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Review

Urban climate resilience in Africa: a review of nature-based solution in African cities' adaptation plans

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Abstract
Cities are globally exposed to climate change effects, which revealed that 55% of the world's population is at risk. Despite their low contribution to global greenhouse gas emissions, African cities are paying the highest cost of the threats caused by climate change due to their rapid urban community growth, high population density, and inadequate urban planning. This review has explored and demonstrated the benefit of Nature-based Solutions (NbS) implementation for urban climate crisis resilience that have been implemented globally for sharing information on sustainable city planning in Africa. The analysis is based on the African countries' Nationally Determined Contribution (NDC) reports, the institution's review, and scientific articles. The successful implementation of NbS since 2015 in developed countries confirms that NbS has a multi-functional environmental benefit for urban and pre-urban populations. It reduces cities' vulnerability to climate threats and advances numerous Sustainable Development Goals (SDGs) achievement. It revealed only 15 (27,7%) African countries have implemented NbS with 119 projects to adapt and tackle climate change in water, agriculture, forest and woodland, coastal and marine habitat, grassland, and mountain habitat sectors. Rural areas are paid more attention than cities despite the rapid urbanization in the face of extreme climate effects. Furthermore, the review process observed some challenges in translating the approaches of NbS into measurable actions for African urban climate resilience: (i) issues in the governance of urban planning and policies; (ii) insufficient mobilization of resources and lack of private sector involvement in financing NbS; and (iii) lack of comprehensive evidence-based strategies and knowledge for successful operationalization of NbS in African cities.

Keywords Nature-based solutions · African Union agenda · Sustainable cities · Climate resilience · Africa

1 Introduction

Natural resources such as natural gas extracted from the environment provide raw materials for energy production to support transport, industries, and human activities and cause a lot of damage to the global urban environment. The most important damage nowadays is climate change which is leading to natural habitat destruction and many natural ecosystems and species on Earth's planet [1]. Indeed, in the last four centuries, living organisms including human beings have been occupying environments to which they have been able to adapt and become comfortable [2]. Any quick variation

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or change in environmental conditions is problematic to all living organisms. The global environmental challenge in the twenty-first century is climate extreme effects, which have become an important threat to humans and biodiversity [3]. Unless the rate at which greenhouse gases are being emitted is reversed, the temperature rise is likely to continue, and climate change impacts are likely to harm more human settlements in urban areas, based on projected significant population concentration in cities [4].

Currently, the global population living in urban areas is estimated at 55%, and this growth is expected to rise up to 68% by 2050 [5]. Due to people explosion, and inadequate infrastructure planning, cities are mainly vulnerable to natural disasters and climate extreme impact [5]. Urbanization contributes more than 70% of global greenhouse gas (GHG), which brings it to the center of the climate agenda [6].

Intensive urbanization in emerging countries has accelerated climate change extreme events and risks potential to the urban population [7]. Flooding is one such climate change hazard, which affects communities with environmental and economic implications that are regularly exacerbated the intensity. These impacts are particularly significant for low-income urban populations whose means of support recovery might take longer, which makes them the most vulnerable [2].

Based on the latest United Nations estimates [8], Africa's current population is estimated at 1.4 billion inhabitants. This represents 16.72% of the global population, of which 43.8% are living in Cities [8, 9]. Furthermore, according to the United Nations report on urbanization, Africa has 15 rapidly growing cities and is projected to have a rapid urban growth rate [10]. By 2050, African cities will have an additional 950 million people. The considerable growth of cities occurs in small and medium towns. Accelerated urbanization has been revealed to be one of the major environmental threats that lead to visible consequences such as deforestation and land degradation [5, 11]. Cities' buildings develop an ecological footprint on which natural resources are encroached upon, and surrounding ecosystem services are affected [11]. This situation affects the comfort of the urban population and public health due to the reduction of these ecosystem services, particularly in the current ecological context [12]. Consequently, some of the sustainable development goals may not be achieved in Africa without meaningfully transmuting the city's master plans and management of urban development strategies. Therefore, building urban resilience with the NbS strategy is vital to minimize social, and economic losses while enlightening the sustainability of urbanization to protect the environment by reducing disaster risks, and climate change impact [13]. Managing urban centers or city regions' resources environmentally friendly, considering the ecological capital that can support these trends, is progressively becoming a critical point of planning and management concern. [11]. Therefore, the main questions in addressing these issues are: how can we make cities sustainable and resilient to climate change effects? How can we build urban resilient societies and economies with NbS in Africa? What are the challenges of urban NbS solutions implementation in Africa? This review consists of an overview of the NbS implementation for African urban climate change resilience. It evaluated the dynamic of African cities in the context of extreme climate effects and explored the best approaches of NbS that can be adopted to address urban climate resilience.

The objectives of this review are: to evaluate NbS for urban climate resilience; explore African nations' NbS actions toward urban climate resilience implementation; and identify the challenges and constraints of NbS actions for African urban climate resilience.

2 Approach of nature-based solutions (NbS)

2.1 Concept aspects

The NbS was positioned globally to address environmental threats, such as flooding, droughts, and landslides [14]. NbS was announced and presented by the World Bank at the end of the 2000s [15] to underline and raise the reputation of biodiversity conservation and ecosystem services in climate mitigation and adaptation. Hence, the concept was coined by IUCN to negotiate climate change strategies and solutions that came up with the Paris Agreement. It was centered on climate mitigation and adaptation, particularly in the sector of water, food, and energy including reducing poverty besides driving economic progress [16]. IUCN has recommended many principles that comprise NbS fundamentals actions. They included cost-effectiveness, connecting or harnessing public and private capital including funding, facilitation of communication among stakeholders, and the replicability or reproduction of solutions adopted by any party [16]. Therefore, these principles raised the high importance of NbS in addressing environmental challenges both locally and globally. Currently, the European Commission defines NbS as "actions which are inspired by, supported by, or copied

from nature" [17]. It clearly emphasizes connecting biodiversity conservation through sustainability goals to reinforce climate resilience [18], and represents innovative implementable solutions that can strengthen SDG achievement.

Conferring to the NbS consideration by the Convention on Biological Diversity (CBD), it includes adaptation strategies based on ecosystems that can use biodiversity and ecological services for overall natural disaster adaptation approaches that support people's existence to the extreme climate adverse effects [19]. Furthermore, this approach of CBD has led the United Nations to approve biological ecosystems as an important natural element or tool to cope with the extreme climate [20, 21]. The implementation of NbS approaches has demonstrated environmental, and socio-economic co-benefits in developed countries. This consideration has led IUCN to state that NbSs are actions that protect the living environment and restore modified biological ecosystems which address societal challenges and simultaneously provide human well-being and biodiversity conservation benefits [22].

2.2 Environmental benefit of NbS development for urban climate resilience

Globally, NbSs are known to mainly enhance environmental development actions that address social and economic challenges. Their implementation contributes to the sustainable resilience of societies, and are progressively perceived as a serious tool for answering the climate change crisis. For instance, NbS actions can contribute to cooling small to large cities, energy reduction demand, flood management, and urban heat wave reduction [22]. The implementation of NbS is highly contributing to multiple Sustainable Development Goals (SDGs) achievements such as SDG 11, SDG 15, SDG 6, SDG 7, SDG 8, SDG 9, SDG 10, SDG 2, SDG 3 [23]. Thus, the NbS implementation is imperative for SDG's achievement including ecosystem restoration with local communities' leadership and engagement actions for global impact [24]. In addition, to address the challenges of reaching 'net zero' targets and building back SDG 15, urban expansion must be redesigned to accommodate growing populations while emphasizing sustainable and inclusive city planning [17, 22]. The capability to achieve numerous SDGs is part of what makes NbS implementation more attractive for climate resilience in many economies toward the Paris Agreement achievement [25]. Overall, NbS implementation can set a range of areas or sectors and thematic of social importance [26] as water resources, forests, urban ecosystems, agricultural development (urban agriculture), infrastructure, and management of coastal areas including mangroves. Thus, NbS can address a range of sustainability goals at the local level for global impact (Table 1).

As mentioned in Table 1, the implementation of NbS enhances cities' resilience to extreme climates and their adaptation to natural disasters. NbS can play an excellent role in the global achievement of UN SDGs'. For instance, it stated that cities' actions that concern SGD 11, can deliver 40% of the Paris Agreement goal [27]. It particularly concerned three ain targets of SDG11 where NbS can play a substantial role in its achievement. For targets 11.2 and 11.3, the NbS implementation in the area of infrastructure and construction that consists of using ecological materials including green infrastructure and space development, can reinforce sustainable urban planning, transport systems, and human settlement in cities. Thus, green infrastructure development could significantly contribute to restoring the urban ecosystem and the achievement of target 11.6 which consists of reducing the environmental adverse impact per capita of cities, including air quality and waste management [28]. This can therefore contribute to addressing climate change effects in cities such as urban heat attenuation, management of heavy precipitation, and the reduction of greenhouse gas emissions (Table 1). Since SDGs are interlinked, the implementation of NbS for SDG 11, can involve SDG 3, where green space and infrastructure, including sustainable management of waste, can reduce illnesses from air and water pollution (target 3.9), which therefore contribute to human well-being in urban areas [29]. NbS can be the best approach that can also involve SDG 10 related to the reduction of inequalities, with the potential of reflecting the core commitment within the SDGs "leave no one behind" for all countries' adaptation to environmental change using nature [30]. Considering synergies and complementarities between SDGs, there has been mentioned in the United Nations' recent report an influence of 79 percent of all targets across the SDGs achievements with NbS implementation in urban infrastructure [30]. It addresses the infrastructure gap while contributing to sustainable development, natural environment restoration, and biodiversity conservation at the local level with a global impact.

Furthermore, the strategy of adopting ecosystem-based adaptation with NbS can improve cities' adaption to extreme climate adverse through ecosystem services. For instance, NbS in coastal cities helps protect coastal habitats and forests which provide flood defenses and the management of sea levels [20, 21]. The same approach in landlocked countries can help urban reforestation and revitalize clean water supplies during drought periods in cities including sustainable drainage to reduce flooding [23]. This can help achieve SDG 3, 6, 11, and 13 (Table 1). However, this implementation

Table 1 benefit of NbS for urban climate resilience

Area	NbS Options	NbS Benefits	Climate impacts addressed	SDGs
Water management	Urban drainage systems Sustainability, rivers, streams, and floodplains management, restoration of wetlands and lakes, sustainable water and forest management sensitivity, controlled floodplains	Water cycle regulation effective flood mitigation, water quality enhancement, effective erosion management and soil degradation. Reduction of biodiversity losses. Human reconnection with nature improves urban public health and people's well-being	Drought, flood	3, 6, 11, 13
Forests and urban ecosystem	Reinforcement of Urban Forest restoration and protection urban ecosystem effective management, cities greening and enhancement of urban landscape view	The water cycle regulation, flood reduction, soil and water quality enhancement cities' biodiversity loss reduction and urban centers' cooling, Reinforcement of urban carbon sequestration. Aesthetic and recreational in cities. Air purification and well-being,	Droughts, floods, fires, heat waves	3, 9, 6, 11, 13, 15
Agriculture	Improved soil and water for urban agriculture. Urban crop management, including diversification and rotation in suburban areas. Agroforestry, garden, with urban fresh food supply. s	Reutilization of turbidity water from water canals. Soil quality improvement with organic waste. Urban heat stress mitigation. agricultural biodiversity management carbon sequestration disease control including soil fertility and pest management	Drought flood, urban heat stress	2, 9, 6, 11, 13
Infrastructure	Green infrastructure development, Green roof, Urban planning, sustainable road construction	Accessibility and affordability to urban transport and mobility, road accident reduction, urban heat, quality air	Urban heat, heavy, precipitation, GHG emissions	3, 7, 8, 9, 10, 11, 13, 15

Adapted from [25, 26]

depends on the city's environmental area, geographical location and scale, urban planning, and the main purpose of the type of city.

2.3 NbS implementation at the city's scale

The implementation of NbS in cities concerns infrastructure development and other areas mentioned in Table 1. It concerns green construction which incorporates numerous elements and materials naturally taken from the biological cycle processes and utilization that neglect effects on the environment [6, 31]. They include high energy consumption that generates carbon emissions. Therefore, green infrastructure can be integrated with structure development plans to include afforestation components such as facade greens, green roofs, houses, living walls, and community trees. The Urban greening approach focuses on open spaces with water sources, and vegetation land adjacent to buildings that play blue-green cities value and, can contribute to addressing the challenges of reaching 'net zero' targets and building back SDG 15 [17, 32]. The establishment of blue-green cities provides environmental services resilient to climate change to address many challenges for example noise pollution control generated from automobiles and climate change mitigation. NbS aims to restore and improve natural processes in urban environments at different levels or scales of the city (Table 2).

The implementation of NbS depends on the city's scale and varies from micro to mesoscale city. At the microscale, the main actions can be taken by individuals, households, or the community. These actions can effectively address local societal challenges to climate change and reduce community vulnerability to natural disasters. At the mesoscale, the implementation requires actions from decision-makers with their responsibility to engage stakeholders with NbS. This approach can allow companies and parties to understand their responsibilities for successful NbS actions. It will therefore enhance their engagement in addressing and solving strategic environmental challenges such as urban pollution including carbon dioxide emissions, climate resilience, and future natural resource scarcity in city management [33]. This is an important roadmap to achieve SDG 11, particularly target 3 (11.3) which consists of enhancing sustainable inclusive urbanization, and sustainable urban settlement planning in all countries [30, 34].

3 Method and, materials

The methodology is based on literature reviews, institution reports, and scientific articles. It included the assessment of National Determined Contributions (NDC) of the 54 African country's projects report submitted to the UN Framework on Climate Change (UNFCC) (https://unfccc.int/NDCREG) and assessed by 11 January 2024. This is to identify the evidence and trends of NbS implementation in Africa. African Union Agenda 2063 toward sustainable development in Africa (https://au.int/en/agenda2063/overview), assessed by 20 February 2023. The GIS data was retrieved from (https://www.igismap.com/download-world-shapefile-free-country-borders-continents/) which is the IGISMAP open-source platform. It was downloaded by December 11, 2023. The African country's total population and urban population data are retrieved from the United Nations data portal respectively at https://data.unhabitat.org/, and https://population.un.org/wup/Download/, accessed by March 2024.

Table 2 Urban Planning and NbS Implementation

Planning Scale	Actions to be taken or key interventions
Micro (1 hectare-100 km^2): Building and street	Development of the street pavement. Meadow landscape protection. Individual or community garden development, and greening areas within buildings. Sustainable gutter to improve urban drainage systems. green roofs incorporating renewable energy
Meso (100 km-500 Km^2): county, district, or neighborhood	All modes of transportation and mobility including road construction. Urban street equipment and pavement. Urban relaxed green areas. Microclimate management for cities cooling. Green walls and vegetation including street trees development. Public and allocation gardens for recreation. Urban vegetating areas and parks
Macro (500 Km^2 and +): Big City and Regional development	Urban agriculture, Wetland restoration, green street systems. Urban forests, and biological conservation corridor. Cities master planning, riverbanks, flood plains, including stream conservation

Adapted from [6, 25, 26]

Scientific journal articles including books have been searched using search engines like Google Scholar, and Research Gate with the use of the Boolean operator *"AND"* within words using the keywords: *Nature-based Solutions*; *Sustainable Cities*; extreme *climate resilience*; Natural *Disaster, Environmental risk*. Moreover, the contents of international journals that focus on Urban Climate Resilience have been assessed using the same keywords, such as nature-based solutions, urbanization, urban ecological systems, and urban greening. This approach allowed us to analyze 32 documents linked to the topic under study. Since the concept is new, we identified the main sectors of NbS implementation and their contribution to SDGs (Table 1). This also includes urban planning in conjunction with NbS at different geographical scales (Table 2).

The materials or software used to analyze data gathering were Microsoft Excel 2019 for statistical data, Qgis 3.20 [35] for geospatial data analysis, R 4.2.1 [36], including R packages ggplot2 3.5.0 [37], and Mendeley for reference management.

4 Results

4.1 Urban population dynamic in Africa

The analysis of UN global population data [8] revealed an average growth rate of 3% for the African urban population in 2018 with an average estimated urban population of 1.9 million inhabitants. The high and low growth rates of African countries' cities revealed a wide variety of urbanization performances for different national population growth rates. The findings indicated a disparity in population settlement between African countries. According to World Population Reports, Africa has one city with more than 20 million inhabitants, such as Cairo in Egypt, two cities with 15 million population, Kinshasa, Lagos, and more than 12 cities with 5 to 10 million population [9, 38]. More than 58 cities have above 1 million populations Fig. 1.

Africa has been experiencing the highest urbanization for the last two decades. Thus, with a growth rate (3.5%) per year the continent is likely to be maintained this growth dynamic until 2050. The urban population projection scenarios indicated from 2010 to 2025, many cities in Africa will growth up to 85% of their population [39]. Whereas, between 1960 and 1982, the ratio of Africans residing in cities raised from 11 to 22% of the population [39, 40]. Several factors are contributing to this urbanization process including urban natality, rural migration, and resettlements of the rural population in the cities. The city's development speed, including the underlying population factors, is interlinked to the urban economic transformation. It includes spatial planning with housing, infrastructure development, and the challenges of urban service delivery.

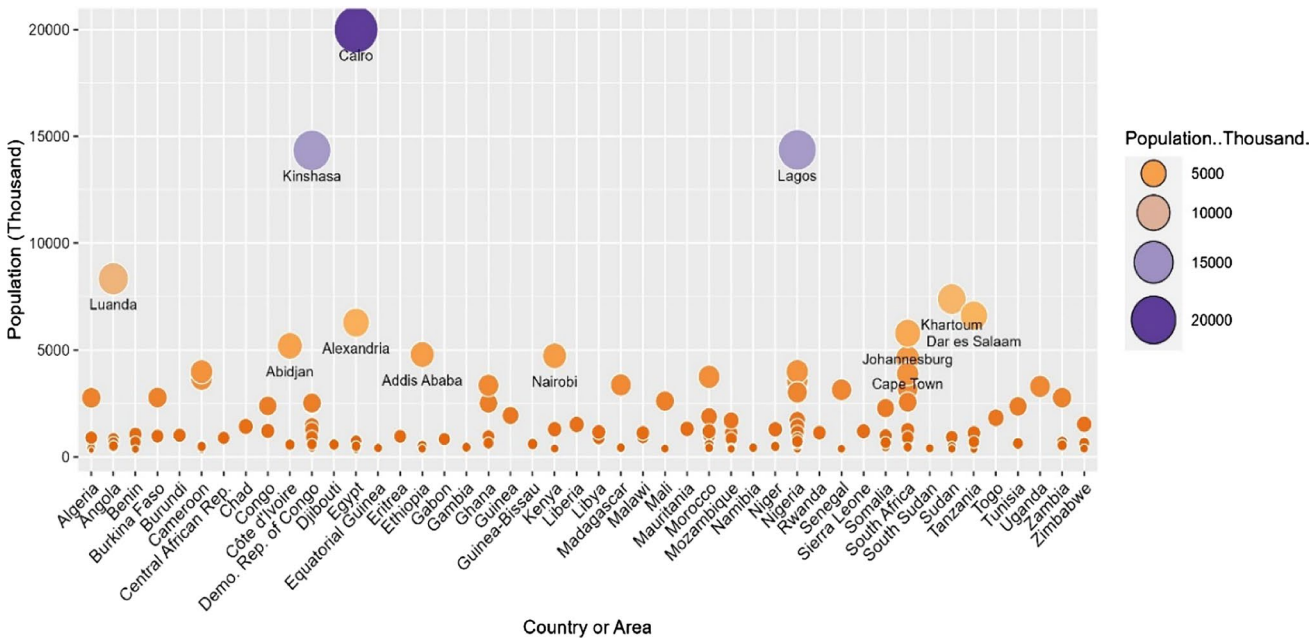

Fig. 1 African urban population in 2018

There were about 47 countries in Africa with more than 20% threshold of urbanization in 2010. That threshold in countries' urbanization will reach 50%, more than the doubled by 2025. The population size, and factors that determine urban population settlement influence significantly the urbanization rate when considering the whole African urban population. For example, Egypt which has the most populated city in Africa, has an 12% of African urbanization rate, while Nigeria has 17% (Fig. 2).

Furthermore, the African urbanization rate flew from 1960 by 15 to 40% in 2010. It has projected to growth up to 60% in 2050 [8, 41]. Urban populations are expected to triple in the 50 coming years, which will change the profile of many African regions. This will challenge policymakers in the development of NbS projects for sustainable and inclusive urbanization [42]. Mainly associated with the resettlement of rural people in the city as mentioned previously, this urbanization to pay more attention in Africa. In general, more than 70% of the urban population, are located in the towns of less than 100,000 inhabitants with connection to very low-density road networks. [43]. Despite what institutions and scientists have written about the phenomena, it is impossible to deal with poverty and urban population challenges without adopting an effective urbanization action plan in the face of extreme climate impacts. Furthermore, a recent report by the World Bank revealed the African population has tripled mainly in African sub-Saharan cities, and quadrupled in the Northern part of Africa and, by eight in the intertropical zone [39]. The rapid urbanization that occurs in Africa leads to the African cities' high vulnerability to extreme climate effects.

4.2 African urbanization and cities' vulnerability to extreme climate impacts

The Climate Adaptation Initiative of Notre Dame (ND-GAIN) revealed different vulnerability exposure indices. It highlighted that the top six countries extremely exposed to climate extremes are all in Africa. They include Guinea Bissau, the D.R Congo, Eritrean country, the Central African Republic, Chad Republic, and South Sudan (Fig. 3b). The report included the country's ability measurement to cope or adapt to the negative effects of extreme climate bearing. While, the vulnerability expresses the exposure score of the country and its sensitivity to the extreme climate on the main activity sectors such as food security, water resources, public health, natural ecosystem service, human settlement and habitat, and development of infrastructure (Fig. 3a). The African vulnerable countries, have therefore high scores of their urban community's exposures to the extreme climate [44]. The extreme climate vulnerability score of the country compared to its capability adaptation index could guide decision-makers to anticipate the climate resilience of cities where there's a high density of human population. For example, countries like Morocco, Algeria, South Africa, Egypt, Tunisia, and Botswana

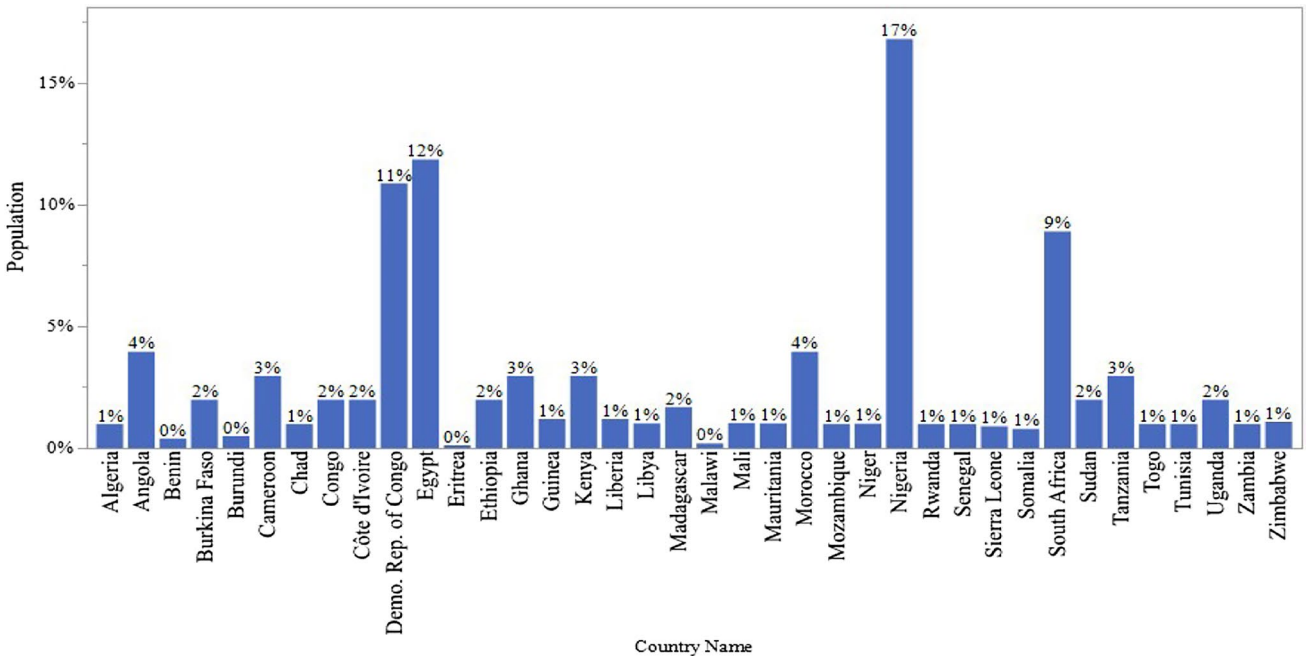

Fig. 2 Share of African urbanization

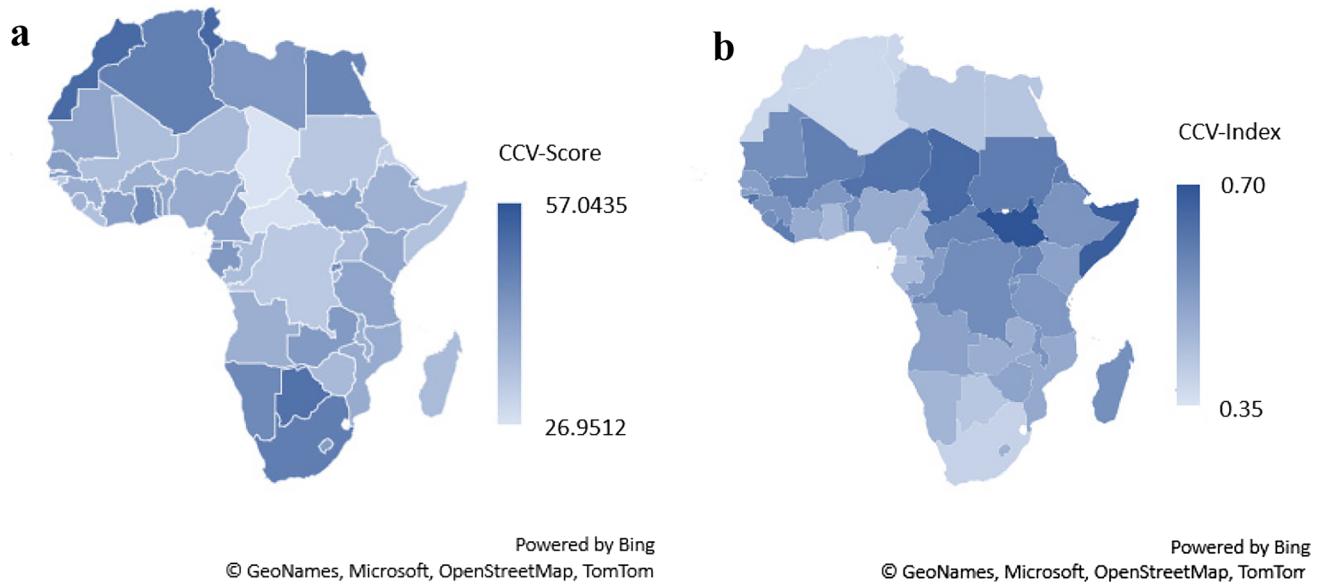

Fig. 3 Climate Change Vulnerability (CCV) in Africa (**a**- Vulnerability score, **b**-Vulnerability index). Data source: Copyright © 2024 University of Notre Dame Notre Dame Global Adaptation Initiative

have a high score of vulnerability (Fig. 3a), but a low vulnerability index (Fig. 3b), which demonstrates their capability to adapt, if there is a good adaption policy *(*Fig. 3*)*.

Additionally, the 2022 report of the World Bank and Verisk Maplecroft has highlighted that African urban centers are highly vulnerable to extreme climate. Thus, from Alger to Cap-Town, and Nouakchott to Somalia, African cities are the most highly exposed to climate extreme events with 70% of high vulnerability to flooding, urban heat waves, drought, and storms [39]. Indeed, a higher temperature and the growing severity including frequency of this climate extreme will undoubtedly change the quality of living and economic projections of African cities. This could come off worse given the continent is not only most exposed to extreme climate events, but is also least able to mitigate their impacts [45]. So, Africa could pay the heaviest cost of climate threats since climate change will multiply weather-related risks [46] despite its very low contribution (4%) to greenhouse gas emissions in the world. For example, the index of climate vulnerability has highlighted that none of the African cities is at low risk of extreme climate threats. The most populous and fastest-growing cities such as Lagos, Kinshasa, and Luanda are facing climate extreme threats, while Johannesburg, Nairobi, and Dakar are among those at the highest risk (Fig. 4).

In terms of human settlement, most African big cities are located in the coastal zones, where they are therefore exposed to rising sea levels. The cities like Cairo, Lagos, Lome, and Saint-Louis are rapidly expanding and bordered by lagoons [5, 39]. Thus, the most extreme climate change events affecting African cities are extreme heat waves, floods, water shortages, extreme drought, and dust, storms, heavy precipitation. In this context, NbS can integrate development, climate, and nature into comprehensive interventions that could reinforce African cities' extreme climate resilience.

4.3 Implementation of NbS in African countries for urban climate resilience

From 2015 to 2022, the 54 African countries have submitted 103 NDCs to the UNFCC. In general, the reports revealed 75 reports included projects for the country' extreme clamate adaptation and mitigation mechanisms with natural ecosystems. There were 28 countries that have exclusively reported in their NDC as their mitigation strategies. It means all of the African countries' reports have developed an intention to adapt and mitigate climate change impact using natural ecosystems towards the Paris Agreement achievement. Among 103 NDCs revised submitted by the 54 countries in 2022, only 32 countries (59.25%) have explicitly intended to apply NbS in their adaptation and mitigation plans. Indeed, only 15 countries have explicitly mentioned the term NbS in their implementation project for climate adaptation and mitigation *(*Fig. 5*)*.

It highlights that 27,7% of African countries are implanting NbS for climate change adaptation through their NDCs submitted to UNFCC. Countries with the highest climate vulnerability score such as South Africa, Morocco, and Egypt did not explicitly express NbS implementation in their NDC. The main sectors that have been targeted in NbS implementation

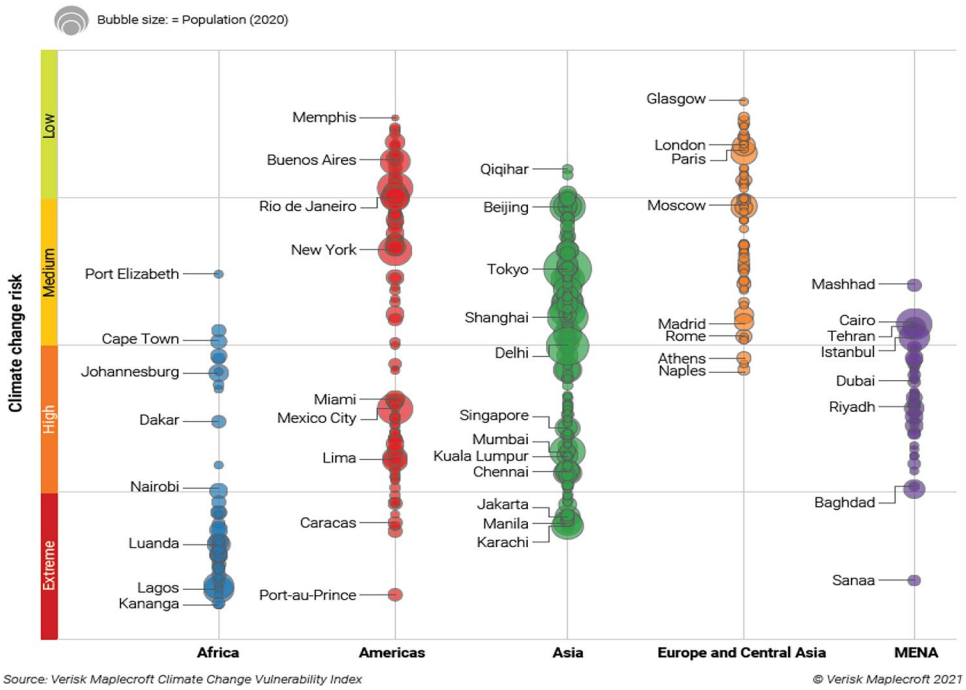

Fig. 4 Climate Change threat to Africa's largest cities. Source: Verisk Maplecroft Climate Change Vulnerability Index ©Verisk Maplecroft, 2021

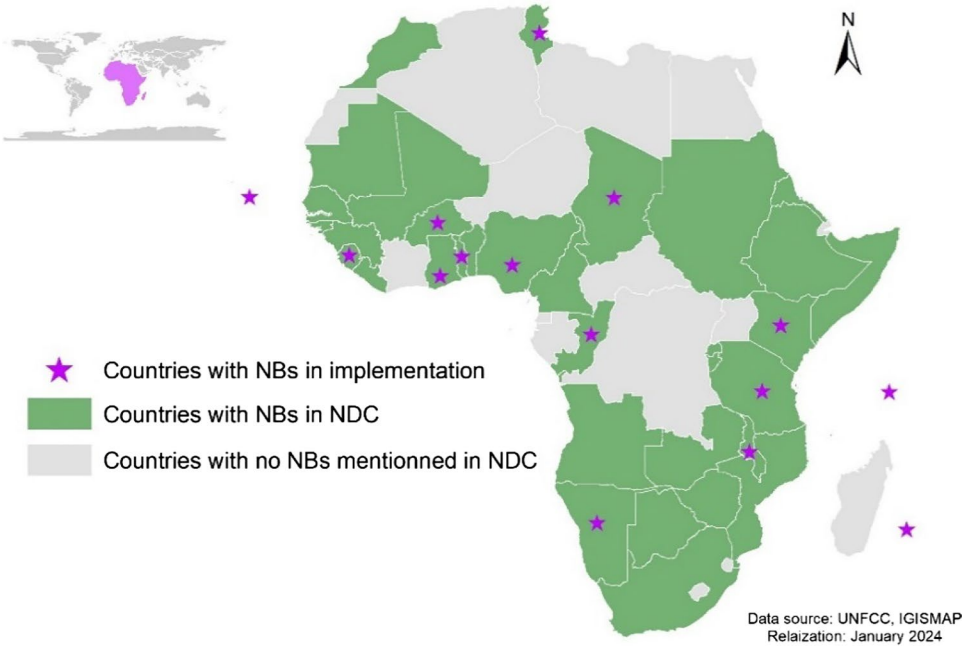

Fig. 5 Map of Africa-NbS revised from NDCs

for climate adaptation are Agriculture, water bodies, Grassland, Forest and Woodland, Coastal areas, Marine Habitat, and Mountain Habitat *(*Fig. 6*)*.

African countries' NbS implementation targets 119 projects including 27 projects in the agriculture sector, 22 projects for water management (River catchment habitat), 14 for Grasslands and rangelands, 35 projects for forest and woodlands, 18 projects for Coastal and marine habitats, and 3 projects for mountain habitat. in terms of classification forest and woodland represent 29%, agricultural 23%, water management 18%, coastal and marine habitat 15%, grassland 12%, and mountain habitat 3% *(*Fig. 6*)*. Most ecosystems prioritized are, therefore, forest and woodlands projects and Mountain habitat projects are less implemented.

Among the mitigation strategies, biodiversity is one of the top three sectors stated as most high extreme climate risk, and urban areas are most less vulnerable according to the NDC report (Source [47]: Figure 7).

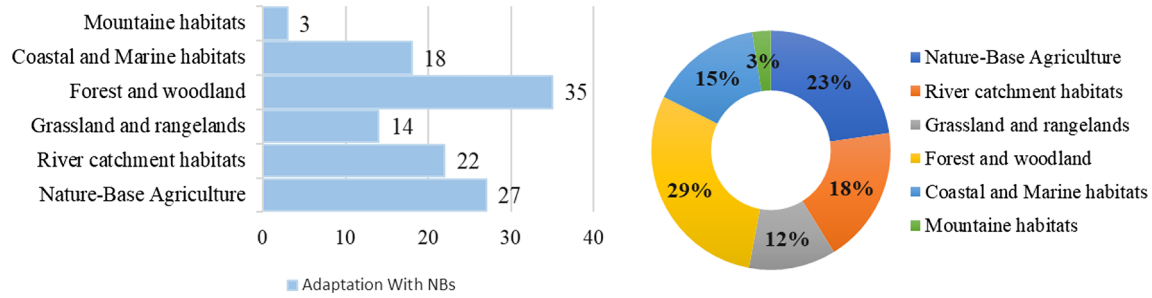

Fig. 6 African NbS in extreme climate effects adaptation analyzed from NDCs

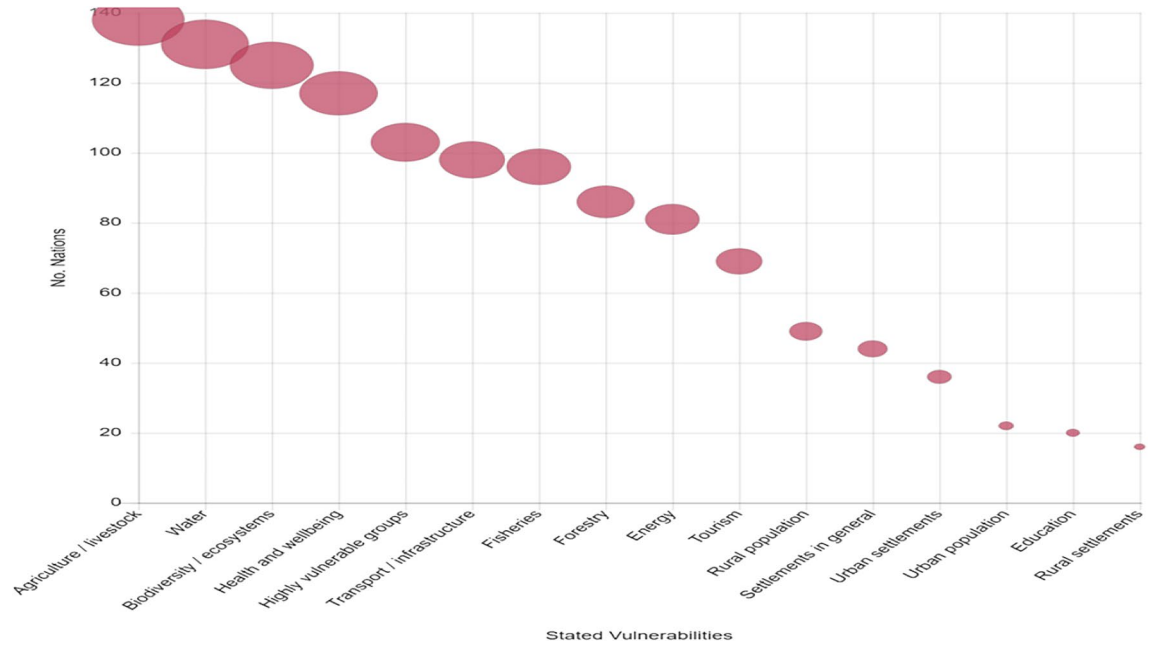

Fig. 7 Prioritization of mitigation strategies with NbS in Africa. Source: [47]

Despite cities being threatened by erosion and floods in the West African coastal region for example, it has been observed water scarcity in the continental or hinterland cities in the Northern and Southern Africa [42]. Thus, urban centers are given lower priority in the areas covered by the NbS implementation project in Africa. The boldness of many African countries in NbS implementation is green space planning which is repeatedly expressed entirely through prompted actions and straight interventions to a perceptible problem with no long-standing plan [48]. These actions are temporary and yield less or no effects due to the limited time frame in planning and implementation. The possible outcomes are recurrent flooding, erosion, pollution including urban waste management challenges, and urban hotness in African cities [48, 49]. Although some countries have paid less attention to the cities' public green space including urban infrastructure greening, others countries such as Nigeria, South Africa, Egypt, and Ethiopia are yielding positive results in NbS actions [49]. Therefore, some African municipal programs are promising in the nature greening actions and development policies to increase sustainable utilization of renewable sources [50]. Awareness programs are still low, and the cost of participation is very high and not open to all stakeholders to reach out to the concerned parties in the entire population. Additionally, African urban slums frequently face flood insecurity and poverty as major problems. Much research indicated that these challenges can be achieved through numerous and diverse urban development programs including ecosystem-based adaptation and urban agriculture [21, 51]. Thus, for the African smart city to be achieved, the African Union agenda 2063 should contribute massively towards the cause.

4.4 NbS for African urban adaptation: the role of African Union African Agenda 2063

Urban populations in Africa are expected to be multiplied by three in the next 50 years. Thus, this will shape and change the profile Africa, and will challenge policymakers in cities' planning for sustainable and inclusive economic growth [42]. To cope with African development challenges in this context, the African Union (AU) has set a roadmap for sustainable development: Agenda 2063. Adopted by January 2015 in Ethiopia, the agenda is a regional development framework that aims to address a set of seven visionary aspirations. The vision of each of the seven aspiration has a goal that lined with the AU development global vision, if achieved can significantly move Africa closer to achieving many UN SDGs [43]. For the first time, this regional development roadmap reflects the desire of Africa for shared prosperity and population wellbeing. The first one includes sustainable development and targeting citizens' well-being with a high standard living, and quality of life. It considers urbanization challenges and human habitats for environmentally friendly adaptation of urban communities. It particularly putting in place some actions to measure sustainable management actions of the biodiversity, forests, land, and waters including to address extreme climate risks. This can move African countries toward to the achievement of SDG 15 related to ecosystem and biodiversity conservation. Thus, the agenda 2023 is highlighting the volunteer implementation of NbS for climate adaptation and resilience. This objective could help to achieve sustainable city development by 2063 if well implemented. It can also expand and enhance NbS implementation for African urban climate resilience which should pass by urban green infrastructure and public areas development by reinforcing local governance leaders' capability in NbS actions. Furthermore, to manage the rapid population growth which accelerates African cities' development, the AU could lay on the successful implementation of NbS for urban climate resilience to achieve the African Development Agenda 2063 vision. This approach can be developed from the experiences of developed countries sharing with high implications of African municipalities authorities. It can help limit some barriers and challenges of NbS implementation for African Urban climate resilience. Those challenges that AU Agenda 2063 could focus on are urban governance, finance, and engagement of stakeholders. It could therefore be seen as knowledge challenges, policy, and finance mobilization of NbS actions for African urban climate resilience implementation. In this context, the African Union could be a facilitator to address resource mobilization, urban NbS awareness, and policy including the sharing of knowledge.

5 Discussion

Global implementation of NbS is more and more involving all economic sectors and geography globally. This implementation is highly targeted natural resources effective protection including water management, forests, agriculture sector, agroforestry, urbanization, coastal and mountainous areas [13]. Thus, improving and increasing the implementation of the NbS in the face of extreme climate mitigation and disaster risk reduction has been demonstrated by the European Environmental Agency (EEA). This demonstration has screening more than 107 European NbS cases successful implemented projects [18, 25, 52]. The screening assessment has consisted of retrieving information from platforms of knowledges established in Europe to help achieving NbS implantation [13]. It highlighted how NbS implementation can reduce the city's vulnerability from 11 selected cases [53]. The screening has assessed NbS implementation, and its multiple benefits, opportunities, and limitations [53, 54]. Such screenings, expose the type and scale of NB actions and have revealed that the successful implementation in practice is lined with governance and financing arrangements, and policy frameworks. These NbS actions in Europe can inspire African countries, particularly for cities' climate resilience. For example, AU through its Agenda 2063 can help screen all NbS implementation in African countries for the shake of sharing NbS implementation experiences among African countries, particularly.

Regardless of the considered sector, the case project addresses flood hazards, whereas other climate impacts adopted high-relevance heatwaves in urban areas. Green roofs for example in Basel and Hamburg reconnected green areas and increased cities' resilience to climate heatwaves, floods, and high temperatures impact. This was similar in Bratislava and Stuttgart in Europe [17, 52]. Large-scale NbS programs in cities to restore floodplains, and green corridors are significantly important in dealing with the climate crisis [13, 55]. Unbuilt spaces in urban and peri-urban performs a significant role in reconnecting some NbS actions such as management of forested areas and wetlands. This strategy can lead to dropping the risk of cities' hotness waves and floods while enhancing carbon sequestration and biodiversity conservation. This has promoted citizens' health and well-being in many developed countries [53].

Generally, green places are good for environmental conservation which provides cities with ecosystem profits ranging from sustaining biodiversity to regulating urban climate [49]. It includes the natural biological conservation, defense natural resources depletion, including the management vulnerable biota in addition to educational entertainment [56]. For example, a study conducted in Turkey indicates that green public infrastructure can deliver many functions for species reproduction, plants, soil, and water resources protection [57]. Green public spaces provide an excellent connectivity between different elements in nature. They can serve as wildlife corridors and maintain viable populations of species that might disappear in urban areas [58].

Despite NbS being an attractive tool for urban climate resilience and many SDGs target achievement in Africa, some challenges that limit the full potential implementation in cities remain. These challenges have been raised in South Africa where ecosystem based-adaptation approach that presents more comprehensive and cost-efficient in urban flood disaster risk management needs to be established regionally and nationally to deliver effective flood disaster adaptation [21]. Indeed, the study reports that floods happened in this country resulting in many damages including a significant loss of life and livelihoods in cities. Despite all efforts in implementing NbS through ecosystem-based adaptation, many communities have not been able to recover from these events [21]. Thus, Busayo et al., (2022) have recommended raising the mindfulness of ecosystem-based solution implementation to improve collective approval of flood risk management in South Africa. This study revealed how lower cities are paying attention to the implementation of NbS in South Africa, which is also valid for all other African countries where rural areas are getting much attention. This situation can be explained by many factors including inadequate urban planning, lack of resources, and local communities' awareness of the potentiality of NbS actions for cities' climate resilience. It is clear that without synergies actions for NbS implementation for cities' climate resilience, the SDGs and climate objectives could be very far from reach in Africa [34, 53]. Furthermore, the implementation of the macro development outlines such as AU Vision 2063 and SDG 2030 face significant challenges in Africa regarding the disparity between implementation by African governments. This situation can affect the potential implementation of NbS for urban climate resilience in Africa.

6 Conclusion and recommendations

NbS solution implementation is a key alternative that could contribute to SDG's achievement, particularly SDG11. NbS can integrate development, climate, and nature into comprehensive involvements that reinforce the short-term resilience of the physical and natural capital of cities. However, globally its implementation did not have the same attention or priority. The areas covered by the NbS implementation project in Africa show that urban areas are given lower priority despite the rapid urban population growth. The implementation is much more developed in coastal cities than in the continental zones. The analysis highlighted that NbS implementation seek local community engagement, the institutional arrangements establishment that integrate sustainable development in urban transformation. This review was to evaluate the challenges of NbS implementation for African cities' climate adaption. Thus, we observed a challenge that have to be addressed and release the possible potential of NbS for urban extreme climate resilience in Africa:

- Gaps in governance and policy formulation that deal with urban planning processes and strategies at urban scale;
- Lack of accurate knowledge and identification of key projects for NbS implementation according to the geography, and the environment of the city;
- Lack of finance and mobilization of stakeholders for successful implementation of NbS in the African urban areas.

The urban development with high density of population in the context of extreme climate, the depletion of natural resources is predicted to continue if no visionary actions are taken. Given the environmental and social benefits, NbS provides an opportunity to handle urban transformative change and sustainable development goals achievement in African cities. This calls on local and national governments, NGOs, municipalities, researchers and other related institutions of decision-makers to advocate for urban NbS implementation in Africa by:

- Involving private sectors and, an inclusive variety of actors or stakeholders;
- Leverage innovation and technology development to unlock the full potential of NbS in cities;
- Strengthening the capability of city leaders and policymakers at the local, and national with regional collaboration to address equity, and sustainability in cities with NbS in Africa;

- Identify and address multiple sustainability goals according to the scale of the geography of the city, and its social challenges;
- Create NbS national framework for urban climate resilience by monitoring and assessing sustainable urban transformation.

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Declarations

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