Lagos floods

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2021/2022

Interconnected Disaster Risks

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1. Introduction

In July 2021, major floods hit the centre of Lagos, Nigeria, one of Africa's biggest cities, submerging cars and houses and bringing many parts of the metropolis to a standstill. Lagos is a low-lying city with a flat topography and many areas at or below sea level, with an average elevation of only 1.5 m above sea level (Ajibade, 2017), Lagos is sinking at a rate of up to ~87 mm per year (Ikuemonisan and Ozebo, 2020), meaning that the sea is increasingly encroaching at the city's edges. Low elevation and sinking land combined with massive drainage problems due to waste-clogged drainage systems mean that water is trapped and builds up quickly following heavy rainfall or storms (Adeloye and Rustum, 2011). Although images from news coverage of such a big city underwater were shocking, Lagos has in fact been facing increasingly severe flooding during both of its two annual rainy seasons with the April to July rains being the most intense (Ikuemonisan and Ozebo, 2020). The cost to Lagos in terms of damages, economic productivity and mortality is estimated to be as high as $4 billion per year (Croitoru and others, 2020).

To make matters worse, Lagos' low coastline is eroding as sea levels continue to rise, and storm surges exacerbate the flooding (Ajibade and others, 2016). Up to 84 per cent of the Lagos shoreline has washed away in the past 50 years, retreating at an average rate of 2.64 m per year (Osanyintuyi and others, 2022). This erosion is in part due to booming levels of urbanization and the sand mining trade that feeds it, both of which push both coastal ecosystems and communities that depend on them into increasingly vulnerable positions. If this trend of rising seas, flooding and coastal degradation continues, the habitability of the city itself could be under threat by the end of this century (Popoola, 2012). As well as being a present-day example of the vulnerability of climate change to coastal cities around the world, the floods in Lagos also highlight the threat of unregulated urbanization in exposed areas, and the often-overlooked cost of extracting resources to support it. In particular, the unregulated, unsustainable rush to dig up sand and the environmental and social impacts the construction industry causes in Lagos and around the world must be addressed.

2. Impacts

2.1 Infrastructure damage

Exact numbers related to flooding impacts at the city level in Nigeria are challenging to determine due to various issues around data collection and access (Lucas, 2021). However, frequent flooding in Lagos results in damage and destruction of critical infrastructure, homes, small businesses, schools, markets, roads, water facilities, communication networks, health centres, electric power poles and other public infrastructure (Lucas, 2021; Adegun, 2022; Odunuga and others, 2012) at an estimated cost of $22.2 million each year (InsuResilience Solutions Fund, 2021).

2.2 Ecosystem damage and biodiversity loss

In addition to the damage to human infrastructure, the annual flooding in Lagos and the drivers behind it result in impacts on biodiversity and local ecosystems. Flooding impacts local aquatic ecosystems by washing waste, polluted sediments and fertilizers from farmland into water bodies threatening the health of aquatic organisms (Echendu, 2020; Chukwu Okeah and others, 2018). In the nearby Niger Delta, region for example, water quality impacts due to flooding threaten fish productivity at local fishing ports (Chukwu Okeah and others, 2018).

2.3 Health impacts

Flooding in Lagos negatively affects human health through the contamination of water bodies and increasing incidences of waterborne diseases like malaria, cholera, typhoid, yellow fever, diarrhoea, leptospirosis and hepatitis A (Echendu, 2020; Olanrewaju and others, 2019). Due to the continuing overflow of raw sewage and waste dumps, wells and boreholes used for domestic purposes get contaminated, exacerbating the lack of access to fresh water in Lagos (Olanrewaju and others, 2019; Atufu and Holt, 2018; Anabaraonye and others, 2021).

2.4 Loss of life

There is a shortage of data on flood-related deaths in Lagos, meaning accurate and updated numbers are hard to come by; but it is known that they occur annually (Adelekan, 2016; Olanrewaju and others, 2019; Nkwunonwo and others, 2016). The World Bank estimates that 55 people died because of floods in Lagos in 2018 (Croitoru and others, 2020). In all of Nigeria, around 150 flood-related deaths occurred in 2020 (Usigbe, 2021) and 158 were recorded in 2019 (Nigeria Hydrological Services Agency (NIHSA), 2021). In Nigeria, the total number of flood-related deaths between 2011 and 2020 was 1,187 (Umar and Gray, 2022).

2.5 Water insecurity

Floods can impact water insecurity in Lagos in two ways. First, it contaminates water infrastructure, such as wells and municipal pipes, that supply drinking water for urban coastal communities in Lagos (Adelekan, 2010; Echendu, 2020). Second, floods contaminate safe drinking water sources, a problem already critical in Nigeria, where 63 million people lack access (Echendu, 2020). In Lagos, many of the communities living in informal settlements most vulnerable to flooding and with limited economic means also struggle with access to clean water and sanitation services (Aliu and others, 2021). Water insecurity resulting from floods is thus a threat to achieving Sustainable Development Goal 6 (SDG6) of the UN's 2030 Agenda (clean water and sanitation) as resulting pollution of water bodies and damage to sanitation facilities have cascading impacts on health in affected areas (Raimi and others, 2018; Olanrewaju and others, 2019). Recent reviews report that progress achieving SDG6 targets by 2030 will already be a major challenge for Nigeria and other sub-Saharan African countries (Kremere and others, 2019).

2.6 Migration / displacement

Given that flooding is an annual event in Lagos (Nkwunonwo and others, 2016), human displacement resulting from floods is not new. Around 90,000 inhabitants of Lagos are impacted by flooding annually (InsuResilience Solutions Fund, 2021), which resulted in approximately 4,000 residents being displaced by floods in 2021 (Usigbe, 2021). Many thousands more have been displaced due to floods in the past few decades. In 2012, for example, a particularly severe flood event in Lagos displaced an estimated 2 million people (Atufu and Holt, 2018).

3. Drivers

3.1 Slower, wetter and more frequent storms

One of the drivers of floods in Lagos is the increasing frequency and intensity of precipitation accelerated by climate change. Studies have shown more high-intensity, short-duration rainfall and more low-intensity, long-duration rainfall compared to 30 years ago (Odjugo, 2006; Nkwunonwo and others, 2016; Dike and others, 2020). These increasing rainfall rates threaten to exceed the absorption capacity of Lagos City and its drainage system, leading to increased flood risk. Additionally, climate is likely to drive an increase in the frequency of one- to five-day extreme rainfall events and wind speeds that will subsequently lead to pluvial flooding (Intergovernmental Panel on Climate Change (IPCC), 2021a). Rainfall in Lagos is predicted to increase in 2022 to 1,750 mm from 1,627 mm the previous year (Nigerian Meteorological Agency (NiMet), 2022).

3.2 Sea level rise

The city of Lagos is bordered by several freshwater streams, a lagoon and the Atlantic Ocean. Its geographical location combined with its relatively flat topography and an average elevation of only 1.5 m above sea level (Ajibade and others, 2016) make this megacity vulnerable to coastal flooding, which will be exacerbated by the rising sea level (Odunuga and others, 2014; Obiefuna and others, 2021; Kaoje and Ishiaku, 2017). Sea level rise does show regional differences on Earth, and the coastline of Nigeria will see above average changes in sea level. Sea level projections for the region of Lagos in the most recent IPCC report show by 2100 a 54-cm sea level rise under the RCP4.5 scenario and a 75-cm rise under the RCP8.5 scenario (Figure 1) (IPCC, 2022). In Lagos, regional sea level rise combines with widespread subsidence (sinking of the land) mainly caused by groundwater extraction and urbanization, with subsidence rates varying between 2 and 87 mm per year across the city and shown to be highest in coastal areas and in areas where heavy buildings are placed on landfills (Ikuemonisan and Ozebo, 2020). The combined effects of subsidence and sea level rise in the region mean that an increase in global warming of more than 2°C could lead to a relative sea level rise of more than 90 cm in Lagos by the year 2100 (IPCC, 2013; Jevrejeva and others, 2016; Bamber and others, 2019; Johnson, 2021).

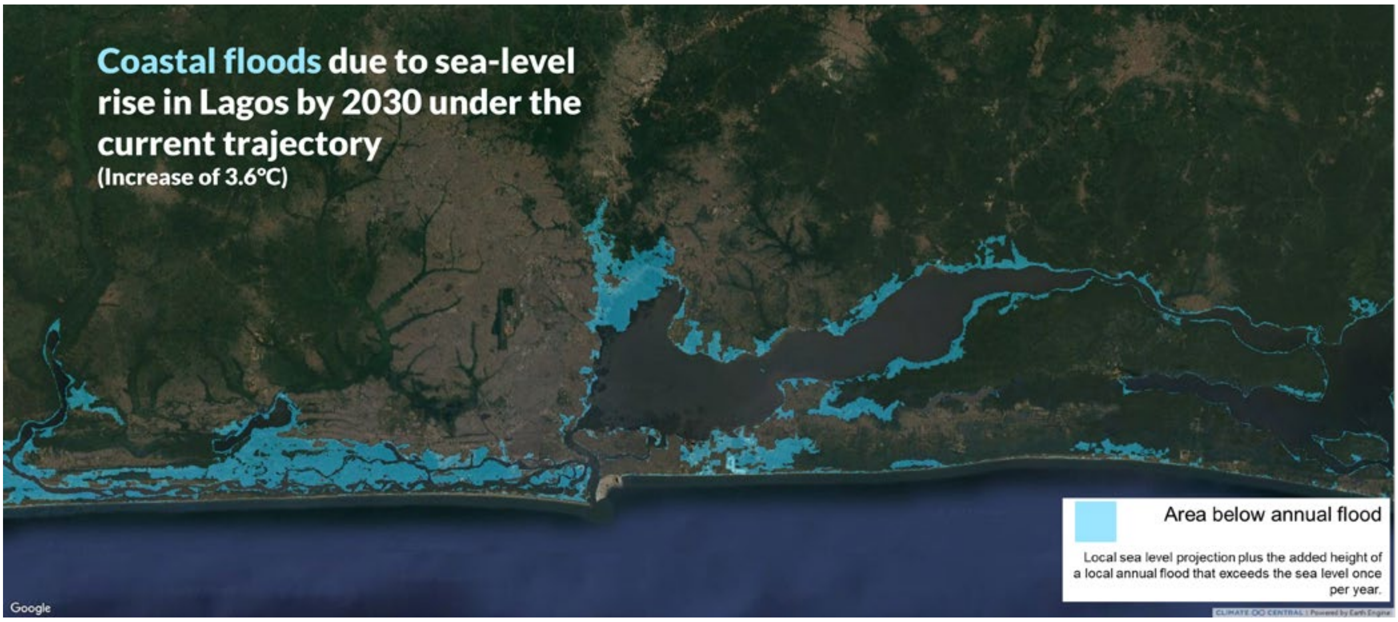

Figure 1: Coastal floods due to sea level rise in Lagos by 2030 SSP3.0-7 (extracted from Climate Central, 2021)

3.3 Sand mining

Sand resources, including sand, gravel, crushed stone and aggregates (United Nations Environment Programme (UNEP), 2022), are mined along the coast of Lagos for the construction of roads and building, contributing to the erosion of the coastline (Agence France-Presse, 2019). Lagos consumes approximately 40 million m^3 of sand per year in construction projects alone (Adebayo, 2017) to develop the buildings and key infrastructure required to operate as the industrial, financial and administrative centre of Nigeria and Africa (United Nations Human Settlements Programme (UN-Habitat), 2018).

Along the coastal region of Lagos, sand mining is big business and has become the livelihood for many, involving a variety of actors, ranging from big companies to informal artisanal and small-scale miners (Aliu and others, 2022). Even though a few sand mining operators are licensed, most are unauthorized citizens who mine sand illegally from waterfront settlements (Rageh, 2014). Given the lack of regulations and the limited monitoring and enforcement capacity of local authorities (UNEP, 2022), some actors have exploited sand deposits without control, leading to significant environmental impacts, such as coastal and river erosion, and groundwater salinization (UNEP, 2019). An analysis of 14 sand mining operations in Lagos showed that each site dredges over 16 tons of sand per day from coastal areas (Aliu and others, 2022), which becomes a massive amount when considering the hundreds of extraction spots around the city.

The unsustainable dredging of sands is causing the loss of water habitats, destruction of wetlands, weakening of the seabed, loss of fishes, loss of livelihoods, coastal erosion and increasing perennial flooding in the communities that are bordered by the lagoon and Atlantic Ocean (Aliu and others, 2022; Adekunbi and others, 2018). As a result, communities – even those distant from mining activities – face risks not only of flooding but also of landslides and subsidence, among other hazards.

Sand miners in Lagos. (Image credit: Sebastian Barros)

3.4 Urbanization in hazard-prone areas

The yearly flood occurrence in Lagos is attributed to increasing development and urban expansion – encroachment on natural water channels, unregulated land reclamation and sand-filling of lagoons (Wahab and Ojolowo, 2018; Johnson, 2021) – as well as historical dredging and sea reclamation to increase the urban territory (Whiteman, 2012). As of the year 2019, the built-up areas accounted for about 50 per cent of land use in Lagos, twice as much as there was in 2000 (Figure 2) (Kasim and others, 2021). This change has subsequently increased the areas vulnerable to flooding from 1 per cent of the city in 2000 to nearly 35 per cent in 2019 (Kasim and others, 2021). As Lagos is already a very congested city, its annual population growth of 5.7 per cent, inadequate law enforcement, regulations, poor land-use planning and the creation of informal settlements have led to development in wetlands and waterways, replacing natural drainage systems with impervious surfaces and bringing people into areas with high flood risk (Adelekan, 2010; Adeloye and Rustum, 2011; Dano and others, 2020). Additionally, urbanization into wetland and floodplain areas is by far the biggest driver of loss of coastal ecosystems valuable for coastal protection and coping capacity of coastal communities. In the past decade alone, 59 per cent of the wetlands in Lagos have already been lost, attributable to urbanization, which is directly linked to the reduction of flood protection capacity and the worsening flood problem (Israel, 2021).

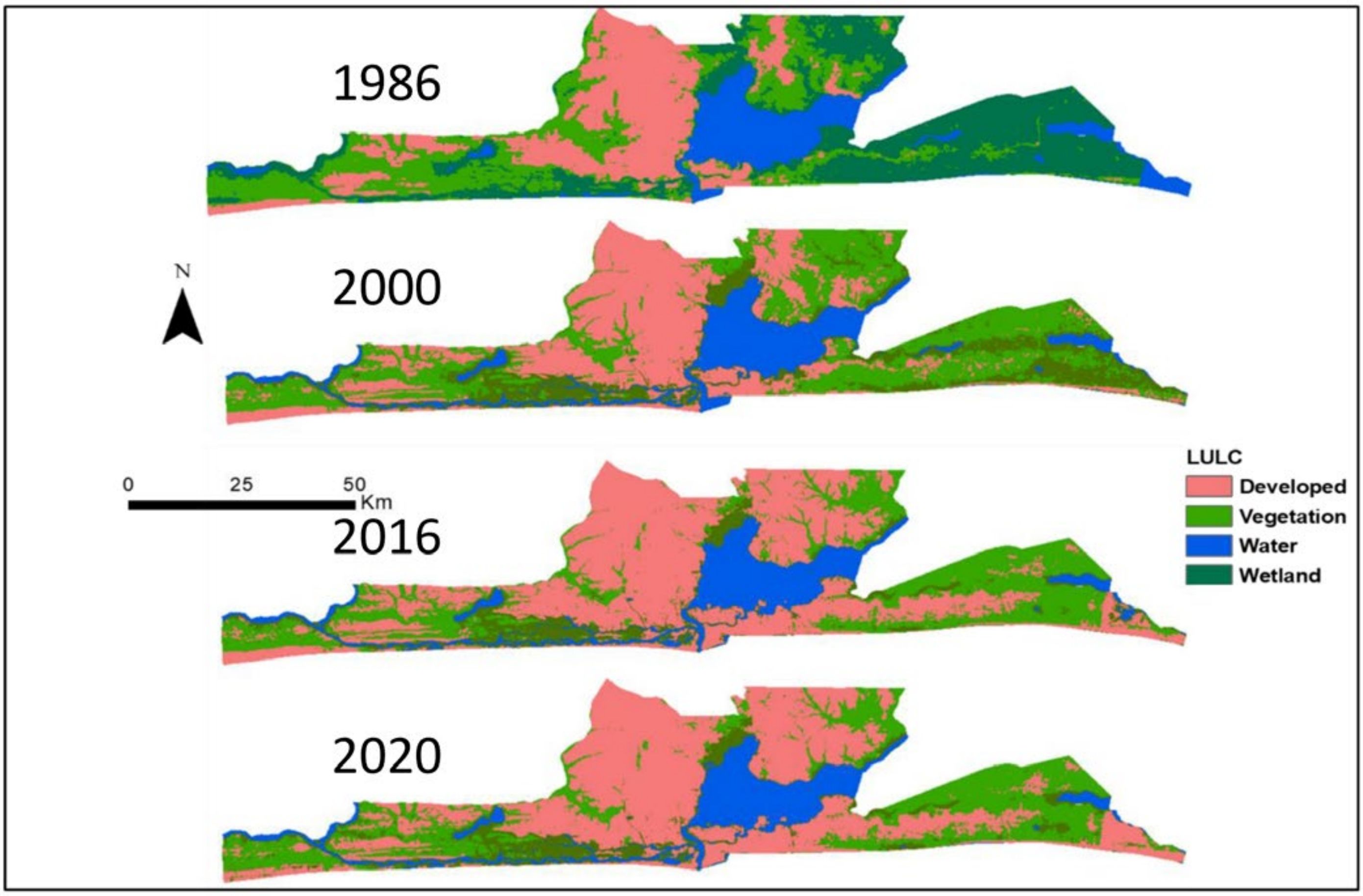

Figure 2: Extent of Land-Use Land Cover change in Lagos (adapted from Idowu and Zhou, 2021)

The unsustainable building patterns of Lagos are coupled with the large amount of waste generated (about 10,000 tons/day) that make the existing waste management system insufficient (Ojolowo and Wahab, 2017). In that sense, the almost 1,000 km^2 of Lagos, with its heavy traffic congestion and inaccessible areas (e.g. Makoko, which can only be accessed by canoe), make the frequency and coverage of the waste collection system unable to cope with the volume of waste generated (Ojolowo and Wahab, 2017; Ayantoyinbo and Adepoju, 2018). In response to this inefficiency and lack of waste disposal facilities, residents of Lagos often dump solid waste in drainage canals, ditches, vacant lots and bodies of water (Ayodele, 2017; Adelekan, 2016; Adewole, 2009). In fact, about 60 per cent of the garbage generated in the city is improperly disposed of (Ayodele, 2017; Ojolowo and Wahab, 2017). Consequently, the accumulation of waste impedes a rapid runoff discharge, contributing further to flooding (Adelekan, 2016; Olokesusi and others, 2015).

3.5 Insufficient early warning system

Flood early warning is one of the crucial aspects of flood disaster risk reduction if communicated effectively (Nkwunonwo, 2020). Despite the latest efforts of NiMet and NIHSA in improving the accuracy of its prediction and flood forecasting models, the early warning systems still have some serious limitations. For example, low access to high-quality and high-resolution data needed for flood vulnerability and risk assessment hinders the establishment of an effective early warning system (Lucas, 2021). Similarly, flood models and vulnerability assessments for Lagos are inaccurate considering that they lack calibration and validation with ground truthed data (Nkwunonwo and others, 2016; Nkwunonwo, 2020).

Moreover, the success of early warning systems depends largely on the effectiveness of risk communication. In the case of Nigeria, the need to integrate various risk communication methods using traditional, modern and digital communication systems, as well as adapting them to different cultural contexts and linguistic capabilities, has been emphasized as an urgently needed national improvement (Nkwunonwo, 2020). Particularly for Lagos, regular power outages in some parts of the city prevent warnings from reaching inhabitants in a timely manner, which contributes to the low effectiveness of government responses to manage flood events (Atufu and Holt, 2018). Also, when flood warnings are received by inhabitants, mistrust in official announcements contributes to not taking the necessary action to prepare for and respond to the predicted flooding (Olokesusi and others, 2015). This mistrust started in 1990, when the government used evacuation messages to evict slum residents on Victoria Island (Atufu and Holt, 2018; Ajibade and McBean, 2014). Furthermore, when messages are received, the lack of knowledge of some citizens about how to prepare for and react to floods coupled with unclear indications from the warning messages lead to inadequate responses with disastrous effects (Nkwunonwo, 2020; Adelekan, 2016).

4. Root causes

4.1 Human-induced greenhouse gas emissions

Human-induced greenhouse gas emissions and subsequent rises in ocean and atmospheric temperatures were the main drivers for the increasing global mean sea level since at least 1971. Global mean sea level had risen 20 cm by 2018 when compared to that in 1901 (IPCC, 2021b). Regional and local sea level change can strongly differ from the global mean, as processes such as land subsidence can contribute to relative sea level rise in those areas (see section 3.2, Sea level rise). Furthermore, climate change is responsible for increased monsoon precipitation, more frequent and intense rainfall patterns, and more recurrent pluvial floods in West Africa (IPCC, 2021a).

4.2 Global demand pressures

Around the world, the trend of growing cities and urban populations is fuelling a rampant demand for sand, making sand mining a lucrative option, particularly as sufficient regulation and environmental protection in mined areas is lacking. As such, sand is currently the world's second most used natural resource after water and is crucial for multiple economic sectors, particularly construction, which globally consumes between 15 and 29 billion tons of sand resources per year (Wesley and Puffer, 2019; UNEP, 2019). The global average sand demand per person per day is around 18 kg — 6,570 kg per year (Figure 3) (Hernandez and others, 2021). Although most of the extracted sand resources are consumed regionally due to the high cost of transportation (UNEP, 2014), sand dredged in Lagos has also been used for urban development and mega-projects in countries such as the United Arab Emirates (Adebayo, 2017). The staggering pace of the construction boom in Lagos is also bringing in materials not only from the local area but also from wider Nigeria and international sources like China, extending the reach of the mining impacts related to the city's urban growth (Olajide and Lawanson, 2021; Ugochukwu and others, 2014).

The coastal location of Lagos and the ecological dynamics occurring on its waterfront make it a preferred destination for sand miners. Lagos has the two sand sources relevant to the construction sector: on the one hand, sand from the seabed, which is mainly used for land reclamation; and on the other hand, sand from shorelines, rivers and lakes, which is ideal for construction material due to its shape and cut (Hernandez and others, 2021). Due to its quality and purity the price of sand dredged from the sea is approximately four times higher than sand shovelled from the coastline (Adebayo, 2017).

Considering that the construction industry is the most promising sector in Nigeria, with an expected annual growth of 3.2 per cent for the 2021-2025 period given its high infrastructure deficit and its 30-year National Integrated Infrastructure Master Plan 2014-2043 (ITA, 2021), several international companies have found in Lagos a fresh market and safe future for the expansion of their operations into Africa (Green Economy Media, 2019). In Nigeria, construction projects are driven by both government and private investors through public-private partnerships, which has allowed obtaining external loans of about $22 billion for the execution of the National Infrastructure Master Plan (International Trade Administration (ITA), 2021). From this perspective, the focus on economic and urban development in Lagos is fueled by international investments, highlighting the role of the international community in the environmental crises that the city and its marginalized sectors are facing. In 2021, most ($5.8 billion) of the $6.7 billion in Foreign Direct Investment for Nigeria poured into Lagos from countries like the United Kingdom, Mauritius, the United States and South Africa (with $1.64 million solely for construction) (National Bureau of Statistic (NBS), 2021). Likewise, foreign capital is flowing from countries like France, Canada, Germany, Italy, Saudi Arabia, the United Arab Emirates, Turkey, Egypt and China to other major sectors in Nigeria that require infrastructural development to operate in the national economy (Green Economy Media, 2019; Ihua-Maduenyi, 2019).

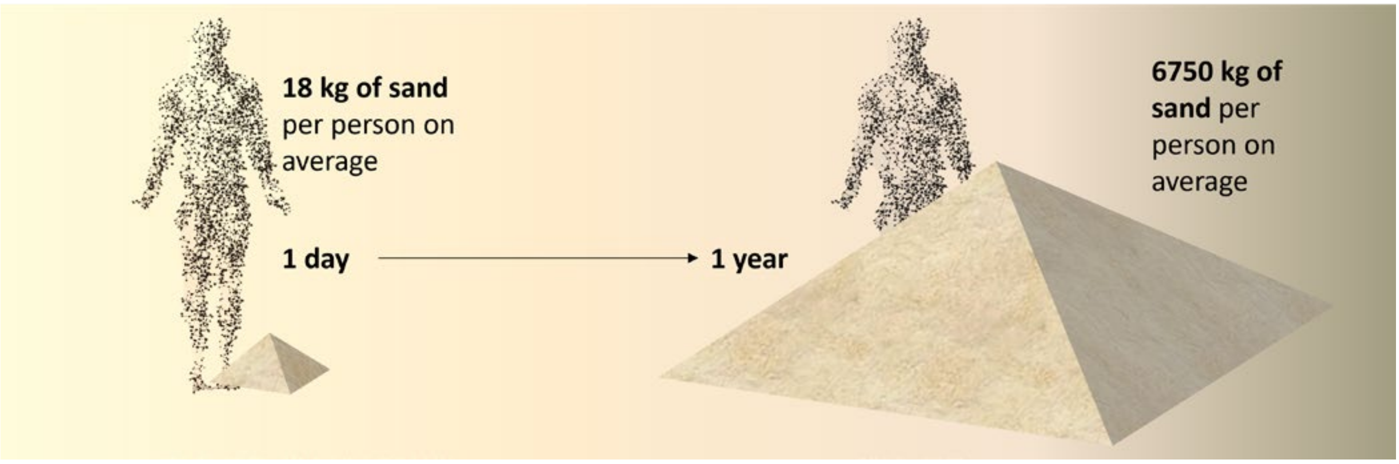

Figure 3: Average sand demand per person (based on Hernandez and others, 2021).

4.3 Inequality of development and livelihood opportunities

The population in Lagos is predicted to grow from around 15 million in 2022 to over 88 million in 2100 (Hoornweg and Pope, 2017), via “push factors” (migration out of rural areas to cities from lack of livelihood options or low wages) and “pull factors” (attracting migrants to cities through higher wages or urban lifestyle) (Aworemi and others, 2011). In a study on “coordinated migration” using Facebook-user data comparing home towns with current residences, Lagos ranked first in the world as a destination city, growing 18.6 per cent between 2000 and 2012, with 96 per cent of migrants coming from other parts of Nigeria (Okujala, 2014). The disparity between relative poverty and disadvantage in rural areas compared to urban areas, and the perceived neglect by the government in assisting with land reforms and agricultural productivity, have been cited as major catalysts for such migration, often bringing the rural poor into vulnerable positions in the city (Nwokocha, 2009; Emordi and Osiki, 2008).

An estimated three out of four Lagos citizens live in slum conditions (UN-Habitat, 2015). High living costs, unaffordable housing and unemployment has led about 70 per cent of the population of the Lagos metropolitan area to form over 100 slum communities (Adelekan, 2010; Dano and others, 2020). These informal urban neighbourhoods, often built in hazard-prone areas, lack adequate drainage and waste disposal systems, making them the most susceptible to frequent flooding (Adelekan, 2010). Also, areas in Lagos with lower socioeconomic status and higher gender inequality and levels of disability have less coping capacity and are thus more vulnerable to pluvial flooding (Nkwunonwo, 2017). Slum creation is exacerbated by the high social disparity and power imbalance between classes in Lagos society. One example is the case of Otodo Gbame, a fishing settlement of over 1,000 homes that was burned and destroyed by the authorities in 2017, leaving 4,700 residents homeless (Adebayo, 2017). Its proximity to Lekki and Ajah (booming real estate areas) and its privileged waterfront attracted the attention of building developers and sand dredgers, who were the main beneficiaries of the massive eviction (Adebayo, 2017; Bamidele, 2021).

Sand miners in Lagos. (Image credit: Sebastian Barros)

Sand mining is a lucrative industry and attracts many people, especially young people, looking to increase incomes and boost livelihoods. Thus, some of the residents living close to the coast who used to be farmers and fishermen turned towards sand mining as their sole means of livelihood, attracted by the revenue and economic gain from the burgeoning sand markets in Lagos (Aliu and others, 2022). Thus, inequality in Lagos has only created more risk-prone areas, prompting a vicious cycle of vulnerability (Adebayo, 2017; Bamidele, 2021).

4.4 Undervaluing environmental costs

Ecosystems across Nigeria are being degraded, inhibiting their capacity to buffer floods (NIHSA, 2021). Given the high demand for raw materials to make cement, concrete, glass and asphalt needed for infrastructure projects, the exploitation of sand resources is leading to an irreversible loss of natural barriers against rising sea levels and increasing storms (UNEP, 2022). Although sand resources play a strategic role in delivering ecosystem services, maintaining biodiversity and securing livelihoods within communities (UNEP, 2022), these resources are being exploited for development purposes (Adebayo, 2017). Sand mining has been highly responsible for habitat destruction, water pollution and increased water turbidity, which has severely impacted biodiversity (Adebayo, 2017; Adekunbi and others, 2018). Despite the environmental impacts, authorities are lax in controlling sand mining – especially unregulated miners – facilitating dredging in remote areas (Adebayo, 2017) and the growth of a business that degrades the environment at the same pace at which it spreads.

Additionally, from 1984 to 2013, land reclamation activities for urban development have reduced 6,717 ha of mangroves, 1,314 ha of wetlands and 1,740 ha of water bodies, eliminating natural flood control infrastructure. Although reclaimed lands are vulnerable to flooding and seawater resurgence, land reclamation in Lagos continues to increase at the expense of coastlines and wetlands (Adegboyega and others, 2019). For example, the Eko-Atlantic City project aims to build an island on 10 million m2 of land reclaimed from the Atlantic Ocean on the coast of Victoria Island, one of the most affluent neighbourhoods in Lagos (Ajibade, 2017). Although protected by a planned 8-km long seawall of concrete blocks dubbed "The Great Wall of Lagos," there is evidence that erosion is displaced further east along the coastline as a result, where some communities like Alpha Beach have experienced "catastrophic erosion" (Mendelsohn, 2018).

4.5 Insufficient risk governance

The first aspect of insufficient risk governance is the ineffective implementation of the national flood risk management plan, which is reflected in the gap in investments for climate change adaptation, the absence of risk-informed spatial planning (InsuResilience Solutions Fund, 2021; Dano and others, 2020) and a lack of inter-institutional coordination for flood emergency preparedness, management and response (Olanrewaju and others, 2019). Despite the various emergency response centres established by the National and State Emergency Management Agency, there are numerous gaps in the institutional response to flood victims in Lagos state, given the low capacity of response staff, lack of equipment, corruption and poor management (Ouikotan and others, 2017). Another aspect of governance that does not sufficiently factor in risk is the neo-liberal approach to land-use planning that facilitates the uncontrolled urbanization that drives vulnerability to flooding (Figure 4) (see section 3.4, Urbanization in hazard-prone areas). Despite having land-use plans and zoning regulations in place, real estate developers ignore planning restrictions and rules, erecting buildings on flood plains, the coastline and drainage ways (Adelekan, 2016; Adeloye and Rustum, 2011). This is coupled with scarce storm water systems and inadequate drainage structures (Adeloye and Rustum, 2011).

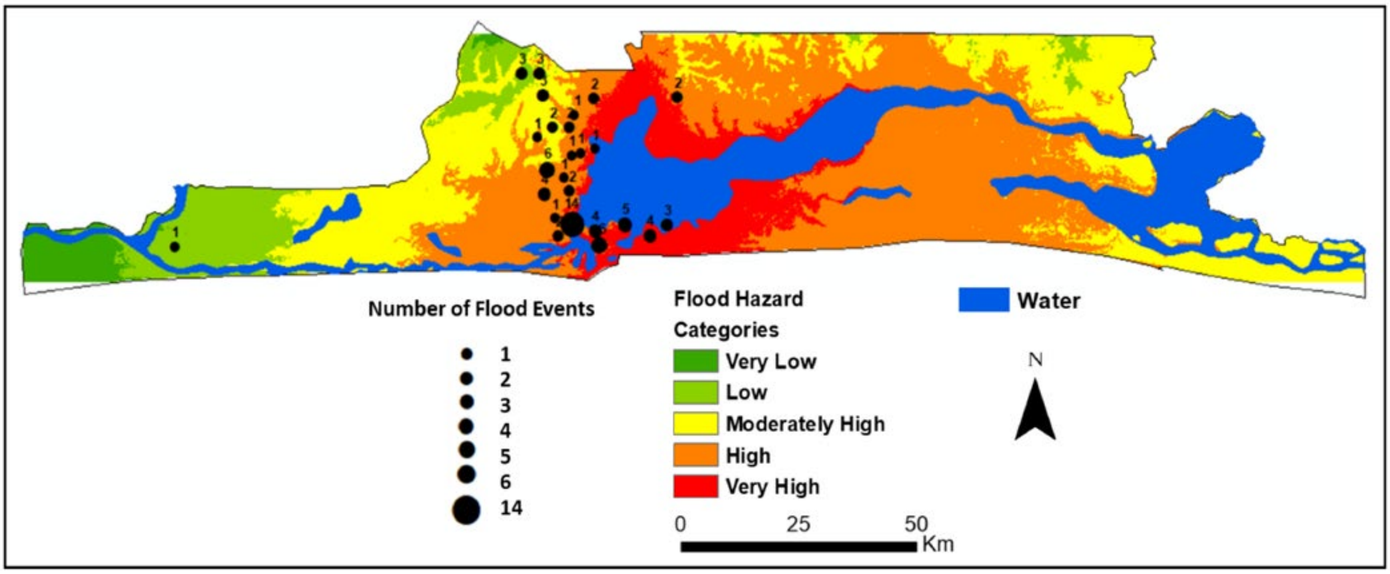

Figure 4: An overlay of developed areas on the flood hazard map (extracted from Idowu and Zhou, 2021)

5. Big picture

Globally, an estimated 40-50 billion tons of material are extracted from quarries, pits, rivers, coastlines and the marine environment each year (Peduzzi, 2014; Beiser, 2018), driving unsustainable and often illegal practices, which are degrading ecosystems and increasing vulnerability to various hazards. Around half of this amount is to satisfy the booming demand for construction materials around the world (UNEP, 2014). Despite being one of the most sought after and traded resources on the planet (UNEP, 2019), the sustainable sourcing, transport and use of sand resources is still flying largely under the radar of government policy and public awareness.

Like in Lagos, many other parts of the world have insufficient, or even lack, regulations for sand mining (UNEP, 2022). In fact, in many countries, sand resource extraction falls in between the gaps of competing and conflicting legal and political frameworks related to land-use, mineral, environment, water and marine management. This issue becomes more complex when sand extraction occurs in dynamic environments like rivers, lakes and coasts governed by various policies and laws. In many cases, none of the environmental regulatory frameworks, including water resources management, coastal zone management, infrastructure, urban development plans, land-use planning, conservation and biodiversity policies, address sand extraction governance and management adequately (UNEP, 2022). Addressing those gaps is key for sustainability and reducing future risk, particularly in places such as Lagos that are increasingly threatened by sand mining induced coastal erosion.

Render of a floating community in Lagos. (Image credit: NLĖ)

6. Solutions

6.1 Let nature work

Conservation and restoration of coastal ecosystems can help them stabilize coastlines and build resilience to threats such as sea level rise, erosion and storm surge. Mangrove forests, for example, are found extensively along Nigeria's coast, including in Lagos, and are being degraded at an alarming rate. Restoring mangrove forests and other vegetated ecosystems can provide multiple coastal benefits for addressing the drivers of flood risk in Lagos and other parts of the world. The root system of mangroves is particularly good at diffusing the energy of waves, for example. Wave height can be reduced by up to 66 per cent per 100 m of mangrove forest, and storm surge height can be reduced by up to 50 cm per km. By slowing the water flow along the coast, the root system therefore also allows sediments to settle and accumulate in an area, thereby preventing erosion and possibly encouraging active soil build-up along the coast (Spalding and others, 2014). Though grey infrastructure, such as the sea wall built at Eko Atlantic (see above), can also protect the coast from flooding, it is not only built from concrete (likely resulting from sand mining) but also displaces erosion further down the coast (Mendelsohn, 2018).

Figure 5: Makoko floating school (NLÉ, 2022)

6.2 Innovate

Considering Lagos' experience with flooding, the concept of floating architecture has emerged in recent years as a possible adaptation to current flooding and future sea level rise (Rubin, 2022; The Energy Mix, 2022; UN-Habitat, 2022; Amusement Logic, 2021). Although floating houses are not a new concept, their design is adaptable to variations in water levels and therefore suitable for areas prone to flooding or high tides (Penning-Rowsell, 2020; Lin and others, 2019). For example, in the Makoko neighbourhood - called the "Venice" of Africa because it sits on the water - a floating school (Figure 5) was ingeniously constructed using empty plastic drums and designed pyramidally to stabilize the structure while dispersing heavy rain (Johnson, 2021).

Such an innovative and pragmatic initiative evolved into the Makoko Floating System (MFS)[1], consisting of larger, demountable and transportable versions of the school, which are being replicated in other regions and with a wide range of uses, such as health centres, culture centres and housing (Amusement Logic, 2021). Projects currently being implemented in cities around the world are investigating different types of building materials and architectural strategies to deal with the challenges of flooding and sea level rise stemming from population pressure and climate change by designing ways to live on the water or adapt traditional approaches, including in the Netherlands, the U.K. and Bangladesh (Penning-Rowsell, 2020).

Additionally, sustainable urban drainage systems (SUDS) have been effectively implemented for flood management in other coastal cities, such as London and New York, so researchers and city planners have pushed for their adoption in Lagos (Adeloye and Rustum, 2011; Mezue; Charlesworth and others, 2016; Odunuga and others, 2017). Through innovative material combinations (e.g. porous asphalt), SUDS aim to mimic natural drainage processes to properly manage storm water while recreating more enjoyable and multipurpose public spaces. Given Lagos' high dependence on groundwater, this solution takes on greater resonance as it allows for the natural recharge of aquifers while regulating run-off flow, containing storm water, improving surface water quality and supporting wildlife (Adeloye and Rustum, 2011; Mezue).

6.3 Work together

Addressing flooding in Lagos should also involve tackling improper waste disposal through participatory waste management (Echendu, 2020). This approach involves bringing regional and municipal governments together with community groups and residents to secure funds, organize training and co-develop waste management plans, and has been implemented successfully to address waste management issues in countries such as Japan, the Netherlands, Uganda, Thailand and India (Kalra, 2020). The informal waste economy in Lagos operates on the trade of recyclable materials in West Africa, and incorporating this into the city's waste reform agenda would advance inclusive development that can improve people's lives (Nzeadibe and others, 2021). Incorporating the informal waste economy in such a way would also include integrating informal garbage collectors using wheelbarrows (known as "cart pushers") into formal municipal waste management systems, considering their role in reaching interior and flood-prone areas, while minimizing the amount of unregulated dumping (Ojolowo and Wahab, 2017). Hence, a more inclusive waste management system would in turn increase the capacity for waste evacuation and disposal while reducing the tendencies of indiscriminate disposal of waste.

[1] Other iterations of the MFS are MFS II, MFS III, MFS IIIX3 and MFS™ IV (NLÉ, 2022)

6.4 Consume sustainably

Circular approaches are currently revolutionizing the world economy. Based on the redesign, reuse, repair, recycling, recovery and regeneration of materials, circular solutions have emerged in recent years. Their main purpose is to reduce the demand for and consumption of natural resources and to avoid or minimize the generation of waste and emissions.

One option has been to look for alternative and more sustainable materials in the construction industry. A promising material is massive timber (popularly known as “mass timber”), a material made of several glued laminated pieces of wood made of coniferous (e.g. pine, spruce or fir) or deciduous (e.g. birch, ash, beech) species from sustainably managed forests (Vinoski, 2019; Roberts, 2020). Mass timber aims to replace concrete building materials, alleviating the need for sand while significantly reducing the greenhouse gas emissions associated with the production and transportation of these materials and current building methods, which altogether account for 11 per cent of global greenhouse gas emissions (Vinoski, 2019; Roberts, 2020; Tollefson, 2017). For instance, between 14 per cent and 31 per cent of global CO2 emissions from building and bridge construction could be reduced by replacing concrete and steel with wood (Oliver and others, 2014). Other concrete alternatives are being developed from biomaterials made from fungal-based mycelial composites or straw. Grown rather than manufactured, mycelium creates a super-dense network of threads as a binding matrix for use in construction that can be cheaper and less energy-intensive than traditional building materials (Alemu and others, 2022).

Additionally, the demand for sand can be reduced by reclaiming materials through urban mining. Urban mining consists of storing, processing and recovering raw material from urban waste, such as construction and demolition waste, which can then be used again in construction or other sectors at a comparable cost to the original raw materials (Di Maria and others, 2013). While urban mining provides useful pathways to more sustainable consumption of resources and a reduced demand pressure to mine raw materials, governments need to step up and provide regulations, incentives and support, including the enhancement of producer responsibility, to make this solution more effective (Kazançoglu and others, 2020).

If alternative building materials are not feasible in a given context, then promoting responsible sand purchasing is another way to reduce sand consumption. Using certifications and public procurement policies as strategies to encourage sustainable sand management along the supply chain, both social and environmental standards in the extraction, production and disposal of sand-related materials (e.g. ceramics, microchips, glass, steel, asphalt and cement), can be ensured (UNEP, 2022).

6.5 Boost early warning

Investing in early warning systems can reduce the impacts of flood events by warning relevant people of oncoming danger and giving them time to prepare. One way to do this is to utilize mobile applications or text messages to provide real-time flood forecast and “nowcast” information to residents (Samonte and others, 2017; FloodMapp, 2022). This method can complement existing media announcements, such as those from newspapers, radio and television, as a mode of communicating flood predictions to a wider audience. Additionally, there is a need for more public education and awareness about flood early warning; such a program would influence residents’ perception and improve their preparedness, which will subsequently preclude flood hazards from leading to disaster.

6.6 Conclusion

The solutions outlined above are only a selection of possible solutions for flood risk reduction in Lagos. There are many other possible solutions, such as improved flood forecasting, "smart" urban governance or green infrastructure, which would also be necessary for a more holistic risk management strategy. The solutions outlined above should ideally guide a shift in our collective mindset to address root causes and drivers, thereby reducing the impact of and augmenting resilience to increasingly frequent and intense floods in a holistic way. Therefore, the solutions are intended to work together as a package that can take advantage of different co-benefits and synergies to address multiple challenges while minimizing trade-offs. The solution package approach also represents the idea that none of these solutions are sufficient if they are implemented in isolation; only through this integrated, multifaceted approach can the problem truly be addressed and a successful adaptation achieved.

7. References

Adebayo, Bukola (2017). Shifting Sands: Lagos Communities Count the Cost of Dredging, 14 September. Available at https://pulitzercenter.org/stories/shifting-sands-lagos-communities-count-cost-dredging

Adegboyega, S. A., and others (2019). Evaluation of unsustainable land use/land cover change on ecosystem services in coastal area of Lagos state, Nigeria. *Applied Geomatics*, vol. 11, No. 1, pp. 97–110. DOI: 10.1007/s12518-018-0242-2

Adegun, Olumuyiwa B. (2022). Climatic disasters within a flood-prone coastal slum in Lagos: coping capacities and adaptation prospects. *International Journal of Disaster Resilience in the Built Environment.* DOI: 10.1108/IJDRBE-11-2021-0154

Adekunbi, Falilu O., and others (2018). Impact of Sand Dredging Activities on Ecosystem and Community Survival in Ibeshe Area of Lagos Lagoon, Nigeria. *Journal of Geoscience and Environment Protection*, vol. 6, No. 2, pp. 112–25. DOI: 10.4236/gep.2018.62008

Adelekan, Ibidun O. (2010). Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria. *Environment and Urbanization*, vol. 22, No. 2, pp. 433–50. DOI: 10.1177/0956247810380141

__________ (2016). Flood risk management in the coastal city of Lagos, Nigeria. *Journal of Flood Risk Management,* vol. 9, No. 3, pp. 255–64. DOI: 10.1111/jfr3.12179

Adeloye, Adebayo J., and Rabee Rustum (2011). Lagos (Nigeria) flooding and influence of urban planning. *Proceedings of the Institution of Civil Engineers - Urban Design and Planning,* vol. 164, No. 3, pp. 175–87. DOI: 10.1680/udap.1000014

Adewole, Taiwo (2009). Waste management towards sustainable development in Nigeria: A case study of Lagos state. *International NGO Journal,* vol. 4, No. 4, pp. 173–79. Available at https://academicjournals.org/article/article1380901268_Adewole.pdf

Agence France-Presse (2019). Waves of change: Nigeria's Lagos battles Atlantic erosion, 10 July. Available at https://www.france24.com/en/20190710-waves-change-nigerias-lagos-battles-atlantic-erosion

Ajibade, Idowu, and others (2016). Sustainability Transitions: Exploring Risk Management and the Future of Adaptation in the Megacity of Lagos. *Journal of Extreme Events,* vol. 03, No. 03, art. 1650009. DOI: 10.1142/S2345737616500093

Ajibade, Idowu (2017). Can a future city enhance urban resilience and sustainability? A political ecology analysis of Eko Atlantic city, Nigeria. *International Journal of Disaster Risk Reduction,* vol. 26, pp. 85–92. DOI: 10.1016/j.ijdrr.2017.09.029

Ajibade, Idowu, and Gordon McBean (2014). Climate extremes and housing rights: A political ecology of impacts, early warning and adaptation constraints in Lagos slum communities. *Geoforum,* vol. 55, pp. 76–86. DOI: 10.1016/j.geoforum.2014.05.005

Alemu, Digafe, Mesfin Tafesse Gemeda and Ajoy Kanti Mondal (2022). Mycelium-Based Composite: The Future Sustainable Biomaterial. *International Journal of Biomaterials,* vol. 2022, art. 8401528. pp. 1–12. DOI: 10.1155/2022/8401528

Aliu, I.R., I.S. Akoteyon and O. Soladoye (2021). Living on the margins: Socio-spatial characterization of residential and water deprivations in Lagos informal settlements, Nigeria. *Habitat International,* vol. 107, art. 102293. pp. 1–17. DOI: 10.1016/j.habitatint.2020.102293

__________ (2022). Sustaining urbanization while undermining sustainability: the socio-environmental characterization of coastal sand mining in Lagos Nigeria. *GeoJournal,* pp. 1–21. DOI: 10.1007/s10708-021-10563-7

Amusement Logic (2021). Floating architecture, the example of Lagos in Nigeria, 13 April. Available at https://amusementlogic.com/general-news/floating-architecture-the-example-of-lagos-in-nigeria/

Anabaraonye, B., and others (2021). MAR Case Reports: A Brief Look at Flooding and Its Impacts on Nigeria's Health Sector. Available at https://www.researchgate.net/profile/charles-anukwonke/publication/359119425_mar_case_reports_a_brief_look_at_flooding_and_its_impacts_on_nigeria's_health_sector

Atufu, Cynthia E., and Christopher P. Holt (2018). Evaluating The Impacts Of Flooding On The Residents Of Lagos, Nigeria. *WIT Transactions on the Built Environment,* vol. 184, pp. 81–90. DOI: 10.2495/FRIAR180081

Aworemi, Joshua Remi, Ibraheem Adegoke Abdul-Azeez and Nurain A. Opoola (2011). An Appraisal of the Factors Influencing Rural-Urban Migration in Some Selected Local Government Areas of Lagos State Nigeria. *Journal of Sustainable Development,* vol. 4, No. 3, pp. 1–6. DOI: 10.5539/jsd.v4n3p136

Ayantoyinbo, Boye, and Olusegun Onifade Adepoju (2018). Analysis of Solid Waste Management Logistics and Its Attendant Challenges in Lagos Metropolis. *Logistics, vol. 2,* No. 2, pp. 1–10. DOI: 10.3390/logistics2020011

Ayodele, John Oluropo (2017). Attitudes of Lagos Residents to waste disposal as major causes to yearly flooding. *Journal of Basic and Applied Research,* vol. 3, No. 1, pp. 33–39. Available at https://jbarbiomed.com/index.php/home/article/view/145/142

Bamber, Jonathan L., and others (2019). Ice sheet contributions to future sea-level rise from structured expert judgment. *Proceedings of the National Academy of Sciences,* vol. 116, No. 23, pp. 11195–200. DOI: 10.1073/pnas.1817205116

Bamidele, Alabi (2021). Urban Redevelopment as Metaphor for Gentrification in the Making of a Mega-City: The Forced Displacement of Otodo Gbame/Ebute Ikate Community, Lagos State. In *Rethinking Institutions, Processes and Development in Africa.* Ernest Aniche and Toyin Falola, eds. Lanham, Maryland: Rowman & Littlefield.

Beiser, Vince (2018). *The World in a Grain: The Story of Sand and How it Transformed Civilization.* New York: Riverhead Books.

Charlesworth, S., and others (2016). The potential for Water Sensitivity, sustainable drainage and adaptive management in West Africa using Lagos, Nigeria, as a case study. 9th International Conference on planning and technologies for sustainable management of Water in the City, June 2016. Lyon, France. Available at https://hal.archives-ouvertes.fr/hal-03304538/document

Chukwu Okeah, G. O., V. E. Wekpe and C. F. Ikebude (2018). Impact of Coastal Flooding on Fish Production in Brass, Niger Delta Nigeria, Implication for Coastal Resource Management. *Oceanography & Fisheries Open Access Journal,* vol. 6, No. 1, pp. 1–6. DOI: 10.19080/OFOAJ.2018.06.555678

Climate Central (2021). Land projected to be below annual flood level in 2030. Available at https://coastal.climatecentral.org/map/12/3.4418/6.554/?theme=sea_level_rise&map_type=year&basemap=satellite&contiguous=true&elevation_model=best_available&forecast_year=2030&pathway=ssp3rcp70&percentile=p50&refresh=true&return_level=return_level_1&rl_model=gtsr&slr_model=ipcc_2021_med

Croitoru, Lelia, and others (2020). *The Cost of Coastal Zone Degradation in Nigeria: Cross River, Delta and Lagos States.* Washington, D.C.: World Bank. DOI: 10.1596/34758

Dano, Umar Lawal, and others (2020). Transformative urban governance: confronting urbanization challenges with geospatial technologies in Lagos, Nigeria. *GeoJournal,* vol. 85, No. 4, pp. 1039–56. DOI: 10.1007/s10708-019-10009-1

Di Maria, Francesco, and others (2013). Urban mining: quality and quantity of recyclable and recoverable material mechanically and physically extractable from residual waste. *Waste management,* vol. 33, No. 12, pp. 2594–99. DOI: 10.1016/j.wasman.2013.08.008

Dike, Victor Nnamdi, Zhao-Hui Lin and Chikwem Coleman Ibe (2020). Intensification of Summer Rainfall Extremes over Nigeria during Recent Decades. *Atmosphere,* vol. 11, No. 10, art. 1084. pp. 1–20. DOI: 10.3390/atmos11101084

Echendu, Adaku Jane (2020). The impact of flooding on Nigeria's sustainable development goals (SDGs). *Ecosystem Health and Sustainability,* vol. 6, No. 1, art. 1791735. DOI: 10.1080/20964129.2020.1791735

Emordi, E. C., and Omon M. Osiki (2008). Lagos: the 'villagized' city. *Information, Society and Justice Journal,* vol. 2, No. 1, pp. 95–109. DOI: 10.3734/isj.2008.2107

FloodMapp (2022). RISE Update: FloodMapp launches integration with Waze helping reroute drivers in Virginia, USA, 7 January. Available at https://www.floodmapp.com/post/rise-update-floodmapp-launches-integration-with-waze-helping-reroute-drivers-in-virginia-usa

Green Economy Media (2019). International construction companies eye the Nigerian market as the Big 5 launches in Lagos. Available at https://greeneconomy.media/international-construction-companies-eye-the-nigerian-market-as-the-big-5-launches-in-lagos/

Hernandez, Marco, Simon Scarr and Katy Daigle (2021). Shifting sands: The messy business of sand mining explained, 18 February. Available at https://graphics.reuters.com/GLOBAL-ENVIRONMENT/SAND/ygdpzekyavw/

Hoornweg, Daniel, and Kevin Pope (2017). Population predictions for the world's largest cities in the 21st century. *Environment and Urbanization,* vol. 29, No. 1, pp. 195–216. DOI: 10.1177/0956247816663557

Idowu, Dorcas, and Wendy Zhou (2021). Land Use and Land Cover Change Assessment in the Context of Flood Hazard in Lagos State, Nigeria. *Water,* vol. 13, No. 8, art. 1105. DOI: 10.3390/w13081105

Ihua-Maduenyi, Maureen (2019). Foreign brands renew interest in Nigeria's real estate. *The Punch,* 16 September. Available at https://punchng.com/foreign-brands-renew-interest-in-nigerias-real-estate/

Ikuemonisan, Femi Emmanuel, and Vitalis Chidi Ozebo (2020). Characterisation and mapping of land subsidence based on geodetic observations in Lagos, Nigeria. *Geodesy and Geodynamics,* vol. 11, No. 2, pp. 151–62. DOI: 10.1016/j.geog.2019.12.006

InsuResilience Solutions Fund (2021). *CLIMADA Climate Risk Analysis: Urban flood resilience against riverine floods in Uganda and Nigeria.* Available at https://www.insuresilience-solutions-fund.org/content/1-our-work/1-climate-risk-analysis/climate-risk-analysis_uga-nga_5-pager_final.pdf

Intergovernmental Panel on Climate Change (2013). Sea level change. In *Climate Change 2013: The Physical Science Basis: Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Stocker, T. F., and others, eds., Cambridge University Press. Cambridge and New York. Available at https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter13_FINAL.pdf

__________ (2021a). *Sixth Assessment Report: Working Group I - The Physical Science Basis. Regional fact sheet - Africa.* Available at https://www.ipcc.ch/report/ar6/wg1/downloads/factsheets/IPCC_AR6_WGI_Regional_Fact_Sheet_Africa.pdf

__________ (2021b). Summary for Policymakers. In *Climate Change 2021: The Physical Science Basis.* Masson-Delmotte, V., and others, eds. Cambridge and New York. Available at https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

__________ (2022). Chapter 9: Africa, Final Draft. In *Sixth Assessment Report: Working Group II - Climate Change 2022 - Impacts, Adaptation and Vulnerability.* Available at https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_FinalDraft_Chapter09.pdf

International Trade Administration (2021). Nigeria - Country Commercial Guide: Construction Sector, 23 June. Available at https://www.trade.gov/country-commercial-guides/nigeria-construction-sector

Israel, Augustine O. (2021). Loss of Wetlands in Lagos (Nigeria) and the adjacent territory: Implications for flood control. *Journal of Meteorology and Climate Science,* vol. 19, No. 1, pp. 10–21. Available at https://www.ajol.info/index.php/jmcs/article/view/221021

Jevrejeva, Svetlana, and others (2016). Coastal sea level rise with warming above 2 °C. *Proceedings of the National Academy of Sciences,* vol. 113, No. 47, pp. 13342–47. DOI: 10.1073/pnas.1605312113

Johnson, Ayodele (2021). How Africa's largest city is staying afloat, 22 January. Available at https://www.bbc.com/future/article/20210121-lagos-nigeria-how-africas-largest-city-is-staying-afloat

Kalra, Natasha (2020). Community Participation and Waste Management. In *Sustainable Waste Management: Policies and Case Studies.* Sadhan Kumar Ghosh, ed., Springer, Singapore. DOI: 10.1007/978-981-13-7071-7_10

Kaoje, Ismail Usman, and Ibrahim Ishiaku (2017). Urban Flood Vulnerability Mapping Of Lagos, Nigeria. *MATTER: International Journal of Science and Technology,* vol. 3, No. 1, pp. 224–36. DOI: 10.20319/mijst.2017.s31.224236

Kasim, Oluwasinaayomi F., Bolanle Wahab and Michael F. Oweniwe (2021). Urban expansion and enhanced flood risk in Africa: The example of Lagos. *Environmental Hazards,* pp. 1–22. DOI: 10.1080/17477891.2021.1932404

Kazançoglu, Yigit, and others (2020). Analysis of the barriers to urban mining for resource melioration in emerging economies. *Resources Policy,* vol. 68, art. 101768. pp. 1–12. DOI: 10.1016/j.resourpol.2020.101768

Kremere, Eva, Edward Morgan and Pedi Obani (2019). Case Study: Nigeria and SDG6. In *SDG6 – Clean Water and Sanitation: Balancing the Water Cycle for Sustainable Life on Earth.* Kremere, Eva, and others, eds. Bingley, U.K. Emerald Publishing Limited. DOI: 10.1108/978-1-78973-103-320191009

Lin, Yuan-Ho, Yung Chih Lin and Han-Shih Tan (2019). Design and functions of floating architecture – a review. *Marine Georesources & Geotechnology,* vol. 37, No. 7, pp. 880–89. DOI: 10.1080/1064119X.2018.1503761

Lucas, Brian (2021). Urban flood risks, impacts, and management in Nigeria. K4D Helpdesk Report 948. Brighton, UK: Institute of Development Studies. DOI: 10.19088/K4D.2021.018

Mendelsohn, Ben (2018). Making the Urban Coast: A Geosocial Reading of Land, Sand, and Water in Lagos, Nigeria. *Comparative Studies of South Asia, Africa and the Middle East,* vol. 38, No. 3, pp. 455–72. DOI: 10.1215/1089201x-7208801

Mezue, MargaretInvestigating the potential of using simple SuDS in informal settlements in Lagos, Nigeria to transition to a sustainable surface water management system. PhD dissertation, Conventry University. Available at https://pureportal.coventry.ac.uk/files/31116431/suds_thesis_redacted.pdf

Muhlern, Owen (2020). Sea Level Rise Projection Map - Lagos, 30 July. Available at https://earth.org/data_visualization/sea-level-rise-by-2100-lagos/

National Bureau of Statistics (2021). Nigerian Capital Importation: Q4 2021. Available at https://nigerianstat.gov.ng/elibrary/read/1241154

Nigeria Hydrological Services Agency (2021). *2021 Annual Flood Outlook.* Abuja. Available at https://nihsa.gov.ng/wp-content/uploads/2021/05/2021-AFO.pdf

Nigerian Meteorological Agency (2022). *Seasonal Climate Prediction.* Available at https://nimet.gov.ng/scp/

Nkwunonwo, Ugonna C. (2017). Assessment of Social Vulnerability for Efficient Management of Urban Pluvial Flooding in the Lagos Metropolis of Nigeria. *Journal of Environmental Studies,* vol. 3, No. 1, art. 11. pp. 1–11. DOI: 10.13188/2471-4879.1000014

__________ (2020). Current Issues in Early Warning and Development Initiatives Towards Enhanced Flood-Related Resilience in Nigeria. *In Flood Impact Mitigation and Resilience Enhancement.* Guangwei Huang, ed., InTech. DOI: 10.5772/intechopen.91247

Nkwunonwo, Ugonna C., M. Whitworth and B. Baily (2016). Review article: A review and critical analysis of the efforts towards urban flood risk management in the Lagos region of Nigeria. *Natural Hazards and Earth System Sciences,* vol. 16, No. 2, pp. 349–69. DOI: 10.5194/nhess-16-349-2016

Nwokocha, E. E. (2009). Deconstructing the burden of rural-urban migration in a non-regulatory system: the case of Lagos, Nigeria. *South-South Journal of Culture and Development,* vol. 11, No. 2, pp. 105–30. Available at http://ir.library.ui.edu.ng/handle/123456789/1169

NLÉ (2022). Architecture & Design, 7 July. Available at https://www.nleworks.com/category/architecture-design/

Nzeadibe, Chidi, and others (2021). Informal waste management in Lagos is big business: policies need to support the trade, 12 January. Available at https://theconversation.com/informal-waste-management-in-lagos-is-big-business-policies-need-to-support-the-trade-151583

Obiefuna, Jerry, and others (2021). Flood risks to urban development on a coastal barrier landscape of Lekki Peninsula in Lagos, Nigeria. *Scientific African,* vol. 12, art. e00787, pp. 1-17. DOI: 10.1016/j.sciaf.2021.e00787

Odjugo, Peter A.O. (2006). An analysis of rainfall patterns in Nigeria. *Global Journal of Environmental Sciences,* vol. 4, No. 2. DOI: 10.4314/gjes.v4i2.2455

Odunuga, S., and others (2017). Simulating the Effects of Urbanisation on Urban Flooding in Ashimowu Watershed, Lagos, Nigeria. *Unilag Journal of Humanities,* vol. 4, No. 2, pp. 170–92. Available at http://journals.unilag.edu.ng/index.php/ujh/article/view/93

Odunuga, S., G. Badru and O. M. Bello (2014). Climate change, sea level rise and coastal inundation along part of Nigeria Barrier Lagoon Coast. *Journal of Applied Sciences and Environmental Management,* vol. 18, No. 1, pp. 41–47. DOI: 10.4314/jasem.v18i1.6

Odunuga, S., L. Oyebande and A. S. Omojola (2012). Social-economic indicators and public perception on urban flooding in Lagos, Nigeria. *Hydrology for Disaster Management,* pp. 82–96. Available at https://publications.unaab.edu.ng/index.php/nahs/article/view/915

Ojolowo, S., and B. Wahab (2017). Municipal solid waste and flooding in Lagos metropolis, Nigeria: Deconstructing the evil nexus. *Journal of Geography and Regional Planning,* vol. 10, No. 7, pp. 174–85. DOI: 10.5897/JGRP2016.0614

Okujala, Ayo (2014). Facebook Reveals: Lagos Leads Global Urban Migration. Available at https://www.smartcitiesdive.com/ex/sustainablecitiescollective/facebook-reveals-lagos-leads-global-urban-migration/259896/

Olajide, Oluwafemi, and Taibat Lawanson (2021). Urban paradox and the rise of the neoliberal city: Case study of Lagos, Nigeria. *Urban Studies,* vol. 59, No. 9, pp. 1763-1781. DOI: 10.1177/00420980211014461

Olanrewaju, Caroline C., and others (2019). Impacts of flood disasters in Nigeria: A critical evaluation of health implications and management. *Jamba,* vol. 11, No. 1, art. a557. pp. 1–9. DOI: 10.4102/jamba.v11i1.557

Oliver, Chadwick D., and others (2014). Carbon, Fossil Fuel, and Biodiversity Mitigation With Wood and Forests. *Journal of Sustainable Forestry,* vol. 33, No. 3, pp. 248–75. DOI: 10.1080/10549811.2013.839386

Olokesusi, F., and others (2015). Awareness of and Responses to the 2011 Flood Warnings Among Vulnerable Communities in Lagos, Nigeria. In *Global Sustainability: Cultural Perspectives and Challenges for Transdisciplinary Integrated Research.* Benno Werlen, ed., Springer, Cham. DOI: 10.1007/978-3-319-16477-9_11

Osanyintuyi, Abiola John, Yonghong Wang and Nor Aieni Haji Mokhtar (2022). Nearly five decades of changing shoreline mobility along the densely developed Lagos barrier-lagoon coast of Nigeria: A remote sensing approach. *Journal of African Earth Sciences,* vol. 194, art. 104628. pp. 1–11. DOI: 10.1016/j.jafrearsci.2022.104628

Ouikotan, R. B., and others (2017). Gaps and challenges of flood risk management in West African coastal cities. *XVI World Water Congress,* Quintana Roo, Mexico. Available at https://www.iwra.org/member/congress/resource/ABSID329_ABSID329_full_paper.pdf

Peduzzi, Pascal (2014). Sand, rarer than one thinks. *Environmental Development,* vol. 11, pp. 208–18. DOI: 10.1016/j.envdev.2014.04.001

Penning-Rowsell, Edmund (2020). Floating architecture in the landscape: climate change adaptation ideas, opportunities and challenges. *Landscape Research,* vol. 45, No. 4, pp. 395–411. DOI: 10.1080/01426397.2019.1694881

Popoola, Olusola Olalekan (2012). Sea Level Rise and Sustainability of the Nigerian Coastal Zone. PhD dissertation, Plymouth University. Available at https://pearl.plymouth.ac.uk/bitstream/handle/10026.1/907/2012Popoola10111858PhD.pdf?sequence=1&isAllowed=y

Rageh, Rawya (2014). Sand mining damages Nigeria's shoreline, 3 September. Available at https://www.aljazeera.com/economy/2014/9/3/sand-mining-damages-nigerias-shoreline

Raimi, Morufu Olalekan, and others (2018). The sources of water supply, sanitation facilities and hygiene practices in oil producing communities in central senatorial district of Bayelsa state, Nigeria. *MOJ Public Health,* vol. 7, No. 6, pp. 337–45. DOI: 10.15406/mojph.2018.07.00265

Roberts, David (2020). The hottest new thing in sustainable building is, uh, wood, 15 January. Available at https://www.vox.com/energy-and-environment/2020/1/15/21058051/climate-change-building-materials-mass-timber-cross-laminated-clt

Rubin, Shira (2022). Why the Dutch embrace floating homes, 8 February. Available at https://www.bbc.com/future/article/20220202-floating-homes-the-benefits-of-living-on-water

Samonte, Mary Jane C., and others (2017). Crowdsourced mobile app for flood risk management. ICCIP '17: *Proceedings of the 3rd International Conference on Communication and Information Processing,* pp. 65–71. DOI: 10.1145/3162957.3162962

Spalding, Mark, and others (2014). Mangroves for coastal defence: Guidelines for coastal managers & policy makers. Ede, the Netherlands: Wetlands International and The Nature Conservancy. Available at https://www.nature.org/media/oceansandcoasts/mangroves-for-coastal-defence.pdf

The Energy Mix (2022). Amsterdam's Floating Suburb Offers Solutions to Rising Waters, 10 January. Available at https://www.preventionweb.net/news/amsterdams-floating-suburb-offers-solutions-rising-waters

Tollefson, Jeff (2017). The wooden skyscrapers that could help to cool the planet. *Nature,* vol. 545, No. 7654, pp. 280–82. DOI: 10.1038/545280a

Ugochukwu, Stanley C., George O. Ogbuagu and Fidelis E. Okechukwu (2014). An Appraisal of the Sources, Quantities and Prices of Imported Building Materials in Nigeria. *International Journal of Advanced Research,* vol. 2, No. 9, pp. 871–89. Available at https://www.journalijar.com/uploads/877_IJAR-4061.pdf

Umar, Nura, and Alison Gray (2022). Flooding in Nigeria: a review of its occurrence and impacts and approaches to modelling flood data. *International Journal of Environmental Studies,* DOI: 10.1080/00207233.2022.2081471

United Nations Environment Programme (2014). *Sand, Rarer than One Thinks: UNEP Global Environmental Alert Service (GEAS) - March 2014.* Geneva. Available at https://wedocs.unep.org/20.500.11822/8665

__________ (2019). *Sand and Sustainability:* Finding New Solutions for Environmental Governance of Global Sand Resources. Geneva. Available at https://wedocs.unep.org/20.500.11822/28163

__________ (2022). *Sand and Sustainability:* 10 strategic recommendations to avert a crisis. Geneva. Available at https://www.unep.org/resources/report/sand-and-sustainability-10-strategic-recommendations-avert-crisis

United Nations Human Settlements Programme (2015). *Slum Almanac 2015/2016: Tracking Improvement in the Lives of Slum Dwellers.* Nairobi. Available at https://unhabitat.org/sites/default/files/documents/2019-05/slum_almanac_2015-2016_psup.pdf

__________ (2018). *Lagos: City Context Report.* Nairobi. Available at https://www.globalfuturecities.org/resources/lagos-city-context-report

__________ (2022). UN-Habitat and partners unveil OCEANIX Busan, the world's first prototype floating city, 27 April. Available at https://unhabitat.org/un-habitat-and-partners-unveil-oceanix-busan-the-worlds-first-prototype-floating-city

Usigbe, Leon (2021). Dogged by massive floods, Nigeria ramps up actions to tackle climate crisis, 27 October. Available at https://www.un.org/africarenewal/magazine/november-2021/dogged-massive-floods-nigeria-ramps-actions-tackle-climate-crisis

Vinoski, Jim (2019). Is Mass Timber The Path To Sustainable Construction?, 20 December. Available at https://www.forbes.com/sites/jimvinoski/2019/12/20/is-mass-timber-the-path-to-sustainable-construction/?sh=1752ed3e71d2

Wahab, Bolanle, and Saeed Ojolowo (2018). Drivers and Spatial extent of Urban Development in Flood-prone Areas in Metropolitan Lagos. *Journal of Sustainable Development,* vol. 11, No. 2, p. 98. DOI: 10.5539/jsd.v11n2p98

Wesley, David T., and Sheila M. Puffer (2019). The End of Sand: Confronting One of the Greatest Environmental Challenges of the New Millennium. In *Reusable and Sustainable Building Materials in Modern Architecture.* Gülşah Koç and Bryan Christiansen, eds., Hershey, Pennsylvania: IGI Global. DOI: 10.4018/978-1-5225-6995-4.ch001.

Whiteman, Kaye (2012). *Lagos: A Cultural and Literary History, v.5, Cities of the imagination.* Exeter, U.K.: Andrews UK Limited.

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People attempt to pull out a car washed away by flood water on a street affected by floods following a heavy downpour, in Lugbe, Abuja, Nigeria, on September 13, 2021.

https://doi.org/10.53324/WQUH9842

e-ISBN: 978-3-944535-70-8
e-ISSN: 2304-0467