Assessing the Impacts of Climate Change in Cities and their Adaptive Capacity: towards transformative approaches to climate change adaptation and poverty reduction in urban areas in a set of developing countries

Leal Filho W, Balogun A-L, Olayide OE, Azeiteiro UM, Ayal DY, Chavez Munoz PD, Nagy GJ, Bynoe P,
Oguge O, Toamukum NY, et al.

SCIENCE OF THE TOTAL ENVIRONMENT 692:1175-1190 20 Nov 2019
http://doi.org/10.1016/j.scitotenv.2019.07.227

Abstract

Many cities across the world are facing from the many problems climate change poses to their populations, communities and infrastructure. These vary from increased exposures to floods, to discomfort due to urban heat, depending on their geographical locations and settings. However, even though some cities have a greater ability to cope with climate change challenges, many struggle to do so, particularly in cities in developing countries. In addition, there is a shortage of international studies which examine the links between climate change adaptation and cities, and which at the same time draw some successful examples of good practice, which may assist future efforts. This paper is an attempt to address this information need. The aim of this paper is to analyse the extent to which cities in a sample of developing countries are attempting to pursue climate change adaptation and the problems which hinder this process. Its goal is to showcase examples of initiatives and good practice in transformative adaptation, which may be replicable elsewhere. To this purpose, the paper describes some trends related to climate change in a set of cities in developing countries across different continents, including one of the smallest capital cities (Georgetown, Guyana) and Shanghai, one the world´s most populous cities. In particular, it analyses their degree of vulnerability, how they manage to cope with climate change impacts, and the policies being implemented to aid adaptation. It also suggests the use of transformative approaches which may be adopted, in order to assist them in their efforts towards investments in

low-carbon and climate-resilient infrastructure, thereby maximizing investments in urban areas and trying to address their related poverty issues. This paper addresses a gap in the international literature on the problems many cities in developing countries face, in trying to adapt to a changing climate.

Keywords: Adaptation, Climate change, Developing cities, Policies, Poverty, Vulnerability

1. Introduction: Cities and Climate Change

Climate change and its attendant consequences are acknowledged to be one of the most pressing challenges posed to humanity in present times. Climate change influences many settings and contexts, be it in rural or urban areas. Concerning the latter, a direct relationship between climate change and urbanization has been established (Hoornweg, Sugar, & Trejos Gomez, 2011). As hubs of socio-cultural, scientific and technological innovations, cities attract a growing population which poses heavy demands on their resources, especially on their natural resources (Rosenzweig, Solecki, Hammer, & Mehrotra, 2011). In this introduction, we review the existing literature based on 3 criteria: firstly, the relevance to the topic of climate change, especially the literature related to cities. Secondly, the application to the reality of developing countries, the focus of the paper. Thirdly, the deployment of literature which is recent and refer to concrete attempts to foster the understanding of the connections between climate change adaptation and efforts to foster poverty reduction in urban areas. This line of thinking was also used in the methodology.

This century's unprecedented urbanization, industrialization, waste disposal and their related effects on the urban environment, accelerate air and environmental pollution thereby aggravating vulnerability to climate change. Africa and Asia have been identified as two of the most vulnerable regions to the impacts of climate change (Busby et al., 2018; Adenle et al., 2017), which is due to several factors such as high population growth rate and proliferation of slums (Lutz & Muttarak, 2017; UN-HABITAT, 2016). The many needs of a significant urban population are responsible for about 80% of the world's anthropogenic greenhouse gas

emissions, although the spatial coverage of cities is only 2% of the globe (Satterthwaite, 2008; UN-HABITAT, 2016). The predominant source of urban GHG stems from energy consumption through the burning of fossil fuels for transport, energy in-use in buildings and appliances (IEA, 2008). About 30% of GHG emissions through energy use is attributed to the buildings sector, whereas GHG emissions induced by global energy use will rise to 76% by 2030. The effects of such processes are far-reaching and ultimately contribute to global warming.

Climate change leads to depletions in water supplies due to increased evaporation. It also disrupts public health and transportation especially among illegal slum communities in less developed countries and low altitude shoreline cities (McGranahan, Balk, & Anderson, 2007; Revi et al., 2014; Rosenzweig et al., 2011). Urbanization aggravates incidences of heat waves, drought, storms, erratic precipitation, strong wind, tropical and mid-latitude cyclones, among others. These, in turn, affect cities through sea level rise, storm surges, scarcity of water, landslides, air pollution and inland and coastal flooding (UN-Habitat, 2008).

As the expansion of urbanization induces and exacerbates climate change, it, on the other hand, could be seen as a promising opportunity to assist climate change adaptation and mitigation efforts (Pachauri et al., 2014; Parry et al., 2007), especially but not only in coastal areas (Walter Leal Filho et al., 2018a). Science and technology breakthroughs are crucial to initiate adaptation and mitigation measures in cities, or to spread awareness about the causes and consequences of climate change to make it a priority policy concern for governments (Pachauri et al., 2014; Revi et al., 2014).

The aim of this paper is to analyse the extent to which cities in a sample f developing countries are attempting to pursue climate change adaptation and the problems which hinder this process. Its goal is to showcase examples of initiatives and good practice in transformative adaptation, which may be replicable elsewhere".

1.1. Limitations in harnessing the knowledge

There are severe limitations in harnessing the knowledge that cities generate to alleviate the impacts of climate change. One of them is the fact that there are regional differences in understanding and implementing climate disaster risk management. Urban planning without due consideration climate change adaptation and mitigation components is unfortunately commonplace (Fuchs, Conran, & Louis, 2011; Kem, 2015). As a result, most vulnerable cities in continents such as Africa, lack the infrastructure to withstand the harmful effects of climate change (UN-Habitat, 2008). Initiating and implementing proactive measures are known to be difficult because of rapid urbanization, low awareness about the risks posed by climate change, and by poor governance. There are also political, financial, technological & socio-cultural and behavioural bottlenecks. Accordingly, disaster risk management through early warning and prevention is weak in many cities (Parry et al., 2007; Rosenzweig et al., 2011). Much remains to be done to tackle problems of incomplete information, knowledge gap, poor stakeholder coordination & cooperation and contradictory legislation (González, 2005).

Great exposure and limited adaptive capacity to climate change make city life risky, especially to the poor in developing countries. Despite the imminent threat to cities, there are relatively few studies on the adaptive capacities of cities on a global scale. Most adaptation monitoring studies have been undertaken at the national level rather than city level (Doherty, Klima, & Hellmann, 2016; Lesnikowski, Ford, Biesbroek, Berrang-Ford, & Heymann, 2016). Detailed studies on the extent to which global cities are adapting to climate change are scant (Araos et al., 2016; Leal Filho, 2015). Effective and efficient adaptation strategies are mostly unknown (Doherty et al., 2016). This latter study addresses this gap by undertaking detailed an international research on the extent of climatic impacts in different cities and various adaptive strategies being adopted. It focuses on cities in developing countries since they are generally more vulnerable than cities in developed countries, creating a catalogue of policies and socio-economic adaptation interventions in diverse urban contexts. This study is pertinent and timely considering that most cities that are vulnerable to the impacts of climate change are situated in the studied regions (Elsharouny, 2016; Weiler, Klöck, & Dornan, 2018) Similarly, understanding perspectives of cities in developing countries, and how they relate both to development and climate change would enhance proper policy intervention. It would foster deliberate policy interventions aimed at enhancing their potential for achieving sustainable development (Mfune et al., 2016)

1.2. How climate change affects cities and the need for transformative approaches to adaptation

The previous sections outlined the essential connections between climate change and cities namely the urban risks and vulnerabilities. This section goes further and focuses on a description of its impacts and outlines the role of climate change adaptation. As stated by Reckien et al. (2017), "Climate change is acknowledged as the largest threat to our societies in the coming decades", and in that sense urbanization, sustainable development and climate change interpenetrate (Reckien et al., 2017) and are interrelated dimensions of this global societal challenge. United Nations estimates that 54 per cent of the world's population lives in urban areas, a proportion that is expected to increase to 66 per cent by 2050. As a result of this urban growth and global urbanisation trends, cities are facing several risks that affect populations and interfere with their capacity for climate adaptation and mitigation (Landauer, Juhola, & Söderholm, 2015; Li & Bou-Zeid, 2013).

A growing number of low-lying urban areas are particularly exposed to sea level rise, with increases in coastal erosion and flooding (Adelekan, 2010). These vulnerable coastal communities (tropical developing countries and small island developing states - SIDS) are a significant challenge to be faced (Betzold, 2015; Kelman, 2015). A major problem is water supply that can be caused by various natural and social reasons (Li & Bou-Zeid, 2013). Another problem is the loss of urban biodiversity and ecosystem services in urban areas involving socio-economic costs and affecting socio-cultural values. Urban ecosystem services may enhance resilience in cities (Gómez-Baggethun & Barton, 2013), and the understanding of the management of urban ecosystem services is fundamental to ensuring sustainable urban planning (Luederitz et al., 2015) and economic activities (Arku, Angmor, & Adjei, 2017) in a climate change context.

Extreme climatic events pose a significant threat to cities. Kaspersen and Halsnæs (2017) and Franz-Vasdeki (2011) detailed the impacts of exposure to extreme events on cities' built environment/infrastructure. Water quantity and quality in cities are also being impacted negatively (Duran-Encalada, Paucar-Caceres, Bandala, & Wright, 2017; Li & Bou-Zeid, 2013) and require significant investments for tangible interventions (McDonald et al., 2011). Extreme heat events in cities such as the urban heat island (UHI) effect (Arnfield, 2003) are also

153 increasing, with severe consequences (Argüeso, Evans, Pitman, & Di Luca, 2015; Zhao et al.,
154 2016). Cities' urban environment activities can enhance heat waves (Li & Bou-Zeid, 2013), and
155 recent research (Argüeso et al., 2015; Suzuki-Parker, Kusaka, & Yamagata, 2015) suggest that
156 global warming and growing urbanization will lead to even more heat extremes.
157
158 Inter and multidisciplinary solutions are needed and transdisciplinary approaches to bridging
159 boundaries and practices (science, policy, practitioners, governance) are critical in addressing
160 this societal challenge (McPhearson et al., 2016; Solecki, Seto, & Marcotullio, 2013) namely to
161 "build resilience and societal preparedness" (Biagini, Bierbaum, Stults, Dobardzic, & McNeeley,
162 2014), building resilient pathways and climate change governance (Broto & Bulkeley,
163 2013). Several examples of adaptation strategies have been documented (Austin et al., 2015;
164 Heidrich, Dawson, Reckien, & Walsh, 2013; Reckien et al., 2014; Reckien, Flacke, Olazabal, &
165 Heidrich, 2015). However, these are mainly focused on developed countries and to a lesser
166 extent, cities. Structured global assessments of urban adaptation are scarce, particularly at the
167 city level (Araos et al., 2016). Publicly available data have been utilized for the country and
168 regional level analyses to evaluate the adaptation state in several cities, often in developed
169 contexts (Austin et al., 2015; Reckien et al., 2014). Developing and underdeveloped cities in
170 Africa and other emerging economies are seldom extensively studied (Cabral et al., 2017;
171 Nkhonjera, 2017). It is therefore essential to investigate the impact and extent of climate change
172 on diverse cities in developing countries. How well are these cities coping with climatic threats
173 and how effective are their adaption strategies concerning each other? Is the country-level
174 adaption readiness index a reliable indicator of city-level readiness in developing countries?
175
176 ***1.3. The use of transformative approaches***
177
178 The above state of affairs suggests that transformative approaches can be beneficial.
179 Transformative climate change adaptation may for this paper be defined as adaptation processes
180 which go beyond the conventional adaptation through physical changes (e.g. higher flood
181 barriers), which at times are expensive and difficult to implement and move towards building
182 resilience. This means, in practice, long-term changes in the way we handle climate impacts.
183 Transformative approaches are characterized by some key features such as:

a) they help to enhance resilience,

b) they help to promote sustainability,

c) they help to reduce vulnerability

d) they take into account the risks in implementation,

e) they pay due attention to the socio-economic contexts of a given community.

Transformative approaches may vary from initiatives tackling intense urban heat by employing tree plantation with the local populations, on by fostering changes in conventional agriculture by deploying heat and drought tolerant crops which may help to reduce poverty and prevent malnutrition. Herein, poverty refers to the part or complete lack of the means necessary to meet basic personal needs such as food, health care, clothing and shelter.

Figure 1 outlines some of the elements associated with poverty.

Figure 1. Some of the elements associated with poverty in a developing country context.

Following these questions, this paper aims to assess the adaptation readiness level of different cities in developing countries through cross-check of adaptation measures and strategies; highlight unique and general challenges being faced, and recommend possible solutions that could be shared across regions and continents.

2. Methodology

The literature related to trends in climate change in cities in industrialised countries is rather prolific. The same is not right to developing nations, where there is proportionally little literature. Based on the need to address this gap, this papers focuses on trends in developing countries, adding to the body of knowledge available. It should be outlined that the purpose of this paper is not to offer comparisons. Instead, we outline some of the main problems the sampled cities face when trying to implement climate change adaptation. Also, the choice was not only based on convenience. The others factors which led to the choice of the sample were: a

geographical distribution of cities in profoundly different developing countries across three continents, the choice of cities of different sizes, from small ones such as Georgetown, to Shanghai, and the socioeconomic and human development status of the countries where the studied cities are located. For clarity, the above factors are included in the methodology.

2.1 Analytical Framework

The methodology adopted in this work is based on the review of recent literature on trends and dimensions of climate change impacts in cities and adaptive capacity. The analytical framework, i.e. the logical basis which provided a basis for the study and the interpretation of its findings, follows the rationale that vulnerability, that is to say, the measure of a country's (or city's) exposure, sensitivity and ability to adapt to the negative impact of climate change (ND-Gain, 2018), is particularly acute in urban centres in developing countries. Therefore, cities with a significant level of vulnerability (or less adaptive capacity) would be prone to be impacted -and their inhabitants may suffer- in the face of climate change. Conversely, a resilient city will seek to reinforce its adaptive capacity, including governance systems (Figure 2). Low-income urban populations are among the most impacted by climate change (IHC, 2011). The indexes used herein such as the Notre Dame Global Adaptation Initiative (ND-Gain) and World Bank's Worldwide Governance Indicators-WGI (World Bank 2017) integrate income indicators (e.g. Gross Domestic Product-GDP) on the one hand, and efficiency, political stability, and regulation indicators on the other. Therefore, a correlation between cities' income level, human development, and governance quality, and adaptation capacity is to be expected. The three characteristics shown in figure 2 (drivers, outcomes, adaptive capacity) interact; herein drivers determine vulnerability elements, whereas adaptive capacity/resilience is understood as the critical factor because it is independent of external forces. This integrated framework underscores a theoretical, practical and contemporary approach to climate change impact research, that combines the triple-bottom-line of sustainability (social, economic and environmental) with the cross-cutting issues of governance (Brugère & De Young, 2015) with a continuous feedback mechanism on mitigation, adaptation and resilience building systems.

Although the relevant literature reviewed in the paper provides various analytical frameworks, our paper distils the current approach and interconnections succinctly in understanding the impact of climate change on cities and outlines some appropriate responses.

2.2 Data Exploration

We extracted data from different secondary sources for the analyses of official government reports and published papers, and combined it with the first-hand experience from the authors who live in the sampled cities and experience the problems and constraints posed by the investigated climate issues daily. Publicly available data on climate change adaptation policies was also consulted. The data analyses performed were aimed at offering an accurate overview of all relevant trends. In addition to publicly available city-level data, we inferred implications for the sustainability of cities based on available empirical secondary data sources, including the Notre Dame Global Adaptation Initiative Urban Assessment (ND-GAIN UA) vulnerability and readiness index (ND-Gain, 2018). The ND-Gain UA measures a city's exposure, sensitivity and ability to adapt to the negative impacts of climate change.

Even though climate risks are often discussed at the national scale, urban areas are increasingly seen as having a role in the climate agenda. Despite this need, decision-makers face significant challenges including (ND-Gain 2018):

- Uncertainty of urban climate hazards.
- Lack of measurement to prioritize adaptation actions.
- Lack of data to understand and track urban vulnerability to climate change.
- Difficulty integrating adaptation information into current procedures.

Based on these challenges, inferences were also drawn from National-level indicators, which are used for quantifying the adaptive capacity for policy formulation (Vincent, 2007). Although international organizations usually require national-level indicators, there were adopted as proxies in this study due to the lack of reliable city-level indicators. While national level indicators could be used as proxies for assessing cities' adaptation readiness in the absence of reliable city level indicators (Leal Filho et al., 2018b), this approach might have some limitations due to possible differences in national and city level readiness level. Hence our reliance on authors' first-hand experience as a supplementary means of validating the reliability of the proxy data.

We identified six issues which influence the impacts of climate change in cities (see Table 2). This list is by no means comprehensive but serves the purpose of measuring to some extent the ways climate change may negatively influence cities. These cities were chosen based on three

criteria: they have a wide geographical coverage representing the various world regions; they are known to be struggling to cope with the impacts of climate change; they represent different sizes, from small ones (e.g. Georgetown, Guyana) to large ones (e.g. Shanghai, China). The issues to be examined were classified as drivers (geographical position, population); outcomes (occurrence of extreme events, problems experienced, exposure and sensitivity to climate changes and extreme events); and policy response (adaptive/resilience capacity) (Figure 2). Each item per se offers limited information, but combined, they offer a rough profile which indicates the ability of a given city to be more (or less) resilient to climate change (and climate hazards).

The definitions of the ND-Gain Urban Assessment indicators are as follows:

Resilience: Capacity of a system or city to absorb stresses and maintain function in the face of external stresses imposed upon it by climate change and adapt, reorganize, and evolve into more desirable outcomes that improve the sustainability of the system, leaving it better prepared for future proofing climate change impacts.

Risk: Potential for something of value to be at stake because of its presence in a changing climate.

Exposure: Percent of the population that experiences a climate hazard.

Climate Hazard: Potential occurrence of a biophysical event, trend or impact caused by climate change

Sensitivity: Extent to which an urban area will be affected by, or responsive to, a climate hazard. Risk is a function of climate hazard and exposure and vulnerability of the social system.

Vulnerability: Measures the degree to which an urban area is unable to cope with the impacts of climate hazards on its human population.

Adaptive Capacity: Ability of an urban area to prepare for or cope with a climate hazard

Readiness: General features of urban areas that will enable policy change and action implementation to reduce vulnerability to climate hazards. It is composed of the measure of economic conditions, governance support, and social capacities.

Few nations have reliable information on climate change at regional to local levels (Adenle et al., 2017). We identify the significant impacts of climate change on the studied developing cities and evaluate their adaptive capacities and policy interventions. We analyze the extreme events being

faced and readiness of the cities to manage these challenges. Specifically, this study adopts three indicators to assess the adaptive capacity and resilience of the studied cities to climate change: urban poverty, infrastructure (here exemplified by roads, provision of water services, electricity and social services) and community facilities (e.g. the provision of public health care (e.g. hospitals, clinics, ambulatory care centres), emergency services including rescue and fire vehicles, as well as telecommunications).

Figure 2. Interactions of climate change drivers, outcomes and adaptive capacity in cities.

There are several frameworks on climate change adaptation in cities (Biagini et al., 2014; Broto & Bulkeley, 2013). The Urban Sustainability Directors Network (USDN, 2016) has a compilation of seven adaptation frameworks based on specific cities in developed countries. However, our framework presents a systematic context for understanding climate change and adaptive capacity in developing countries. The framework is non-linear and encapsulates the interactions of climate change drivers, outcomes and adaptive capacity in cities. It is linked to policy responses on sustainability dimensions with a view to future-proofing developing cities in the pathways to social, economic and environmental progress.

2.3 Scope of the Study

The review and analyses in this paper cover nine cities of developing countries and/or emerging economies spread across three regions of the world. The cities are Georgetown (Guyana), Montevideo (Uruguay), Lima (Peru), Ibadan (Nigeria), Nairobi (Kenya), Lomé (Togo), Kuala Lumpur (Malaysia), Dhaka (Bangladesh), and Shanghai (China). This is a convenience sampling based on the geographical location of the researchers, combined with the need to have a balanced distribution of the areas, being spread across three continents (Africa, Latin America, Asia) and is also indicative of the different realities seen among developing countries. The studied countries show differences in socioeconomic and human development among them, ranging from low to very high Human Development Index (HDI) (Table 1). The HDI integrates three

indicators (per capita GDP, education level, and life expectancy) (UNDP, 2018). At the sub-national HDI level, most metropolitan areas have a much higher score than their countries (e.g. Shanghai, Lima).

Since climate vulnerability is strongly dependent on the exposure and sensitivity to climate change and extreme weather events, whereas the capacity to effectively formulate and implement sound policies lies mainly on development and governance factors, sharp differences in vulnerability, readiness, and adaptation among the selected cities are to be expected.

Table 1. Socioeconomic and Human Development Index of the studied countries and cities.

2.3.1 Georgetown, Guyana

Georgetown, the capital and largest city of Guyana has a population of 25,849 people (in the City itself) and 118,363 people (within the current boundaries of the City) , thereby accounting for two-thirds (61.7 percent) of the country's total urban population[1] . It is located on the low Coastal Plain at approximately 1.5 meters below mean sea level (MSL) and geologically characterized by impermeable clay soil that drains poorly and therefore becomes submerged during heavy rainfall (Daniel, 1984). Heavy rainfall, sea-level rise (SLR) and storm surges are projected to increase due to climate change. The city's infrastructure has not been adequately maintained in recent times thereby affecting its resilience and adaptive capacity (Villamizar et al., 2017; Hickey and Weis, 2012; Bynoe, 2007).

2.3.2 Montevideo, Uruguay

Montevideo is Uruguay's capital, and its metropolitan area (RMU) extends over 70 km along Rio de la Plata river estuary with over 1.6 million people. The RMU is i) moderately to highly vulnerable to SLR and storm surges (Villamizar, Gutiérrez, Nagy, Caffera, & Leal Filho, 2017), ii) the exposure to coastal flooding is high (Calil, Reguero, Zamora, Losada, & Méndez, 2017). The Government Office of Climate Change (DCC) has developed the GEF Project: Implementation of Coastal Adaptation Pilot Measures (2008-2014) (Nagy, Gómez-Erache, &

[1] Urban distribution refers to segments of the population that are found within the urban centres and settlements.

Kay, 2015) and is developing the National Adaptation Plan (NAP) for Cities and Infrastructures (2017-19), while the subnational coastal governments are developing the Metropolitan Climate Plan for Urban and Coastal Adaptation for the RMU (Verocai, Gómez-Erache, Nagy, & Bidegain, 2015).

2.3.3 Lima, Peru

Lima is the capital and largest city of Peru, with over 10 million inhabitants. More than 70% of the world's tropical glaciers are found in Peru and Lima is deemed one of the most vulnerable cities (Stern et al., 2006) due to the impact of climate change on glacial melting and access to water. Severely low rainfall and Melting glaciers are affecting water supply in the city, which is provided mainly by wells and rivers flowing from the Andes, from glacier melting and rainfall in the winter season. Hydroelectric energy supplies are also being affected by an erratic and dwindling water supply. Existing and proposed interventions are focusing on the capture and storage of rainwater during the wet season, and increasing government investment in dams, tunnels and reservoirs where significant investments are to be made such as tunnel-channeling water from the Atlantic side of the Andes towards the Pacific Rim.

2.3.4 Ibadan, Nigeria

Ibadan is Nigeria's largest city by geography as well as the most populous city at the independence of Nigeria in 1960. Ibadan is located in south-western Nigeria, 128 km inland northeast of Lagos and 530 km southwest of the Federal Capital Territory, Abuja. Ibadan is Capital of Oyo State and a prominent transit point between the coastal region and the areas in the hinterland of the country. Ibadan was the country's centre of administration of the old Western Region of Administration during British colonial rule, and parts of the city's ancient protective walls still stand to this day. The uncoordinated expansion of the city of Ibadan has led to the emergence of slums which exacerbate the impact of climate change and weaken climate change resilience capacity. Ibadan city is not just a compelling case of the understanding slums and human settlements in Africa, but also a panorama and dynamics of the impact of climate change on African cities (Ajayi et al., 2012).

2.3.5 Nairobi, Kenya

Nairobi became the capital of Kenya in 1907 (Vogel, 2008). Much of its urban footprint is unplanned settlement driven by rapid population growth and urban poverty leading to sprawling informal settlements. These are situated in the city's most fragile areas such as floodplains, steep slopes, river valleys, or adjacent to sewers or dump sites making inhabitants vulnerable to climate variability and change. Climate change affects urban agriculture leading to increases in costs of food commodities and food insecurity to urban poor comprising 45% of the city's population (NCC, 2017). Shocks such as flooding due to heavy rains are likely to increase in frequency and magnitude impacting on livelihoods, economic activity, and individual well-being, particularly for the poorest and most vulnerable within the affected communities. Climate change will likely exacerbate impacts of the high pollution levels experienced in the city due to vehicular (Kinney et al., 2011; NCC, 2017) and industrial (NCC 2017) emissions further eroding the resilience of the vulnerable groups through exposure to chronic air pollution-induced diseases.

2.3.6 Lomé, Togo

Lomé is the capital city of Togo and the country's only major city with a population approaching one million. Coastal erosion is the city's main hazard threats (Koudahe, Kayode, Samson, Adebola, & Djaman, 2017). 40 km of the entire coastline of Lomé is being eroded at an average yearly rate of 6-10 meters with possibilities of reaching 15meters during increased severe conditions. The city of Lomé together with the maritime regions of the country harbours about 40% of the country's' population and about 90% of the domestic industries. The city's overcrowded and unplanned settlements are also vulnerable to flooding and droughts, which hinder agriculture and other economic activities. Exposure to climatic impacts is exacerbated by its weak and inadequate infrastructure (Gadédjisso-Tossou, 2015).

2.3.7 Kuala Lumpur, Malaysia

Kuala Lumpur, Malaysia's largest and federal capital city, is regarded as one of South-East Asia's most prominent, developed and sophisticated cities (Bunnell, Barter, & Morshidi, 2002). The city has witnessed rapid urbanization in the last two decades, fueled by continued economic development and substantial physical as well as social transformations (Shokoohi & Nikitas,

2017). At 2%, the growth rate of its urban population is one of the fastest in the East Asian region. Its high population density and the large concentration of industries are mostly responsible for the equally high energy consumption rate and CO_2 emissions from housing and transport. These are combined with the depletion of green areas, which make conditions favourable for the urban heat islands effect. Indeed, high energy consumption, encroachment on green spaces, environmental degradation, and the development of non-climate resilient infrastructures- among others- compound the impact of climate change in addition to weakening climate change resilience capacity. As a given city continues to develop, its population grows and becomes more affluent, and its urbanization rate increases, CO_2 emissions are projected to keep increasing thereby further exposing the city to more climate risks (Halawa et al., 2018).

2.3.8 Dhaka, Bangladesh

Dhaka, the capital city of Bangladesh, is located at the lower edge of the Ganges-Brahmaputra delta system, which is the most vulnerable mega delta (Parry et al., 2007). Whole Dhaka city which is only 270 km from the Bay of Bengal and located 1 to 14 meter above sea level is highly vulnerable to climate extreme events including floods, cyclones, and SLR. Dhaka is among the top five cities at extreme risk to climate change (Pachauri et al., 2014). Higher vulnerability of this city is attributed to i) high exposure to extreme events; ii) higher sensitivity of its economy (mainly agro-based), infrastructure (drainage congestion), and unplanned settlements to extreme events; and iii) low adaptive capacity of city dwellers due to limited access to technology, health services, quality education and training. The further rise in temperature, rainfall, sea-level (32 cm) and intensity of storms (up to 45%) are projected to occur by the middle of this century which might make Dhaka more vulnerable.

2.3.9 Shanghai, China

Shanghai is one of the most populous cities in the world with a population of more than 24 million as of 2014 (SBS, 2015) Shanghai is prone to urban pluvial flood, heat waves, storm surges and land subsidence. The combined effects of SLR, storm-surge, coastal erosion and saltwater intrusion have significantly impacted Shanghai’s sensitivity to climate change (WWF, 2009). The city's vulnerability to extreme events is worsened by its heavy dependence on artificial coastal defenses with systemic failures leading to widespread problems (WWF, 2009).

For the flood, its vulnerability includes natural vulnerability (topography with flat and low altitude) and social vulnerability (urbanization, population and economy growth) (Xian, Yin, Lin, & Oppenheimer, 2018). Its energy sector, comprising power and gas supply, is not resiliently capable of dealing with extreme weather events (He, 2015). The expansion of green spaces and use of green infrastructure (e.g., installation of green roofs) is also increasingly used in Shanghai as mitigation and adaption strategy (Gill, Handley, Ennos, & Pauleit, 2007).
Figure 3 shows the spatial distribution of the sampled cities.

Figure 3. World map showing the sampled cities.

2.4 Data on selected cities

The summary of the data on selected cities is presented in Table 2. Detailed analysis of the data is presented in the results and discussion session.

Table 2. Characteristics and climate change pressures as seen in the selected cities

3. Results and Discussion:

Apart from a very substantial review of the literature, the paper documents for the first time the experiences and problems of a set of cities in a sample of developing countries across three continents, in an integrated way. The approach used in the in-depth analysis is outlined in Figure 4.

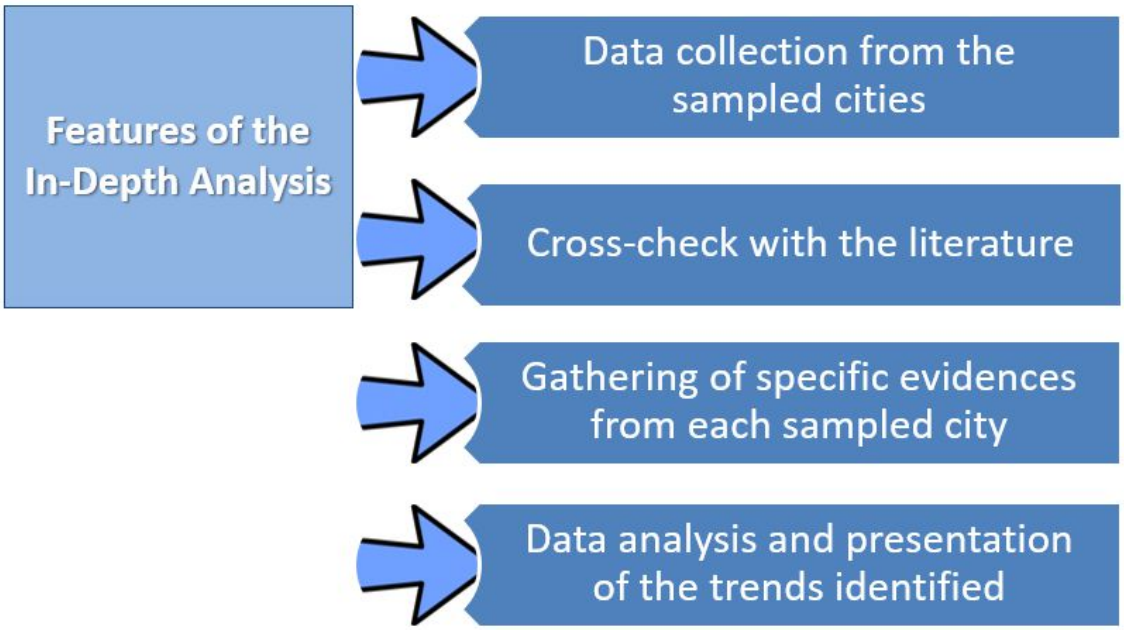


Figure 4- Approach used in in-depth analysis

Data gathered as part of the study and presented in Table 3 showcase the policies currently being implemented by the different cities, the challenges faced in implementing them, and the adaptive capacity of the cities. These give an overview of the complexity of the climate challenges they face. The international community has recently adopted three landmark agreements for a more sustainable future of cities: "The Urban Dimension in Climate Change Action", taken into account in Tables 2 and 3, which are: I) the 2030 Agenda for Sustainable Development Goals (SDGs), II) the Paris Agreement on Climate Change, and III) the New Urban Agenda.

The New Urban Agenda takes into account: i) risk-informed urban development, ii) sustainable use of land and resources, iii) reduction of environmental impacts and carbon emissions, iv) disaster risk reduction, v) climate change adaptation and mitigation. The SDGs are highly congruent with this approach, e.g. the SDG Target 11.b calls for: "[By 2020], substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards mitigation and adaptation to climate change".

The city analysis presented in this section provides some insights on the climatic problems being experienced in some cities in the African, Asian, and Latin-America continents. A valuable assessment of adaptation initiatives in cities in developing countries is provided, using publicly available data as our primary data source. The work expands on previous studies which have mainly focused on progress made in developed cities and nations, and documented adaptation initiatives at a national level (Austin et al., 2015; Lesnikowski et al., 2016).

Table 3. Cities' Adaptation and Resilience Indicators

3.1 Evaluation of Cities' Resilience and Adaptation Capacity

Three indicators are used to measure the cities' resilience and adaptive capacity: a) unemployment rate, b) the efficiency of public infrastructure and c) availability of community facilities. This is related to the Rockefeller foundation's resilience indicators (100 resilient cities, 2018). Kuala Lumpur has the lowest documented unemployment rate among the sampled cities (3.3%), followed by Shanghai (4.1%), Dhaka (4.81%), Montevideo (8%), Lomé (8%), Ibadan (9%), Georgetown (11.4%), Lima (14%), and Nairobi (14.7%). The unemployment data of Guyana was used as a proxy for Georgetown while the unemployment data of Oyo state, Nigeria was used as a proxy for Ibadan. An assessment of the available data reveals that the Asian cities have the lowest unemployment rates.

Despite having the third lowest unemployment rate, Dhaka (Bangladesh) ranks poorly on the ND-GAIN readiness index. Lomé (Togo) and Ibadan (Nigeria) also perform poorly on the readiness index despite their relatively low unemployment figures. In contrast, Lima (Peru), which has the second highest unemployment rate, has a better national level resilience and adaptive capacity than most of the other countries with lower city-level unemployment rates. On the other hand, the low unemployment rates of Kuala Lumpur (Malaysia), Shanghai (China) and Montevideo (Uruguay) match their positive ND-GAIN readiness ratings.

The disparity in the unemployment rates of some cities and their corresponding country readiness presents some interesting findings. While mostly reliable, national level data might not be accurate proxies for measurement of city-level adaptive capacity. A country might be well-

prepared nationally, but this does not necessarily translate to city-level preparedness or readiness (Ford et al., 2015). Furthermore, reducing a city's unemployment rate will be more impactful in enhancing its adaptive capacity if it is done in tandem with other chronic stress relievers such as the provision of proper infrastructure and adequate community facilities. Availability of good infrastructure is a vital component that can aid adaptation projects (Adenle et al., 2017). Despite its low unemployment rate, a large percent of Dhaka's residents is poor slum dwellers (Table 3). With a low per capita income, inequality and urban space constraints, many residents are unable to afford decent houses. The above trend implies that a low unemployment rate is not necessarily synonymous with the eradication of urban poverty.

The city's major infrastructure is also ageing and failing thus limiting its resilience and adaptive capacity. Lomé and Ibadan's relatively low unemployment rates are also not matched by poverty reduction and infrastructural development. Similar to Dhaka, a large proportion of Lomé's residents live in flood-prone slums. The city's slum upgrading initiative and road infrastructural development is still underway and will require some time to complete and boost the city's adaptive capacity. Ibadan also has a significant proportion of slum dwellers. A vital infrastructure capable of strengthening the city's resilience to climatic shocks such as efficient public transportation facilities and drainages is just beginning to receive some attention from the government. Nairobi's high poverty level, high level of insecurity, inadequate water supply and inefficient waste management system, as well as limited health facilities make its residents highly vulnerable to the impacts of climate change, faring better than only Ibadan amongst the nine studied cities.

All cities in countries within the upper income and upper-middle-income category have a relatively robust infrastructure to facilitate adaptation. These cities also have low unemployment and urban poverty rates. In contrast, cities in low-income countries have inadequate infrastructural facilities and a high rate of urban poverty even though the unemployment rate might be relatively low, making adaptation more difficult. This agrees with earlier studies that developing countries generally have the least resources to cope and adapt, and development, in general, tends to increase resilience (Weiler et al., 2018). Lima and Georgetown are exceptions to this trend. Peru is an upper middle-income country but its capital city-Lima- is not well

placed in this study's city-level adaptation rating. It has the second highest unemployment rate among the studied cities and a high poverty rate. The major infrastructure needed to support the city's daily activities, reduce chronic stress and enhance coping capacity thereby boosting its adaptation readiness are absent. Guyana, on the other hand, is a lower middle-income country but its capital city-Georgetown-is prioritized in the national government's intervention and thus receives substantial funds to enhance its adaptation. Access to health care, repair of the road network and efficient energy consumption are also boosting the city's resilience.

3.2 Impact of Population and Good Governance on Adaptation

From this study, there is no significant negative relationship between population size and the ability to adapt well to climatic stress. Although a large population stresses necessary infrastructure and could cause unemployment and an increase in urban poverty (Adenle et al., 2017), it is not a barrier per se to a city's adaptation capacity. Shanghai despite being the most populous of the studied cities (24 million) has a relatively good adaptation status because of its adequate infrastructure, low poverty rate, and health facilities for residents, including aged and disabled. Lomé has a low population but weak adaptation status due to weak infrastructure and high poverty rate. If a city has a reliable infrastructure, the large population should not be a significant hindrance to resilience and adaptation. In their research on the pattern of distribution of aid for climate change adaptation, Weiler et al. (2018), observed that populous countries received the bulk of adaptation aid. Populous cities like Dhaka thus stand a good chance of accessing foreign aids to put in place the necessary infrastructure for better adaptation. Good governance is another critical consideration in foreign aid allocation. Better governed countries are substantially more likely to receive adaptation aid and utilize them judiciously (Weiler et al., 2018). Ironically, several cities in developing countries periodically confront governance challenges ranging from political, institutional and organizational to coordination and leadership problems. The World Bank's Worldwide Governance Indicators (WGI) data (2016/2017) in Table 4 shows selected governance indicators for the studied cities.

Table 4. Worldwide Governance Indicators (WGI) of Developing Countries

3.3 Adaptation Policies and Challenges and the Role of Transformation

As earlier outlined (1.3) transformative approaches to climate change adaptation are important so as to yield long-term benefits. Transformative approaches also bear in mind the need to consider the connections between the global and the national levels, and between the national and local levels.

Table 3 –for instance- shows that most of the surveyed developing cities adopt climate policies which are being implemented at the national level, and only a few of them have mechanisms at the local level (e.g. city-wide climate programmes). Montevideo, Kuala Lumpur, Lomé and Shanghai have dedicated city level adaptation policies. This is in line with earlier findings that most adaptation initiatives globally are targeted at national level issues with the limited city and local engagement (Araos et al., 2016; Ford et al., 2015). Three of the four cities with city-level adaptation policies are located in upper income/upper-middle-income countries (Table 1). This suggests some relationship between a city's economic status and capacity to develop and sustain city-level adaptation policies. Sound city-level policies have the potential to effectively respond to climate risks peculiar to individual developing cities to national policies that are targeted at national level issues. Most of the adaptation policies address climatic challenges such as flooding and other disasters by proposing to develop pertinent infrastructure and early warning systems. The development of a climate-friendly city master plan is also a standard feature, and many of the policies identify the danger of poor community awareness and the need for public enlightenment to strengthen adaptation.

Some of the cities show some signs of the use of transformative approaches, i.e. they go beyond the sole goal of trying to pursue climate change adaptation. For instance, cities with a large concentration of industries such as Kuala Lumpur and Shanghai encourage reductions in greenhouse gas emissions, by proposing city-wide green development through climate resilient infrastructural plans and city greening projects.

This sort of action is much needed. For instance, Kuala Lumpur's average temperature witnessed a sharp increase from 38.8 °C to 47.8 °C during 1997 and 2013 (Yusuf, Pradhan, & Idrees, 2014), which is indicative of its rapid urbanization, causing high energy consumption and CO_2 emissions that contribute to global warming. The less advanced cities have relatively fewer industries, less energy consumption rates and CO_2 emission. This explains why their policies are not generally focused on reductions carbon of emissions, as done by their more advanced counterparts.

Although these policies look promising on paper, in reality, actual implementation has been a challenge to almost all cities, which is similar to challenges identified in literature (Leal Filho et al., 2018b; Wilson, 2014). This state of affairs illustrates why transformative approaches to climate change adaptation are needed. They may assist in adaptation efforts in various ways. For instance:

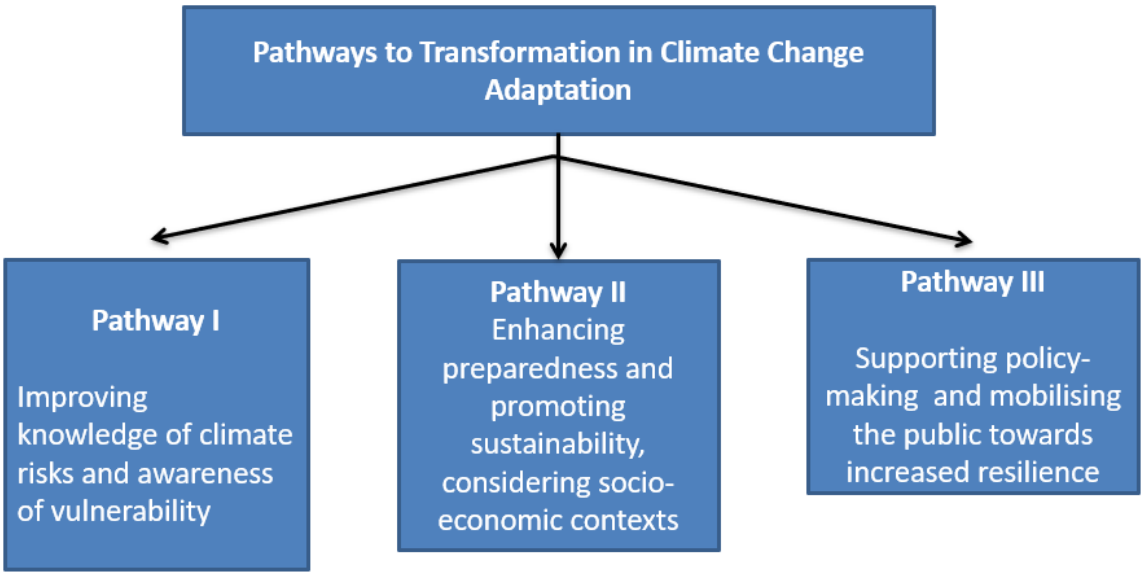
a) they may help to improve the coordination in the implementation of climate change adaptation;
b) they catalyze an integrated urban design framework
c) integrative approaches, which are synergetic by nature, may help to alleviate the pressures posed by limited financial resources
d) they can enable inclusive implementation, meaning that the relevant stakeholders have a voice;
e) they raise both the interest and the awareness on the part of residents.

Moreover, transformative approaches to climate change adaptation may support governance and strengthening of institutions, which play a crucial role in the success of adaptation policies across the board, irrespective of geographic location of the cities (Table 3). Most countries where the studied cities are domiciled rank poorly in the WGI percentile ranking (Table 4). Uruguay (76) and Malaysia (69) are the only countries with satisfactory mean ranks. China has an average ranking of 50, while the rest of the countries are below- average. Poor governance severely affects the way internally generated funds are utilized for necessary adaptation actions such as infrastructural development and poverty alleviation. Poorly governed countries are also less likely to receive foreign aids and technical support from developed countries and global bodies due to concerns about the ability to properly utilize donated resources. Beyond formulating policies, a holistic approach is needed to address the adaptation challenges of developing cities. Apart from the specific challenges identified in Table 3, it is imperative to take concrete steps to improve the cities' standing concerning the indicators in Table 4. Failure to address these broader issues will continue to compromise adaptation initiatives in developing cities, and hinder transformation.

3.4 Lessons Learned

The data gathered from the study allow the drawing of some lessons in respect of As summarized in Figure 5, there are various pathways leading to transformative adaptation.

Figure 5- Some pathways to transformative adaptation



Individual initiatives may follow one or more of these pathways. In addition, some specific lessons from the study and from the first-hand experiences from the studied cities, which may act as measures in order to address some of the current problems, realizing the potential of transformation in climate change adaptation, are as follows:

1. The need for prioritizing: many cities have set bold goals to cope with climate change, but little funding or economic incentives to implement them are provided. This, in turn, may perpetuate the problems they face. It makes more sense to agree and commit to less ambitious measures, which can be performed according to the resources available to

675 public administration. This may, in turn, make their implementation more probable and
676 will add a degree of sustainability to them.
677
678 2. The importance of proper planning: the data gathered in the study suggests that a higher
679 priority should be given to climate change planning. The examples shown in the sampled
680 cities suggest that some of the current problems occur as a result of a lack of emphasis on
681 climate considerations as part of city development plans. Poor planning may, among
682 other things, lead to maladaptation. In the spirit of transformation, it is essential that
683 planning be careful established, focus on the reduction of vulnerability and improvements
684 in the resilience capacity of cities, and hence contribute to securing a sound basis upon
685 which cities may be less prone to suffer from extreme events and other related climate
686 phenomena.
687
688 3. The need for an integrated and transformative approach embedded into climate change
689 adaptation plans: as the case studies have shown, climate change poses a variety of
690 pressures and problems to cities, both in respect of structural issues (e.g. vulnerability of
691 buildings and infrastructure), health matters (e.g. urban heat island and thermic
692 discomfort) and impacts to property (e.g. from floods). The complexity of these issues
693 means that transformative adaptation efforts need to be pursued, among other things
694 taking fully into account the constraints seen in respect of staff, time and resources, and
695 preferably integrated with general public services (e.g. city gardens, municipal utilities,
696 or water management), so as to allow effective results to be achieved.
697
698 4. Emphasis on the poorer and vulnerable communities: the impacts of climate change to
699 cities tend to affect more prominently the most impoverished communities in cities. Since
700 their ability to cope with climate-related problems is somewhat limited for a variety of
701 reasons, it is vital that great attention is given to their needs. Also here, transformative
702 approaches may be deployed, since due consideration to socio-economic issues and
703 sustainability as part of planning and execution, can decrease the risks of social
704 exclusion, maximizes the use of the available financial resources, and ensures that
705 affected communities can have a voice in the decision-making.

706

707 **4. Conclusions**

708

709 This paper contributes to the literature in two main ways. Firstly, it assesses and reflects on the
710 problems cities in developing countries face in trying to cope with climate change, and how these
711 efforts are hindered by poor infrastructure, services and governance. Secondly, the paper
712 documents for the first time trends in cities across Latin America, Africa and Asia, which are
713 seldom investigated in such an integrated manner, and where a dearth of literature is available.
714 This also adds a small degree of novelty to it.
715 This paper has outlined some of the challenges climate change poses to cities and describes some
716 of the adaptation strategies being used today. The need for these strategies can be better
717 understood if one considers the fact that, without them, there can be little hope that the current
718 challenges will be addressed in the long term. Several hundred million people living in cities are
719 already suffering from the problems associated with climate change, from increases in
720 precipitation and frequency of inland floods to periods of more extreme heat and cold. In
721 particular, over 80% of all urban areas are coastal, which implies an increased risk of floods and
722 threats to property due to rising sea levels.
723 Both the study data and the own experience of the authors as inhabitants of the sampled cities
724 show that most of the cities in this study suffer from a lack of proper (rational) planning. This
725 coupled with a chronic underfunding of climate change adaptation measures. In some occasions,
726 policy, planning, and governance responses to climate change are characterized by a short-term
727 view, as opposed to a long-term perspective: for instance, there is a reluctance to provide funding
728 for capital projects to increase the resilience of cities to storms or flooding. However, this seems
729 to oversee the fact that substantial expenditures need to be made in order to handle the impacts of
730 storms and flooding, which disrupts both business operations and city budgets. In this context, by
731 efforts towards transformative approaches to climate change adaptation can play an important
732 role.

733

734 A further conclusion which derives from the research is that, since similar climate-related
735 problems and socio-economic constraints are seen across other geographical regions in the
736 developing world, integrated approaches to tackle them are necessary. However, since the scope

of the geopolitical conditions and governance systems are different across the regions, there is a need to seek specific solutions for each one of them. Indeed, in order to yield the expected benefits, the search for regional and local solutions needs to take into account local particularities such as topography, social behaviour and political settings. On the other hand, the diversity of situation and contexts means that much could be gained by more cooperation between cities trying to tackle the challenges posed by climate change so that they can learn from one another.

Finally, it seems essential that successful handling options are disseminated, not in order to have them copied, but as means of inspiration and motivation to cities, encouraging them to pursue their solutions to the problems they face.

References

100RC (2017) 100 Resilient Cities, Montevideo. http://www.100resilientcities.org/cities/montevideo. Accessed September 2018

Adelekan, I. O. (2010). Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria. *Environment and Urbanization, 22*(2), 433-450.

Adenle, A. A., Ford, J. D., Morton, J., Twomlow, S., Alverson, K., Cattaneo, A., . . . Helfgott, A. (2017). Managing climate change risks in Africa-A global perspective. *Ecological economics, 141*, 190-201.

Ahmed, S., Nahiduzzaman, K.M., Hasan, M.M.U. (2018). Dhaka, Bangladesh: unpacking challenges and reflecting on unjust transitions. *Cities*, 77, 142-157

Ajayi, O., Agbola, S., Olokesusi, B., Wahab, B., Gbadegesin, M., Taiwo, D., . . . Olutade, O. (2012). Flood management in an urban setting: A case study of Ibadan metropolis. *Special Publication of the Nigerian Association of Hydrological Sciences*, 65-81.

Araos, M., Berrang-Ford, L., Ford, J. D., Austin, S. E., Biesbroek, R., & Lesnikowski, A. (2016). Climate change adaptation planning in large cities: A systematic global assessment. *Environmental Science & Policy, 66*, 375-382.

Argüeso, D., Evans, J. P., Pitman, A. J., & Di Luca, A. (2015). Effects of city expansion on heat stress under climate change conditions. *PLoS one, 10*(2), e0117066.

Arku, F. S., Angmor, E. N., & Adjei, G. T. (2017). Perception and responses of traders to climate change in downtown, Accra, Ghana. *International Journal of Climate Change Strategies and Management, 9*(1), 56-67.

773 Arnfield, A. J. (2003). Two decades of urban climate research: a review of turbulence, exchanges of
774 energy and water, and the urban heat island. *International journal of climatology, 23*(1), 1-26.
775 Austin, S. E., Ford, J. D., Berrang-Ford, L., Araos, M., Parker, S., & Fleury, M. D. (2015). Public health
776 adaptation to climate change in Canadian jurisdictions. *International journal of environmental*
777 *research and public health, 12*(1), 623-651.
778 Betzold, C. (2015). Adapting to climate change in small island developing states. *Climatic Change, 133*(3),
779 481-489.
780 Biagini, B., Bierbaum, R., Stults, M., Dobardzic, S., & McNeeley, S. M. (2014). A typology of adaptation
781 actions: A global look at climate adaptation actions financed through the Global Environment
782 Facility. *Global Environmental Change, 25*, 97-108.
783 Broto, V. C., & Bulkeley, H. (2013). A survey of urban climate change experiments in 100 cities. *Global*
784 *Environmental Change, 23*(1), 92-102.
785 Brugère, C., & De Young, C. (2015). Assessing climate change vulnerability in fisheries and aquaculture:
786 available methodologies and their relevance for the sector. *FAO Fisheries and Aquaculture*
787 *Technical Paper (FAO) eng no. 597*.
788 Bunnell, T., Barter, P. A., & Morshidi, S. (2002). Kuala Lumpur metropolitan area: A globalizing city–
789 region. *Cities, 19*(5), 357-370.
790 Busby, J., Smith, T.G., Krishnan, N., Wight, C., Vallejo-Gutierrez. (2018). In harm's way: Climate security
791 vulnerability in Asia. *World Devevlopment, 112, 88-118.*
792 Bynoe, P. (2007). Urban Dynamics and Environmental Sustainability (MDG # 7):A Case Study of Seven
793 Squatting Areas in Georgetown, Guyana. In Aragon (Ed.), *Population and the Environment in*
794 *Pan-Amazonia*.
795 Cabral, P., Augusto, G., Akande, A., Costa, A., Amade, N., Niquisse, S., . . . Mlucasse, R. (2017). Assessing
796 Mozambique's exposure to coastal climate hazards and erosion. *International journal of disaster*
797 *risk reduction, 23*, 45-52.
798 Calil, J., Reguero, B. G., Zamora, A. R., Losada, I. J., & Méndez, F. J. (2017). Comparative Coastal Risk
799 Index (CCRI): A multidisciplinary risk index for Latin America and the Caribbean. *PLoS one,*
800 *12*(11), e0187011.
801 Cervigni, R., et al. (2013). Toward climate-resilient development in Nigeria, *The World Bank*.

802 Daniel, J. (1984). *Geomorphology of Guyana: an integrated study of natural environments*: University of
803 Guyana, Department of Geography.

804 DBKL .(2019). Kuala Lumpur Structure Plan 2020.
805 Doherty, M., Klima, K., & Hellmann, J. J. (2016). Climate change in the urban environment: Advancing,
806 measuring and achieving resiliency. *Environmental Science & Policy, 66*, 310-313.
807 DOSM .(2018). Federal Territory of Kuala Lumpur @ a Glance.
808 Duran-Encalada, J. A., Paucar-Caceres, A., Bandala, E., & Wright, G. (2017). The impact of global climate
809 change on water quantity and quality: A system dynamics approach to the US–Mexican
810 transborder region. *European Journal of Operational Research, 256*(2), 567-581.
811 Elsharouny, M. R. M. M. (2016). Planning coastal areas and waterfronts for adaptation to climate change
812 in developing countries. *Procedia Environmental Sciences, 34*, 348-359.
813 FGN (2013) Nigeria Post Disaster Needs Assessment of 2012. Nigeria.

814 Ford, J. D., Berrang-Ford, L., Bunce, A., McKay, C., Irwin, M., & Pearce, T. (2015). The status of climate
815 change adaptation in Africa and Asia. *Regional Environmental Change, 15*(5), 801-814.
816 Franz-Vasdeki, J. (2011). Built environment: cities to suffer. *Nature Climate Change*.
817 Fuchs, R., Conran, M., & Louis, E. (2011). Climate change and Asia's coastal urban cities: Can they meet
818 the challenge? *Environment and Urbanization Asia, 2*(1), 13-28.

Gadédjisso-Tossou, A. (2015). Understanding farmers' perceptions of and adaptations to climate change and variability: The case of the Maritime, Plateau and Savannah Regions of Togo. *Agricultural Sciences, 6*(12), 1441.
Gill, S. E., Handley, J. F., Ennos, A. R., & Pauleit, S. (2007). Adapting cities for climate change: the role of the green infrastructure. *Built environment, 33*(1), 115-133.
Global Data Lab (2019) Retreived from https://globaldatalab.org/
Gómez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological economics, 86*, 235-245.
Government of Shanghai (2016) Shanghai Statistical Yearbook 2016.
Government of Guyana (2011) Guyana Poverty Reduction Strategy Paper. 2011-2015.
Government of Guyana (2015) Guyana's Revised Intended Nationally Determined Contribution
Government of Kenya (2010) National Climate Change Response Strategy. Nairobi, Kenya
Government of Kenya (2012) National Climate Change Action Plan 2013 - 2017. Nairobi Kenya
Halawa, E., Ghaffarianhoseini, A., Ghaffarianhoseini, A., Trombley, J., Hassan, N., Baig, M., . . . Ismail, M. A. (2018). A review on energy conscious designs of building façades in hot and humid climates: Lessons for (and from) Kuala Lumpur and Darwin. *Renewable and Sustainable Energy Reviews, 82*, 2147-2161.
He,J.Y., Qi, K (2015). Shanghai Energy Sectors Adapting to Climate Change Current Situation and Countermeasures Research (pp. 633-637): Shanghai Energy Conservation.
Heidrich, O., Dawson, R. J., Reckien, D., & Walsh, C. L. (2013). Assessment of the climate preparedness of 30 urban areas in the UK. *Climatic Change, 120*(4), 771-784.
Hickey, C., Weis, T. (2012) The challenge of climate change adaptation in Guyana. *Climate and Development, 4(1), 1-12.* DOI: 10.1080/17565529.2012.661036
Hoornweg, D., Sugar, L., & Trejos Gomez, C. L. (2011). Cities and greenhouse gas emissions: moving forward. *Environment and Urbanization, 23*(1), 207-227.
IEA. (2008). *World Energy Outlook* Paris.
INE (2016) Línea de Pobreza. Montevideo, Uruguay.
INE (2018) Actividad, empleo y desempleo. Montevideo, Uruguay.
Informática I-INdEe (2016) Producción y Empleo Informal en el Perú, Cuenta Satélite de la Economía Informal 2007-2016. Lima, Peru
Informática I-INdEe (2017) Compendio Estadístico Provincia de Lima Lima, Peru
International Monetary Fund I (2014) Togo: Poverty Reduction Strategy Paper vol 14(224). IMF Country Report,
Kaspersen, P. S., & Halsnæs, K. (2017). Integrated climate change risk assessment: A practical application for urban flooding during extreme precipitation. *Climate Services, 6*, 55-64.
Kelman, I. (2015). Difficult decisions: migration from small island developing states under climate change. *Earth's Future, 3*(4), 133-142.
Kem, L., Fuchs, R. and Bettinger, K. . (2015). *Urban climate change adaptation and resilience—A training manual*: Honolulu: AECOM, East-West Center, and Institute for Global Environmental Strategies (IGES).
Khan, M. (2002) National Climate Change Adaptation Policy and Implementation Plan for Guyana. Georgetown
Kinney, P. L., Gichuru, M. G., Volavka-Close, N., Ngo, N., Ndiba, P. K., Law, A., . . . Sclar, E. (2011). Traffic impacts on PM2. 5 air quality in Nairobi, Kenya. *Environmental Science & Policy, 14*(4), 369-378.
Koudahe, K., Kayode, A. J., Samson, A. O., Adebola, A. A., & Djaman, K. (2017). Trend analysis in standardized precipitation index and standardized anomaly index in the context of climate change in Southern Togo. *Atmospheric and Climate Sciences, 7*(04), 401.

Landauer, M., Juhola, S., & Söderholm, M. (2015). Inter-relationships between adaptation and mitigation: a systematic literature review. *Climatic Change, 131*(4), 505-517.

Leal Filho, W. (2015). *Handbook of Climate Change Adaptation*: Springer, Berlin.

Leal Filho, W., Balogun, A.-L., Ayal, D. Y., Bethurem, E. M., Murambadoro, M., Mambo, J., . . . Fudjumdjum, H. (2018b). Strengthening climate change adaptation capacity in Africa-case studies from six major African cities and policy implications. *Environmental Science & Policy, 86*, 29-37.

Leal Filho, W., Modesto, F., Nagy, G. J., Saroar, M., YannickToamukum, N., & Ha'apio, M. (2018a). Fostering coastal resilience to climate change vulnerability in Bangladesh, Brazil, Cameroon and Uruguay: a cross-country comparison. *Mitigation and Adaptation Strategies for Global Change, 23*(4), 579-602.

Lesnikowski, A., Ford, J., Biesbroek, R., Berrang-Ford, L., & Heymann, S. J. (2016). National-level progress on adaptation. *Nature Climate Change, 6*(3), 261.

Li, D., & Bou-Zeid, E. (2013). Synergistic interactions between urban heat islands and heat waves: The impact in cities is larger than the sum of its parts. *Journal of Applied Meteorology and Climatology, 52*(9), 2051-2064.

Luederitz, C., Brink, E., Gralla, F., Hermelingmeier, V., Meyer, M., Niven, L., . . . Sasaki, R. (2015). A review of urban ecosystem services: six key challenges for future research. *Ecosystem Services, 14*, 98-112.

Lutz, W., & Muttarak, R. (2017). Forecasting societies' adaptive capacities through a demographic metabolism model. *Nature Climate Change, 7*(3), 177.

McDonald, R. I., Green, P., Balk, D., Fekete, B. M., Revenga, C., Todd, M., & Montgomery, M. (2011). Urban growth, climate change, and freshwater availability. *Proceedings of the National Academy of Sciences, 108*(15), 6312-6317.

McGranahan, G., Balk, D., & Anderson, B. (2007). The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. *Environment and Urbanization, 19*(1), 17-37.

McPhearson, T., Parnell, S., Simon, D., Gaffney, O., Elmqvist, T., Bai, X., . . . Revi, A. (2016). Scientists must have a say in the future of cities. *Nature News, 538*(7624), 165.

Metropolitana M-MdL (2018) Plan Anual de Evaluación y Fiscalización Ambiental - PLANEFA. Lima, Peru.

Mfune, O., Mutisya, E., Popoola, L., Mungai, D., Fuh, D., & Olayide, O. (2016). Changing Rural Urban Linkages in Africa in a Globalizing Economy. *African Journal of Sustainable Development, 6*(2), 109-134.

Nagy, G. J., Gómez-Erache, M., & Kay, R. (2015). A risk-based and participatory approach to assessing climate vulnerability and improving governance in coastal Uruguay. *Climate change and the coast. Building resilient communities*, 357-378.

NCC. (2017). *Nairobi County Intergrated Development Plan 2018-2022*. Retrieved from http://www.nairobi.go.ke/home/downloads/

ND-Gain. (2018). Urban Adaptation Assessment. Retrieved from https://gain.nd.edu/assets/256491/new_uaa_indicator_list.pdf

Nkhonjera, G. K. (2017). Understanding the impact of climate change on the dwindling water resources of South Africa, focusing mainly on Olifants River basin: A review. *Environmental Science & Policy, 71*, 19-29.

Pachauri, R. K., Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., . . . Dasgupta, P. (2014). *Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change*: IPCC.

Parry, M., Parry, M. L., Canziani, O., Palutikof, J., Van der Linden, P., & Hanson, C. (2007). *Climate change 2007-impacts, adaptation and vulnerability: Working group II contribution to the fourth assessment report of the IPCC* (Vol. 4): Cambridge University Press.

Reckien, D., Creutzig, F., Fernandez, B., Lwasa, S., Tovar-Restrepo, M., Mcevoy, D., & Satterthwaite, D. (2017). Climate change, equity and the Sustainable Development Goals: an urban perspective. *Environment and Urbanization, 29*(1), 159-182.

Reckien, D., Flacke, J., Dawson, R. J., Heidrich, O., Olazabal, M., Foley, A., . . . Hurtado, S. D. G. (2014). Climate change response in Europe: what's the reality? Analysis of adaptation and mitigation plans from 200 urban areas in 11 countries. *Climatic Change, 122*(1-2), 331-340.

Reckien, D., Flacke, J., Olazabal, M., & Heidrich, O. (2015). The influence of drivers and barriers on urban adaptation and mitigation plans—an empirical analysis of European cities. *PLoS one, 10*(8), e0135597.

Revi, A., Satterthwaite, D. E., Aragón-Durand, F., Corfee-Morlot, J., Kiunsi, R. B., Pelling, M., . . . Solecki, W. (2014). Urban areas. *Climate change*, 535-612.

Rosenzweig, C., Solecki, W. D., Hammer, S. A., & Mehrotra, S. (2011). *Climate change and cities: First assessment report of the urban climate change research network*: Cambridge University Press.

Roubaud, F., Torelli, C. (2013). Employment, unemployment, and working conditions in the urban labor markets of sub-Saharan Africa: Main stylized facts Urban labor markets in sub-Saharan Africa World Bank: Washington:37-79

Saroar, M.M., Routray, J.K., Leal Filho, W. (2015). Livelihood vulnerability and displacement in coastal Bangladesh: Understanding the nexus. In: Climate change in the Asia-pacific region. Springer, pp 9-31

Satterthwaite, D. (2008). Cities' contribution to global warming: notes on the allocation of greenhouse gas emissions. *Environment and Urbanization, 20*(2), 539-549.

SBS. (2015). Shanghai Economic and Social Development Statistical Bulletin 2014 (in Chinese).

SEES. (2008). *An Integrated Assessment of Georgetown*. Guyana.

Shokoohi, R., & Nikitas, A. (2017). Urban growth, and transportation in Kuala Lumpur: Can cycling be incorporated into Kuala Lumpur's transportation system? *Case studies on transport policy, 5*(4), 615-626.

Singh, D. (2017). Guyana has the 7th Highest Unemployment Rate Among CARICOM Member States. Guyana Budget & Policy Institute.

Solecki, W., Seto, K. C., & Marcotullio, P. J. (2013). It's time for an urbanization science. *Environment: science and policy for sustainable development, 55*(1), 12-17.

Statistics, N. B. O. (2017). Labor Force Statistics Vol. 1: Unemployment and Underemployment Report (Q1-Q3 2017). N. National Bureau of Statistics.

Stern, N., Peters, S., Bakhshi, V., Bowen, A., Cameron, C., Catovsky, S., . . . Edmonson, N. (2006). *Stern Review: The economics of climate change* (Vol. 30): HM treasury London.

Suzuki-Parker, A., Kusaka, H., & Yamagata, Y. (2015). Assessment of the impact of metropolitan-scale urban planning scenarios on the moist thermal environment under global warming: a study of the Tokyo metropolitan area using regional climate modeling. *Advances in Meteorology, 2015*.

Swapan MSH, Zaman AU, Ahsan T, Ahmed F. (2017). Transforming Urban Dichotomies and Challenges of South Asian Megacities: Rethinking Sustainable Growth of Dhaka, Bangladesh Urban Science 1:31

Tachiwou, A.M., Hamadou, O. (2011). Infrastructure Development and Economic Growth in Togo International Journal of Economics and Finance 3:131

United Nations Development Programme UNDP (2018).Human Development Reports. Retrieved from http://hdr.undp.org/en/2018-update

UN-Habitat. (2008). Cities at risk from rising sea levels. *UN-Habitat, State of the World's Cities 2008/2009*, 224, 140-155: Earthscan, London

UN-HABITAT. (2016). *Urbanization and Development: Emerging Futures*. Retrieved from http://wcr.unhabitat.org/

Unidas CEpALyeCCdlN (2017) Panorama Social de América Latina. Documento informativo. Sgo de Chile

USDN, U. S. D. N. (2016). Developing Urban Climate Adaptation Indicators. Retrieved from file:///C:/Users/HP%20PC/Desktop/Papers%20for%20Publication%202018/CC%20&%20Cities.Revisions/New%20Reference%20Materials/Developing%20Urban%20Climate%20Adaptation-Indicators_USDN%20Report.pdf.

Verocai, J. E., Gómez-Erache, M., Nagy, G. J., & Bidegain, M. (2015). Addressing climate extremes in Coastal Management: The case of the Uruguayan coast of the Rio de la Plata System. *Revista de Gestão Costeira Integrada-Journal of Integrated Coastal Zone Management, 15*(1).

Villamizar, A., Gutiérrez, M. E., Nagy, G. J., Caffera, R. M., & Leal Filho, W. (2017). Climate adaptation in South America with emphasis in coastal areas: the state-of-the-art and case studies from Venezuela and Uruguay. *Climate and Development, 9*(4), 364-382.

Vincent, K. (2007). Uncertainty in adaptive capacity and the importance of scale. *Global Environmental Change, 17*(1), 12-24.

Vogel, M. (2008). History of Urban Planning of Nairobi: ETH Studio Basel Nairobi.

Weiler, F., Klöck, C., & Dornan, M. (2018). Vulnerability, good governance, or donor interests? The allocation of aid for climate change adaptation. *World Development, 104*, 65-77.

Wilson, R. H. (2014). *Climate Change and Cities in Africa: Current Dilemmas and Future Challenges*. Retrieved from

World Bank Group (2019). New country classifications by income level: 2018-2019. Retrieved from https://blogs.worldbank.org/opendata/new-country-classifications-income-level-2018-2019

WWF. (2009). *Mega-stress for mega-cities: a climate vulnerability ranking of major coastal cities in Asia*. Retrieved from

Xian, S., Yin, J., Lin, N., & Oppenheimer, M. (2018). Influence of risk factors and past events on flood resilience in coastal megacities: Comparative analysis of NYC and Shanghai. *Science of the Total Environment, 610*, 1251-1261.

Yan, F. (2018). Urban poverty, economic restructuring and poverty reduction policy in urban China: Evidence from Shanghai, 1978–2008 Development Policy Review

Yin, J., Yin, Z., Xu, S. (2013). Composite risk assessment of typhoon-induced disaster for China's coastal area. *Natural hazards*, 69,1423-1434

Yusuf, Y. A., Pradhan, B., & Idrees, M. O. (2014). Spatio-temporal assessment of urban heat island effects in Kuala Lumpur metropolitan city using landsat images. *Journal of the Indian Society of Remote Sensing, 42*(4), 829-837.

Zhao, Y., Sultan, B., Vautard, R., Braconnot, P., Wang, H. J., & Ducharne, A. (2016). Potential escalation of heat-related working costs with climate and socioeconomic changes in China. *Proceedings of the National Academy of Sciences, 113*(17), 4640-4645.

Zipjet (2018) The 2017 Global Least & Most Stressful Cities Ranking. https://www.zipjet.co.uk/2017-stressful-cities-ranking. Accessed 22 February 2018