation, environmental change, sustainability, risk reduction, urban transitions and community resilience were also included the review (see supplementary data S1 of the search string table).

Titles, abstracts and texts were extracted and screened independently against the inclusion criteria by three reviewers, namely: Buyana Kareem (BK), Shuaib Lwasa (SL) and Jaqueline Walubwa (JW). The abstracts, texts, methodology and results of the included papers were reviewed using three complimentary strands: (1) identification of titles and abstracts on interventions for CR in AC; (2) internal validity of the material with regard to how well the methodology and results answered the research question(s) set in the paper being reviewed; and (3) external validity of material which refers to how well the methodology and results answered the review question. Each paper was reviewed independently twice, with disagreements resolved through discussion and consensus with the rest of the co-authors as third party reviewers. Full text articles were reviewed by Paul Mukwaya (PM) and Samuel Owuor (SO) for final decisions regarding inclusion, with disagreement resolved by consulting the other reviewers, that is; Denis Tugume (DT), Peter Kasaija (PK), Hakim Sseviiri (HS), Gloria Nsangi (GN), and Disan Byarugaba (DB).

Quality appraisal

Quality appraisal of the included academic literature was undertaken using the ten-item Critical Appraisal

Skills Programme (CASP) checklist for qualitative research (Critical Appraisal Skills Programme 2018). Despite its demerits, the CASP tool is commonly used in qualitative research (Hannes *et al* 2010). Three evaluators (BK, SL and JW) independently assessed the quality of each study with discrepancies resolved through consensus and discussion with third party evaluators (PM and SO). No studies were excluded on the basis of quality, as per the summary of the results in supplementary data S2.

Systematic mapping of policy and planning documents

Academic literature was triangulated with a purposive online search for climate change strategies and action plans mounted by African city authorities of government. The plans were purposively selected to achieve representation across regions of East, West, North and Southern Africa. The plans that were mapped are: (i) the City of Alexandria Energy and Climate Change Action Plan (North Africa); (ii) the Durban Climate Change Strategy (South Africa); (iii) the Kampala Climate Change Action Strategy (East Africa); and (iv) Lagos State Climate Change Adaptation Strategy (West Africa). Review of evidence from policies and plans focused on the objectives, key stakeholders, targets and object(s) to be made resilient as well as implementation programmes under each strategy and action plan. The documents were useful in discerning the notions and pathways to mainstreaming climate resilience in city planning and governance processes. City plans published in languages other than English were not considered in the mapping and therefore the evidence presented may not necessarily speak for Anglophone compared to Francophone cities.

Results

Resilience at neighbourhood scale means harnessing the local resource base and technologies

Evidence indicates that resilience at neighbourhood scale often stems from harnessing the local resource base and available technologies. As shown in table 1 below, some of the key pathways to resilience are urban agriculture and forestry for alternative food and income sources (Lwasa *et al* 2015); household energy alternatives from wastes; and plot-level technologies of retention for runoff, using for example vetiver grass for protection against erosion (Eckart *et al* 2011). Recreation along fractured dry riverbeds has taken shape (Sareh *et al* 2016), coupled with reliance on ecosystems, such as mangroves and community reforestation along coastal areas, for defence against storm water surges (Roberts *et al* 2012). Fog-water harvesting is being promoted (Marzol and Sánchez 2008), alongside kitchen or toilet facilities that capture methane gas at the top of the dome for re-use as cooking gas

Table 1. Pathways for resilience to climate change from the included academic studies.

Citation and year	Geographical focus in Africa and city	Ecology of cities	Research aim/questions	Methodological approach	Pathways at city scale	Pathways at neighbourhood scale
Anguelovski <i>et al</i> (2014)	South Africa (City of Durban)	Coastal	The trade-offs associated with different planning pathways and different forms of stakeholder involvement	Qualitative	Effective and integrated planning by local governments	N/A
Simon (2013)	East Africa (Mombasa and Addis Ababa), West Africa (Lagos), South Africa (Johannesburg, Cape town and Durban) North Africa (Cairo)	Coastal, in-land, and semi-arid	How urban green economies can potentially promote prosperity and environmental resilience in different urban contexts of Africa?	Qualitative	Building urban green economies for restoration of green spaces and jobs	N/A
Lwasa <i>et al</i> (2015)	Eight East and West African cities were included in the review: Accra, Addis Ababa, Dakar, Dar es Salaam, Douala, Kampala, Ibadan and Nairobi	Coastal and in-land	The role of urban and peri-urban agriculture and forestry (UPAF) in mediating climate change	Qualitative	Institutional transformation at city to regional scale	Urban and peri-urban agriculture and forestry
Shuaib <i>et al</i> (2012)	East African and West African cities (Kampala, Addis Ababa, Dar es Salaam, Douala, Ibadan, Nairobi, Dakar and Accra)	Coastal and in-land	The role that urban and peri-urban agriculture (UPA) plays in enhancing urban food security and climate change resilience	Qualitative	N/A	Urban and peri-urban agriculture
Cavan <i>et al</i> (2014)	East Africa (Addis Ababa, Ethiopia and Dares Salaam, Tanzania)	Coastal and in-land	Classification of urban morphology types (UMTs) and assessment of urban temperature patterns and the temperature regulation services provided by urban green structures	Quantitative	Residential housing in planned and unplanned settlements with higher proportions and better composition of green structures	
Lwasa <i>et al</i> (2018)	East, West, North and South African Cities	In-land, coastal, mountainous and semi-arid cities	How urbanization in Africa can contribute to limiting global warming at 1.5 degrees	Qualitative	Development financing that switches aid to climate action combining adaptation with mitigation measures in transitions to modern infrastructure systems while leveraging micro- and meso scale green growth interventions Policy and political support to pursue inclusive and sustainable city development pathways	N/A
Herslund <i>et al</i> (2016)	East Africa, Dar es Salaam (Tanzania)	Coastal	Prevailing climate change-induced risks, assessed vulnerability and	Quantitative and qualitative	Integrating climate change issues in city-level plans and strategies and	N/A

Table 1. (Continued.)

Citation and year	Geographical focus in Africa and city	Ecology of cities	Research aim/questions	Methodological approach	Pathways at city scale	Pathways at neighbourhood scale
			proposed policy initiatives in African cities		enabling local actions to initiate a 'learning-by-doing' process of adaptation	
Dobson (2017)	African cities in general		The potential of community-driven resilience-building in African cities	Qualitative	Enhancing slum-upgrading implementation capacity through partnership with organized local communities	N/A
Eckart et al (2011)	East and Central Africa (cities in Uganda, Kenya and Cameroon)	Coastal and in-land	How public authorities can identify and address the future challenges of urban water supply, sanitation, and flood management in cities?	Qualitative and quantitative	Integrated Urban Water Management (IUWM) as a holistic set of planning and management tools	Local technologies for groundwater and grey-water recycling
Taylor et al (2014)	Three South African municipalities —Cape Town, Durban and Theewaterskloof	Coastal and in-land	The factors enabling and constraining climate change adaptation in three South African municipalities	Qualitative	High-level political support for climate adaptation and piloting a number of local adaptation projects	Formal and informal Local businesses centrally positioned in the design and implementation of climate programmes
Chirisa et al (2016)	South, East and North Africa (Harare, Nairobi, Abuja, Cairo and Johannesburg)	In-land and semi-arid	The capacity and limitations of African cities in building resilient infrastructure in the face of climate change	Qualitative	Delivery of resilient infrastructure and services requires overcoming corruption and non-participatory approaches	N/A
Di Ruocco et al (2015)	East, Central and West Africa (Addis Ababa in Ethiopia, Dar es Salaam in Tanzania, Douala in Cameroon, Saint Louis in Senegal and Ouagadougou in Burkina Faso)	Coastal and in-land	Assessment of five main climate change affected hazards: floods, droughts, desertification, heat waves and sea level rise	Qualitative and quantitative	Risk mitigation and adaptation strategies by planners and policy makers with tools for the development of more climate resilient cities	N/A
Thorn et al (2015)	East Africa (Nairobi, Kenya)	In-land	The dynamics of adaptation and risk reduction at the level of the community	Qualitative and quantitative	N/A	Youth groups and savings schemes in urban informal settlements
Roberts et al (2012)	South Africa (Durban)	Coastal	Ecosystem-based adaptation (EBA) as a cost-effective and sustainable approach to improving adaptive capacity	Qualitative	N/A	Community ecosystem-based adaptation and 'bio-infrastructure' for defence against storm water surges and heat waves
Buyana and Lwasa (2011)	East Africa (Kampala)	In-land	The potential of urban waste economies	Qualitative	N/A	Urban waste re-use and recycling for cleaner neighbourhoods and jobs for the urban poor in the informal economy
	North Africa (Sidi Ifni, Morocco)	Coastal		Quantitative	N/A	Fog-water harvesting

Table 1. (Continued.)

Citation and year	Geographical focus in Africa and city	Ecology of cities	Research aim/questions	Methodological approach	Pathways at city scale	Pathways at neighbourhood scale
Marzol and Sánchez (2008)			Exploring the feasibility of harvesting fog water in the Ifni region, Morocco, to help a small community that lives in an arid region and that needs this water			
Okello <i>et al</i> (2013)	East Africa (Kampala city region)	In-land	Bioenergy potential of agricultural and forest residues in Uganda	Quantitative	N/A	Use of residues could contribute to ensuring sustainable supply of biomass energy, while reducing emissions
Swilling and Annecke (2006)	South Africa (Stellenbosch city)	In-land	Demonstrating ecological sustainability criteria relating to sanitation, solid waste removal, energy, building materials and food security at neighbourhood scale	Qualitative	Socially mixed urban development that integrates ecological sustainability into planning	Neighbourhood scale green roofing; restricted hard landscaping; and kitchen or toilet facilities that capture methane gas at the top of the dome, for re-use as cooking gas
Sareh <i>et al</i> (2016)	North Africa (Cairo, Egypt) and the Middle East	Semi-arid	Critical review of landscape design approaches in dryland cities against discourses of modernism, regionalism and critical regionalism	Qualitative	Landscape designs that safely create vital public spaces out of fractured dry riverbeds and open spaces while also preserving their historic hydrologic function	Recreation centers along dry-river beds
Isunju <i>et al</i> (2016)	East Africa (Kampala, Uganda)	In-land	The benefits that informal wetland communities in Kampala, Uganda derive from their location in the wetland and how they adapt to minimize vulnerability to hazards such as floods and disease vectors	Quantitative and qualitative	Informal settlements offer opportunities for coordinated adaptation strategies that involve all stakeholders and that enhance equitable utilization of wetland resources without compromising their ecosystem services and economic benefits	Flood-affected households are raising flood barriers and building resilient structures, filling with soil to raise ground levels, digging trenches around the house, and desilting drainage channels
Ziervogel <i>et al</i> (2017)	African in general	Coastal, in-land and mountainous city	Rights of urban citizens as the object to be made resilient, rather than physical and ecological infrastructures	Qualitative	Develop a justice- and rights-based framework for governing resilience	Local community empowerment using a rights and justice approach
Leck and Simon (2018)	South Africa (Durban City and the adjacent Ugu (predominantly rural) district municipality on the south coast of KwaZulu-Natal province (KZN)	Coastal	Enablers and hindrances for cross-border and inter-municipal collaborations for climate change resilience/adaptation within city regions	Qualitative	Focus on the role of inter-municipal collaboration, especially between neighboring rural, peri-urban and urban municipalities, for coordinating such policies and interventions	N/A

Table 1. (Continued.)

Citation and year	Geographical focus in Africa and city	Ecology of cities	Research aim/questions	Methodological approach	Pathways at city scale	Pathways at neighbourhood scale
Ojo <i>et al</i> (2011)	West Africa (Ibadan and Lagos, Southwestern Nigeria)	In-land and coastal	Assessment of irrigation systems for dry season vegetable production in urban and peri-urban zones	Qualitative and quantitative	N/A	Urban farmers' knowledge of crop-water requirement, irrigation scheduling and skills in maintaining and operating irrigation systems
Aboulnaga <i>et al</i> (2019)	North Africa (Cairo city of Egypt)	Semi-arid/ arid	Sustainable and green measures and actions that are vital for urban areas in hot-arid climatic zones	Quantitative	Use of simulation programs ENVI-met and Design-Builder to assess and measure the resilience and sustainability of urban housing and health projects	low-income housing with passive cooling design configurations, building elevation, buildings' envelopes, vegetation, and water features, and orientation and high albedo
Fahmy <i>et al</i> (2017)	North Africa (Egyptian urban communities)	Semi-arid and coastal	Adaptation opportunities of Egyptian urban communities for climate change by the application of green cover and its effect on domestic energy efficiency in present and future	Quantitative	Housing plans with indoor simulations using DesignBuilderV4.2 which has been applied to predict sites' energy efficiency	Green roofs and facades with micro-climatic effects of coupled outdoor-indoor temperatures

Source: authors' aggregations of the review findings (September 2018–January 2019).

Note: N/A means the study did not contain interventions for resilience at the scale in question.

(Swilling and Annecke 2006). Neighbourhood technological innovations have led to adjustments in irrigation scheduling and household dietary needs (Ojo *et al* 2011). Formal and informal social networks make the diffusion of knowledge and sustainability practices possible, for example through local to local dialogues between local communities and decision-makers at city to national scale (Perry *et al* 2018). Generally, studies contained what is existing and or emerging as well as what can be done to enhance resilience to climate change. Seven out of the twenty five studies contained what is happening at both neighbourhood and city scale. Three studies particularly focused on neighbourhood interventions. These included: waste recycling in Kasubi-Kawaala neighbourhood of Kampala city (Buyana and Lwasa 2011); the Eco-Village pathway in Lynedoch of Stellenbosch city (Swilling and Annecke 2006); and Youth climate champions in Mathare settlement of Nairobi city (Thorn *et al* 2015). Evidence revealed that resilience to climatic change in African cities means harnessing the positive interactions amongst interventions at neighbourhood and city scale. The positive interactions are the conditions for scaling out what is existing and emerging to wider scales. One of the manifestations of positive interactions, is the emphasis on urban forestry, which supports neighbourhoods on food security and jobs, while promoting tree planting closest to pedestrian walkways, buildings and parking lots at city scale, for a cooler climate, protection against surface run-off and dust storms.

City planning for resilience targets buildings, mobility, and energy service delivery but without explicit mechanisms on cross-sector collaboration

Across all the city strategies and action plans in the review (table 2 below), the objects to be made resilient are mainly energy, mobility, and buildings, with a few means to civic engagement with local communities. The plans reviewed are: (i) the City of Alexandria Energy and Climate Change Action Plan (North Africa); (ii) the Durban Climate Change Strategy (South Africa); (iii) the Kampala Climate Change Action Strategy (East Africa); and (iv) Lagos State Climate Change Adaptation Strategy (West Africa). As indicated in table 2, all the overarching targets set by the city of Alexandria are centered on energy and buildings, namely: 'By 2030, all new buildings will be carbon neutral; by 2050, reduce GHG emissions by 80% below 2005 levels; by 2050, 80% of City's energy will be from clean, renewable sources.' In the case of Kampala city, there are targets that interconnect energy with mobility services. These are: 50% of motorists using mass public transport (Buses and Train); 50% of city roads tarmacked; 25 km of non-motorized transport (cycle and Pedestrian) lane length constructed. Evidence on the implementation of plans revealed that emphasis is on the mandates of

individual administrative structures at city and national scales, as the basis for division of responsibilities. Although the energy and mobility targets set by the cities are aligned to the goals of emission reduction and reconfiguration of urban service delivery, there is no explicit indication of building flexible management systems and inter-agency networks, which are usually suited to respond to shocks to energy and mobility urban systems (Frantzeskaki *et al* 2014).

The targets and strategies on energy are devoid of linkages with health interventions, such the effective use of natural ventilation and green roofing for buildings. Health interventions are essential to reducing indoor temperatures in warm months and hot climates to avert risks from heat stroke, indoor dampness and mold, thus providing a natural urban health asset to low-income households, who rarely afford air conditioners, fabricated with hydro fluorocarbons (HFCs) with global warming potential (Rao *et al* 2013). Planning should take into account the trajectories of mobility and energy use at city level and the multiple linkages with individual health at micro-scales. Public transportation as well as the positioning of buildings and choice of building materials have the potential to increase emissions of carbon dioxide (CO₂), periodic dust storms, excessive heat and dampness—all of which are risk factors for respiratory illnesses and other cardiopulmonary diseases, which lessen the capacity of people to handle or recover from other forms of ill health within the urban environment (Mukwaya 2012, Lwasa 2017). This means that policy and planning targets that are based on health-energy-mobility interactions offer opportunities for either trade-offs or co-benefits for scaling up efforts on resilience within and across different sectors.

All the climate strategies in the review are silent on how to harness the opportunities associated with the agile nature and varying degrees of informality in African cities. Evidence from academic literature shows that institutional planning for urban transformations to resilient cities in Africa, calls for the active participation and knowledge from informal city dwellers and businesses, such as street vendors and neighbourhood associations, who are for example involved in the promotion of waste economies, energy-efficient cooking stoves, green roofing for cooler indoor climates, and federations informal transport operators and city traders (Lindell *et al* 2019). It is possible to draw on and leverage the biographies and urban life course perspectives of informal land and business owners in African cities, to understand and design ways in which social networks and relations facilitate junctures and intermediation between sustainability-oriented informal urban structures and city planning for resilience to climate change (Buyana *et al* 2019, Van Breda and Swilling 2019, Monteith and Camfield 2019). For instance, efforts around the mobilization of spatial media technologies to digitally map informal settlements, has potential for use in monitoring and

Table 2. Climate change plans and strategies by city authorities in Africa.

Name of plan/Strategy	Goals/objectives	Key stakeholders	Targets and object(s) to be made resilient	Key implementation programmes
City of Alexandria Energy and Climate Change Action Plan (2012—2020) (North Africa) ^a	<ol style="list-style-type: none"> 1. Adopt targets and establish implementation framework for reducing GHG emission reductions for 2012, 2020 and 2050 2. Institutionalize the consideration of the effects of possible climate changes into long-term planning 3. Prepare and educate city residents and business owners for a carbon-constrained economy and other climate change impacts 4. Increase the City’s preparedness to respond to the possible effects of climate change and environmental emergencies 	<ul style="list-style-type: none"> ■ Office of Environmental Quality Department of Transportation and Environmental Services ■ Alexandria City Council. ■ Alexandria Sanitation Authority ■ Metropolitan Washington Council of Governments ■ National Academy of Science 	<ol style="list-style-type: none"> 1. By 2030: All new buildings will be carbon neutral 2. By 2050: Reduce GHG emissions by 80% below 2005 levels 3. By 2050: 80% of City’s energy will be from clean, renewable sources 	<ul style="list-style-type: none"> ■ City’s Green Building Policy ■ City’s recycling program and the Covanta Energy from-Waste facility ■ \$1.37 million under the federal Energy Efficiency and Conservation Block Grant (EECBG) ■ Eco-City Challenge on the City’s web site for citizen engagement. ■ Alternative Forms of Transportation for City Employees ■ Land Use Planning (e.g. Urban Forestry Master Plan) ■ KwaZulu-Natal (KZN) Sustainable Energy Forum
The Durban Climate Change Strategy, approved in 2015 (South Africa) ^b	<ul style="list-style-type: none"> ■ To convert Durban to a low carbon, green economy that prioritizes the sustainable use of ecosystem services whilst still overcoming the development challenges faced by the majority of Durban residents 	<ul style="list-style-type: none"> ■ Fire Department and Metro Police ■ eThekweni Municipality Climate Protection Branch ■ City Planning Commission ■ City Manager and Executive Management Team 	<ul style="list-style-type: none"> ■ Waste Management ■ Transport and Renewable Energy, ■ Water Conservation and Demand Management ■ Energy Efficiency and Energy Demand ■ Ecosystem services 	<ul style="list-style-type: none"> ■ Shisa Solar Programme ■ Durban Solar Financial Model
The Kampala Climate Change Action Strategy, 2016 (East Africa) ^c	<ul style="list-style-type: none"> ■ Increase renewable energy use ■ Reduce congestion & travel times ■ Improved construction practices. 	<ul style="list-style-type: none"> ■ Kampala Capital City Authority ■ Ministry of Works and Transport ■ National Water and Sewerage Cooperation 	<ul style="list-style-type: none"> ■ 50 Megawatts of renewable energy produced on the territory (solar, waste to energy) ■ 50% of motorists using mass public transport (Buses & Train) ■ 50% of city roads tarmacked • 25 km of NMT (cycle/Pedestrian) lane length constructed 	<ul style="list-style-type: none"> ■ Communication with and engaging local stakeholders to participate ■ Landscaping a more climate resilient and low carbon Kampala ■ Developing smart utilities and community services

Table 2. (Continued.)

Name of plan/Strategy	Goals/objectives	Key stakeholders	Targets and object(s) to be made resilient	Key implementation programmes
Lagos State Climate Change Adaptation Strategy, 2012 (West Africa) ^d	<ul style="list-style-type: none"> ■ To provide an integrated and systematic approach to reducing vulnerabilities to climate change and increase the resilience and sustainable well-being of the people of Lagos State; and ■ To provide a framework for building informed responses and enhancing capacities at individual, community and state levels to implement effective climate change adaptation policies and measures 	<ul style="list-style-type: none"> ■ Ministry of Water and Environment ■ National Environment Management Authority (NEMA) ■ Makerere University ■ Lagos State Emergency Management Authority ■ Ministry of the Environment ■ Governor of Lagos State ■ Nigerian Meteorological Agency ■ Nigerian Institute for Oceanography and Marine Research ■ Ministry of Local Government and Chieftaincy Affairs 	<ul style="list-style-type: none"> ■ 30% of waste recycled ■ 60% of newly approved buildings with water ■ New buildings certified as green buildings ■ Water harvesting units installed ■ 500 000 new trees grown (street, park and household) ■ Integrated coastal zone management in the State ■ Sustainable management of upland wetlands and floodplains ■ Improved quality of information about the State’s wetlands and fresh-water ecosystems ■ A new drainage network in built-up areas taking into account projected sea level rise 	<ul style="list-style-type: none"> ■ Supporting the green economy ■ Integrated waste management in the city ■ Launching a public awareness and sensitization programme to educate Lagosians ■ A tree planting campaign and criminalization of indiscriminate tree felling ■ Landscaping of virtually all open spaces ■ Introduction of a mass transportation system, including the BRT (Bus Rapid Transit) scheme

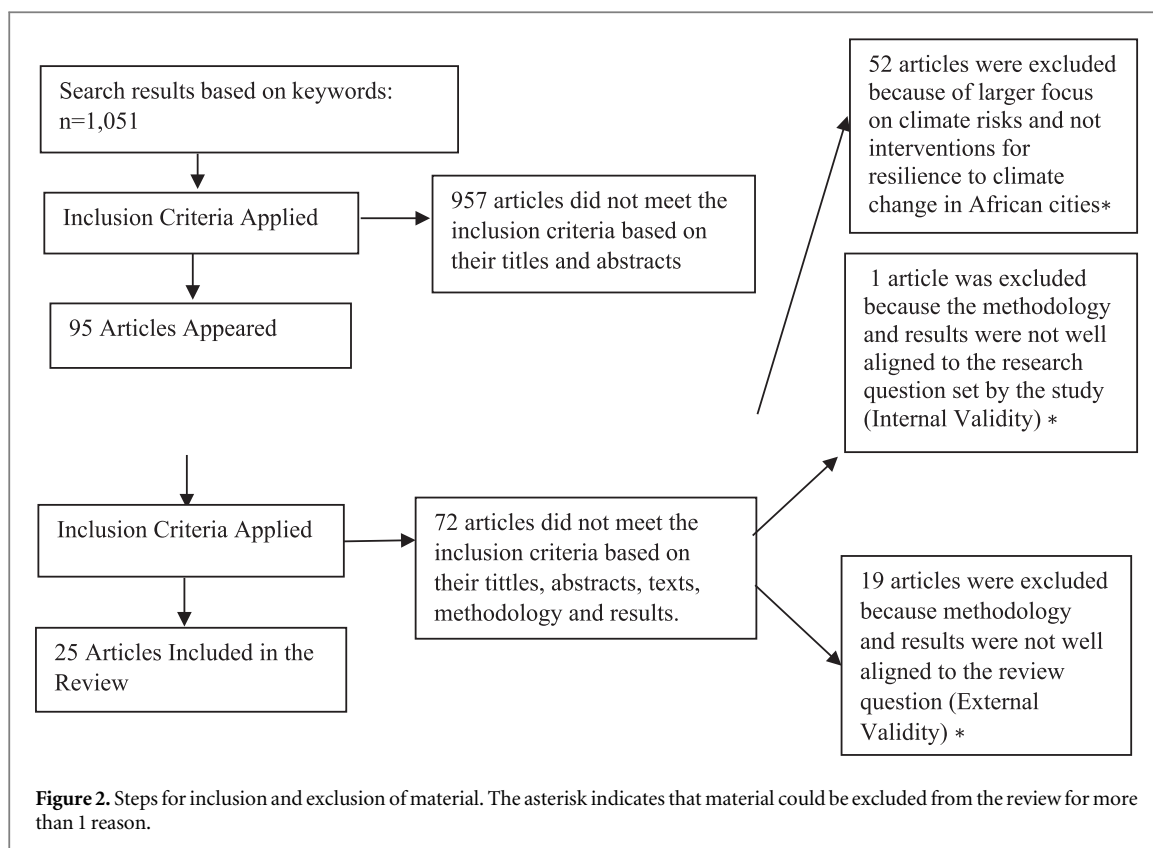
Source: authors’ aggregations of the online resources (January 2019).

^a <https://alexandriava.gov/uploadedFiles/tes/eco-city/info/EnergyClimate%20Action%20Plan%20Final%20June302011.pdf>

^b http://durban.gov.za/City_Services/development_planning_management/environmental_planning_climate_protection/Projects/Pages/Development-of-a-Climate-Change-Adaptation-and-Mitigation-Strategy.aspx

^c <http://kcca.go.ug/uDocs/Kampala%20Climate%20Change%20Action.pdf>

^d <http://csdevnet.org/wp-content/uploads/Towards-aLagos-Adaptation-Strategy.pdf>



reporting progress on climate change targets set by city authorities (Luque-Ayala and Neves Maia 2018).

Discussion

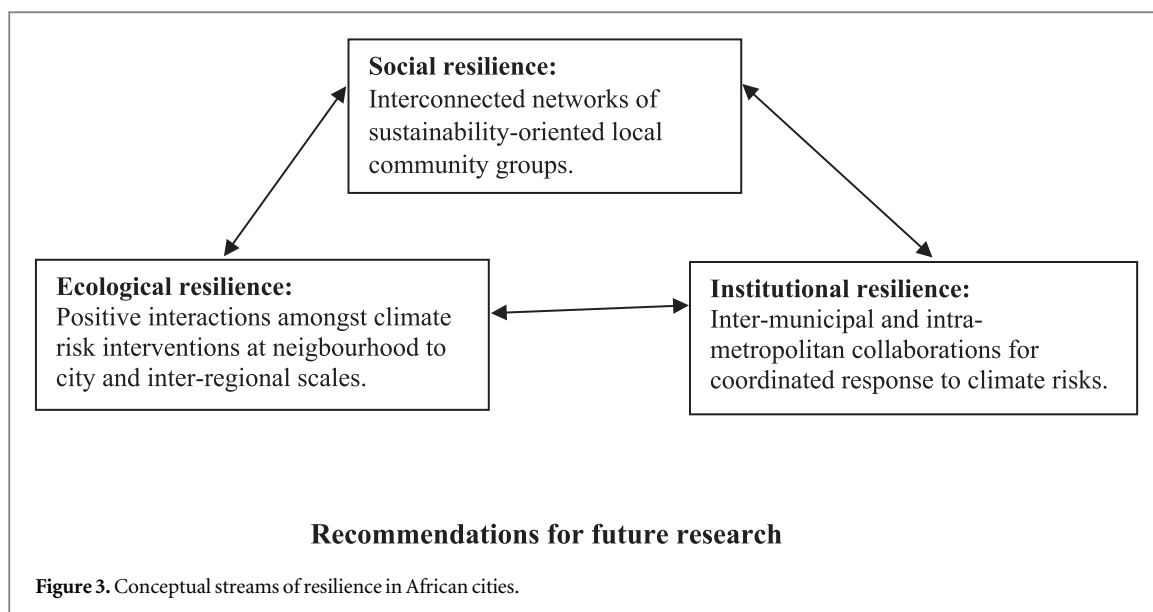
As noted by Nagendra *et al* (2018), the ways in which resilience plays out in cities that are less-built with agile informal settlements and multiple ecologies, is different. However, only two studies in the review contained an explicit definition of what resilience means. Chirisa *et al* (2016) defines resilience as, ‘the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change.’ Ziervogel *et al* (2017) on the other hand, focuses on rights and justice as the point of departure for resilience to support risk management and inclusive development, as opposed to infrastructures, technical engineering and ecosystem services. However, both studies note that much of the resilience agenda has been shaped by policies and discourses from the global north, and therefore its practicability for cities of the global south, particularly African cities, has not been sufficiently addressed. There is need for theoretical perspectives from Africa that shine light on urban transformations to resilient cities, guided by emerging processes across case studies. In order to bring some structure to the debate on resilience in African cities, we postulate three interlinked streams: (i) social resilience as the lens for understanding interconnected networks of local

community actors poised for sustainability-oriented urban experiments and learning; (ii) ecological resilience that means harnessing the positive interactions amongst interventions at neighbourhood to city and inter-regional scales; and (iii) institutional resilience, whose major constitute element is inter-municipal and intra-metropolitan collaborations with flexibility and capacity for coordinated response to climate risks and impacts on systems that make city regions functional (figure 3).

Recommendations for future research

Inter-regional and ecological comparisons require expansion in scope and coverage

Understanding pathways to resilience at different regional and ecological urban scales in Africa, is key to finding novel and context-sensitive ways for implementing climate action. However, evidence on inter-regional differences was mainly amongst East, West and South African cities, and much less amongst cities in Northern and Central Africa. Though there were two studies drawing on cases across Africa (Dobson 2017, Ziervogel *et al* 2017), five specifically focused on South Africa (Swilling and Annecke 2006, Roberts *et al* 2012, Anguelovski *et al* 2014, Taylor *et al* 2014, Leck and Simon 2018). East Africa spoke to five studies, including Buyana and Lwasa (2011), Okello *et al* (2013), Thorn *et al* (2015), Herslund *et al* (2016), and Isunju *et al* (2016). Three studies centered particularly on North Africa, that is: Marzol and Sánchez (2008),



Aboulnaga *et al* (2019), and Fahmy *et al* (2017). Only two studies had content on cities in Central Africa, namely: Eckart *et al* (2011) and Di Ruocco *et al* (2015). This means that North and Central African cities were the least represented in the review, while cities in East, West and South Africa were the most represented. From an ecological point of view, most of the comparisons majorly drew on coastal and in-land cities, with minimal representation of scalable interventions across semi-arid and mountainous cities, like Maseru in Lesotho. The comparative studies on coastal and in-land cities that met the inclusion criteria were 6 out of the 25, whereas studies on semi-arid/arid cities were the least represented (3 out of 25). Many of the excluded studies (72 articles) focused mainly on analyzing the magnitude and severity of risks and not existing or emerging interventions. This means that there is need to expand the scope of inter-regional and ecological comparisons on pathways for resilience to climate change in African cities.

More research is needed on the role played by inter-municipal and inter-metropolitan collaborations in enhancing resilience to climate change in Africa

The growing magnitude of risks and impacts in African cities, means that interdependence amongst actors and decisions in capital and secondary cities is critical for effective planning on the resilience of urban systems. To reckon with, is the recent cyclone that affected urban mobility and housing systems in Mozambique, named Tropical Cyclone Idai. The disaster was reported to be gathering strength over the Indian Ocean that hit the city of Beira in Sofala Province with intensive flooding, but with governance implications for not only Maputo, which is the capital city, but also road connections between Zimbabwe and coastal ports as well as hydro-power projects in neighboring cities and countries (Muller 2019).

Nonetheless, the cities that were most represented in the review are the leading administrative, financial and tourism capitals of Africa. These include: Cairo, Kampala, Nairobi, Mombasa, Dakar, Abidjan, Lagos, Banjul, Bissau, Freetown, Monrovia, Accra, Kumasi, Lome, Conakry, Durban, Cape Town, Port Elizabeth and Alexandra in South Africa. Only 1 out of the 25 studies had a particular focus on the role played by inter-municipal collaborations, that is: Leck and Simon (2018). Therefore there is need for more research that sheds light on the linkages between climate resilience and network planning at various levels of connectivity amongst urban systems in Africa, including: inter-city connectivity, intra-metropolitan connectivity and local-level connectivity.

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Data availability statement

Any data that support the findings of this study are included within the article.

Authors' contributions

BK and SL conceived the paper, framing and drafting, while DT, PM, JW and SO made major reviews to the content and methodological approach. PK, HS, GN and DB led the efforts on data management and developing the map on climate risks in African cities.

Statement on conflict of interest

The authors have no competing interests to declare.

ORCID iDs

Buyana Kareem  <https://orcid.org/0000-0002-7710-3652>

Shuaib Lwasa  <https://orcid.org/0000-0003-4312-2836>

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