WACA West Africa Coastal Areas Management Program

WORLD BANK GROUP
Environment & Natural Resources

THE COST OF COASTAL ZONE DEGRADATION IN WEST AFRICA: BENIN, CÔTE D'IVOIRE, SENEGAL AND TOGO

Lelia Croitoru, Juan José Miranda and Maria Sarraf

MARCH 2019

THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP

1818 H Street NW
Washington DC 20433
Telephone: 202-473-1000
Internet: www.worldbank.org
Email: feedback@worldbank.org

West Africa Coastal Areas Management Program

WORLD BANK GROUP
Environment & Natural Resources

THE COST OF COASTAL ZONE DEGRADATION IN WEST AFRICA: BENIN, CÔTE D'IVOIRE, SENEGAL AND TOGO

Lelia Croitoru, Juan José Miranda and Maria Sarraf

With Fadi Doumani and Jia Jun Lee

MARCH 2019

THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP

Photo Credit: World Bank/Vincent Tremeau.

CONTENTS

Photo Credit: World Bank/Vincent Tremeau.

FOREWORD

Environmental degradation is costly—to individuals, to societies, and to the environment. In West Africa, coastal degradation takes an important toll on people's health and quality of life. From Mauritania to Gabon, millions of people on the coast suffer from severe erosion, flooding and pollution. These take away lands, homes and lives. Climate change and variability, characterized by rising sea levels and more frequent and violent storms, are exacerbating their predicaments.

How large are the impacts of this degradation? In the past, when government officials asked this simple question, the response was often an emphatic "large!". This study quantifies in economic terms how large is "large." As such, it is expected to capture the attention of decision makers to improve coastal policy making in West Africa.

Croitoru, Miranda and Sarraf make an important contribution to the literature by making this work available. For the first time in the region, they present a consistent approach to estimating the impacts of environmental degradation in the coastal areas of four countries, namely Benin, Côte d'Ivoire, Senegal and Togo. Their findings show the urgency to find the knowledge, gather the finance, and stimulate the collaboration needed to protect coastal areas and avoid future damages.

Benoît Bosquet
Director, Environment and Natural Resources
World Bank

Photo Credit: World Bank/Vincent Tremeau.

ACKNOWLEDGMENTS

This report was prepared by a team composed of Lelia Croitoru (Environmental Economist, Consultant) and Juan José Miranda (Environmental Economist), under the guidance of Maria Sarraf (Practice Manager), with valuable contributions from Fadi Doumani (Environmental Economist, Consultant) and Jia Jun Lee (Research Analyst).

The team gratefully acknowledges the support of Benoît Bosquet (Director), Peter Kristensen (Lead Environmental Specialist), Dahlia Lotayef (Lead Environment Specialist) and of the peer-reviewers Richard Damania (Senior Economic Adviser) and Raffaello Cervigni (Lead Environmental Economist). Useful comments and inputs were provided by Idriss Deffry (Natural Resources Management Specialist), John Dixon (Lead Environmental Economist, Retired), Abdoulaye Gadiere (Senior Environmental Specialist), Medou Lo (Senior Environmental Specialist), Brigitte Mobongol (Environmental Specialist) and Stefano Pagiola (Senior Environmental Economist). Special thanks are given to Madjiguene Seck (Communications Officer) and Will Kemp (Graphic Designer) for their valuable contribution to the publication. The report was funded by the World Bank's West Africa Coastal Areas (WACA) management program.

Front and back cover photos: World Bank/Vincent Tremeau.

Photo Credit: World Bank/Vincent Tremeau.

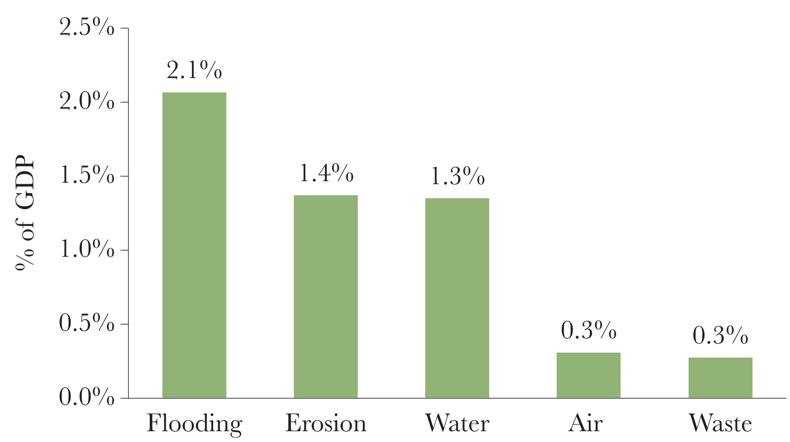
EXECUTIVE SUMMARY

West Africa's coastal areas host about one third of the region's population and generate 56 percent of its GDP. They are home for valuable wetlands, fisheries, oil and gas reserves, and high tourism potential. However, these areas are affected by severe pressures: rapid urbanization along the coast has increased the demands on land, water, and other natural resources; man-made infrastructure and sand extraction have contributed to significant coastal retreat; moreover, climate change and disaster risks are exacerbating these threats. As a result, coastal areas are undergoing **alarming environmental degradation** leading to deaths (due to floods, air and water pollution), losses of assets (houses, infrastructure) and damages to critical ecosystems (mangroves, marine habitat).

This study estimates in monetary terms the Cost of Environmental Degradation (COED) in the coastal areas of Benin, Côte d'Ivoire, Senegal, and Togo[1]. Specifically, it values the impacts of degradation that occur during one year, as a result of three major factors: flooding, erosion, and pollution (from water, air and waste). The final results are expressed in 2017 prices. They are reflected in absolute (US$) and in relative terms, as percentage of the countries' GDP.

Overall, the COED of the four countries is estimated at about **US$3.8 billion**[2], or **5.3 percent of the countries' GDP** in 2017. Flooding and erosion are the main forms of degradation, accounting for more than 60 percent of the total cost (Figure 1). Moreover, coastal degradation causes over **13,000 deaths** a year, primarily due to air and water pollution, and to floods.

FIGURE 1: ESTIMATED COED BY CATEGORY, 2017

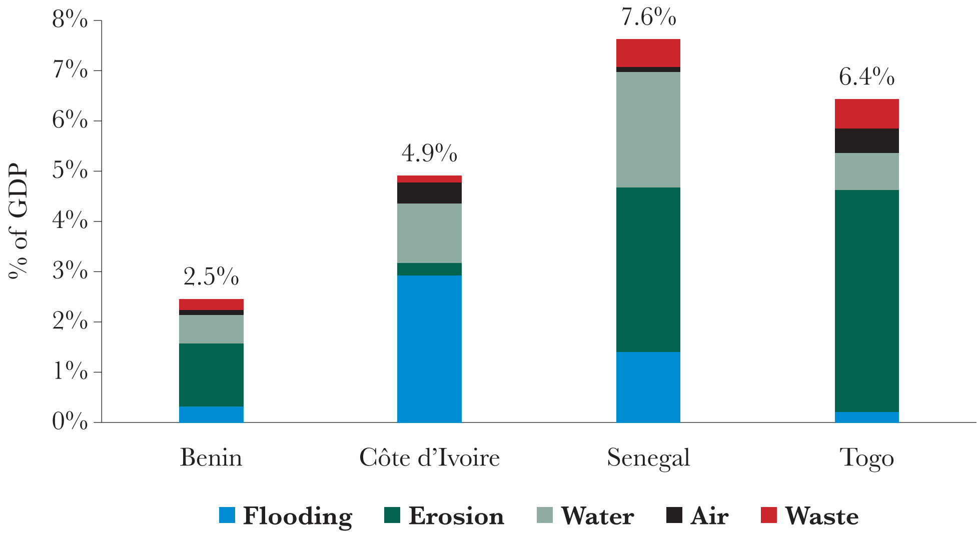


Source: World Bank estimates

1 These countries are part of the West Africa Coastal Areas Resilience Investment Project (WACA ResIP), which aims to strengthen the resilience of communities and areas in coastal West Africa. The project covers Benin, Côte d'Ivoire, Mauritania, São Tomé and Príncipe, Senegal and Togo.

2 If we adjust this figure with the countries' purchasing power parities, we obtain a total loss of 10 billion international $ (PPP-adjusted, 2017).

FIGURE 2: ESTIMATED COED BY COUNTRY, 2017



Source: World Bank estimates

At the country level, coastal degradation imposes costs varying between 2.5 percent of GDP in Benin to 7.6 percent of GDP in Senegal in 2017 (Figure 2 and Table 1).

These estimates are the result of three major factors affecting the coastal area:

- **Flooding** due to high rainfalls (pluvial floods) and overflowing rivers (fluvial floods) causes deaths and leads to major damage to houses, infrastructure and critical ecosystems, such as beaches and mangroves. Floods are extremely damaging in *Côte d'Ivoire*, costing society US$1.2 billion per year, mainly due to large areas affected by pluvial floods (Table 1). In the other countries, flooded areas and the associated water depths are smaller, leading to comparatively lower flooding costs.
- **Erosion** is a result of both natural and human factors. Some areas have no erosion at all, others have land losses (erosion), and others have land gains (accretion). About 56 percent of the coastline in Benin, Côte d'Ivoire, Senegal and Togo is subject to an average erosion of 1.8 meters per year. Erosion is the most damaging factor in *Benin*, *Senegal*, and *Togo*, primarily due to losses of high value urban land. The highest cost, estimated at US$0.5 billion per year, occurs in Senegal. In all countries, the cost of erosion is expected to increase considerably in the future, as the phenomenon is likely to affect larger urban areas.
- **Pollution** from air, water and waste mismanagement imposes an important toll on people's health

TABLE 1: ESTIMATED COED (US$ MILLION, CURRENT PRICES, 2017)

	Benin	Côte d'Ivoire	Senegal	Togo
Flooding	29	1,183	230	10
Erosion	117	97	537	213
Water	53	485	375	36
Air	10	166	17	23
Waste	20	53	90	28
Total	**229**	**1,985**	**1,250**	**310**

Source: World Bank estimates

and quality of life. It can reach as high as US$0.7 billion, in Côte d'Ivoire. In all countries, unsafe *water*, sanitation, and hygiene are particularly harmful, causing more than 10,000 deaths per year; they affect primarily *Côte d'Ivoire* and *Senegal*, with more than 4,000 deaths per country. *Air* pollution and *waste* mismanagement are also important forms of degradation, but are considerably underestimated: the cost of air pollution (2,500 deaths) refers only to the impacts of fine particulate matter in the countries' capitals, while the cost of waste covers only the effects of insufficient collection and inappropriate disposal of municipal waste.

Finally, it should be noted that **data limitations** prevented the estimation of several costs, related to air pollution (e.g. the impacts of air pollution in other cities than the countries' capitals; of air pollutants other ambient $PM_{2.5}$); water pollution (e.g. damages caused by the discharge of untreated agricultural and industrial wastewater); waste management (e.g. damages caused by inappropriate or insufficient disposal of medical, industrial, construction and demolition, e-waste); floods (e.g. damages caused by flooding from sea level rise and storm surges); and erosion (e.g. slower GDP growth in the future due to less real estate on the coastal area). Therefore, the results of this study should be considered **conservative** estimates, which capture only partially the full COED. To refine and complement these estimates, it would be important that future work cover the above aspects, as well as the effects of climate change on floods and erosion, and the combined impacts that erosion and climate change may have on water availability.

The study demonstrates that flooding, erosion and pollution are major challenges facing the West Africa coastal areas. They cause death, decrease the quality of life of citizens and lead to substantial economic damages amounting to over 5.3 percent of the four countries' GDP. Building coastal resilience early on will reduce these damages and save billions of dollars in future damages. The recently established West Africa Coastal Areas (WACA) management program is designed to build resilient coastal communities. The program invests in seawalls, breakwaters, sand barriers, road protection, mangrove restoration, beach replenishment and pollution prevention.

Investing in coastal adaptation now will prevent losing billions of dollars in damages in the future.

Photo Credit: World Bank/Idriss Deffry.

CHAPTER ONE
INTRODUCTION

The West African coast, spanning from Mauritania to Gabon, covers 17 countries,[3] with a diversity of economic, political, and conflict situations. The coastal area is home to one third of the population and generates 56 percent of the GDP (UEMOA, 2010). This study covers four countries—Benin, Côte d'Ivoire, Senegal, and Togo—with a total population of 56 million people and a coastline of 1,223 km (Map 1). The coastal areas of these countries—defined as all districts along the coast —are home to 36 percent of the countries' total population (Table 1.1.1).

MAP 1: COASTAL AREAS OF THE FOUR WEST AFRICAN COUNTRIES COVERED BY THE STUDY

Source: WBG staff using CIESIN Gridded Population of the World (GPWv4) (2015), ESA Global Land Cover (2015)

3 These are Benin, Cabo Verde, Cameroon, Côte d'Ivoire, Equatorial Guinea, Gabon, Ghana, Guinea, Guinea-Bissau, Liberia, Mauritania, Nigeria, São Tomé and Príncipe, Senegal, Sierra Leone, The Gambia, and Togo.

TABLE 1.1.1: SOCIO-ECONOMIC DATA OF THE FOUR WEST AFRICAN COUNTRIES

Country	GDP (US$/ capita)	Total population (million)	Coastline (km)	Coastal districts (#)	Coastal population (million)	Coastal population (% of total)	Urban coastal population (% of coastal population)
Benin	830	10.9	121	5	1.9	17	97
Côte d'Ivoire	1,662	22.7	515	8	8.2	36	57
Senegal	1,033	15.0	531	15	7.8	52	61
Togo	617	7.2	56	2	2.0	28	100
Average/ Total	**1,196**	**55.7**	**1,223**	**30**	**19.9**	**36**	**67**

Sources: data.worldbank.org; www.cia.gov; CIESIN Gridded Population of the World (GPWv4) (2015) and ESA Global Land Cover (2015).

These coastal areas are home to valuable wetlands, rich fisheries, oil and gas reserves, and high tourism potential (UNIDO, 2011). However, they are affected by severe pressures: rapid urbanization and migration to the coast have increased the demands on land, water, and other natural resources (World Bank, 2015a); man-made infrastructure and sand extraction have contributed to significant coastal retreat, which could reach 10 meters per year in highly vulnerable areas (Giardino et al., 2017); moreover, climate change and disaster risks are exacerbating these threats. As a result, coastal areas are undergoing severe environmental degradation leading to deaths (due air and water pollution), losses of assets (houses and infrastructure) and of critical ecosystems (mangroves). For example, flooding in Senegal is estimated to affect 200,000 people annually; while the extreme floods in 2009 caused damages of US$104 million in Dakar only.[4]

Raising awareness on the magnitude of coastal degradation is a critical step towards enacting positive change. This study contributes to this need, by **estimating in monetary terms the Cost of Environmental Degradation (COED) of the coastal areas** in select West African countries[5]: Benin, Côte d'Ivoire, Senegal and Togo. These countries are part of the six-country West Africa Coastal Areas Resilience Investment Project (WACA ResIP),[6] which aims to strengthen the resilience of communities and areas in coastal West Africa.

The four countries were selected due to better data availability on coastal issues compared to other countries of the project, given by the multi-hazard risk assessment of the International Marine & Dredging Consultants (IMDC), multi-sectoral investment plans, national statistics, etc. Overall, estimating the COED in monetary terms will provide an indication of the real magnitude of damage and of the urgency of action needed to protect the coastal areas. Chapter 2 provides an overview of the methods used for estimating the COED and the study's limitations. Chapter 3 estimates the impacts of pollution, while Chapter 4 addresses the cost of flooding and erosion on the coast.

4 https://www.gfdrr.org/senegal

5 This study updates and expands the earlier work on the cost of environmental degradation in Mauritania (World Bank, 2017) and Togo (World Bank, 2015b).

6 which includes Benin, Côte d'Ivoire, Mauritania, São Tomé and Príncipe, Senegal and Togo.

Photo Credit: World Bank/Vincent Tremeau.

Photo Credit: World Bank/Vincent Tremeau.

CHAPTER TWO
METHODOLOGY

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

2.1. OBJECTIVE AND SCOPE

This study aims at estimating in monetary terms the annual COED of the coastal areas of Benin, Côte d'Ivoire, Senegal, and Togo. 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 should be noted that certain activities have short-term impacts: for example, water pollution often causes health problems (such as diarrhea and skin allergy) ranging from a few days to several weeks. Other activities have long-term impacts: for example, erosion of coastal areas often results in losses of assets in the long run. This study estimates the present value (PV) of the current and future impacts caused by activities occurring during the latest year for which data are available. The analysis 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.[7] The results are expressed in 2017 prices. They are reflected in absolute (US$) and in relative terms, as percentage of the countries' GDP.

The study values the impacts of environmental degradation that occurred in 2017 due to *pollution* (related to air, water, and waste), *flooding* and *erosion* on the coast. It focuses on degradation induced by both human (e.g. air pollution due to industrial activities,

7 Assuming that a person of average age will benefit from environmental services for another 30 years.

water pollution due to discharges of untreated wastewater) and natural factors (e.g. flooding). As such, the estimated values provide a more comprehensive picture of the situation of environmental degradation compared to other COED work that focused primarily on degradation induced by human actions (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 triggered, had the COED covered only human-induced losses.

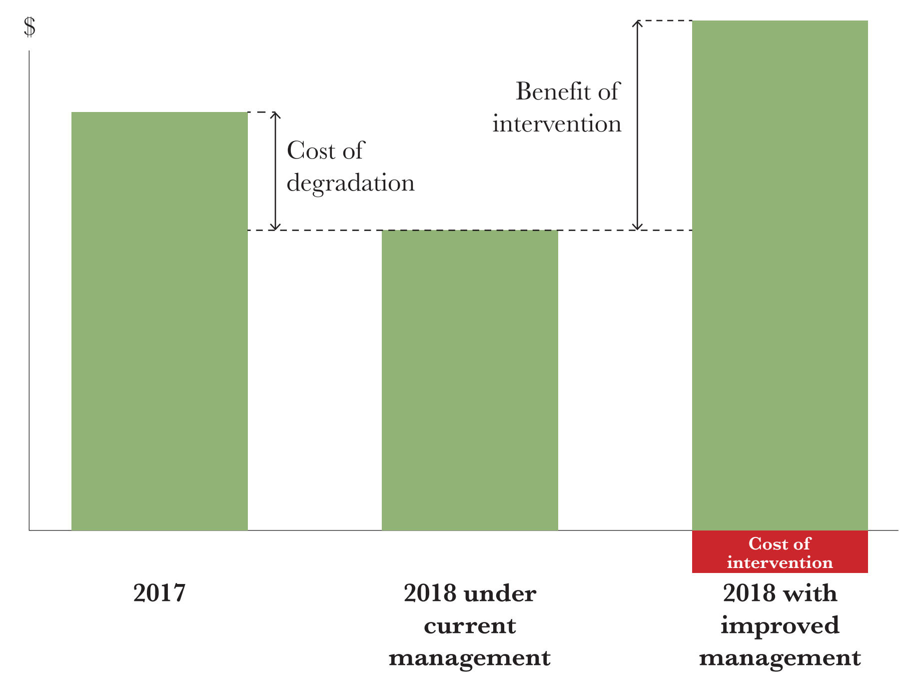
In addition, the valuation of the COED also covers to a certain degree the impacts of climate change (e.g. increased flooding due to higher rainfall). However, it is important to note that: (i) the impacts of climate change cannot be separated from those of other factors; (ii) since the valuation refers to only one year, these impacts are likely to be minor.[8]

2.2. WHAT DOES THE COED MEASURE?

The COED estimates the annual changes in benefits caused by current environmental management practices. Figure 2.1.1 illustrates these values. At any given time, coastal areas provide certain benefits (e.g. industrial and agricultural production, recreational value), depending on the type of management and socioeconomic context. The first column shows the economic value of these benefits for a given year.

The second column presents the value of these benefits in the future; 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 value represents the cost of damage caused by current degradation, namely the COED.

FIGURE 2.1.1: ECONOMIC VALUE OF COASTAL ZONES



Source: Pagiola et al. (2004).

8 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).

It is important to note that the degradation costs only indicate the extent of damage and the areas needing urgent interventions for improvement. They provide no information on the best choice of interventions or their profitability. The third column best reflects this, showing that the profitability of interventions should be measured by comparing their benefits with the costs of intervention.

This study **estimates only the COED** (the difference between the first and the second column). Potential interventions for environmental improvement are identified and their profitability is assessed in the Cost-Benefit Analysis of the WACA ResIP project appraisal document (World Bank, 2018a).

2.2.1 METHODOLOGICAL CONSISTENCY

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). While valuation of marketable goods tends to be straightforward (e.g. by using the market price after eliminating distortions), estimating the value of non-market goods and services is often challenging. This has been long recognized in the environmental literature, and a wide range of valuation methods have been developed (e.g. Dixon et al., 1994; Freeman, 2003; Willis and Garrod, 2012; Johnston et al., 2015). In a valuation exercise such as the COED, ensuring **consistency across the valuation methods is essential for obtaining meaningful results.**

The existing valuation methods are commonly divided into demand curve approaches (that seek to estimate the value of goods and services by explicitly estimating the consumers' demand, or WTP for them) and non-demand curve approaches (that value environmental damages via cost-based methods, such as replacement cost) (Markandya et al., 2002). When no market prices are available to estimate the value of damage itself, this study uses demand curve approaches—WTP measures—to assess the impacts of environmental degradation. For example, the cost of uncollected municipal waste is estimated through the society's WTP for improved collection. Only in two instances does the study apply cost-based methods,[9] while ensuring that they provide conservative results compared to other WTP measures.[10]

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 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). This study uses the **WTP approach,** derived from the available studies in the four countries, or in the West Africa region.

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 COED is estimated based on the valuation methods summarized in table 2.2.1 and described below.

Air pollution. Ambient air pollution is a major contributor to human mortality and morbidity. Exposure to fine particulate matter ($PM_{2.5}$) is especially harmful to health,

9 These are forgone income approach (to value the cost of water borne morbidity) and cost of wastewater treatment (to value the impact of untreated wastewater discharge).

10 Careful attention should be paid when applying cost-based methods. For example, when restoration cost is applied, use of actual expenditures can underestimate the damage, as replacements rarely substitute all the services coming from the original ecosystem; it can also over-estimate, if replacement is undertaken inefficiently.

TABLE 2.2.1: ENVIRONMENTAL DEGRADATION AND VALUATION METHODS USED

	Environmental degradation	Methods used for valuation
Pollution	***Air***	
	Impact of ambient air pollution ($PM_{2.5}$) on health: lower respiratory infections; 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	
	Impact of insufficient water supply, sanitation and hygiene on health: diarrhea	VSL for mortality Forgone income for morbidity
	Discharge of untreated wastewater in the environment	Cost of treating wastewater
	Waste	
	Damage due to uncollected municipal waste	WTP for improved waste collection
	Damage due to inappropriate disposal of municipal waste	Hedonic pricing
Floods	Damage to assets and economic productivity	Market price
	Mortality	VSL for mortality
Erosion	Loss of assets, land and economic productivity	Market price

as it can pass the barriers of the lung and enter the blood stream. This section estimates the impact of exposure to ambient $PM_{2.5}$ on health in the four countries' capitals. Using the latest cause-and-effect relationships developed in the epidemiological literature, it estimates the impact on premature *mortality:* induced lower respiratory infections; ischemic heart disease; stroke; chronic obstructive pulmonary disease; tracheal, bronchus and lung cancer; and 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 death. In addition, the cost of *morbidity* is valued as a fraction (10 percent) of the cost of mortality, based on available studies estimating the WTP for reduced morbidity due to air pollution (World Bank, 2016; Hunt et al., 2016).

Water pollution. Insufficient or inappropriate water supply, sanitation, and hygiene (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 impacts on *health* through the burden of water-borne diseases caused by unsafe WASH in coastal urban and rural areas of the four countries. First, the section quantifies mortality (number of premature deaths) and morbidity (number of disability adjusted life years, DALYs) 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 forgone income approach). In addition, the section values the impact of discharging untreated wastewater on the *environment* through the local cost of treating wastewater in the region.

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 only the impact of inappropriate management of *domestic* waste. First, the damage due to insufficient collection of domestic waste is estimated based on the quantity of uncollected waste and the society's WTP for improving waste collection. Second, the cost of waste disposal in unsanitary landfills is valued based on the observed depreciation of land value located in the proximity of the landfills.

Floods. West African countries experience fluvial floods, which occur when rivers burst their banks as a result of sustained or intense rainfall, and pluvial floods, which occur when heavy precipitation saturates drainage systems, particularly in flat and urban areas. The analysis values the impact of both fluvial and pluvial floods that occur along the coast,[11] 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 land. These indicators are derived as follows:

- *The flooded area* is calculated based on the results of the SSBN Global Flood Hazard Model applied to West Africa. These results show the maximum expected water depth for fluvial and pluvial floods and their corresponding surface for six different return periods (between 1-in-5 and 1-in-100 years). The flooded area is then classified into rural and urban areas.
- *A damage factor*, whose magnitude varies according to water depth, is used to estimate the part of economic value lost to floods (Huizinga et al., 2017).
- *The economic value of land* is estimated based on the available multi-hazard risk assessment on the West African coast (IMDC, 2018 a,b,c). It captures the value of assets (e.g. buildings, roads, other infrastructure) and of economic flows (e.g. industrial and agricultural production) for 2017 for both rural and urban coastal areas.

Erosion. West African 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.[12] 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 present value (PV) of economic flows for the next 30 years; and the value of bare land.

11 It does not address the impacts of floods caused by the sea level rise due to limited modelling exercises.

12 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.

2.3. STUDY'S LIMITATIONS

The study was conducted during September 2018–February 2019, based on available secondary information. Due to time and budget constraints, it was not possible to collect primary data. Despite that, every effort was made to use reliable data and to provide comparable estimates across countries.

It should be noted that **data limitations** prevented the estimation of several costs, related to: air pollution (e.g. the impacts of air pollution in other cities than the country's capital; the impacts of air pollutants—other $PM_{2.5}$—in coastal areas; the impact of indoor air pollution on health); water pollution (e.g. damages caused by the discharge of untreated agricultural and industrial wastewater); waste management (e.g. damages caused by inappropriate/insufficient disposal of waste other than municipal, such as medical, industrial, construction and demolition, e-waste); floods (e.g. damages caused by flooding from sea level rise and storm surges); and erosion (e.g. slower GDP growth in the future due to less real estate on the coastal area). Therefore, the results of this study should be considered conservative estimates, which capture only partially the full COED. Despite these limitations, the results are considered to be reasonable estimates of the magnitude of the COED and to reflect **the true environmental priorities on the coastal zones in these countries.**

Every effort was made to ensure that the environmental damages are estimated by applying consistent valuation methods, as explained in section 2.2.1. Despite these efforts, the study is affected by some **limitations.** For example, when data on the society's WTP was not available for the four countries, valuation was based on benefits transfer of similar measures from other countries of the region, an exercise which involves a certain degree of inaccuracy.[13] In addition, despite the considerable recent improvements of the GBD 2017 compared to the GBD 2016,[14] use of this method is still affected by some limitations, e.g. lack of incorporation of smoking and second-hand smoke into the proportional burden strategy (GBD 2017 Risk Factor Collaborators, 2018).

Another limitation is related to the valuation of mortality. Valuing life in monetary terms could be controversial. The VSL concept has been developed in the environmental economics literature, using people's WTP to avoid the risk of death (Viscusi and Aldy, 2003; Viscusi and Masterman, 2017). 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 the four countries has been obtained through benefits transfer of a base value from OECD countries, following the guidelines of World Bank (2016). It should be noted that the results are very conservative estimates of the VSL and do not capture the real value of life in these countries.

It should be also noted that the COED captures both losses of stocks (e.g. losses of buildings to erosion) and flows (e.g. loss of economic productivity) for the year of analysis, while the GDP is a measure of annual flow. In this study, expressing the COED as a percentage of GDP is meant only to *benchmark the damage against a well-known macro-economic indicator,* and not to directly compare the two values.

13 In general, the accuracy of benefits transfer depends on several parameters, such as reliability of the original study's techniques, similarity of context between the original site and the site where the value is transferred, population characteristics, and so forth (Johnston et al., 2015).

14 The improvements of GBD 2017 compared to GBD 2016 include: updating the integrated exposure responses to include data from new studies (e.g. studies published after the completion of GBD 2016, systematic reviews of all second-hand smoking cohorts, etc.), inclusion of type 2 diabetes as a new outcome (based on a systematic research of scientific literature), calibration of satellite measurements with ground measurements (using Data Integration Model for Air Quality), refinement of the population attributable fractions by using a proportional approach which reduces the overestimation risks (GBD 2017 Risk Factor Collaborators, 2018).

Photo Credit: World Bank/Vincent Tremeau.

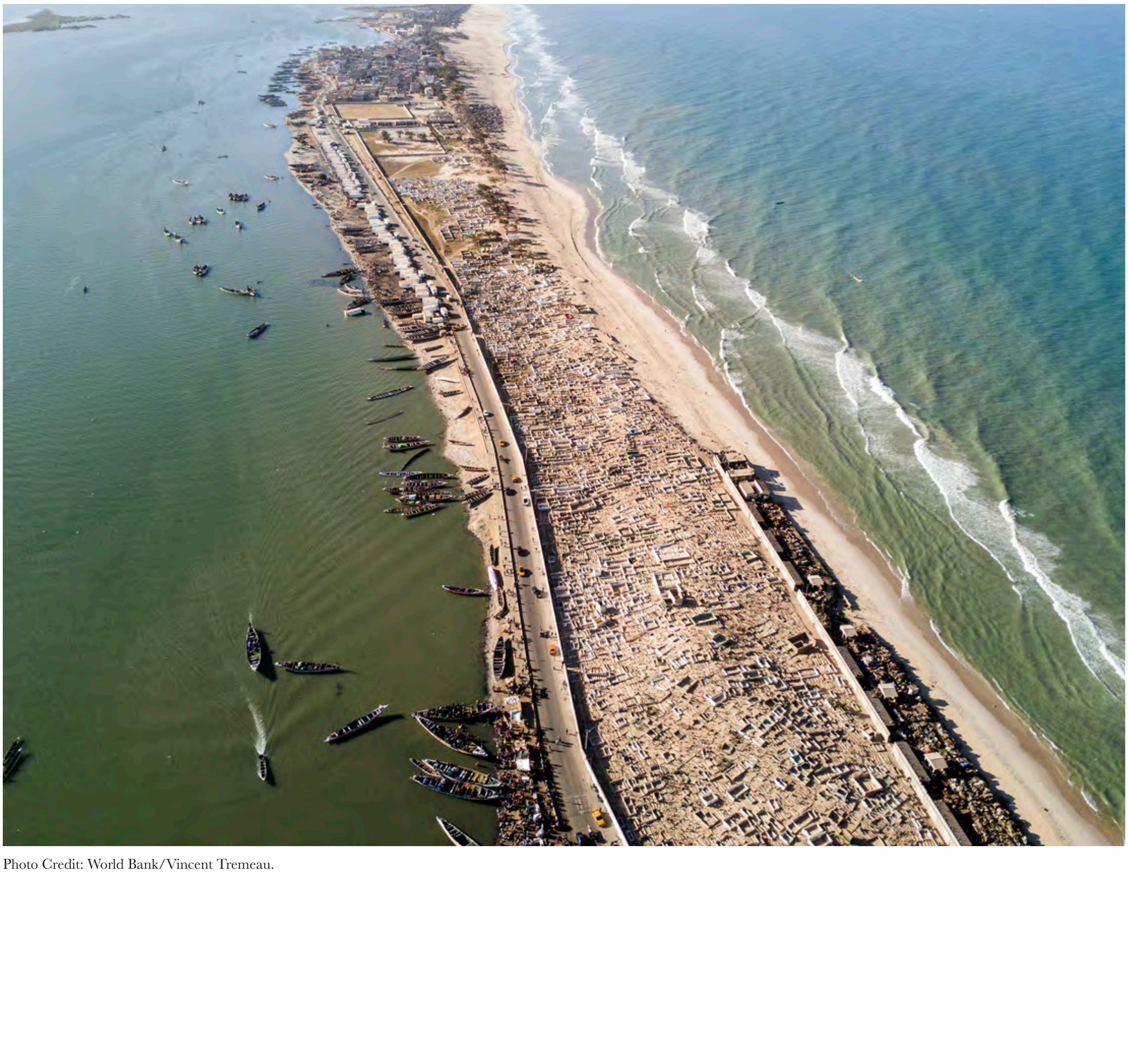


Photo Credit: World Bank/Vincent Tremeau.

CHAPTER THREE
POLLUTION

3.1. AIR

Ambient air pollution is a major contributor to human mortality and morbidity. *Globally,* ambient particulate matter caused about 2.9 million premature deaths in 2017, or 8.6 percent of total global deaths (GBD 2017 Risk factor collaborators, 2018). *In West Africa,* it was responsible for about 79,800 premature deaths in the same year (IHME, 2018). In this region, air quality is increasingly degrading in the agglomerated coastal areas, as a result of urbanization, transport, and industrial development. This section estimates in monetary terms the impacts of ambient fine particulate matter[15] ($PM_{2.5}$) on health in the capitals of the four countries: Cotonou (Benin), Abidjan (Côte d'Ivoire), Dakar (Senegal) and Lomé (Togo). The impacts of air pollution on health in other areas could not be estimated due to data limitations. Additionally, the effects of air pollutants other than $PM_{2.5}$ could not be estimated either, due non-availability of robust methodology linking concentration levels with health impacts.

3.1.1. COST OF URBAN AIR POLLUTION

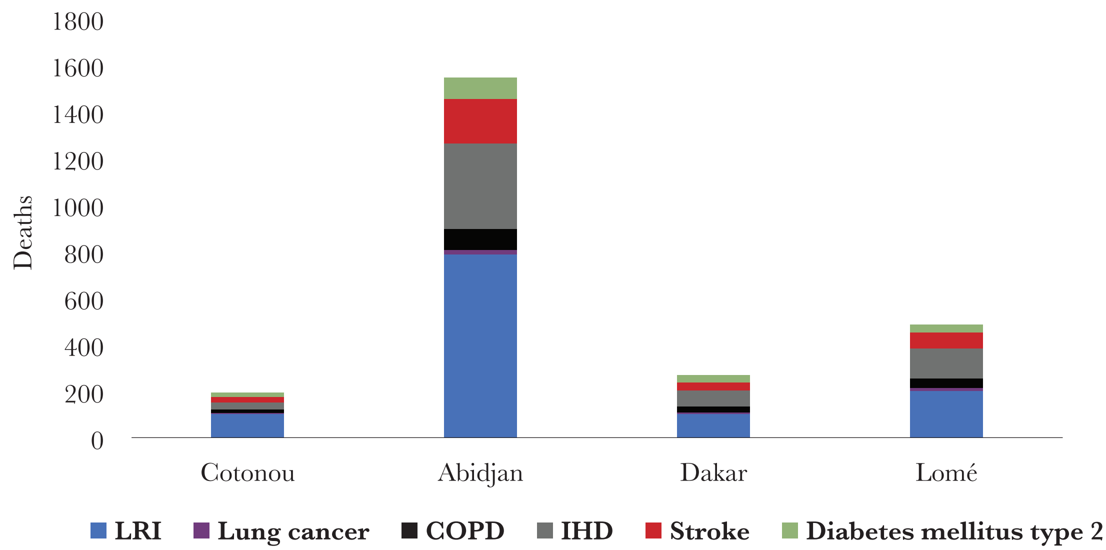
We estimate the impact of $PM_{2.5}$ exposure on **mortality,** in terms of premature deaths due to lower respiratory infections; ischemic heart disease; chronic obstructive pulmonary diseases; tracheal, bronchus, and lung cancer; stroke; and diabetes mellitus type 2[16] (GBD 2017 Risk factor collaborators, 2018); and on **morbidity,** due to problems such as chronic bronchitis, hospital admissions, work loss days, restricted activity days, and acute lower respiratory infections in children (Hunt et al., 2016; World Bank, 2016). The estimation is conducted in four steps, presented below.

Step 1. Measure the $PM_{2.5}$ concentration. In West Africa, ground air quality monitoring is limited to a few monitoring stations in the most agglomerated urban

15 particulate matter with aerodynamic diameter of less than 2.5 microns.

16 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).

FIGURE 3.1.1: MORTALITY DUE TO EXPOSURE TO FINE PARTICULATES ($PM_{2.5}$), BY CITY



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.

areas. The most recent available ground measurements indicate annual average $PM_{2.5}$ of 21 µg/m³ in Dakar (WHO, 2018b[17]), 32 µg/m³ in Abidjan and 32 µg/m³ in Cotonou (Djossou et al., 2018[18]).

No measurement data for Lomé were available. In its absence, satellite-derived data indicate a $PM_{2.5}$ concentration of 75 µg/m³ in 2017[19]. However, it is important to note that satellite-derived data can provide reliable estimates at city level only when calibrated against observations from ground-level monitoring (World Bank, 2016). Though this calibration is not possible for Lomé, a comparison between satellite-derived and ground measured data for Cotonou indicates a proportion of 2.3[20]. Using the same proportion for Lomé, the $PM_{2.5}$ concentration is roughly estimated at 32 µg/m³.

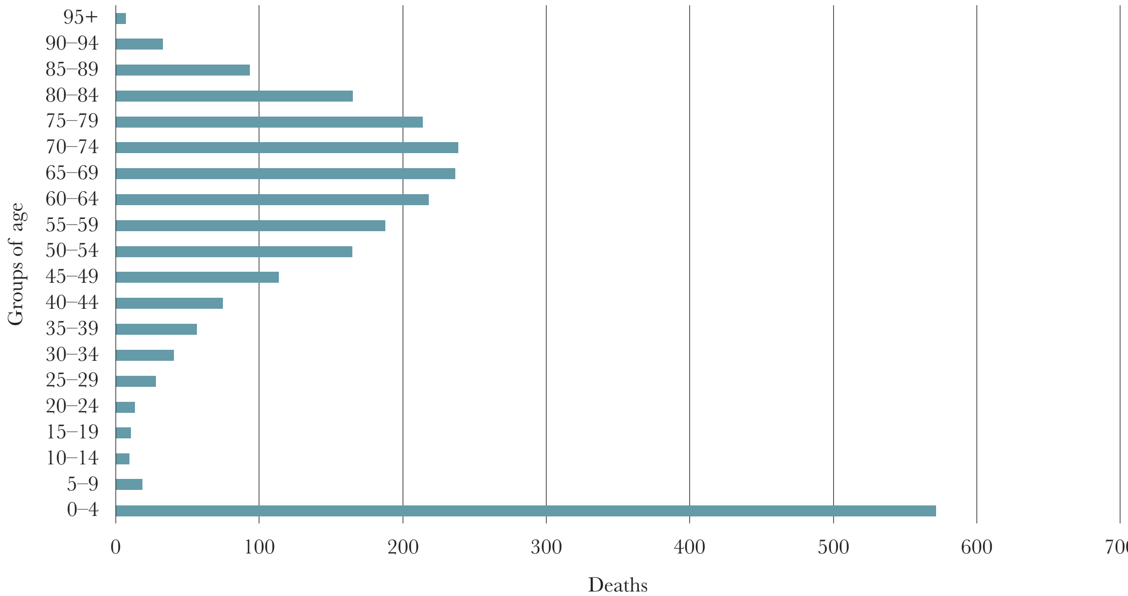
Step 2. Identify the population exposed. Data on the population exposed to ambient air pollution are not available for any measurement stations in the cities considered. As a result, it is assumed that the average level of pollutant concentration calculated in the previous step applies to the total population of each city. Population data are drawn from the most recent demographic census of the four countries and reflect the urban population in each district: 1.1 million people in Dakar (ANSD, 2017[21]); 601,000 people in Cotonou[22], 4.5 million people in Abidjan[23] and 1.5 million people in Lomé.

Step 3. Quantify the health impacts of exposure to $PM_{2.5}$. 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).

17 based on measurements from three stations (industrial, traffic, urban) in 2018.
18 based on measurements from stations representative for traffic during 2015–2017.
19 Based on World Bank satellite data.
20 Obtained as 74 µg/m³ (satellite-derived data)/ 32µg/m³ (ground measurement data) in Cotonou. The same proportion is applied to Lomé, due to similarities between the geographical and environmental contexts of the two cities.

21 The population is related to the Department of Dakar.
22 http://www.insae-bj.org/population.html.
23 http://www.ins.ci/n/templates/Pub/annuaire%20demo.pdf

FIGURE 3.1.2: MORTALITY 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 by disease and age group, based on the 2017 Global Burden of Disease study (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[24].

Figure 3.1.1 summarizes the results. In the four cities, exposure to $PM_{2.5}$ is responsible for about 2,500 deaths in 2017: about 190 in Cotonou, 1,550 in Abidjan, 270 in Dakar and 490 in Lomé. The greatest share (62 percent) of deaths occurred in Abidjan, due to its large population exposed to high pollution levels. In all cities, lower respiratory infections are the leading cause of mortality: they are responsible for nearly half of the deaths—half of which affecting children under five (Figure 3.1.2).

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

- » The cost of **mortality** is valued based on the Value of Statistical Life (VSL), which reflects the society's WTP to reduce the risk of death. The cost of mortality for each country is presented in Table 3.1.1.
- » 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). The literature assessing causal relationships between exposure to $PM_{2.5}$ and morbidity is much more limited than that for mortality (Hunt et al., 2016).

So far, no commonly accepted method has been developed to value the overall cost of morbidity due to air pollution (OECD, 2014). However, 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 proposed a 10 percent markup of mortality cost to account for morbidity (Hunt et al., 2016).

24 For more details, see GBD 2017 Risk Factor Collaborators, 2018. Supplement to: GBD 2017 Risk Factor Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet 2018; 392: 1923–45. doi: http://dx.doi.org/10.1016/S0140-6736(18)32225-6.

TABLE 3.1.1: HEALTH COSTS DUE TO AMBIENT AIR POLLUTION ($PM_{2.5}$), 2017

	Benin (Cotonou)	Côte d'Ivoire (Abidjan)	Senegal (Dakar)	Togo (Lomé)
Mortality* (US$ million)	8.9	150.5	15.3	20.9
Morbidity (US$ million)	0.9	15.0	1.5	2.1
Total (US$ million)	**9.8**	**165.5**	**16.8**	**23.0**
Total (% of GDP)	**0.1%**	**0.4%**	**0.1%**	**0.5%**

Notes: * Based on a VSL of US$46,100 for Benin; US$97,300 for Côte d'Ivoire; US$78,100 for Senegal and US$31,500 for Togo (very conservative estimates obtained from benefits transfer of results from OECD studies, based on World Bank, 2016).

Using this assumption, the cost of morbidity is estimated and presented in Table 3.3.1.

3.1.2. CONCLUSIONS

Overall, the health cost resulting from exposure to $PM_{2.5}$ in the four cities is estimated at about **US$215 million,** or **0.3 percent of the four countries' GDP.** The greatest share of this cost accrues to Abidjan, due to the largest population exposed, high pollution levels, and substantially higher VSL compared to other countries. In all cities, this cost is due to both anthropogenic (e.g. traffic, waste burning) and natural factors (e.g. Saharan dust).

Distinguishing between anthropogenic and naturally-caused $PM_{2.5}$ is important for guiding policies to improve air quality and health. However, in lack of source apportionment studies, it is not possible to distinguish the contribution of each source of pollution to the overall impact. This task is especially challenging for African urban areas, where the intensity of each pollution source varies with season: e.g. pollution linked to domestic fires, traffic and waste burning most likely occur *throughout the year,* while transport of biomass burning emissions and Saharan dust are expected to have impact primarily during *dry season* as well as *December–January* (Djoussou et al., 2018; Doumbia et al., 2012; Liousse et al., 2010).

Overall, ambient air pollution on West African coastal areas is a problem that risks to be aggravated in the future. Although the present estimates refer only to four cities—the only ones for which measurements or estimations could be found—other urban areas also experience harmful impacts of air pollution. Aware of this growing challenge, Togo's National Agency for Environmental Management, in partnership with UNEP, is starting an air quality monitoring program, which is expected to put in place a network of monitoring stations for $PM_{2.5}$ and other pollutants in Lomé (ANGE, 2018).

3.2. WATER

The degradation of water resources on coastal zones is often due to human activities—e.g. poor water and sanitation service provision, mining, tourism, agriculture[25]—and natural factors—e.g. sea level rise leading to salt water intrusion in groundwater. This degradation affects both water quality and quantity, with impacts on people's health and the services provided by ecosystems. Due to data limitation, this chapter quantifies only the impacts of water degradation on human health and that of untreated domestic wastewater on the environment.

3.2.1. WATER-BORNE DISEASES

The burden of water-borne diseases is decreasing globally[26], but remains critically important in Sub-Saharan Africa[27]—especially in slums, peri-urban areas and rural areas. It stems from unsafe water, sanitation and hygiene (WASH[28]), which cover poor water quality, inadequate

25 excess pumping and irrigation as well as pesticide, fertilizer and fungicide runoff

26 According to IHME, the number of deaths due to unsafe water, sanitation and hygiene decreased from 2.8 million in 1990 to 1.6 million in 2017 at the global leve (https://vizhub.healthdata.org/gbd-compare/)

27 http://apps.who.int/gho/data/view.main.INADEQUATEWSHv?lang=en

28 UNICEF-WHO Definition: drinking water services refers to the accessibility, availability and quality of the main source used by households for drinking, cooking, personal hygiene and other domestic uses; sanitation services refer to the management of excreta from the facilities used by individuals, through emp-

TABLE 3.2.1: COASTAL POPULATION AND WATER-BORNE DISEASE RISK FACTORS

Category	Unit	Benin	Côte d'Ivoire	Senegal	Togo
Coastal Population	# million	1.88	8.17	7.84	1.97
Coastal urban population	# million	1.79	4.57	4.89	1.71
Coastal rural population	# million	0.09	3.60	2.95	0.26
WASH risk factors					
Mortality lower bound (urban)	#/100,000	45.7	38.7	39.5	34.2
Mortality higher bound (rural)	#/100,000	86.0	71.3	74.5	67.9
Morbidity lower bound (urban)	DALY/100,000	95	106.2	106.7	105.8
Morbidity higher bound (rural)	DALY/100,000	139.9	156.1	159.4	155.8
Physical valuation					
Mortality in coastal area	#	899	4,338	4,127	762
Morbidity in coastal area	DALY lost	1,833	10,476	9,915	2,216
Economic valuation					
Estimated VSL	US$	46,100	97,300	78,100	31,500
Annual income, 2017	US$	1,600	2,700	1,200	1,200
Estimated mortality cost	US$ million	41	422	322	24
Estimated morbidity cost	US$ million	3	28	12	3
Total	**US$ million**	**44**	**450**	**334**	**27**

Sources: CIESIN Gridded Population of the World (GPWv4) (2015) and ESA Global Land Cover (2015) for the coastal population; https://vizhub.healthdata.org/gbd-compare/ for WASH risk factors.

Notes: To give better context to the above estimates, mortality at the country level due to water-borne diseases was estimated at 7,278 in Benin, 13,237 in Côte d'Ivoire, 7,830 in Senegal and 3,638 in Togo.

sanitation status within households, and lack of hygiene by household members. Over time, climate change will most likely increase the risk of water-borne diseases: for example, coastal flooding can spread fecal contaminants and increase the risk of cholera outbreak, while water shortages due to droughts could escalate the risks of diarrheal diseases.

This analysis relies on the 2017 Global Burden of Disease (GBD) data, which calculates the number of deaths and disability adjusted life years (DALYs) associated with unsafe WASH at the country level. Table 3.2.1. shows the coastal population in urban and rural areas and the available WASH risk factors for water-borne diseases. It is important to note that in the four countries, access to improved WASH is substantially higher in urban compared to rural areas.[29] Thus, the estimation of mortality and morbidity uses the GBD lower-bound risk factors for urban areas, and the higher-bound 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. The estimation of morbidity (DALY lost) is based on the forgone income approach—the average wage per capita in 2017—*in lieu of* the cost of illness. This approach is conservative, as it does not capture the value of medical and transport cost, pain and suffering associated with the burden of water-borne diseases. Accordingly, the cost related to water-borne diseases is estimated **between US$27 million in Togo and US$450 million in Côte d'Ivoire.**

tying and transport of excreta for treatment and eventual discharge or reuse; and hygiene refers to the conditions and practices that help maintain health and prevent spread of disease including handwashing, menstrual hygiene management and food hygiene.

29 For example, data for Benin show differences in improved access to water (81 percent for urban vs. 71 percent for rural), sanitation (59 percent for urban vs. 15 percent for rural) and hygiene (30 percent for urban vs. 21 percent for rural) (https://washdata.org/data/household#!/ben).

3.2.3 UNTREATED WASTEWATER

Untreated domestic, agricultural and industrial wastewater pollutes the environment and affects the carrying capacity of the marine environment, notably lakes, lagoons and the sea. Due to limited data availability, this section only estimates the impact of untreated domestic wastewater on the environment in urban and rural coastal areas.

Table 3.2.2 presents the calculations. For both urban and rural areas, the quantity of untreated domestic wastewater is estimated as the difference between: the total quantity of wastewater, derived from the average water consumption per capita and coastal population; and the treated wastewater quantity, estimated based on the share of population using safely managed sanitation services.[30]

The economic value of wastewater can be estimated through the benefits of improved wastewater treatment (WTP measures), actual damages to productivity (e.g. due to irrigation with wastewater of insufficient quality), or cost of wastewater treatment (UNEP, 2015). Examples of studies estimating the society's WTP for wastewater treatment provide annual WTP of US$53 per household in Hanoi, Vietnam (Trang et al., 2018); US$10 per household in Nairobi, Kenya (Ndunda and Mungatana, 2013) and US$1.3 per household in Chandernagore municipality, located on the banks of the River Ganga in India (Birol and Das, 2010). The wide range of estimates illustrates the difficulty of transferring them to our analysis. Accordingly, we prefer to use an estimate based on the local cost of treating wastewater. This was valued at about US$0.32/m^3, based on Dodane et al. (2012), adjusted to 2017. The estimate is similar to the unit cost of treating domestic wastewater in Morocco (Khattabi and Croitoru, 2015). Accordingly, the cost of untreated domestic wastewater varies between **US$8 million in Benin to US$41 million in Senegal.**

TABLE 3.2.2: COST OF UNTREATED DOMESTIC WASTEWATER

Category	Unit	Benin	Côte d'Ivoire	Senegal	Togo
Amount of water consumed	liters/capita/day	38	37	59	40
Urban					
Quantity of wastewater generated	million m^3/year	24	62	105	25
Quantity of treated wastewater	million m^3/year	0.1	0	25	0
Quantity of untreated wastewater from urban area (1)	***million m^3/year***	***24***	***62***	***80***	***25***
Rural					
Quantity of wastewater generated	million m^3/year	1	49	63	4
Quantity of treated wastewater	million m^3/year	0	0	14	0
Quantity of untreated wastewater from rural area (2)	***million m^3/year***	***1***	***49***	***49***	***4***
Total					
Estimated untreated wastewater from coastal area (1 + 2)	million m^3/year	26	111	129	29
Average cost of wastewater treatment	US$/m^3	0.3	0.3	0.3	0.3
Cost of untreated domestic wastewater	**US$ million**	**8**	**35**	**41**	**9**

Source: https://data.worldbank.org and Dodane (2012). Figures may not add exactly due to rounding.

30 "Safely managed sanitation" is defined as the use of an improved sanitation facility which is not shared with other households and where : (i) excreta is safely disposed in situ or (ii) excreta is transported and treated off-site (https://www.who.int/water_sanitation_health/monitoring/coverage/explanatorynote-sdg-621-safelymanagedsanitationsServices161027.pdf?ua=1).

TABLE 3.2.3: COST OF COASTAL WATER DEGRADATION, 2017

	Benin	Côte d'Ivoire	Senegal	Togo
Water-borne diseases (US$ million)	44	450	334	27
Untreated wastewater (US$ million)	8	35	41	9
Total (US$ million)	**53**	**485**	**375**	**36**
Total (% of GDP)	**0.6%**	**1.2%**	**2.3%**	**0.7%**

3.2.4 CONCLUSIONS

The total cost due to water degradation is estimated between US$36 million in Togo and US$485 million in Côte d'Ivoire (Table 3.2.3). When aggregated across countries, the cost of water degradation along the coastal areas amounts **to US$949 million, which is equivalent to 1.3% percent** of the four countries GDP in 2017.

As noted earlier, this analysis is limited to only a few categories for which data was available. Multiple aspects such as: ballast water and oil spills, untreated industrial wastewater, agricultural seepage and waste leachate were not quantified. As a result, the above estimates represent an underestimate of the true cost of water degradation in the coastal area.

3.3. WASTE

Waste management is a complex challenge, as it relates to a wide range of wastes, which require distinct ways of handling: municipal, medical, industrial, transport, agricultural, construction, demolition waste, etc. Inappropriate management of these wastes can result in serious consequences. In coastal and marine areas, it can cause problems such as deterioration of marine water quality, reduced tourism opportunities, fish contamination, groundwater pollution, and sometimes human deaths. Moreover, the problem of inappropriate waste management has recently become even more acute at the global level, due to growing concerns related to other types of waste, such as plastic and e-waste. These waste streams pose increasing challenges also in West Africa, where countries typically do not have the resources or infrastructure to manage them (Box 3.3.1).

This section estimates the cost of degradation associated with insufficient or inadequate municipal waste

BOX 3.3.1: E-WASTE AND PLASTICS ARE GROWING CONCERNS IN WEST AFRICA

E-waste. The rapid growth of information technology and communication has brought many socio-economic benefits, but it has also caused environmental problems related to electronic waste, or e-waste. E-waste contains a variety of substances that are toxic to human and environmental health, such as brominated flame retardants, heavy metals (e.g., lead, nickel, chromium, mercury), and persistent organic pollutants (e.g., polychlorinated biphenyls, PCBs). Ghana, Kenya, and Nigeria have the highest levels of e-waste in the Sub-Saharan Africa. In Senegal, inappropriate e-waste management has caused severe health problems in recycling sites around Dakar, e.g. 10,000 cases of lead poisoning due to discharge of used batteries in Thiaroye sur Mer; 745 cases of tuberculosis and fatal respiratory failure in Mbeubeusse; and multiple cases of dioxin and lead poisoning in Colobane. E-waste production in West Africa countries is steadily increasing,[1] calling for a specialized management system to be put in place.

Plastic. With increased urbanization and economic growth, Africa is developing large consumer markets for plastic goods and plastic packages. Inadequate waste management around river basins—such as the Niger, Congo, and Senegal rivers—also means that these rivers are likely to transport a large quantity of land-based waste, including plastic pollution, as they make their way to the ocean. Senegal, Gambia, Côte d'Ivoire, and Nigeria have high levels of mismanaged plastic waste in Africa, of more than 0.8 kg per person per day. In many countries of the region, more than 80 percent of plastic waste is inadequately disposed of. This has multiple impacts: when discarded plastic bags fill with rainwater, they can attract malaria-carrying mosquitoes; when they are dumped, they can choke and kill marine life and livestock;[2] plastic trash can block storm

(continued)

1 In Côte d'Ivoire, e-waste production has almost doubled from 7,400 tons in 2010 to an estimated 14,000 tons in 2019.

2 An estimated 70 percent of cattle and sheep deaths in Nouakchott, Mauritania, are from ingesting plastic bags. https://earthpolicyinstitute.wordpress.com/page/2/

drains and cause flooding—a devastating 2015 flood in Ghana caused by plastic-blocked drains killed 150 people.[3] The harmful effects of plastics continue as they photo-degrade: microplastics have been found in tap and bottled water, milk, fish and other food—as well as in human stool—thus posing toxicity risks to the global food chain and to human health.

Sources: World Bank (2015c); World Bank (2014a and b); Jambeck et al. (2018); Andrady (2011); Kosuth et al. (2018); Schwabl et al. (2018).

3 https://www.plasticpollutioncoalition.org/pft/2017/4/11/how-countries-in-africa-are-winning-the-fight-against-plastic-pollution

collection and inappropriate disposal on the coast. Due to data limitations, it does not tackle: the impacts of coastal and marine waste on the tourism industry; the untreated leachate that could contaminate water bodies; the lost opportunity of collecting and reusing recyclables and of capturing methane and generating energy from landfill,[31] and the effects of waste other than municipal waste.[32]

3.3.1 UNCOLLECTED MUNICIPAL WASTE

Insufficient collection of municipal waste on West African coastal areas is a major challenge, leading to bad odors, pollution of environment (e.g. water) and potential health problems. In the four countries, lack of municipal waste collection affects 36-60 percent of urban coastal population and 55–85 percent of the rural one (Table 3.3.1). This section focuses on the cost of insufficient collection of municipal waste in the four countries' coastal urban and rural areas.

Valuing the cost of insufficient municipal waste collection is based on the society's willingness to pay (WTP) for improving waste collection. Contingent Valuation Method has been often applied to estimate the people's WTP for improved waste collection in Africa, with varying results: US$3.1 per capita to improve solid waste management in Mekele City, Ethiopia (Hagos et al., 2012); US$2.7 per capita to improve solid waste collection in Kampala city, Uganda (Banga et al., 2011); US$0.9 per capita to improve solid waste collection in Akinyele Local Government, Nigeria (Olojede and Adelayo, 2014). Despite the available examples, it is difficult to transfer these estimates to the four countries, due to differences in geographical, environmental and socio-economic situations. 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).

Based on the proportion of population not covered by the service, and 1.25 percent of their disposable annual income, the cost of municipal waste collection in urban and rural areas is estimated to vary from about **US$7 million in Benin to US$63 million in Senegal.**

3.3.2 MUNICIPAL WASTE DISPOSAL

Inappropriate 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. This section estimates the impacts of unsanitary landfills located close to the countries' capitals on the value of land. It focuses only on the large disposal sites, and does not address the effects of small dumps on rural coastal areas.

The estimation is based on hedonic pricing, by comparing the average land prices in similar urban or peri-urban locations with those around the landfills. Usually, a property has a collection of attributes: physical characteristics (e.g. surface, construction material, etc.), location (e.g. proximity to businesses, schools, hospitals, etc.), and other environmental features (e.g. clean air, nice view). The price of the property depends on the levels of its attributes. If the quality of the environment surrounding the property declines, the value of the property is also expected to decrease.

We estimate the impact of unsanitary landfills through the depreciation of land value in areas located in the proxim-

31 When municipal waste is not collected appropriately, it is common practice to burn it in the street to get rid of it, which causes air pollution—this is captured under the air section.

32 Medical waste, industrial waste, transport waste (boats, trains and planes), agricultural waste, slaughterhouse waste, construction and demolition waste, tires, oils, hazardous waste, e-waste, ash and sludge should receive specific forms of treatment, but due to poor management, regulation, and enforcement, often find their way into the formal and informal municipal waste streams.

TABLE 3.3.1: COST OF UNCOLLECTED MUNICIPAL WASTE ON THE COAST

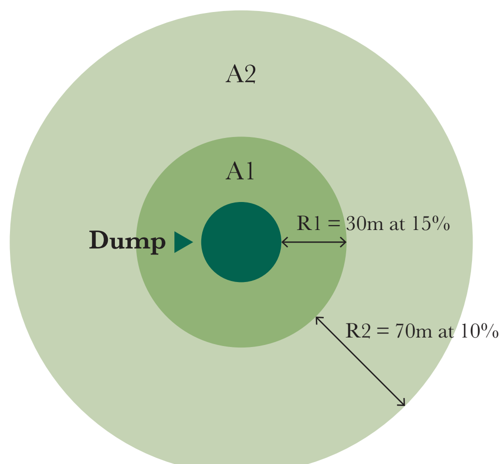
Category	Unit	Benin	Côte d'Ivoire	Senegal	Togo
Urban					
Urban coastal population	million	1.79	4.57	4.89	1.71
- of which, without service	%	50	52	60	36
Disposable income in urban areas	US$/capita	578	810	1,387	1,043
- of which WTP for improved collection	%	1.25	1.25	1.25	1.25
Cost of uncollected urban waste (1)	*US$ million*	*6.4*	*24.0*	*50.8*	*8.0*
Rural					
Rural coastal population	million	0.09	3.60	2.95	0.26
- of which, without service	%	85	65	72	55
Disposable income in rural areas	US$/capita	272	553	459	482
- of which WTP for improved collection	%	1.25	1.25	1.25	1.25
Cost of uncollected rural waste (2)	*US$ million*	*0.3*	*16.2*	*12.1*	*0.9*
Total cost (1 + 2)	**US$ million**	**6.7**	**40.2**	**62.9**	**8.9**

Sources: IIS (2015); INSEED (2017); IMF (2017); IMF (2018); World Bank (2018b); World Bank (2018c) and Raich (2009).

ity of the landfills.[33] Banna and Asermet (2018) study in Senegal assessed the level of depreciation of such areas, based on their distance to landfills: 15 percent depreciation in land prices in the areas located within a radius up to 30 meters around the disposal sites (considered to have a view on the sites); and 10 percent depreciation within a second radius from 30 to 100 meters (Figure 3.3.1).

Table 3.3.2 illustrates the surface of each selected landfill, area A1 (within 30 m radius), and area A2 (within 30–100 m radius) (columns 2–4). It also estimates the losses of land value, based on the above depreciation parameters applied to the average urban prices of each location (columns 5–7). Accordingly, the total cost of inappropriate waste disposal is valued **between US$13 million in Côte d'Ivoire to US$27 million in Senegal.**

FIGURE 3.3.1: LAND DEPRECIATION ASSOCIATED WITH WASTE DISPOSAL



Source: Adapted from Banna et Ansermet (2018).

3.3.3 CONCLUSIONS

The total cost due to waste mismanagement is estimated between US$20 million in Benin and US$90 million in Senegal (Table 3.3.3).

Overall, the insufficient collection and inappropriate disposal of municipal waste generates an economic cost estimated at about **US$192 million, or 0.3 percent** of the four countries' GDP. In absolute terms, the greatest cost accrues to Senegal, particularly due to the high proportion of population not receiving municipal waste collection (60 percent in urban and 72 percent in rural areas) and to the impacts of the unsanitary landfill close to Dakar. Côte d'Ivoire also contributes significantly to this cost mainly because of a large population exposed to low collection coverage.

33 Linear distance is the most common measure of proximity (Chèze, 2008).

TABLE 3.3.2: COST OF MUNICIPAL WASTE DISPOSAL ON THE COAST

Landfill name	Landfill area (m^2)	Area (A1) (m^2)	Area (A2) (m^2)	Loss in land value (A1) (million US$)	Loss in land value (A2) (million US$)	Total loss (million US$)
Benin						
- Cotonou Ouesse	800,000	97,900	250,500	2.9	5.0	7.9
- Porto-Novo Takon	400,000	70,100	169,700	2.1	3.4	5.4
Sub-total Benin						***13.3***
Côte d'Ivoire						
- Cocody Akouedo	1,000,000	109,200	276,700	2.8	4.8	7.6
- Abidjan Kossihouen	33,000	22,100	73,700	1.7	3.8	5.5
Sub-total Côte d'Ivoire						***13.2***
Senegal						
- Dakar Sindia	1,040,000	111,300	281,600	8.7	14.6	23.3
- Saint Louis	25,000	44,600	112,500	0.7	1.5	2.2
- Thies	12,000	14,500	55,800	0.5	1.3	1.7
Sub-total Senegal						***27.2***
Togo						
- Lomé Akepe	800,000	97,900	250,500	7.0	12.0	19.0
Sub-total Togo						***19.0***

Sources: Banna et Ansermet (2018); Brisoux and Elgorriaga (2018); Rodrigue et al. (2018); and World Bank (2018b).

As previously noted, these figures cover only a part of the impacts of municipal waste mismanagement in these countries. As they do not include other effects related to municipal waste (e.g. groundwater pollution, methane emissions from dumps), and the impacts of other types of waste (e.g. e-waste, micro-plastics, etc.), the final results underestimate substantially the true cost of waste management in the four countries.[34]

TABLE 3.3.3: COST OF MUNICIPAL WASTE MISMANAGEMENT ON THE COAST, 2017

Type of cost	Benin	Côte d'Ivoire	Senegal	Togo
Uncollected waste (US$ million)	7	40	63	9
Waste disposal (US$ million)	13	13	27	19
Total (US$ million)	**20**	**53**	**90**	**28**
Total (% of GDP)	**0.2%**	**0.1%**	**0.6%**	**0.6%**

34 Better waste management could help increase coastal tourism, as Benin, Côte d'Ivoire and Senegal have signed the *Charte africaine du tourisme durable et responsable* at the COP22 in Marrakech in November 2016 (AfDB, https://www.afdb.org/en/news-and-events/la-charte-africaine-du-tourisme-durable-et-responsable-voit-le-jour-a-la-cop22-a-marrakech-16562/)

Photo Credit: World Bank/Vincent Tremeau.

Photo Credit: World Bank/Vincent Tremeau.

CHAPTER FOUR
FLOODING AND EROSION

4.1. FLOODING

Globally, the shocks most frequently reported are natural hazards, especially floods. Immediate impacts of flooding include loss or damage to property, loss of human life, destruction of crops, and deterioration of health conditions owing to waterborne diseases. As communication links and infrastructure such as power plants, roads and bridges are damaged and disrupted, some economic activities may come to a standstill, people are forced to leave their homes and normal life is disrupted[35]. Coastal low-lying areas are prone to natural flooding. Coastal flood-prone areas are dynamic, as daily erosion and accretion affect the contours of the coast, which are exacerbated by human activities through land use and land cover.

West African countries are severely affected by floods. Flood frequency has increased in the past 50 years and are expected to increase in the future (Niang et al., 2014). This section estimates in monetary terms the impacts of floods in Benin, Côte d'Ivoire, Senegal and Togo. 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[36].

4.1.1. COST OF COASTAL FLOODING

When translated into socioeconomic 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

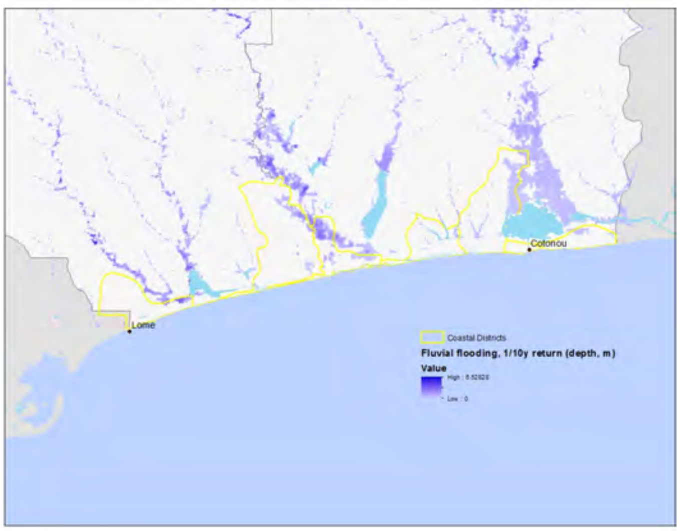
35 Queensland Government (2011), Understanding Floods: Questions and Answers, July 2011.Link: https://www.chiefscientist.qld.gov.au/publications/understanding-floods/flood-consequences/ (retrieved on March 1, 2019).

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

MAP 4.1.1: FLUVIAL FLOODING FOR 1/10 YEARS RETURN PERIOD BY COUNTRY

Senegal

Côte d'Ivoire



Togo and Benin

Source: SSBN Global Flood Hazard Model.

impact of fluvial and pluvial flooding according to three 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 applied to West Africa. These results show the maximum expected water depth for fluvial and pluvial floods and its corresponding surface for six different return periods (between 1-in-5 and 1-in-100 years)[37]. Model inputs include past floods, precipitation, as well as geographic characteristics to model future floods.[38] Map 3.1.1 shows the estimated fluvial flood for 1/10 years return period by country and its corresponding flooded area.

37 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.

38 Information on past flood events for West Africa is limited and biased toward extreme events.

TABLE 4.1.1: 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).

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. These areas are then classified into rural and urban areas. About 99 percent of the flood events occur in rural areas.

Step 2. Translate flood events into asset losses. Not all flood events are severe floods. Flood water depth and its corresponding area are translated into losses, using flood damage functions. To reflect the damage functions for West African countries, we use Huizinga et al. (2017), who conducted a review of worldwide literature on flood damage functions. Table 4.1.1 shows these damage functions, according to water depth.

TABLE 4.1.3: UNIT COST PER LAND USE (US$/HA)

	Urban	Rural
Benin	190,100	11,700
Côte d'Ivoire	347,800	23,900
Senegal	260,700	12,800
Togo	96,000	11,500

Sources: Adapted from IMDC (2018a, b, c) and World Bank estimates.

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

The damages to assets and economic production are estimated based on the flooded area (derived from Step 1), the damage function (derived from Step 2) and the unit value of land. The latter was derived by IMDC (2018a, b and c) for a one-hectare grid cell for Benin, Côte d'Ivoire and Togo. 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. We applied a similar approach for Senegal. Table 4.1.2 shows the distribution of the economic flows and stocks for urban and rural land. In rural areas, stock values are more important than flow values (82 percent vs. 18 percent); while in urban areas, flow values are slightly higher than stock values (58 percent vs. 42 percent).

Based on the above distribution, Table 4.1.3 estimates the unit value of land for the four countries. These values are used to estimate the damages to assets and economic production due to fluvial and pluvial floods, and the results are reported in Table 4.1.4.

TABLE 4.1.2: DISTRIBUTION OF FLOW AND STOCK PER LAND USE PER YEAR (PERCENTAGE)

Rural/Urban	Flow/Stock	Côte d'Ivoire	Benin	Togo	Senegal	Average
Rural	Flow	15	19	26	12	18
	Stock	85	81	74	88	82
Urban	Flow	59	53	63	57	58
	Stock	41	47	37	43	42

Sources: IMDC (2018a,b,c) and World Bank estimates.

TABLE 4.1.4: ECONOMIC COST OF FLOODING ON THE COAST, 2017

	Benin	Côte d'Ivoire	Senegal	Togo
Damages* due to pluvial floods (US$ million)	9	760	77	4
Damages* due to fluvial floods (US$ million)	18	398	134	5
Mortality due to pluvial and fluvial floods (US$ million)	3	25	20	2
Total (US$ million)	**29**	**1,183**	**230**	**10**
Total (% of GDP)	**0.3%**	**2.9%**	**1.4%**	**0.2%**

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

Cost of mortality. Following IMDC (2018a, b, c), there are 0.16 expected deaths per 1000 people exposed, 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 the four countries. Accordingly, the total number of deaths is estimated at 640 per year, on average. Similar to chapter 3.1, the cost of mortality is estimated based on the VSL, which reflects the society's WTP to reduce the risk of death. The results are presented in Table 4.1.4.

4.1.2. CONCLUSIONS

Adding up the damages to assets, economic production and mortality, the total cost of floods in coastal districts is estimated between US$10 million in Togo to US$1.2 billion in Côte d'Ivoire. This corresponds to a range between 0.2 percent and 2.9 percent of the countries' GDP (Table 4.1.4).

Overall, damages due to flooding account for **US$1.45 billion, or 2.1 percent of the four countries' GDP.**

4.2. EROSION

Coastal erosion is a major environmental problem throughout West Africa. Globally, 24 percent of coastal areas are eroding at rates exceeding 0.5 m per year (Luijendijk et al., 2018). 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. West African coastal areas are further exposed to erosion due to higher population growth and migration to coastal areas, concentration of economic activity[39], and sea level rise. This section estimates in monetary terms the impact of erosion on the four countries' coastal areas.

4.2.1. COST OF EROSION

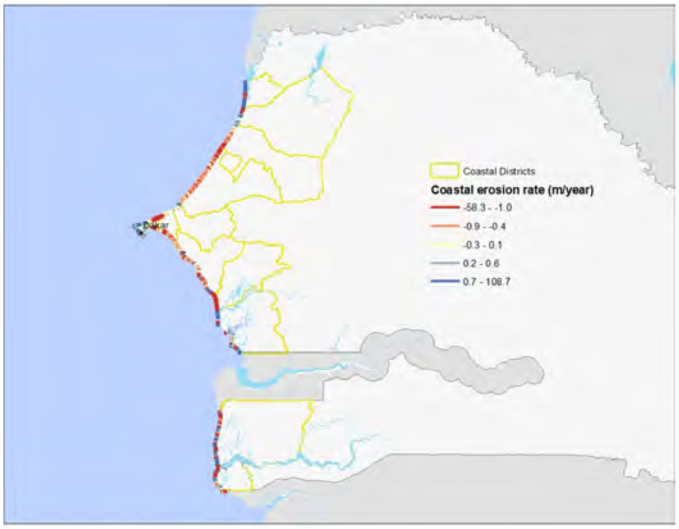
The valuation of the cost of erosion assumes that the land, assets, and economic flows are lost in the long run. The estimation is conducted in three steps, presented below.

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 in shoreline over 1984–2016, by comparing cloud-free historical Landsat images with resolution of 30 m (Luijendijk et al., 2018)[40]. 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 country is subject to land erosion. However, the coastline is differently affected. Map 4.2.1 shows for each country the level of erosion and its heterogeneity from a location to another. Some areas have no erosion at all, others have lost land (erosion) and some have gained land (accretion). Table 4.2.1 estimates the long-term erosion rates only for areas subject to land loss (500 m spaced transects). Column 2 provides the average erosion rates, expressed in m/year. As noted in the table, average erosion rates, per transect, are much higher in Benin (nearly 4 meters/year) and Togo (2.4 meters/year) compared to Côte d'Ivoire (1.4 meters/year) and Senegal (1.6 meters/

39 Coastal areas are home to most capitals, major industries, including agro-industry, fisheries, offshore petroleum exploration and production, and tourism.
40 Luijendijk et al. (2018) is the only study that measure erosion globally, allowing cross-country comparisons.

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



Senegal

Côte d'Ivoire

Togo and Benin

Source: SSBN Global Flood Hazard Model.

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

Country	% of coastline subject to erosion	Long-term Erosion Rate Average (m/year)	Long-term Erosion Rate Total (ha/year)
Benin	65	−4.06	−29.0
Côte d'Ivoire	47	−1.40	−33.4
Senegal	65	−1.60	−50.6
Togo	52	−2.40	−7.8

Source: Luijendijk et al. (2018)

year). Column 3 indicates that total eroded area varies from 8 ha (Togo) to 50 ha (Senegal) on average. We use these estimates in the next steps of the valuation.

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 land cover classification of the European Space Agency's Global Land Cover database[41], and the European Commission's definition of urban areas (i.e. areas with population greater than 300 people per km^2). Accordingly, coastal urban land is predominant in Togo (70 percent), compared to the other three countries: Benin (16 percent), Côte d'Ivoire (2 percent) and Senegal (17 percent).

Step 3. Estimate the impacts of erosion. Similar to the estimation of flood damages (chapter 4.1), we use the annual value of land per hectare also to estimate the cost of erosion. It should be noted that the flooding valuation focuses on what is ***on*** the land, without considering the value of the land itself. However, this section includes also the value of bare land, considering that it is lost permanently. Thus, the cost of erosion captures: (i) the value of lost assets (e.g. buildings, roads, other infrastructure); (ii) the PV of economic flows during the next 30 years; and (iii) the value of bare land.

TABLE 4.2.2: UNIT PRICE OF LAND (US$/M^2)

	Urban	Rural
Benin	200	5
Côte d'Ivoire	200	50
Senegal	515	20
Togo	460	15

Source: World Bank Estimates.

To estimate the value of bare land in coastal areas, we conducted a rapid assessment of coastal land prices in the four countries. Table 4.2.2 shows the results. The value of bare land is estimated as a PV of annual rents for the next 30 years, based on the following assumptions: a rent-to-price ratio of 8 percent[42]; an average annual increase of 8 percent of urban land value and of 5 percent of rural land value[43]; a 3 percent annual increase of GDP; and annual growth of urbanization for the period 2014–2050, as estimated by the United Nations[44]; and a discount rate of 3 percent, to account for the high importance of the erosion impacts in the future.

4.2.2. CONCLUSIONS

The total cost of erosion is estimated between US$97 million in Côte d'Ivoire and US$537 million in Senegal (Table 4.2.3). Overall, the cost of erosion in the four countries is **US$964 million, or 1.4 percent of their GDP.**

TABLE 4.2.3: ECONOMIC COSTS ASSOCIATED WITH EROSION, 2017

	Benin	Côte d'Ivoire	Senegal	Togo
Assets lost (US$ million)	1	1	1	0.2
Production lost* (US$ million)	35	16	103	25
Land lost (US$ million)	81	80	432	188
Total (million US$)	**117**	**97**	**537**	**213**
Total (% of GDP)	**1.3%**	**0.2%**	**3.3%**	**4.4%**

Source: World Bank estimates. *Analysis based on 30-year return.

41 Link: https://www.esa-landcover-cci.org/

42 This value corresponds to one of the lowest in the US (see, e.g., here https://smartasset.com/mortgage/price-to-rent-ratio-in-us-cities) and half of the ratio in a South American developing country, like Peru (BCRP, 2018).

43 While there is no systematic data on these values, in Peru it is estimated the annual increase in urban land in 9 percent (BCRP, 2018).

44 United Nations (2014). World Urbanization Prospects: The 2014 Revision.

Photo Credit: World Bank/Vincent Tremeau.

REFERENCES

Agence Nationale de la Statistique et de la Démographie (ANSD). 2017. Recensement General de la Population et de l'Habitat, de l'Agriculture et de l'Élevage. Rapport Régional Définitif. Région de Dakar. République du Senegal.

Agence Nationale de Gestion de l'Environnement (ANGE). 2018. Surveillance de la qualité de l'air à Lomé. Ministère de l'Environnement et des Ressources Forestières. République Togolaise.

Andrady, A. 2011. Microplastics in the marine environment. Marine Pollution Bulletin 62: 1596–1605.

Apte, J., Marshall, J., Cohen, A. and M. Brauer. 2015. Addressing Global Mortality from Ambient PM2.5 Environmental Science & Technology 49, 8057–8066. DOI: 10.1021/acs.est.5b01236

Arrow K., Solow R., Portney P.R., Leamer E.E., Radner, R. and H. Schuman. 1993. Report of the NOAA Panel of Contingent Valuation. Federal Register 58: 4601–4614.

Banco Central de Reserva del Perú (BCRP). 2018. Indicadores del Mercado Inmobiliario en Peru. Notas de Estudios del BCRP No. 56 - 9 de agosto de 2018.

Banga, M., Razack B. Lokina and A. F. Mkenda. 2011. Households' Willingness to Pay for Improved Solid Waste Collection Services in Kampala City, Uganda. The Journal of Environment and Development. Volume: 20 issue: 4, page(s): 428–448.

Banna, F. M. and P. J. Ansermet. 2018. Gestion des Déchets Solides Municipaux au Sénégal: Défis et Opportunités d'Amélioration. World Bank Group and Korea Green Growth Trust Fund. Washington, D.C.

Bateman, I. 1994. Research methods for valuing environmental benefits. In: Dubgaard, A., Bateman, I. and M. Merlo (Eds.). Economic Valuation of Benefits from Countryside Stewardship. Wokshop Proceedings. 7-8 June 1993. Kiel, Germany.

Birol, E. and S. Das. 2010. The Value of Improved Public Services: An Application of the Choice Experiment Method to Estimate the Value of Improved Wastewater Treatment Infrastructure in India. Madras School of Economics. Working paper 51/2010.

Brisoux, L. et P. Elgorriaga. 2018. *Les Enjeux de la Gestion des Déchets à Abidjan: La vitrine de la Côte d'Ivoire face aux défis de l'insalubrité. Rapport d'expertise Année 2017–2018.* IMT Atlantique, Rennes et Sciences Po Rennes. Rennes.

Carson R., W., Hanemann M., Kopp, R. J., Krosnick, J. A., Mitchell, R. C., Presser, S., Ruud, P. A., and V. Kerry Smith. 1996. Was the NOAA Panel Correct about Contingent Valuation? http://public.econ.duke.edu/Papers//Other/Kerrys/noaa-pan.ps

Center for International Earth Science Information Network (CIESIN) Columbia University. 2015. Gridded Population of the World, Version 4 (GPWv4): Administrative Unit Center Points with Population Estimates. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC).http://dx.doi.org/10.7927/H4F47M2C. Accessed 20 November 2018.

Chèze, B. 2008. Economic valuation of environmental damages of waste sites. What can Meta-Analysis tell us about variations in amenity costs estimates? EconomiX-CNRS, University of Paris 10 and ADEME. Paris.

Cohen, A., Brauer, M., Burnett, R., Anderson, H.R., Frostad, J., Estep, K., Balakrishnan, K., Brunekreef, B., Dandona, L., Dandona, R., Feigin, V., Freedman, G., Hubbell, B., Joblin, A., Kan, H., Knibbs, L., Liu, Y., Martin, R., Morawska, L., Pope, C.A., Shin, H., Straif, K., Shaddick, G., Thomas, M., van Dingenen, R., Donkelaar, A., Vos, T., Murray, C.J.L. and M.H. Forouzanfar. 2017. Estimates and 25-Year Trends of the Global Burden of Disease Attributable to Ambient Air Pollution: An Analysis of Data from the Global Burden of Diseases Study 2015. The Lancet, 389: 1907–1918.

Croitoru, L. and M. Sarraf, (Eds.) 2010 The Cost of Environmental Degradation. Case Studies from the Middle East and North Africa. Directions in Development. World Bank. D.C.

Dixon, J. A., Scura, L. F., Carpenter, R.A., and P. B. Sherman. 1994. Economic Analysis of Environmental Impacts. London, UK: Earthscan.

Djossou, J., Léon J.-F., Barthélemy Akpo A., Liousse C., Yoboué, V., Bedou, M., Bodjrenou M., Chiron, C., Galy-Lacaux, C., Gardrat, E., Abbey, M., Sékou, K., Bahino, J., N'Datchoh, E., Ossohou, M. and C. Awanou. 2018. Mass concentration, optical depth and carbon composition of particulate matter in the major southern West African cities of Cotonou (Benin) and Abidjan (Côte d'Ivoire). Atmospheric Chemistry and Physics 18: 6275–6291.

Dodane, P-H., Mbéguéré, M., Sow, O. and L. Strande. 2012. Capital and Operating Costs of Full-Scale Fecal Sludge Management and Wastewater Treatment Systems in Dakar, Senegal. Environmental Science and Technology. Policy Analysis. p. 3705–3711.

Doumbia, E. H. T., Liousse, C., Galy-Lacaux, C., Ndiaye, S. A., Diop, B., Ouafo, M., Assamoi, E. M., Gardrat, E., Castera, P., Rosset, R., Akpo, A., and L. Sigha. 2012. Real time black carbon measurements in West and Central Africa urban sites, Atmos. Environ., 54, 529–537, https://doi.org/10.1016/j.atmosenv.2012.02.005.

Freeman, A. M., III. 2003. The Measurement of Environmental and Resource Values: Theory and Methods. 2nd edition. Washington, DC: Resources for the Future.

Global Burden of Disease (GBD) 2017 Risk Factor Collaborators. 2018. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet 392: 1923–94.

European Space Agency Climate Change Initiative. 2015. Global Land Cover (1992–2015).

Giardino, A., Schrijvershof R., Brière C., Nederhoff K., Tonnon P. K., and S. Caires. 2017. Human Interventions and Climate Change Impacts on the West African Coastal Sand River. Washington, DC: World Bank.

Hagos, D., Mekonnen, A., and Z. Gebreegziabher. 2012. Households' Willingness to Pay for Improved Urban Waste Management in Mekelle City, Ethiopia. Environment for Development Discussion Paper Series. EfD and RFF.

Huizinga, J., Moel, H. de and W. Szewczyk. 2017. Global flood depth-damage functions. Methodology and the database with guidelines. EUR 28552 EN. doi: 10.2760/16510

Hunt, A., Ferguson, J., Hurley, F. and A. Searl. 2016. Social Costs of Morbidity Impacts of Air Pollution, OECD Environment Working Papers, No. 99, OECD Publishing, Paris.

Institut Ivoirien de la Statistique (IIS). 2015. Statistiques de l'environnement. République de Côte d'Ivoire, DGPLP et MEMPD financé par la Banque mondiale, le PAM, l'Agepe, l'UNICEF, l'AFRISTAT et le PNUD. Abidjan.

Institut National de la Statistique et des Etudes Economiques et Démographiques (INSEED). 2017. *Comptes Nationaux du Togo 2015 Comptes Définitifs.* République Togolaise, Ministère de la Planification du Développement financé par l'Union européenne. Lomé.

Institute for Health Metrics and Evaluation (IHME). 2018. Global Burden of Disease 2017. http://www.healthdata.org/gbd

International Monetary Fund (IMF). 2017. *Senegal Article IV.* Washington, D.C.

International Monetary Fund (IMF). 2018. *Benin Article IV.* Washington, D.C.

International Marine and Dredging Consultants (IMDC). 2018a. Coût de la dégradation environnementale, évaluation du risque multi-aléas et analyse coût-bénéfice des solutions pour la zone côtière. Bénin. The World Bank/Nordic Development Fund.

IMDC. 2018b. Coût de la dégradation environnementale, évaluation du risque multi-aléas et analyse coût-bénéfice des solutions pour la zone côtière. Côte d'Ivoire. The World Bank/Nordic Development Fund.

IMDC. 2018c. Coût de la dégradation environnementale, évaluation du risque multi-aléas et analyse coût-bénéfice des solutions pour la zone côtière. Togo. The World Bank/Nordic Development Fund.

Jambeck, J., Hardesty, B., Brooks, A. L., Friend, T., Teleki, T., Fabres, J., Beaudoin, Y., Bamba, A., Francis, J., Ribbink, A., Baleta, T., Bouwman, H., Knox, J. and C. Wilcox. 2018. Challenges and emerging solutions to the land-based plastic waste issue in Africa. Marine Policy 96: 256–263.

Johnston, R.J., Rolfe, J., Rosenberger, J. and R. Brouwer. 2015. Benefit Transfer of Environmental and Resource Values: A Handbook for Researchers and Practitioners. Springer.

Khattabi, A. and L. Croitoru. 2015. Chapitre 3. Eau. In: Croitoru, L. and M. Sarraf (Eds.) Le Coût de la Dégradation de l'Environnement au Maroc. Environment and Natural Resources Global Practice Discussion Paper 5. World Bank.

Kosuth, M., Mason, S. A., and E. V. Wattenberg. 2018. Anthropogenic contamination of tap water, beer, and sea salt. PLOS ONE 13(4): e0194970.

Liousse, C., Guillaume, B., Grégoire, J. M., Mallet, M., Galy, C., Pont, V., Akpo, A., Bedou, M., Castéra, P., Dungall, L., Gardrat, E., Granier, C., Konaré, A., Malavelle, F., Mariscal, A., Mieville, A., Rosset, R., Serça, D., Solmon, F., Tummon, F., Assamoi, E., Yoboué, V., and Van Velthoven, P.: Updated African biomass burning emission inventories in the framework of the AMMA-IDAF program, with an evaluation of combustion aerosols, Atmos. Chem. Phys., 10, 9631–9646, https://doi.org/10.5194/acp-10-9631-2010, 2010.

Luijendijk, A., Hagenaars, G., Ranasinghe, R., Baart, F., Donchyts, G., and S. Aarninkhof. 2018. The state of the world's beaches. Scientific Report Vol. 8, pp. 6641.

Markandya, A., Harou, P., Bellu, L.G. and V., Cistulli. 2002. Environmental Economics for Sustainable Growth: A Handbook for Practitioners. Chelthenam, UK: Edward Elgar.

Niang, I., Ruppel, O.C., Abdrabo, M.A., Essel, A., Lennard, C., Padgham, J. and Urquhart, P. (2014) Africa. In: Barros, V.R., Field, C.B., Dokken, D.J., Mastrandrea, M.D., Mach, K.J., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R. and White, L.L., Eds., Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, 1199–1265.

Ndunda, E. and E., Mungatana. 2013. Evaluating the Welfare Effects of Improved Wastewater Treatment Using a Discrete Choice Experiment. Journal of Environmental Management, Vol. 123, pp. 49–57.

Olojede, M. and A. Adelayo. 2014. Household Willingness to Pay for Improved Solid Waste Management in Akinyele Local Government Area. Journal of Biology, Agriculture and Healthcare Vol.4, No.18: 76–82.

Organization for Economic Cooperation and Development (OECD). 2014. The Cost of Air Pollution: Health Impacts of Road Transport. OECD Publishing, Paris.

Pagiola, S., von Ritter, K., and J., Bishop. 2004. Assessing the economic value of ecosystem conservation. Environment Department Paper No.101. Washington: World Bank.

Raich, U. 2009. The State of Solid Waste Management in Maputo, Mozambique: Presentation. World Bank. Washington, D.C.

Rajagopalan, S. and R.D., Brook. 2012. Air pollution and type 2 diabetes: mechanistic insights. Diabetes 2012; 61: 3037–45.

Rodrigue, K. A., Essi, K., Cyril, K. M. and A. Trokourey. 2018. Estimation of Methane Emission from Kossihouen Sanitary Landfill and Its Electricity Generation Potential (Côte d'Ivoire). Journal of Power and Energy Engineering, Vol. 6: 22–31.

Schwabl, P., Liebmann, B., Köppel, S., Königshofer, P., Bucsics, T. Trauner, M. and T. Reiberger. 2018. Assessment of microplastic concentrations in human stool. United European Gastroenterology Week. Medical University of Vienna and Austria Environment Agency. Vienna.

Trang, T., Rañola, R. and N. Van Song. 2018. Households' Willingness-to-Pay for Wastewater Treatment in Traditional Agro-Food Processing Villages, Nhue-Day River Basin, Vietnam: Case Study in Hanoi City. Journal of Environmental Protection (9): 1021–1033.

Union Économique et Monétaire Ouest Africaine (UEMOA). 2010. Regional Study for Shoreline Monitoring and Drawing up a Development Scheme for the West African Coastal Areas: Diagnostic. Report number 4. Ouagadougou.

United Nations (2014). World Urbanization Prospects: The 2014 Revision.

United Nations Environment Programme (UNEP). 2015. Economic valuation of wastewater. The cost of action and the cost of no action. GPA/UN/IWMA.

United Nations Industrial Development Organization (UNIDO). 2011. The Economic and Social Value of The Guinea Current Ecosystem—A First Approximation. Interim Guinea Current Commission/ UNIDO.

Viscusi, W. K. and J.E. Aldy. 2003. The Value of a Statistical Life. A Critical Review of Market Estimates throughout the World. NBER Working paper series. National Bureau of Economic Research.

Viscusi, W. K. and C. J. Masterman. 2017. Income Elasticities and Global Values of a Statistical Life. J. Benefit Cost Anal.: 8(2):226–250.

Willis, K. and G. Garrod (Eds.). 2012. Valuing Environment and Natural Resources. Edward Elgar Publishing.

World Bank. 2014a. Côte d'Ivoire. Sustainable E-waste Management in Sub-Saharan Africa. World Bank.

World Bank. 2014b. Sénégal. Gestion des déchets électriques et électroniques en Afrique Sub-Saharienne. World Bank.

World Bank. 2015a. West Africa Coastal Areas Management Program: A Partnership for Saving West Africa's Coastal Assets. http://www.worldbank.org/en/programs/west-africa-coastal-areas-management-program

World Bank. 2015b. Republic of Togo. Rapid Cost of Environmental Degradation with a focus on coastal zones. World Bank.

World Bank. 2015c. Green ICT: Sustainable E-waste Management in Sub-Saharan Africa. Environment and Natural Resources Global Practice (GENDR) Africa Region.

World Bank. 2016. The Cost of Air Pollution. Strengthening the Economic Case for Action. Methodology for Valuing the Health Impacts of Air Pollution. Discussion of Challenges and Proposed Solutions. World Bank/ Institute for Health Metrics and Evaluation. Washington D.C.

World Bank. 2017. Mauritanie. Coût de la dégradation et de la restauration de l'environnement côtier, marin et maritime: 2014. WACA. Programme d'assistance technique à la gestion du littoral de l'Afrique de l'Ouest. World Bank.

World Bank. 2018a. West Africa Coastal Areas Resilience Investment Project. Project Appraisal Document. World Bank. Washington D.C. Report No: PCBA-SIC0096602.

World Bank. 2018b. World Development Indicators. Washington, D.C.

World Bank. 2018c. What a Waste. Washington, D.C.

WORLD BANK GROUP

1818 H Street, NW
Washington, D.C. 20433 USA
Telephone: 202-473-1000
Internet: www.worldbank.org/environment