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THE COST OF COASTAL ZONE DEGRADATION IN NIGERIA: CROSS RIVER, DELTA AND LAGOS STATES

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FOREWORD

Nigeria is Africa's richest economy. The country has a large population, abundant natural resources, and diverse cultures. Coastal areas are particularly unique: extending along more than 800 km, they are home to rich ecosystems, thriving industries, and booming opportunities. But these areas are also fragile. Every year, floods, erosion, and pollution of air and water have alarming consequences: they cause death, sicken children, and wash away land and houses. The poor bear the brunt. How big is the damage?

This report provides a clear answer to this important question. Using a consistent valuation methodology, it estimates the cost of coastal degradation in three Nigerian states: Cross River, Delta and Lagos. The results are striking: in 2018 alone, floods, erosion and pollution in these three states cost society US$9.7 billion, or 2.4 percent of the country's GDP. As this estimate covers less than a half of the country's coastline, the total cost of coastal degradation in Nigeria is certainly higher.

This report demonstrates the benefits of doing a coordinated study that builds on state and local level analyses. Its findings will inform the country's multi-sectoral investment plan for the coastal zone, and will support its efforts to mobilize financing for coastal resilience as part of the West Africa Coastal Areas program. Investing in coastal resilience will save lives and prevent future damages. The time is now.

Shubham Chaudhuri
Country Director, Nigeria
World Bank

Photo Credit: Joseph Akpokodje, World Bank.

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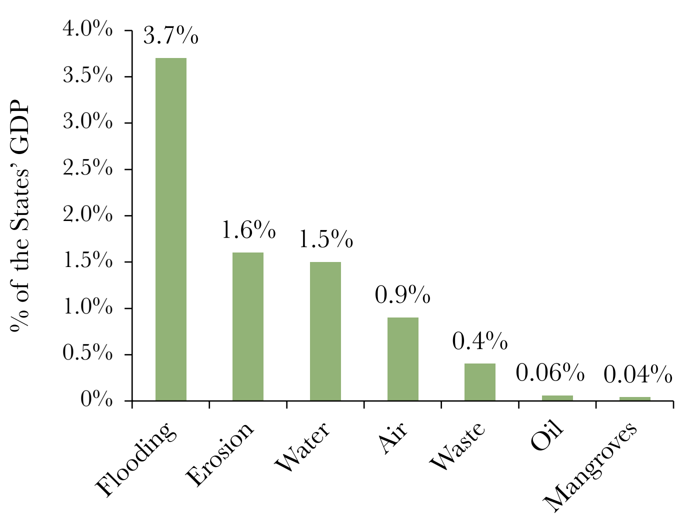
EXECUTIVE SUMMARY

Nigeria is home to Africa's largest economy and population. The country is endowed with abundant natural resources: the biggest oil and natural gas reserves on the continent[1], plentiful water, and the largest mangrove ecosystems in Africa. The coastal zone, which stretches along 853 km, is crucial to the country's economy, by housing activities related to oil and gas exploration and exploitation, fishing, shipping, and agriculture. Lagos State alone contributes an estimated 25 percent of the country's economy[2].

Despite its rich resources and economic opportunities, the coastal zone is affected by severe pressures: unplanned urbanization has increased people's exposure to air pollution, poor sanitation, unsafe drinking water, and toxic wastes; floods and erosion have increasingly devastating effects; moreover, sea level rise is exacerbating these threats. Thus, the coastal zone is undergoing **alarming environmental degradation,** leading to deaths from air and water pollution; losses of assets such as houses and infrastructure; and degradation of critical ecosystems, such as mangroves. For example, in 2018, ambient air pollution in Lagos caused about 11,200 premature deaths, and generated a health cost estimated at US$2.1 billion[3].

FIGURE 1: ESTIMATED COED BY CATEGORY, 2018



Source: World Bank estimates.

1 Based on https://www.worldbank.org/en/country/nigeria/overview

2 Based on an estimated Lagos GDP of US$98 billion (World Bank calculations, August 2020, based on data derived from the Lagos Bureau of Statistics) and country GDP of US$398 billion in 2018 (https://data.worldbank.org, accessed August 2020).

3 It should be noted that this estimate accounts for the cost of ambient air pollution in the entire Lagos city (Croitoru et al., 2020)–not only in the coastal districts, for which the cost is reported in Table 1.

TABLE 1: ESTIMATED COED ON THE COASTAL ZONE OF THE THREE STATES (US$ MILLION, 2018)

	Cross River	Delta	Lagos	Total
Flooding	94	300	3,992	4,386
Erosion	158	85	1,650	1,893
Water	161	186	1,480	1,827
Air	96	82	895	1,073
Waste	27	48	377	453
Oil	n.n.	66	3	69
Mangroves	6	37	1	44
Total	**543**	**805**	**8,397**	**9,746**
% of the state's GDP	**6.8%**	**5.7%**	**8.6%**	**8.1%**

Source: World Bank estimates. n.n. = negligible, based on available data. The totals might not add up exactly due to rounding.

Understanding the magnitude of coastal degradation is a critical step for reconciling development and environmental conservation. For the first time ever, this study estimates the Cost of Environmental Degradation (COED) on the coastal zone in three Nigerian states: Cross River, Delta, and Lagos[4]. Specifically, it values the impacts of degradation that occurs during one typical year, as a result of four major factors: pollution (related to air, water, waste, and oil), flooding, erosion, and mangrove loss. The final results are expressed in 2018 prices. They are reflected in absolute (US$) and in relative terms, as percentages of the states' GDP.

Overall, the coastal COED in the three states is estimated at **US$9.7 billion**, or **8.1 percent of their GDP** (Table 1). This corresponds to about 2.4 percent of Nigeria's GDP. Flooding, erosion, and water pollution are the main forms of degradation, accounting for more than 80 percent of the total cost (Figure 1). Moreover, coastal degradation causes over **15,000 premature deaths** a year, primarily due to water and air pollution. At the state level, the COED varies between 5.7 percent of Delta's GDP and 8.6 percent of Lagos' GDP. The highest degradation cost occurs in Lagos, the state most affected by flooding, erosion, and pollution from water, air, and waste. Delta stands out with the highest cost of oil spills and mangrove loss among the three states.

Overall, the main drivers of coastal degradation include:

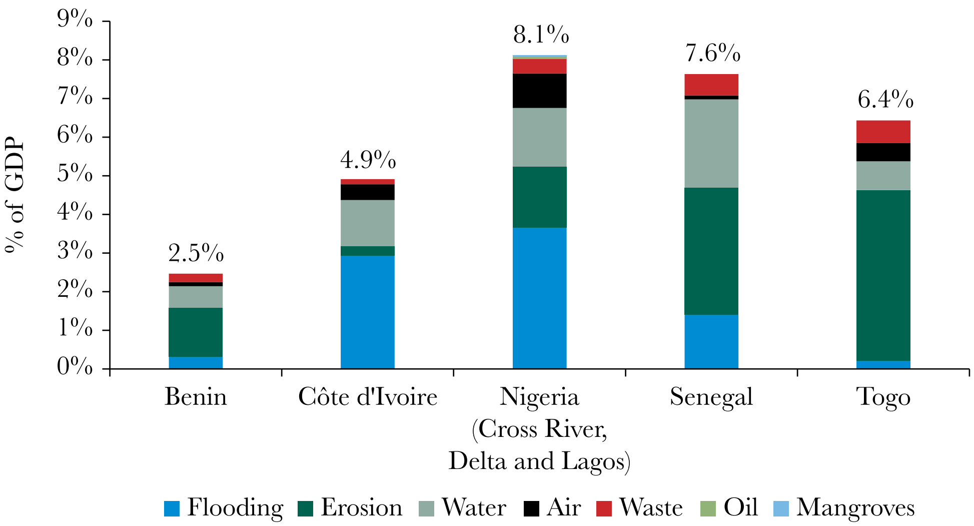
» ***Flooding*** is the most damaging problem, causing about 45 percent of the total COED. In all three states, damages due to flooding are primarily a result of overflowing rivers (fluvial floods), and to a lesser extent, of extreme rainfall (pluvial floods). The economic cost is particularly high in Lagos (US$4 billion per year) due to its relatively large flooded area, and to high value assets and large population at risk. Flooding is also the most damaging factor in Delta—the state with the largest flooded area among the three (2,500 ha per year, on average).

» ***Erosion*** is caused by both natural and human factors. As in the case of floods, the largest cost of erosion occurs in Lagos, due to the high value of assets, land, and production lost. Cross River has the largest area eroded (169 ha per year) among the three states. In all states, the cost of erosion is expected to increase, as the phenomenon is likely to affect larger urban areas.

» ***Pollution*** imposes an important toll on people's health, quality of life, and environment. In all states, *unsafe water, insufficient sanitation, and poor hygiene* are particularly harmful, causing nearly 9,400 premature deaths per year. Poor air quality is responsible for about 5,700 deaths—mainly a result of household air pollution in Cross River and Delta, and of ambient air pollution in Lagos. Other important forms of degradation are *waste* mismanagement (due to the high cost of uncollected waste) and *oil pollution* (due to the cost imposed on Delta's society and ecosystems), though these are considerably underestimated. Nigeria has the highest production of plastic waste in Africa, and the fastest growing e-waste problem in the Sub-Saharan region.

4 The three states were selected because they are representative of different socio-economic and environmental situations, and they have better data availability than other states, being part of ongoing Bank initiatives.

FIGURE 2: ESTIMATED COASTAL COED IN WEST AFRICA



Sources: Authors, for Cross River, Delta and Lagos; Croitoru et al. (2019) for the other countries.
Note: The result for Nigeria represents the percentage of the combined GDP of the three Nigerian states.

Figure 2 places the estimated COED (8.1 percent of the three states' GDP) in a broader context of other West African countries: a recent study estimated it between 2.5 percent of Benin's GDP and 7.6 percent of Senegal's GDP[5]. Interestingly, the main degradation drivers differ from country to country (e.g. flooding in Nigeria and Côte d'Ivoire; erosion in Senegal and Togo), and from a Nigerian state to another (e.g. flooding in Delta and Lagos; water pollution and erosion in Cross River).

This study demonstrates that flooding, erosion, and pollution are major challenges facing the Nigerian coastal areas. In the three coastal states, they cause death, decrease the quality of life, and lead to substantial economic damages, amounting to about **2.4 percent of Nigeria's GDP**. As this estimate covers less than a half of the country's coastline, **the COED of the entire country's coastal zone is certainly higher**. These results will inform the country's multi-sectoral investment plan for the coastal zone, and will support the ongoing efforts to mobilize financing for coastal resilience as part of the West Africa Coastal Areas (WACA) program. The program provides technical advice and investments to protect coastal livelihoods, prevent pollution, and develop coastal infrastructure, such as breakwaters, sand barriers, and mangrove restoration.

It should be noted that data limitations prevented the estimation of several costs, related to: air pollution (e.g. the impacts of pollutants other than $PM_{2.5}$ and lead on people's health, the effect of gas flaring, illegal refineries, etc.), water pollution (e.g. losses in fisheries, impact of emerging pollutants, etc.), waste management (e.g. damages caused by inappropriate disposal of waste other than municipal and e-waste, losses due to forgone opportunities to recycle, damages due to specific waste categories, such as plastic), oil spills (e.g. impacts on health), floods (e.g. damages caused by flooding from sea level rise and storm surges), erosion (e.g. slower GDP growth in the future due to less real estate on the coastal area), mangroves (e.g. degradation due to invasive Nypa palm); and other effects (e.g. impact of sand mining, transboundary impacts of flooding and oil spills, effects of greenhouse gas emissions, etc.) Therefore, the final results should be considered **underestimates** of the real magnitude of the COED. To refine and complement them, it would be important that future work cover the above aspects, as well as the effects of climate change on floods, erosion, and water resources.

5 It should be noted that the result of this study reflects the percentage of the combined GDP of only the three Nigerian states, thus it is not fully comparable with the estimates for the other four countries (Benin, Côte d'Ivoire, Senegal and Togo), which represent percentages of the entire countries' GDP.

Photo Credit: Irene Abdou/Alamy Stock Photo.

CHAPTER 1
INTRODUCTION

Nigeria is a key regional player in Africa. With a gross domestic product of US$398 billion and 196 million people[6], the country has the biggest economy and the largest population on the continent. It is also well endowed with natural resources: the largest oil and natural gas reserves in Africa[7], other valuable minerals (e.g. coal, tin), plentiful water resources, and a rich diversity of forests and wildlife. Coastal areas are crucial to the country's economy, by housing activities related to oil and gas exploration and exploitation, fishing, shipping and agriculture. The coastline stretches on 853 km, along nine states: Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Lagos, Ogun, Ondo and Rivers[8]. Lagos State alone is believed to contribute about 25 percent of the country's economy[9].

Despite the rich natural resources and economic opportunities, coastal areas[10] are affected by severe pressures: unplanned urbanization has increased exposure to air pollution, poor sanitation, unsafe drinking water, toxic wastes, etc. (Aliyu and Amadu, 2017); floods and erosion have increasingly devastating effects; moreover, sea level rise and disaster risks are exacerbating these threats. As a result, coastal areas are undergoing **alarming environmental degradation** leading to deaths (e.g. due air and water pollution), losses of assets (e.g. houses and infrastructure) and of critical ecosystems (e.g. beaches and mangroves). For example, in 2018, ambient air pollution in Lagos

6 Data refer to 2018, based on https://data.worldbank.org, accessed August 2020.

7 Based on https://www.worldbank.org/en/country/nigeria/overview

8 https://www.cia.gov/library/publications/the-world-factbook/geos/ni.html

9 Based on an estimated Lagos GDP of US$98 billion (World Bank calculations, August 2020, based on data derived from the Lagos Bureau of Statistics), and country GDP of US$398 billion in 2018 (https://data.worldbank.org, accessed August 2020).

10 It should be noted that the National Environmental Standards and Regulations Enforcement Agency (NESREA) is the apex Government body empowered to enforce all environmental laws in the Nigerian environment and has several National Environmental Regulations aimed at controlling the anthropogenic activities on the coast, including: National Environmental (Air Quality Control) Regulations of 2014, National Environmental (Control of Alien and Invasive Species) Regulations of 2013, National Environmental (Coastal and Marine Area Protection) Regulations of 2011, National Environmental (Soil Erosion and Flood Control) Regulations of 2011, National Environmental (Surface and Ground Water Quality Control) Regulations of 2011, etc.

MAP 1: COASTAL ZONE OF CROSS RIVER, DELTA AND LAGOS STATES

Source: World Bank, using the Database of Global Administrative Areas for national, state and district boundaries.

caused about 11,200 premature deaths and generated a health cost estimated at US$2.1 billion (Croitoru et al., 2020).

Raising awareness on the magnitude of coastal degradation is critical to reconciling development and conservation. This study contributes to this need, by estimating in monetary terms the Cost of Environmental Degradation (COED) of the coastal zone in three Nigerian states: Cross River, Delta and Lagos[11] (Map 1). These states were selected due to a few reasons: they are representative of different socio-economic and environmental situations[12], and they have improved data availability compared to other states, being part of other ongoing Bank initiatives[13]. It is expected that the results of this study will inform the country's multi-sectoral investment plan, and will support the ongoing efforts to mobilize financing for coastal resilience as part of the West Africa Coastal Areas (WACA) program.

In this study, the coastal zone[14] has been identified with all Local Government Authorities (LGAs) bordering the

11 The Country Environmental Analysis of 2006 estimated the COED at the national level at 7.7 percent of Nigeria's GDP (World Bank, 2006). This estimate accounts for the impacts of environmental degradation on health, land, flood and global damages, without focus on coastal degradation.

12 Lagos is highly urbanized, with air and water pollution problems; while the coastal zones of the other states are mostly rural, dealing with problems of erosion (Cross River), and oil spills and deforestation (Delta).

13 World Bank Pollution Management and Environmental Health/Air Quality Monitoring Project (PMEH/AQM) in Lagos, and Nigeria Erosion and Watershed Management Project (NEWMAP) in Cross River and Delta States.

14 There is no standard definition of the coastal zones. For example, USAID (2014) identified the coastal zone in Nigeria with the inland area within a 200 km strip from the coastline inland. World Bank defined coastal zone in other West African countries as all districts bordering the coastline and coastal water bodies (Croitoru et al., 2019). Similarly, the present study identifies coastal zone with all Local Government Authorities (LGAs) bordering the coastline and coastal water bodies (e.g. rivers, lagoons) in the three states. This definition allows improved data availability (e.g. in terms of population and economic activities), as well as direct comparability of results with the other West African countries: Benin, Côte d'Ivoire, Senegal and Togo.

TABLE 1.1: SOCIO-ECONOMIC DATA RELATED TO THE THREE NIGERIAN STATES (2018)

State	GDP (US$ billion)	Total population (million)	Coastline (km)	Coastal LGAs (#)	Coastal population (million)	Coastal population (% of state's total)
Cross River	8.0	4.1	97	4	1.0	24
Delta	14.0	6.0	103	4	1.1	19
Lagos	97.9	25.6	164	11	10.2	40
Total Nigeria	**398.2**	**195.9**	**853**	**42**	**16.6**	**8**

Sources: GDP for Nigeria: https://data.worldbank.org, accessed in August 2020; GDP for the three states: World Bank calculations, based on data derived from National Bureau of Statistics and Lagos Bureau of Statistics, August 2020. Population data are derived from the Nigeria's latest population census of 2006 and further projections, based on National Population Commission and National Bureau of Statistics for Cross River and Delta; National Population Commission and Lagos Bureau of Statistics for Lagos; https://data.worldbank.org for Nigeria. Coastline: GIS analysis by World Bank. Coastal LGAs: based on the proximity to the coastline and other water bodies, these include: Akpabuyo, Bakassi, Calabar South and Odukpani (in Cross River); Burutu, Warri North, Warri South and Warri South-West (in Delta); Amuwo Odofin, Apapa, Badagry, Epe, Eti-Osa, Ibeju/Lekki, Ikorodu, Lagos Island, Mainland, Oju and Shomolu (in Lagos).

coastline and coastal water bodies (e.g. rivers, lagoons) in the three states. As such, it covers 19 LGAs. These areas are home to about 12.3 million people, or 74 percent of the country's coastal population—most of it concentrated in Lagos. Their coastline, extending along 364 km, accounts for about 43 percent of the country's entire coastline (Table 1.1).

The study builds on a similar methodology used in a recent report that estimated the cost of coastal degradation in Benin, Côte d'Ivoire, Senegal and Togo (Croitoru et al., 2019); however, the present study **adds value** by refining the valuation approaches to improve methodological consistency, and by estimating a wider range of impacts compared to the previous report. Additional impacts estimated by this study are related to *air pollution* (e.g. the impact of both ambient and household $PM_{2.5}$ in all urban and rural coastal areas vs. only the ambient $PM_{2.5}$ on the countries' capitals in the previous study); *water* degradation (e.g. indirect impacts of inadequate water, sanitation and hygiene—WASH–on health, cost of untreated industrial wastewater); *waste* (e.g. loss of opportunities related to electricity production, and the impact of e-waste on health); and the cost of *oil spills* and *mangrove loss*.

Photo Credit: Joseph Akpokodje, World Bank.

CHAPTER 2
METHODOLOGY

A solid methodology is needed to ensure that the costs imposed on society by environmental degradation are captured as accurately and consistently as possible across different environmental impacts. This chapter describes the methodology used for estimating the COED. It presents the objective and scope of the study (section 2.1), discusses the methodological consistency and the valuation methods used (section 2.2), and presents the study's limitations (section 2.3).

2.1. OBJECTIVE AND SCOPE

This study aims at estimating in monetary terms the annual COED of the coastal zone of Cross River, Delta and Lagos States. It assesses damages at three levels: *economic*, such as damages to assets (e.g. buildings and roads) due to coastal floods; *environmental*, for example, reduced aesthetic value in the areas located near unsanitary landfills; and *social*, such as premature deaths caused by exposure to high levels of air and water pollution. It only focuses on the damages caused to the three states, and does not consider the cost to global community (e.g. greenhouse gas emissions).

It should be noted that certain activities have *short-term impacts*: for example, inadequate WASH often causes diarrhea, with a duration ranging from a few days to weeks. Other activities have *long-term impacts*: for example, erosion of coastal areas often results in losses of assets and productivity in long run[15]. This study estimates the present value (PV) of the current and future impacts caused by activities occurring during a **typical year**[16]—often, the latest year for which data are available[17]—and expresses them in

15 It is important to note that some phenomena (e.g. floods and erosion) are dynamic processes, which impacts can vary from a year to another. The present study does not aim to assess the evolution of these phenomena in time, but rather, estimate their impacts during an average year.

16 In the current context, COVID-19 is causing a slowdown of economic growth and is increasing uncertainty on future economic projections. However, as there is not consensus on the magnitude and the timeline of the impact, this study estimates the COED under a typical situation (without COVID-19).

17 In some instances, the latest year for which data are available does not necessarily reflect a "typical year", as is the case of mangrove loss and erosion. In these cases, the study considers the annual average extent of degradation during the most recent period (e.g. 10 years).

2018 prices. It uses a 3 percent discount rate due to the high importance given to the future impacts of erosion, and a time horizon of 30 years[18].

The study estimates the impacts of environmental degradation that occurred due to **pollution** (related to air, water, waste, and oil spills), **flooding**, **erosion**, and **mangrove loss** on the coast. It focuses on degradation induced by both *human* (e.g. air pollution due to industrial activities, water pollution due to discharges of untreated wastewater) and *natural* factors (e.g. flooding and erosion). As such, the estimated values provide a more comprehensive picture of the situation of environmental degradation compared to much of the previous COED work which focused primarily on human-induced degradation (Croitoru and Sarraf, 2010). For example, knowing that floods might cause high coastal damages would trigger an urgent call for installing protective measures—which would not have been prompted, had the COED covered only human-induced losses.

In addition, the valuation of the COED also covers to a limited degree the impacts of *climate change* (e.g. increased flooding due to higher rainfall). However, it is important to note that in this study: (i) the impacts of climate change cannot be separated from those of other factors; (ii) since the valuation refers to only one year, these impacts are likely to be minor[19].

2.2. WHAT DOES THE COED MEASURE?

Figure 2.1 illustrates the economic value of coastal zones under different management practices. The left column shows that for a given year (2018), these areas provide certain benefits (e.g. industrial and agricultural production, recreational and aesthetic value), depending on the type of management and socio-economic context. The middle column presents the value of these benefits in the following year ("2019, under current management"); they are assumed to be lower because of degradation, due to either sub-optimal management (e.g. discharge of untreated municipal wastewater, air pollution caused by industrial activities) or natural factors, exacerbated by climate change (e.g. coastal erosion and flooding). The difference in these benefits represents the cost of damage caused by current degradation, namely the COED. This is what the present study measures in monetary terms.

It is important to note that the COED only indicates the extent of damage, and the areas needing urgent interventions for improvement. It provides **no information on mitigation solutions, or their profitability.** The right column best reflects this point: it shows that the profitability of interventions should be measured by comparing their benefits with the costs of intervention, based on the Cost-Benefit Analysis method ("2019, with improved management"). This study does not address potential solutions for environmental improvement.

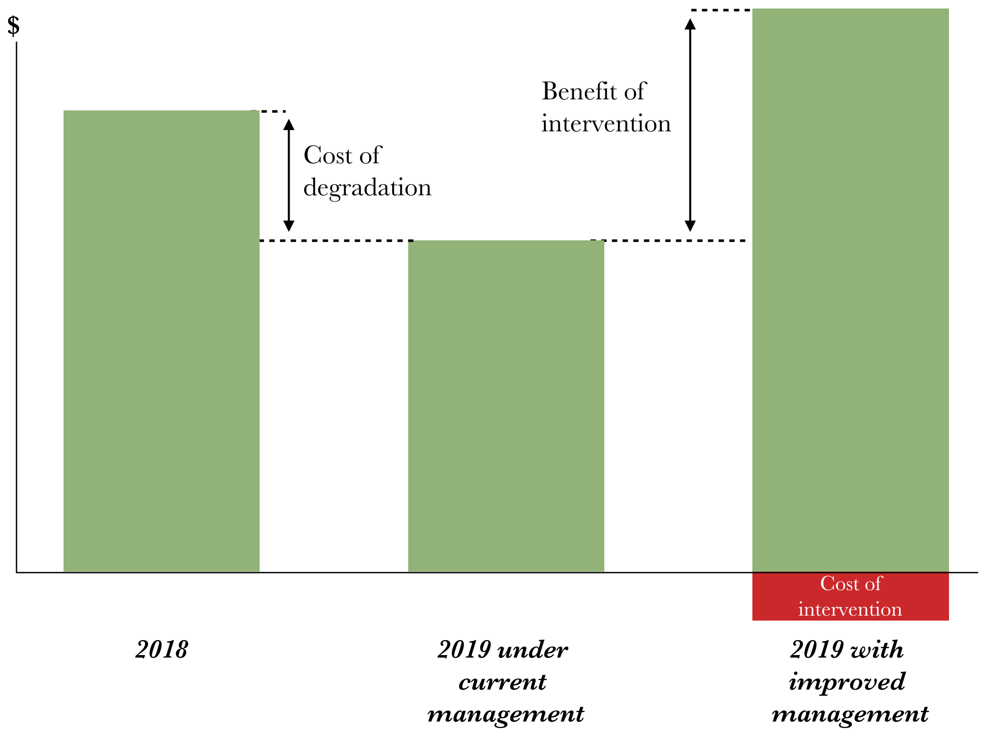
2.2.1. METHODOLOGICAL CONSISTENCY

In a complex valuation exercise such as the COED, using **similar measures of value** that can be aggregated is essential to obtain meaningful results. Past COED efforts made large contributions in advancing countries' environmental agenda; however, many have been criticized for adding up estimates reflecting different measures of value (welfare-based measures, such as contingent valuation or travel cost, and exchange value-based measures, such as production functions). Such differences were often a result of: data unavailability to estimate different degradation costs through the same measure, or the belief that using the same measure would not capture the true cost of degradation. For example, using *income-based measures* to estimate all COED would certainly provide compatible, but very partial results: e.g. valuing the cost of mortality through the forgone income approach would seriously underestimate the real magnitude of loss due to death. On the other hand, using *welfare-based measures* to estimate the overall COED is not possible in many cases: e.g. there are not sufficiently informed studies, if any, to value erosion damages through the people's Willingness to Pay (WTP) for adaptive measures. Thus, despite several decades of improving methodological approaches and data, challenges persist in relation to valuation consistency.

18 Assuming that a person of average age will benefit from environmental services for another 30 years. The same parameters have been used also in other studies, such as Croitoru et al. (2019) and World Bank (2020).

19 To capture the overall impacts of climate change on the coast, a study should use projections of impacts on a much longer time horizon (e.g. 30-50 years).

FIGURE 2.1: ECONOMIC VALUE OF COASTAL ZONES



Source: Based on Pagiola (2004).

This valuation problem is an important one for COED studies, as estimating the COED involves valuing damages to some goods and services that have market prices (e.g. houses and land lost to erosion), and to some that do not (e.g. pollution due to uncollected municipal waste). In this study, the COED is assessed by measuring the loss in people's wellbeing due to environmental degradation, through the WTP approach[20]. In other words, it aims to measure the **total WTP** to improve environmental quality on the coastal zone of the three states. In economic theory, the WTP for a good or service covers both the *exchange value* (i.e. the benefit incurred through the payment of the price of a good) and the *consumer surplus* (i.e. the benefit a person receives above what is paid) (Figure 2.2).

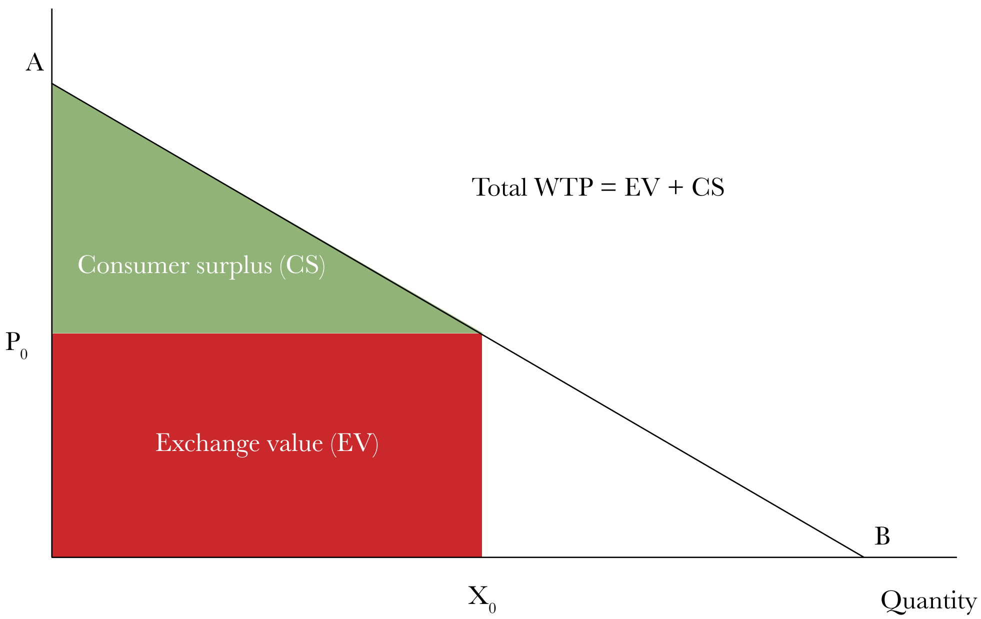
In this study, the losses of marketable goods are estimated through their *exchange value*, e.g. damages to assets from floods and erosion, losses of electricity opportunities from waste, loss of oil due to spills; other losses are estimated through the *total WTP*, e.g. WTP for waste collection and disposal, WTP to reduce health risks.[21] While the above measures are still imperfect (e.g. as WTP differs from the exchange value), they are all components of the total WTP. As such, the estimates presented in this study provide a **partial picture of the total WTP** to improve environmental quality on the coastal zone of the three states[22].

20 Demand curve approaches include: revealed preference methods, based on observation of actual consumer behavior in markets for goods and services; and stated preference methods, based on elicitation of consumers' WTP for a benefit or willingness to accept (WTA) a compensation for a loss (Bateman, 1994). Measures based on observed behavior are usually preferred to those relying on hypothetical behavior, as the latter can result in biased responses. In addition, the perception of the value of service/damage differs from the WTP/WTA perspective. The National Oceanic and Atmospheric Administration (NOAA) Panel suggested that WTP should be always used to evaluate a service; it is commonly argued that this constitutes the most conservative (and therefore, preferred) option (Arrow, 1993; Carson et al., 1996).

21 This is often the case of valuing environmental services with no market prices, for which there is no exchange value.

22 Only in one instance the study applies cost-based methods (cost of oil clean-up and recovery), while ensuring that they provide conservative results compared to other WTP measures.

FIGURE 2.2: EXCHANGE VALUE, CONSUMER SURPLUS AND WILLINGNESS TO PAY



Source: Markandya (2020).

It is important to note that the valuation efforts are often affected by risks of double counting. The most common causes include: ambiguity in the definition of ecosystem services, e.g. confusion between ecosystem functions and final services for humans; interdependence among ecosystem services, e.g. among supporting, regulating, provisioning and cultural services; and potential overlap of valuation methods, e.g. assessing the decrease in value of a polluted lake by aggregating results of travel cost method (to estimate losses in tourism) and hedonic price method (to estimate the decline in house prices) (Fu et al., 2011). In this report, careful attention was paid to avoid or reduce potential double-counting risks, by: accounting only for the final services to end-users (e.g. impacts on health, environment and economy); ensuring that the same cost is not accounted more than once across the report; and using appropriate methods that reflect consistent valuation measures. The effort to reach conceptual consistency has been affected by several limitations, which are discussed in section 2.3.

While the above discussion provides a quick glimpse on the efforts made to achieve methodological consistency in this study, it is important to dedicate additional effort to specifically review the methods used in the COED and similar studies, rank valuation methods in terms of their consistency with other methods, their relative desirability, the likelihood that data will be available to apply them, and the type of bias the resulting estimates might contain.

2.2.2. VALUATION METHODS

The impacts estimated in this study are summarized in Table 2.1 and described below. Due to methodological and data limitations, other impacts could not be valued in monetary terms; these are listed in Section 2.3.

Air pollution. Air pollution is a major contributor to human mortality and morbidity. Exposure to fine particulate matter ($PM_{2.5}$) is especially harmful to health, as it can pass the barriers of the lung and enter the blood stream. This section estimates the impact of exposure to ambient and household $PM_{2.5}$ on health on the coastal zone. Using the latest cause-and-effect relationships developed in the epidemiological literature, it estimates the impact on premature ***mortality:*** lower respiratory infections, induced ischemic heart disease; stroke; chronic obstructive pulmonary disease; tracheal, bronchus and lung cancer; and

TABLE 2.1: ESTIMATED COED AND VALUATION METHODS USED

	Environmental degradation	Methods used for valuation
Pollution	***Air***	
	Impact of ambient and household air pollution ($PM_{2.5}$) on health: LRI, ischemic heart disease; stroke; chronic obstructive pulmonary disease; tracheal, bronchus and lung cancer; and diabetes mellitus type 2	VSL for mortality WTP for morbidity
	Water	
	Direct effects of unsafe WASH: e.g. diarrhea	VSL for mortality
	Indirect effects of unsafe WASH: measles, protein-energy malnutrition and LRI	VSLY for morbidity
	Discharge of untreated municipal and industrial wastewater in the environment	WTP for treating wastewater
	Waste	
	Damage due to uncollected municipal waste	WTP for improved waste collection
	Damage due to sub-optimal disposal of municipal waste	WTP for improved waste disposal
	Loss of opportunities related to electricity production	Market price
	Health impacts from exposure to lead (e-waste)	VSL for mortality VSLY for morbidity
	Oil spills	Market price (for the value of lost oil, cost of clean-up and recovery)
	Impact of oil spills	Benefits transfer (for the unit value of damage)
Floods	Damage to assets and economic productivity	Market price
	Mortality	VSL
Erosion	Loss of assets, land and economic productivity	Market price
Mangrove	Loss of mangrove area	Market price (for loss of wood and fishing) and avoided damage method (for flood risk reduction)

Notes: LRI = lower respiratory infections, VSL = value of statistical life; VSLY = value of statistical life years.

diabetes mellitus type 2 (GBD 2017 Risk factors collaborators, 2018). The cost of mortality is estimated based on the VSL, which reflects the society's WTP to avoid the risk of death (Box 2.1). In addition, the cost of ***morbidity*** is valued as a fraction (10 percent) of the cost of mortality, based on available studies on the WTP for reduced morbidity due to air pollution (World Bank, 2016; Hunt et al., 2016).

Water pollution. Insufficient or inappropriate WASH can affect human health (e.g. due to water-borne diseases) and the environment (e.g. due to discharge of untreated wastewater). This section estimates the direct and indirect impacts of unsafe WASH on ***health*** through the burden of water-borne diseases on the coastal areas of the three states. First, the section quantifies mortality (number of premature deaths) and morbidity (number of years lost to disability, YLDs) based on the 2017 Global Burden of Disease (GBD) data. It then estimates the economic cost of mortality (based on the VSL) and morbidity (based on the Value of Statistical Life Years, VSLY, as discussed in Box 2.1). In addition, the section assesses the impact of untreated municipal and industrial wastewater on the ***environment*** through the WTP for improved wastewater treatment.

Waste management poses complex challenges, as it relates to a wide range of wastes—e.g. municipal, medical, industrial, demolition, electronic waste—which must be handled in distinct ways. Inappropriate management of these wastes can result in: reduced tourism opportunities, fish contamination, groundwater pollution, and sometimes human deaths. This section addresses several impacts: damages due to insufficient *collection* of

BOX 2.1: ESTIMATING THE IMPACTS OF ENVIRONMENTAL DEGRADATION ON HEALTH IN NIGERIA

Environmental degradation is often due to unsafe WASH, ambient and household air pollution and waste mismanagement. These issues pose high risks to human health, in terms of premature mortality and morbidity. The concepts of VSL, VSLY, and cost of illness are often used to estimate in monetary terms the health cost of environmental degradation. These approaches have several limitations, which are widely acknowledged by the environmental literature and briefly reported in Section 2.3.

This report estimates the cost of ***premature mortality*** based on the VSL concept. It reflects the society's WTP to reduce the risk of death, or in other words, the local trade-off rate between fatality risk and money (Viscusi and Masterman, 2017; Kniesner and Viscusi, 2019). However, even though this concept is now commonly used, its application is still subject to challenges, e.g.: (i) in countries where primary surveys have been conducted, its application often generated a wide variety of results, depending on the approach used, type of survey, etc.; (ii) in countries with no primary surveys, the VSL has been usually obtained through benefits transfer of a value from a different country. The latter is the case of the present study, where the VSL for Nigeria (US$167,400) has been obtained through benefits transfer of a base value of US$3.8 million (2011 US$, purchasing power parity), from a sample of studies conducted in Organisation for Economic Co-operation and Development (OECD) countries, following the guidelines provided by the World Bank (2016).

Estimating the cost of ***morbidity*** should ideally be based on the number of cases and the WTP to avoid illness. However, studies to avoid morbidity related to specific diseases are often scarce in developing countries. Due to this limitation, existing literature suggests four possible valuation measures, from the most to the least preferred ones (Robinson and Hammitt, 2018): (1) WTP estimates to avoid morbidity and third party averted costs; (2) monetizing the Disability Adjusted Life Years by using a valuation function and third party averted costs; (3) monetizing the Disability Adjusted Life Years or Quality-Adjusted Life Years by using a constant VSLY and third party averted costs; (4) individual and third party averted costs. In this report, information on the WTP to reduce morbidity (measure 1 above) is available only for *air pollution*. For *water* and *e-waste*, in the absence of similar data, the valuation relies on a less preferred option, based on the VSLY to estimate the value of a year lived with disability (measure 3 above).

municipal waste, estimated based on the society's WTP for improved waste collection; the cost of sub-optimal *disposal*, valued based on the WTP for improved waste disposal; loss of opportunities, estimated based on forgone net income from electricity production; and health impacts from exposure to lead (primarily due to e-waste), valued through the cost of mortality and morbidity.

Oil spills cause damages to the environment and economy in many areas of Niger Delta. Among the three states, Delta is particularly affected. A spatial analysis of the oil spill locations across the country indicates that oil contamination of coastal zones originates from quantities spilled off-shore; in the coastal districts; and from specific locations of non-coastal districts (i.e. spillage areas close to the hydrographic network[23]). This section estimates the damages due to oil spills in terms of the economic value of oil lost, actual cost of clean-up and recovery, and damages caused by the remaining oil spilled. Carrying out a comprehensive primary study on the WTP to reduce the impacts of oil spills in Niger Delta is necessary to refine the monetary estimates of damage obtained.

Floods. Nigeria experiences *fluvial floods*, which occur when rivers burst their banks as a result of sustained or intense rainfall, and *pluvial floods,* which take place when heavy precipitation saturates drainage systems, particularly in flat, saturated and urban areas. The analysis estimates the impact of both fluvial and pluvial floods that occur on the coastal zone of all states, through: (i) the cost of ***mortality,*** estimated based on the number of deaths due to flooding and the VSL; and (ii) the ***damage to assets and economic production,*** based on: the flooded area for a typical year, a damage factor (coefficient of loss), and the unit economic value of assets and production on the coast. These indicators are derived as follows:

- *The flooded area* is calculated based on the results of the SSBN Global Flood Hazard Model applied to Nigeria. These results show the maximum expected water depth for fluvial and pluvial floods and their corresponding surface for six different return periods (between 1/5 and 1/100 years). The flooded area is then classified into rural and urban areas.

23 Derived from a digital elevation model of 900 m resolution, and 100 Accumulation Flow Threshold.

- *The economic value of assets and production* is estimated based on the available multi-hazard risk assessment on the West African coast (IMDC et al., 2018). It captures the value of assets (e.g. buildings, roads, other infrastructure) and of economic flows (e.g. industrial and agricultural production) for 2018 for both rural and urban coastal areas, estimated based on asset prices and other economic data collected from each state.
- *A damage factor,* whose magnitude varies according to water depth, is used to estimate the part of economic value lost to floods, based on a study that developed damage factors for Africa, and other regions (Huizinga et al., 2017).

Erosion. Nigerian coastal areas are affected by erosion due to population growth, economic activity, and sea level rise. Estimating the cost of erosion assumes that the land, assets, and economic flows are lost in the long run[24]. The valuation is based on the following indicators:

- *The eroded area* is estimated as an annual average value of land area lost to erosion, based on a study which estimated the change in shoreline over 1984-2016, by comparing cloud-free historical Landsat images with resolution of 30 m (Luijendijk et al., 2018).
- *The unit economic value of eroded land* captures: the value of assets (e.g. buildings, roads, other infrastructure); the PV of economic flows for the next 30 years; and the value of bare land.

Mangrove loss. With about 636,000 ha of mangrove area, Nigeria has the largest mangrove ecosystem in Africa, and the third largest in the world (Menendez et al., 2020; UNEP, 2007). Despite that, these mangroves are subject to deforestation and degradation, due to many factors, e.g. oil and gas operations, coastal development, wood harvesting, conversion for agriculture and bio-fuel plantations. This section estimates the economic cost of mangrove loss based on the area of mangroves annually lost, and the *per hectare* mangrove benefit in terms of fishing, logging, and flood risk reduction. Due to data limitations, the estimate does not capture the loss in ecosystem services due to degradation of existing mangroves; however, a part of this loss—cost of mangrove degradation due to oil spills—is captured in Section 3.4.

24 In reality, these losses can be replaced through reconstruction of similar assets in areas located nearby; however, this is often not possible, for example due to land scarcity (e.g. driven by high urbanization rate on the coast). Even when reconstruction is possible, this induces diverting budget from other investments other would have otherwise happened – hence, inducing lost economic opportunities.

2.3. STUDY'S LIMITATIONS

The study was conducted during September 2019–July 2020, and is based on secondary information only. The World Bank team worked in close collaboration with Nigerian stakeholders from Cross River, Delta and Lagos to gather local and state level data that are representative for the coastal environment in the three states. A virtual consultation with the Nigerian stakeholders was held on June 25, 2020 to discuss the findings of the study. The feedback received is incorporated in the present report.

Every effort was made to ensure that the environmental damages are estimated through consistent measures of value, as explained in section 2.2.1. Despite that, the study is affected by several limitations. **Methodological limitations** relate to several aspects, including: (i) use of WTP approach often provides low estimates in developing countries, due primarily to low income levels–hence low ability to pay, despite the high level of natural resource degradation (Greenstone and Jack, 2015); (ii) use of VSL concept to estimate mortality can be challenging; the results vary among countries[25] and do not fully capture the tragedy of death and the social cost of pain and suffering; (iii) use of VSLY to estimate morbidity, in the absence of reliable studies on WTP to reduce non-fatal health risks—although accepted by recent literature, the valuation based on a constant VSLY is limited by using some simplifying assumptions (see Robinson and Hammitt, 2018); (iv) despite considerable improvements of the GBD 2017 compared to the GBD 2016, use of this method can lead to overestimation (e.g. by assuming that all people are exposed to given $PM_{2.5}$ levels) or underestimation (e.g. by not considering the avertive expenditures).

25 As the VSL reflects individuals' WTP for a change in fatality risk, higher income countries tend to have a higher VSL than lower income countries (Robinson et al., 2019). Estimates can vary within the same region, e.g. for Benin (US$46,100), Côte d'Ivoire (US$97,300), Senegal (US$78,100) and Togo (US$31,500) (Croitoru et al., 2018).

In addition, the study is subject to several **data limitations**, such as use of : (i) benefits transfer of WTP measures from other African countries, when local data are not available (e.g. to estimate the cost of wastewater treatment); (ii) national-level data, in the absence of state-level data (e.g. mortality rate, by disease and age, GBD WASH risk factors); (iii) annual averages obtained from long-term trends of data, when recent trends are not available (e.g. annual rate of erosion is estimated based on 1986-2016 trends); (iv) past information, when recent monitored data are not available (e.g. $PM_{2.5}$ concentration). While the above limitations affected the overall study, the following chapters present in detail specific constraints related to individual valuations (e.g. see Section 3.4.4. for specific considerations related to oil spill valuation).

The above limitations **prevented the estimation of several costs**, primarily related to: air pollution (e.g. the impacts of pollutants other than $PM_{2.5}$ and lead on people's health, the effect of gas flaring, illegal refineries, etc.); water pollution (e.g. losses in fisheries, impact of emerging pollutants, etc.); waste management (e.g. damages caused by inappropriate/insufficient disposal of waste other than municipal and e-waste, losses due to forgone opportunities to recycle); floods (e.g. damages caused by flooding from sea level rise and storm surges); erosion (e.g. slower GDP growth in the future due to less real estate on the coastal area); mangroves (e.g. ecosystem degradation due to invasive Nypa palm); and other effects (e.g. impact of sand mining, effects of greenhouse gas emissions, transboundary impacts of flooding, oil spills, etc.). Therefore, the results of this study should be *considered* conservative estimates, which capture only partially the real COED on the coast.

To address the above data limitations and refine the estimates of this study, it would be important to: collect state-level data on mortality and morbidity by disease and age group; conduct systematic measurements of ambient and household $PM_{2.5}$ concentration in urban and rural areas; undertake primary studies on WTP to avoid oil spill damages and plastic pollution, WTP to improve wastewater treatment and WTP to avoid morbidity cases related to different diseases (e.g. pulmonary, water-borne diseases, etc.); conduct systematic erosion measurements at different coastal locations; and apply/calibrate flood damage models based on analyses of past flood events in Nigeria.

Finally, it should be noted that there are conceptual differences between the COED estimated in this study and GDP. First, while the COED is estimated based on the WTP approach, the GDP is an income-based measure. Secondly, the COED captures losses of stocks (e.g. losses of buildings to erosion) and flows (e.g. loss of economic productivity), while the GDP is a measure of flow. Due to these differences, the COED and GDP are not directly comparable (World Bank, 2016). Thus, in this study, expressing the COED as a percentage of GDP is meant only to **benchmark the magnitude of damage against a well-known macro-economic indicator**, and not to directly compare the two values.

Photo Credit: Jordi Clave Garsot/Alamy Stock Photo.

Photo Credit: Joseph Akpokodje, World Bank.

CHAPTER 3
POLLUTION

3.1. AIR

Air pollution is an important cause of death and disease. Globally, exposure to $PM_{2.5}$ caused about 4.6 million premature deaths in 2017, or 8.2 percent of the total number of deaths (GBD 2017 Risk factor collaborators, 2018). In Sub-Saharan Africa, ambient and household $PM_{2.5}$ were responsible for more than 562,000 premature deaths in the same year (IHME, 2018). The problem is particularly severe in Nigeria, the country with the **highest number of premature deaths due to $PM_{2.5}$ pollution in this region** (113,300)[26]. It is particularly critical in industrialized areas such as Lagos and the Niger Delta (Croitoru et al., 2020; Offor et al., 2016; Tawari and Abowei, 2012). This section estimates the impacts of ambient and household air pollution on human health on the coastal areas of the three states.

3.1.1. AMBIENT AIR POLLUTION

Using the most updated methodology (IHME, 2018; Burnett et al., 2018), we estimate the impact of $PM_{2.5}$ exposure on **premature mortality** resulting from lower respiratory infections; ischemic heart disease; chronic obstructive pulmonary diseases; tracheal, bronchus, and lung cancer; stroke; and diabetes mellitus type 2[27]; and on **morbidity**, due to problems such as cases of chronic bronchitis, hospital admissions, work loss days, restricted activity days, and acute lower respiratory infections in children (GBD 2017 Risk factor collaborators, 2018; Hunt et al., 2016; World Bank, 2016). The valuation is based on the steps presented below.

(1) Collect $PM_{2.5}$ concentration data. Currently, there are no operational air quality monitoring stations in the three states. Available ground-level monitored data are largely based on short-term and irregular measurements, using air samplers. Based

26 The estimate includes 49,100 premature deaths due to ambient air pollution and 64,200 due to household air pollution in Nigeria in 2017 (IHME website, https://vizhub.healthdata.org/gbd-compare/).

27 Evidence suggests that exposure to $PM_{2.5}$ can be linked to type 2 diabetes through altered lung function, vascular inflammation, and insulin sensitivity (Rajagopalan and Brook, 2012).

on a review of available publications, the paragraphs below reveal the most reliable information collected on a relatively long-term basis for each state.

- ***Cross River***. Ikamaise et al. (2013) monitored the total suspended particulate matter in Calabar zone during a two-year period. For the *urban* area (Calabar metropolis), the authors measured the concentration of total suspended particulates (TSP) in different sites[28] representative for low-density residential, high-density residential, industrial, and transport area, leading to a mean concentration of 175 µg/m^3. Using a conversion factor of 16 percent (Ngele and Onwu, 2015), this corresponds to a $PM_{2.5}$ concentration of about[29] 28 µg/m^3. In addition, the authors found a TSP concentration of 109 µg/m^3 for the *rural* area of the same basin, which is equivalent to a $PM_{2.5}$ concentration of 17 µg/m^3. Accordingly, we use a $PM_{2.5}$ concentration of about *28 µg/m³* for the urban areas (Calabar), and *17 µg/m³* for the rural areas of the state's coastal zone.
- ***Delta***. Available studies for urban areas indicate an annual PM10 concentration of 127 µg/m^3 in Warri metropolis, based on one-year monitoring (Offor et al., 2016; Efe and Efe, 2008). Using a conversion factor of 25 percent (Ngele and Onwu, 2015), this is equivalent to[30] 32 µg/m^3. No data was found on the $PM_{2.5}$ concentration in rural areas of Delta State; in its absence, a similar value to that in Cross River's rural areas is assumed. Thus, we use a $PM_{2.5}$ concentration of *32 µg/m³* in the urban areas (Warri), and *17 µg/m³* in the rural areas of Delta's coastal zone.
- ***Lagos.*** Only two studies provided data monitored over relatively long periods of time: Owoade et al. (2013) for nine months, and Ezeh et al. (2018) for one year. Among them, Ezeh et al. (2018) monitored $PM_{2.5}$ concentration more frequently over a longer period of time in three locations[31]. Based on these results, the population-weighted ambient $PM_{2.5}$ concentration for Lagos State was estimated at *68 µg/m³* (Croitoru et al., 2020). This is an average estimate for both urban and rural areas of Lagos' coastal zone.

(2) Estimate the population exposed. Everyone is exposed to some level of ambient air pollution; however, a part of the population, i.e. that using solid fuel for cooking, is exposed to *both* ambient and household air pollution. The population exposed to ambient air pollution *only* is estimated as: (i) the coastal population not using solid fuel[32]; and (ii) a share of the population exposed to both ambient and household air pollution, estimated using the proportional approach[33] developed by the GBD 2017 Risk factors collaborators (2018, supplement). Accordingly, the exposed population to ambient air pollution is estimated at 204,100 in Cross River, 559,100 in Delta and 8.9 million in Lagos. Rural population has a dominant share in the population exposed in Cross River (99 percent) and Delta (96 percent), and much less in Lagos (38 percent).

(3) Quantify the health impacts of exposure to ambient $PM_{2.5}$. Several epidemiological studies revealed strong correlations between long-term exposure to $PM_{2.5}$ and premature mortality (e.g. Apte et al., 2015; Cohen et al., 2017, etc.). Recent research associated $PM_{2.5}$ exposure with mortality related to five diseases in adults over 25: ischemic heart disease; stroke; chronic obstructive pulmonary disease; tracheal, bronchus and lung cancer; and diabetes mellitus type 2; and to lower respiratory infections in all ages (GBD 2017 Risk factor collaborators, 2018).

28 These are Mbukpa in Calabar South (176 µg/m^3, high-density residential area), University of Calabar staff quarters (138 µg/m^3, low-density residential area), export processing zone premises (118 µg/m^3, industrial area), and Itiat Orok roundabout (270 µg/m^3, transport area).

29 This is in the same range with the $PM_{2.5}$ concentration of 23 µg/m^3 for the period 2001-2015 modelled by Shaibu and Ngwabara (2017).

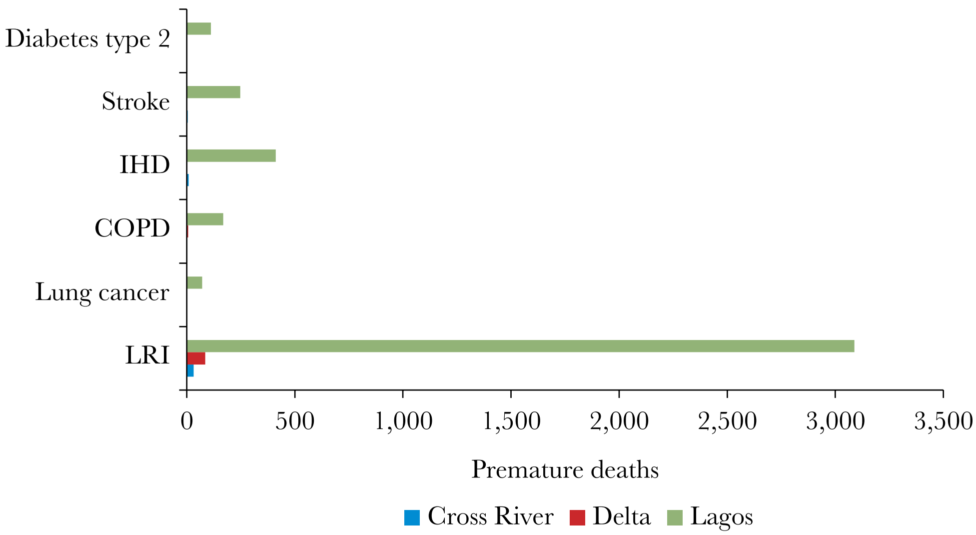
30 This is a conservative estimate compared to that of the WHO air pollution map, which puts it in the range of 36 – 60 µg/m^3 (http://maps.who.int /airpollution/)

31 These are Ikeja (industrial zone), Mushin (high density residential) and Ikoyi (low density residential).

32 Nigeria's Demographic and Health Survey of 2018 provides the percentage of the population using solid fuels in Cross River (56 percent in urban areas and 90 percent in rural areas), Delta (20 percent in urban areas and 58 percent in rural areas), and Lagos (99 percent in urban areas and 1 percent in rural areas) (National Population Commission, 2019).

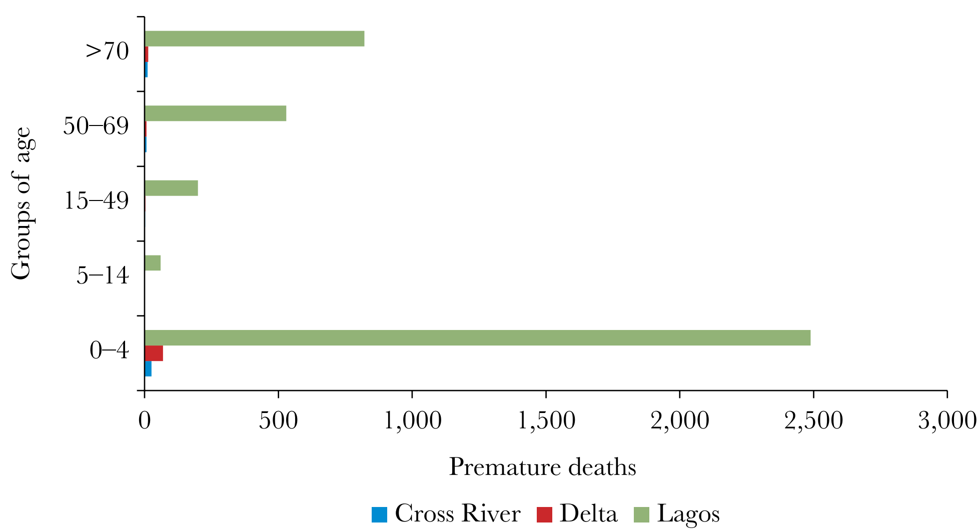
33 The approach estimates the proportion between the exposure to ambient air pollution in total exposure to ambient and household air pollution.

FIGURE 3.1.1a: MORTALITY DUE TO EXPOSURE TO AMBIENT $PM_{2.5}$, BY CAUSE



Source: Authors, based on data from IHME (2018) and GBD 2017 Risk factors collaborators (2018).
Notes: IHD = ischemic heart disease; LRI = lower respiratory infections; COPD = chronic obstructive pulmonary diseases.

FIGURE 3.1.1b: MORTALITY DUE TO EXPOSURE TO AMBIENT $PM_{2.5}$, BY GROUP OF AGE



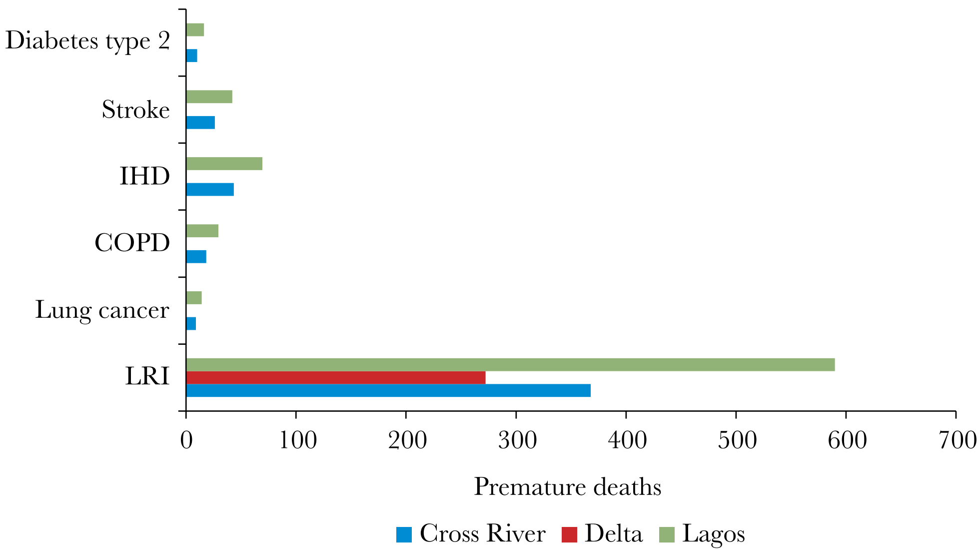
Source: Authors, based on data from IHME (2018) and GBD 2017 Risk factors collaborators (2018).

We estimate the number of deaths attributable to air pollution ($PM_{2.5}$) using data on: (i) mortality[34] by disease and age group, based on the 2017 Global Burden of Disease study, adjusted to 2018 (IHME, 2018); (ii) proportion of deaths due to $PM_{2.5}$ calculated by using the integrated exposure response functions developed by GBD 2017 Risk factors collaborators (2018), which are available by disease, age and $PM_{2.5}$ concentration[35].

34 Similar to other countries, mortality data by age and disease in the three states are not readily available. In the absence of these data, the estimation uses national-level information, which are adjusted based on the ratio between the population on the coastal areas of the three states and that at the national level. The base information at the national level was derived from IHME database (http://ghdx.healthdata.org/gbd-results-tool).

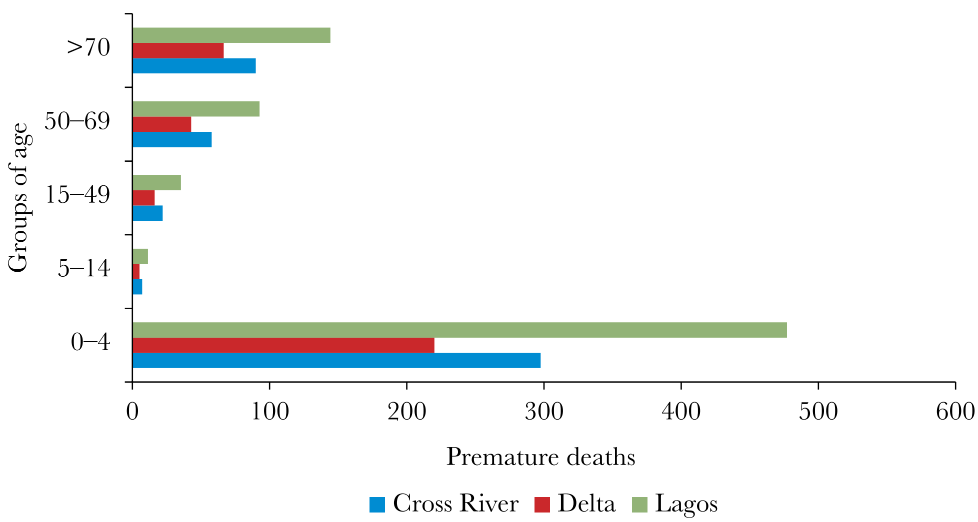
35 For more details, see GBD 2017 Risk Factor Collaborators, 2018: http://dx.doi.org/10.1016/S0140-6736(18)32225-6.

FIGURE 3.1.2a: MORTALITY DUE TO EXPOSURE TO HOUSEHOLD $PM_{2.5}$, BY CAUSE



Source: Authors, based on data from IHME (2018) and GBD 2017 Risk factors collaborators (2018)
Notes: IHD = ischemic heart disease; LRI = lower respiratory infections; COPD = chronic obstructive pulmonary diseases.

FIGURE 3.1.2b: MORTALITY DUE TO EXPOSURE TO HOUSEHOLD $PM_{2.5}$, BY GROUP OF AGE



Source: Authors, based on data from IHME (2018) and GBD 2017 Risk factors collaborators (2018)

The results show that exposure to ambient $PM_{2.5}$ is responsible for ***about 4,240 premature deaths*** on the three states' coastal zone: 4,100 in Lagos, 90 in Delta and 50 in Cross River. The largest share (97 percent) of deaths occur in Lagos, due to its large population exposed to high pollution levels. In all three states, lower respiratory infections are the leading cause of mortality. Children under five are the most affected group, accounting for about 60 percent of total deaths. This is consistent with the 2017 GBD study at the national level in Nigeria, which found that children under five account for a similar proportion in the total ambient $PM_{2.5}$-related deaths.[36] It is important

36 The number of deaths due to ambient $PM_{2.5}$ in Nigeria was estimated at 49,100, of which children under five accounted for 29,900, or 61 percent of the total (http://ghdx.healthdata.org/gbd-results-tool).

to note that under five mortality due to lower respiratory infections (all causes combined) in Nigeria is the second highest in the world, after India[37].

(4) Estimate the health impacts of exposure to ambient $PM_{2.5}$. We estimate in monetary terms the impacts of $PM_{2.5}$ on health as follows:

The cost of *mortality* is estimated based on the Value of Statistical Life (VSL), which reflects people's WTP for a reduction in mortality risk. We use a VSL for Nigeria of about[38] US$167,400, based on benefits transfer of a base value from a meta-analysis conducted in OECD countries (World Bank, 2016). Accordingly, the cost of mortality is estimated between US$8 million in Cross River and US$686 million in Lagos.

The cost of *morbidity* includes resource costs (i.e. financial costs for avoiding or treating pollution-associated illnesses), opportunity costs (i.e. indirect costs from the loss of time for work and leisure), and disutility costs (i.e. cost of pain, suffering, or discomfort). It is important to note that available literature on the willingness to pay to avoid morbidity (e.g. chronic bronchitis, hospitalization) is more limited than that on mortality risks, and lacks a commonly agreed method to measure the cost of morbidity. Empirical results of studies conducted in several OECD countries indicate that morbidity costs account for a small percentage of mortality costs (Hunt et al., 2016; OECD, 2014; World Bank, 2016). On this basis, OECD and WHO recommend using 10 percent of mortality cost to account for morbidity (Hunt et al., 2016; World Bank, 2016). This might be a significant underestimate: recent research estimated the cost of morbidity at about 66 percent of the mortality cost in China (Barwick et al., 2018) and about 74 percent in Poland (Ligus, 2017)[39]. In the absence of studies in Nigeria, we use the most conservative assumption from the above (10 percent)—thus estimating morbidity cost between US$1 million in Cross River and US$69 million in Lagos.

Based on the above, the cost of mortality and morbidity due to ambient air pollution on the coastal zone is estimated at **US$9 million in Cross River, US$17 million in Delta,** and **US$754 million in Lagos** (Table 3.1).

3.1.2. HOUSEHOLD AIR POLLUTION

The cost of household air pollution is estimated based on similar steps with those of the previous section.

(1) Collect $PM_{2.5}$ concentration data. The $PM_{2.5}$ concentration in households using solid fuel for cooking varies considerably, depending on the location of the kitchen, type of solid fuel, type of stove and ventilation practices, duration of cooking, structure of the dwelling, etc. A survey conducted in a few coastal states of Nigeria showed that household air pollution results from use of generators, cooking in poorly ventilated kitchens, and sleeping with actively burning candles or kerosene lamps in locked rooms (Omole et al., 2016). Available studies measured household $PM_{2.5}$ concentrations of 150 μg/m^3 in urban and semi-urban settings of South Eastern Nigeria (Ubuoh and Nwajiobi, 2018); and between 130 μg/m^3 and 1400 μg/m^3 in rural South Western Nigeria[40] (Oluwole et al., 2013). This valuation uses conservatively a $PM_{2.5}$ concentration of *130 μg/m^3* for household air pollution in the three states. It is in the same range with the value found for rural households in Ghana (129 μg/m^3, based on Van Vliet, 2016).

(2) Estimate the population exposed. As mentioned in section 3.3.1, the population using solid fuel for cooking is exposed to *both* household and ambient air pollution. We estimate the population exposed to household air pollution *only*, by using the proportional approach developed by the GBD 2017 Risk factors collaborators (2018). As such, the exposed population is estimated at

37 Based on IHME, under five mortality due to lower respiratory infections was 153,100 cases in Nigeria and 185,400 in India (https://vizhub.healthdata.org/gbd-compare/).

38 Other estimates for the VSL in Nigeria are US$485,000 by Viscusi and Masterman (2017), and US$489,000 by Yaduma et al. (2013), which are based on benefits transfer of a base value from United States. This report uses a lower figure (US$167,400), estimated based on the World Bank (2016) guidelines which suggest using a base value derived from a meta-analysis of values from several OECD countries, rather than just for one country (United States).

39 These costs were estimated in terms of part of total healthcare spending (Barwick et al., 2018) and willingness to pay to avoid morbidity (Ligus, 2017).

40 The estimates refer to households using improved cooking stoves (130 μg/m^3) and households using biomass fuel for cooking (1414 μg/m^3).

776,000 in Cross River, 574,100 in Delta and 1.2 million in Lagos.

(3) Quantify the health impacts of exposure to household $PM_{2.5}$. Similar to section 3.1.1, the estimation of premature mortality due to household $PM_{2.5}$ is based on data on: (i) mortality[41] by disease and age group, based on the 2017 Global Burden of Disease study (IHME, 2018); (ii) proportion of deaths due to household $PM_{2.5}$ calculated by using the integrated exposure response functions developed by GBD 2017 Risk factors collaborators (2018), which are available by disease, age and $PM_{2.5}$ concentration[42].

The results show that exposure to household $PM_{2.5}$ is responsible for ***about 1,510 premature deaths*** on the three states' coastal zone: 480 in Cross River, 270 in Delta and 760 in Lagos. In all three states, lower respiratory infections are the leading cause of mortality. Children under five are the most affected group, accounting for about 63 percent of total deaths. This result is consistent with the 2017 GBD study at the national level in Nigeria, which found that children under five account for a similar proportion in the total household $PM_{2.5}$-related deaths.[43]

(4) Estimate the health impacts of exposure to household $PM_{2.5}$. Similar to section 3.1.1, we estimate in monetary terms the impacts of $PM_{2.5}$ on health on mortality (based on the VSL) and morbidity (as 10 percent of mortality cost). Accordingly, the cost of health due to household air pollution is estimated at **US$87 million in Cross River**, **US$65 million in Delta** and **US$140 million in Lagos** (Table 3.1).

41 Similar to other countries, mortality data by age and disease in the three states are not readily available. In the absence of these data, the estimation uses national-level information, which are adjusted based on the ratio between the population on the coastal areas of the three states and that at the national level. The base information at the national level was derived from IHME database (http://ghdx.healthdata.org/gbd-results-tool).

42 For more details, see GBD 2017 Risk Factor Collaborators, 2018: http://dx.doi.org/10.1016/S0140-6736(18)32225-6.

43 The number of deaths due to household $PM_{2.5}$ in Nigeria was estimated at 64,200, of which children under five accounted for 40,400, or 63 percent of the total (http://ghdx.healthdata.org/gbd-results-tool).

TABLE 3.1: HEALTH COST DUE TO AIR POLLUTION (US$ MILLION, 2018)

	Cross River	Delta	Lagos
Ambient air pollution			
Mortality	8	16	686
Morbidity	1	2	69
Cost of ambient air pollution (1)	***9***	***17***	***754***
Household air pollution			
Mortality	79	59	127
Morbidity	8	6	13
Cost of household air pollution (2)	***87***	***65***	***140***
Total health cost due to air pollution	**96**	**82**	**895**
% of the States' GDP	**1.2%**	**0.6%**	**0.9%**

Source: Authors, based on IHME (2018) for methodology and mortality data, and National Population Commission (2019) for information on solid fuel use.

3.1.3. CONCLUSIONS

Overall, the health cost due to air pollution is estimated at about **US$1.1 billion**, or **0.9 percent of the three states' GDP**. Coastal population of Cross River and Delta is mostly affected by household air pollution, due to the high concentration of rural population using solid fuel for cooking.[44] By contrast, in the coastal Lagos, ambient air pollution is the major cause of health damage, due to a large proportion of the urban population not relying on solid fuel.

The above analysis is based on the most recent available methodology for the quantification of the health impacts from air pollution, developed by the IHME. However, it should be noted that the analysis is subject to several data **limitations**, including use of ambient $PM_{2.5}$ concentration data from 2010-2011 (e.g. for Lagos), and of mortality rates by age and disease at the national level.

44 In coastal Cross River, 99 percent of coastal population is rural (see Table 1, Chapter 1) of which 90 percent uses solid fuel (National Population Commission, 2019). In coastal Delta, 98 percent of coastal population is rural (see Table 1, Chapter 1), of which 58 percent relies on solid fuel (National Population Commission, 2019). In coastal Lagos, only 38 percent of the population is rural, of which 40 percent uses solid fuel, while the rest use kerosene (National Population Commission, 2019).

In addition, valuation of health damages from household air pollution is based on the IHME methodology which addresses exposure to indoor pollution from use of solid fuels *only* (e.g. wood, charcoal, etc.). However, in Nigeria, **kerosene** is largely used to meet households' energy needs, covering 83 percent of fuel use in Lagos, 39 percent in Delta and 23 percent in Cross River (National Population Commission, 2019). Although it is believed to be a highly polluting fuel, the current methodology establishing the cause and effect relationship between exposure to kerosene and premature mortality is yet to be developed (communication with IHME, Prof. Michael Brauer, January 2020). Thus, the results of this chapter are likely major underestimates of the true damage of air pollution in the three states.

3.2. WATER

According to the National Water Master Plan, Nigeria's water resources potential is about 375 billion m^3 per year, including the inflow from neighboring countries (FMWR-JICA, 2014). Water quality is threatened by several factors, such as oil spills, discharge of untreated effluents, pollution from agricultural leachates, seepage from dumpsites and climate change (Idu, 2015). These result in declining water quality, with negative implications on environment, e.g. damage to aquatic life and recreation. In addition, exposure to unsafe WASH poses enormous threats to human health. **Nigeria is the country with the highest number of premature deaths due to inadequate WASH in Africa** (160,000[45]). Children under five account for more than 75 percent of these deaths[46]. This chapter estimates the impacts associated to water-borne diseases and untreated wastewater. Other impacts are captured in other chapters, e.g. oil spill and waste.

3.2.1. WATER-BORNE DISEASES

Unsafe WASH is affecting people's health in several ways. It has direct effects, such as diarrhea, acute lower respiratory infections, and typhoid (Prüss-Ustun et al., 2014; Fewtrell et al., 2007); and indirect effects (e.g. lower respiratory infections, measles, and protein-energy malnutrition) due to poor nutritional status caused by repeated diarrheal infections related to exposure to inadequate WASH in early childhood.

Direct effects. In 2017, unsafe WASH was responsible for premature deaths primarily from diarrheal diseases (132,400) and lower respiratory infections (27,400). The valuation relies on the GBD methodology, which calculates the rates of mortality and morbidity risks (years of life lost with disability, YLDs) associated with unsafe WASH. Table 3.2.1. shows the coastal population in urban and rural areas and the available WASH risk factors for water-borne diseases. Access to improved WASH is substantially higher in the urban compared to rural areas[47]. Thus, the estimation of mortality and morbidity uses GBD lower risk factors for urban areas, and higher risk factors for rural areas.

Similar to the chapter 3.1, the economic valuation of mortality (deaths due to water-borne diseases) relies on the VSL. Estimating morbidity should ideally be based on the number of cases and the WTP to avoid water-borne diseases. A few WTP studies were found for developing countries, but with unreliable results[48]. Thus, the estimation of morbidity in this chapter is based on the YLDs lost and the VSLY approach (Robinson and Hammitt, 2018; Narain and Sall, 2016). The VSLY is estimated by dividing the VSL by the discounted number of years remaining in the average person's expected lifespan (Viscusi, 2010; Cropper and Khanna, 2014). Accordingly, the cost of direct water-borne diseases is estimated at **US$142 million in Cross River, US$163 million in Delta,** and **US$1.3 billion in Lagos**.

45 It represents 25 percent of the total premature deaths due to inadequate WASH in Africa in 2017 (http://ghdx.healthdata.org/gbd-results-tool).

46 Children under five account for 121,800 premature deaths due to inadequate WASH, of which 82 percent are due to diarrhea (http://ghdx.healthdata.org/gbd-results-tool).

47 Data for 2018 show differences in access to improved water (92 percent for urban vs. 66 percent for rural), sanitation (81 percent for urban vs. 48 percent for rural) and hygiene (73 percent for urban vs. 71 percent for rural) (https://washdata.org/data/downloads#NGA).

48 For example, Berry et al. (2019) found a median WTP of US$1.12 to avoid one episode of children's diarrhea, or about US$40 to avoid the loss of 1 YLD. This chapter does not use these figures, as they underestimate considerably the pain and suffering caused by water-borne diseases in children.

TABLE 3.2.1: DIRECT HEALTH IMPACTS FROM INADEQUATE WASH

Category	Unit	Cross River	Delta	Lagos
Coastal population	**# million**	**1.0**	**1.1**	**10.2**
Coastal urban population*	# million	0.0	0.0	5.6
Coastal rural population	# million	1.0	1.1	4.6
WASH risk factors				
Mortality lower bound (urban)	#/100,000	59.3	59.3	59.3
Mortality high bound (rural)	#/100,000	77.5	77.5	77.5
Morbidity lower bound (urban)	YLDs/100,000	121	121	121
Morbidity high bound (rural)	YLDs/100,000	180	180	180
Physical quantification				
Mortality in coastal area	# deaths	758	874	6,872
Morbidity in coastal area	YLDs lost	1,761	2,025	15,021
Economic valuation				
VSL	US$	167,400	167,400	167,400
Estimated mortality cost	US$ million	127	146	1,150
Estimated morbidity cost**	US$ million	15	17	128
Total	**US$ million**	**142**	**163**	**1,278**

Sources: Table 1.1 for the coastal population. *Urban population was identified with the population of the areas classified as having urban land cover–which have a density higher than 300 people per km^2 (ESA, 2017; CIESIN, 2017). https://vizhub.healthdata.org/gbd-compare/ for WASH risk factors. VSL derived from benefits transfer of results of a quality-screened sample of studies in OECD countries, based on World Bank (2016). ** Based on the VSLY, estimated at US$8,500, using a life expectancy in Nigeria of 54 years, https://data.worldbank.org/

TABLE 3.2.2: INDIRECT HEALTH IMPACTS FROM INADEQUATE WASH

Category	Unit	Cross River	Delta	Lagos
Coastal population	# million	1.0	1.1	10.2
Indirect health impacts				
–Lower respiratory infections	# deaths	23	27	241
–Measles	# deaths	3	4	33
–Protein-energy malnutrition	# deaths	42	49	439
Total malnutrition deaths	# deaths	**69**	**79**	**713**
VSL	US$	167,400	167,400	167,400
Total cost	**US$ million**	**11**	**13**	**119**

Sources: Table 1.1 for the coastal population and ESA (2017) and CIESIN (2017) for urban/rural; https://vizhub.healthdata.org/gbd-compare/ for mortality rates due to child underweight; Fewtrell et al. (2007) and GBD Risk factors collaborators (2018) for attributable fractions. VSL derived from benefits transfer of results of a quality-screened sample of studies in OECD countries, based on World Bank (2016).

Indirect effects. The valuation focuses on mortality due to the following illnesses caused by diarrhea from poor WASH: lower respiratory infections, measles and protein-energy malnutrition (Table 3.2.2). The physical estimation is based on: (i) the number of premature deaths related to these illnesses due to child underweight, based on GBD data on mortality rates for Nigeria[49]; (ii) fractions attributable to unsafe WASH, based on Fewtrell et al. (2007) and adjustments for multiple risks (GBD Risk

49 Premature mortality rates (lower bound estimates) due to child underweight in Nigeria are 0.6 per 100,000 people for measles, 8.6 per 100,000 people for protein-energy malnutrition, and 5.3 per 100,000 people for lower respiratory infections (https://vizhub.healthdata.org/gbd-compare/)

TABLE 3.2.3: COST OF UNTREATED WASTEWATER

Category	Unit	Cross River	Delta	Lagos
Coastal urban population	# million	0.0	0.0	5.6
Coastal rural population	# million	1.0	1.1	4.6
WTP for improved wastewater treatment	US$/capita	8.1	8.1	8.1
Estimated cost of untreated wastewater	**US$ million**	**8.0**	**9.2**	**82.8**

Sources: Table 1.1 for the coastal population and ESA (2017) and CIESIN (2017) for urban/rural distinction; Woldemariam et al. (2016) and Ndunda and Mungatana (2013) for base WTP estimates.

factor collaborators, 2018). Based on the VSL approach, the cost of indirect health impacts is estimated at **US$11 million in Cross River, US$13 million in Delta,** and **US$119 million in Lagos**.

3.2.3. UNTREATED WASTEWATER

Discharge of untreated domestic, agricultural and industrial wastewater pollutes the environment and affects negatively the value of coastal ecosystems, notably rivers, lagoons and the ocean. The economic value of wastewater can be estimated through the actual damages to productivity (e.g. due to irrigation with wastewater of insufficient quality), benefits of improved wastewater treatment (WTP measures), or cost of wastewater treatment (UNEP, 2015). As the actual damages to productivity are not known in Nigeria, the following paragraphs estimate the cost of discharging untreated wastewater through the WTP for improved wastewater treatment, to ensure methodological consistency with previous chapters.

No study on the WTP to improve wastewater treatment was found for Nigeria. A few reliable studies are available in Africa, suggesting an annual household WTP of US$21 for Addis Ababa (Woldemariam et al., 2016) and about US$27 to improve wastewater treatment for urban and peri-urban areas surrounding Nairobi city (Ndunda and Mungatana, 2013). Adjusting these figures to 2018, and calibrating them to account for the GDP per capita differences, the WTP for improved wastewater treatment in Nigeria is estimated at US$39 per household per year. Considering the household size of 4.7 persons (National Population Commission, 2019), the WTP corresponds to about US$8 per capita. Based on the total population on the coastal zone, Table 3.2.2 shows that the cost of untreated wastewater is about ***US$8 million in Cross* River, US$9 million in Delta,** and **US$83 million in Lagos**. Similar results can be obtained from an alternative valuation based on the untreated quantity of industrial and municipal wastewater discharged on the coastal zones of the three states and the local cost of treatment[50].

3.2.4. CONCLUSIONS

Table 3.2.4 estimates the cost of water degradation on the coastal zone of the three states. When aggregated across the three states, it corresponds to about **US$1.8 billion, or 1.5 percent of the combined GDP in the three states**. Water-borne diseases due to inadequate WASH represent the major contributor to this damage. Overall, the valuation suggests that through its direct and indirect effects, inadequate WASH is responsible for nearly 9,400 premature deaths a year[51]. It should be noted that the above analysis was limited to only a few impacts, for which data were available. Other water-related impacts were captured in separate chapters (e.g. water pollution due to oil spills, and to inadequate disposal of solid waste), while others could not be estimated at all, e.g. impact of emerging pollutants[52] in water and wastewater, and of groundwater pollution.

50 The valuation can be based on: (i) quantity of untreated *domestic* wastewater from urban and rural areas, estimated based on water consumption per capita for each state, and share of coastal households without safely managed sanitation services; (ii) quantity of untreated *industrial* wastewater discharged from each state; (iii) local cost of treating wastewater. Using local level information from discussion with stakeholders, and World Bank data on the share of population with safely managed sanitation services, the total cost can be estimated at about US$106 million (of which about US$3 million in Cross River, US$5 million in Delta and US$98 million in Lagos). These figures are in the same range with those obtained if using the WTP approach, as described in the main text.

51 of which about 7,600 in Lagos, 1,000 in Delta and 800 in Cross River.

52 These are defined as any synthetic or naturally-occurring chemical or any microorganism that is not commonly monitored or regulated in the environment with potentially known or suspected adverse ecological and

TABLE 3.2.4: COST RELATED TO WATER DEGRADATION (US$ MILLION, 2018)

	Cross River	Delta	Lagos
Water-borne diseases	153	177	1,397
Untreated wastewater	8	9	83
Total	**161**	**186**	**1,480**
% of the States' GDP	**2.0%**	**1.3%**	**1.5%**

3.3. WASTE

Waste generation in Nigeria has increased at alarming rates over recent decades, due to demographic growth, industrial development, fast urbanization, and rise in living standards. Despite that, appropriate waste management—e.g. generation, collection, transport, recycling, and disposal—is a serious challenge in the country (Agbesola, 2013). Nigeria suffers from a lack of advanced technology, difficulty of waste separation at the source, weakness of solid waste management policy and enforcement, insufficient environmental education and awareness, and poverty (Abel, 2007; Ajani, 2007). These problems have negative consequences on the environment and human health. This section estimates the cost of degradation associated primarily with the mismanagement of municipal solid waste[53] on the coastal zones of the three states.

3.3.1. OVERVIEW

About 32 million tons of solid waste are generated annually in Nigeria—mainly by households and in some cases, by local industries, artisans and traders (Wale, 2019). The rate of solid waste generation is estimated between 0.26 and 1.02 kg/capita/day (Akindayo, 2019)[54]. Overall, only **20-30 percent** of solid waste is collected, while the remaining is carelessly discharged, leading to obstruction of sewers, drainage systems, and water bodies (Wale, 2019). In almost all Nigerian states, waste collection and disposal are provided only in cities; in most rural areas, people freely dump or burn waste (Duru et al., 2019). Overall, the common methods of disposing solid waste are via unsanitary landfills, open dumpsites, water bodies, and sometimes burial or burning (Odjo, 2014; Onwughara et al., 2010; Remigios, 2010; Babayemi and Dauda; 2009). Less than 5 percent of the waste disposed in landfills is recovered through informal activities carried out by scavenger/waste handlers around open waste dumpsites, as is the case in the Warri Metropolis (Asibor and Edjere, 2017).

Solid waste density ranges from 200 to 400 kg/m^3 (Amber et al., 2012). The composition of waste depends on various parameters such as origin of waste, population' income, location, density, culture, consumption patterns, and season (Ezechi et al., 2017). Typically, food waste constitutes almost 50 percent of the municipal solid waste in Nigerian cities (Nnaji, 2015). Over time, Nigeria has witnessed an increase in the use of plastic materials for packaging and storing purposes, due to their low cost, durability and light weight. Nowadays, the country is the ***biggest generator of plastic waste*** in Africa[55]. Plastic pollution is a serious challenge, accounting for more than 30 percent of the solid waste generated annually (Rigasa, 2018). An initial inventory of plastic imports in Nigeria indicated that a large volume (23.4 million tons[56]) of plastic went into the country's technosphere between 1996 and 2014; however, less than 12 percent of the resulting waste was recycled (Babayemi et al., 2018).

In addition, the rapid growth of information technology and communication has brought—aside from many

human health effects. They include chemicals found in pharmaceuticals, personal care products, pesticides, industrial and household products, metals, surfactants, industrial additives and solvents (https://en.unesco.org/emergingpollutantsinwaterandwastewater).

53 There are different types of waste, e.g. solid waste, hazardous waste, medical waste, waste water, etc. Solid waste is defined as non-liquid and non-gaseous products of human activities regarded as being useless and could take the form of refuse garbage and sludge (Leton and Omotosho, 2004).

54 A study on the status of municipal solid waste generation and disposal in Nigeria found that solid waste generation rate varies from 0.13 kg/capita/day in Ogbomosho to 0.71 kg/capita/day in Ado-Ekiti (Chidozie Nnaji, 2015).

55 The country's share of the global mismanaged plastic waste was estimated to increase from 2.7 percent in 2010 to 3.6 percent in 2025—the highest percentage in Africa (https://ourworldindata.org/plastic-pollution). Globally, the economic cost of plastic pollution is estimated at about US$13 billion (WWF, 2018).

56 It includes imported plastic, newly produced plastic and plastic components.

socio-economic benefits—environmental problems related to electronic waste, or e-waste. Nigeria has ***the fastest growing e-waste problem in Sub-Saharan Africa*** (World Bank, 2015). Every year, the country imports about 60,000 tons of used electrical and electronics equipment, of which almost 16,000 tons are e-waste (Odeyingbo et al., 2019). The e-waste country assessment suggests that Nigeria generates around 0.4 million tons of e-waste yearly[57]; other authors provide even higher numbers[58]. As a result, huge piles of e-waste are accumulating around the country, as the available repair outlets lack the capacity and appropriate technology to safely repair, recycle, or eliminate them (Adama et al., 2019).

Overall, the insufficient collection and inappropriate disposal of solid waste cause several negative impacts, e.g. deterioration of surface and marine water quality, groundwater pollution, fish contamination, flooding, reduced tourism opportunities, air pollution and related health problems, and greenhouse gas emissions. Some of these impacts are exemplified below:

- ***Declining water quality.*** In Calabar city, Cross River State, dissolved waste materials and leachates infiltrated into the borehole water and polluted groundwater flow from the North to the South (Eni et al., 2014). Using this water for drinking or other domestic purposes without treatment posed serious toxicological risk (Udofia et al., 2016 and 2019). In Warri, Delta State, the dumpsite soil revealed the presence of trace metals (e.g. lead, mercury, chromium, arsenic), which could contaminate both surface and groundwater (Nwajei, 2013). In Lagos, e-waste dumped in landfills caused serious heavy metal contamination of groundwater, particularly in the boreholes located in the proximity of Olusosun, Soluos, and Ewu-Epe landfills (Idehai, 2015).
- ***Health impacts.*** Insufficient collection and inappropriate disposal of solid waste caused disease and discomfort, as a result of: contact with smoke and gaseous emissions from waste burning (Oluranti and Omosalewa, 2012); pungent odor from landfill pollution (Alimba et al., 2011); and contamination of surface water and groundwater by leachates from dumpsites and landfills (Sowunmi, 2019)[59]. As almost 40 percent of public water supply in Nigeria relies on groundwater, e.g. well water or borehole water, this poses high risks for human health (Bassey et al., 2015; Nwankwoala, 2016). Moreover, high concentrations of lead and magnesium were found in the blood of e-waste scavengers at Jakande dumpsite, Lagos (Popoola et al., 2019).
- ***Floods and loss of aesthetic value.*** Solid waste is responsible for about 33 percent of floods due to blockage of drainage channels (Jiboye et al., 2019; Folorunso and Awosika, 2001). In addition, indiscriminate dumping of plastic (e.g. water sachet bags, single-carrier bags, and other disposable plastic products) on the roadside, under bridges, and in drainage channels contributes to flooding and marine pollution (Dumbili and Henderson, 2019).

3.3.2. SOLID WASTE CONTEXT IN THE THREE STATES

Cross River. Available studies on solid waste management focused on Calabar city and Calabar South LGA. Dickson and Ejemot-Nwadiaro (2019) indicated that throughout Calabar city, there are untended waste dumps by the road sides, open drains and open spaces, as well as paper and vegetable waste in markets and residential areas; this affects considerably the aesthetic aspect of the city, despite the efforts provided by the Calabar Urban Development Authority to manage waste. In addition, high density and low-income residential areas of Calabar South LGA are not well served by solid waste management and disposal systems (Essien et al., 2012). In general, residents of Calabar South are not satisfied with the current waste management services, due to significant health effects generated by the waste indiscriminately disposed (Eneji et al., 2016). Overall, the rate of solid waste

57 http://www.basel.int/Portals/4/Basel%20Convention/docs/eWaste/EwasteAfrica_Nigeria-Assessment.pdf

58 About 1.1 million tons of e-waste (https://www.eterra.com.ng/news/e-waste-nigeria-west-africa-brink-disaster/)

59 Radionuclides have also been reported in leachates, groundwater, and rivers (Agbalagba et al., 2013 ; Ehirim and Itota, 2013) and associated with dumpsites and landfills in Lagos State (Oladapo et al., 2012; Olubosede et al., 2012), Rivers State (Avwiri and Olatubosum, 2014), Delta State (Avwiri and Esi, 2014) and other areas (Jibiri et al., 2014; Sombo et al., 2018). According to NESREA (2011), the concentrations of dangerous substances to human health in groundwater are above acceptable standards.

generation is about *0.3 kg/capita/year*,[60] while collection rate is estimated at about 15 percent in the state.

Delta. In general, the solid waste management system in the state is quite basic and not very efficient, primarily due to the poor state of equipment and transport vehicles (Adeoti and Obidi, 2010). Based on data provided by the Delta State Waste Management Board, the state generates about 1.2 million tons of solid waste a year, corresponding to an average rate of *0.55 kg/capita/year*. In places like Ughelli and Warri South, the generation rate is higher than the state's average[61].

About 30 percent of solid waste is formally collected in Delta State; the remainder is discharged directly by its producers in open dump fields, rivers, roadsides or burned in backyards. Unsanitary landfilling is the most commonly used method of waste disposal in the state. The majority of solid waste is disposed in open dumpsites located on the outskirts of urban areas, forming breeding sites for disease and environmental pollution. Only 10-15 percent of disposed waste is recycled (Egun et al., 2016; Egun, 2009).

Lagos. Rapid population growth and industrialization contributed to high levels of waste in the state. Lagos generates between 0.5 and 0.72 kg of solid waste per capita per day, averaging to about *0.61 kg/capita/day* (Olukanni and Oresanya, 2018).[62] The Lagos State Waste Management Agency (LAWMA) is in charge with the municipal waste management in Lagos. The rate of municipal solid waste generation is beyond the agency's management capacity (Chidiebere et al., 2018). Less than 20 percent of solid waste has been collected between 2014 and 2017 (LAWMA, 2017)[63]. Waste is not collected on time, leading to waste bin overflows and pollution of surroundings (Wale, 2019). Six unsanitary landfills are currently used for disposal, i.e. Solous, Olusosun, Badagry Iyafin, Abule-Egba, Epe and Ewu-Elepe (communication with LAWMA, March, 2020). There are several initiatives aiming at improving waste management in the state. These include buy back of recyclables, which consists in installing recycling facilities for plastic, metal, and paper, and raising awareness about potential health issues among waste-pickers in all dumpsites across the state (LAWMA, 2017). However, as the initiative is still in its incipient stage, it is too early to evaluate its impact on the recycling rate in the state.

3.3.3. COST OF WASTE MISMANAGEMENT

Uncollected municipal waste cause major challenges, such as bad odors, marine pollution and potential health problems. Uncollected waste on the coastal zones originate from: (i) households of *coastal* districts, who are not served by municipal collection services; (ii) a portion of the households of neighboring *non-coastal* districts of the same states, which uncollected waste have been disposed directly by producers in river catchments, and transported by water flows to the coastal zones (Table 3.3.1).

Valuing the cost of insufficient municipal waste collection is based on the society's WTP for improving waste collection. Contingent Valuation Method has been often applied to estimate people's WTP for improved waste collection in Nigeria, with varying results (US$/household/year, adjusted to 2018): US$3 to remove rice husk waste in Ebonyi State (Nwofoke et al., 2017); US$29–167 to improve solid waste collection in Oyo State (Olojede and Adeoye, 2014; Yusuf et al., 2007); US$32 to improve solid waste management (particularly collection) in Akwa Ibom State (Ini-mfon et al., 2017); US$43 for improved solid waste management (mainly collection) in Asaba, Delta State (Adeoti and Obidi, 2010); and US$62 to improve solid waste collection in a commercial area of Ogun State[64] (Onukogu et al., 2017). The large differences between the available examples makes it difficult to transfer them to the coastal zones of the three states.

60 This is based on the latest available data (20,900 tons of solid waste and 189,100 people in 2007) provided by Calabar Development Authority. The generation rate can be considerably higher in 2018, due to economic development leading to higher solid waste production.

61 Production of solid waste is about 0.64 – 0.71 kg/capita/day in Ughelli (Sunday, 2013), and about 1.04 kg/capita/day in Ogbe-Ijoh community (Owamah et al., 2015).

62 Urban wastes are about 10,000 tons generated every day (Wale, 2019). The state produces medical solid waste with amounts lying between 0.562 and 0.670 kg/bed/day (Longe and Williams, 2006).

63 In addition, data from LAWMA indicates that about 1.3 million metric tons of solid waste were disposed of in different landfills in 2017.

64 Per street vendor, instead of household.

TABLE 3.3.1: COST OF UNCOLLECTED MUNICIPAL WASTE

	Unit	Cross River	Delta	Lagos
Coastal population	million	1.0	1.1	10.2
Share of coastal population without collection service [(a)]	%	85	70	80
Non-coastal population [(b)]	million	0.5	2.4	9.7
Share of non-coastal population whose uncollected waste reaches the coast [(c)]	%	50	50	50
Disposable income [(d)]	US$/capita	1,340	1,340	1,340
WTP for improved collection [(e)]	%	1.25	1.25	1.25
Cost of uncollected waste	**US$ million**	**18**	**34**	**218**

Sources: Table 1.1 for the coastal population and ESA (2017) and CIESIN (2017) for urban/rural ; https://tradingeconomics.com/nigeria/disposable-personal-income, based on data from the National Bureau of Statistics; [(a)] See section 3.3.2; [(b)] It covers the population of *neighboring* coastal districts, i.e. Akampka and Biase (in Cross River); Bomadi, Ethiope West, Ethiope East, Sapele, Okpe, Udu, Ughelli North, Ughelli South, and Uvwie (in Delta); and Alimosho, Kosofe, Ifako, Ikeja, Surulere and Oshodil (in Lagos); [(c)] Conservatively estimated as half of the total solid waste generated. [(d)] https://tradingeconomics.com/nigeria/disposable-personal-income, based on the National Bureau of Statistics data; [(e)] Raich (2009) and World Bank (2018).

Thus, the valuation uses the World Bank benchmark of 1.25 percent (1 to 1.5 percent) of the annual disposable income as a proxy for the people' WTP for improved collection (Raich, 2009; World Bank, 2018).

Based on the proportion of population not covered by the collection service, and 1.25 percent of their disposable annual income, the cost of insufficient municipal waste collection on the coastal areas is estimated at **US$18 million in Cross River, US$34 million in Delta,** and **US$218 million in Lagos.**

Sub-optimal disposal of municipal waste can result in many negative externalities, such as groundwater pollution, air pollution and depreciation of the value of land and houses surrounding the unsanitary landfills. Based on communications with the Waste Management Agency in Cross River state, about 45 percent of coastal population live in the proximity of sites with inadequate disposal of solid waste (e.g. unsanitary landfills, roads, etc.). In lack of more accurate information, we assume the same percentage also for the coastal population of Delta and Lagos states.

The annual WTP to improve waste disposal has been estimated at about US$40 in Osun State (Adepoju and Salimonu, 2011), and US$48 per household per year in Enugu State[65] (Fonta et al., 2008). Using the average of the two figures, the cost of sub-optimal waste disposal is valued at about **US$4 million in Cross River, US$5 million in Delta,** and **US$43 million in Lagos** (Table 3.3.2).

Loss of opportunities related to electricity production. Solid waste can be a resource of economic value. It can be used, for example, in production of biogas in landfills (Wilson-Osigwe and Akiyode, 2016). There are significant opportunities of converting waste to energy through landfill methane capture[66]. Based on Yusuf et al. (2019), 1 ton of municipal solid waste can be used to produce about 130 kWh electricity. At a local price of US$0.1/kWh, this corresponds to about US$13 per ton of solid waste. Assuming that the cost of electricity production represents about 15 percent of the total cost[67], the forgone net revenue from electricity production is about US$11 per ton. Accordingly, Table 3.3.3 estimates the loss of opportunities related to electricity production

65 after adjustment to 2018 prices. In addition, Akinjare et al. (2011) indicated an increase in property values located further away from the landfills, suggesting that residential houses located in close proximity to the landfills suffered value loss. Olorumfemi (2009) showed that people's willingness to pay for improved environmental quality decreases consistently as distance away from landfills increases.

66 A study assessed state-level production potential of electricity from municipal solid waste in Nigeria and estimated to be 26,744 GWh/year, at waste generation capacity of 0.53 kg/cap/day (Onabanjo, 2017). For Lagos, Opejin and Pijawka (2016) estimated that Olushosun, the biggest and the only currently operating landfill in the city could generate sufficient gas to produce 5.2 million MWh of electricity between 1997 and 2020. They also argue that three planned landfills in the city have an opportunity to incorporate the green infrastructure and technology to produce electricity from methane capture.

67 Based on other countries' experience, see for example IREN (2012).

TABLE 3.3.2: COST OF SUB-OPTIMAL WASTE DISPOSAL

	Unit	Cross River	Delta	Lagos
Coastal population	million people	1.0	1.1	10.2
Average size of household	# people	4.7	4.7	4.7
Coastal households	million households	0.2	0.2	2.2
–living close to unsanitary disposal sites (%)	%	45	45	45
WTP for improved disposal services	US$/household	44	44	44
Cost of sub-optimal disposal services	**US$ million**	**4.1**	**4.8**	**43.0**

Sources: Table 1.1 for the coastal population and ESA (2017) and CIESIN (2017) for urban/rural; National Population Commission (2019) for the average size of households; communications with the Waste Management Agency in Cross River State for the share of population living close to unsanitary disposal sites.

TABLE 3.3.3: FORGONE NET REVENUE FROM ELECTRICITY PRODUCTION

		Cross River	Delta	Lagos
Coastal population[a]	million people	1.0	1.1	10.2
Non-coastal population which waste reaches the coast[a]	million people	0.2	1.0	3.9
Rate of solid waste generation[b]	kg/capita/day	0.30	0.55	0.61
Total solid waste generated	million tons/year	0.1	0.4	2.7
Estimated net revenue from electricity[c]	US$/ton	11	11	11
Total loss of opportunities related to electricity	**US$ million**	**1**	**5**	**35**

Sources: [a] Table 3.3.1; [b] section 3.3.2; [c] Yusuf et al. (2019) and IREN (2012), see main text.

for the three states. In addition, transformation of solid waste into landfill gas would contribute to global benefits in terms of reduction in the ozone layer depletion.

Health cost due to exposure to lead (e-waste). Nigeria, along with Ghana, is one of the world's leading destinations for electronic waste[68]. The country receives 71,000 tons of used consumer goods from the European Union and other industrialized countries every year. Exposure to e-waste is particularly damaging in Lagos, which hosts two hubs for used electrical and electronic equipment: Tin Can Island Port Complex and Lagos Port Complex Apapa (Odeyingbo et al., 2019). The e-waste is delivered primarily to Olusosun, Igodun and Ikorodu dumpsites[69]. Thus, exposure to e-waste is particularly damaging to the health of Lagosians, through direct contact with harmful materials (lead, cadmium, PCBs, etc.) as well as from accumulation of chemicals in soil, water and food[70]. The valuation captures the cost of mortality and morbidity, as a result of exposure to lead[71]. Similar to chapter 3.2, the economic valuation of mortality relies on the VSL, and that of morbidity (YLDs lost) on the VSLY approach (Robinson and Hammitt, 2018; World Bank, 2016). Accordingly, Table 3.3.4 estimates the total health cost in the three states. A more refined analysis is needed to estimate specific health impacts, such as IQ loss in children, based on local data on lead exposure.

3.3.4. CONCLUSIONS

Table 3.3.5 presents the estimated total cost due to solid waste mismanagement on the coastal zone. This corresponds to a total of **US$453 million**, or **0.4 percent of the three states' GDP**. The cost of uncollected

68 https://www.unenvironment.org/news-and-stories/story/dark-skies-bright-future-overcoming-nigerias-e-waste-epidemic

69 https://ejatlas.org/conflict/e-waste

70 https://www.who.int/ceh/risks/ewaste/en/. In addition, Popoola et al. (2019) indicated high concentrations of lead and magnesium in blood samples of e-waste scavengers in Lagos, Nigeria.

71 Exposure to lead can lead to increased incidence of cardiovascular diseases, neurological problems (e.g. loss of IQ in children) and other.

TABLE 3.3.4: COST DUE TO EXPOSURE TO LEAD

Category	Unit	Cross River	Delta	Lagos
Coastal population	million people	1.0	1.1	10.2
Mortality				
Death rate due to exposure to lead	Per 100,000 people	1.62	1.62	3.03
Deaths due to exposure to lead	Number /year	16	18	309
VSL	US$/person	167,400	167,400	167,400
Cost of mortality due to exposure to lead	*US$ million/year*	***2.7***	***3.1***	***51.7***
Morbidity				
YLDs	Per 100,000 people	16	16	31
Cost of morbidity due to exposure to lead*	*US$ million/year*	***1.3***	***1.5***	***27.0***
Health cost due to exposure to *lead*	**US$ million/year**	**4.0**	**4.6**	**78.7**

Sources: Table 1.1 for the coastal population; http://www.healthdata.org/gbd for death and YLDs rates; the rates for Lagos are assumed twice as much as for the other states due to its very high concentration of e-waste; VSL derived from benefits transfer of results of a quality-screened sample of studies in OECD countries, based on World Bank (2016). * Based on the VSLY, estimated at US$8,500, using a life expectancy in Nigeria of 54 years, https://data.worldbank.org/

TABLE 3.3.5: COST DUE TO SOLID WASTE MISMANAGEMENT (US$ MILLION, 2018)

Type of cost	Cross River	Delta	Lagos
Uncollected waste	18	34	218
Sub-optimal waste disposal	4	5	43
Loss of opportunities related to electricity production	1	5	37
Health cost due to exposure to lead (e-waste)	4	5	79
Total	**27**	**48**	**377**
% of the States' GDP	**0.3%**	**0.3%**	**0.4%**

waste represents the greatest contributor to the damage in all states. These figures underestimate the real impact of waste mismanagement, as they do not include impacts of groundwater pollution, of micro-plastics, losses due to forgone opportunities of reuse/recycling[72] or composting, and health consequences from burning waste and from exposure to toxic substances other than lead.

Efforts to improve solid waste management should consider opportunities related to waste separation and recycling, e.g. recycling metals, plastics, papers and cardboards, transforming organic waste into fertilizers and biogas, etc. In addition to economic benefits, these activities would provide employment for the socially and economically vulnerable segments of population, such as waste pickers and poor residents.

3.4. OIL SPILLS

Oil industry has been one of Nigeria's main economic sectors since its exploitation in commercial amounts in 1958. The country's main stocks of crude oil are found in Niger Delta region. In 2016, the daily production of crude oil was 1.9 million barrels per day, making Nigeria the largest oil producer in Africa, the seventh largest under OPEC

72 Estimating these losses would require an in-depth analysis of the different types of recyclables (e.g. plastic, metal, paper, etc.), concrete options for pollution reduction (through waste reduction at source, reuse, and recycling), and information on net returns from these options.

and the thirteenth largest in the world[73] (Ekpo et al., 2018). Petroleum products account for more than 90 percent of the country's foreign exchange in 2019[74], however many areas in Niger Delta suffer enormous environmental degradation (Oshienemen et al., 2018). This section estimates the impacts of oil spills on the coastal areas of the three states.

3.4.1. OVERVIEW

According to the National Oil Spill Detection and Response Agency (NOSDRA, 2020), the average quantity of oil spilled recorded in Nigeria was about 57,500 barrels per year between 2006 and 2014. The quantity spilled has reduced in recent years, averaging to about 35,700 barrels a year during 2015-2019[75] (Figure 3.1a). Niger Delta is the main oil producing region in Nigeria, and one of the largest in the world. In this region, where so many oil companies are settled, oil operations have entailed recurrent spills and massive gas flaring (Chinedu and Chukwuemeka, 2018) (Figure 3.1b). By some estimates, the Niger Delta has endured the equivalent of the Exxon Valdez spill[76] every year for the past 50 years (Conley, 2012; Kadafa, 2012). During 2006-2015, there were over 9,000 spills in the Niger Delta region (Ndimele et al., 2018).

Oil spills in Nigeria are mainly associated with acts of sabotage, negligence of equipment, oil blowouts from the flow stations, disposal of used motors oil into the drainage system, vandalism and other vices (Ekpo et al., 2018). Most acts of sabotage and oil thefts occur in easily accessible pipelines. An analysis of the oil spill database in Nigeria indicated that sabotage caused about 66 percent of oil spills, and operational failures about 31 percent (Obida et al., 2018).

Crude oil is a complex mixture of hydrocarbon and non-hydrocarbon compounds, containing heavy metals. When spilled, it can contaminate aquatic and terrestrial environments. The effects of oil toxicity depend largely on the physical and chemical composition of the oil (Saadoun, 2015). In Nigeria, oil spills are considered to be a major source of pollution (Aboje et al., 2016), with severe and long-term negative effects on human health and ecosystems (Aniefiok et al., 2018). Recent research confirmed impacts on:

- ***Health.*** An analysis of spatial data from the Nigerian Oil Spill Monitor and Demographic and Health Surveys showed that nearby oil spills (within 10 km distance) that occur before conception could increase neonatal mortality by almost 38 deaths per 1,000 live births (Bruederle and Hodler, 2019). In addition, consumption of sea animals in Ogulagha community of Delta State was associated with considerable health risks due to the bioaccumulation of heavy metals, polycyclic aromatic hydrocarbons (PAH) and total hydrocarbon contents (THC) (Oyibo et al., 2018). Another study in the same state indicated that oil spills affected 51-75 percent of the population living on one-third of the coastline[77] between 2007 and 2015 (Obida et al., 2018). Overall, high level of emotional distress in the Niger Delta region is part of everyone's life. People fear pipeline explosions, oil spill pollution and fires, which would expose them to extreme risks. At the community level, this emotional anguish can be an important signal of health problems (Nriagu et al., 2016). Moreover, unregulated gas flaring activities in Niger Delta have been associated with health issues, such as hypertension (Maduka and Tobin-West, 2017).
- ***Agriculture and fisheries.*** Oil spills contributed significantly to declining livelihoods of farming and fishing communities (Akpokodje and Salau, 2015; Ekpo et al., 2018; Ejiba et al., 2016; Osuagwu and Olaifa, 2018; Nwozor et al., 2019). For example, in Delta State, a 10 percent increase in oil spill reduced crop yields by 1.3 percent and farm income by 5 percent during 2001-2004[78] (Inoni et al., 2006). Other studies showed critical values of physico-chemical parameters, heavy metal content, PAH

73 The national production in 2018 amounts to 1.9 million barrels per day.

74 https://www.cfr.org/blog/debt-servicing-tax-revenue-and-oil-nigeria

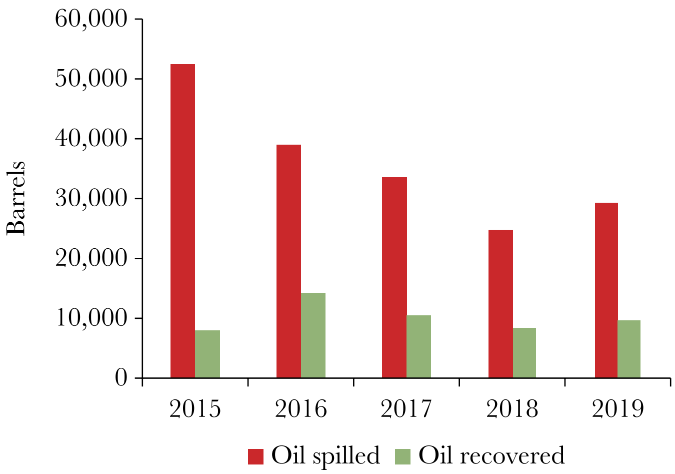
75 only about 10,100 barrels per year have been recovered during the same period.

76 The Exxon Valdez oil spill occurred in Prince William Sound, Alaska on March 24, 1989, when the Exxon Valdez oil tanker struck Prince William Sound's Bligh Reef and spilled 260,000 barrels of crude oil. It is considered the worst oil spill worldwide in terms of damage to the environment.

77 In addition, the study suggested that up to 25 percent of the population was affected on the remaining one third of the coastline.

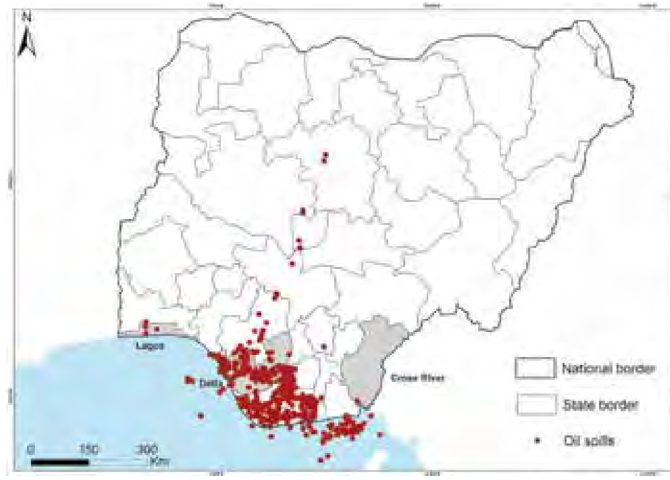
78 The study covered 10 communities of 5 LGAs of Delta State.

FIGURE 3.1a: OIL SPILLED AND RECOVERED



Source: Authors, based on NOSDRA (2020).

FIGURE 3.1b: OIL SPILL LOCATIONS (2015-2019)



and THC in water and in fish in different communities of the state (Onyegeme-Okerenta, et al., 2017; Ogeleka, et al., 2017; Ubiogoro & Adeyemo, 2017).

» ***Forests and water.*** Oil pollution had adverse effects on forests, soils, and water bodies in host communities in the Niger Delta and Lagos area (Makinde and Tologbonse, 2017; Elum et al., 2016). Large areas of the mangroves and fish hatcheries were unable to survive the toxicity resulting from oil spills (Adeyeme et al., 2009). In Agaye community of Lagos State, the contamination of soil and water sources by heavy metals due to frequent gasoline spills led to the degradation of water quality (Ogunlaja et al., 2019).

3.4.2. TYPES OF COSTS

The cost of oil spills includes: (i) the value of lost oil[79]; (ii) the cost of clean-up and rehabilitation of any equipment damaged by oil spill; and (iii) damages to society, in terms of environmental (e.g. reduced aesthetic value), economic (e.g. losses of agriculture and fisheries) and health damages (e.g. increased health risks due to exposure to oil, or anxiety)[80]. The extent of the social costs depends on many factors, including the type and quantity of oil spilled, weather conditions and sensitivity of the area exposed. Although oil spills are associated with the three types of costs, there are trade-offs among them: active and timely restoration (e.g. clean-up efforts) tend to reduce the damages to environment and economy (Navrud et al., 2017). In general, the first category (i) is relatively straightforward to estimate, based on the average price of crude oil (**US$70/barrel** in 2018[81]), while the other categories (ii, iii) are more complex to assess.

Cost of oil clean-up and recovery. There have been many initiatives to estimate the costs of oil spills worldwide. A review of literature shows a large variety of unit costs of clean-up. After adjustment to 2018 prices, actual expenditures can vary between US$500/barrel for Jiyeh power plant spill in Lebanon in 2006 (World Bank, 2007) to as high as US$14,000/barrel for Exxon Valdez in 1989 (Cohen, 2010). The cost depends largely on the type and volume of oil spilled—for example, spills greater than 100 barrels of heavy persistent oil can entail costs estimated between US$18,900 and US$53,600 per barrel (Catalyst Environmental Solutions, 2019). In Nigeria, the cost per barrel is about **US$3,900 for clean-up** and **US$60 for recovery**, based on communications with

79 Overall, the Nigerian economy lost an estimated US$10 million revenue due to oil spills during the period of 1984-2012 (Nwokedi, et al., 2017). This amount accounted only for the value of oil, without inclusion of any remediation cost, third party costs and impacts on the environment. Considering a total of 1184 oil spill events during this period, this corresponds to an average economic loss of about US$9,200 per incident.

80 Other types of costs may include containment costs to stop or reduce further oil spillage, cost of litigation, loss of life and injury to workers etc. (Cohen, 2010).

81 https://www.statista.com/statistics/262858/change-in-opec-crude-oil-prices-since-1960/

NOSDRA[82]. The clean-up cost figure is very similar to that estimated by Etkin (2004) for spills smaller than 500 barrels[83].

Damage costs. Similar to the clean-up costs, available literature provides a very wide range of estimates of the environmental and economic damages from an oil spill. Damages per barrel vary largely: US$1,100 for Jiyeh in Lebanon (World Bank, 2007), US$1,700 for Prestige in Spain (Loureio, 2009); US$2,800−US$6,900 for spills in Caspian Sea (Hildrew, 2001), US$7,900 for Vietnam (Thi Thu Trang, 2006) and US$21,200 for Exxon Valdez (Cohen, 2010) (adjusted to 2018 prices).

A few analyses of damages from oil spills have been conducted in Nigeria. One indicated that the compensation for damages induced by two oil spills in Nigeria in 2008 was settled at US$83.4 million in 2016[84]; as the quantity spilled is not known with certainty[85], a unit value of damage cannot be estimated based on the settled value[86]. Other studies estimated people's WTP for reducing oil spill occurrences: for example, Bello (2015) estimated the WTP for environmental protection against damages caused by oil spills of about US$17 per person in Uzere and Emadadja communities in Delta State; Ukpong (2019) indicated that in Bayelsa state, people are willing to pay less than US$1 to secure at least 1 percent reduction in oil spill resulting in land and water pollution. However, as the quantities of oils spills considered in these studies were not specified, the chapter does not use these estimates.

Etkin (2004) provided a methodology and unit estimates of the environmental and economic damages from oil spills, for different sizes of spill and types of oil[87]. Niger Delta usually faces primarily crude oil spills (Chinedu and Chuwuemeka, 2018) of relatively large size (about 80 barrels per spill[88] on average). Using Etkin's methodology and unit estimates for crude oil and relatively large spill sizes, the damage cost is valued at **US$6,900 per barrel**. Although this is in the same wide range with damages from other oil spills cited above, it should be considered a *crude estimate*, which needs to be refined based on more comprehensive primary surveys in Niger Delta. As it does not capture the negative health impacts that can be caused by oil spills, this valuation underestimates the true value of oil spill damages.

3.4.3. ESTIMATED COSTS OF OIL SPILLS

Based on NOSDRA data, among the three states, Delta is the most contaminated by oil spills, while Cross River is least affected. Map 3.1 illustrates the locations of oil spills during 2015-2019, many of which were registered in the coastal areas (in grey) and close to the hydrographic network of non-coastal areas (in blue). Since the quantity of oil spilled varies across years, we consider that the average annual quantity of oil spilled during 2015-2019 is a better reflection of the most recent trend in oil spills than the quantity spilled in one single year.

It is important to note that coastal zones can be contaminated from spills occurring *off-shore*; in *coastal districts*; and in *non-coastal districts*, close to rivers that flow in the ocean. Therefore, based on a spatial analysis of the oil spill locations during the above period, the annual quantity of oil spilled on the coastal zone of each state is estimated as: (i) the annual average quantity spilled from incidents occurring *off-shore* and in the *coastal districts*, and (ii) a portion of the quantity of oil spilled close to rivers in the *non-coastal districts* of each state. Because this portion

82 Earlier efforts estimated the cost of restoring Ogoniland at US$1 billion over 5 years (UNEP, 2011). Later on, Adekola et al. (2015) extrapolated the unit cost of Ogoniland restoration to the whole Niger Delta, obtaining an annual cost of about US$758 million.

83 Etkin (2004) estimated the cost of clean-up between US$3,570/barrel of light fuels and US$16,200/barrel of heavy oils, using mechanical approach (2004 prices).

84 https://www.greenpeace.org/usa/shell-oil-settlement-ogoniland/

85 The leakage was estimated between 4,000 barrels by the producer and more than 500,000 barrels by the victims (https://www.reuters.com/article/us-shell-nigeria-spill/shell-to-pay-out-83-million-to-settle-nigeria-oil-spill-claims-idUSKBN0KG00920150107).

86 In addition, the compensation of victims of oil spillage is not always guaranteed due to lacunae and statutory defenses in the Nigerian municipal legislation regulating the oil and gas industry (Kingston and Nweke, 2018). In fact, valuation for compensation for environmental contamination of all sorts is multi-faceted, multi-dimensional and multi-disciplinary (Kayode and Ukabam, 2018). An analysis of 30 valuation reports on compensation for oil spills in Nigeria (Babawale, 2013) concluded that the valuation models employed were not appropriate.

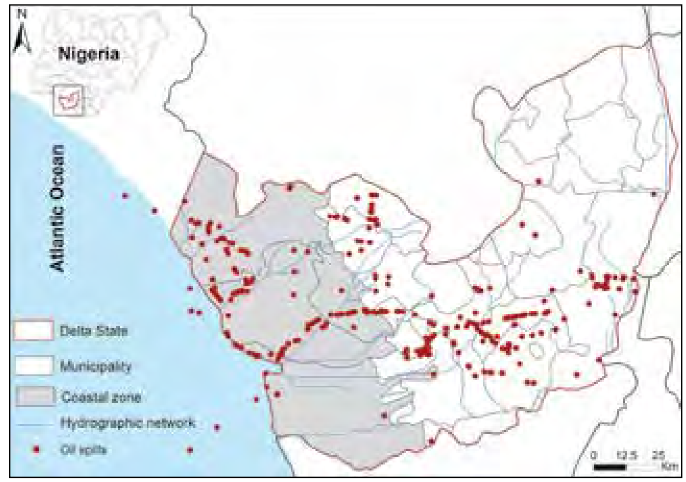
87 The author developed the Basic Oil Spill Cost Estimation Model, using data from nearly 43,000 spills of at least 50 gallons occurring during 1980-2002.

88 Estimated based on NOSDRA data on the total quantity of spills during 2015-2019 (186,981 barrels) and the number of recorded spills (2315).

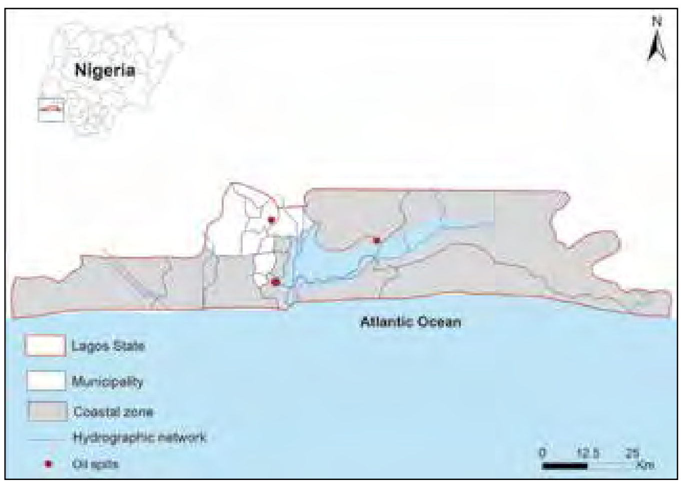
MAP 3.1: OIL SPILL LOCATIONS IN THE THREE STATES (2015-2019)

Cross River

Delta



Lagos



Source: Based on NOSDRA (2020) for geographic location of the spills. The off-shore spills are located within 100 km of the coastline.

has not been quantified on the ground, it is conservatively assumed to be about 50 percent of the oil spilled close to the hydrographic network. All quantities are derived from the NOSDRA database[89].

Table 3.4.1 estimates the cost of oil spills for each state. The monetary valuation is based on the quantities of oil reported in the table and the unit monetary values presented in the previous section.

89 For the oil spill events for which quantities are not recorded, the analysis attributes the average quantity per event (excluding the outliers), based on the events for which quantities are recorded.

3.4.4. CONCLUSIONS

Overall, the estimated cost of oil spills is dominant on coastal Delta, accounting for about **US$66 million**, or **0.5 percent of the state's GDP**. The overall cost, totaling US$69 million in the three states (0.06 percent of their combined GDP), is a considerable underestimate of the real costs, because: (i) it is based only on the spill events recorded by NOSDRA, which most likely do not capture the real number of spills that occurred; (ii) it does not account for the effect of wind, currents and other parameters, that might affect the trajectory of spills towards these states (e.g. Cross River); (iii) it

TABLE 3.4.1: ESTIMATED QUANTITY AND COST OF OIL SPILLS (2018)

	Unit	Cross River	Delta	Lagos
Oil spilled on the coast	barrels/year	**0.05**	**7,457**	**307**
–from coastal districts	barrels/year	0.05	3,493	307
–from non-coastal districts	barrels/year	0	3,964	1
Oil recovered from the coast	barrels/year	**0**	**1,426**	**215**
Cost of oil lost (a)	US$ million	n.n.	0.2	0.0
Cost of oil clean-up (b)	US$ million	n.n.	14.5	0.6
Cost of oil recovery (c)	US$ million	n.n.	0.1	0.0
Economic and environmental damages (d)	US$ million	n.n.	51.3	2.5
Total cost	**US$ million**	**n.n.**	**66.1**	**3.2**
	% of GDP	**n.n.**	**0.5%**	**0.0%**

Sources: NOSDRA (2020) for the quantity of oil spilled and recovered. (a) Estimated based on the quantity of oil spilled from coastal districts and the average price of crude oil (US$70/barrel, see section 3.4.2). (b) As part of the oil spilled will be biodegraded or hard to clean, this cost considers 50 percent of the quantity of oil spilled on the coast and the unit cost of clean-up (US$3,900/barrel, see section 3.4.2). (c) Based on the quantity recovered and the unit cost of recovery (US$60/barrel, see section 3.4.2). (d) Estimated based on the quantity spilled on the coast and the unit value of damage (US$6,900/barrel, see section 3.4.2). n.n. = negligible, based on available data.

does not estimate the cumulative effect of the oil spills that occurred over the past decades, but only during one year; (iv) it does not capture the health impacts from oil spills and the effects of gas flaring (e.g. air and noise pollution, CO_2 emissions, forgone opportunities to generate electricity) (PWC, 2019). It is important to note that carrying out a comprehensive primary study on the WTP to reduce the impacts of oil spills in Niger Delta is necessary to refine the monetary estimates of damage obtained in this chapter.

Photo Credit: Friedrich Stark / Alamy Stock Photo.

Photo Credit: Joseph Akpokodje, World Bank.

CHAPTER 4

FLOODING AND EROSION

4.1. FLOODING

Floods are the most frequent and widespread natural disasters in Africa (Niang et al., 2014). West Africa has recently experienced severe flooding, causing the death and displacement of considerable numbers of people. Flood frequency has increased in the past 50 years and they are expected to increase in the future (Niang et al., 2014). The most common flood impacts in the region include loss or damage to property, loss of human life, destruction of crops, and deterioration of health conditions owing to waterborne diseases.[90]

Nigeria is severely affected by floods. They are becoming yearly events, which occur in different forms: coastal, river, flash and urban floods. Devastating flood events date back to 1963 in the country. In the last decades, many states and cities have witnessed unusual and devastating floods, which undermined the government's capability to mitigate their impacts. Between 2011 and 2012 alone, Lagos state recorded at least 8 major floods (Komolafe et al., 2015). The worst of all occurred in between July and October 2012 and affected at least 33 states—of which 24 were severely affected, including Delta and Cross River (Nkwunonwo et al., 2015; GFDRR, 2013). Moreover, rainfall has become significantly heavier in recent years due to climate change. For instance, in 2018, the Niger River at Lokoja reached 11.06 meters above sea level, close to the record 12.84 meters of 2012[91].

This section estimates in monetary terms the impacts of floods on the coastal zone of the three states. It focuses on **fluvial and pluvial floods in coastal areas**. Fluvial floods occur when rivers burst their banks as a result of sustained or intense rainfall. Pluvial floods occur when heavy precipitation saturates drainage systems, particularly in flat and urban areas. Coastal flooding caused by seawater is not included in the analysis, due to data limitations[92].

90 Queensland Government (2011), Understanding Floods: Questions and Answers, July 2011.Link: https://www.chiefscientist.qld.gov.au/publications/understanding-floods/flood-consequences/ (retrieved on March 1, 2019).

91 http://floodlist.com/africa/nigeria-floods-niger-benue-rivers-september-2018

92 Available modelling exercises are mostly relevant for long-term planning.

4.1.1. COST OF FLOODING

When translated into socio-economic and environmental terms, coastal floods affect livelihoods (forgone economic activity), public and private assets (infrastructure, businesses, and properties), welfare (injuries, drowning, psycho-physical stress, migration, coping, social dislocation, etc.) and ecosystem services. In this study, we address the impact of fluvial and pluvial flooding according to two main categories: forgone economic activity, damage to assets, and mortality. The estimation is conducted in three steps, presented below.

Step 1. Measure flood areas. The flooded area in coastal districts was calculated based on the results of SSBN Global Flood Hazard Model for Nigeria. These results show the expected water depth for fluvial and pluvial floods and its corresponding surface for six different return periods (between 1/5 and 1/100 years)[93]. Model inputs include past floods, precipitation, as well as geographic characteristics to model future floods.[94] Map 4.1.1 shows, as example, the estimated fluvial and pluvial flood for 1/10 years return period by state, and its corresponding flooded area.

Each return period informs about the probability of flood occurrence. For instance, a 20-year return period event indicates a 5 percent chance of occurrence per year, while a 100-year return period suggests a 1 percent chance of occurrence per year. By combining the probability of flood occurrence with the associated affected areas, we estimate the total flooded areas for each return period for a typical year.

Table 4.1.1 reports the estimated flooded area as an annual average, for every state. It shows that overall, fluvial floods affect considerably larger areas than pluvial floods. Delta State is most affected by both pluvial and fluvial floods.

93 Flooding could be measured in terms of speed (extraordinary event catching the population off-guard or natural event that determines the rapidity of the flooding phenomena), duration (number of days) and depth (water level rise that will determine the affected coastal area given the morphology of the area). This exercise is based on the latter approach.

94 Systematic information on past flood events for Nigeria is limited and biased toward extreme events.

TABLE 4.1.1: AVERAGE AFFECTED AREA PER STATE (ha)

	Fluvial	Pluvial
Cross River	954	81
Delta	2,521	83
Lagos	1,383	26
Total	**4,858**	**190**

Source: World Bank estimates.

Step 2. Translate flood events into asset losses. Not all flood events are severe floods. The flood water depth and its corresponding area are translated into losses using flood damage functions. To assess the flood damages for Nigeria, we use Huizinga et al. (2017), who produced damage functions for different regions, based on a meta-analysis of damage functions worldwide. Table 4.1.2 shows these damage functions, according to water depth. Most of the estimated water depth falls in the second category, where only 22 percent of assets are lost. It should be noted that these functions do not consider other parameters (e.g. speed of currents) that might also affect the level of damage.

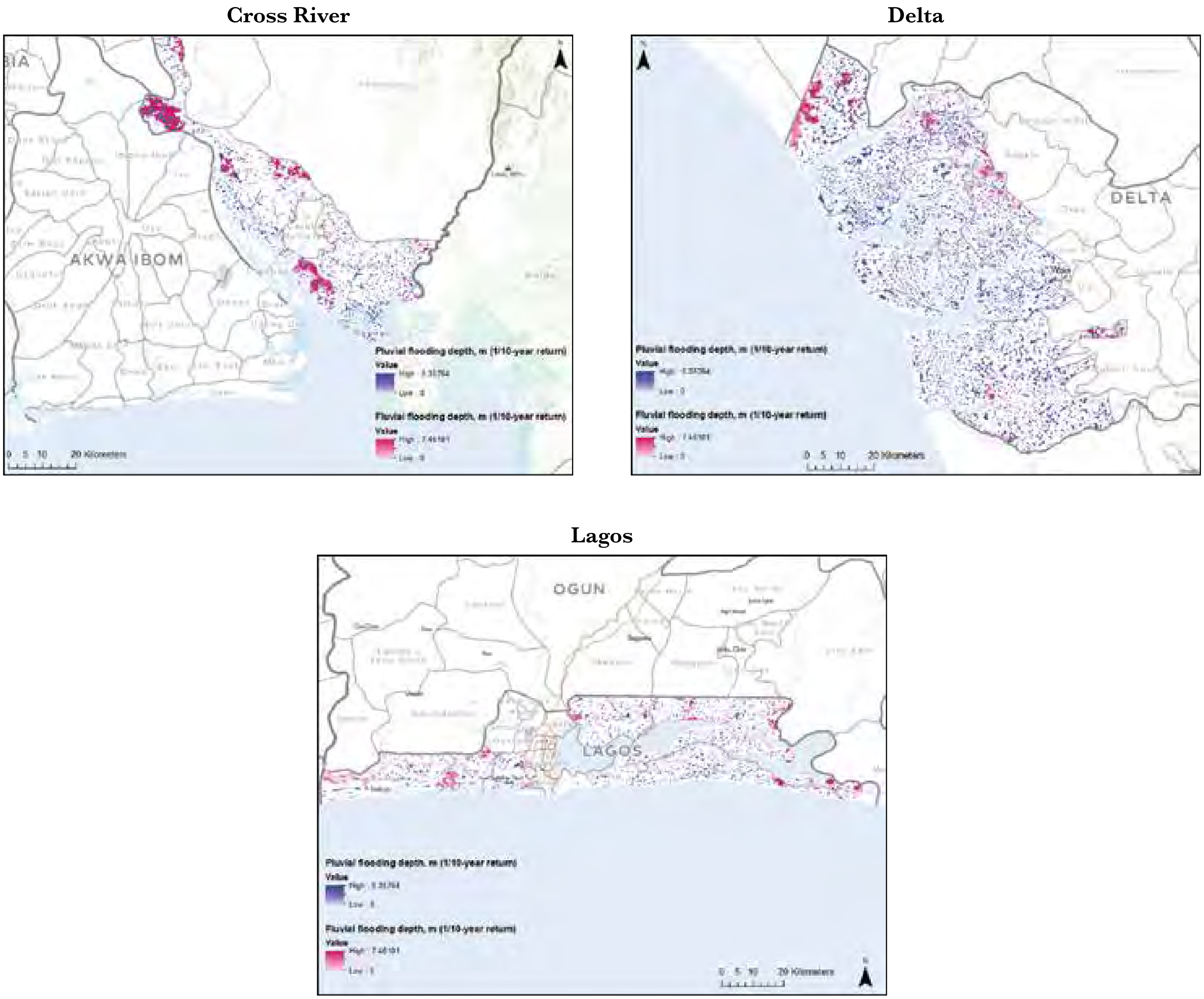
TABLE 4.1.2: DAMAGE FUNCTION BY WATER DEPTH

Water depth (meters)	Damage function (%)
0	0
0.5	0.22
1	0.38
1.5	0.53
2	0.64
3	0.82
4	0.9
5	0.96
6	1

Source: Huizinga et al. (2017).

Step 3. Quantify flood impacts. The impacts of floods are estimated in terms of damages to assets and economic production; and cost of mortality.

MAP 4.1.1: FLUVIAL AND PLUVIAL FLOODING FOR 1/10 YEARS RETURN PERIOD BY STATE



Source: World Bank, using SSBN Global Flood Hazard Model data, based on Sampson et al. (2015).

Damages to assets and economic production. These are estimated based on (i) the flooded area, derived from Step 1; (ii) the damage function, derived from Step 2; and (iii) the unit value of assets (stock) and production (flow) on the flooded land.

The unit value of assets was derived based on the methodology used by IMDC et al. (2018) for a one-hectare grid cell[95] and a rapid assessment of coastal housing prices by local stakeholders in the three states[96]. It includes the value of buildings, airports, roads and other infrastructure

95 It was obtained by combining the value of economic flows (i.e., GDP per hectare, based on the value-added per employee per hectare) with that of stocks (i.e., value of assets per hectare) for one year. The housing value was estimated based on a rapid assessment of coastal housing prices in the three states. Accordingly, the asset (stock) value was estimated at about US$83,300/ha in Cross River, US$113,200/ha in Delta and US$5 million/ha in Lagos, on average; while the production (flow) value was estimated at about US$2,800/ha/year in Cross River, US$8,800/ha/year in Delta and US$189,800/ha/year in Lagos. These estimates are weighted averages according to the value of stocks and flows in the urban and rural areas of each state.

96 Data from Nigeria Property Center were used to draw house value estimates for Lagos.

on the land. The same damage function is applied to both stocks and flows for the year of analysis. This is a conservative assumption, as in reality, the decline of production flows might persist several years after the floods.

Cost of mortality. According to the IMDC et al. (2018), there are 0.16 expected deaths per 1000 people exposed to floods, based on the average number of deaths in the floods of 2009 and 2010 in Togo (0.25) and Benin (0.07). We use this damage function to estimate the number of victims from coastal floods in Nigeria. Accordingly, the total number of premature deaths is estimated at about 400 per year: about 30 in Cross River, 40 in Delta and 330 in Lagos, on average. These estimates are similar to the Post-Disaster risk Assessment for Nigerian floods in 2012 (GFDRR, 2013). The cost of mortality is estimated based on the VSL, which reflects the society's WTP to reduce the risk of death.

4.1.2. CONCLUSIONS

Adding up the damages to assets, economic production and mortality, the total cost of floods is estimated at US$94 million in Cross River, US$300 million in Delta, and US$4 billion in Lagos (Table 4.1.3). Lagos has the highest cost both in absolute and relative terms, primarily due to the high value of assets and economic flows on the coastal zone. Overall, the total cost of floods is estimated at **US$4.4 billion**, or **3.7 percent of the combined GDP** of the three states.

TABLE 4.1.3: ECONOMIC COST OF FLOODING ON THE COAST (US$ MILLION, 2018)

	Cross River	Delta	Lagos
Damages due to fluvial floods*	82	285	3,835
Damages due to pluvial floods*	7	9	103
Mortality due to pluvial and fluvial floods	5	6	55
Total damages due to floods	**94**	**300**	**3,992**
% of the States' GDP	**1.2%**	**2.1%**	**4.1%**

Source: World Bank estimates. * Refers to damages to assets and economic production.

4.2. EROSION

Coastal erosion is a major environmental problem in Nigeria, resulting from both natural and anthropogenic forces. Among the latter, one can note the increasing economic development, primarily driven by population growth and migration to the coast, seaport activities, and oil exploration and exploitation. As a result, trees and infrastructure have been disappearing gradually; towns and villages located close to the shoreline, where most of the economic activity takes place, are likewise threatened.

Available estimates suggest high erosion on different coastal locations. For instance, Oyegun (1990) indicates observed erosion rates of 25 m to 30 m per year at Bar Beach in Lagos, before works were carried out; and of 16 m to 22 m per year in Forcados South Point in Delta State. Okude and Taiwo (2006) estimate that a shoreline retreat in Lagos of 100 m is expected by the year 2060, with worst case erosion rates expected to be up to 600 meters by the year 2060, if no action is taken. More recently, Dada et al. (2018) suggested that 82 percent of Delta state' coastline retreated during 1950–1987; and 69 percent between 2007 and 2012. This section estimates in monetary terms the impact of erosion on the coastal zone of the three Nigerian states.

4.2.1. COST OF EROSION

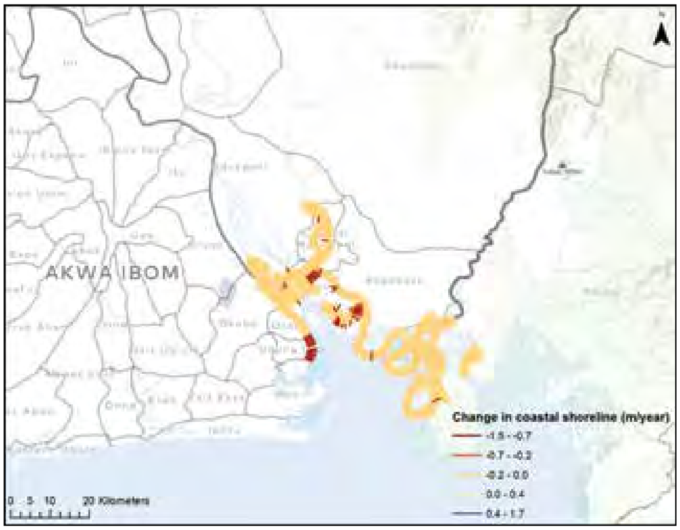
The valuation assumes that the land, assets, and economic flows on the land subject to erosion are lost in the long run[97]. The estimation is conducted in three steps, presented below.

Step 1. Estimate the erosion rate. The eroded area is estimated as an annual average value of land area lost to erosion, based on a study which quantified the change

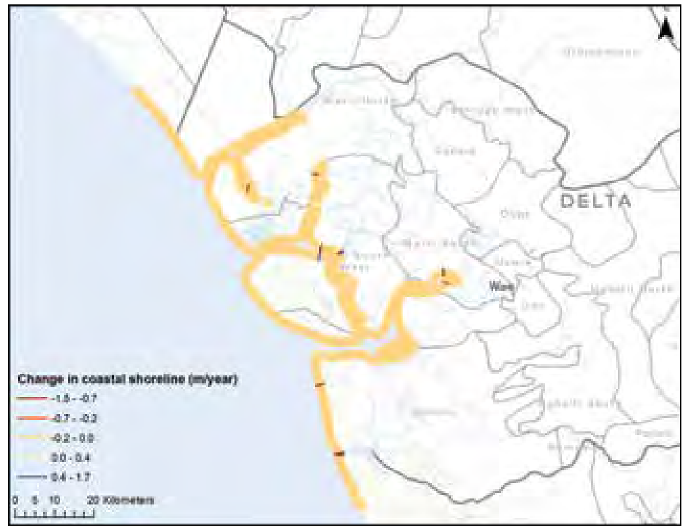
97 In reality, these losses can be replaced through reconstruction of similar assets in areas located nearby; however, this is often not possible, for example due to land scarcity (e.g. driven by high urbanization rate on the coast). Even when reconstruction is possible, it diverts budget from other investments which would have otherwise happened—hence, inducing lost economic opportunities.

MAP 4.2.1: LONG-TERM AVERAGE EROSION RATE (1984–2016) BY STATE

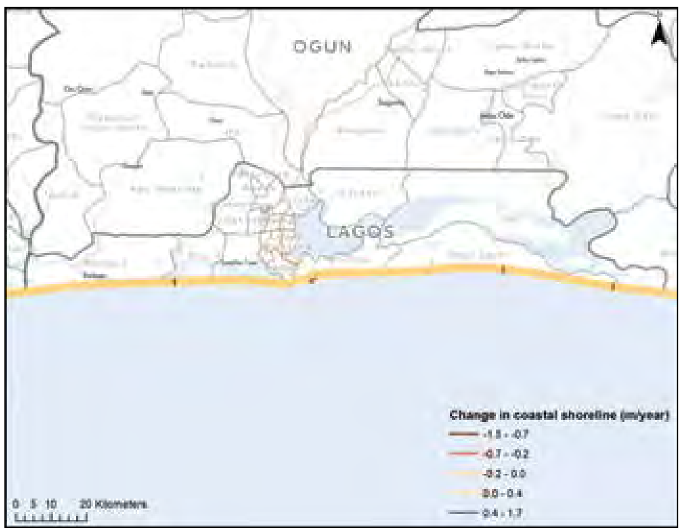
Cross River



Delta



Lagos



Source: World Bank, using data from Luijendijk et al. (2018).

in shoreline over 1984-2016, by comparing cloud-free historical Landsat images with resolution of 30 m (Luijendijk et al., 2018)[98]. For each 500 m transect, the authors computed the rates of shoreline change (m/year) by applying linear regression to all shoreline positions at that location.

Each state is subject to land erosion. However, the coastline is differently affected. Map 4.2.1 shows for each state the level of erosion and its heterogeneity from a location to another. The largest part of the coastal zone has mild erosion levels, marked in orange and red on the map; only a small portion of the coastal zone has no erosion at all, or has gained land (accretion).

Table 4.2.1 estimates the long-term erosion rates only for areas subject to land loss (500 m spaced transects). The second column presents the percentage of coastline subject to erosion: the highest share occurs in Lagos (86 percent), followed by Cross River (60 percent) and Delta (52 percent). The third column provides the *average annual erosion rates,* per transect: these are much higher in Cross River

98 This is the only study to date that measure erosion globally, allowing cross-country comparisons.

TABLE 4.2.1: LONG-TERM EROSION RATE (1984–2016)

State	% of the state's coastline subject to erosion	Long-term erosion rate	
		Average (m/year)	Total (ha/year)
Cross River	60.3	89.1	169.3
Delta	51.9	13.1	61.4
Lagos	85.9	8.2	24.9

Source: Luijendijk et al. (2018).

(89 m/year) compared to Delta (13 m/year) and Lagos (8 m/year). In perspective, these estimates are much higher than those of other West African countries. For instance, erosion rate is nearly 4 m/year in Benin, 2 m/year in Togo and Senegal, and 1 m/year in Côte d'Ivoire (Croitoru et al., 2019). The *total eroded area* varies from 25 ha (Lagos) to 169 ha (Cross River), on average.

Step 2. Classify the eroded land into urban and rural areas. Urban land has higher intrinsic economic value than rural land, and not all coastal areas are urbanized. We divide the eroded coastal land into urban and rural areas, using the population maps databases and the European Commission's definition of urban areas (i.e. areas with population greater than 300 people per km^2). The results are shown in Table 4.2.2. Coastal urban areas are predominant in Lagos (55 percent), but not in the other two states: Cross River (0.5 percent) and Delta (2.2 percent).

Step 3. Estimate the impacts of erosion. The valuation includes the economic losses on the area annually eroded. Specifically, the cost of erosion captures: (i) the loss of assets (e.g. buildings, roads, other infrastructure); (ii) the PV of production flows lost for the next 30 years; and (iii) the value of bare land. To estimate (i) and (ii), we use the unit value of assets and production flows reported in Table 4.1.3. To value (iii), we estimate the value of bare land as a PV of annual rents for the next 30 years, based on the following assumptions: a rent-to-price ratio of 10 percent (Onwuany, 2015); an average annual increase of 8 percent in land value[99]; an annual rate of urbanization of 4 percent for Lagos and 2 percent for the other states for the period 2014–2050 (United Nations, 2014); and a discount rate of 3 percent, to account for the high importance of the erosion impacts in the future.

TABLE 4.2.2: DISTRIBUTION OF URBAN AND RURAL POPULATION (%)

State	Urban	Rural
Cross River	0.5%	99.5%
Delta	2.2%	97.8%
Lagos	55.1%	44.9%

Source: ESA (2017) and CIESIN (2017).

TABLE 4.2.3: ECONOMIC COST OF EROSION (US$ MILLION, 2018)

	Cross River	Delta	Lagos
Assets lost	89	43	835
Production lost*	13	14	124
Land lost	57	28	691
Total cost of erosion	**158**	**85**	**1,650**
% of the States' GDP	**2.0%**	**0.6%**	**1.7%**

Source: World Bank estimates. *Analysis based on 30-year return and 3 percent discount factor.

4.2.2. CONCLUSIONS

When we add up the loss of assets, economic production, and land, the total cost of erosion is estimated at US$158 million in Cross River, US$85 million in Delta and US$1.7 billion in Lagos (Table 4.2.3). As in the case of floods, the largest cost of erosion occurs in Lagos, primarily due to the high unit value of assets, land and production. The overall cost in the three states amounts to **US$1.9 billion**, or **1.6 percent of their combined GDP**.

99 While there is no systematic data on these values, in Peru it is estimated at 9 percent (BCRP, 2018).

Photo Credit: Nigeria Conservation Foundation.


Photo Credit: Joseph Akpokodje, World Bank.

CHAPTER 5
MANGROVES

With about 636,000 ha of mangrove area (Menendez et al., 2020), Nigeria has the largest mangrove ecosystem in Africa (35 percent of the total mangrove area), and the third largest in the world, after India and Indonesia (UNEP, 2007). These forests provide valuable ecosystem services, e.g. breeding grounds for fisheries, biodiversity, water quality maintenance, prevention of coastal erosion and tidal surge, and climate change mitigation and adaptation (Himes-Cornell et al., 2018; Salem and Mercer, 2012; Brander et al., 2012; Barbier et al., 2011). Despite that, Nigerian mangroves are subject to deforestation and degradation, due to many factors, e.g. oil and gas operations, coastal development, wood harvesting, conversion for agriculture and bio-fuel plantations[100] (Feka et al, 2011; UNEP, 2007). This chapter estimates the economic impacts of mangrove loss[101] in the three states. The valuation is based on the steps presented below.

Step 1. Estimate the rate of mangrove loss. In the absence of a national mangrove spatial dataset for Nigeria, the loss in mangrove area[102] is estimated using global data on mangrove cover from Global Mangrove Watch[103], which is based on publicly available Landsat satellite imagery. Specifically, based on a GIS analysis for each state, we estimate the area of mangrove loss through the difference in mangrove cover between the years 2010 and 2016—the most recent years for which data is available. Table 5.1 indicates that that annual loss of mangrove cover is the highest in

100 less than 4 percent of Nigeria's mangrove areas fall within protected areas (UNEP, 2007).

101 This chapter measures mangrove loss, i.e. the negative change in mangrove extents over time. The cost of mangrove loss does not include the diminished ecosystem services provided by existing mangroves which may be in degraded conditions due to factors such as oil spills. Hence, the calculations in this chapter are conservative figures for the cost of mangrove loss.

102 Mangrove loss is defined as the change in mangrove cover from year 2010 to 2016, whereby mangroves are present in 2010 but no longer in 2016.

103 Global Mangrove Watch is a collaboration between Aberystwyth University (U.K.), solo Earth Observation (soloEO; Japan), Wetlands International, the World Conservation Monitoring Centre (UNEP-WCMC) and the Japan Aerospace Exploration Agency (JAXA). The primary objective of the GMW has been to provide countries lacking a national mangrove monitoring system with first cut mangrove extent and change maps, to help safeguard against further mangrove forest loss and degradation.

TABLE 5.1: COST OF MANGROVE LOSS (2018)

	Cross River	Delta	Lagos
Mangrove cover (ha)	22,600	147,000	2,600
Annual mangrove loss (2010-2016, ha)	66.5	404.2	8.9
Value of mangrove benefits (US$/ha/year)	4,700	4,700	4,700
Annual cost of mangrove loss (US$/year)	312,500	1,899,700	41,800
Cost of mangrove loss* (US$ million)	**6.1**	**37.2**	**0.8**
% of the States' GDP	**0.1%**	**0.3%**	**0.0%**

Sources: World Bank estimates using Global Mangrove Watch data, based on Thomas et al. (2017)—for mangrove area; Menendez et al. (2020) and Adekola et al. (2015) for mangrove benefits. *PV based on 3% discount rate and 30-year period.
Note: totals might not add up exactly due to rounding.

Delta (404 ha per year[104]), followed by Cross River (66 ha per year), and Lagos (9 ha per year)[105]. Map 5.1 illustrates the loss in mangrove area during 2010-2016, and the spatial extent of mangroves in 2016 for each state.[106]

Step 2. Estimate the value of ecosystem services provided by mangroves. Several global studies have been conducted to estimate the economic value of mangroves, e.g. Brander et al. (2012), de De Groot et al. (2012), Salem and Mercer (2012), Eppink et al. (2014), and Himes-Cornell et al. (2018). However, all these studies are based on existing results primarily from Asia, and to a very little extent from West Africa.

In Nigeria, mangroves are beneficial particularly for their contribution to coastal protection, fishing, and wood production (Numbere, 2019; Nwosu and Holzlohner, 2016). Only a few studies estimated these benefits in the country. Menendez et al. (2020) measured the flood risk reduction benefit at about US$400/ha/year, through an expected damage function approach[107]. In addition, Adekola et al. (2015) estimated the direct use values of Niger Delta wetland at US$12,500/ha/year, including cropping, material collection, fishing, hunting and logging, based on household surveys. Among these benefits, fishing accounted for about US$3,800/ha/year, and wood for US$500/ha/year, after adjusting to 2018 prices. Adding up the unit values of flood risk reduction, fishing, and wood, the economic benefit of mangroves in Nigeria is estimated at about US$4,700/ha/year[108].

Step 3. Estimate the cost of mangrove loss. Based on the results of the previous steps, Table 5.1 presents the annual cost of mangrove loss for the coastal zone of the three states. The highest occurs in Delta. Assuming a constant loss of services from lost mangroves for 30 years, the total cost is estimated at US$37 million, or 0.3 percent of the Delta's State GDP. These losses are substantially lower in the other two states, due to much lower mangrove loss per year. Overall, the total losses account for about **US$44.2 million**, or **0.04 percent of the combined GDP** of the three states. This is a conservative estimate, as it does not capture the loss in ecosystem services due to degradation of existing mangroves; however, a part of this loss—cost of mangrove degradation due to oil spills—is estimated in Section 3.4.

104 Most of this area occurs in the LGAs of Warri South–West, Warri North And Warri South.

105 Most mangrove loss occur in coastal districts, since coastal districts are also where mangroves are mostly located. Lagos' initial mangrove extent was very low even in 2010.

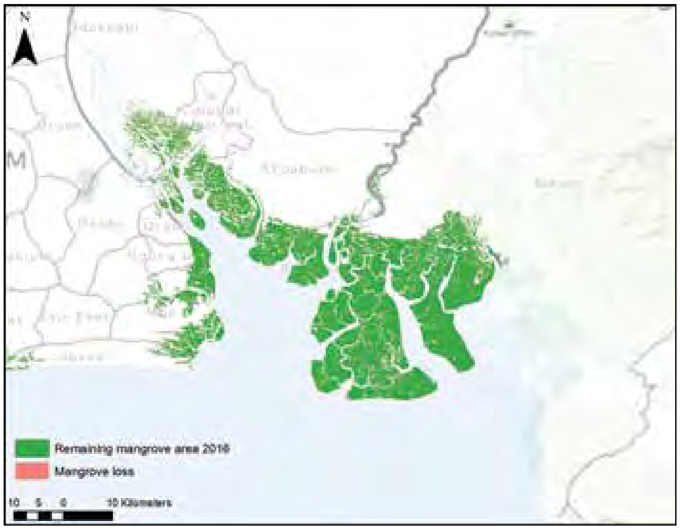
106 Since there is no information on significant changes in mangrove loss in 2018 compared to the period 2010 and 2016, the authors apply the annual mangrove loss rate during 2010-2016 to 2018.

107 The authors provide high resolution estimates of the economic value of mangroves forests for flood risk reduction every 20 km worldwide. They develop a probabilistic, process-based valuation of the effects of mangroves on averting damages to people and property.

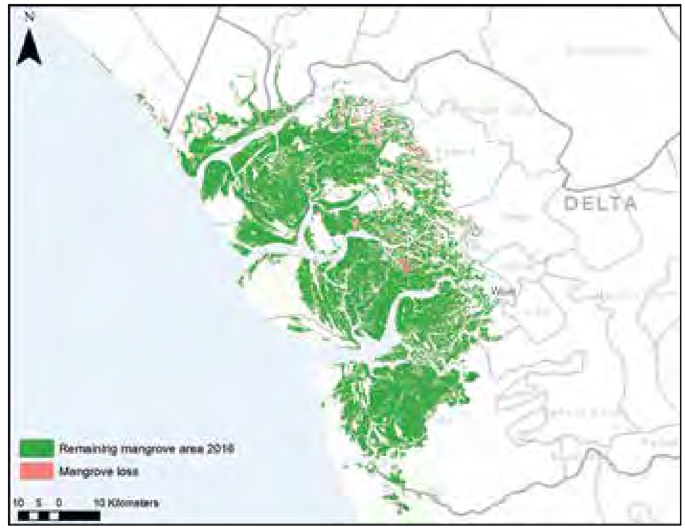
108 This is in line with the estimated value of US$2,000 – 9,000 per hectare of mangroves provided by UNEP (2007).

MAP 5.1: AREA OF MANGROVE LOSS DURING 2010–2016, AND REMAINING COVER IN 2016

Cross River



Delta



Lagos

Source: World Bank analysis using Global Mangrove Watch data, based on Thomas et al. (2017).

Photo Credit: Joseph Akpokodje, World Bank.

CHAPTER 6

CONCLUSIONS

The study assessed the coastal COED in the three states at **US$9.7 billion**, or **8.1 percent of their GDP** (Table 6.1). Flooding, erosion, and water pollution are the main forms of degradation, accounting for more than 80 percent of the total cost. Moreover, coastal degradation is estimated to cause over **15,000 premature deaths** a year, primarily due to water and air pollution, and to floods. At the state level, the COED varies between 5.7 percent of Delta's GDP and 8.6 percent of Lagos' GDP. The highest degradation cost occurs in Lagos—the state most affected by flooding, erosion, and pollution from water, air, and waste. Delta stands out with the highest cost of oil spills and mangrove loss among the three states.

Overall, the main drivers of degradation include:

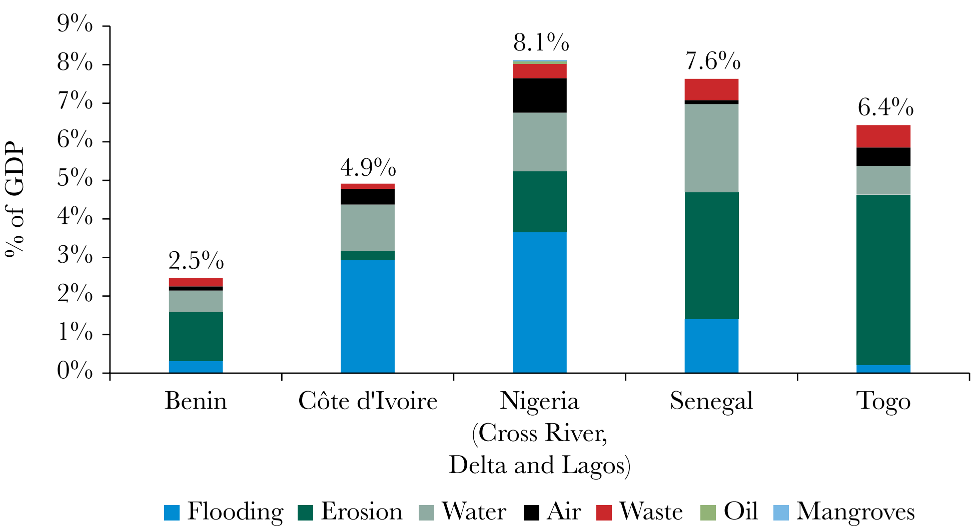
- ***Flooding*** is the most damaging factor, causing about 45 percent of the total COED. In all three states, flood damages are primarily a result of overflowing rivers (fluvial floods), and to a lesser extent, of extreme rainfall (pluvial floods). The economic cost is particularly high in Lagos (US$4 billion per year) due to its relatively large flooded area, and to high value assets and large population at risk. Flooding is also the most damaging factor in Delta—the state with the largest flooded area among the three (2,500 ha per year, on average).
- ***Erosion*** is caused by both natural and human factors. Some areas have no erosion at all, others have land losses (erosion), and others have land gains (accretion). As in the case of floods, the largest cost of erosion occurs in Lagos, due to the high value of assets, land, and production lost. Cross River has the largest area subject to erosion (169 ha per year) among the three states. In all states, the cost of erosion is expected to increase, as the phenomenon is likely to affect larger urban areas.
- ***Pollution*** imposes an important toll on people's health, quality of life, and environment. In all states, *unsafe water, insufficient sanitation, and poor hygiene* are particularly harmful, causing nearly 9,400 premature deaths per year. Poor air quality is responsible for about 5,700 deaths—mainly a result of household air pollution in Cross River and Delta, and of ambient air pollution in Lagos. Other important forms of degradation, though considerably underestimated, are *waste* mismanagement (due to the high cost of uncollected waste)

TABLE 6.1: ESTIMATED COASTAL COED IN THE THREE NIGERIAN STATES (2018)

	Cross River	Delta	Lagos	Total	
	US$ million	*US$ million*	*US$ million*	*US$ million*	*of the 3 states' GDP*
Flooding	94	300	3,992	4,386	3.7%
Erosion	158	85	1,650	1,893	1.6%
Water	161	186	1,480	1,827	1.5%
Air	96	82	895	1,073	0.9%
Waste	27	48	377	453	0.4%
Oil	n.n.	66	3	69	0.06%
Mangroves	6	37	1	44	0.04%
Total	**543**	**805**	**8,397**	**9,746**	**8.1%**
% of the state's GDP	**6.8%**	**5.7%**	**8.6%**	**...**	**...**

Source: World Bank estimates. n.n. = negligible, based on available data. The totals might not add up exactly due to rounding.

FIGURE 6.1: ESTIMATED COASTAL COED IN WEST AFRICA



Sources: Authors, for Cross River, Delta and Lagos; Croitoru et al. (2019) for the other countries.
Note: The result for Nigeria represents the percentage of the combined GDP of the three Nigerian states.

and *oil pollution* (due to the cost imposed on Delta's society and ecosystems). It is important to note that Nigeria has the highest production of plastic waste in Africa, and the fastest growing e-waste problem in the Sub-Saharan region.

Figure 6.1 places the estimated COED (8.1 percent of the three states' GDP) in a broader context of other West African countries: a recent study estimated it between 2.5 percent of Benin's GDP and 7.6 percent of Senegal's GDP[109]. Interestingly, the main degradation drivers differ from country to country (e.g. flooding in Nigeria and Côte d'Ivoire; erosion in Senegal and Togo), and from a Nigerian state to another (e.g. flooding in Delta and Lagos; water pollution and erosion in Cross River).

109 It should be noted that the result of this study reflects the percentage of the combined GDP of only the three Nigerian states, thus it is not fully comparable with the estimates for the other four countries (Benin, Côte d'Ivoire, Senegal and Togo), which represent percentages of the entire countries' GDP.

This study demonstrates that flooding, erosion, and pollution are major challenges facing the Nigerian coastal areas. In the three coastal states, they cause death, decrease the quality of life of residents, and lead to substantial economic damages amounting to about **2.4 percent of Nigeria's GDP**. As this estimate covers less than a half of the country's coastline, **the COED of the entire country's coastal zone is certainly higher**. It is expected that these results will inform the country's multisectoral investment plan, and will support the ongoing efforts to mobilize financing for coastal resilience as part of the West Africa Coastal Areas (WACA) program.

It should be noted that data limitations prevented the estimation of several costs, related to: air pollution (e.g. the impacts of pollutants other than $PM_{2.5}$ and lead on people's health, the effect of gas flaring, illegal refineries, etc.), water pollution (e.g. losses in fisheries, impacts of emerging pollutants, etc.), waste management (e.g. damages caused by inappropriate disposal of waste other than municipal and e-waste, losses due to forgone opportunities to recycle, damages due to specific waste categories such as plastic), oil spills (e.g. impacts on health), floods (e.g. damages caused by flooding from sea level rise and storm surges), erosion (e.g. slower GDP growth in the future due to less real estate on the coastal area), mangroves (e.g. ecosystem degradation due to invasive Nypa palm); and other effects (e.g. impact of sand mining, effects of greenhouse gas emissions, transboundary impacts of flooding, oil spills, etc.) Therefore, the final results should be considered **underestimates** of the real magnitude of the COED. To refine and complement them, it would be important that future work cover the above aspects, as well as the effects of climate change on floods, erosion, and water resources.

Photo Credit: Joseph Akpokodje, World Bank.

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