

Further, Delhi's response to climate change is often less-than-effective as well as piecemeal because its efforts are primarily project-oriented. In the experience of the Delhi government, incentives—subsidies and grants—have been effective for initiating projects, but operation and management frequently remain neglected. For instance, subsidies to install rainwater-harvesting systems have created demand but subsequent maintenance is too-often ignored and many systems fall into disrepair. Such experiences hold the potential to inform adaptation efforts as well.

Gradually the city is developing a programmatic approach, but there is a need to coordinate between departments and among levels of government. For example, while the Prime Minister of India has recently released the National Action Plan for Climate Change, Delhi's local efforts will need to be reconciled with regional and national priorities.

4.3 Lagos

Lagos is Africa's second most populous city, which grew explosively, from 300,000 in 1950 to an expected 18 million by 2010, when it will be ranked as one of the world's ten largest cities. The metropolitan area, an estimated 1,000 square kilometers, is a group of islands surrounded by creeks and lagoons and bordered by the Atlantic Ocean. With a GDP triple that of any other West African country, Lagos is the commercial and industrial hub of Nigeria. Lagos is home to many industries and much large commercial infrastructure, and has greatly benefited from Nigeria's natural resources of oil, natural gas, coal, fuel wood and water. For an overview of the state of Nigerian cities see UN-Habitat (2004).

The climate of Lagos is affected by ocean and atmospheric interactions both within and outside its environment, in which the Inter-Tropical Convergence Zone (ITCZ) plays a controlling factor. The movement of the ITCZ is associated with the warm humid maritime Tropical air mass with its southwestern winds and the hot and dry continental air mass with its dry northeasterly winds. Maximum temperatures recorded during the dry season are high and range from 28–33°C when the region is dominated by the dry northeast trade winds. Minimum temperature of about 24–26°C is experienced during the wet season of May to September.

The city of Lagos experiences relatively high to very high temperatures throughout the year. The mean annual temperature is about 28°C and the maximum and minimum temperature is 33°C and 26°C respectively. High to very high monthly rainfall is also experienced between May and November, although significant variations in monthly rainfall peak values are experienced. For example, between 1950 and 2006, more than 10 instances were recorded with a maximum rainfall of over 700 millimeters. Minimum monthly rainfall of less than 50 millimeters is experienced between December and March. Occasionally, extreme precipitation events are experienced in June. On June 17, 2004, for example, 243 millimeters of rain was experienced in Victoria Island

and the Lagos environs. This resulted in flooding of streets and homes, collapsing of bridges, and massive erosion of the main road linking Lekki to Lagos Island. About 78 percent of the total rainfall amount for the month was experienced in one day in June. The city was ill-prepared for that amount of rainfall.

Hazards

This trans-administration megacity is bounded in the south by the Atlantic Ocean (Bight of Benin), in the east by the Lagos Lagoon and the southwest by the Badagry Creek. The west and northern limits merge into the gently undulating agricultural lands of Ado Odo, Ota local government area, and the north-central edge of the city is located in the Ogun River flood plain (see Figure 27 for built-up area along the coast and Figure 28 for topography identifying low lying areas prone to flooding).

The study by Ekanade et al. (2008) is one study that has localized the nature and magnitude of the climate change hazards for the city level using different (GHG) emission scenario models. The IPCC (2001a) Special Report on Emission Scenarios A2 and B1 climate change scenarios were utilized to project 30-year time-slices for temperature and rainfall values for the City of Lagos and Port-Harcourt and the coastal areas of Nigeria. This study did not, however, project sea level rise.

Temperature: Records from the two stations (Ikeja and Lagos) used in this analysis show that monthly maximum temperature is increasing at about 0.1°C per decade from 1952 to 2006, while monthly minimums are decreasing at about 0.5°C per decade; since the 1900s average temperature has increased 0.07°C per decade (Figures 4 and 14). At the extremes, monthly maximum temperatures for Lagos have reached above 34°C during seven of the last twenty years. The number of heat waves in Lagos has also increased since the 1980s (see Table 17). There are very few incidences of unusually cold months of less than 20°C since 1995. Projected temperature for Lagos for 2050s anticipates a 1 to 2°C warming (see Table 4 and Figure 14).

Precipitation: According to historical records, the total annual precipitation in Lagos has decreased by 8 millimeter per decade since 1900 (see Figure 8). In keeping with the overall precipitation trends, most of Lagos has experienced decreases in rainfall amounts during the rainy season. For example, between 1950 and 1989 more than 20 months experienced rainfall amounts of over 400 millimeters. In the recent period between 1990 and 2006 however, very few (4) rainy months recorded over 400 millimeters of rain. In the 21st century, precipitation in Lagos is expected to be less frequent but more intense, projected precipitation for Lagos for 2050s anticipates an uncertain 5 percent change in mean precipitation (see Table 4).

Storm surge is a concern. Lagos as well as the entire Nigerian coast is projected to experience more storm surges in the months of April to June and September to October annually. This increase in storminess is projected to be accompanied by greater extreme wave heights along the coasts. According to Folorunsho & Awosika (1995) the

months of April and August are usually associated with the development of low pressure systems far out in the Atlantic Ocean (in the region known as the 'roaring forties'). Normal wave heights along the Victoria beach range from 0.9m to 2m. However, during these swells, wave heights can exceed 4m. The average high high-water (HHW) level for Victoria Island is about 0.9m above the zero tide gauge with tidal range of about 1m. However, high water that occurs as surges during these swells has been observed to reach well over 2m above the zero tide gauge. These oceanographic conditions are aggravated when the swells coincide with high tides and spring tide.

An extreme event, which can be considered a case study for future threats, was observed between August 16 and 17, 1995, when a series of violent swells in the form of surges were unleashed on the whole of Victoria Beach in Lagos. The most devastating of these swells occurred on August 17, 1995 between 06.00 to 10.00 GMT. The surge coincided with high tide thus producing waves over 4 meters high flooding large parts of Victoria Island. Large volumes of water topped the beach and the Kuramo waters, a small lagoon separated from the ocean by a narrow—fifty meters wide—strip of beach, was virtually joined to the Atlantic Ocean. Many of the streets and drainage channels were flooded resulting in an abrupt dislocation of socio-economic activities in Victoria and Ikoyi Islands for the period of the flood.

Sea Level Rise: Coastal erosion is very prevalent along the Lagos coast. The Bar beach in Lagos has an annual erosion rate of 25 to 30m. Earlier IPCC scenarios have been used to estimate the effects of 0.2, 0.5, 1 and 2.0m sea level rise for Lagos. Along with coastal flooding, and erosion, another adverse effect of sea level rise on the Lagos coastal zone as earlier assessed by Awosika et al. (1992, 1993a, 1993b) is increased salinization of both ground and surface water. The intrusion of saline water into groundwater supplies is likely to adversely affect water quality, which could impose enormous costs on water treatment infrastructure.

Vulnerability

As a group of islands, Lagos is bordered by mainland Nigeria to the north and west, other islands to the east and the Atlantic Ocean to the south. Lagos has an extremely dense slum population, many of whom live in floating slums. These are neighborhoods that extend out into the lagoons scattered throughout the city. The Barrier Lagoon system in Lagos, which comprises Lagos, Ikoyi, Victoria and Lekki, will be adversely affected through the estimated displacement of between 0.6 to 6 million people for sea level rise of between 0.2 to 2m (Awosika et al., 1993a).

In their study of the impacts and consequences of sea level rise in Nigeria, French et al. (1995) recommended that buffer zones be created between the shoreline and the new coastal developments. A more generalized multi-sectoral survey of Nigeria's vulnerability and adaptation to climate change was funded by the Canadian

International Development Agency (CIDA) through its Climate Change Capacity Development Fund (CCCDF). This study has served to create awareness of climate change issues and of the need for manpower development.

Even more worrisome is the general sensitivity of the megacity to climate change due to its flat topography and low elevation location, high population, widespread poverty and weak institutional structures. Many more vulnerabilities stem from these characteristics including the high potential for backing up of water in drainage channels, inundation of roadways, and severe erosion. The barrier lagoon coastline in the western extremity, including the high-value real estate at Victoria Island and Lekki in Lagos, could lose well over 584 and 602 square kilometers of land respectively from erosion, while inundation could completely submerge the entire Lekki barrier system (Awosika et al., 1993a, 1993b), (see Figure 31). Moreover, flooding poses greater threats to the urban poor in several African cities (Douglas & Alam, 2006).

Intense episodes of heatwaves will likely severely strain urban systems in Lagos, by inflicting environmental health hazards on the more vulnerable segments of the population, imposing extraordinary consumptions of energy for heating and air conditioning where available, and disrupting ordinary urban activities.

It is very likely that heat-related morbidity and mortality will increase over the coming decades; however net changes in mortality are difficult to estimate because, in part, much depends on complexities in the relationships among mortality, heat, and other stresses. High temperatures tend to exacerbate chronic health conditions. An increased frequency and severity of heat waves is expected, leading to more illness and death, particularly among the young, elderly, frail, and poor. In many cases, the urban heat island effect may increase heat-related mortality. High temperatures and exacerbated air pollution can interact to result in additional health impacts.

Impacts are projected to be widespread as urban economic activities will be likely affected by the physical damages caused to infrastructure, services and businesses, with repercussions on overall productivity, trade, tourism and on the provision of public services.

Built-up Area and Population Density: As mapped from the SPOT5 2.5 meter image of 2004 (Figure 27), the contiguously built-up area of Lagos megacity is about 872 square kilometers. This is located within 17 local government areas in Lagos State with a total of 642.22 square kilometers (73.6 percent) and 4 local government areas in Ogun State with 229.8 square kilometers (26.4 percent). The distribution of the built-up area by local government jurisdictions is presented in Table 20. Alimosho local government area has the largest built-up area of about 144 square kilometers while Lagos Island, also in the Lagos State sector has the smallest built-up area of about five square kilometers. Most of the local government areas in Lagos are almost completely built with virtually no further space to grow (see Figure 27).

Lagos megacity is one of the world's fastest growing urban centers. The UN-Habitat (2006) estimated the city's population to be about 15 million in 2006 with 600,000 additional migrants added each year and projected its population to reach 20.2 million by 2010.

The city's high aggregate population is an indication of its enhanced sensitivity to hazards. Thus, the effects of any negative consequences of climate change and climate variability extremes are likely to be felt by a large number of people, most especially the urban poor living on the marginal flood-prone areas of the city (see Table 19 and Figure 28). The built-up area breakdown shows that the Lagos State side of the megacity, which is made up of about 74 percent of the built-up area, has about 85 percent of the megacity's population, while Ogun state, with 26 percent of the built-up area, accounts for about 15 percent of the megacity's population. The elevation of the built-up area of the city ranges between 1m in the coastal areas to about 75 meters above sea level at its northern fringes (Ogun State Government, 2005).

The average population density of the city's constituting local government areas is about 2094 per square kilometer with the minimum of 164 per square kilometer in Owoode Obafemi local government area of Ogun State and a maximum of 55,939 per square kilometer in Ajeromi Ifelodun local government area in Lagos State. A better picture of the city's high population density can be inferred by a breakdown of each local government area's population density by the built-up areas. The local government areas in the Lagos State side have an average density of 13,194 per square kilometer. Ajeromi, Ifelodun local government area has a staggering density of 60,204 per square kilometer.

Lagos City, Urban Form, and Poverty: In 1983, 42 slums or blighted areas covering 1,622 hectares were officially documented by Lagos State. The number rose to about 62 out of the 2,600 communities in the state in 1995 (UN-Habitat, 2006). Due to the lack of secure land tenure slum communities are vulnerable to the threat of eviction (Morka, 2007). More recently, the Report of the Presidential Committee Redevelopment of Lagos Mega-City (Federal Republic of Nigeria, 2006) put the number of slum or blighted areas at over 100 in the Lagos portion with another 31 areas in the Ogun State portion of the megacity. The growth of the slums was also described in the report as a testimony to the city's difficulties in producing affordable housing for the urban poor. A 2002 survey in the megacity by Nubi and Omirin (2006) similarly revealed that over 70 percent of the built-up area of the metropolis is blighted. Most of the slums are located on marginal lands that are mainly flood-prone with virtually no physical and social infrastructure (see Figure 28). Lagos State government has, however, been making attempts at the inventory, management and upgrade of some of the slums through the Lagos State Urban Renewal Authority (LASURA) and the World Bank (IDA)-assisted Lagos Metropolitan Development and Governance Project (LMDGP).

Some of the planned and affluent neighborhoods in many parts of the city still experience flooding during “normal” rainfall. This may be attributed to the little-to-no attention often given to the provision and maintenance of sewer and storm drains in these supposedly “planned” affluent neighborhoods. For instance, Ikoyi, one of the most highly-priced neighborhoods in the city, was actually developed from an area originally covered by about 60 percent wetland. Also, Victoria Island and Lekki neighborhoods were formally low-lying barrier lagoon systems interspersed by wetlands and tidal flats with an elevation of about 0-3 meters before they were developed (see Figure 28).

Urban poverty has been described as one of the most daunting challenges currently facing the city’s administrators (UN-Habitat, 2006). The average monthly household income for the 1.1 million inhabitants of the 158,000 households in the LMDGP project was about US\$170 (Abosedo, 2006, 2008). Also, despite the city contributing more than 60 percent of Nigeria’s Gross Domestic Product, 65 percent of national investments and 65 percent of the nation’s Value Added Tax (VAT), about 65 percent of the residents are estimated to live below the poverty level. The deplorable state of the urban form and poverty is indicative of the expected low resilience of most of the inhabitants of the city to external hazard stressors such as those often associated with climate extreme events.

Adaptive Capacity

Even with active membership in the C40 Large Cities Climate Leadership network, Lagos megacity still does not have a comprehensive analysis of the possible climate risks facing it. The Goethe Institute and the Heirich Boll Stiftung Foundation, Lagos were NGOs at the fore of raising the alarm specifically on the vulnerability of the city to inundation due to the sea level rise associated with climate change.

It would be untrue to say that there are no activities on climate change in Nigeria, most especially by the scientific community, but there is a disconnect between the scientists, the people and the political class. The implication is that there is an urgent need to address the obvious lack of awareness of the vulnerability of Lagos to climate change and the need to begin to plan adaptation strategies. Recently, tackling the problem of flooding and coastal erosion has been given more attention by the Lagos State government in the form of a sea wall along Bar Beach in Victoria Island. This activity, however, is evidence that local awareness appears to be lacking of the full scope of the city’s vulnerability to climate change.

Although the attention of the city managers is more focused on filling its long physical infrastructural gap due to years of neglect, the lack of concern or awareness of likely sea level rise in Lagos is worrisome. There continues to be sand-filling of both the Lagos lagoon and the Ogun River flood plain in the Kosofe local government area to

about 2 meters above sea level for housing developments. Such activities need to be done with projections of sea level rise due to climate change as part of the planning process.

Emerging issues

Currently, the leading actor on climate change issues in the city is the Lagos State government, which has been influenced by its membership of the C40 Large Cities Climate Summit. Some of the mitigation actions being pursued by the Lagos State government in the city include:

1. Improvement of the solid waste dump sites that are notable point sources of methane—a greenhouse gas—emissions in the city.
2. The new bus rapid transport (BRT) mass transit system is already shopping for green technology to power vehicles in its fleet.
3. Commencement of tree planting and city greening projects around the city.
4. Proposed provision of 3 air quality monitoring sites for the city.

The full picture of the nature of climate change and variability, its magnitude and how it will affect the city is yet to be analyzed to support any informed adaptation actions. Thus, the climate risk reduction adaptation actions presently taken in the city are primarily spin-offs from the renewed interest of the city's management in reducing other risks and taking care of developmental and infrastructural lapses, rather than being climate change-driven. Some of these adaptation activities include:

1. The sea wall protection at Bar Beach on Victoria Island to protect the coastal flooding and erosion due to storm surges.
2. Primary and secondary drainage channel construction and improvement to alleviate flooding in many parts of the city.
3. Cleaning of open drains and gutters to permit easy flow of water and reduce flooding by the Lagos State Ministry of Environment Task Force locally referred to as "Drain Ducks."
4. Slum upgrade projects by the LMDGP project.
5. Awareness and education campaigns such as the formation of Climate Clubs in Primary and Secondary Schools in Lagos, and organisation of training sessions and workshops on climate change issues.

Due to the increasing activity in the Ogun State sector of the city, a regional master plan for the years 2005–2025 (Ogun State Government, 2005) has been developed for its management. However, the issue of climate change risks to infrastructures and the different sectors such water and wastewater (Iwugo et al., 2003), health, energy and the like is not yet reflected in the report.

"Normal" rainfalls are known to generate extensive flooding in the city largely because of inadequacies in the provision of sewers, drains and wastewater management even in government-approved developed areas. Consequently, an increase in the

intensity of storms and storm surges is likely to worsen the city's flood risks. Since the local governments are very close to the people and the communities threatened by climate risks, there is the need to create the awareness at the local government level. There is an urgent need to empower them intellectually, technically and financially to identify, formulate and manage the climate-related emergencies and disasters, as well as longer-term risks more proactively.

4.4 New York

With 8.2 million people, a \$1.1 trillion GDP (Bureau of Economic Analysis, 2008) and an operating budget of over \$40 billion, New York City is the largest city in the United States both in population and economic productivity (The City of New York, 2007, 2009). The distribution of wealth within the City, however, has been described as an "hourglass economy" where there is a shrinking of the middle class and growth in both the upper and lower-income populations (Rosenzweig & Solecki, 2001).

New York City is an archipelago with five boroughs spread out over three islands—Long Island, Manhattan and Staten Island—and the mainland of the United States (see Figure 32). Once a major manufacturing center, New York is now one of the world's most important international financial hubs. As a coastal city, most of New York City sits at a relatively low elevation with approximately 1 percent of the city below 3 meters (10 feet) (Rosenzweig & Solecki, 2001). Much of Manhattan's very low-lying land is home to some of the most important economic infrastructure in the world. Lower Manhattan, including the Wall Street financial district, and portions of both LaGuardia and John F. Kennedy airports sit at this low elevation.

New York City has a temperate, continental climate characterized by hot and humid summers as well as cold winters and consistent precipitation year round. Tables 5, 9, and 11 show the historic, observed weather conditions for temperature, precipitation, and sea level in New York City for the period 1900–2005. Using a baseline period of 1971–2000, these records show an average temperature of 12.7°C with precipitation averaging 109 to 127 centimeters per year. Recent climate trends show an increase in average temperature of 1.4°C since 1900 and a slight increase in mean annual precipitation (New York City Panel on Climate Change [NPCC], 2009).

As with other cities, climate change risks in New York City are a function of the hazards that the city faces, the vulnerability of its population and infrastructure to those hazards, and the adaptive capacity of the city to address climate change mitigation and adaptation needs. Hazards come in the form of increasing incidence of heatwaves, droughts and floods, and sea-level rise and associated storm surges. Adaptive capacity in New York City has been bolstered by the high-level adoption at the Mayoral and the State levels of the need to develop climate change adaptation strategies. Agencies, departments and public authorities are now developing and being provided with the tools necessary to undertake climate change mitigation and adaptation strategies.