SPC Journal of Environmental Sciences, 6 (1) (2024) 19-25

SPC Journal of Environmental Sciences

Website: www.sciencepubco.com/index.php/JES

Research paper

The implications of climate variability and change on urban water security of Lagos mega-city, Nigeria: a narrative review

Oluwole Akiyode *

Biological & Environmental Sciences Department Kampala International University, Kampala, Uganda
**Corresponding author E-mail: woleakiyode@gmail.com*

Abstract

There has been continuous population growth in some of the cities in the sub-Saharan African coastal region since the mid-20th century. This has led to the emergence of mega-cities, which include Lagos in Nigeria. However, rapid urbanization alongside the threats of climate variability and change may alter the intensity of the features of urban water security in these cities. The framing of the concept of urban water security by policymakers and academia is to make society aware of the urban water threats, for the sake of managing them effectively. This study is a narrative review of literature of the changes in the features of urban water security of Lagos Mega-city. The study indicates that changing climate alongside urbanization trends has implications on the features of urban water security in the city.
Keywords: urbanization, Lagos Mega-city, urban water security, changing climate, Climate variability and change, and water security.

Keywords: *Urbanization; Lagos Mega-City; Urban Water Security; Changing Climate; Climate Variability and Change; and Water Security.*

1. Introduction

In the year 2018, the population of the world living in urban areas grew to 55 per cent as against 30 per cent in 1950 (United Nations., 2018a:1). It is also expected that 60 per cent of the global population will reside in cities by 2030, which equals one in every three persons (United Nations, 2016). Also, 93% of the anticipated urban growth is expected to be located in developing economy countries (Zhang, 2015). Presently, the world is experiencing some of its growing cities becoming mega-urban centers with striking populations. Thus, to accommodate the continuously growing cities and urban areas to mega-urban centers towards the end of the last century, the concept of mega-city was developed by the policymakers and in few years, it became an acceptable paradigm by the academia in literature and the world at large. The concept was initiated to assess the level of urban growth and expansion but with a principal emphasis on only the population figures of the cities. Consequently, mega-cities are defined as urban centers having more than 10 million inhabitants. Moreover, the rapid urbanization trends in many of the growing cities are most times connected to the increase in urban socio-economic and commercial activities, thereby encouraging and attracting migrants and settlers from rural areas to the cities in search of socio-economic empowerment (Awumbila, 2017; Cobbinah et al., 2015; Farrell, 2018; Wolff et al., 2019).

However, in Sub-Saharan African countries nearly all the population growth and expansion outstripped the growth of their infrastructure thereby increasing pressure on the urban system (Adama, 2018; Akiyode et al., 2017; Farinmade et al., 2018; Soyinka et al., 2018). This creates an avenue for negative implications on their socio-environmental conditions (Adelekan, 2016; Toka, 2022). Therefore, the processes of rapid urbanization in some of these cities may tend to generate urban goods and create societal burden that tend to increase the susceptibility and vulnerability of residents to the adverse impacts of climate variability and change. Subsequently, the emerging mega-urban centers and mega-cities located mostly in the developing world continue to grow unabatedly when compared to the ones in the developed world that grow strategically (Ajibade et al., 2015). The number of Mega-cities in the entire globe increased to 33 in 2018 and 27 of them situated in the developing nations in the global south (United Nations, 2018b: 5). Unfortunately, the growth of cities in developing countries sometimes shows a corresponding growth of sprawl and slums with implications on service provision, socio-economic activities and environment (Akanle & Adejare, 2017; Israel, 2017; Mberu et al., 2017).

Records have shown that the continuously growing mega-urban centers in Sub-Saharan Africa region include Lagos in Nigeria (population in 2016 of above 13 million) which is located at the coast of the Atlantic Ocean (United Nations, 2016). However, the rapid urbanization occurring in most of the growing cities is expected to have implications on nature, through alterations of the internal equilibriums between population growth, economic activities, provision of services, infrastructural development, and pollution (Mishra et al., 2021). Israel (2017) surmises that the making of cities will encompass landscape alterations, transformation of ecosystems, earth reconfiguration, plants and animals' removal, that are consciously replaced with roads, buildings, structures and infrastructure. This sometimes creates socioeconomic and environmental challenges with implications on human society (Toka, 2022). Thereby, increased urbanization leads to greater demands for water (typically domestic water) while increasing landscape alteration that occurs mostly in growing cities always come with less permeable or impervious surfaces with consequences on the flow rate of surface water or stormwater (Adelekan, 2016; Sartipi & Sartipi,

2019; Toka, 2022). In addition, previous literature emphasizes that the development pressures associated with urbanization coupled with the impacts of changing climate have implications on water resources (Mcdonald et al., 2014; Meza et al., 2014).
Consequently, climate variability and change are a threat multiplier of urban water challenges and other negative implications of rapid urbanization in growing cities. Nazemi & Madani, (2017) assert that water-related threats and stresses in cities are likely to become frequent, more intense, and may easily spread under urban climate variability and change. Hence, this study assesses the features of urban water security influenced by climate variability and change in a Sub-Saharan continuously growing coastal city using Lagos Mega-city as a case. Thus, it identifies the water security component of the city that encourages the changes in the features of its urban water security. These included its rainfall, flooding, and coastal erosion. In the end, the study advocates that urban societies and cities in the sub-Saharan African region need to embrace the paradigm of urban water security tenets as part of their sustainable environmental management approaches expected to boost their sustainable development.

2. Methodology

The study is a narrative review of past and relevant literature on the paper scope using certain keywords tailored towards achieving the intended objectives. The utilized keywords are urbanization, Lagos Mega-city, urban water security, changing climate, climate variability and water security. It employed mainly google scholars in its searching for the articles engaged for its investigation. Hereafter, a total of 81 journal papers, reviewed articles and reports of institutions were considered by the author to demonstrate the interrelatedness of the concept of urbanization and climate variability and change with urban water security. It primarily explored papers on urban water security framework which is the object of the topic as basis to the discussion. Afterwards, it examined articles that embraced the paradigm of rapid urbanization and city growth focusing on Lagos Mega-city in Nigeria which is the case. It relates climate variability and change to the issues of continuous growing city in relation to the case tailoring its analysis to the existing features of urban water security and urban water insecurity.

3. Urban water security framework

To sustain humans and their environment towards the end of the twentieth century came the developments and designs of some paradigms of security by academia and policymakers. These concepts are expected to enhance the assessments of stressors and threats to human life and its societal ecological resources. However, almost all their definitions and proposed themes are still not yet stable or fully established but are evolving progressively, thereby resulting in the enlargement of the scopes of the security paradigm.
Water Security is one of the recently developed concepts of security at the turn of the last century that is intended to support the attainment of a sustainable society (Allan et al., 2019; Gadzalo et al., 2018; Zadawa & Omran, 2018). The concept of water security emerged as a common force among researchers and policymakers mostly in the fields of hydropolitics and international relations as an aftermath of the previous sustainable water management frameworks that include Integrated Water Resources Management (IWRM) (Staddon & Scott, 2018). It represents a multidimensional, interdependent and complex set of subjects (Mishra, et al., 2021)
The paradigm of water security is necessary because, water challenges or crisis is considered a global risk of deepest concern that may be influenced by developmental parameters and environmental factors (Santos et al., 2018, Olaniyi, et al., 2023). It emerged to address the absence of a clear goal for the management of water resources (Varady et al., 2016). However, the implications of changing climate and climate extremes on water resources globally are making the concept of water security gain global acceptance (Jaramillo & Nazemi, 2017; Lu et al., 2015). Hence, water Security is identified with the dual nature of water as a resource and sometimes as a hazard (Varady et al., 2016). Thus, it includes water governance with the expectation of increasing government capacity in the efficient and effective management of the resource (Mishra et al, 2021). Thereby, it could be defined as a process of providing and securing adequate water resources with equitable benefit and identifying the capacity to mitigate the hazards that water may present to society (Sadoff et al., 2017). Its discourse is expected to include the examination of both water quality and quantity from hydrological, ecological, engineering, and societal perspective (Gunda, et al., 2019; Varady et al., 2016).
At times water security could be transboundary when water is shared across political boundaries (Gökçeku & Bolouri, 2023). Thereby, it is a local, regional, and international concept with a profound aim of environmental sustainability. Moreover, its assessment is essential to ameliorate the concern of the threat of water to the human and environmental well-being of the society in the bid to encourage societal socioeconomic development. Water security captures the indispensability and threats of water to its immediate society by preferring an amenable solution to its sustainable management. Some of the previous studies identify equity, welfare, water-related risks, and sustainability as emphases for the concept (Hoekstra et al., 2018). Therefore, sustainable society and its urban health is dependent on the level of its water security which necessitate urgent attention by policymakers in designing adequate approaches and management for its sustainability to promote sustainable development.
In recent years, there has been increasing policy usage and aggressive research on the concept of water security in different parts of the world (Gerlak et al., 2018). This has generated diverse frameworks and approaches that are expected to ameliorate the stress of water in different localities and regions. Therefore, the development of the concept of urban water security is to examine holistically the management of water resources in cities, especially with the increasing rapid urbanization in some parts of the world and the reality of a changing climate. Equally, it was developed to respond to the distinctive water challenges that are faced by cities especially those that are having an increasing concentration of people (Dou et al., 2019; Jensen & Wu, 2018). However, since it is an emerging concept, it has diverse definitions but with the same foundational goal of urban water sustainability (Aboelnga et al., 2019; Allan et al., 2019).
Urban water security is one of the security concepts developed in the aftermath and the outcomes of the Gro Brundtland Commission of 1987 propositions for the achievement of sustainable development. It is multi-faceted and is interrelated with broader frameworks such as urban metabolism, risk management, ecological security, integrated urban water management, water-sensitive cities, the web of water-energy-food securities, adaptive water, and resilience (Aboelnga et al., 2019). Therefore, it is a component of urban environmental security. Urban water security is an offshoot of the concept of water security but with a focus on the cities, urban agglomeration, or a municipality with distinctive governance that is based on municipal policies that lend support from national regulations (Hoekstra et al., 2018). Therefore, its assessment is paramount to the sustainability of every city with a process of upholding its water security. Moreover, it entails issues of planning for the growing population and focuses majorly on the city's water quality, water quantity, safe and equitable access to water, and risk of a water-related disaster such as droughts and floods, etc. (Gerlak et al., 2018; Grasham et al., 2019; Huang et al., 2015).
The concept of urban water security is to make society aware of the urban water threats, for the sake of managing them effectively and thereby promoting the sustenance of healthy water in cities. So, it is envisioned to reduce the risks, vulnerabilities, and threats of multiple

challenges of water in the city that are associated with human society including having the primary intention of securing the urban future (UN-Water, 2013). This is done through the innovation of better water outcomes through the engagement of sustainable policies, practices, and technology (Charles et al., 2020).

Thereby, it is expected to bridge the gap between learning and approaches that are focused on urban dynamics thereby, shaping the interactions between urban regional systems, urbanization, regimes, users, and a complex resource (Romero-lankao & Gnatz, 2016). Thus, it is an extensive concept that addresses the implementation of the different water challenges through consideration of the overall welfare, social equity, risks, and environmental sustainability of the city (Hoekstra et al., 2018). However, it is framed in diverse ways (Aboelnga et al., 2019). It may be broad like Integrated Water Resources Management (IWRM) and sometimes in some cases, it may be framed narrowly by examining only the demands and supply of water to the city (Pandey, 2020; van Ginkel et al., 2018). Thereby, making its focus at present not precise but altogether with a sole purpose of enhancing sustainable society.

4. Features of urban water and changing climate in Lagos Mega-city, Nigeria

Lagos Mega-city in Nigeria has continued to increase its land area and decrease its water area through urban developments through the years. The major water areas in the city are the Lagoons in different parts of the mega-city and also Yewa and Ogun Rivers that plunged their waters into them (Ayeni et al., 2016). Map 1 shows Lagos Mega-city, its local governments, and its surrounding water.

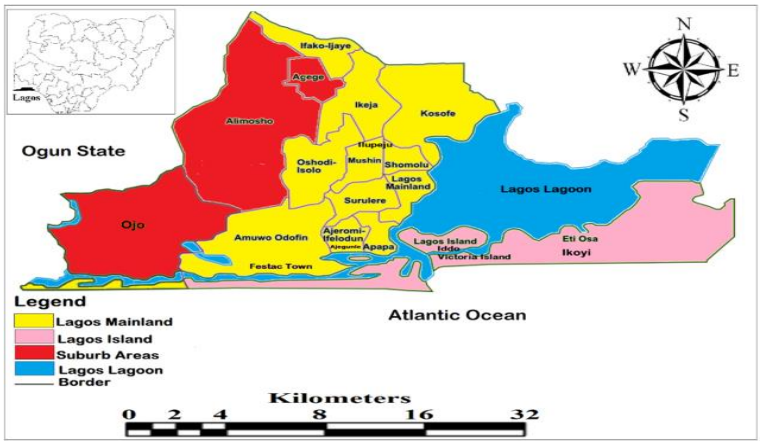

Fig. 1: Lagos Mega-City and Its Surrounding Waters (Dano et al., 2019).

As of 2017, the total land area of the city was 2,797.72 square kilometers (approximately 72% of the city), while its total water area was 779.58 square kilometers (approximately 28% of the city) (LBS, 2017; Wang & Maduako, 2018). Fig. 2 shows the proportion of the total land area to the total water area in Lagos in a pie chart.

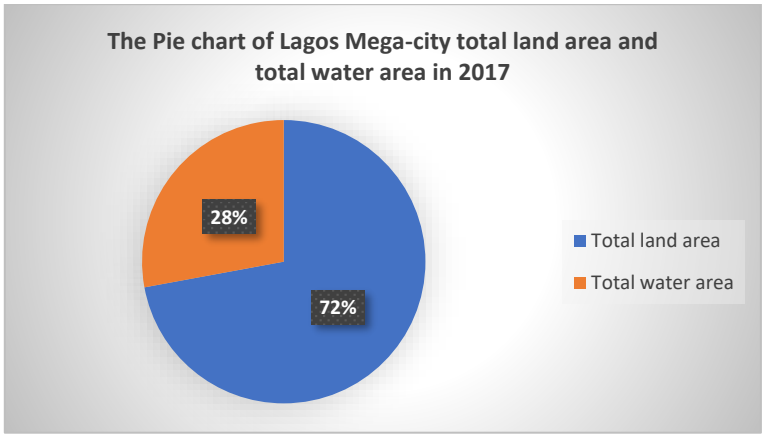

Fig. 2: Pie chart of Lagos Mega-City Total land area and Total water area in 2017. (Data from LBS, 2017).

The features of urban water is indispensable in the determination of the level of the expected impacts of changing climate and its variability on a city and ultimately may determine the expected response (Reckien et al., 2017; Wong et al., 2014). Though, the city land area is fast extending beyond the boundaries of Lagos State to the adjoining Ogun State. However, the susceptibility of the geomorphology of most of the coastal cities to external disturbance cannot be overemphasized because of the dynamics and interconnectedness of the anthropogenic along with natural elements which include the rapid urbanization that alters the surface morphology beside and beyond their coastlines (Sengupta et al., 2017). That is why all over the world, low-lying coastal cities are expected to have increasing adverse impacts such as submergence, coastal erosion, and coastal flooding that is caused by relative sea-level rise due to changing climate but whose levels of implications are enhanced by their diverse local conditions (Wong et al., 2014). Therefore, the increasing pressures of human impacts on the water and land environment in the growing cities also have the tendency to increase their vulnerability to climate variability and change (Wheater & Gober, 2015). Hence, Lagos mega-city coastal geomorphology has continued to change its biodiversity, and unrelentingly reshape its lagoon barrier because of the natural and anthropogenic influences, coastal gradation that results from aggradation and degradation processes, and weathering (Odunuga et al., 2014). Therefore, the geomorphology of Lagos predisposes it to urban water insecurity that could be heightened by climate variability and change.

Lagos Mega-city is comprised of mainly coastal plain sands and tidal flats alongside alluvium with a low-lying topography coastline communities that are having 1 to 4% slope and an elevation of 0-2m above sea level which increases its susceptibility (Idowu & Home, 2015; Sojobi et al., 2016). Thereby, the city was ranked 15th position in the world based on the population exposed to coastal flooding (Sojobi et al., 2016). The OECD (Organization for Economic Cooperation and Development) project report on cities and changing climate in 2007 affirms 357,000 people and assets worth 2.12 billion dollars were vulnerable and exposed to climate extremes such as the surge-induced flood in the year 2005 and projected that 3,297,000 and asset worth 117.32 billion dollars will face the same exposure in 2070 (Baker, 2012; Nicholls et al., 2008).

Lagos is the economic hub of Nigeria with over eighty per cent of its international air traffic, seventy percent of seaport activities including maritime cargo flight, and over sixty per cent of the manufacturing industry in the country embracing about ten thousand commercial ventures, two thousand industrial complexes, and twenty-two industrial estates (Adelekan, 2016). The city has been rated as one of the fifty most vulnerable cities to extreme sea-level rise (Idowu & Home, 2015). Hence, the susceptibility and vulnerability of the city are aggravated by a high concentration of its gross domestic product alongside the manufacturing industries, insufficient infrastructures, and the dense population of its coastal communities (Odunuga et al., 2014). However, the susceptibility and increasing vulnerability of the city to climate extremes are not singly influenced by urban growth but are mostly enhanced and encouraged by the process, factors and features of urban change alongside inadequate urban planning and management (Ajibade et al., 2015; Aliyu & Amadu, 2017; Collier & Venables, 2016; Farinmade et al., 2018). Thereby, the city is predisposed to external shocks and stresses that put millions of its residents in jeopardy and worsen the conditions of the urban poor that are the most vulnerable (Filho et al., 2018; Grasham et al., 2019; UN-Habitat, 2015).

5. Lagos Megacity, changing climate and its water insecurity

Climate variability and change is expected to increase the propensity for flooding in coastal cities such as Lagos Mega-city. The city's enlargement and growth have been accompanied by growing impervious surfaces that encourage the rate of buildup of water at the ground surface than the rate of percolation thereby increasing runoff under high-intensity rainfall and enhancing the severity of flooding (Adelekan, 2016; Elias, 2018; Israel, 2017). Also, the incidences of flooding are intensified in the city because of irregulated urban planning that allows the erection of building on flood plain and coastlines with no adherence to stipulated boundaries (Adelekan & Asiyanbi, 2015; Kasim et al., 2022; Wahab & Ojolowo, 2017). Data from the Lagos State Ministry of Environment indicated that 1,403 streets out of the 7,857 which is approximately 17.9% in the city are prone to flooding (LOSMOE, 2014; Ojolowo & Wahab, 2017). So in the city, excessive flooding at many times has led to insecurity, public health concerns, negative socio-economy, property damage, and sometimes loss of lives in affected urban communities and cities (Adelekan & Asiyanbi, 2015; Cirella & Iyalomhe, 2018; Nkwunonwo, 2017). It also disrupts community lifestyles, societal activities, and negatively impacts urban food security (Nkwunonwo et al., 2016). Consequently, flooding in the city is becoming a significant stressor and threat to its sustainable urban water security. For example, one of the highbrow communities in the city, 'Lagos Island' is exposed to potential coastal flooding and beach erosions because of its being below 0.15m above the sea level (Birkmann et al., 2016).

However, the exposure and increasing vulnerability of the city's residents may also be influenced by their social and economic challenges with negative influence on its urban water security (Elias, 2018; Filho et al., 2018; Grasham et al., 2019). Such socio-economic factors include widespread poverty, high levels of unemployment and, low-income earnings of most of the residents which cannot match the exorbitant house rents in a physically stable environment creating an avenue for informal settlements in hazardous places such as marginal lands, low lying, and wetlands, etc.(Ajibade et al., 2017; Lukeman et al., 2014; Sojobi et al., 2016). Records indicate that about two-thirds of Lagos residents live in slums and marginal areas that are not serviced by basic urban amenities which include urban piped-water (Cheeseman & Gramont, 2017; Gbadegesin et al., 2016). Such slums in the city include some communities in Amukoko, Makoko, Itire, Ketu, Badiya, Oyingbo, Ajegunle, Ijeshatedo, Iwaya, etc. Also, only about 10% of Lagos residents have access to wholesome piped-borne water from the city water corporation while 90% depends on water vendors, wells and boreholes (Olaniyi et al., 2023). Meehem et al., (2020) emphasizes that secure water is a critical element of health and sustainable communities and also basic human right but infrastructural inequalities such as the case of plumbing deficiencies reflects structural inequalities.

Olaniyi et al., (2023) surmises that Lagos Mega-city industrialization alongside its rapidly increasing population with huge waste generation, inadequate sewerage systems and its coastal belt saline incursion into the coastline contribute to its increasing water resource contamination. This is basically because economic growth alongside rising population outpaced piped-borne water supplies (Danert & Healy, 2021). Reckien et al. (2017) affirm that living in environmentally riskier areas without adequate risk-reducing and management measures enhances the vulnerability of the society mostly the poor to risks of water insecurity. Hence, the increasing vulnerability of the city residents may be compounded by changing climate and its variability.

Also, the practice of reclamations of land is a common phenomenon in the Mega-city. Basically, extensive parts of the foremost Lagos town which are Lagos Island, Lekki, and Victoria Island are reclaimed land from the wetland (Adegboyega et al., 2017; Idowu & Home, 2017). Hence, towards the end of the last century, two high brows residential areas, Dolphin and Banana estates on Lagos Island were also developed or reclaimed from the lagoon (Adejumo, 2019). This practice of land reclamation is presently becoming more intense in Lekki, and Ajah axes of the mega-city, for the sake of accommodating the unending growing population and creating room for development. For example, the prime city project termed Eko Atlantic City project has reclaimed 6.66km^2 of land from the Atlantic Ocean as of January 2017 (Sengupta et al., 2017). Idowu and Home (2015) and Sengupta et al. (2017) surmises that reclamations could trigger environmental imbalance that may predispose cities to adverse effects of climate variability and change which include water insecurity.

6. Conclusion

Water is an environmental resource of inestimable value which is essential for sustainable living. However, the risk of inadequate management of water resources in every urban society may be hazardous and fatal. Rapid urbanization and growth in cities alongside climate variability and change increase the threats and stresses of urban water resources. So, the design of the concept of urban water security by academia and policymakers supports the sustainable management of water resources in cities and protect residents and facilities from its risks and dangers. Therefore, urban water security paradigm supports the assessments of stressors and threats to city water resources and advocates the sustainable approaches that will inspire its sustainable management.

This study affirms the vulnerability of Lagos mega-city to climate variability and change with negative implications on its water resources. . This is because, climate variability and changing climate may multiply and enhance its threat and stress on urban residents and infrastructure through excessive rainfall that could culminate in flooding and coastal erosion in Lagos Mega-city and other coastal cities that are ill-

prepared for the rapid urbanization they are witnessing. Therefore, the study advocates that urban societies and cities need to adopt and align with the paradigm and tenets of urban water security as part of their sustainable environmental security and sustainability approaches expected to boost their urban growth and sustainable development. This is on the basis that adequate urban water security is indispensable for humans and societal sustainability.

References

[1] Aboelnga, H. T., Ribbe, L., Frechen, F. B., & Saghir, J. (2019). Urban Water Security: Definition and Assessment Framework. Resources, 8(178), 1–19. https://doi.org/10.3390/resources8040178.

[2] Adama, O. (2018). Urban imaginaries: funding mega infrastructure projects in Lagos, Nigeria. GeoJournal, 83(2), 257–274. https://doi.org/10.1007/s10708-016-9761-8.

[3] Adegboyega, S. A., Oloukoi, J., Olajuyigbe, A. E. & Ajibade, O. E. (2017). Evaluation of unsustainable land use/land cover change on ecosystem services in coastal area of Lagos State, Nigeria. Applied Geomatics (Springer). https://doi.org/10.1007/s12518-018-0242-2.

[4] Adelekan, I. O. (2016). Flood risk management in the coastal city of Lagos, Nigeria. Journal of Flood Risk Management, 9(3), 255–264. https://doi.org/10.1111/jfr3.12179.

[5] Adelekan, I. O., & Asiyanbi, A. P. (2015). Flood risk perception in flood-affected communities in Lagos, Nigeria. Natural Hazards. https://doi.org/10.1007/s11069-015-1977-2.

[6] Adejumo, T.O (2019). Valorization of Sand Barrier-Lagoon Ecological Assets in Lagos Smart City Conceptualization. Chapter in the Book: African Smart City Agenda. Leke Oduwaiye, Taibat Lawanson and Victor Onifade (Ed). University of Lagos Press. Faculty of Environmental Sciences. University of Lagos, Lagos. Nigeria. Pp 140-159.

[7] Ajibade, I., Armah, F. A., Kuuire, V. Z., Mcbean, G., Tenkorang, E. Y., Ajibade, I., … Tenkorang, E. Y. (2015). Assessing the bio-psychosocial correlates of flood impacts in coastal areas of Lagos, Nigeria. Journal of Environmental Planning and Management, 58(3), 445–463. https://doi.org/10.1080/09640568.2013.861811.

[8] Ajibade, I., Pelling, M., Agboola, J., & Garschagen, M. (2017). Sustainability Transitions : Exploring Risk Management and the Future of Adaptation in the Megacity of Lagos. J.Extreme Events, 3(3), 1–25. https://doi.org/10.1142/S2345737616500093.

[9] Akanle, O., & Adejare, G. S. (2017). Conceptualising megacities and megaslums in Lagos, Nigeria Urban ecology and Marxian. Africa's Public Service Delivery and Performance Review, 5(1), 1–9. https://doi.org/10.4102/apsdpr.v5i1.155.

[10] Akiyode, O. O., Tumushabe, A. & Abdu, Y. A. (2017). Urban environmental security in a continuously growing in Sub-Saharan Africa in the climate change era : A case of Kampala, Uganda. American Journal of Environmental Policy and Management, 3(4), 24–30.

[11] Aliyu, A. A., & Amadu, L. (2017). Urbanization, Cities, and Health: The Challenges to Nigeria – A Review. Annals of African Medicine, 16(4), 149–158. https://doi.org/10.4103/aam.aam_1_17.

[12] Allan, J. V, Kenway, S. J., & Head, B. W. (2019). Urban water security-what does it mean? Urban Water Journal, 1–12. https://doi.org/10.1080/1573062X.2019.1574843.

[13] Awumbila, M. (2017). Drivers of Migration and Urbanization in Africa: Key Trends and Issues Drivers of Migration and Urbanization in Africa: Key Trends and Issues. Population Division Department of Economic and Social Affairs of United Nations Secretariat New York, 7-8 September. Retrieved from http://www.un.org/en/development/desa/population/events/pdf/expert/27/papers/III/paper-Awunbila-final.pdf.

[14] Ayeni, A. O., Omojola, A. S., & Fasona, M. J. (2016). Urbanization and Water Supply in Lagos State, Nigeria: the Challenges in a Climate Change Scenario. In 7th International Water Resources Management Conference of ICWRS, 18-20 May 2016, Ochum, Germany.

[15] Baker, J. L. (Ed.). (2012). Climate change risk, and the urban poor: Cities Building Resilience for a Changing World (Urban Deve). Washington D.C.: The World Bank. https://doi.org/10.1596/978-0-8213-8845-7.

[16] Birkmann, J., Agboola, J. I., Welle, T., Ahove, M., Odunuga, S., Streit, J. von, & Mark, P. (2016). Vulnerability, Resilience and Transformation of Urban Areas in the Coastal Megacity Lagos : Findings of Local Assessments and a Household Survey in Highly Exposed Areas. J.Extreme Events, 3(3), 1–24. https://doi.org/10.1142/S2345737616500196.

[17] Charles, K. J., Octavianti, T., Hylton, E., & Remmington, G. (2020). Equity and Urban Water Security. In S. J. Dadson, D. E. Garrick, Edmund C. Penning-Rowsell, J. W. Hall, R. Hope, & J. Hughes (Eds.), Water Science, Policy, and Management: A Global Challenge (First Edit, pp. 329–343). John Wiley & Sons Ltd. https://doi.org/10.1002/9781119520627.ch18.

[18] Cheeseman, N., & Gramont, D. D. (2017). Managing a mega-city: Learning the lessons from Lagos Managing a mega-city : learning the lessons from Lagos. Oxford Review of Economic Policy, 33(3), 457–477. https://doi.org/10.1093/oxrep/grx033.

[19] Cirella, G. T., & Iyalomhe, F. O. (2018). Flooding Conceptual Review: Sustainability-Focalized Best Practices in Nigeria. Appli. Sci., 8(1558), 1–14. https://doi.org/10.3390/app8091558.

[20] Cobbinah, P. B., Erdiaw-kwasie, M. O., & Amoateng, P. (2015). Africa's urbanisation: Implications for sustainable development. Cities. https://doi.org/10.1016/j.cities.2015.03.013.

[21] Collier, P., & Venables, A. J. (2016). Urban infrastructure for development. Oxford Review of Economic Policy, 32(3), 391–409. https://doi.org/10.1093/oxrep/grw016.

[22] Danert, K. & Healy, A. (2021). Monitoring groundwater use as a domestic water source by urban households: analysis data from L:agos State, Nigeria and Sub-Saharan African with implications for policy and practise. Water, 13, 56. https://doi.org/10.3390/w13040568.

[23] Dano, U. L., Balogun, A., Abubakar, I. R., & Aina, Y. A. (2019). Transformative urban governance: confronting urbanization challenges with geospatial technologies in Lagos, Nigeria. GeoJournal. https://doi.org/10.1007/s10708-019-10009-1.

[24] Dou, M., Shi, Y., & Li, G. (2019). Optimized urban water security regulation schemes driven by industrial development pattern. Water Policy, 1–16. https://doi.org/10.2166/wp.2019.198.

[25] Elias, P. (2018). The Challenges of Climate Change Communication for Lagos Coastal Communities. Climate Change Management, 2, 129–145. https://doi.org/10.1007/978-3-319-70066-3_10.

[26] Farinmade, A., Soyinka, O., Wai, K., & Siu, M. (2018). Assessing the effect of urban informal economic activity on the quality of the built environment for sustainable urban development in Lagos, Nigeria. Sustainable Cities and Society, 41(June 2017), 13–21. https://doi.org/10.1016/j.scs.2018.05.020.

[27] Farrell, K. (2018). An Inquiry into the Nature and Causes of Nigeria's Rapid Urban Transition. Urban Forum, 29, 277–298. https://doi.org/10.1007/s12132-018-9335-6.

[28] Filho, W. L., Balogun, A. L., Ayal, D. Y., Bethurem, E. M., Murambadoro, M., Mambo, J., … Mugabe, P. (2018). Strengthening climate change adaptation capacity in Africa- case studies from six major African cities and policy implications. Environmental Science and Policy, 86, 29–37. https://doi.org/10.1016/j.envsci.2018.05.004.

[29] Gadzalo, Y., Romashchenko, M., & Yatsiuk, M. (2018). Conceptual framework to ensure water security in Ukraine. In International Association of Hydrological Sciences (IAHS) (Vol. 3, pp. 63–68). https://doi.org/10.5194/piahs-376-63-2018.

[30] Gbadegesin, J. T., Heijden, H. Van Der, & Boelhouwer, P. (2016). Land Accessibility Factors in Urban Housing Provision in Nigeria Cities: Case of Lagos. In ENHR2016: the European Network for Housing Research Conference, Territory and Housing (pp. 1–15).

[31] Gerlak, A. K., House-Peters, L., Varady, R. G., Albrecht, T., Zúñiga-Terán, A., de Grenade, R. R., … Scott, C. A. (2018). Water security: A review of place-based research. Environmental Science and Policy, 82(October 2017), 79–89. https://doi.org/10.1016/j.envsci.2018.01.009.

[32] Grasham, C. F., Korzenevica, M., & Charles, K. J. (2019). On considering climate resilience in urban water security: A review of the vulnerability of the urban poor in sub-Saharan Africa. WIREs Water, 1–11. https://doi.org/10.1002/wat2.1344.

[33] Gunda, T., Hess, D., Hornberger, G. M., & Worland, S. (2019). Water security in practice: The quantity-quality-society nexus. Water Security, 6. https://doi.org/10.1016/j.wasec.2018.100022.

[34] Gökçeku¸H.; Bolouri, F. (2023). Transboundary waters and their status in today's water-scarce World. Sustainability, 15, 4234. https://doi.org/10.3390/su15054234.

[35] Hoekstra, A. Y., Buurman, J., & van Ginkel, K. C. H. (2018). Urban water security: A review. Environmental Research Letters, 13, 1–14. https://doi.org/10.1088/1748-9326/aaba52.

[36] Huang, Y., Xu, L., Yin, H., Cai, Y., & Yang, Z. (2015). Dual-level material and psychological assessment of urban water security in a water-stressed coastal city. Sustainability (Switzerland), 7(4), 3900–3918. https://doi.org/10.3390/su7043900.

[37] Idowu, T. E., & Home, P. (2015). Probable effects of Sea level rise and land reclamation activities on coastland and wetlands. In The 2015 JKUAT Scientific Conference on Water, Energy, Environment and Climate (pp. 207–220).

[38] Israel, A. O. (2017). Nature, the built environment and perennial flooding in Lagos, Nigeria: The 2012 flood as a case study. Urban Climate. https://doi.org/10.1016/j.uclim.2017.06.009.

[39] Jaramillo, P., & Nazemi, A. (2017). Assessing urban water security under changing climate : Challenges and ways forward. Sustainable Cities and Society, (April), 1–12. https://doi.org/10.1016/j.scs.2017.04.005.

[40] Jensen, O., & Wu, H. (2018). Urban water security indicators: Development and pilot. Environmental Science and Policy, 83, 33–45. https://doi.org/10.1016/j.envsci.2018.02.003.

[41] Kasim, O. F., Wahab, B. & Oweniwe, M. F. (2022). Urban expansion and enhanced flood risk in Africa. The examples of Lagos. Environmental Hazards, 21(2). https://doi.org/10.1080/17477891.2021.1932404.

[42] LBS. (2017). Abstract of Local Government Statistics. Lagos Bureau of Statistics, Ministry of Economic Planning and Budget Secretariat Alausa, Ikeja, Lagos, Nigeria.

[43] LOSMOE. (2014). Number of Streets prone to flood. Drainage Department, Lagos State Ministry of Environment, Alausa.

[44] Lu, S., Bao, H., & Pan, H. (2016). Urban water security evaluation based on similarity measure model of Vague sets. International Journal of Hydrogen Energy, 1–7. https://doi.org/10.1016/j.ijhydene.2016.05.007.

[45] Lukeman, Y., Bako, A. J., Omole, F. K., Nwokoro, I. I. C., & Akinbogun, S. O. (2014). Socio-Economic Attributes of Residents of Slum and Shanty Areas of Lagos State, Nigeria. Mediterranean Journal of Social Sciences, 5(9), 656–662. https://doi.org/10.5901/mjss.2014.v5n9p656.

[46] Mberu, B., Béguy, D., & Ezeh, A. C. (2017). Internal Migration, Urbanization and Slums in Sub-Saharan Africa. In H. Groth & J. May (Eds.), In Search of a Demographic Dividend (pp. 315–332). Springer, Cham. https://doi.org/10.1007/978-3-319-46889-1.

[47] Mcdonald, R. I., Weber, K., Padowski, J., Flo, M., Schneider, C., Green, P. A., … Boucher, T. (2014). Water on an urban planet: Urbanization and the reach of urban water infrastructure. Global Environmental Change, 27, 96–105. https://doi.org/10.1016/j.gloenvcha.2014.04.022.

[48] Meehem, K., Jurjevich, J. R., Chun, M. M. J., Sherrill, J. (2020). Geographies of insecure water access and the housing-water nexus in US cities. PNAS, 117(46). https://doi.org/10.1073/pnas.2007361117.

[49] Meza, F. J. ., Vicuña, S., Jelinek, M., Bustos, E., & Bonelli, S. (2014). Assessing water demands and coverage sensitivity to climate change in the urban and rural sectors in central Chile. Journal of Water and Climate Change, 5(2), 192–203. https://doi.org/10.2166/wcc.2014.019.

[50] Mishra, B. K., Kumar, P., Saraswat, C., Chakraborty, S. & Gautam, A. (2021). Water security in a changing environment concept, challenges and solutions. Water2021, 13,490. https://doi.org/10.3390/w13040490.

[51] Nazemi, A., & Madani, K. (2017). Urban Water Security: Emerging Discussion and Remaining Challenges. Sustainable Cities and Society. https://doi.org/10.1016/j.scs.2017.09.011.

[52] Nicholls, R. J., Hanson, S., Herweijer, C., Corfee-Morlot, J., Château, J., & Muir-Wood, R. (2008). Ranking Port Cities with High Exposure and Vulnerability to Climate Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposures Estimates. OECD Publishing. https://doi.org/10.1787/011766488208.

[53] Nkwunonwo, U. C. (2017). Assessment of Social Vulnerability for Efficient Management of Urban Pluvial Flooding in the Lagos Metropolis of Nigeria. Journal of Environmental Studies, 3(1), 1–11. https://doi.org/10.13188/2471-4879.1000014.

[54] Nkwunonwo, U. C., Whitworth, M., & Baily, B. (2016). A review and critical analysis of the efforts towards urban flood risk management in the Lagos region of Nigeria. Nat. Hazards Earth Syst. Sci., 16(349), 369. https://doi.org/10.5194/nhess-16-349-2016.

[55] Odunuga, S., Badru, G., & Bello, O. M. (2014). Climate change, sea level rise and coastal inundation along part of Nigeria Barrier Lagoon Coast. J. Appl. Sci. Manage. and Environmental Science, 18(1), 41–47. https://doi.org/10.4314/jasem.v18i1.6.

[56] Ojolowo, S., & Wahab, B. (2017). Municipal solid waste and flooding in Lagos metropolis , Nigeria: Deconstructing the evil nexus. Journal of Geography and Regional Planning, 10(7), 174–185. https://doi.org/10.5897/JGRP2016.0614.

[57] Olaniyi, T. K., Nwankwo, N. & Idahose, U. E. (2023). Assessment of health, safety and environmental management in the Global South: a case study of Lagos, Federal Republic of Nigeria. International Journal of e-Healthcare Information System, 9(1), 239-249. https://doi.org/10.20533/ijehis.2046.3332.2023.0032.

[58] Pandey, C. L. (2020). Managing urban water security: challenges and prospects in Nepal. Environment, Development and Sustainability. https://doi.org/10.1007/s10668-019-00577-0.

[59] Reckien, D., Creutzig, F., Fernandez, B., Lwasa, S., Tovar-restrepo, M., & Satterthwaite, D. (2017). Climate change, equity and the Sustainable Development Goals: an urban perspective. Environment & Urbanization, 29(1), 159–182. https://doi.org/10.1177/0956247816677778.

[60] Romero-lankao, P., & Gnatz, D. M. (2016). ScienceDirect Conceptualizing urban water security in an urbanizing world. Current Opinion in Environmental Sustainability, 21, 45–51. https://doi.org/10.1016/j.cosust.2016.11.002.

[61] Sartipi, M. & Sartipi, F. (2019). Stormwater retention using pervious concrete pavement: Great Western Sydney case study. Case Studies in Construction Materials. https://doi.org/10.1016/j.cscm.2019.e00274.

[62] Sadoff, C. W., Borgomeo, E., & Waal, D. de. (2017). Turbulent Waters: Pursuing Water Security in Fragile Contexts (Water Glob). World Bank Group. https://doi.org/10.1596/26207.

[63] Santos, S. Dos, Adams, E., Neville, G., Wada, Y., Sherbinin, A. De, Bernhardt, M., … Sherbinin, A. De. (2018). Urban growth and water access in sub-Saharan Africa: Progress , challenges, and emerging research directions. Science of the Total Environment, Elseiver., 497–508. https://doi.org/10.1016/j.scitotenv.2017.06.157.

[64] Sengupta, D., Chen, R., & Meadows, M. E. (2017). Building beyond land : An overview of coastal land reclamation in 16 global megacities Building beyond land : An overview of coastal land reclamation in 16 global megacities. Applied Geography, 90(December), 229–238. https://doi.org/10.1016/j.apgeog.2017.12.015.

[65] Sojobi, A. O., Balogun, I. I., & Salami, A. W. (2016). Climate change in Lagos State, Nigeria: what really changed? Environmental Monitoring and Assessment, 188(556), 1–42. https://doi.org/10.1007/s10661-016-5549-z.

[66] Soyinka, O., Wai, K., & Siu, M. (2018). Urban Informality and Infrastructure Planning in Hong Kong and Lagos Metropolis : Professionals Perspectives. Advances in Human Factors, Sustainable Urban Planning and Infrastructure, Advances in Intelligent Systems and Computing 600, 282–292. https://doi.org/10.1007/978-3-319-60450-3.

[67] Staddon, C., & Scott, C. A. (2018). Putting water security to work: addressing global challenges. Water International, 43(8), 1017–1025. https://doi.org/10.1080/02508060.2018.1550353.

[68] Toka, S. O. (2022). Geospatial assessment of land use/ cover rainfall. and flood incidents in Eti-Osa, Lagos, Nigeria. South African Journal of Geomatics, 11(2), 202-217. https://doi.org/10.4314/sajg.v11i2.3.

[69] UN-Habitat. (2015). Guiding Principles for City Climate Action Planning. UN-Habitat.

[70] United Nations. (2016). The World's Cities in 2016: Data Booklet (ST/ESA/SER.A/392). United Nations, Department of Economic and Social Affairs, Population Division (2016). The World's Cities in 2016 – Data Booklet (ST/ESA/ SER.A/392). https://doi.org/10.18356/8519891f-en.

[71] United Nations. (2018a). Word Urbanization Prospects: The 2018 Revision (key Facts). Word Urbanization Prospects: The 2018 Revision (Key Facts). United Nations. Department of Economic and Social Affairs. Population Division. Retrieved from https://population.un.org/wup/Publications/Files/WUP2018-KeyFacts.pdf.

[72] United Nations. (2018b). The World's cities in 2018. Data Booklet (ST/ESA/SER.A/417). United Nations, Department of Economic and Social Affairs, Population Division.

[73] van Ginkel, K. C. H., Hoekstra, A. Y., Buurman, J., & Hogeboom, R. J. (2018). Urban Water Security Dashboard: Systems Approach to Characterizing the Water Security of Cities. J. Water Resour. Plann. Manage, 144(12), 1–11. https://doi.org/10.1061/(ASCE)WR.1943-5452.0000997.

[74] Varady, R. G., Zuniga-teran, A. A., Garfin, G. M., Martin, F., & Vicuna, S. (2016). Adaptive management and water security in a global context: definitions, concepts, and examples. Current Opinion in Environmental Sustainability, 21, 70–77. https://doi.org/10.1016/j.cosust.2016.11.001.

[75] Wahab, B., & Ojolowo, S. (2017). Building contraventions and incidence of flood in the Lagos Metropolis, Nigeria. Journal of Environmental Planning and Management, 1–21. https://doi.org/10.1080/09640568.2017.1311249.

[76] Wang, J., & Maduako, I. N. (2018). Spatio-temporal urban growth dynamics of Lagos Metropolitan Region of Nigeria based on Hybrid methods for LULC modeling and prediction. European Journal of Remote Sensing, 51(1), 251–265. https://doi.org/10.1080/22797254.2017.1419831.

[77] Wheater, H. S., & Gober, P. (2015). Water Security and the Science Agenda. Water Resour. Res., 51, 5406–5424. https://doi.org/10.1002/2015WR016892.

[78] Wolff, E., Grippa, T., Forget, Y., Georganos, S., Shimoni, M., & Linard, C. (2019). Diversity of urban growth patterns in Sub-Saharan Africa in the 1960-2010 Diversity of urban growth patterns in Sub-Saharan Africa in the 1960 – 2010 period. African Geographical Review, 1–13. https://doi.org/10.1080/19376812.2019.1579656.

[79] Wong, P. P., Losada, I. J., Gattuso, J.-P., Hinkel, J., Khattabi, A., McInnes, K. L., … Sallenger, A. (2014). Coastal systems and low-lying areas. In C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, … L. . White (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 361–409). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

[80] Zadawa, A. N., & Omran, A. (2018). Climate Change and Water Security Issues in Africa: Introducing Partnership Procurement for Sustainable Water Projects in Nigeria. The Impact of Climate Change on Our Life. Springer Nature Pte Ltd. https://doi.org/10.1007/978-981-10-7748-7_6.

[81] Zhang, X. Q. (2015). The trends, promises and challenges of urbanization in the world. Habitat International, (13). https://doi.org/10.1016/j.habitatint.2015.11.018.