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### A systematic map of responses to climate impacts in urban Africa

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**TOPICAL REVIEW**

## A systematic map of responses to climate impacts in urban Africa

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Over time African cities and their residents have responded to climate impacts in increasingly creative ways, based on local knowledge and available resources. Overviews of adaptation policy, plans and actions have largely been lacking for Africa, particularly at the local, city level. We applied a systematic map to assess what the human responses to climate impacts are in African cities, noting the climate drivers of these actions, the range of responses, where they have taken place, and who the actors are. Standardized, pre-selected search terms were used to systematically search peer-reviewed and grey literature, using Web of Science, Scopus, and Google. Publications were screened based on pre-approved inclusion criteria, and actions described in included articles were coded using categories from key conceptual framing papers on climate change adaptation. Of 2 042 peer-reviewed and 60 grey-literature publications, 252 underwent full-text screening, with 121 included for coding. We recorded 1 504 actions, taking place in 41 cities from 21 African countries, in response to various climate drivers. Anticipatory and reactive actions were taken by actors, from individuals to international agencies, and we highlighted successful adaptations, those taking advantage of climate impacts, and maladaptive actions. Combinations of climatic and non-climatic stimuli induced adaptive responses, which were frequently based on local knowledge, and provided a base upon which government action could build. Residents of informal settlements had less adaptive capacity than those in formal settlements, and government action could build their resilience. Since development is affected by climate impacts, climate change information should be integrated into development programmes.

### 1. Background

Over half (55%) of the world's population live in urban areas. In Africa, urbanization rates are high, and the urban population is projected to increase from 43% to 59% by 2 050 (UNDESA 2018a). The impact of floods, droughts, and high temperatures has historically been recorded across many parts of Africa, with residents having to find ways to adapt to and live with these impacts (Hannaford and Nash 2016). Given Africa's particular vulnerability to the impacts of climate change compared to other regions (Serdeczny *et al* 2017, Schleussner *et al* 2018), a better understanding of what African cities and their residents are doing to withstand these impacts can help inform adaptation planning in vulnerable communities globally. The recent Intergovernmental

Panel on Climate Change (IPCC) special report on the impacts of global warming of 1.5 °C above pre-industrial levels identified urban areas and infrastructure as one of four major systems that need unprecedented transformation to ensure an equitable low carbon and climate resilient future (IPCC 2018b). A key question then is: how can African cities build resilience to climate impacts?

In its special report, the IPCC defined 'adaptation' as 'the process of adjustment to actual or expected climate and its effects', which, in human systems, seek to moderate or avoid harm or exploit beneficial opportunities (IPCC 2018a). Thorn *et al* (2015) defined adaptation strategies as being 'actions that people employ not only to reduce adverse effects of specific environmental changes, but also to enhance opportunities for well-being'; undertaken

unconsciously (as autonomous adaptation) or deliberately aimed at a desired state. In addition, individual coping actions have led to communal and anticipatory learning, collaboration, and collective action, making the distinction between adaptation and coping responses ambiguous (Thorn *et al* 2015).

Many cities in the global North have adaptation plans for dealing with the impacts of climate change, and comprehensive reviews of these plans have been undertaken extensively for Europe (Reckien *et al* 2014, 2018) and Canada (Austin *et al* 2015). As part of the global South, cities in Africa have faced widespread challenges (including poor planning, a large proportion of informal dwellers and growing populations) making them more vulnerable to the effects of weather extremes (Iwasa *et al* 2018, Satterthwaite *et al* 2018), and hampering adaptive responses. Even where these cities have adaptation policies, these have not had concrete effects on reducing vulnerability (Ford *et al* 2015). Given increasing rates of urbanization, under-prepared and under-resourced African cities are among the most vulnerable to the impacts of climate change. However, these cities also have potentially transformative opportunities, namely the potential to leap-frog resource intensive development directly to more sustainable options and avoid being locked in to carbon- or energy-intensive development (Roberts 2012, Rogelj *et al* 2018). To realize this potential, knowledge of what is currently occurring in these cities, what works, and where obstacles lie, is essential.

Data and knowledge on adaptation to climate-related impacts, both to short-term variability and long-term climate change, are difficult to find. Epule *et al* (2017)'s systematic tracking of climate change adaptation in the Sahel region of Africa provides the most detailed insight into this topic in Africa. Other reviews of climate change adaptation in Africa have relied on municipal and national level adaptation reports as the primary sources of information (Araos *et al* 2016), where adaptation reporting has been taken as a proxy sample or indicator of human adaptation (Berrang-Ford *et al* 2011). Importantly the number of adaptations is not necessarily indicative of a more resilient society, since adaptation actions may be maladaptive or have little impact (Ford and Berrang-Ford 2016). Berrang-Ford *et al* (2011), in their systematic review of adaptation to climate change at a global level, found low-income countries to be characterized by reactive adaptations in response to short term motivations (particularly changing market conditions), with adaptation more likely to include community-level mobilization than institutional, governmental, or policy tools. Epule *et al* (2017), found the most frequently employed adaptive responses to be income diversification, water harnessing, soil conservation, and planting high yielding crop varieties. These studies provide valuable regional examples of adaptation, but do not provide

detailed urban-specific adaptations in Africa. In fact, most systematic reviews on Africa have focussed on documenting adaptation policy rather than adaptation actions (e.g. Araos *et al* 2016 on cities of greater than one million; Ford *et al* 2015 on hotspot regions), and African cities are generally underrepresented in climate change research and assessments of successful adaptation initiatives (Leal Filho *et al* 2018).

Because there is no internationally agreed definition of 'urban' (Revi *et al* 2014b), and because most urban residents in low- and middle-income countries live in cities with populations of less than one million (Moser and Stein 2011), we decided to use the United Nations (UN) list of urban agglomerations with 300 000 inhabitants or more (UNDESA 2018a).

In 2018, the landmark IPCC co-sponsored Cities and Climate Change Science Conference in Edmonton, Canada, provided an opportunity for discussions between the research, policy and practitioner communities, and led to the development of a Global Research and Action Agenda (Prieur-Richard *et al* 2018). The agenda identified key knowledge and research gaps, and this paper helps to address these by providing data on the adaptive responses of people in cities, and touches on informality and urban planning, two of the research gaps highlighted in the co-produced agenda.

Thus far, no studies have systematically examined the human responses to climate impacts in urban Africa. The primary goal of this review is to document and describe responses to climate-related impacts (including both short-term variability and long-term climate change) in urban Africa, since these impacts are projected to increase in frequency and severity under global climate change (Niang *et al* 2014). The objective was to include both formalised adaptation efforts and coping strategies, highlight knowledge gaps to guide future research, and inform local governments and international urban and climate change organisations on the current situation, what has worked, what has not worked, and where further work is required. This was achieved by extracting the physical location of each study, mapping the climate drivers, actors, responses to climate impacts and timing of actions.

We have documented the application of a systematic map to the central research question, 'What are people doing to respond to climate impacts in African cities?', supported by sub-questions: 'What are the climatic drivers of these responses?', 'What are the range of human responses to climate impacts in African cities?', 'Where are these responses taking place?' and 'Who are the actors?'

This paper describes what people are doing in urban Africa to cope with climate impacts, while also elucidating geographic and socio-economic or organisational knowledge gaps to guide future research.

## 2. Methods/design

### 2.1. Search strategies

The peer-reviewed literature search was conducted in ‘title’, ‘abstract’ and ‘keywords’ for Scopus (Elsevier B V, The Netherlands), and in ‘topic’ for Web of Science (Clarivate Analytics, USA)<sup>4</sup> on 26 March 2019. The search was limited to the years 1975 to the present (with articles from 1980 to 2019 present after abstract screening) following Epule *et al* (2017), and using the search terms outlined in table 1.

Google was searched for PDF documents (on 17 September 2019), using the methods described by Ford *et al* (2015), and the following search terms:

‘climat\* change’ adapt\* Africa (outcome OR action OR strategy OR plan OR ‘risk reduction’) AND (urban OR city OR cities) filetype:pdf.

The title and description provided within the standard Google search engine was reviewed to determine the relevance of each result. While we attempted to use the methods of Ford *et al* (2015) to ensure a manageable number of hits and a representative sample of the grey literature, this approach was not possible because Google PDF search options changed their limits. This prevented the authors from screening more than 60 results.

### 2.2. Article screening and inclusion criteria

Peer-reviewed literature results were initially exported into a reference manager (EndNote X9, Clarivate Analytics, USA), and duplicates deleted. The remaining results were exported into Excel (Microsoft Corporation, USA), and uploaded onto Google Drive (Google LLC, USA), so that the two reviewers (authors NH and MN) could screen all titles and abstracts simultaneously, applying the inclusion/exclusion criteria outlined in table 2.

The same inclusion and exclusion criteria were applied to the grey literature, with each reviewer screening half of the literature.

While all searches were conducted in English, all articles (including two in French: one focused on Niamey, Niger, another on Dakar, Senegal) that met the inclusion criteria were retained for full text screening. Google Translate was used to translate non-English articles into English.

To ensure consistency, both reviewers separately screened and coded a subset of the peer-reviewed

records (9.5% overlap), and discussed and resolved any differences (see SI.1.2). Each reviewer screened and coded half of the remaining full texts, retaining borderline texts for discussion and resolution.

All included publications were obtained through the University of KwaZulu-Natal library, except three (listed in the Supplementary Information, SI.2), with six books obtained via interlibrary loan, and two book chapters and one journal article having to be purchased.

Articles were not excluded based on critical appraisal, as this project aimed to map as wide a range of literature as possible (from social science, interview-based studies, to engineering projects), erring on the side of over-inclusion rather than being exclusionary at this stage.

### 2.3. Coding of articles and study data

Metadata from included full-text articles were recorded using a Microsoft Excel workbook on Google Drive, with columns containing codes and metadata, including basic publication data (year, title, source, DOI), the affiliation and country of the first author, and details of the study (country and city of adaptation, the year of the study, climate drivers of the response, years of impact, main methods used for the study, and their target population) (per Epule *et al* (2017)). For articles describing adaptation in more than one location, each location was recorded in a separate row so that the location of every African city studied could be plotted on a map.

The climatic drivers of responses were categorised as being one of the following, based on what the studies reported: wind, temperature extremes (including heat waves and extreme cold), excess rainfall (including floods and resulting landslides), decreased rainfall (including water shortages, drought and dry periods), sea-level rise, seasonal unpredictability (usually relating to precipitation and planting crops), extreme weather (including storms, cyclones, storm surge), multiple impacts (when actions were in response to more than one impact), and climate change in general (this refers to papers that do not give more specific climate impact detail but only refer to ‘climate change’, usually for studies of planned adaptations to improve resilience).

Adaptation actions (adjustment to actual or expected climate change and its effects, ranging from grassroots to formal adaptation programmes) were extracted into a separate sheet, listing one or more actions per study. Information on the source of each action (citation of the article describing it, country, city, climate driver, timing, and scale of action) (figure 1), and adaptation categories for adaptation tracking (figure 2) were recorded and coded for each adaptation action.

Categories for adaptation tracking, were identified *a priori* from highly-cited conceptual framing papers on global adaptation to climate change

<sup>4</sup>For Web of Science (a platform) ‘All Databases’, our institutional subscription allows us to search the following databases: **Web of Science Core Collection** (1945–present); Science Citation Index Expanded (1945–present); Social Sciences Citation Index (1956–present); Arts & Humanities Citation Index (1975–present); Emerging Sources Citation Index (2015–present); **KCI-Korean Journal Database** (1980–present); **MEDLINE®** (1950–present); **Russian Science Citation Index** (2005–present); **SciELO Citation Index** (1997–present).

**Table 1.** Definitions of components of the review question and general search terms.

	Definition	Search terms <sup>a</sup>
<b>Population (P)</b>	African cities <sup>b</sup> > 300 000 people in 2018 (UNDESA 2018b)	<b>African country names</b> and all major translations and <b>African city names</b> for Web of Science and Scopus (supplementary information SI.1.1(available online at <a href="https://stacks.iop.org/ERL/15/103005/mmedia">stacks.iop.org/ERL/15/103005/mmedia</a> )) AND ‘urban’ and synonyms <i>urban OR city OR cities OR town* OR metro* OR municipal* OR slum* OR ‘informal settlement’</i>
<b>Exposure (E)</b>	Climate drivers of adaptation response	<b>climate change</b> synonyms and <b>climate impacts</b> ‘global warming’ OR ‘climat* change’ OR ‘changing climate’ OR ‘global change’ OR ‘climate forcing’ OR ‘drought*’ OR ‘sea level rise’ OR ‘sea-level rise’ OR ‘flood*’ OR ‘extreme weather’ OR ‘disaster*’ OR ‘water security’
<b>Outcome (O)</b>	Human responses that are adaptive or maladaptive, reactive, or preparatory, individual or institutional	<b>adaptation responses, adaptive capacity</b> and synonyms <i>adapt*</i> OR <i>mitigat*</i> OR <i>response</i> OR <i>vulnerable</i> OR <i>resilien*</i> OR <i>program*</i> OR <i>alleviat*</i> OR <i>ameliorat*</i> OR <i>cope</i> OR <i>coping</i>

<sup>a</sup> Separate strings (numbered 1–4) joined with the Boolean operator ‘AND’.

<sup>b</sup> Africa defined as UN African member countries + Western Sahara.

**Table 2.** Inclusion and exclusion criteria for selection of papers to include in systematic map (decided *a priori*).

Inclusion criteria	Exclusion criteria
– Research, reviews	– Opinion pieces, editorials, commentaries, suggestions
– Actual programmes and projects	– Projections, modelling, prospective studies
– Meets the definitions outlined in table 1	– Ecological impact without human impacts
	– Climate impacts with no human response
	– Climate change mitigation
	– Do not describe any applied human responses

(Berrang-Ford *et al* 2011, 2014, Biagini *et al* 2014), adaptation to climate change in countries from the global South (Frayne *et al* 2012, Epule *et al* 2017) and global North (Lesnikowski *et al* 2011, Austin *et al* 2015). Detailed definitions for the coding of the adaptation categories can be found in the supplementary information (SI.3).

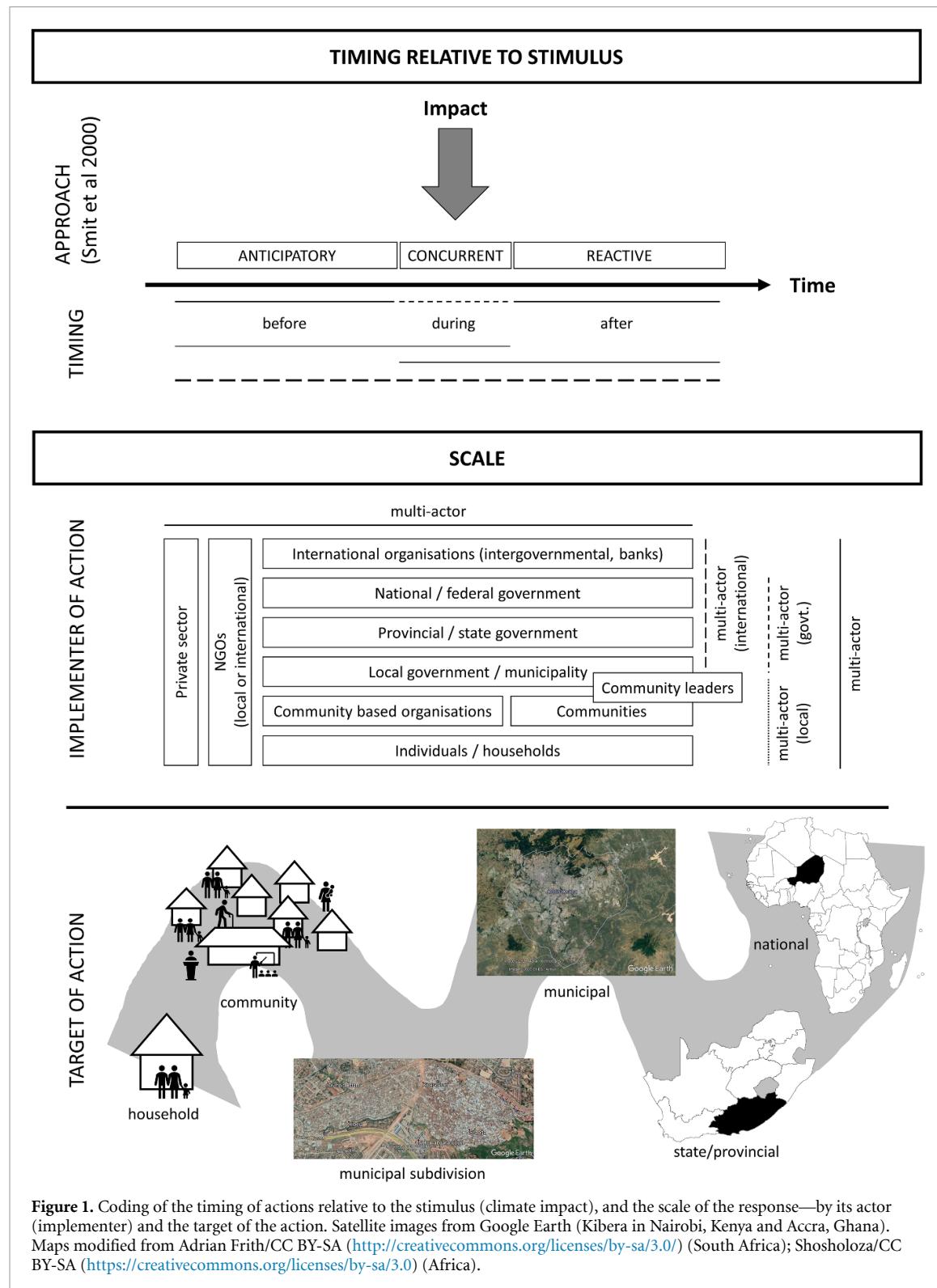
Since many of the adaptations did not fit any of these categories, an additional set tailored to this work was created (table 3).

As noted, this study has applied the IPCC’s definition of adaptation (IPCC 2018a), yet it has also sought to build on previous adaptation research and to ensure that all the relevant responses to climate impacts in urban Africa are accounted for, including

coping strategies. In line with the emphasis of Ford and Berrang-Ford (2016) on adaptation tracking, we identified ‘real or concrete adaptations’, as defined by Epule *et al* (2017) and Lesnikowski *et al* (2015b, 2011). The latter, in their work documenting adaptation in the health sector, outlined detailed and explicit criteria by which policy responses are classified as adaptations. Distinctions were made among statements of recognition, groundwork actions and adaptation actions. Statements of recognition refer to where climate change was identified as a problem, while groundwork actions are considered to be the first steps necessary to inform and prepare for adaptation, but which do not explicitly indicate tangible changes in policy or delivery of government services (e.g. vulnerability assessments, research on adaptation options, conceptual tools, stakeholder, and networking opportunities). Lastly, adaptation actions refer to tangible changes in response to predicted or experienced impacts of climate change.

Adaptation actions described for each city were checked for repeated mentions across studies. The same actions mentioned more than once were condensed to a single action and all studies referring to it were cited together. This allowed a rough comparison of the ‘number of actions’, between cities, or by adaptation categories.

The systematic map has followed the ROSES framework for systematic evidence synthesis for tracking, recording and reporting the process (Haddaway *et al* 2017).



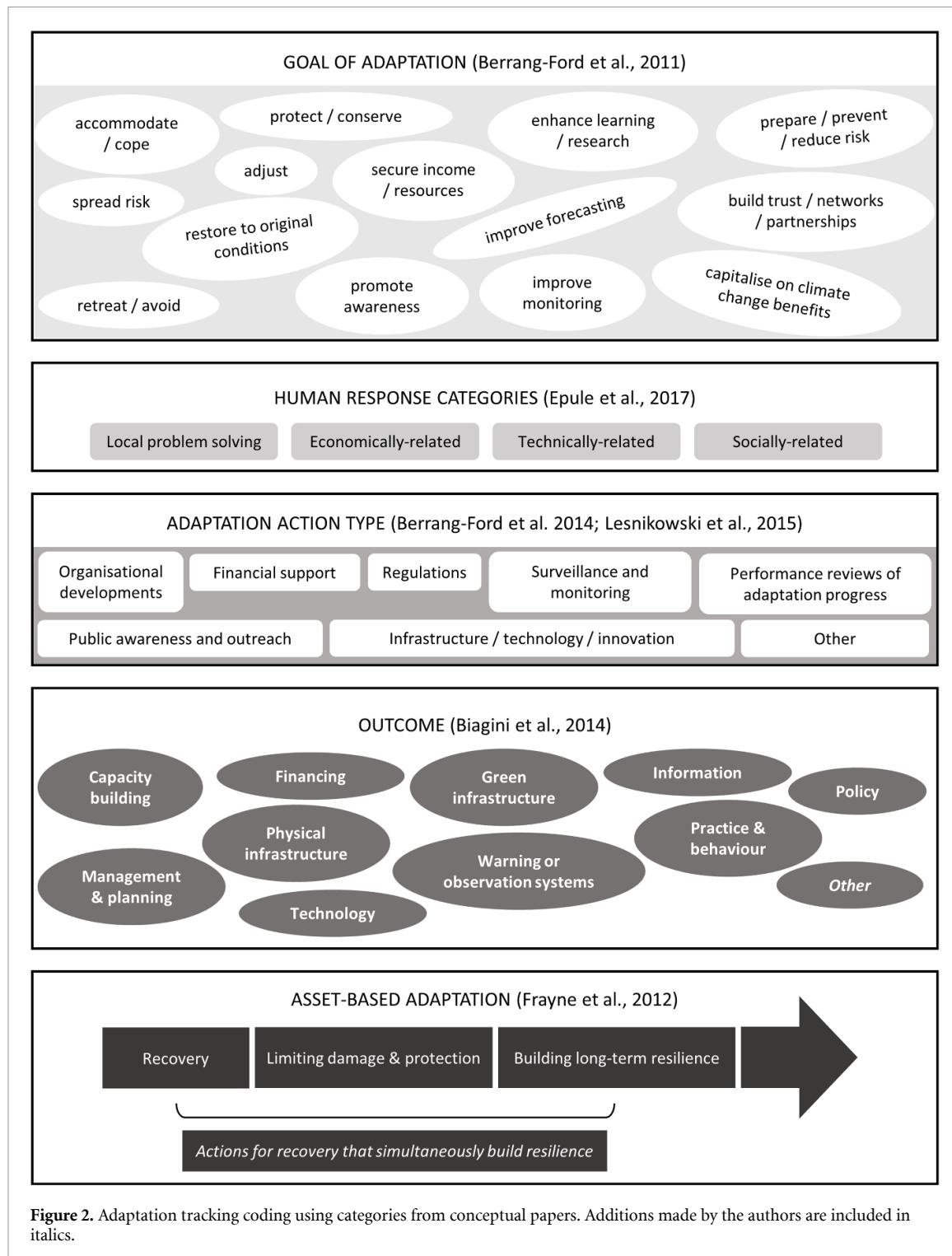
### 3. Results

#### 3.1. Summary of the evidence

In total, 2 823 results were obtained from peer-reviewed databases, and 60 from the Google PDF search, of which 781 duplicates were deleted (figure 3; refer to SI.2 for full list of publications).

#### 3.2. Overview of included articles and studies

There has been a recent surge in publications describing how African cities and their residents are responding to climate impacts, with most of the literature published in the last decade (figure 4). Various article types were included in this systematic map, namely journal articles ( $n = 96$ , from 60 journals), book chapters ( $n = 18$ , from 10 books), conference



**Figure 2.** Adaptation tracking coding using categories from conceptual papers. Additions made by the authors are included in italics.

proceedings ( $n = 3$ ), magazine articles ( $n = 2$ ), a local government report, and a doctoral paper. The journal publishing the most articles included in this review was Environment & Urbanization (SAGE Publications), with 14 articles.

Included publications were led by authors from 30 different countries, with African authors leading more than half of these (58%). Most were led by academic researchers (94 publications, or 74%), followed by practitioners (8), and employees of governmental (7), and non-governmental (7), organisations.

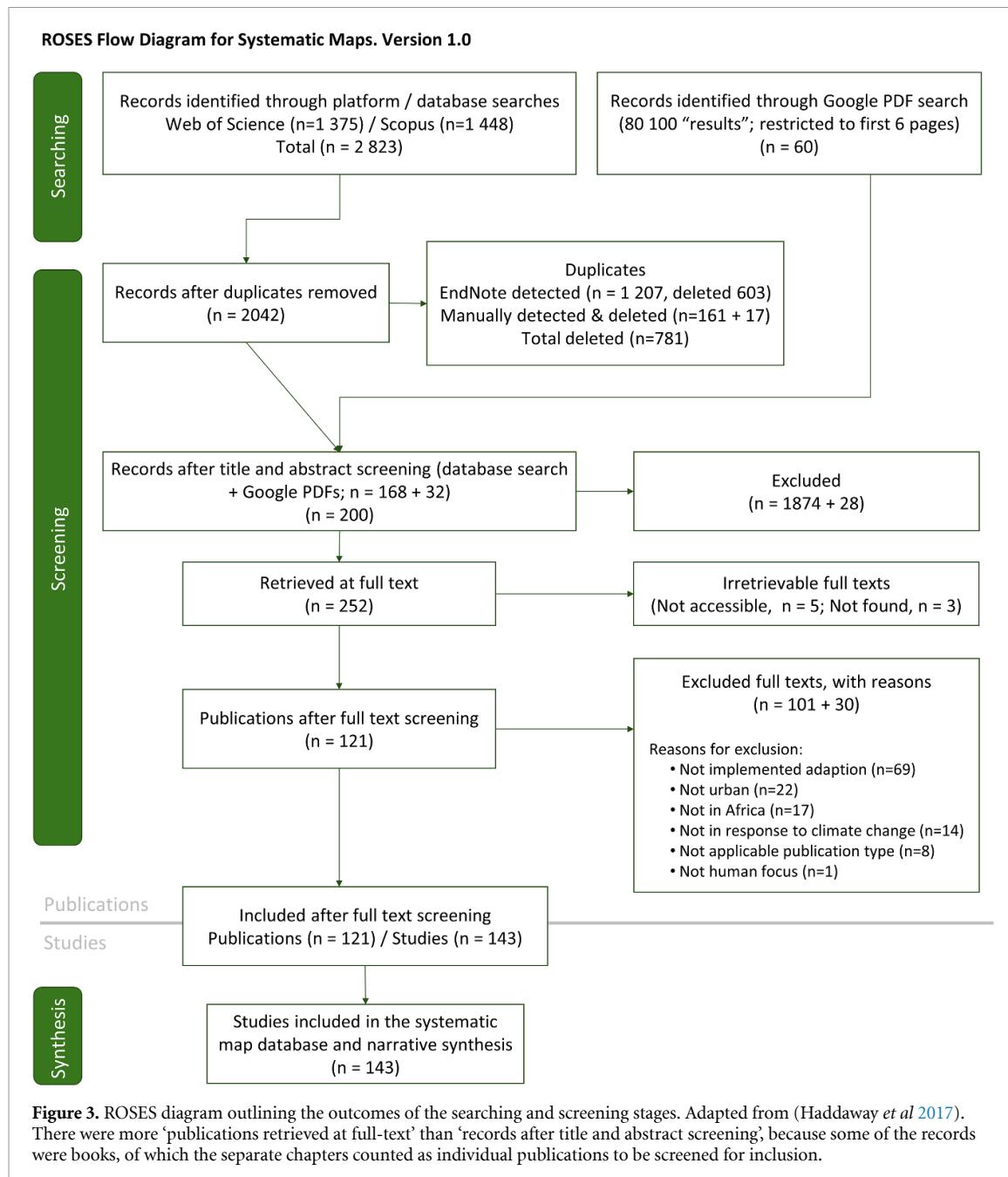
The five countries with the most studies on urban adaptation were South Africa (35 studies), Nigeria (20), Ghana (16), Tanzania (13), and Kenya (10). The literature describing responses to climate impacts in Africa only covered 41 cities from 21 African countries, of a total of 221 cities with a population of (300 000) more (UNDESA 2018b) in 55 African countries (figure 5; a list of the cities featured is included in the supplementary information (SI.4)). A few cities were relatively overrepresented, including Cape Town and Durban in South Africa (18 and

**Table 3.** Additional response categories developed by this study, based on the range of responses reported in the literature, based on the range of responses reported in the literature, grouped according to Berrang-Ford *et al* (2014)'s adaptation tracking categories.

Adaptation action type <sup>a</sup>	Response category <sup>b</sup>	Examples
Financial support	Relief/aid	Flood rescue teams, raising funds for those affected
	Construction of barriers	Sandbags to redirect flood waters; elevate houses, sea walls, groyne, retaining walls
	Construction/reconstruction	Re-roofing after damage, plastic sheets, rebuild, retrofit, upgrade
	Improving drainage	Culverts, digging trenches, ditches, cleaning blocked drains
	Mobility	Blocks, sand or wood shavings in house or on flooded streets to walk on, (in)formal (wooden) bridges, canoes for transportation, use of raised walkways, widening of streets, alternative routes, improve access to dwellings
Infrastructure/technology/innovation	Sanitation	Sanitation technology, advancements, or infrastructure
	Waste management	Solid waste removal
	Water management	Water storage, tanker services, water restrictions
	Use/preservation of ecosystem services	Conserving river basins, urban greening, rehabilitate mangroves
Organisational developments	Rice cultivation, aquaculture, seedling distribution actions	Rice cultivation, aquaculture, seedling distribution actions
	Unique and innovative actions that do not fit into the categories above	Unique and innovative actions that do not fit into the categories above
	Disaster early warning system, government adaptation programme	Disaster early warning system, government adaptation programme
	Formation/resident groups to cope with lack of services, community-based organisations	Forming resident groups to cope with lack of services, community-based organisations
	Education about risks, climate impacts, how to respond, disaster prevention and control, early warning messages	Education about risks, climate impacts, how to respond, disaster prevention and control, early warning messages
	Setback lines, zoning	Setback lines, zoning
	Reporting systems, monitoring climate/weather, pollution	Reporting systems, monitoring climate/weather, pollution
Public awareness and outreach	Enhancing awareness	
Regulations	Urban planning	Training for alien plants control programme
	Monitoring	Children to clinic, prevent grey water/solid waste accumulation, mosquito control
Surveillance and monitoring		Renting out part of dwelling, sell belongings for cash
		Transfer valuables to neighbours/higher ground, dismantle and move structures
		Reduce expenses, seek credit/loans, prioritize expenses, savings
		Cleaning houses, drying affected items, replacement of damaged goods, equipment, animals
Other	Reliance on faith	Prayers, seeking advice from a holy man
	Relocation	Resettlement measures, eviction, removal of homes, migration, build new houses on higher ground, move temporarily, evacuating family
	Self-preservation	Rain gear manipulation of diet, sleep on tables, stay indoors/at home from work or school, abandon shops
	Social ties	Community/family support

<sup>a</sup> Adaptation tracking categories developed by Berrang-Ford *et al* (2014) and Lesniowski *et al* (2011; 2015a);

<sup>b</sup> categories developed during this study



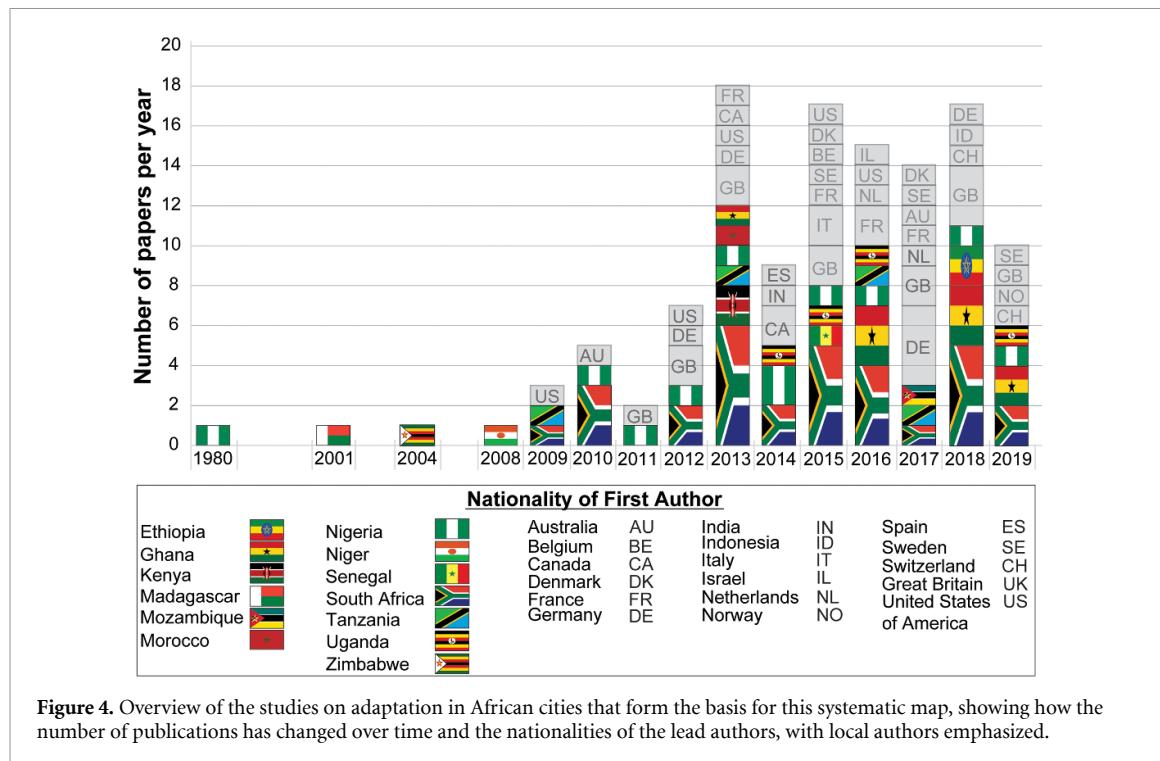
14 studies, respectively), and Accra, Ghana (12 studies).

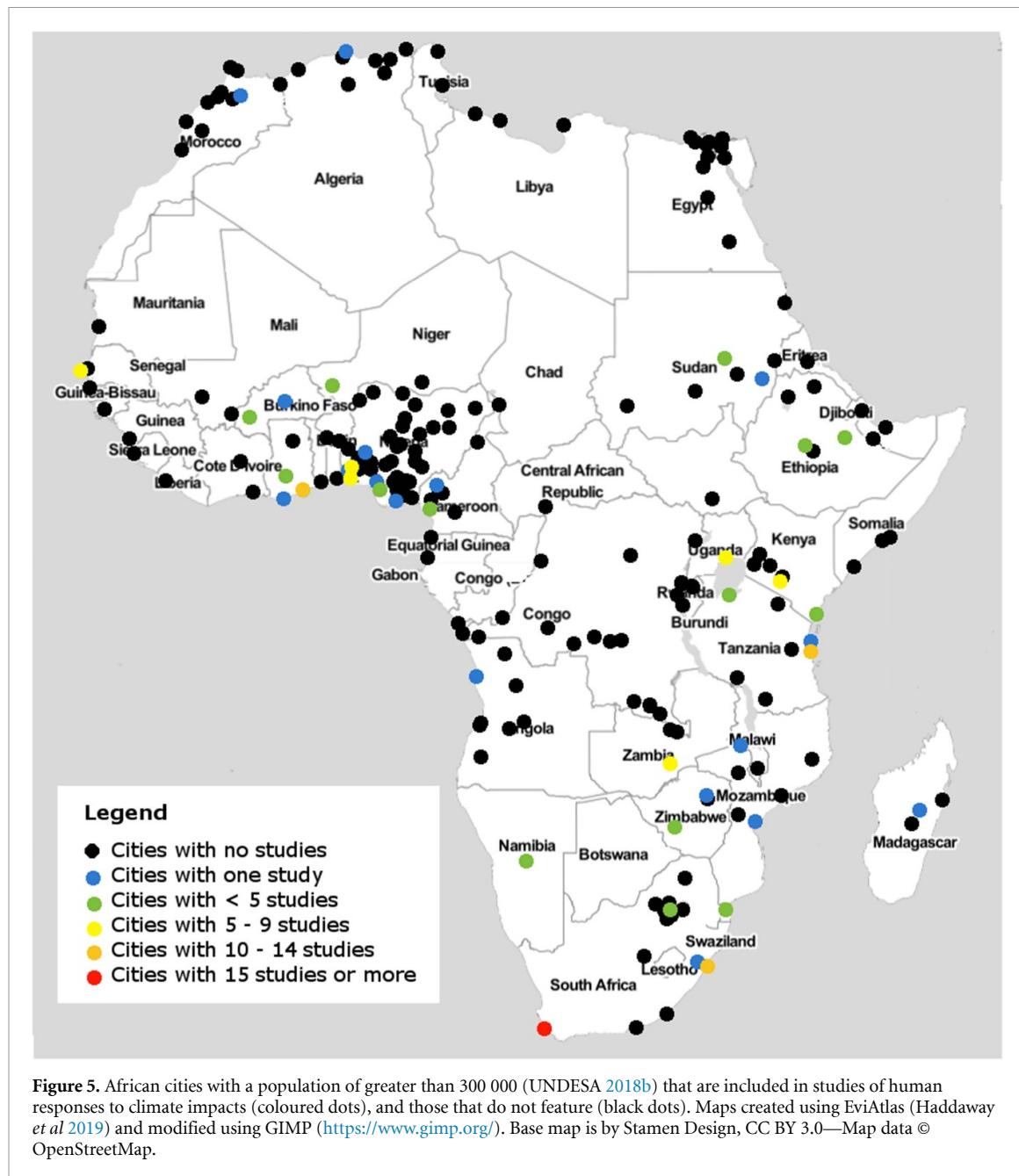
Studies incorporated in the systematic map used a variety of research methods, usually in combination. The methods most frequently employed included interviews (used by 66 of the publications), questionnaires (39), group discussions (35), information from field/site visits, which included participant observation (34), document reviews (29), and the description of NGO projects or government programmes (21). Less frequently used methods included geographical or satellite map or planning information (16), workshop information (10), policy and planning documents (7), data from archives (6), and precipitation and water usage data (7). In addition, some studies sourced data from case studies and mainstream and social media.

### 3.3. Key findings

1 504 actions taken in response to one or more climate events were listed in the 143 studies across 121 publications.

Excess rainfall, most frequently in the form of recurrent, seasonal flooding, was the single most important climate driver of adaptation in the literature, with 58 studies focused on it, describing 1 084 adaptations (1 069 specifically to flooding; see figure 6). Thirty-three studies mentioned multiple climate impacts and 14 mentioned extreme weather. Drought (15), including reduced or below-normal rainfall, was also a frequent driver. Thirteen studies focussed on ‘climate change’, rather than specific drivers, nine on seasonal unpredictability, and only one on temperature extremes.

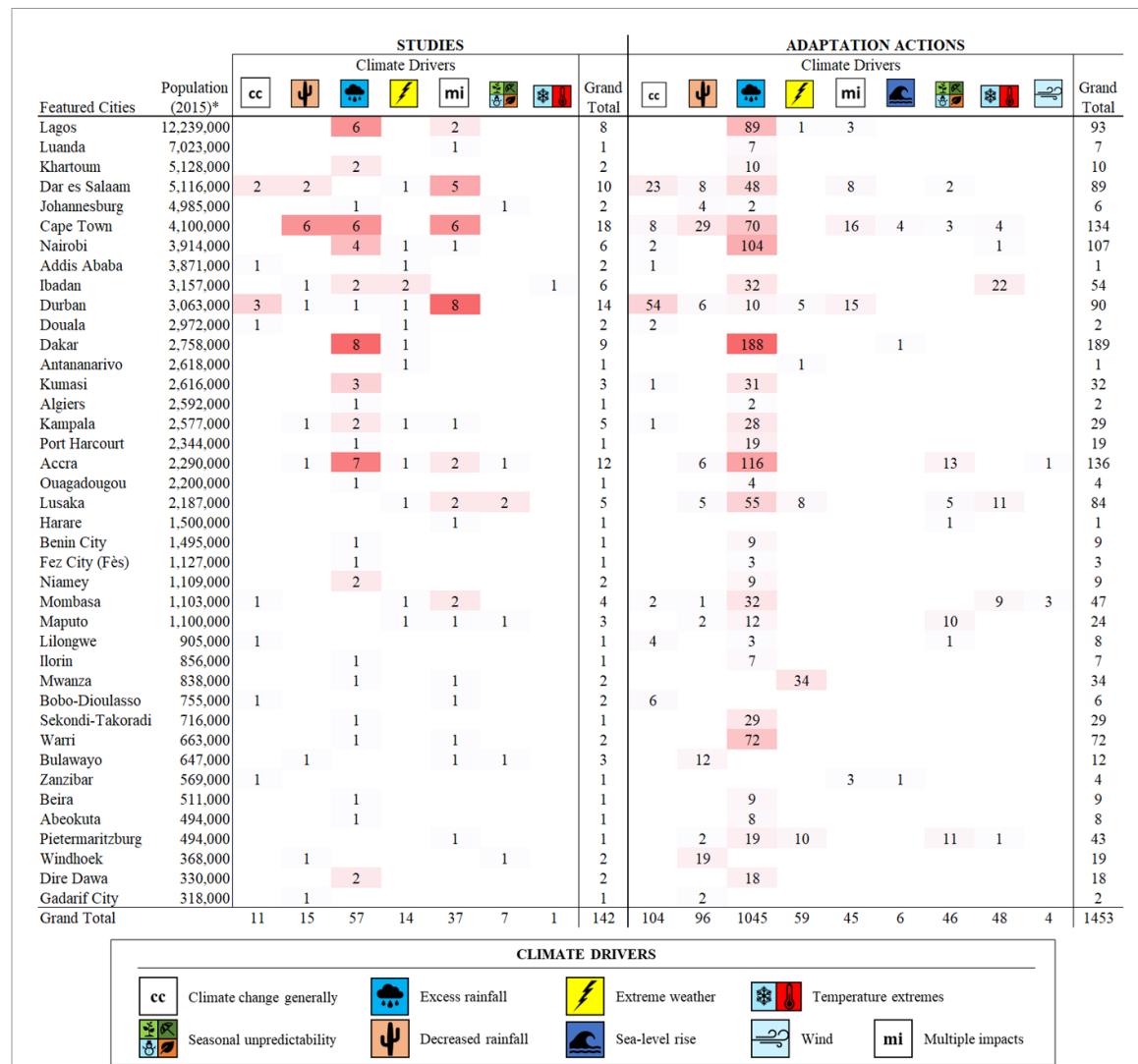




before excess rainfall), 329 ‘during’ (use of rainwater collection tanks (Simpson 2018) during decreased rainfall), and only 166 ‘after’ (volunteers mobilised in the immediate aftermath of floods (Williams *et al* 2018)). In all, 309 actions took place ‘before and after’ (the early transfer of items to safe places, after one occurrence of excess rainfall and before another (Owusu Twum and Abubakari 2019)), while 152 actions occurred ‘before, during and after’ (Ethiopian Programme of Adaptation to Climate Change (Leal Filho *et al* 2018)). Eighty actions took place ‘before and during’ the climate event (raising shelters with rubble, sand, cement or stilts (Drivdal 2016) before and during excess rainfall), while 122 occurred ‘during and after’ the event (the use of netted doors and windows to keep mosquitos out (Chukwuma and Uchenna 2018) during and after excess rainfall).

Almost half of the actions (737 or 49%) were anticipatory, while a third (35% or 527) were reactive. Overall, 247 actions (16%) were concurrent—both anticipatory and reactive, for example, preventing children from swimming in flood water (Odemerho 2015, Udelsmann Rodrigues 2019).

Actors varied widely, from individual or household level, to communities, local, regional, or national governments, international organisations, as well as combinations where actors worked together to implement adaptations. Overall, most (71%) of the responses were autonomous, with only 24% being planned (i.e. ‘adaptation that is the result of a deliberate policy decision’ (IPCC 2001)). More than half (55%) of local government responses were planned, whereas all individual and household responses and 98% of community level responses were autonomous.



**Figure 6.** Relative number of responses to each climate driver, by city (ranked by population). Adaptation actions from studies of multiple cities where the actual location of each action was not discernible were not included in this figure. One city (Bamenda) was removed from the heatmap of studies (left) because it did not feature in the individual adaptation actions.

Approximately 40 studies reported successful adaptations, although in most cases it was not possible to evaluate success, since the definition of a ‘successful’ adaptation may vary depending on the time-frame from implementation, and on the perspective from which the adaptation was assessed (Adger *et al* 2005). Successful adaptations noted emerging resilience, for example the strengthening of social safety nets (a strong community structure) and collective action among residents of informal settlements, despite the lack of institutional support (Schaer 2015, Leclercq 2017, Amoako 2018). Further examples included informal, decentralized, off-grid responses to improve resilience of households (Simpson 2018), and collaboration among actors (such as NGOs, communities, local government) to design and implement changes to infrastructure, open spaces, or services that align with community needs (Spekker and Heskamp 2017, Tauhid and Zawani 2018). Other successes included long-lasting behavioural changes in residents of drought-stricken cities like Cape Town,

Windhoek, and Bulawayo (Gumbo 2004, Simpson 2018, Booyens *et al* 2019).

A few of the studies (18 of 143) reported actions that may be regarded as taking advantage of climate impacts, for example, by benefitting from excess rainfall or flooding. This was achieved through rainwater harvesting and storage (Simatele *et al* 2012) to increase aquaculture capacity (Adewole *et al* 2015) for use in sanitation units, or for sale during the dry season (Dobson *et al* 2015). Water was also stored in water retention ponds for fishing and irrigation of high-value crops (Buyana *et al* 2019), while in other instances urban agricultural practices were altered to include water-loving species like rice (Simatele *et al* 2012, Simatele 2013). Other examples where climate impacts were taken advantage of include adaptation actions with multiple co-benefits, such as improving biodiversity and ecosystem services, providing employment and community resilience (e.g. community reforestation initiatives, (Chu *et al* 2017, Douwes *et al* 2016), or framing adaptation as a

means of achieving other development priorities or equity goals to improve the likelihood of achieving both (Carmin *et al* 2012). Finally, there were several examples where individuals or businesses were able to capitalize on climate impacts, by charging for services like waste removal or drain cleaning (Odemerho 2015, Mulligan *et al* 2017, Hlahla and Hill 2018), international contracts to build flood infrastructure (Rouillard 2013), or by taking advantage of relief to obtain items not previously available (Jordhus-Lier *et al* 2019).

It is not possible to state conclusively whether the remaining studies were unsuccessful, or did not have any benefits associated with climate impacts, however, because the interpretation of the adaptations as being successful or not, or taking advantage of climate impacts or not, were heavily dependent on the perspectives and wording of the authors of these studies.

### 3.4. Adaptation tracking

The most useful method of assessing responses was the ‘goal of adaptation’ of Berrang-Ford *et al* (2011) (tables 5 and 7). Most actions listed are clearly aimed at preparing for or preventing/reducing risk, coping with or accommodating the new normal, or protecting/conserving belongings—particularly when dealing with flooding. Of the African-based ‘human response categories’ (Epule *et al* 2017), most responses involved local problem solving (45%), followed by technically-based responses (38%, table 5, see table 6 for examples of responses). The ‘adaptation action’ categories developed by Berrang-Ford *et al* (2014), despite minor modifications to expand their definitions (see SI.3), were unable to sufficiently capture most of the adaptation actions in the African urban context. In all, 532 actions (36%) fell into the ‘other’ category which we have classified using categories based on the study findings (see table 3). Similarly, the ‘adaptation outcomes’ of Biagini *et al* (2014) were not very applicable to the African situation, with about a third (529) of the actions included as ‘other’ (see table SI.5). Of the three forms of asset-based adaptation identified by Frayne *et al* (2012), 1 038 (69%) of the actions identified in the literature were about limiting damage and protection, with only 321 (21%) actions building long-term resilience. The remaining actions were about rebuilding after the climate event and we identified 43 recovery actions (2.9%) that included an additional element of building resilience.

When assessing adaptation tracking categories by climate driver, it is evident that most reactive, coping actions are in response to excess rainfall, with people relying heavily on physical infrastructure and technology to reduce risk (table 7). Conversely, drought and seasonal change tended to trigger adjustment of existing behaviours in people. Some of the major shortfalls of the existing tracking categories are that

**Table 5.** Tracking ‘adaptation’ responses to climate impacts in African cities. Sources of the adaptation tracking categories are shown in figure 2.

Adaptation tracking categories	% of total (n=1504)
<b>Goal of adaptation</b>	
Accommodate/cope	20.7
Adjust	8.6
Build trust/networks/partnerships	1.5
Capitalise on climate change benefits	0.5
Enhance learning/research	2.5
Improve forecasting	0.2
Improve monitoring	1.3
Prepare/prevent/reduce risk	22.7
Promote awareness	4.6
Protect/conserve	18.9
Restore to original conditions	2.2
Retreat/avoid	8.2
Secure income/resources	5.5
Spread risk	2.5
<b>Human response</b>	
Economically related	7.4
Local problem solving	45.1
Social-related	9.6
Technically related	37.9
<b>Adaptation action</b>	
Financial support	4.7
Infrastructure/technology/innovation	43.1
Organisational developments	6.1
Public awareness and outreach	6.1
Regulations	3.5
Surveillance and monitoring	1.3
Other	35.4
<b>Outcome of adaptation</b>	
Capacity building	3.6
Financing	2.9
Green infrastructure	4.9
Information	2.4
Management and planning	10.2
Physical infrastructure	29.9
Policy	1.1
Practice and behaviour	6.4
Technology	0.9
Warning or observation systems	2.5
Other	35.2
<b>Asset-based adaptation</b>	
Limit damage & protection (cope & resist)	69.0
Recovery (rebuilding after the event)	6.8
Recovery (rebuilding after the event) + building resilience	2.9
Building long-term resilience	21.3

they do not adequately cover human responses to temperature extremes, seasonal unpredictability, and extreme weather. Responses to these climate impacts include *inter alia* actions that rely on social ties, or involve urban agriculture, relocation, or diversification of income.

### 3.5. Non-climatic drivers of adaptation

While reviewing the included literature, it became evident that adaptation takes place in response to multiple stimuli, not just climate, with non-climatic factors influencing the adaptive capacity of urban residents. Therefore, this section records these other (non-climatic) drivers of adaptation.

Frequently mentioned environmental factors included topography/morphology (for example, settlements in river valleys, floodplains, or marshlands),

**Table 6.** Examples of actions for several climate drivers, based on Epule *et al* (2017)s categories of human responses.

	Local problem solving	Technically based	Socially based	Economically based
Seasonal unpredictability	Income diversification Relief/aid Self-preservation Urban agriculture Water management	Water management	Reliance on faith Social ties Urban agriculture	Income diversification Rationing expenditure Self-preservation Social ties Water management Self-preservation
Decreased rainfall	Income diversification Relief/aid  Self-preservation Social ties Urban agriculture Water management	Education and training Enhancing awareness	Enhancing awareness Formation of committees/groups  Monitoring Move good/assets Urban agriculture Urban planning Use/preservation of ecosystem service	Education and training Enhancing awareness Formation/implementation of government unit or programme Education and training Enhancing awareness
Climate change	Income diversification Relief/aid  Relocation Self-preservation Social ties	Improving drainage  Monitoring Move goods/assets	Enhancing awareness Formation of committees/groups  Social ties Use/preservation of ecosystem services	Education and training Enhancing awareness Formation/implementation of government unit or programme Construction of barriers Education and training
Extreme weather	Urban agriculture Use/preservation of ecosystem services Water management	Urban agriculture Urban planning Use/preservation of ecosystem services	Formation/implementation of government unit or programme Construction of barriers Education and training  Enhancing awareness Water management Formation/implementation of government unit or programme	Income diversification Rationing expenditure  Relief/aid  Health and hygiene Social ties Formation/implementation of government unit or programme

**Table 7.** Tracking adaptation to climate impacts in African cities, for each climate driver. Sources of the adaptation tracking categories are shown in figure 2, climate driver symbols based on figure 5.

Adaptation tracking categories	n=	cc	cactus	rain	lightning	mi	wave	plants	snow	thermometer	water
		116	96	1079	59	45	6	51	48	4	
<b>Goal of adaptation</b>											
Accommodate/cope		2	15	228	7	6		14	40		
Adjust		16	31	53	8	4	1	14	1	3	
Build trust/networks/ partnerships		3	1	17	1			1			
Capitalise on climate change benefits				7	1						
Enhance learning/research		8	6	22	1	1					
Improve forecasting				3							
Improve monitoring		3	3	10					3		
Prepare/prevent/reduce risk		47	23	228	10	19	3	9	2	2	
Promote awareness		6	7	54	2						
Protect/conserve		14	2	237	19	9	2	1			
Restore to original conditions				1	31		1				
Retreat/avoid		3		113	4	3				1	
Secure income/resources		4	4	65	1	1		6		1	
Spread risk		10	3	12	5	1		6			
<b>Adaptation action</b>											
Financial support		1	1	61	3	4		1			
Infrastructure/technology/ innovation		57	54	451	32	19	6	23	5	1	
Organisational developments		20	5	57	3	6					
Public awareness and outreach		5	12	70	3	1					
Regulations		9	12	19	2	10					
Surveillance and monitoring		2	2	13					2		
Other		22	10	408	16	5		27	41	3	
<b>Outcome of adaptation</b>											
Capacity building		13	7	32	1	1					
Financing				41	1				1		
Green infrastructure		39		24	1	3	1	2	2		
Information		3	4	29							
Management and planning		31	32	72	4	12		3			
Physical infrastructure		1	4	402	20	14	4	3	2		
Policy		4		7	2	3					
Practice and behaviour		7	21	55		3		9		1	
Technology		2	8	4							
Warning or observation systems		1	2	31	2				2		
Other		15	18	382	26	9	1	33	42	3	

impervious/impermeable surfaces, low-lying land, land reclamation, land use change/practices (including land management challenges, and land tenure systems), proximity to rivers, lagoons, and dams with rising water levels. Other drivers noted were deforestation, loss of mangroves, land and ecosystem degradation (including soil erosion, and the destruction and pollution of water bodies), high/rising water tables and coastal erosion. Other environmental factors mentioned were sedimentation and siltation of water bodies, permanent storm-water retention pools, sandy soils (with little or no vegetation cover), ground subsidence, removal of sand (from coastal sandbars, beaches and rivers), steep slopes, quarrying and overgrazing (with resultant erosion, rock-falls, landslides and mudslides), and overexploitation of resources (including groundwater abstraction).

These factors included many aspects of failure of government institutions to provide adequate services including sanitation, waste collection or management, water, drainage and road infrastructure (and maintenance), health care, and land use planning and

regulation. This failure was attributed to government negligence, neglect, weak or lack of institutional capacity, lack of enforcement, a resource- and skills-poor environment, and corruption. Further governance issues included governance changes, numerous governing authorities resulting in uncertain mandates, and a lack of or inadequate disaster warnings. Further, a lack of judicial backing for environmental policies, and socio-political factors such as land tenure and redistribution problems, and the disruption of commercial farming were also noted.

Frequently mentioned social factors included population growth and increased urbanisation, informal settlements, poor housing, and, to a lesser extent, a refusal to vacate flood plains. Social inequality, mistrust of government, supernatural factors, and the deterioration of urban labour markets, as well as a lack of diverse livelihood strategies, and unemployment were further social factors. Economic factors included household and individual poverty, and local, national, or international fluctuations or lack of funding, and the urban cash economy.

**Table 8.** Characteristics of local government responses for each of the top 10 cities, by adaptation tracking categories.

Adaptation tracking categories	n=	Accra	Cape Town	Dakar	Dar es Salaam	Durban	Ibadan	Lagos	Lusaka	Nairobi	Warri
<b>Goal of adaptation</b>											
Accommodate/cope		1	18	6		3				1	1
Adjust			5			4					
Build trust/networks/partnerships			1	1							
Capitalise on climate change benefits											
Enhance learning/research		2	4		1	4					
Improve forecasting											
Improve monitoring		1	5			2					
Prepare/prevent/reduce risk		9	28	4	15	43			2		12
Promote awareness		1	6		2			1			
Protect/conserve		4	8	3	6	9	1	2			4
Restore to original conditions				1							
Retreat/avoid		2	3	2						2	
Secure income/resources				1							
Spread risk											
<b>Adaptation action</b>											
Financial support		1	9	1						1	
Infrastructure/technology/innovation		8	32	5	13	37	1	2	2	2	11
Organisational developments		1	8	3	3	15					
Public awareness and outreach		3	9	1	2	1			1		
Regulations			8		4	7					3
Surveillance and monitoring		1	4			1					
Other		6	10	6	2	4					3
<b>Outcome of adaptation</b>											
Capacity building		2	4		2	2					
Financing				1							
Green infrastructure					2	17					1
Information			4								
Management and planning		5	18	4	4	28			1		3
Physical infrastructure		7	17	7	13	9	1	2			7
Policy			5		1	1					
Practice and behaviour			1	1						1	
Technology						2					
Warning or observation systems		2	6					1			
Other		4	25	3	2	6			3		6

### 3.6. Highlighted cities

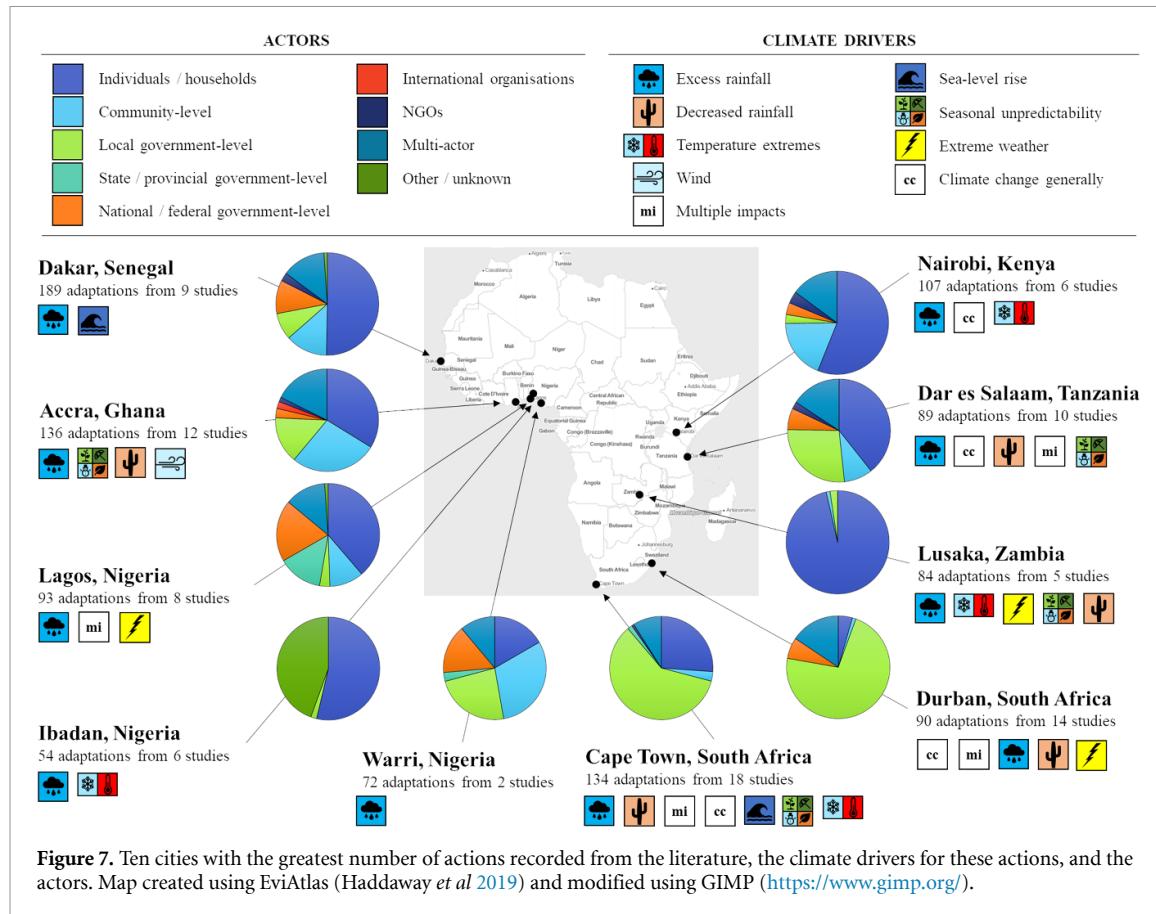
The ten cities with the greatest number of adaptation actions described in the literature were Dakar (189 actions), Accra (136), Cape Town (134), Nairobi (107), Lagos (93), Durban (90), Dar es Salaam (89), Lusaka (84), Warri (72), and Ibadan (54). This does not imply that other cities had fewer responses, just that actions in response to climate impacts have been studied, recorded, and published, in these cities.

Climate drivers of adaptation and the actors responding to these drivers varied among these cities (figure 7), although for most, adaptation responses to climate impacts were at the individual or household level, where residents were doing their best to cope with climate impacts. National/federal, provincial/state, and local governments also drove adaptation responses to varying extents, with local government a major actor in the actions reported for Durban and Cape Town, and, to a lesser extent, in Dar es Salaam and Warri. Community-based organisations, the communities themselves and their leaders played significant roles in adapting in Warri, Accra, Nairobi, Dakar, and Lagos.

Individual or household level actions dominated the recorded responses in four of these cities. In

Lusaka, Zambia, for example, 97% of the responses to climate impacts were implemented by individual households. Residents adapted their urban agricultural practices to changing conditions, by including traditional methods like zero tillage, avoiding burning crop residues or grass, cultivating more drought-resistant crop varieties, and changing planting times. They diversified their incomes by accessing savings, working in the informal economy, or selling assets. Activities to improve health featured prominently, including cleaning up surroundings, immunisation, purchase of medicines and boiling drinking water. The bases of pit latrines and homes were raised using crushed stones, soils, cement, or blocks, and informal drains were dug around homes, latrines and crop-lands to reduce the risk of flooding (Gumbo 2004, Simatele *et al* 2012, Simatele 2013, Simatele and Simatele 2015).

There was a strong sense of community in the responses recorded for Warri, Nigeria (30% of actions). Communities created a flood rescue task force, assisted flood victims, and organised the improvement and clearing of drainage infrastructure (Odemeaho 2015, Chukwuma and Uchenna 2018). In Dakar, Senegal, community-based



**Figure 7.** Ten cities with the greatest number of actions recorded from the literature, the climate drivers for these actions, and the actors. Map created using EviAtlas (Haddaway *et al* 2019) and modified using GIMP (<https://www.gimp.org/>).

organisations played an important role in assisting individual homeowners cope with climate impacts (22 actions or 11%). These organisations helped with improving and maintaining drainage and flood barriers, organised demonstrations, and worked with the media to increase awareness of the lack of service provision in their areas. They organised shelter for severely affected families, formed zonal committees that served as focal points for organising flood relief, assisted with savings, provision of loans, and the management of informal savings groups, and extended formalized support to sub-municipal entities to increase coordination between decision makers and the affected people (Schaer 2015, Diop and Remvikos 2016, Leclercq 2017, Bottazzi *et al* 2019).

Since the actions of only a few local governments are published in the peer-reviewed literature, it is not possible to fully assess African local government responses to climate change or variability. Table 8 illustrates the characteristics of local government responses for the ten cities. The limited number of published local government actions from Ibadan, Lagos, Lusaka, Nairobi and Warri is noteworthy. In terms of the goal of adaptation, even in cities with relatively more evidence of local government action, there is a lack of aspiration towards building trust, networks and partnerships, capitalising on climate change benefits, improving forecasting, restoration to original conditions, securing income or

resources, and spreading risk. Instead, cities appear to focus on preparing, preventing or reducing risk, and protecting or conserving their populations or assets. The City of Cape Town has the broadest focus, with a diverse range of actions across most of the categories. Local government adaptation actions involving infrastructure, technology and innovation is frequently reported for all cities, whereas actions involving financial support, organisational developments, public awareness and outreach, regulations, and surveillance and monitoring are largely lacking. Regarding the outcome of adaptation, all the cities appear to achieve adaptation management and planning, as well as construction or maintenance of physical infrastructure. However, there are clear gaps with regard to financing, practice and behaviour, technology, green infrastructure (apart from Durban, which is a leader in ecosystem services related actions), and policy, information and warning or observation systems (apart from Cape Town, which exhibits a number of programmes in these areas).

In Durban, South Africa, where local government was responsible for the greatest share of responses, some examples of local government actions included: the creation of municipal sectoral adaptation plans and administrative branches to deal with climate protection and biodiversity, and the implementation of a municipal climate protection programme, which led to *inter alia* the management of urban greenspace

to protect ecological infrastructure, conservation of river basins, biodiversity, and ecosystem services, and reforestation projects. Other actions revolved around urban planning (upgrading informal settlements, various tools for managing urban green-space, and use of development setback lines), education or training programmes, and improvement of sanitation through the extension of the sewer network, recycling waste water, and the development and implementation of urine diversion toilets (Roberts 2010, Carmin *et al* 2012, Galvin 2013, Roberts and O'Donoghue 2013, Anguelovski *et al* 2014, Mather and Roberts 2014, Revi *et al* 2014a, Chu *et al* 2017).

Other actors such as national government, NGOs, tertiary institutions, and collaborating groups of actors, also played important roles in the adaptation to climate change in these cities.

### 3.7. Maladaptation

Fifty-two of the publications contained examples of maladaptation, which are defined by the IPCC as actions that may lead to increased risk of adverse climate-related outcomes, including increased vulnerability to climate change, or diminished welfare, now or in the future (IPCC 2018a). Since most of the studies pertain to excess rainfall, most of the maladaptation information is relevant to excess rainfall, and much of it relates to accessibility and managing the increasing water levels. Construction of wood, stone or block bridges was not always adequate and increased the vulnerability of those crossing them (Mahmood *et al* 2017, Hambati and Yengoh 2018). In extreme cases, houses had to be broken to allow the water to pass (Frick-Trzebitzky 2017). Usually drainage and flood barriers were used by households to protect their houses, and while making the household less vulnerable, had the effect of redirecting the flow of water. This sometimes increased exposure and vulnerability of neighbours and others in the community to an increase in stagnant waters, increased erosion, or interpersonal conflict (Schaer 2015, Cissé and Sèye 2016, Frick-Trzebitzky 2017, Schofield and Gubbels 2019).

Staying home from work or school to deal with the flood had implications for children and workers, particularly day labourers who suffered with reduced earning power and future coping capacity (Schaer 2015, Cissé and Sèye 2016). It is not clear whether this resulted in increased vulnerability for rural family members, but some relief provided by urban friends and relatives resulted in financial burden to them (Kervyn *et al* 2015). Other relief came in the form of unflooded schools taking in children from flooded schools. These schools then operated with very large classes, in addition to sheltering flood victims, which also impacted on how the schools could function (Cissé and Sèye 2016).

Much maladaptation relating to excess rainfall had to do with rationing of food which reduced the

ability to withstand other shocks, including health impacts. This rationing involved the manipulation of diet and quantity of food consumed, either through reducing the number of meals, meal sizes, variety of foods eaten, or eating non-preferred foods (Battersby 2013, Thorn *et al* 2015, Boubacar *et al* 2017). Some self-preservation involved taking on debt or spending savings (Boubacar *et al* 2017, Salami *et al* 2017, Bottazzi *et al* 2018). Some individuals also placed themselves at risk by climbing on the house roof to escape the water below, went to sleep (Kiensi 2016, Schofield and Gubbels 2019) or waited for water levels to lower (Erena *et al* 2018, Udelsmann Rodrigues 2019). Roofing offered a further source of risk in instances where stones used to keep the corrugated iron roofing down during storms became projectiles during storms (Hambati 2013).

As part of the demand for urban land, migration to swampy areas took place to access better irrigated land for urban agriculture, but at an increased risk of flooding (Lawanson *et al* 2014). In other cases, flooding resulted in having to pay to stay in a guesthouse (Schofield and Gubbels 2019), temporary abandonment of houses with resultant security risk (Schaer 2015, Thorn *et al* 2015), permanent abandonment of the ground floor and only living on the first floor (Schaer and Hanonou 2017), and permanent abandonment of houses which were taken over by criminals, followed by a rise in rape and assault cases (Cissé and Sèye 2016).

Perhaps the most striking maladaptation in these flood exposed cities was forced eviction (often accompanied by demolition of buildings) as part of government programmes to do away with unapproved and/or illegal occupation in flood prone areas. Landlords were no longer able to receive their sources of income (Mitra *et al* 2017). Residents were sometimes left with no home (Chukwuma and Uchenna 2018, Amoako *et al* 2019) and in one study, this was because there was no land set aside for relocation (Thorn *et al* 2015). In one case the relocation area was nearby and inexpensive (Mitra *et al* 2017), but planned relocations usually involved provision of a new location far from the original site—for instance, one hour away from Dakar as part of Plan Jaxay. This meant that social and economic infrastructure was distant, transportation scarce and costly, social networks disrupted, local economic opportunities limited, and basic services lacking (Hungerford 2013, Lassailly-Jacob and Peyraud 2016, Bottazzi *et al* 2019). Certainly, these factors exacerbated conditions of poverty and inequality.

In terms of raising awareness of the need to evacuate, information sometimes came too late (Owusu-Ansah *et al* 2019). In other cases, residents did not trust the NGO creating awareness or providing relief, believing that these organisations come and go without implementing change. Little attention was therefore paid to the information provided, and

the aid was a source of conflict between neighbours (Schaer 2015).

Another maladaptation issue was that of water restrictions during periods of decreased rainfall. In one particular study it was shown that water restrictions—which did not account for the number of people per household and had lower limits for poor areas than wealthier ones—meant that households stopped growing vegetables in their gardens (Musemwa 2009). This reduced their ability to cope with increased food prices in the city, thus reducing household food security. Another study showed that the introduction of water management devices had implications for health and hygiene (Mahlanza *et al* 2016): ‘our toilets are now inside our home, they are not sitting outside, the way we use(d) to have it in the old days. Now you really need to have the water. It is a daily thing’. Insufficient water allocation compromised households’ livelihood strategies and quality of life, which led to a growing resentment towards water services, and a general mistrust of the city (Musemwa 2009). Children were also unable to bathe or have clean washed uniforms which meant they missed school. Growing illegal water reconnections were evident within the community (Mahlanza *et al* 2016), which had negative consequences for city-wide water consumption. Urban farming was also susceptible to decreased rainfall and climate variability, which reduced the effectiveness in times when supplemental food was most needed (Tawodzera 2013, Hlahla and Hill 2018). Finally, in some drought-affected African cities, over-reliance on groundwater without regulation will lead to depletion of the aquifers, and/or the contamination of groundwater resources by agriculture, industries, mining, and seawater intrusion (Klugendo 2009, Sappa and Luciani 2015, Madonsela *et al* 2019).

#### 4. Discussion

The publications in our review made use of a wide range of research methods and documented an array of adaptive actions at different levels—individual, household, community, governmental—providing insight into urban adaptive responses across the African continent. The most mentioned climate driver was excess rainfall, and the sheer number of studies documenting the responses to flooding in African cities was striking. There were also a number of non-climatic factors—environmental, social, economic—which impacted on adaptive action, but a lack of or poor government action exacerbated the challenges (such as poor or no urban planning, or a lack of services such as waste collection). Some government action, such as the eviction from and demolition of houses in flood-prone areas, and the lack of provision of alternate housing far from their original homes, resulted in maladaptation and this placed these households in extremely compromised

positions. People were anticipating climatic events and preparing for them—evidenced by more than half of the adaptation actions being anticipatory and almost a quarter of the actions planned. Less than three-quarters of the actions were autonomous. Various factors contributed towards successful adaptation, and there were actions which took advantage of climate impacts. Importantly, however, the adaptive action reviewed was mainly to do with limiting damage and protection, as opposed to building long-term resilience.

Adaptation is difficult to classify since it occurs at different scales (from local to global) and by different actors (such as government, community, household) (Berrang-Ford *et al* 2011). There are not only various definitions and understandings of what adaptation is by different bodies (Thornton and Manasfi 2010, Ford *et al* 2013, Biagini *et al* 2014, Thorn *et al* 2015), there is also wide-ranging debate over what constitutes actual adaptation and successful adaptation (Ford and Berrang-Ford 2016). Some authors (e.g. Dupuis and Biesbroek (2013)) prefer a narrow view of adaptation which regards non-standard activities—such as awareness creation and capacity building—as not having a direct relationship with adaptation. Others (Ford and Berrang-Ford 2016) favour a broad approach which recognises that adaptation is a process of multiple stages and involves addressing broader socio-economic determinants of climate vulnerability. These authors argue that failing to capture important capacity building activities essential for reducing vulnerability is problematic, and indeed Biagini *et al* (2014) found capacity building to be a vital part of all Global Environment Facility adaptation projects they assessed. Where adaptation reporting, such as the National Adaptation Programme of Action, has been taken as a proxy for adaptation actions, one type of action may be described in multiple ways by different authors, which has only added to the complexity. There are also multiple ways to assess adaptation (Biagini *et al* 2014), and there is little agreement or standardization on how adaptation reporting should be used for adaptation tracking purposes. It is therefore critical for authors to be clear about what they define as adaptation to allow for replication of their study by other researchers, and clearly acknowledge the limits implied by the definition used (Ford and Berrang-Ford 2016).

Our aim was to provide the wide view of people’s actions in response to climate impacts in African urban settings, and we therefore included both coping and adaptation responses. Future researchers may explore in more depth which actions are ‘standard’ adaptation responses as opposed to coping. Many of the actions taken in these African cities did not fit the categories designed by previous reviews of adaptation, which we found had to be amended or added to, or their definitions expanded upon (see SI.3). This is likely because most of the systematic reviews on

adaptation in urban areas have been at the global scale (Berrang-Ford *et al* 2011, 2014), or from countries from the global North (Reckien *et al* 2014, 2015, 2017, 2018, Austin *et al* 2015, 2016, Lesnikowski *et al* 2015a, 2015b). It was necessary to broaden the definitions of these authors to include the kinds of actions documented in adaptation studies of urban Africa. The additions and amendments to these categories should be a useful starting point for other studies reviewing adaptation actions for Africa or similar global South contexts. We have been transparent about our approach to enable replicability and for this study to serve as a baseline from which further research can expand in years to come.

While a strength of this study was that only two people screened, read and coded the information, thereby increasing consistency, the process was not uncomplicated. One challenge was the fact that none of the grey literature surveyed was eligible to be included in this review. Also there were a marked lack of studies on adaptation in many African cities and on some climate drivers (e.g. sea level rise and temperature extremes) which could be because some relevant research does not reference adaptation specifically, but rather development, and because the actions being taken are not being published in an online-accessible space. Cities described in numerous studies about climate adaptation have tended to be those with either climate research hubs, strong academic/research institutions, or those with municipal players championing adaptation research.

In future reviews of this nature, search terms should include development actions not covered by the term adaptation, to capture this literature. It would also be interesting to include the adaptations of the middle-class to wealthy urban residents, which were almost entirely absent from this review. Many of the studies describing ‘higher’ level adaptation, including local government programmes and regulations, were not able to be included, because the actions described in them are too vague or ‘high level’ to be regarded as tangible or implemented. Our recommendation to authors going forward, is to be as specific as possible about how the methods are implemented or serve as adaptations to climate impacts. We also found the differences in adaptation responses to various climate drivers to be an important distinction and recommend that future adaptation reviews provide the actions by type of climate driver.

Unlike reports from previous studies (e.g. Berrang-Ford *et al* 2011), individuals and households in African cities are adapting in anticipation of climate impacts, particularly flooding. Additionally, local governments are implementing actions in anticipation of the long-term impacts of climate change, by protecting and conserving valuable ecosystem services, investing in infrastructure upgrades, and setting up departmental units to ensure climate change is incorporated into governmental decision-making.

Previous experience made it more likely that successful anticipatory adaptation was undertaken (Thorn *et al* 2015), and this was evident, for instance, in societies located in regions traditionally exposed to extreme climate conditions, such as low-lying areas repeatedly experiencing flooding (Cissé and Sèye 2016, Desportes *et al* 2016, Bottazzi *et al* 2019), or arid environments with cyclical periods of drought (Scott *et al* 2018). The formation of certain ideologies and belief systems through this long history of exposure has led to an increased heeding of early warning signs, the formation of kinship ties, community support and reciprocity, the development of several resilience capacities to reduce exposure to extreme weather events and facilitate recovery and reconstruction, and the building of significant organisational knowledge on how to deal with the impacts of severe climate events (Linnenluecke *et al* 2012, Kuruppu and Willie 2015). If people are actively anticipating negative climate events, the state is able to support their actions in ways that make it easier for people to continue doing what they are already doing instead of having to convince people of the necessity for action.

In countries from the global South, many of the responses to climate impacts were based on local knowledge (Kpadonou *et al* 2012, Naess 2013), a finding reinforced by this study. Potential responses by government, policy makers and practitioners should therefore support the current actions of communities (Thorn *et al* 2015)—provided they are not detrimental—rather than imposing top-down scientific-based actions that may not be fit for the context.

Adaptation takes place in response to multiple stimuli not just climate (Berrang-Ford *et al* 2011), and non-climatic factors (such as informality and lack of urban planning) strongly influence the adaptive capacity of urban residents. The urban centres with the least adaptive capacity were generally in low- and middle-income nations with large populations living in informal settlements, and also had the largest deficits in infrastructure and service provision (Revi *et al* 2014a). Over sixty percent of the urban population in Africa is estimated to be living in these settlements which are more vulnerable to climate impacts than other urban areas (Lwasa *et al* 2018). There seems to be agreement that it is not ideal for people to live in informal settlements, and that reducing the number of people in such settlements is desirable; however, a still frequent government response is eviction and demolition, which is in direct contrast to calls for improvements to living conditions *in situ* (UN-Habitat 2008). Engagement of local government with informal settlement populations with the goal of building relationships (see for instance Ziervogel (2019)), flexibility and a willingness to adopt non-conventional responses that are different to those used in the global North, as

well as a willingness to co-produce solutions with informal settlement residents, all enhance resilience for these vulnerable populations (Satterthwaite *et al* 2018). There has been a proliferation of participatory upgrading programmes in informal settlements in Africa in recent years (Otsuki 2016), and these have been shown to expand and improve provision of infrastructure and services, support housing improvements and even legal tenure provision (Satterthwaite *et al* 2018). If local adaptation is to succeed, it is important that measures are taken at the local, state and national level through cooperative multilevel governance (Revi *et al* 2014a). Global funds for adaptation have to find a way to work with local governments and the inhabitants of informal settlements represented by organizations and federations (Satterthwaite *et al* 2018). Locally successful practices should be consulted when searching for solutions, or to enhance scaled-up versions of existing practices. For example, acknowledging that people will persist in living in flood- or landslide-prone areas, one approach may be to educate and help them work around the risks by building secure and resilient houses and working with green infrastructure rather than evicting them (e.g. (Riise and Adeyemi 2015, Hambati and Yengoh 2018)).

It could be that activities targeting adaptation may or may not be successful while some development actions achieve adaptation to climate impacts. While a distinction has been made between adaptation and development programmes, there is in fact much overlap and synergy between adaptation and development (Adger *et al* 2003). Development interventions such as investment in health services or in road infrastructure will increase resilience and adaptive capacity (Mcgray *et al* 2007), and may achieve adaptation to climate impacts. Similarly, education initiatives and income diversification which may be part of adaptation-funded work will contribute towards development objectives (Mcgray *et al* 2007). Adaptation should be a core part of development planning rather than a separate consideration, and likewise addressing a specific climate risk without addressing existing vulnerabilities caused by poverty or marginalisation will not foster resilience (Huq and Reid 2004, Chan and Amerasinghe 2018). A coordination of climate adaptation and development funding should enable more effective support for both sustainable development and climate change adaptation (Smith *et al* 2011). A climate rationale—how any activity would address climate-related risks, impacts and vulnerabilities—should be integrated into all relevant development planning. Affected communities need to be engaged, potential competing interests between stakeholders should be resolved, and the positives and negatives of different actions over time should be considered (Chan and Amerasinghe 2018). Climate change cuts across all sectors of society, thus cross-disciplinary teams must

be maintained, whether in research, policy or practice (Börner *et al* 2010).

## 5. Conclusions

The results of this review show that as climate events increasingly impact the lives of urban Africans, adaptive actions have become increasingly anticipatory rather than reactive. Additionally, most of the actions were based on local knowledge, and took place in response to multiple stimuli, with non-climatic factors (including informality and urban planning) influencing adaptive capacity. These points all provide a platform from which government action can build, supporting or working together with local knowledge and anticipatory action. Moreover, informal settlements are ‘here to stay’ and local governments are ideally positioned to contribute towards the resilience of these settlements. Adaptation and development interventions may be difficult to distinguish but the distinction is artificial since the two are linked. Synergies between the two approaches should be identified and a coordinated approach adopted in which climate-focused thinking is integrated into development programmes since development is affected by climate impacts. Adaptation has been difficult to classify since it occurs at different scales, by different actors and may be described in multiple ways by different authors. Transparency in research approaches, as used in this paper, will facilitate replication and adaptation tracking.

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## Data availability statement

All data that support the findings of this study are included within the article (and any supplementary information files).

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