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

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9 **Oguge O, Toamukum NY, et al.**

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12
13 **Abstract**

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

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

35

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

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40

41 **1. Introduction: Cities and Climate Change**

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

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

62 emissions, although the spatial coverage of cities is only 2% of the globe (Satterthwaite, 2008;
63 UN-HABITAT, 2016). The predominant source of urban GHG stems from energy consumption
64 through the burning of fossil fuels for transport, energy in-use in buildings and appliances (IEA,
65 2008). About 30% of GHG emissions through energy use is attributed to the buildings sector,
66 whereas GHG emissions induced by global energy use will rise to 76% by 2030. The effects of
67 such processes are far-reaching and ultimately contribute to global warming.

68

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

76

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

84

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

89

90 ***1.1. Limitations in harnessing the knowledge***

91

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

105

106 Great exposure and limited adaptive capacity to climate change make city life risky, especially to
107 the poor in developing countries. Despite the imminent threat to cities, there are relatively few
108 studies on the adaptive capacities of cities on a global scale. Most adaptation monitoring studies
109 have been undertaken at the national level rather than city level (Doherty, Klima, & Hellmann,
110 2016; Lesnikowski, Ford, Biesbroek, Berrang-Ford, & Heymann, 2016). Detailed studies on the
111 extent to which global cities are adapting to climate change are scant (Araos et al., 2016; Leal
112 Filho, 2015). Effective and efficient adaptation strategies are mostly unknown (Doherty et al.,
113 2016). This latter study addresses this gap by undertaking detailed an international research on
114 the extent of climatic impacts in different cities and various adaptive strategies being adopted. It
115 focuses on cities in developing countries since they are generally more vulnerable than cities in
116 developed countries, creating a catalogue of policies and socio-economic adaptation
117 interventions in diverse urban contexts. This study is pertinent and timely considering that most
118 cities that are vulnerable to the impacts of climate change are situated in the studied regions
119 (Elsharouny, 2016; Weiler, Klöck, & Dorman, 2018) Similarly, understanding perspectives of
120 cities in developing countries, and how they relate both to development and climate change
121 would enhance proper policy intervention. It would foster deliberate policy interventions aimed
122 at enhancing their potential for achieving sustainable development (Mfune et al., 2016)

123 *1.2. How climate change affects cities and the need for transformative approaches to*
124 *adaptation*

125 The previous sections outlined the essential connections between climate change and cities
126 namely the urban risks and vulnerabilities. This section goes further and focuses on a description
127 of its impacts and outlines the role of climate change adaptation. As stated by Reckien et al.
128 (2017), "Climate change is acknowledged as the largest threat to our societies in the coming
129 decades", and in that sense urbanization, sustainable development and climate change
130 interpenetrate (Reckien et al., 2017) and are interrelated dimensions of this global societal
131 challenge. United Nations estimates that 54 per cent of the world's population lives in urban
132 areas, a proportion that is expected to increase to 66 per cent by 2050. As a result of this urban
133 growth and global urbanisation trends, cities are facing several risks that affect populations and
134 interfere with their capacity for climate adaptation and mitigation (Landauer, Juhola, &
135 Söderholm, 2015; Li & Bou-Zeid, 2013).

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

147 Extreme climatic events pose a significant threat to cities. Kaspersen and Halsnæs (2017) and
148 Franz-Vasdeki (2011) detailed the impacts of exposure to extreme events on cities' built
149 environment/infrastructure. Water quantity and quality in cities are also being impacted
150 negatively (Duran-Encalada, Paucar-Caceres, Bandala, & Wright, 2017; Li & Bou-Zeid, 2013)
151 and require significant investments for tangible interventions (McDonald et al., 2011). Extreme
152 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 adaptation strategies concerning each other? Is the country-level
174 adaptation 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:

- 184 a) they help to enhance resilience,
- 185 b) they help to promote sustainability,
- 186 c) they help to reduce vulnerability
- 187 d) they take into account the risks in implementation,
- 188 e) they pay due attention to the socio-economic contexts of a given community.

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

194 Figure 1 outlines some of the elements associated with poverty.

195
196 **Figure 1.** Some of the elements associated with poverty in a developing country context.

197
198 Following these questions, this paper aims to assess the adaptation readiness level of different
199 cities in developing countries through cross-check of adaptation measures and strategies;
200 highlight unique and general challenges being faced, and recommend possible solutions that
201 could be shared across regions and continents.

202 203 **2. Methodology**

204
205 The literature related to trends in climate change in cities in industrialised countries is rather
206 prolific. The same is not right to developing nations, where there is proportionally little
207 literature. Based on the need to address this gap, this papers focuses on trends in developing
208 countries, adding to the body of knowledge available. It should be outlined that the purpose of
209 this paper is not to offer comparisons. Instead, we outline some of the main problems the
210 sampled cities face when trying to implement climate change adaptation. Also, the choice was
211 not only based on convenience. The others factors which led to the choice of the sample were: a

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

216 ***2.1 Analytical Framework***

217 The methodology adopted in this work is based on the review of recent literature on trends and
218 dimensions of climate change impacts in cities and adaptive capacity. The analytical framework,
219 i.e. the logical basis which provided a basis for the study and the interpretation of its findings,
220 follows the rationale that vulnerability, that is to say, the measure of a country's (or city's)
221 exposure, sensitivity and ability to adapt to the negative impact of climate change (ND-Gain,
222 2018), is particularly acute in urban centres in developing countries. Therefore, cities with a
223 significant level of vulnerability (or less adaptive capacity) would be prone to be impacted -and
224 their inhabitants may suffer- in the face of climate change. Conversely, a resilient city will seek
225 to reinforce its adaptive capacity, including governance systems (Figure 2). Low-income urban
226 populations are among the most impacted by climate change (IHC, 2011). The indexes used
227 herein such as the Notre Dame Global Adaptation Initiative (ND-Gain) and World Bank's
228 Worldwide Governance Indicators-WGI (World Bank 2017) integrate income indicators (e.g.
229 Gross Domestic Product-GDP) on the one hand, and efficiency, political stability, and regulation
230 indicators on the other. Therefore, a correlation between cities' income level, human
231 development, and governance quality, and adaptation capacity is to be expected. The three
232 characteristics shown in figure 2 (drivers, outcomes, adaptive capacity) interact; herein drivers
233 determine vulnerability elements, whereas adaptive capacity/resilience is understood as the
234 critical factor because it is independent of external forces. This integrated framework
235 underscores a theoretical, practical and contemporary approach to climate change impact
236 research, that combines the triple-bottom-line of sustainability (social, economic and
237 environmental) with the cross-cutting issues of governance (Brugère & De Young, 2015) with a
238 continuous feedback mechanism on mitigation, adaptation and resilience building systems.
239 Although the relevant literature reviewed in the paper provides various analytical frameworks,
240 our paper distils the current approach and interconnections succinctly in understanding the
241 impact of climate change on cities and outlines some appropriate responses.

242 ***2.2 Data Exploration***

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

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

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

260

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

270

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

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

283

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

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

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

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

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

294 Sensitivity: Extent to which an urban area will be affected by, or responsive to, a climate hazard.

295 Risk is a function of climate hazard and exposure and vulnerability of the social system.

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

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

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

302 Few nations have reliable information on climate change at regional to local levels (Adenle et al.,
303 2017). We identify the significant impacts of climate change on the studied developing cities and
304 evaluate their adaptive capacities and policy interventions. We analyze the extreme events being

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

311

312

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

314

315

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

324

325 ***2.3 Scope of the Study***

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

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

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

342

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

344

345 ***2.3.1 Georgetown, Guyana***

346 Georgetown, the capital and largest city of Guyana has a population of 25,849 people (in the
347 City itself) and 118,363 people (within the current boundaries of the City) , thereby accounting
348 for two-thirds (61.7 percent) of the country’s total urban population¹ . It is located on the low
349 Coastal Plain at approximately 1.5 meters below mean sea level (MSL) and geologically
350 characterized by impermeable clay soil that drains poorly and therefore becomes submerged
351 during heavy rainfall (Daniel, 1984). Heavy rainfall, sea-level rise (SLR) and storm surges are
352 projected to increase due to climate change. The city's infrastructure has not been adequately
353 maintained in recent times thereby affecting its resilience and adaptive capacity (Villamizar et
354 al., 2017; Hickey and Weis, 2012; Bynoe, 2007).

355

356 ***2.3.2 Montevideo, Uruguay***

357 Montevideo is Uruguay's capital, and its metropolitan area (RMU) extends over 70 km along Rio
358 de la Plata river estuary with over 1.6 million people. The RMU is i) moderately to highly
359 vulnerable to SLR and storm surges (Villamizar, Gutiérrez, Nagy, Caffera, & Leal Filho, 2017),
360 ii) the exposure to coastal flooding is high (Calil, Reguero, Zamora, Losada, & Méndez, 2017).
361 The Government Office of Climate Change (DCC) has developed the GEF Project:
362 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.

363 Kay, 2015) and is developing the National Adaptation Plan (NAP) for Cities and Infrastructures
364 (2017-19), while the subnational coastal governments are developing the Metropolitan Climate
365 Plan for Urban and Coastal Adaptation for the RMU (Verocai, Gómez-Erache, Nagy, &
366 Bidegain, 2015).

367

368 **2.3.3 Lima, Peru**

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

379

380 **2.3.4 Ibadan, Nigeria**

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

392

393

394 **2.3.5 Nairobi, Kenya**

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

408

409 **2.3.6 Lomé, Togo**

410 Lomé is the capital city of Togo and the country's only major city with a population approaching
411 one million. Coastal erosion is the city's main hazard threats (Koudahe, Kayode, Samson,
412 Adebola, & Djaman, 2017). 40 km of the entire coastline of Lomé is being eroded at an average
413 yearly rate of 6-10 meters with possibilities of reaching 15meters during increased severe
414 conditions. The city of Lomé together with the maritime regions of the country harbours about
415 40% of the country's' population and about 90% of the domestic industries. The city's
416 overcrowded and unplanned settlements are also vulnerable to flooding and droughts, which
417 hinder agriculture and other economic activities. Exposure to climatic impacts is exacerbated by
418 its weak and inadequate infrastructure (Gadédjisso-Tossou, 2015).

419

420 **2.3.7 Kuala Lumpur, Malaysia**

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

425 2017). At 2%, the growth rate of its urban population is one of the fastest in the East Asian
426 region. Its high population density and the large concentration of industries are mostly
427 responsible for the equally high energy consumption rate and CO₂ emissions from housing and
428 transport. These are combined with the depletion of green areas, which make conditions
429 favourable for the urban heat islands effect. Indeed, high energy consumption, encroachment on
430 green spaces, environmental degradation, and the development of non-climate resilient
431 infrastructures- among others- compound the impact of climate change in addition to weakening
432 climate change resilience capacity. As a given city continues to develop, its population grows
433 and becomes more affluent, and its urbanization rate increases, CO₂ emissions are projected to
434 keep increasing thereby further exposing the city to more climate risks (Halawa et al., 2018).

435

436 **2.3.8 Dhaka, Bangladesh**

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

448

449 **2.3.9 Shanghai, China**

450 Shanghai is one of the most populous cities in the world with a population of more than 24
451 million as of 2014 (SBS, 2015) Shanghai is prone to urban pluvial flood, heat waves, storm
452 surges and land subsidence. The combined effects of SLR, storm-surge, coastal erosion and
453 saltwater intrusion have significantly impacted Shanghai's sensitivity to climate change (WWF,
454 2009). The city's vulnerability to extreme events is worsened by its heavy dependence on
455 artificial coastal defenses with systemic failures leading to widespread problems (WWF, 2009).

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

463
464
465 **Figure 3.** World map showing the sampled cities.
466
467
468

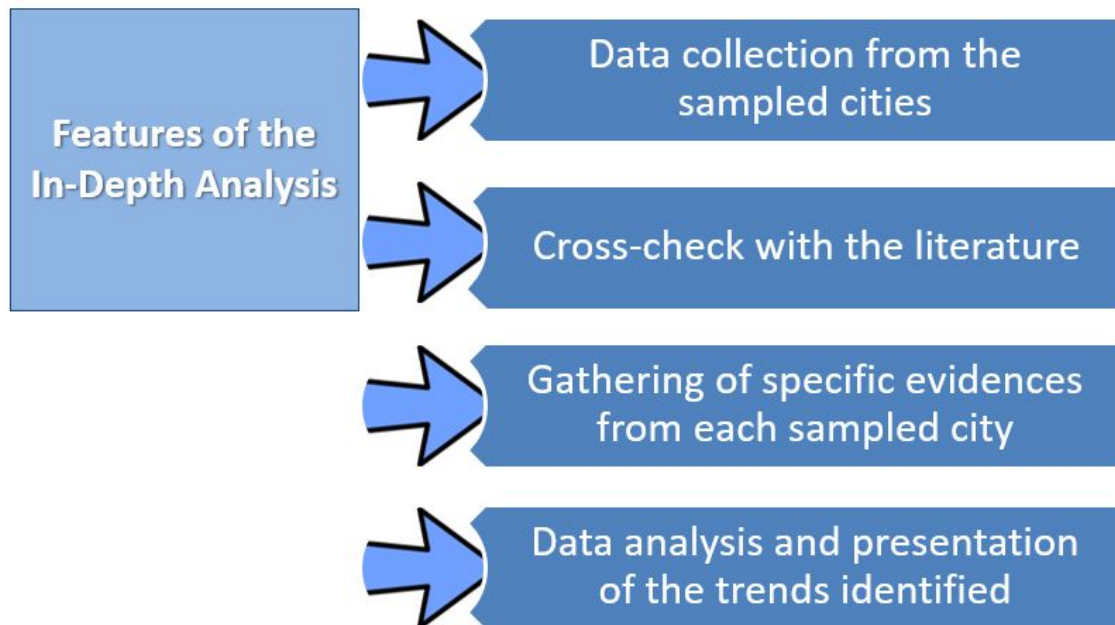
469 ***2.4 Data on selected cities***

470 The summary of the data on selected cities is presented in Table 2. Detailed analysis of the data
471 is presented in the results and discussion session.
472

473 **Table 2.** Characteristics and climate change pressures as seen in the selected cities
474

475 **3. Results and Discussion:**

476
477 Apart from a very substantial review of the literature, the paper documents for the first time the
478 experiences and problems of a set of cities in a sample of developing countries across three
479 continents, in an integrated way. The approach used in the in-depth analysis is outlined in Figure
480 4.
481
482



483

484

485 **Figure 4- Approach used in in-depth analysis**

486

487

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

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

501

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

508

509 **Table 3. Cities' Adaptation and Resilience Indicators**

510

511 ***3.1 Evaluation of Cities' Resilience and Adaptation Capacity***

512 Three indicators are used to measure the cities' resilience and adaptive capacity: a)
513 unemployment rate, b) the efficiency of public infrastructure and c) availability of community
514 facilities. This is related to the Rockefeller foundation's resilience indicators (100 resilient cities,
515 2018). Kuala Lumpur has the lowest documented unemployment rate among the sampled cities
516 (3.3%), followed by Shanghai (4.1%), Dhaka (4.81%), Montevideo (8%), Lomé (8%), Ibadan
517 (9%), Georgetown (11.4%), Lima (14%), and Nairobi (14.7%). The unemployment data of
518 Guyana was used as a proxy for Georgetown while the unemployment data of Oyo state, Nigeria
519 was used as a proxy for Ibadan. An assessment of the available data reveals that the Asian cities
520 have the lowest unemployment rates.

521

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

529

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

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

542
543 The city's major infrastructure is also ageing and failing thus limiting its resilience and adaptive
544 capacity. Lomé and Ibadan's relatively low unemployment rates are also not matched by poverty
545 reduction and infrastructural development. Similar to Dhaka, a large proportion of Lomé's
546 residents live in flood-prone slums. The city's slum upgrading initiative and road infrastructural
547 development is still underway and will require some time to complete and boost the city's
548 adaptive capacity. Ibadan also has a significant proportion of slum dwellers. A vital
549 infrastructure capable of strengthening the city's resilience to climatic shocks such as efficient
550 public transportation facilities and drainages is just beginning to receive some attention from the
551 government. Nairobi's high poverty level, high level of insecurity, inadequate water supply and
552 inefficient waste management system, as well as limited health facilities make its residents
553 highly vulnerable to the impacts of climate change, faring better than only Ibadan amongst the
554 nine studied cities.

555
556 All cities in countries within the upper income and upper-middle-income category have a
557 relatively robust infrastructure to facilitate adaptation. These cities also have low unemployment
558 and urban poverty rates. In contrast, cities in low-income countries have inadequate
559 infrastructural facilities and a high rate of urban poverty even though the unemployment rate
560 might be relatively low, making adaptation more difficult. This agrees with earlier studies that
561 developing countries generally have the least resources to cope and adapt, and development, in
562 general, tends to increase resilience (Weiler et al., 2018). Lima and Georgetown are exceptions
563 to this trend. Peru is an upper middle-income country but its capital city-Lima- is not well

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

571

572 ***3.2 Impact of Population and Good Governance on Adaptation***

573 From this study, there is no significant negative relationship between population size and the
574 ability to adapt well to climatic stress. Although a large population stresses necessary
575 infrastructure and could cause unemployment and an increase in urban poverty (Adenle et al.,
576 2017), it is not a barrier per se to a city's adaptation capacity. Shanghai despite being the most
577 populous of the studied cities (24 million) has a relatively good adaptation status because of its
578 adequate infrastructure, low poverty rate, and health facilities for residents, including aged and
579 disabled. Lomé has a low population but weak adaptation status due to weak infrastructure and
580 high poverty rate. If a city has a reliable infrastructure, the large population should not be a
581 significant hindrance to resilience and adaptation. In their research on the pattern of distribution
582 of aid for climate change adaptation, Weiler et al. (2018), observed that populous countries
583 received the bulk of adaptation aid. Populous cities like Dhaka thus stand a good chance of
584 accessing foreign aids to put in place the necessary infrastructure for better adaptation. Good
585 governance is another critical consideration in foreign aid allocation. Better governed countries
586 are substantially more likely to receive adaptation aid and utilize them judiciously (Weiler et al.,
587 2018). Ironically, several cities in developing countries periodically confront governance
588 challenges ranging from political, institutional and organizational to coordination and leadership
589 problems. The World Bank's Worldwide Governance Indicators (WGI) data (2016/2017) in
590 Table 4 shows selected governance indicators for the studied cities.

591

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

593

594 ***3.3 Adaptation Policies and Challenges and the Role of Transformation***

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

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

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

619 This sort of action is much needed. For instance, Kuala Lumpur's average temperature witnessed
620 a sharp increase from 38.8 °C to 47.8 °C during 1997 and 2013 (Yusuf, Pradhan, & Idrees,
621 2014), which is indicative of its rapid urbanization, causing high energy consumption and CO₂
622 emissions that contribute to global warming. The less advanced cities have relatively fewer
623 industries, less energy consumption rates and CO₂ emission. This explains why their policies are
624 not generally focused on reductions carbon of emissions, as done by their more advanced
625 counterparts.

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

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

639

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

655

656

657 **3.4 Lessons Learned**

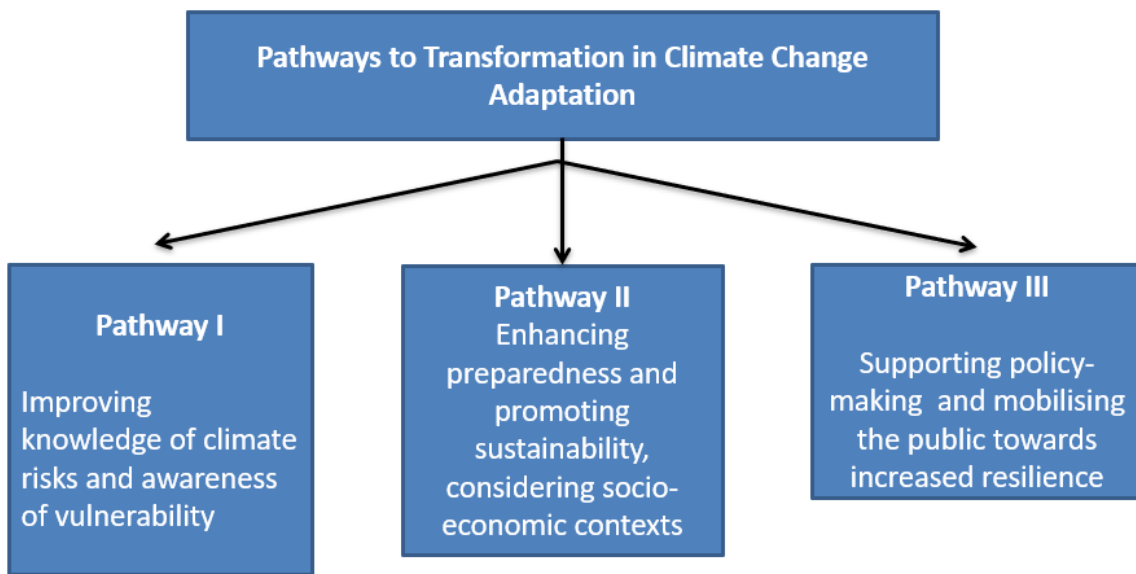
658

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

661

662 **Figure 5- Some pathways to transformative adaptation**

663



664

665

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

670

- 671 1. The need for prioritizing: many cities have set bold goals to cope with climate change,
672 but little funding or economic incentives to implement them are provided. This, in turn,
673 may perpetuate the problems they face. It makes more sense to agree and commit to less
674 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 carefully 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 thermal
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

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

743
744 Finally, it seems essential that successful handling options are disseminated, not in order to have
745 them copied, but as means of inspiration and motivation to cities, encouraging them to pursue
746 their solutions to the problems they face.

747
748

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750

751

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