Evidence Report

Assessment of Pollution In Mozambique

Prepared by:

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Disclaimer Information

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Executive Summary

This document presents the current pollution assessment of Mozambique, produced by Eduardo Mondlane University (UEM), as part of the Memorandum of Agreement (MoA), with the Joint Nature Conservation Committee (JNCC – United Kingdom), on local content about pollution in the context of the Reducing Pollution Through Partnership project. This project aims to help designing a broader pollution program which could increase the capacity of Official Development Assistance (ODA) Countries, to manage chemicals and reduce air, chemical and waste pollution. The main objective of the program is essentially to reverse biodiversity loss, build resilience environment and improve human health. Mozambique was one of the countries selected as a pilot country for the implementation of this project.

The methodology used to prepare this report involved a review of the relevant literature on pollution, biodiversity and national legal framework policies. National and international reports were also used as bibliographic sources. SciVal Elsevier, Google Scholar, ResearchGate and other platforms were used to assess available information. The main sources and impacts of pollution on biodiversity are discussed, with emphasis on existing and available knowledge, gaps and weaknesses, as well a social and economic overview of Mozambique were described.

The report is divided into seven chapters, aiming at bringing up the current pollution status in Mozambique, its sources and main hotspots, pollution impacts, current legislation and institutions involved with, implementation level of the United Nations (UN) Sustainable Development Goals (SDG's), challenges and constraints in order to improve waste management actions and reduce the biodiversity loss.

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1. Introduction

Environmental pollution is not a new phenomenon; it remains the world's greatest problem facing humanity and the leading environmental causes of morbidity and mortality (Ukaogo *et al*., 2020).

Pollution can take many forms, ranging from organic compounds and other chemical substances to different types of energy (United Nations Environment Programme, 2017). Some types of pollution are easily noticed such as certain forms of contaminated water, poor air quality, industrial waste, litter, light, heat and noise while others, as presence of pesticides in food, mercury in fish, excess nutrients in the sea and aquatic systems, endocrine-disrupting chemicals in drinking-water, and other micro-pollutants in fresh and marine water are less visible (United Nations Environment Programme, 2017).

Pollution is largely controllable and often avoidable, but considerably neglected (United Nations Environment Programme, 2017). Pollution touches all parts of the planet (United Nations Environment Programme, 2017). It is affecting our health through the food we eat, the water we drink and the air we breathe (United Nations Environment Programme, 2017).
While the world has achieved significant economic growth over the past few decades, it has been accompanied by large amounts of pollution, with significant impacts on human health and ecosystems and the ways in which some of the major Earth systems processes, such as the climate, are functioning (United Nations Environment Programme, 2017).

In general, environmental pollution is higher in low-to-middle and income countries than in developed countries, possibly due to poverty, poor legislation and low awareness of pollution forms, so that unfortunately humans face pollution daily without knowing it (Ukaogo *et al*., 2020). Its impacts are not only on humans but also in other aquatic and terrestrial animals including microorganisms (Ukaogo *et al*., 2020).

Developed countries have been able to identify and control pollution enactment of environmental laws and enforcement of regulations, while developing countries are not playing enough attention to current environment problems (Fayiga *et al*., 2017).

In Africa, environmental degradation is a result of urbanization and rapid economic growth, where movements of populations from villages to cities and towns have been observed (Ukaogo *et al*., 2020). Pollution in Mozambique is a problem mainly from terrestrial activities, particularly those associated with agriculture, caused by sedimentation, pesticide and fertilizer runoffs, industrial activities such as discharges of untreated effluents (heavy metals, hydrocarbons, etc.) and sewage and domestic waste, most of which released directly to the rivers or sea with no treatment, mining, which causes extensive erosion and silting and commercial operations in ports and harbours (ASCLME, 2012; Wingqvist, 2011). As developing country, Mozambique is challenged with poor treatment and disposal of waste due to the growing quantities resulting from industries activities, rapid population growth and lifestyle improvement (Langa *et al*., 2021).

This report aims to bring up the current pollution status in Mozambique, its sources and main hotspots, pollution impacts, current legislation and institutions involved with pollution, the implementation level of the United Nations (UN) Sustainable Development Goals (SDGs), challenges and constraints faced during actions to improve waste management and reduce biodiversity loss.

2. Environmental and Social Baseline

2.1. Biophysical Description

2.1.1. Country Location

Mozambique is located on the latitude 10º 27'S and 26º 52'S and longitudes 30º 12'E and 40º 51'E, on the south-eastern coast of Africa, bordering South Africa, Eswatini (Swaziland), Zimbabwe, Zambia, Malawi, and Tanzania, with an Indian Ocean coastline (Figure 1) of 2,700km and a total surface area of 799,380.00 km^2 (Gani *et al*., 2020).

The country is divided into 11 provinces, including Maputo City, which is considered a province and is the capital of the country (Figure 1).

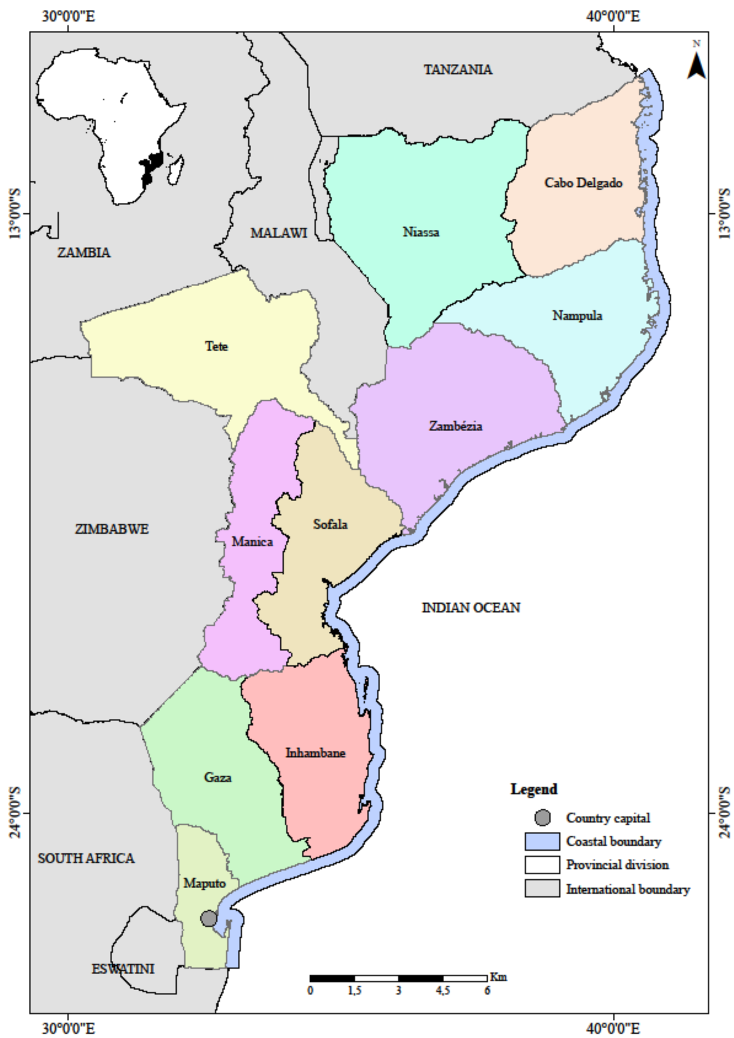

Figure 1: Map of Mozambique's location, administrative divisions (provinces) and neighboring countries (Source: UEM, 2022).

2.1.2. Topography

Mozambique is, in general, a low-lying plateau of moderate height descending to the Indian ocean with a coastal belt covering about 44% of the country, a middle plateau ranging from 200 - 1000 meters in elevation and covering about 29% of the country, and a plateau and highland region with average elevations of around 1000m to the north of the Zambezi River covering about 27 % of the country (Figure 2). The highest points in the country of 2,436.00m are located in Massururero at the slopes of Manica, followed by 2,419.00m in the Namuli foothills and 2,000.00m in the mountain range of Serra da Gorongosa (Ministry of Coordination of Environmental Affairs, 2014).

The coast is characterized by a shallow continental shelf with extensive intertidal areas and numerous offshore coral reefs.

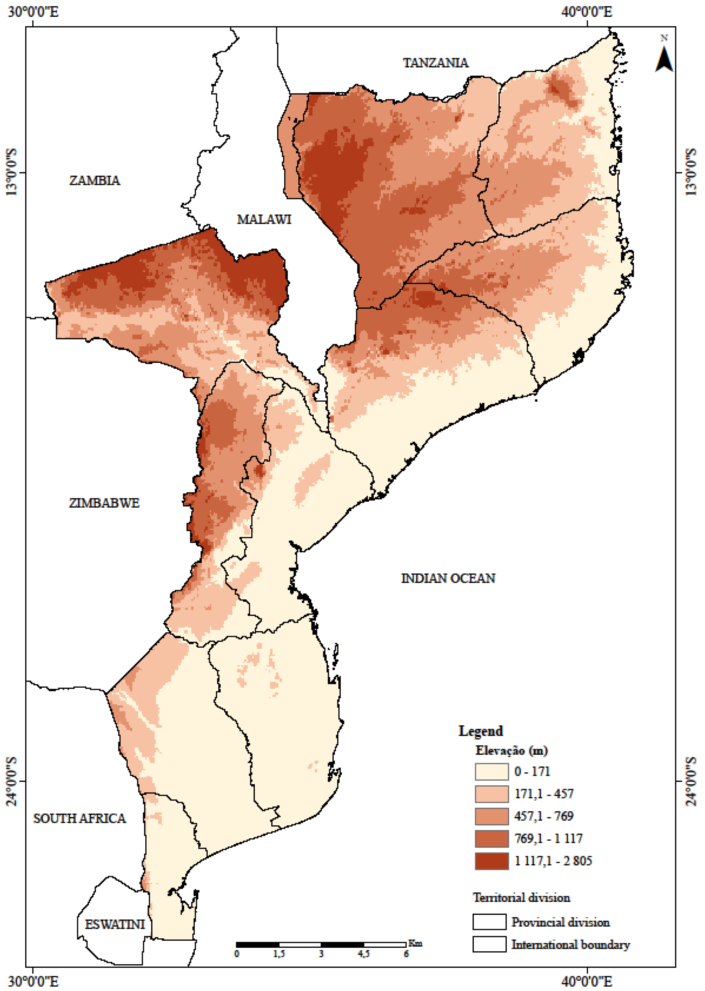

Figure 2: Map of Mozambique's topography: mountains, plateaus and plains (Source: UEM, 2022).

2.1.3. Hydrology and Drainage

In terms of surface water resources, the country has extensive resources flowing from the West to the coast. Mozambique is crossed by thirteen major water basins from the South to the North (Figure 3).

As Mugabe *et al*. (2012) states, Mozambique is a downstream from nine major international river basins and there is a pathway of tropical cyclones that move across the Mozambique Channel, which makes it one of most prone to flooding countries in the world.

The large floodplains are associated with the mouths of the Zambezi and Limpopo rivers, which rise in the centre of the continent and passthrough Mozambique on their way to the Indian Ocean. Among these rivers, the Zambezi, Save and Limpopo rivers are the largest and most impacting on Mozambique's social and political economy (Mugabe *et al*., 2012). According to Parker (2001), the Zambezi River constitutes the largest freshwater body, with a surface area of over 3,000 km^2, including the Cahora Bassa Dam.

The variability of rainfall from year to year is also much higher in the south than in the northern and central regions of Mozambique with almost no flow observed in some rivers in dry years in the south. The intensity of heavy rain events is expected to increase by 10% (2010-2100), while their frequency is projected to increase by 6%, more floods can be expected across the country especially during the rainy season. While the north is likely to experience floods more frequently, the magnitude and damage of floods will often be higher in the south (Ministry of Foreign Affairs, 2018).

The major rivers and their floodplains have been profoundly affected by impoundments and steadily increasing off-takes of water upstream in neighbouring countries. The extent to which this has caused ecological changes has not been monitored and can only be estimated (Parker, Vincent 2001).

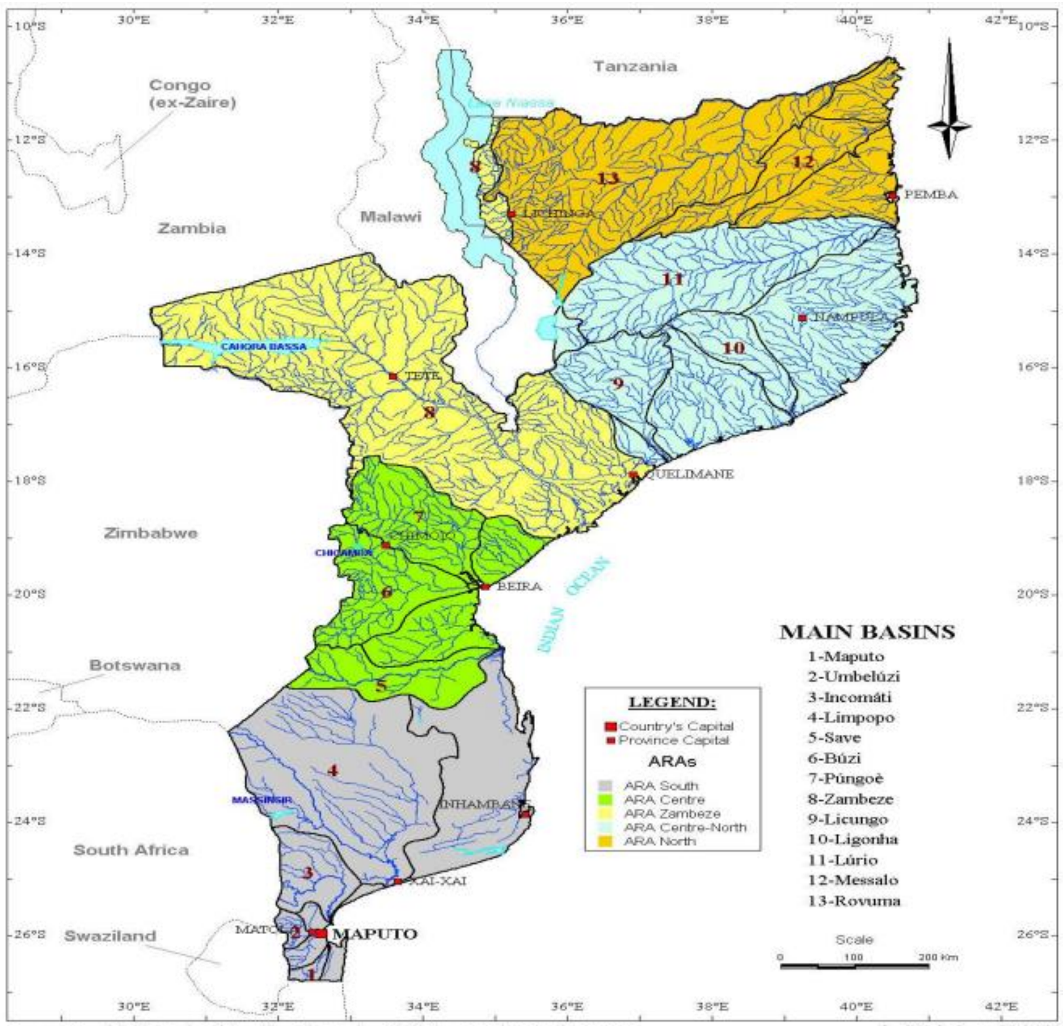

Figure 3: Distribution map of the main water basins in Mozambique and location of Regional Water Administration divisions (ARA) (Source: Water Resources of Mozambique, DNA, 1999).

2.1.4. Climate

In general, Mozambique has a tropical humid to sub-humid climate with a relatively dry winter season (see Figure 4) (ASCLME, 2012). The climate in the northern region of Zambezi River is influenced by the equatorial low- pressure zone with northeast (NE) and southwest (SW) monsoon during the southern summer (October-March) and winter (May-August) (MICOA, 2003). In the northern region, winds are influenced by monsoon system with NE winds during the southern summer and SW winds during the southern winter (MICOA, 2003). The central and southern Mozambique, south of Zambezi River is under influence of Indian Ocean subtropical anti-cyclonic system, dominated by the southeast (SE) trade winds (MICOA, 2003).

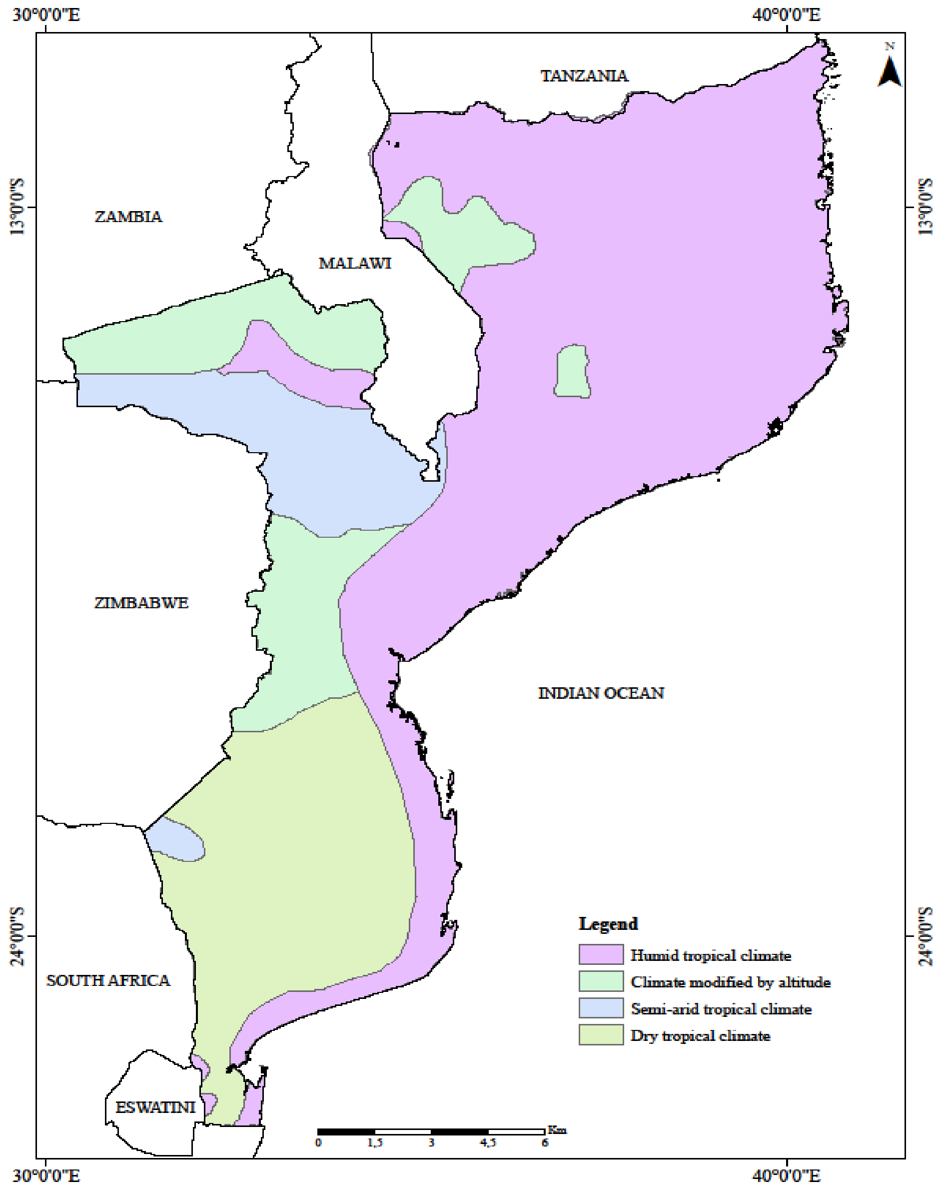

Figure 4: Map of distribution of climate region in Mozambique (Source: UEM, 2022).

The average air temperature in Mozambique varies from 18° to 24° C. The annual average temperature is 23°C along the southern coast, 26°C along the northern coast and the northern region experiences the highest temperatures (25-26°C in the coastal lowlands) (ASCLME, 2012). However, freezing temperatures are common in high altitudes in Tete, Manica, and Niassa provinces. Maputo during the dry season also, as an effect of the weather changes in South Africa. The highest temperatures ensue at same period as the highest rainfall and tropical cyclones (ASCLME, 2012). The tropical cyclones occur regularly during the late NE monsoon period (ASCLME, 2012) and its frequency is increasing in the last decades in the central and northern region (Table 1).

Table 1: List of tropical cyclones and tropical storm in Mozambique, location and categories based in Saffir-Simpson scale. N.A is where the category is undefined (Source: Adapted from Mozambique News reports & clippings).

Name	**Year**	**Region - Provinces**	**Category**
Tropical Cyclone			
Gombe	2022	North – Nampula	3
Guambe (Storm)	2021	South – Maputo, Gaza and Inhambane	2
Eloise	2021	Centre - Sofala	1
Idai	2019	Centre - Sofala, Tete, Zambézia	3
Kenneth	2019	North - Cabo Delgado	4
Dineo	2017	South - Inhambane	2
Funso	2012	North - C. Delgado	2
Jokwe	2008	Centre - Zambézia	3
Favio	2007	Centre - Inhambane	3
Japhet	2003	South – Inhambane and Gaza	2
Connie	2000	South - Maputo	N.A
Eline	2000	Centre - Beira	3
Bonita	1996	Centre - Zambézia	1
Nadia	1994	North & Centre - Nampula, Sofala Zambézia	1
Filao	1988	Centre- Zambézia	2
Tropical Storm			
Ana	2022	North & Centre - Cabo Delgado, Niassa, Nampula, Zambézia and Sofala.	N.A
Chalane	2020	Centre - Zambézia, Manica and Sofala	N.A
Domoina	1984	South	N.A

The categories used are based in Saffir-Simpson scale at landfall, with maximum sustained winds for one minute of:

- **i.** Category 4: 209-251 km/h
- **ii.** Category 3: 178-208 km/h

iii. Category 2: 154-177 km/h
iv. Category 1: 119-153 km/h
v. Tropical storm: 63-118 km/h
vi. Tropical depression: < 63 km/h

Although the number of cyclones was exceptional across the region, most of the deaths and damage occurred as a result of the Intense Tropical Cyclone Idai and then, exacerbated with the appearance of the Intense Tropical Cyclone Kenneth.

The highly variable climate in Mozambique is greatly influenced by the amount, timing, and frequency of precipitation events. Rainfall varies considerably within annual cycles with 60-80% of the annual precipitation falling in the period from December to March. The annual average rainfall ranges from over 2000mm to about 500mm in north and south Mozambique, respectively. Floods and droughts occur in the southern and central regions of Mozambique, while cyclones for example, are frequent along the coast (ASCLME, 2012).

Climate projections show a significant average temperature rise (ranging from a minimum increase of 1.0 °C for 2010-2100 to a maximum increase of 4.6 °C for 2010-2090). The highest increases are expected for inland and southern regions, especially the Limpopo and Zambezi valleys (up to 3.0 °C increase by 2055), but also in coastal areas.

2.2. Socio economic description

2.2.1. Human Population

The global population trackers put the population of Mozambique at 33 million in February 2022. The latest population census, in 2017, projected Mozambique's population to 30,832,244.00 in 2021, out of which 48% were men and 52% were women. Among this population, 68% live in rural areas and 60% live along the coastline, livelihoods in Mozambique depend to a large extent on natural resources, such as rain-fed agriculture and fishing (INE, 2017). The population in Mozambique grows at an average rate of 2.9% per year (Mavume *et* al., 2021) and the Figure 5, shows the prediction of population growth (in thousands of people) until 2030.

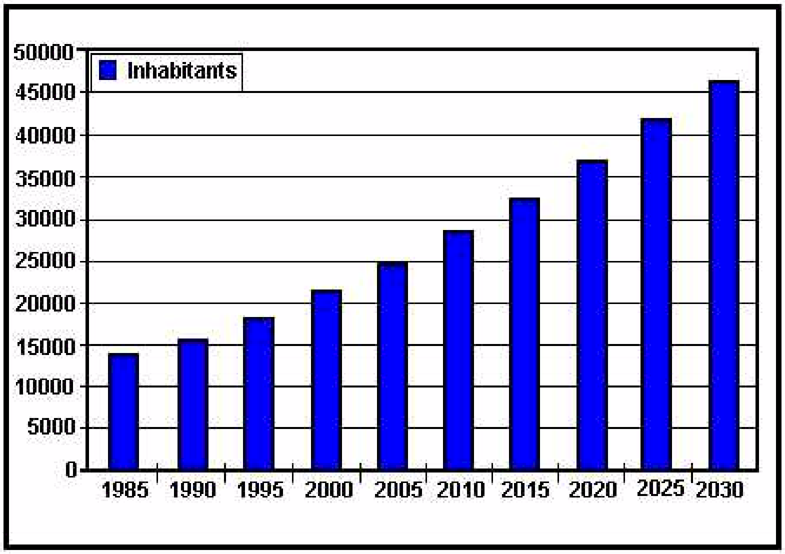

Figure 5: Prediction of Mozambique's population growth (in thousands of people) (Source: MICOA, 2003).

The gross birth rate per 1,000 inhabitants is 37.2 %, 66.2 % of infantile mortality rate, 1.23 % of GDP growth rate and the per capita GDP in 2020 was US$467.[1] Nampula and Zambezia are the topmost populated in the country (about 39%) while Gaza and Maputo City are the least populated provinces of Mozambique (Table 2).[2] In average, the population density is about 32 people/km^2 (Ministry of Coordination of Environmental Affairs, 2014).

Table 2: Number and percentage (%) of inhabitants by Mozambican provinces (Source: INE 2017 Population Census).

Province	Number of Inhabitants	Percentage (%)
Nampula	5,758,920	20.6
Zambézia	5,164,732	18.5
Tete	2,648,941	9.5
Cabo Delgado	2,320,261	8.3
Sofala	2,259,248	8.1
Maputo Province	1,968,906	7.1
Manica	1,945,994	7.0
Niassa	1,810,794	6.5
Inhambane	1,488,676	5.3

[1] http://www.ine.gov.mz/ accessed January 15, 2022.
[2] Visit: http://www.ine.gov.mz/noticias/populacao-mocambicana-para-2021 accessed 15 January 2022.

Province	Number of Inhabitants	Percentage (%)
Gaza	1,422,460	5.1
Maputo City	1,120,867	4.0

2.2.2. Culture and Ethnic Groups

The geographical situation and history of this country, marked by migratory processes, has resulted in a heterogeneous population group, with multicultural and multi-ethnic characteristics (Figure 6) (Gani *et al*., 2020).

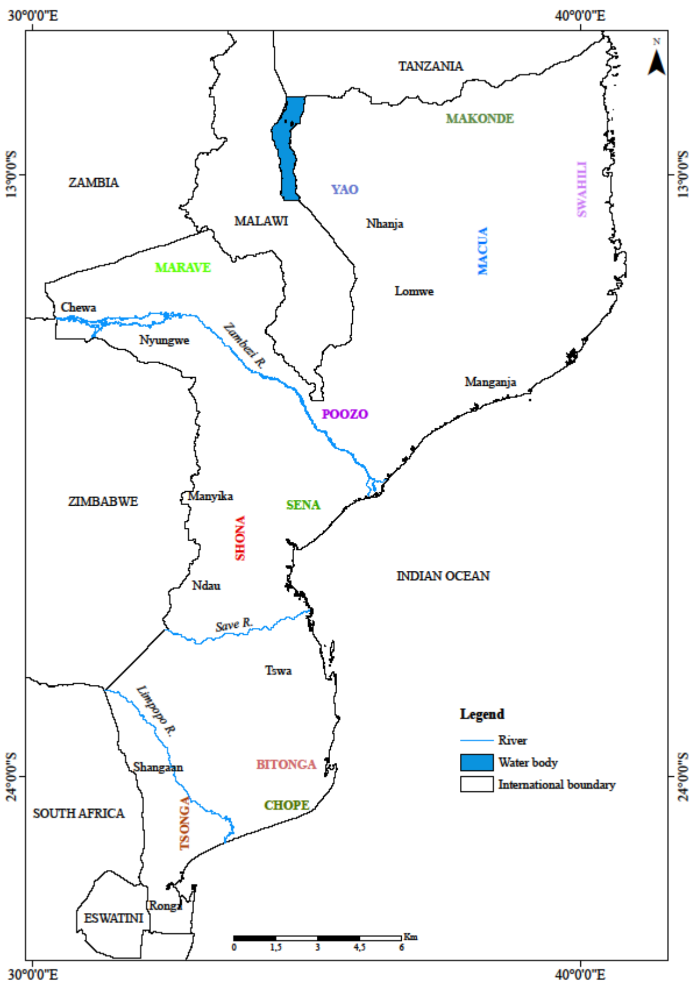

Figure 6: Map of the Mozambican Ethnolinguistic groups (Source: Adapted from Santos, 2010).

The Limpopo, Save and Zambezi rivers divide the country into three vast ethnolinguistic groups (Figure 6). According to Weinstein (2002), the northern most third of the country, above the Zambezi River, is home to matrilineal groups (the Mokonde, Macua-Lomwe, and Yao) with historic links to the Islamic influences of the Eastern African littoral. A diverse array of smaller ethnic groups that cluster along the valley of Zambezi divides the north from the patrilineal Shona-speakers (Manyika, Ndau, and Teve) of the centre, which is the region that borders Zimbabwe (Weinstein, 2002). Bellow the Save River, in southern Mozambique, are the Tsonga and other related groups from a distinct band, with strong links to the Swazi and people of South Africa (Weinstein, 2002). There are more than 40 Bantu languages spoken in Mozambique, but the official language is Portuguese (Weinstein, 2002).

2.2.3. Health

Mozambique provides primary health care to its population for free. Sanitation services and access to potable water is insufficient or short. Half the urban population lives below the national poverty line and only a quarter have access to piped water (MICOA, 2003). As the number of people living in major towns and cities grows so, the need for better water and sanitation services increases.

The sewer system in Maputo, only covers a small part of the city. With no organized system in place to deal with toilet waste, there is a huge need to invest in better on-site sanitation methods so that waste can be safely collected and avoid contaminating the water supplies. Table 3, below show the percentage of population with access to potable water and without toilet (sanitation) in some provinces. The lack of access to improved sanitation has a direct impact on health and economic growth in the poorest communities.

Table 3: Percentage (%) of population with access to potable water and household without Sanitation in some provinces compared to Mozambique (Source: Adapted from INE – Household Survey 2014/15).

Percentage of the population with access to potable water			**Lack of toilet/ sanitation**
Province/ Year	**2008/9**	**2014/15**	**2014/15**
Niassa	41.7	30.1	14.3
Nampula	35.1	38.1	46.0
Zambézia	20.1	30.6	65.2
Tete	48.8	49.7	44.1
Maputo	59.7	87.1	8.0
Mozambique	40.5	50.3	37.5

Burn followed by buries and lay on the vacant lot are the three main types of treatment of domestic waste. Figure 7 shows that only 7.6% of domestic waste is collected by the authorities (INE, 2017).

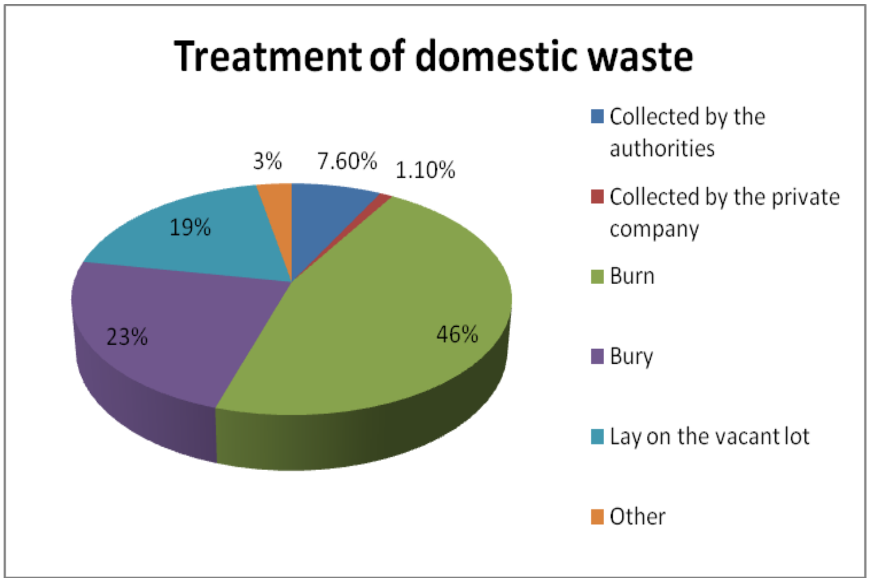

Figure 7: Treatments (%) of domestic waste in Mozambique (Source Adapted from INE, 2017).

Malaria is pointed to first most epidemic disease, affecting the whole country, principally the southern area, in terms of the percentage of affected population as it's observed in Gaza Province (Figure 8) (MICOA, 2003). The second and third most frequent epidemic diseases are diarrhoea (Figure 9), with incidences in the central and southern regions, such as Maputo City, and cholera with incidences in the central regions of Sofala and Zambézia provinces and in northern Mozambique, such as Nampula and Cabo Delgado provinces (Figure 10) (MICOA, 2003).

Cholera is among the deadliest gastrointestinal diarrhoea maladies in tropical areas resulting almost exclusively from ingestion of water contaminated with *Vibrio cholerae*, but any faecal-oral pathway can potentially transmit the disease (Vitorino et al., 2018). In Mozambique, cholera and all other diarrhoeal diseases are the fourth major cause of death of children bellow five years old, with about 13.105 demises per annum (Cambaza *et al*., 2020).

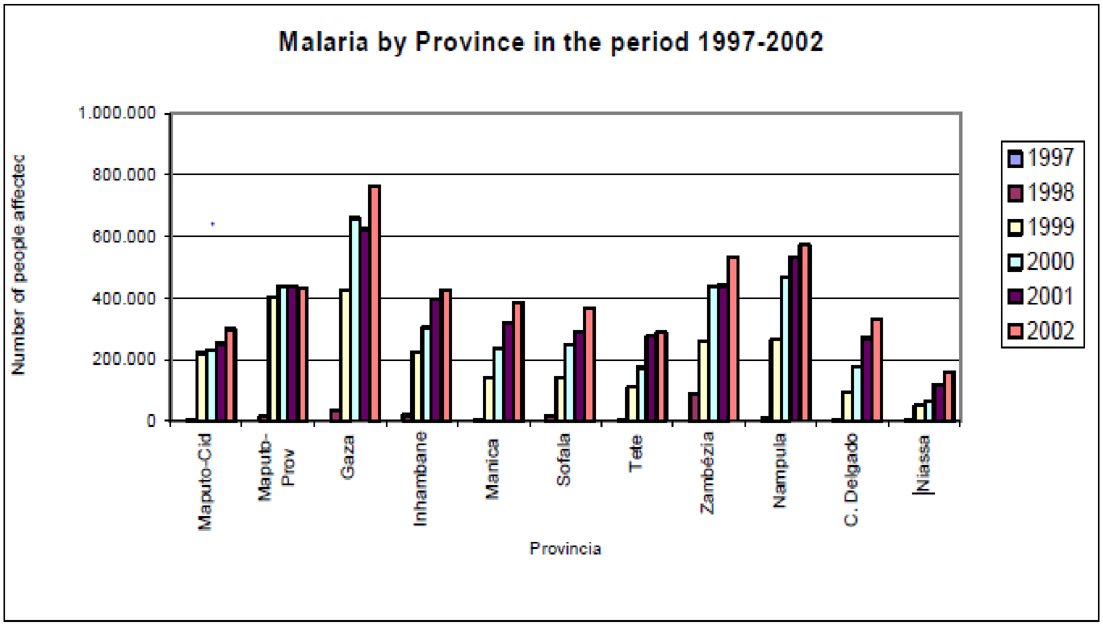

Figure 8: The Incidence of Malaria in Mozambique by Province.

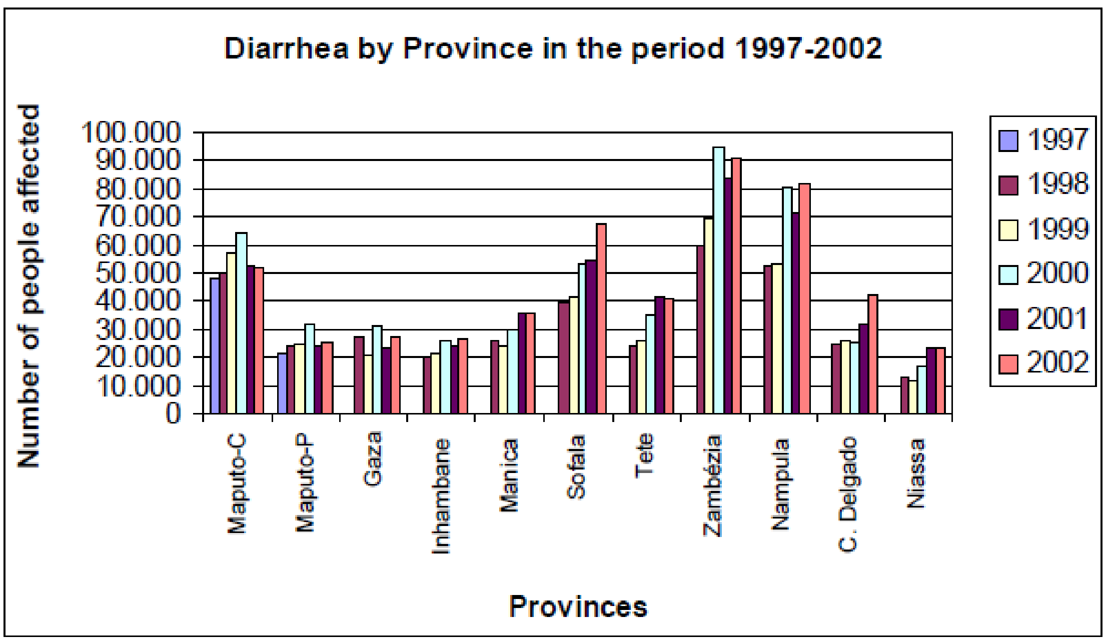

Figure 9: The Incidence of Diarrheoa in Mozambique by Province.

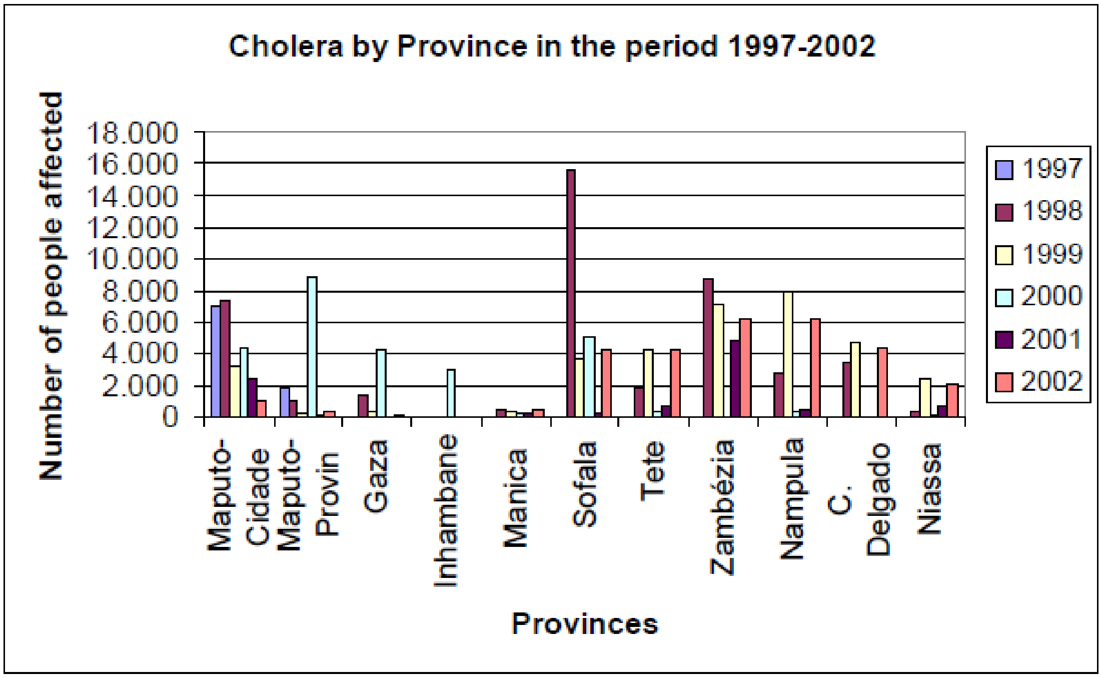

Figure 10: The Incidence of Cholera in Mozambique by Province.

2.3. Natural Habitats and Ecosystems

2.3.1. General Description

Mozambique has four important natural ecosystems: (i) terrestrial, (ii) marine, (iii) coastal and (iv) aquatic ecosystems (Ministry of Coordination of Environmental Affairs, 2014). Figure 11 shows the major ecosystems and their conservation status.

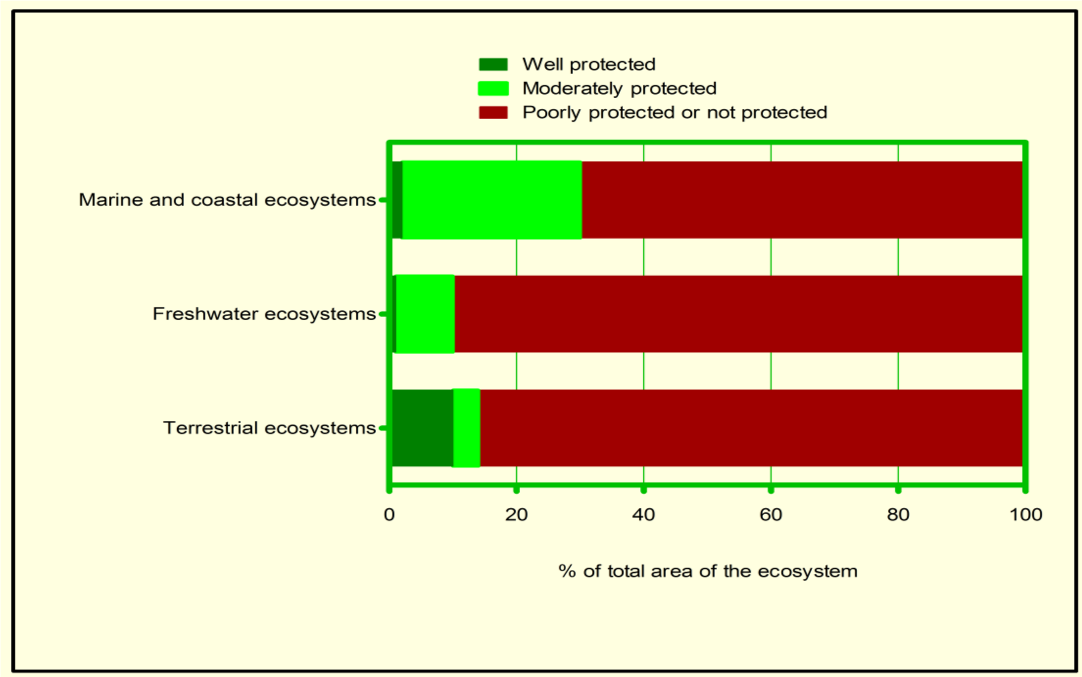

Figure 11: Conservation status (% of total area of the ecosystem protected) of four predominant ecosystems in Mozambique. Source: Ministry of Coordination of Environmental Affairs (2014).

The country is also part of the five main phytogeographical zones of Southern Africa, namely: (i) Regional Mosaic Maputaland-Tongoland; (ii); Afromonantane Endemism Centre; (iii) Zambezian Regional Centre of Endemism; (iv) Swahilian Regional Centre of Endemism (Regional Mosaic Zanzibar- Inhambane) and (v) Regional Swahilian-Maputaland Transition Zone, which are represented below (Figure 12a) (MITADER, 2015) and has six centres of endemism: (i) Rovuma, (ii) Mulange-Namuli-Ribaue, (iii) Chimanimani-Nyanga, (iv) Inhambane, (v) Lebombo Mountains and (vi) Maputaland (Darbyshire et al. 2019).

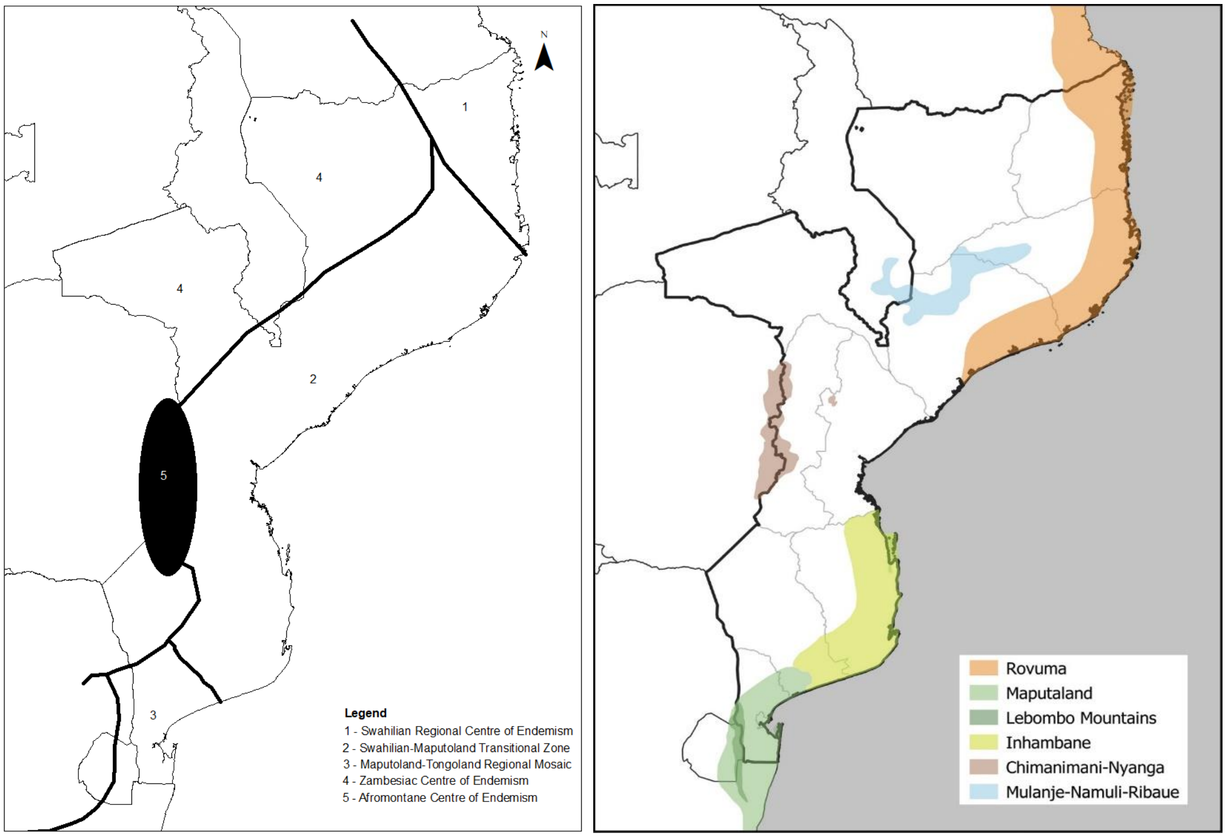

Figure 12: (a) The Phytogeographic areas of Mozambique (Source: MITADER, 2015).; (b) centres of endemism of Mozambique.

In these phytoregions, there are five different phyotocoria, subdivided into 12 ecoregions that are in different states of conservation (Table 4) and represent important biodiversity hotspots and endemic areas (MITADER, 2015). Six centres of endemsm occur in Mozambique and four of them are transfrontier namely: Maputaland, Lembobo Mountains, Chimanimani-Nyanga and Rovuma (Fig 12b).

Table 4: Biomes, Ecoregions and their status of conservation in Mozambique (Source: MITADER, 2015).

Biomes	**Ecoregions**	**Conservation States**
Arid and Semi-arid forest	Coastal mosaic forests of the south of Zanzibar-Inhambane	Critical
	Mosaic of Maputaland costal forest	Critical
Tropical and subtropical	Shrub mopane of the	Considerably stable

Biomes	Ecoregions	Conservation States
rangelands, savannas, thickets and woodlands	Zambeze	
	Oriental Shrub Miombo	Considerably stable
	Southern Shrub Miombo	Vulnerable
	Shrub thicket of Southern Africa	Endangered
Floodplains and savannas	Zambezi flooded Savannas	Critical
	Zambeze Floodplains	Considerably stable
	Hallophytes of Makgadikgadi	Considerably stable
Mountain Grasslands and Thickets	Mosaic of forest and grasslands of the Rift montane	Endangered

The number of species recorded within the main major taxonomic groups and their relative proportions is illustrated in Figure 13 (Ministry of Coordination of Environmental Affairs, 2014).

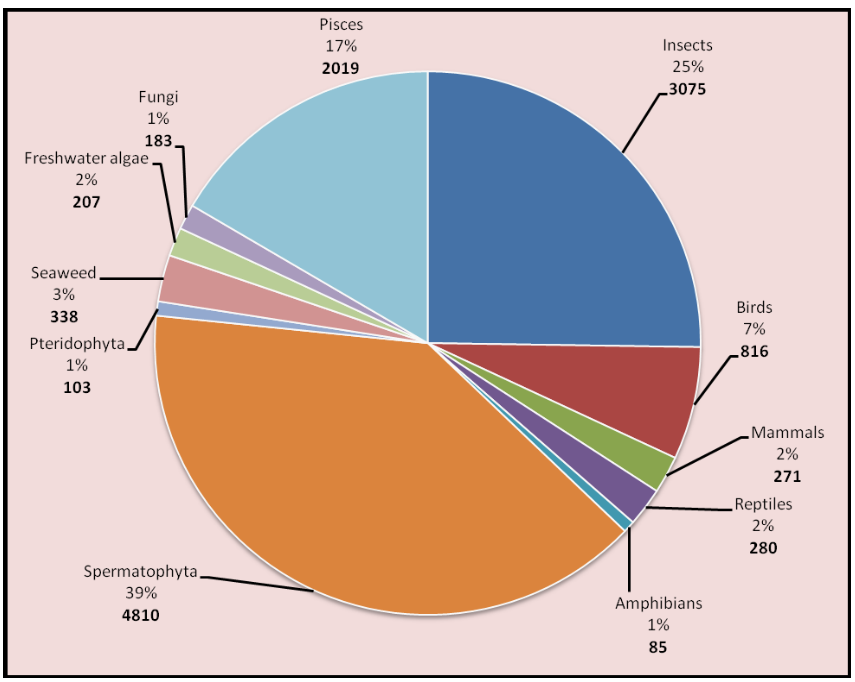

Figure 13: Species diversity; number of species and their relative proportion (%). Source: Ministry of Coordination of Environmental Affairs (2014).

According to the census of wildlife conducted in 2008, there are four main regions where the richness of wildlife is particularly high, namely: (i) North Zone (Niassa National Reserve, Chipanje Chetu Safari area and Vicinity), where there are huge populations of Buffalo, Eland, Impala, Wildebeest and Zebras (MITADER, 2015). Three sub-species of large mammals are endemic in this region, such as *Equus burchelli* subsp. boehmi (Zebra), *Connochaetes taurinus* subsp. johnstonii (Blue wildebeest of Niassa) and *Aepycerus melampus* subsp. johnstonii (Impala Johnstonii); (ii) Central Zone (Gorongosa National Park, Marromeu National Reserve and Coutadas 10, 11, 12 and 14); and (iii) South Zone (Complex Limpopo-Banhine-Zinave and the Maputo Special Reserve) (MITADER, 2015).

At the national level, there are 671 Bird species, of which 29 are endangered and endemic (MITADER, 2015). There are 16 Important Bird Areas (IBA) because of their high diversity and endemism, of which 2 are marine and the remaining terrestrial (representing an area of 1.708 million ha) (MITADER, 2015).

2.3.2. Fauna

The level of knowledge of species diversity occurring in Mozambique remains weak, given to the recognized potential of the country as regards the wealth of ecosystems and habitats and their productivity (MITADER, 2015). Although, in terms of terrestrial fauna, the number is estimated at 4.271, in which insects make up the majority, with 72% of total species (Figure 14) (MITADER, 2015).

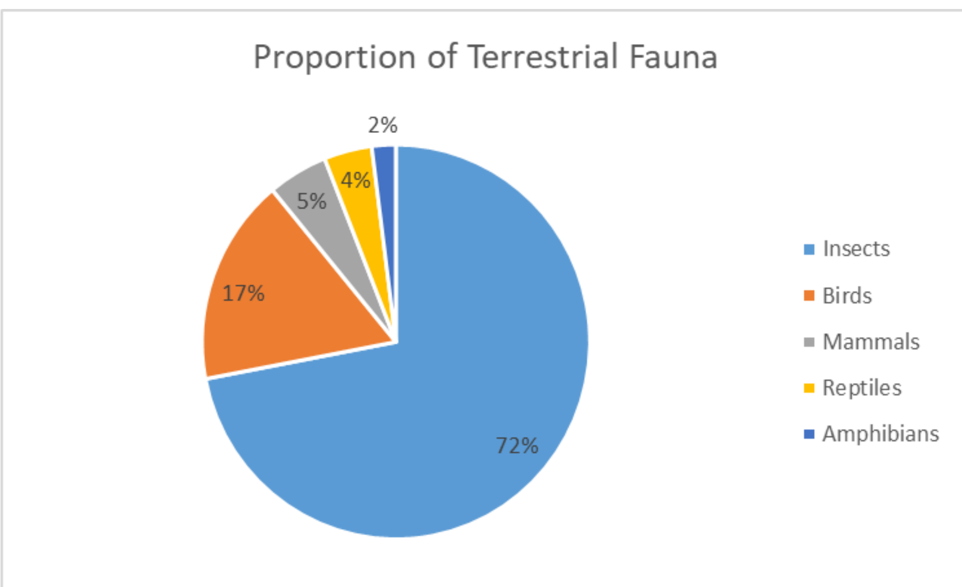

Figure 14: Terrestrial fauna groups (Source: Adapted from MITADER, 2015).

The wildlife composition and diversity are highly dependent on the nutritional value of the vegetation types. The soil characteristics and rainfall seasonality contribute to a low nutritional value of the miombo vegetation and hence the low density of larger herbivores.
Mozambique is rich in wildlife of small and big size animals. These include elephants (*Loxodonta africana*), lions (*Panthera leo*), leopards (*Panthera pardus*), cheetah (*Acinonyx jubatus*) buffalos (*Syncerus caffer*), kudu (*Tragelaphus strepiceros*), roan antelope (*Hippotragus equinus*), bushbuck (*Tragelaphus scriptus*), grey duiker (*Sylvicappra grimmia*), impala (*Aepyceros melampus*), reedbuck (*Redunca arundinum*), Zebra (*Equus burchelli*), bush pig (*Potamochoerus larvatus*), warthog (*Phacochoerus africanus*) and fowls such as the guinea fowl (*Numida meleagris*) (Neves et al. 2018).

However, the long history of human activity associated with the destruction of habitats and poaching resulted in a decrease in the number of large mammals. Other reasons responsible for that decrease include the Civil War, uncontrolled fires, lack of inspection, and the non-involvement of local communities in the management of the resources.

In terms of marine species, Mozambique has considerable diversity, including turtles, mammals, fish, molluscs and crustaceans (see Figure 15 below) (MITADER, 2015).

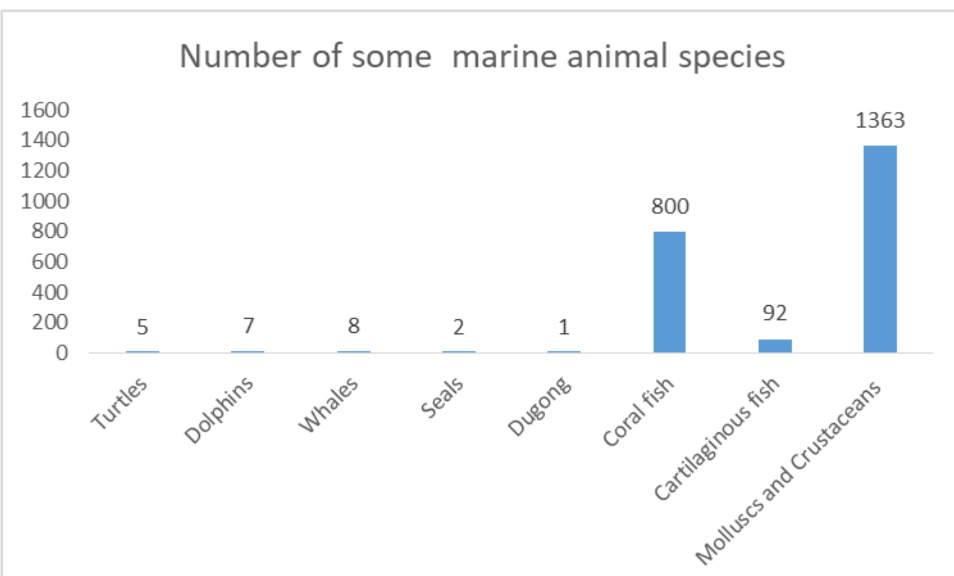

Figure 15: Representation of some marine fauna (Source: Adapted from MITADER, 2015).

2.3.3. Flora

The main diversity hotspot and plant endemism in Mozambique include the Endemic Centres of Maputaland and Chimanimani, coastal forests and the mountains-islands "*Inselbergs*" in northern Mozambique (MITADER, 2015). Recent estimates indicates that the total number of plant species in Mozambique is about 6.000, out of which, more than 300 species are on the International Union for Conservation of Nature (IUCN) Red List of threatened species, 22% of which are endemic (MITADER, 2015).

The Maputaland-Pondoland-Albany biodiversity hotspot is a remarkable area due to its high level of biological diversity and the life-sustaining systems it maintains for millions of people. Characterized by a vegetation type called subtropical thicket, which is unique to the region, the hotspot expands east to west from the Indian Ocean coast to The Great Escarpment and is the meeting point of six different biomes. Several factors contribute to the region's biodiversity, including the rugged topography, underlying geology, and a climate that ranges from hot and humid in the north (with temperatures around 30°C and humidity of 90% in the summer) to parts of South Africa along the escarpment that see topographically induced rainfall and frost in the winter. The result is a region suitable for a wide range of vegetation types and one that is the second richest floristic region in an Alliance for Zero Extinction Site. Recognized as one of the most important biodiversity areas in the country, the habitats are a mosaic of East Afromontane Ecosystem forest and grassland communities.

In 2005 it was identified the Mount Mabu, which hosts unique species of flora and fauna in Zambezia province and included in the Afromontane biodiversity hotspot. The medium-altitude forest below 1600m has an increased presence of *Albizia gummifera and Newtonia buchananii, Ficus spp*. and various Sapotaceae trees such as *Chrysophyllum gorungosanum, Englerophytum magalismontanum and Synsepalum sp* (Timberlake et al 2009).

Grassland occurs along most of the riverbeds at the altitude between 400m and 1000m occupied by the Miombo vegetation. The miombo vegetation is widely distributed from the central to the northern part of the country. The Miombo woodlands are composed mainly of deciduous woody vegetation where *Brachystagia spp* and *Strichnos spinosa* are the dominant species in some locations. Sometimes they appear in the pure stands. Brachystagia is commonly associated with *Julbernadia globiflora, Pterocarpus angolensis (Umbila), Burkea* *africana, Bridelia micrantha, Cynometra sp., Dalbergia melanoxylon, Swartiziamadagascariensis, Millettiastuhlmannii (PangaPanga, etc. while Strichnos* is usually associated with *Combretum spp, Terminalia spp, Pteleopsis myrtilifolia etc* (Soto, 2007). Secondary woodlands contain *Markhamia obtusifolia, Fernandoa magnifica, Trema orientalis, Erythrina sp*. In lower areas this type of vegetation turns into savanna tree with *Combretum sp., Commiphora sp., C. africana, Dalbergia melanoxylon,* interspersed with a layer of *Andropogonaceae and Poaceae* or into *Acacia savanna* with *A. nigrescens, A. polyacantha, Tamarindus indica*, occurring commonly on termite mounds with *Oxythenanthera abyssinica* in lower areas with clayey grey soils (Albano, 2008).

Mozambican mangrove forests are composed by nine species (MITADER, 2015). Mangrove forests cover an area of 357.000 hectares and located mainly in the deltas and estuaries of major rivers, but also in the south of Save River (Inhambane-Bay, Limpopo River, Maputo-Bay) and in the northern region (from Angoche to Rovuma River) (Macamo et al. 2015).
The seagrass meadows cover an area of 439 km^2 and generally occur in intertidal zone (Bandeira and Gell 2003). The most important sites for conservation of this ecosystem (composed by 13 species) and other associated species are the Quirimbas archipelago, Bay Fernão-Veloso, Bazaruto archipelago and the Islands of Inhaca and Ponta-do-Ouro (Bandeira & Gell 2003).

2.3.4. Economic Development

Mozambique is among the eight poorest countries in the world (MICOA, 2003), with about 50% of the population living below absolute poverty level (ASCLME, 2012). Currently the economy of the country is dominated by small scale agriculture, transportation and extractive industry, particularly coal and natural gas (Gani *et al*., 2020; Orre & Ronning, 2017).

Poverty in Mozambique is multi-faceted and the causes can be traced back to six factors: low rate of economic growth (about 7.5%) throughout the early nineties, poor education levels especially among women, high household dependency rates, low agriculture productivity, lack of employment opportunities and infrastructure constrains, particularly in rural areas, where the incidence of poverty is higher, about 71% (MICOA, 2003).

Howsoever, the country’s location, and resources potentialities, such as natural gas, oil, coal, precious minerals and metals, forest and fishery resources offer ample space for the country’s rapid social and economic growth (Ferrari *et al*., 2017). Located in the seaside, Mozambique offers harbour and transportation facilities to the neighbouring countries, a variety of natural resources, including marine and coastal, large fertile areas, several forests rich wildlife, minerals, water bodies and high potential for hydroelectric power production (MICOA, 2003).

2.3.5. Water and Fisheries Resources

Fresh water plays an important role in the country socio-economic development, mainly for irrigation which is the major consumer, energy production, domestic and public supply, fish production (mainly in Lake Niassa and in the Cahora Bassa reservoir) and in tourism industry (MITADER, 2015).

The country's potential for fish production, derived from its coastal location is quite high with more than 2,700.00 of coastal line and 200 miles of exclusive economic zone what provides 586,000.00 Km^2 of surface ocean water (Ministry of Coordination of Environmental Affairs, 2014). Although more than 50% of the run-off comes from upstream countries (Inguane et al., 2014), there are 25 rivers with permanent flow of water that provide fish to the population during the year (Ministry of Coordination of Environmental Affairs, 2014).

Most of the fisheries' resources are located in two major shelfs: The Sofala Bank (in the centre) Bank and Delagoa Bight (in the south) an in the Bays, of which include: Shallow water Shrimp, in Sofala Bank, deep water crustacean in both Sofala Bank and Delagoa Bight, demersal fish in the northern and southern regions and molluscs is coastal zones (MICOA, 2003). The fisheries sector employs up to 60,000.00 people, representing 40% of the total export earnings (MICOA, 2003). The artisanal and semi-industrial methods contribute with more than 50% of the total fish production (MICOA, 2003).

Artisanal fishing is crucial and fish products contribute with more than 20% of animal protein or even being the only source of animal protein in some areas (Ministry of Coordination of Environmental Affairs, 2014). The fishery sector contributes about 2% of the national Gross Domestic Product (GDP) (Ministry of Coordination of Environmental Affairs, 2014).
With an extensive water size and high biological diversity, the country's fishing potential is about 295,500.00 tonnes (Ministry of Coordination of Environmental Affairs, 2014).

2.3.6. Agriculture and Forest Sectors

Occupying about 70% of the country's territory (about 55.3 million hectares), forest resources contribute to poverty reduction as well of economic development by providing energy from firewood and charcoal, medicinal plants and other non-timber products for population survival (Ministry of Coordination of Environmental Affairs, 2014). Aside from socio-economic contribution, forest resources have an important role in mitigating climate change by contributing to carbon sequestration and the protection of water catchment areas (Ministry of Coordination of Environmental Affairs, 2014).

Agriculture which divides the country in two regions (South and North of the Save River), is one of the most important sectors in Mozambique, contributing with more than 40% of the county's exportations value (MICOA, 2003). While in the southern region the soil is relatively fertile and variable climate conditions, the northern region of the Save River is favourable in most part of year but with deficient soils (MICOA, 2003). The most fertile areas are located along the river valleys, where the business and familiar sector produce mainly cassava, corn, peanut, rice, been, sorghum, millet, tobacco, sugar cane, cotton, cashew tea, sisal and copra (MICOA, 2003).

With approximately 5,200,000.00ha of arable area (Ministry of Coordination of Environmental Affairs, 2014), agriculture employs around 80% of the rural and urban population in Mozambique, supplying a large share of household income and contributes with 25% of the Gross Domestic Product (GDP) while the forest sector supplies 3-4% to the GDP with increasing foreign investments (Wingqvist, 2011).

2.3.7. Industrial Sector

The country's industrial sector is not developed and is fundamentally composed by micro and small companies that correspond to more than 90% of the industrial market, of which, 63% correspond to micro industries, 31% to small and the remaining 3% correspond to the large Industries (Ministério da Indústria e Comércio, 2016). Notwithstanding the fact that micro industries present themselves in greater numbers, are the ones that employ the least, with the large ones responsible for 71% of employment (Ministério da Indústria e Comércio, 2016).
The industries that contribute the most to the production of the Mozambican industrial sector are metallurgy (35%), food (25%), beverages (13%), non-metallic minerals (10%), tobacco (8%) and

other industries with 9% which are mostly located in the city and province of Maputo and Sofala (see Figure 16) (Ministério da Indústria e Comércio, 2016).

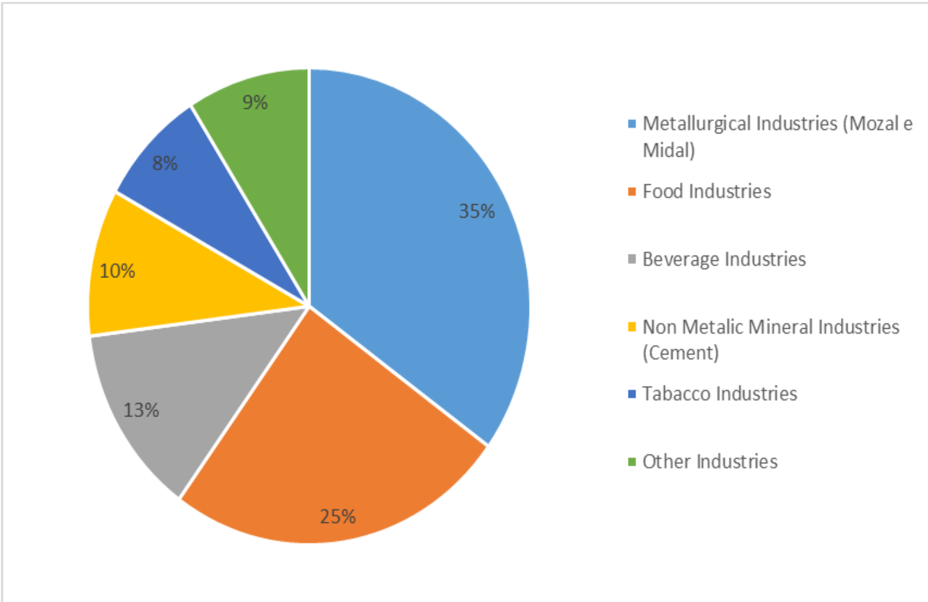

Figure 16: Industrial sector contribution to total industrial production (Source: Adapted from Ministério da Indústria e Comércio, 2016).

The country's predominant minerals can be divided in three groups: energetic (coal, natural gas and petroleum), metallic (gold, copper and iron) and non-metallic minerals (marble and precious stones) (MICOA, 2003). The delta of the Zambezi, Limpopo, Save, Ligonha, Lúrio and Rovuma rivers accumulates amounts of heavy minerals, which can also be found in beaches or sand dunes, such as in Quelimane and Quionga (MICOA, 2003).

The country has a total reserve of natural gas estimated at 127.40 billion m^3, of which, 3.12 billion m^3 of current production and 80 billion m^3 of consumption (Ministry of Coordination of Environmental Affairs, 2014). The total reserve of mineral coal is above 2.50 billion and a current production above 80 thousand (Ministry of Coordination of Environmental Affairs, 2014). Despite the recognition of the potential of the mineral resources in Mozambique, the mineral Industry does not play a major role in the country's economy, contributing with about 2% of GDP (MICOA, 2003).

Most of industries in Mozambique do not have adequate industrial effluent treatment facilities, so that the effluents are discharged directly into tidal channels or in coastal waters, increasing contaminants in water courses (ASCLME, 2012; Ministry of Coordination of Environmental Affairs, 2014).

2.3.8. Harbours/Ports

There are three large ports in Mozambique: Maputo, Beira and Nacala; and several small ports like Inhambane, Quelimane, Pebane, Angoche and Pemba (MICOA, 2003).

Due to its geographical location, Mozambique's channel offers harbour and transportation facilities, what makes it an important route for oil tankers (ASCLME, 2012). Mozambican ports provide services not only for national customers but also, and mostly for the neighbouring countries (MICOA, 2003). Possibly, most of foreign services provided by the country are through its harbours, handling several tons of cargo to and from Swaziland, South Africa, Zimbabwe, Zambia, Malawi and Congo (MICOA, 2003). The Port of Beira has the largest petroleum refinery, about 110.000,00m^3 of capacity and handles most of petroleum products, which is pumped to Zimbabwe with oil spill risks along the way (ASCLME, 2012).

2.4. Political Situation

Politically, Mozambique obtained its independence from Portugal in 1975 following ten years of armed liberation struggle. By 1983, the intensification of civil war together with long spells of natural disasters, forced Mozambique to review its political orientation culminating with the adoption of structural adjustment programs in 1987. This paved the way to the adherence of liberalization of politics and economy. In 1990, Mozambique inaugurates new constitution allowing the creation of political parties. One year later, Mozambique witnessed the outbreak of a civil war that ended with a general peace agreement in 1992. From the inauguration of liberal democracy to date, Mozambique held six general elections, all of which were won by FRELIMO, the party that led the country to independence back in 1975.[3]

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[3] For more on the history of Mozambique see D.Hedges (coord.) *História de Moçambique,* vol.2, *Moçambique no auge do colonialism, 1930-1961, 2a. ed.* (Maputo: Livraria Universitária, Universidade Eduardo Mondlane, 1999); M. Newitt, A History of Mozambique. (Bloomington: Indiana University Press, 1995).

The political and economic landscape of Mozambique evolves around the southern, central and northern regions and due to the Portuguese colonial economy that privileged the extraction of natural resources and exploitation of labour for the benefit of the metropole, Mozambique was conceived as transport's corridor for the territories of the hinterlands (Orre & Ronning, 2017). Since the population lives along the coast, economic development gains expression in these regions and the pressure on coastal and marine resources increasing, and problems such has coastal erosion, sedimentation, water pollution, over-exploitation of resources, deforestation, biological diversity reduction and modification and others are becoming common (ASCLME, 2012).

The location of Maputo, the capital city in the southern tip of the country aimed at serving the interest of South African capital, so that the southern part of Mozambique became relatively industrialized than the rest of the region (Orre & Ronning 2017). This tendency continued after independence from Portugal in 1975 (Orre & Ronning 2017). As an example, we can take the major industrial complex built in Mozambique after independence the Mozal Aluminium Smelter Industry, which was established in Maputo despite protests by environmental activists due to the polluting nature of this type of industry (Orre & Ronning, 2017).

2.4.1. Legal Framework

Mozambique has a comprehensive environmental legal framework that allows the protection of its natural resources. The enormous legal and institutional reform undertaken by the country aims to improve the country's ability to manage the environment. However, the enforcement of the legal framework is a challenge; in a country that extreme weather event occurs with more frequency and high intensity resulting in the damage of lives, socio-economic infrastructures and fragile environment.

2.4.1.1. National Environmental and Social Legal Frameworks

The main law in Mozambique is the Constitution of the Republic of Mozambique, which lays the foundations for what are today the applicable environmental and social legal instruments. It provides that all the citizens have the right to a balanced environment and the duty to protect it. It also provides that the state is required to ensure:

(i) The promotion of initiatives to secure ecological balance and environmental preservation

(ii) The implementation of policies to prevent and control pollution and integrate environmental concerns in all sectored policies to guarantee the citizen the right to live in a balanced environment supported by sustainable development (see appendix 1 for more details of National Guide Instruments).

3. Pollution in Mozambique

3.1. Pollutants and Their Sources

Mozambique is prone to several types of pollution. Pollution is a problem in certain localities, mostly from agriculture, caused by sedimentation, pesticide and fertilizer runoffs, industrial activities such as discharges of untreated effluents (heavy metals, hydrocarbons, etc.) and sewage and domestic waste, most of which released directly to the rivers or sea with no treatment (Wingqvist, 2011). In settings, urban and rural sewage treatment is inadequate, exposing people to potential outbreaks of disease.

Most of pollution problems derive from terrestrial activities in which agriculture practice is the main source with problems correlated to chemical used substances and sedimentation, although activities related to navigation and fuel exploitation are also activities with pollution risks (ASCLME, 2012). From the coast the tankers carrying crude oil from the Arabian Gulf have resulted in contamination of the sea from spills and discharge of polluted ballast waters. Mozambique's emerging offshore and inshore social and environmental impacts such as pollution and public health risks if no adequate environmental management. In some areas, artisanal mining is reported as cause to extensive erosion and silting in some areas (Wingqvist, 2011).

Discharges of chemical and heavy metals derive from industrial, mining activities and commercial agriculture (Wingqvist, 2011). Although the industries represent potential for soil and water pollution, proper implementation of environmental management plans can minimize the effects (MITADER, 2015).

3.1.1. Main Pollutants

3.1.1.1. Fertilizers and Pesticides

Since most of agricultural activities take place close to main river channels such as Monapo, Zambezi, Pungoé, Limpopo and Incomati, soil and close water bodies are the most susceptible to be polluted although, the farming contribution to the pollution of these rivers is however negligible (ASCLME, 2012). Although collected water samples from Monapo, Pungué, Maputo and Incomati rivers have indicated the presence of various pesticide residues, including DDT, Lindane and Hexachlorobenzene in the water (Wingqvist, 2011).

Pesticides and fertilizers used in agriculture are pointed to be extensively used in the intensive farms in Incomati, Umbeluzi and Maputo River Valleys, particularly in the sugarcane plantations in the Umbeluzi River Valley in Swaziland (Wingqvist, 2011). Due to poverty, the use of fertilizers and other chemical products, as pesticides is low so that can be deduced that water pollution by chemical products used in agricultural activities is not significant, but, as there is a potential for these products to be drained into watercourses and wetlands, fish, amphibians, insects, crustaceans and other species can be damaged (Ministry of Coordination of Environmental Affairs, 2014).

In Maputo and Beira Bays, the siltation is further aggravated by dredging of the navigational channels, where a survey by the dredging company EMODRAGA indicated that about 1,200,000.00m^3 and 2,500,000m^3 of sediments are dredged per year in Maputo and Beira Ports respectively (Ministry of Coordination of Environmental Affairs, 2014). Pollution by sediment generation is also originated by mining activities, where impact can range from sediment generation, the transportation caused by poorly maintained roads during the exploration phase, to the silting of watercourses and increased solids in water during the operation phase of the mine (Ministry of Coordination of Environmental Affairs, 2014).

3.1.1.2. Sewage

Despite water abundance, the country faces many challenges to provide appropriate water for domestic, agricultural and industrial use (Wingqvist, 2011) resulting in more than 50% people with no access water free from microbial contamination (Chaúque *et al*., 2021). In this situation, large part of population consumes water from wells, which are mostly located near latrines and with high microorganism density indicating faecal contamination, what makes them susceptible to water-borne diseases (Chaúque *et al*., 2021). Uneven geographies of sanitation in Mozambique play a significant role in shaping distribution of risks of contaminated water and disease (Rusca *et al*., 2021).

High levels of microbial pollution have been found at Beira and Nacala Bays, although the concentrations are lower compared to those observed in Maputo (ASCLME, 2012). In Maputo more than half of the city's population is supplied with groundwater containing nitrate concentrations above the permitted levels of higher than 250 mg L^{-1} that could be from the widespread use of latrines and septic tanks resulted in constant infiltration of its content into the soil and eventually to groundwater sources (Arsenio *et al.*, 2018). In coastal areas, untreated sewage and sediments resulting from agriculture, land-use change, mining and dredging activities contaminate aquatic ecosystems destructing corals, seagrasses and mangroves (Ministry of Coordination of Environmental Affairs, 2014).

3.1.1.3. Heavy Metals

Analysis by the National Laboratory for Food and Water and Maputo Water Authority have revealed the presence of heavy metals in different locations within the Port of Maputo, in the mouths of Matola and Maputo Rivers and in Nacala Bay (ASCLME, 2012). Scarlet and Bandeira (2014) report metals found in some marine invertebrates.

Pollution due to mining processes (metallurgical and hydrometallurgical industries) are large consumers of water and increase the potential of water resources contamination and consequently the biodiversity linked to these resources (Ministry of Coordination of Environmental Affairs, 2014). According to marine pollution compilation work by Scarlet and Bandeira (2014), high levels of lead (Pb) were detected close to the cement plant in Matola (eastern Maputo Bay at Espírito Santo Estuary), however nickel (Ni), cadmium (Cd) and zinc (Zn) were at negligible levels. Heavy metals, particularly Pb were detected in the Port of Maputo, and in the discharges from the Matola and Maputo rivers. Trace metals such as copper (Cu(II)), Cd(II), Pb(II) and Zn(II), were identified by Maia (1999) in sampling points at the mouth of the estuary to the open Bay waters. Very low and negligible levels of heavy metals (aluminium (Al), iron (Fe), cobalt (Co), chromium (Cr), Cu, Ni, strontium (Sr), zirconium (Zr), Zn) were detected in the surface sediments by Achimo (2002). However, five years later, higher levels of Zn, Cr and Pb were detected from a range of sites and Cu at all sites in Maputo Bay (Fogão, 2008; Mahumana, 2010).

3.1.1.4. Fuel Products

Petroleum products transportation in Mozambique, is an activity occurring with a high oil spill risk (ASCLME, 2012). The Port of Beira (one of the main ports in Mozambique) handles mostly petroleum products and has the largest petroleum refinery with a capacity of nearly 110000m^3 (ASCLME, 2012). The pipeline transporting about 1 to 1.5 million tonnes of petroleum to Zimbabwe is connected through the port of Beira (ASCLME, 2012). Annually, about 450 million tonnes of hydrocarbon products transit through the Mozambique Channel and its risk for oil spill is accordingly high, as it was observed when 16.000,00 tonnes of heavy fuel were spilled by Katina P tanker along the coast of Mozambique threatening coastal and marine ecosystem (ASCLME, 2012). Pollution from ships on Mozambican coast is also related mainly to oily bilge water and oil sludge from engine rooms discharged at sea, accidental oil spills from damaged tankers and blasting and cleaning operations (ASCLME, 2012).

3.1.1.5. Solid Waste

Rapid urbanization, districts growth, internal migration, have been increasing the problem related to plastic products usage, such as plastic bags, which are replacing baskets of natural materials and fabrics. This is contributing to increasing plastic pollution and resulting in garbage on the streets and the clogging of rainwater drainage channels (Da Silva, 2020).

The patterns of waste management are still poor and outdated in Mozambique, with poor documentation of waste generation rates and its composition, inefficient storage and collection systems, disposal of municipal wastes with toxic and hazardous waste, indiscriminate disposal or dumping of waste and inefficient utilization of disposal site spaces (Gani *et al*., 2020). Currently, solid household waste collected is deposited in official or unofficial dump sites without proper (if any) treatment or segregation, a situation which is leading to a constant need to create new landfills, mainly in urban areas (Da Silva, 2020). As we can see in many Mozambican cities, lack of awareness and proper education on integrated waste management has contributed to the type of municipal soild waste (MSW) disposal and poor management practices, where MSW are being buried, burnt or disposed haphazardly in the environment (Gani *et al*., 2020).

3.1.1.6. Gases

The sources of air pollution in Mozambique are the industrial activities (manufacturing, mining), transport, energy generation, agriculture and waste (Ministry of Coordination of Environmental Affairs, 2014). Taking into account the system of household production and the use of widespread practice of burning for wood fuel, agricultural activities, land-use change, and forestry are pointed to be responsible of air pollutants, mainly greenhouse gases (GHG), while industrial sector has a low expression (Ministry of Coordination of Environmental Affairs, 2014 & USAID, 2017).

Outdoor air pollution is a problem by mining industries which releases dust, sulphur dioxide (SO_2,) Pb, Arsenic (As) and other smelter gas substances (Wingqvist, 2011).
During mining activities, miners burn the amalgams of gold in open fires spreading the mercury gases throughout the community harming human health by inhalation (Ministry of Coordination of Environmental Affairs, 2014). The exploitation of coal mines poses other environmental problem due to burning fossil fuel, increasing atmospheric carbon dioxide (CO_2)and other GHG during combustion for electricity generation (Ministry of Coordination of Environmental Affairs, 2014).

Another important source of GHG emissions is manure production from livestock, which shows an increasing trend despite being far from the region's level production (Ministry of Coordination of Environmental Affairs, 2014). The 2007's National Forest Inventory identified the use of fire to clear land for agriculture to be an important cause of deforestation resulting in 219,000.00ha of forest lost annually which occurs between August and September to prepare new fields for agriculture, wild animals hunting and to encourage the growth of fresh grass for better pasture for livestock (USAID, 2017). Furthermore, according to USAID (2017), uncontrolled human induced fires in the Miombo woodlands has been identified as contributing 400 million tons of carbon emissions.

3.2. Marine Pollution

The state of pollution of coastal and marine areas is well known for Maputo Bay, presented in the Pollution chapter of Maputo Bay ecosystem (Scarlet & Bandeira 2014). Paula & Bandeira (2014) emphasise the main sources of pollution: the land-based and port activity sources, although little is known of other regions.

The population centres of Maputo and Matola (2 million people) represent the main land-based point and non-point entry of pollutants into the environment around Maputo Bay, as well as the rivers that discharge directly into the Bay providing a diffuse source of pollutants (Da Silva & Rafael, 2014; Scarlet & Bandeira, 2014).

About 80% of the pollution entering the coastal areas and oceans originate from land-based sources as most human activities occur on land (Vikas & Dwarakish, 2015; Morales-Caselles *et al*., 2021). The pollutants or main land-based sources of pollution in Maputo Bay are: sewage (that includes microbial pollution) associated with the storm water, solid waste and marine litter, agriculture, and industrial activities. In Maputo Bay, the most serious pollutions problems are result from sewage and microbial contamination (Scarlet & Bandeira, 2014).

As a key component of land-based pollution, urban sewage is originated mainly from domestic, industrial and agricultural activities as well as storm water runoff drained into coastal, marine and freshwater environments (Wingqvist, 2011). Besides the population growth, the sewerage infrastructure around Maputo City has remained the same over time, leading to inadequate sewage treatment which results in domestic sewage as a major source of pollution in the Bay (Scarlet & Bandeira 2014). Even though Maputo city is the only Mozambican City with a central system for sewage treatment (known as System I), less than 50% of Maputo sewage is treated, the remainder enters septic tanks and pit latrines (70% of the population) or is released directly into the sea or into rivers flowing into Maputo Bay resulting in problems such as water borne diseases (Scarlet & Bandeira 2014).

Studies on the microbiological and chemical quality of waters of Maputo Bay, carried out more than 20 years ago showed an evident seawater contamination around south region of Maputo City (Fernandes *et al*., 1993). Faecal and bacteria coliforms were detected in water and clam tissues at different sites specially Miramar beach, Infulene River, whereas northern bathing areas were almost pristine (Scarlett & Bandeira 2014). Bivalves serve as useful indicators of environmental quality because they accumulate contaminants in their tissues (Scarlett & Bandeira 2014; Khan *et al*., 2020). Average levels of contamination were detected in an impacted mangrove forest at Costa do Sol.

The solid waste accounts around 50% of city output and the main sources of the solid waste are domestic premises, shops, hotels, offices and small factories (Scarlett & Bandeira 2014).

Maputo and Matola municipalities generate respectively about 1,134 and 320 tonnes of waste daily, with organic and plastic waste being similar in both urban and suburban areas (Scarlett & Bandeira 2014). Urban areas produce more paper and less hazardous material, while plastics account for only 10% of the total waste produced (Scarlett & Bandeira 2014). Plastic is the most common litter item observed on beaches, and the major sources of marine litter are shipping garbage, fishing gears, road users, urban storm waters, industrial outfalls, untreated municipal sewage and littering of beaches and coastal picnic/eating areas (Scarlett & Bandeira 2014).

Regarding agriculture, the contribution of farming to the pollution of coastal waters is considered small given the low mechanised farming in the country that covers only 8% of the total cropland (Scarlett & Bandeira 2014). However, the increase in agriculture activity especially in the vicinity of Maputo Bay and the river basins, the main pathway through which agrochemicals (fertilisers and pesticides) enter the coastal and marine environments, resulting in impacts in both humans and other organisms (Scarlett & Bandeira 2014).

The impact of the industrial activities in the Bay waters remains apparently low even though the industrial activity is concentrated in Maputo city and its surroundings and the satellite town of Matola (Scarlett & Bandeira 2014). The main industries of aluminium, food, beverages, chemical, petroleum, textiles, cement and glass produce a non-quantified amount of waste containing heavy metals such as mercury, lead, chromium, manganese, nickel and zinc (Scarlett & Bandeira 2014). Many industries discharge partially or totally untreated effluents into the rivers that enter the Bay via the Espírito Santo Estuary (Scarlett & Bandeira 2014). In addition to all these drivers and pollutants the port activities include dredging and accidental oil spills while transferring from tankers to the port (Scarlett & Bandeira 2014).

4. Case Studies

In Mozambique, it is regrettable that most of the pollution data are centralized on the southern part of the country. This indicates the lack of information about other country regions. Therefore, it is not possible to generalize the level of pollution in the whole country. It is also possible to say that the major topic studied is solid waste (Table 5), an emerging issue about pollution for Mozambique (see appendix 2 for more details about the case studies).

Table 5: List of publication about Mozambique classified by pollution thematic group or case studies, year of publication, authors and type of document.

Thematic group	Year	Authors	Document type		
			Article	Report	Thesis
Solid Waste Pollution	2022	Bernardo, B, C. Candeias & F. Rocha	X		
	2021	World Bank		X	
	2021	World Bank		X	
	2021	World Bank		X	
	2021	World Bank		X	
	2021	Langa, C., J. Hara, J. wang, K. Nakamura & N. Watannabe	X		
	2020	Dos Muchangos, L. & A. Tokai	X		
	2020	Gani, A.H.A., O.M. Aderoju, A.G. Dias & A.A.R. Monjane	X		
	2020	Pucino, M., J. Boucher, A. Bouchet, P. Paruta & M. Zgola		X	
	2017	Sallwey, J., H. Hettiarachchi & S. Hulsmann	X		
	2017	Jambeck, J., B. Hardesty, A. Brooks, T. Friend, K. Teleki, J. Fabres, Y. Beaudoin, A. Bamba, J. Francis, A. Ribbink, T. Baleta, H. Bouwman, J. Knox e C. Wilcox	X		
	2015	Cavalcanti, W. & M. Fernandes			X
	2014	Tas, A. & A. Belon	X		
	2014	Langa, J.	X		
	2012	Fernandes, R., Chemane, A. & M. Louro		X	
	2012	Fernando, A. & S. Lima	X		
	2001	Pereira, M, D. de Abreu, A. da Costa & C. Louro		X	
Hazardous waste	2017	Ferrari, K., R. Gamberini, B. Rimini & H. Abacassamo	X		

Thematic group	Year	Authors	Document type		
			Article	Report	Thesis
Sanitation Sanitation	2021	Rusca, M., N. Gulamussen, J. Westrate, E. Nguluve, E. Salvador, P. Paron e G. Ferrero	X		
	2021	Salamandane, A., F. Vila-Boa, M. Malfeito-Ferreira & L. Brito	X		
	2021	Capone, D., A. Bivins, J. Knee, O. Cumming, R. Nalá & J. Brown	X		
	2021	Chaúque, B., C. Chicumbe, V. Cossa & M. Rott	X		
	2021	Holcomb, D., J. Knee, D. Capone, Trent Sumner, Z. Adriano, R. Nalá, O. Cumming, J. Brown & J. Stewart	X		
	2020	Ricolfi, L., M. Barbieri, p. Muteto, A. Nigro, G. Sappa & S. Vitale			
	2020	Tamele, I. & V. Vasconcelos	X		
	2020	Holcomb, D., J. Knee, T. Sumner, Z. Adriano, E. de Bruijn, R. Nalá, O. Cumming, J. Brown & J. Stewart	X		
Sewage	2019	Weststrate, J., A. Gianoli, J. Eshuis, G. Dilkstra, I. Cossa & M. Rusca	X		
	2019	Capone, D., Z. Adriano, D. Berendes, O. Cumming, R. Dreibelbis, D. Holcomb, J. Knee, I. Ross & J. Brown	X		
	2018	Nhantumbo, C., R. Larsson, M. Larson, D. Juizo & K. Persson	X		
	2017	Jane, A.			X
	2013	Penha-Lopes G., P. Fidalgo e Costa, J. Gil, M. Leal, S. Cannicci, A. Macia, S. Mwangi & J. Paula.	X		

Thematic group	Year	Authors	Document type		
			Article	Report	Thesis
Sewage	2010	Penha-Lopes, G., S. Xavier, J. Okondo, S. Cannicci, E. Fondo, S. Ferreira, C. Macamo, A. Macia, S. Mwangi & J. Paula	X		
	2009	Cannicci, S., F. Bartolini, F. Dahdouh-Guebas, S. Fratini, C. Litulo, A. Macia, E. Mrabu., G. Penha-Lopes, & J. Paula	X		
Metal Pollution	2020	Castigo, P., F. Costa-Nobre & E. Welengane	X		
	2020	Nhantumbo, C., E. Pondja, D. Juizo, A. Cumbane, N. Matsinhe, B. Paqueleque, M. Uamusse, G. França & P. Paron	X		
	2019	Innocent, S. & G. Thomas	X		
	2018	Genthe, B., T. Kapwata, W. Roux & J. Chamier			
	2018	Mafavisse, I.			X
	2017	Nhantumbo, C.	X		
	2016	Nhantumbo, C., R. Larsson, M. Larson, D. Juizo & K. Persson		X	
	2015	Nhantumbo, C., R. Larsson, M. Larson & D. Juizo	X		
	2015	Nhantumbo, C., R. Larsson, M. Larson, D. Juizo & K. Persson	X		
	2015	Kamau, J. P. Kuschk, J. Machiwa, A. Macia, S. Mothes, S. Mwangi, D. Munga & U. Kappelmeyer	X		
	2014	Adddo-Bediako, A., S. Marr, A. Jooste & W. Luus-Powell	X		
	2013	Nhantumbo, C.	X		
	1995	Nussey, G., J. van Vuren & H. Preez	X		

Thematic group	Year	Authors	Document type		
			Article	Report	Thesis
Pesticides	2018	Arsenio, A., I. Salim, M. Hu, N. Matsinhe, R. Scheidegger, L. Rietveld	X		
Pesticides	2016	Sturve, J., P. Scarlet, H. Maja, K. Jenny & A. Macia	X		
	2011	Sumalgy, D.			X
	2005	Godfrey, S., F. Timo & M. Smith	X		
	2004	Louro, C. & M. Pereira		X	
Gas Emissions	2021	Mavume, A.,B. Banze O. Macie & A. Queface	X		
	2020	Sumbana, J., J. Sacarlal & S. Rhubino	X		
	2020	Dos Muchangos, L. & A. Tokai	X		
	2017	Anenberg, D. Henze, F. Lacey, A. Irfan, P. Kinney, G. Kleiman & A. Pillarisetti	X		
		USAID- United States Agency International Development		X	
Others	2011	Mingion, P A. Macia, A. Rosário, J. Machiwa, S. Mwangi & F. Dehairs	X		

5. Pollution Hotspots in Mozambique

5.1. Plastic Pollution Hotspots

Africa, with 16% of the world's population (1.3 billion people), produces 5% and consumes 4% of global plastic volumes, about 16kg per person, compared to the global average of 45 kg per person and 136 kg per person in the Western Europe (Sadan and De Kock, 2021). Below, are the most relevant plastic polymers and typical products (Table 6) compounding the total plastic leakage (Pucino *et al*., 2020).

Table 6: Polymer abbreviations and the typical products (Source: Pucino et al., 2020).

Name	Abbreviation	Typical Products
Polyethylene Terephthalate	PET	Bottles, food wrappings
Polypropylene	PP	Hot food containers, sanitary pad liners
Low-density Polyethylene	LDPE	Bags, container lids
High-density Polyethylene	HDPE	Milk containers, shampoo bottles
Polystyrene	PS	Food containers, disposable cups,
Polyvinyl Chloride	PVC	Construction pipes, toys, detergent bottles

Egypt, Nigeria and South Africa are the largest countries' economies and highest producers and importers of plastic polymers as well products in Africa (Sadan and De Kock, 2021). A recent study by the IUCN included a detailed analysis of plastic material flows in four African countries, Kenya, Mozambique, Tanzania and South Africa (Sadan and De Kock, 2021). Based on studies, while Kenya, Tanzania and Mozambique contribute with 18%, 13% and 7.5% to the total plastic leakage in the Eastern and Southern Africa region, South Africa contributes with 35% of total plastic leakage.

Due to the lack of sanitary landfills and incineration facilities in Mozambique, all plastic waste that is not recycled is mismanaged and is susceptible to leak into waterways (IUCN-EA-QUANTS, 2020). Since less than 1% of generated plastic waste is recycled, the Mismanaged Waste Index (MWI) is above 98% for all polymers (IUCN-EA-QUANTS, 2020). Consequently, there are only two factors that influence whether a polymer is a hotspot or not: The amount of plastic waste generated and its release rate (mostly related to the product size) (IUCN-EA-QUANTS, 2020). In Mozambique, the total and per capita plastic leakage is about 17kt and 0.6kt/capita, respectively (Pucino *et al*., 2020). The figures 17 and 18, show the global view on plastic and the waste generation in Mozambique.

Figure 17: Global view on plastic in Mozambique (Source: Adapted from Pucino et al., 2020).

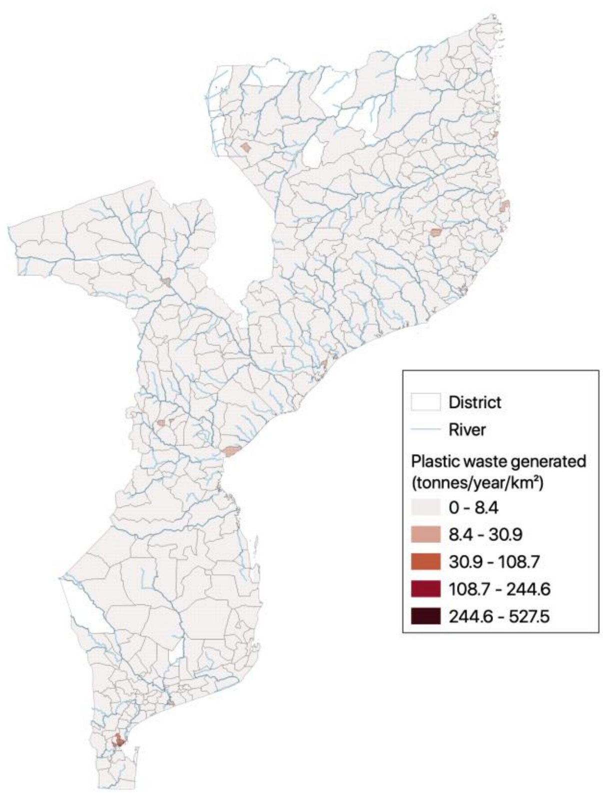

Figure 18: Country's Waste generation by District (Source: IUCN-EA-QUANTIS, 2020).

The most concerning polymers are PET and LDPE (Figures 19 and 120), extensively used in the packing sector, comprises most of the plastic used in packing application (Pucino *et al*., 2020).

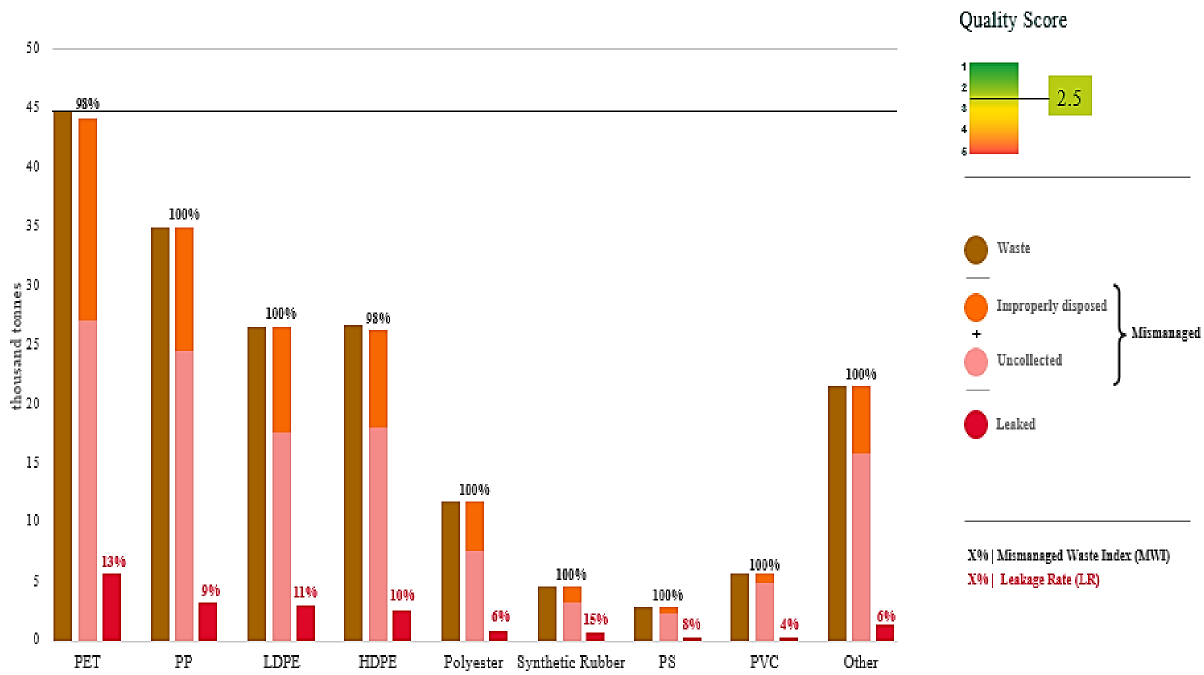

Figure 19: Mismanaged Waste and Leakage by Polymer (Source: IUCN-EA-QUANTIS, 2020)

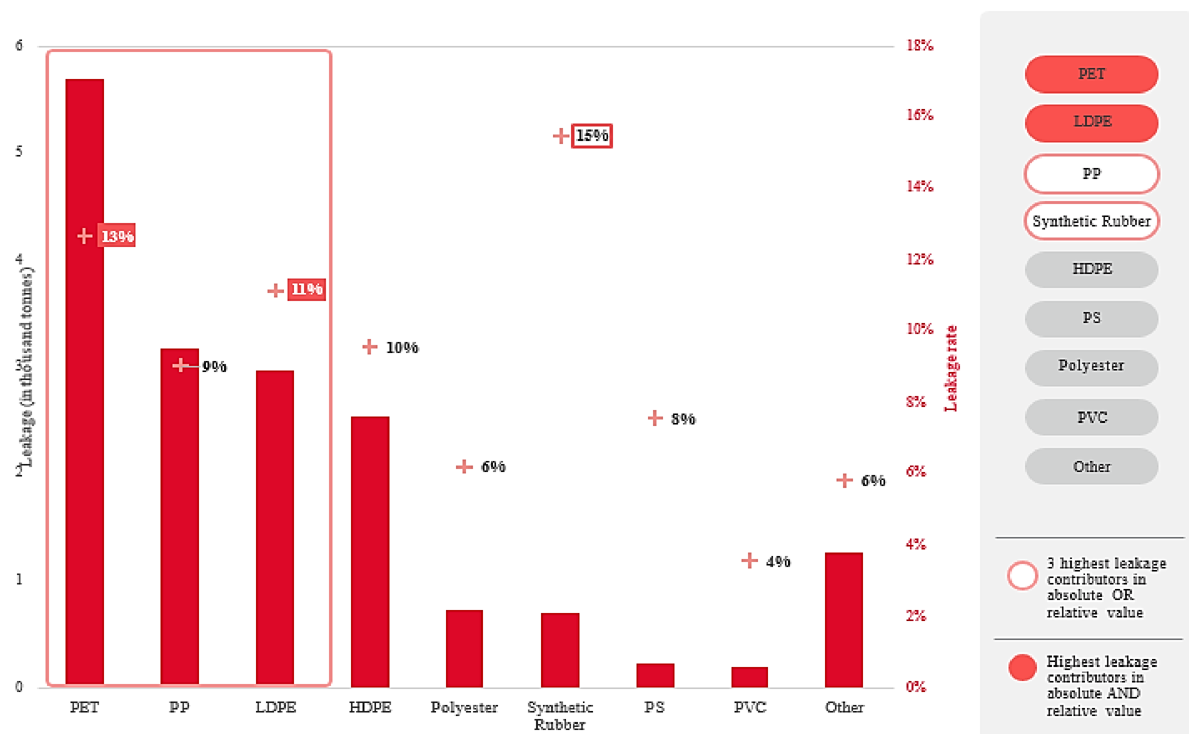

Figure 20: Polymer Hotspot (Source: IUCN-EA-QUANTIS, 2020).

In Mozambique, although the percentage of leakage is higher in rural areas, the concentration is higher in the main cities (Table 7) (Pucino *et al*., 2020).

Table 7: Sources and concentration of leakage in Mozambique. Source: Adapted from Pucino et al. (2020).

Sources of leakage	Main Cities (Inland)	**Main Cities** (Waterside)	**Urban** (Inland)	**Urban** (Waterside)	**Rural** (Inland)	**Rural** (Waterside)
	27%	7%	5%	2%	49%	9%
	Total leakage	17 Kt				
Concentration of leakage	Main Cities (Inland)	**Main Cities** (Waterside)	**Urban** (Inland)	**Urban** (Waterside)	**Rural** (Inland)	**Rural** (Waterside)
	2.8 t/Km^2	4.3 t/Km^2	0.34 t/Km^2	0.48 t/Km^2	0.01 t/Km^2	0.02 t/Km^2
	Average leakage concentration	0.03 t/Km^2				

From the total leakage amount, 16kt make part of macro-leakage, what is common for countries where solid waste is significantly mismanaged (IUCN-EA-QUANTIS, 2020). Micro-leakage contributes with 1kt for the total leakage and has 3 main sources as is showed below (Figure 21) (IUCN-EA-QUANTIS, 2020).

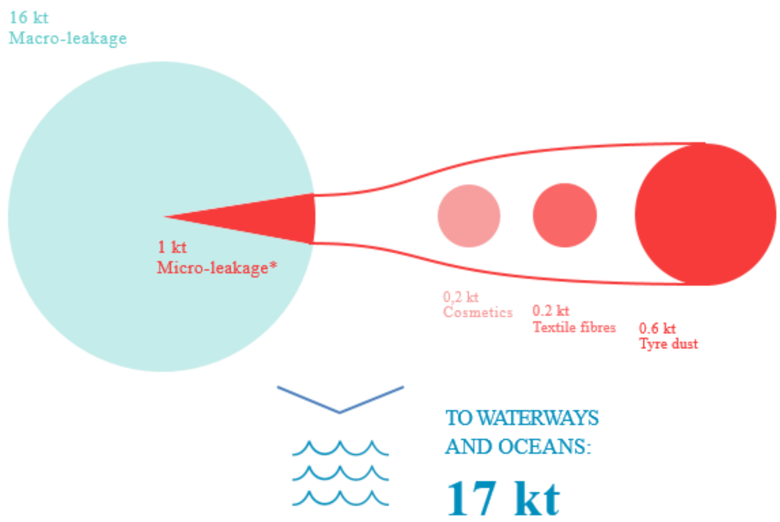

Figure 21: Macro-leakage VS Micro-leakage. (Source: IUCN-EA-QUANTIS, 2020).

While tyre dust due to tyre abrasion from road vehicles is the first cause of primary plastic micro-leakage, textile micro-leakage from clothes washing and of microbeads from cosmetic products are also close in absolute value (IUCN-EA-QUANTIS, 2020). This is possibly due to the absence of wastewater treatment that provides no barrier to the release of primary plastic micro-particles in waterways and oceans (IUCN-EA-QUANTIS, 2020).

The contribution for the total leakage differs for each industrial sector (Figure 22). While the packing sector contributes more than 70% of the total plastic leakage (12.9kt of packing waste leakage) to the oceans and water ways, the textile and automotive-tyres sectors, are the second and third highest contributors to plastic leakage in absolute value (0.7kt each) (IUCN-EA-QUANTIS, 2020). The fishing and medical sectors have low contribution in absolute leakage but have very high leakage rates, 20% and 19%, respectively (IUCN-EA-QUANTIS, 2020).

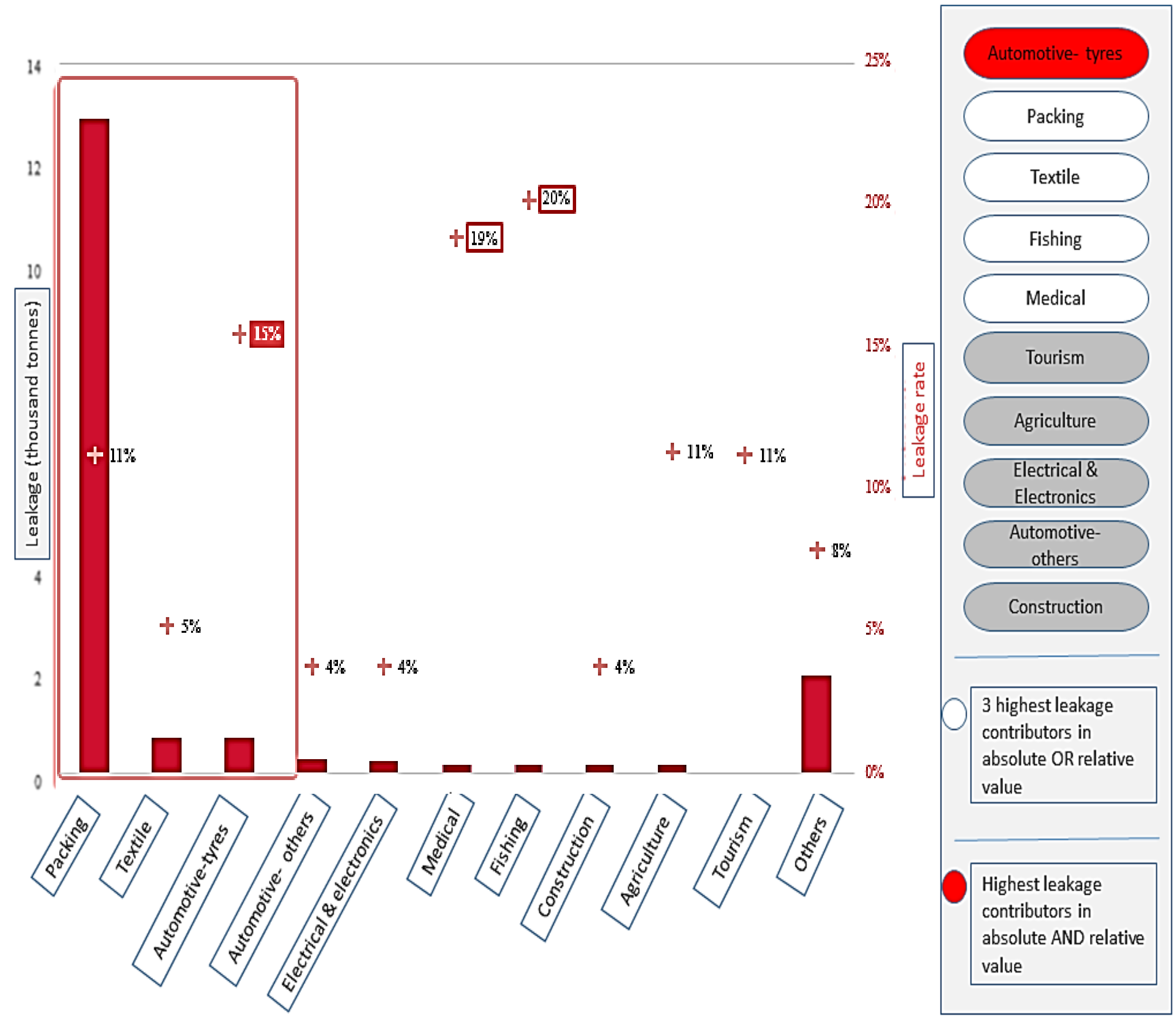

Figure 22: Leakage Hotspot by Sector (Source: IUCN-EA-QUANTIS, 2020).

Among the generated waste, the mismanaging rate is though high in the whole country, which is above 97%, due to the absence of sanitary landfill and incineration facilities (Figures 23 and 24) (IUCN-EA-QUANTIS, 2020). Furthermore, in rural areas, the generated waste is simply not collected (IUCN-EA-QUANTIS, 2020). In general, only 32% of the waste generated is collected (IUCN-EA-QUANTIS, 2020).

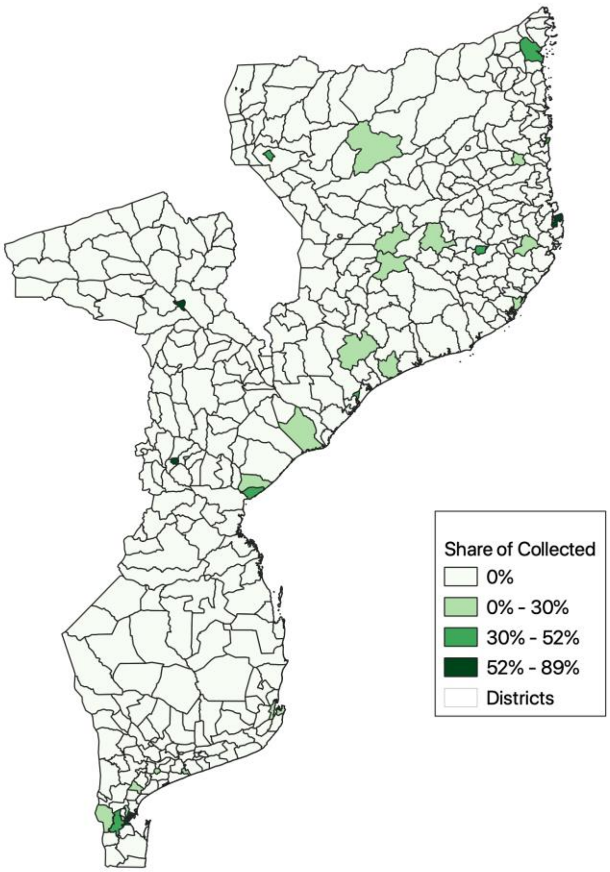

Figure 23: Country's Waste Collection (Source: IUCN-EA-QUANTIS, 2020).

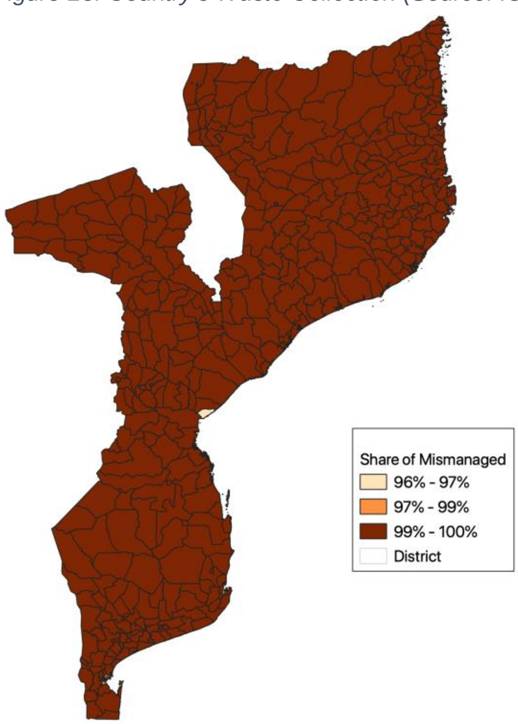

Figure 24: Country's Mismanaged Waste Index (Source: IUCN-EA-QUANTIS, 2020).

5.2. Air Pollution Hotspots

Among the global emissions, Mozambique contributes with 0.14% (2,314.00 tonnes) of the total GHG emissions (USAID, 2017). The main sources of air pollution are Industry (manufacturing services) transport, power generation (corporative, households), agriculture and waste (MICOA, 2014). The main Gases considered within the IPCC Revised Guidelines are divided into two groups (represented in Table 8).

Table 8: The main Greenhouse gases considered in Mozambique (Adapted from MICOA, 2003).

Direct Greenhouse gases	**Indirect Greenhouse gases**
Carbon Dioxide (CO_2)	Carbon Monoxide (CO)
Methane (CH_4)	Nitrogen Oxides (NO_x)
Nitrous Oxides (N_2O)	Volatile Organic Compounds (NMVOC)

According to The World Resources Institute Climate Analysis Indicators Tool (WRI CAIT) the country's 2013 GHG profile is dominated by emissions from the land-use change forest with about 58.8% of the total emissions, followed by agriculture, energy, waste and industrial processes, contributing with 26.8%, 8.9%, 4% and 1.5%, respectively (Figure 25) (MITADER, 2015 & USAID, 2017).

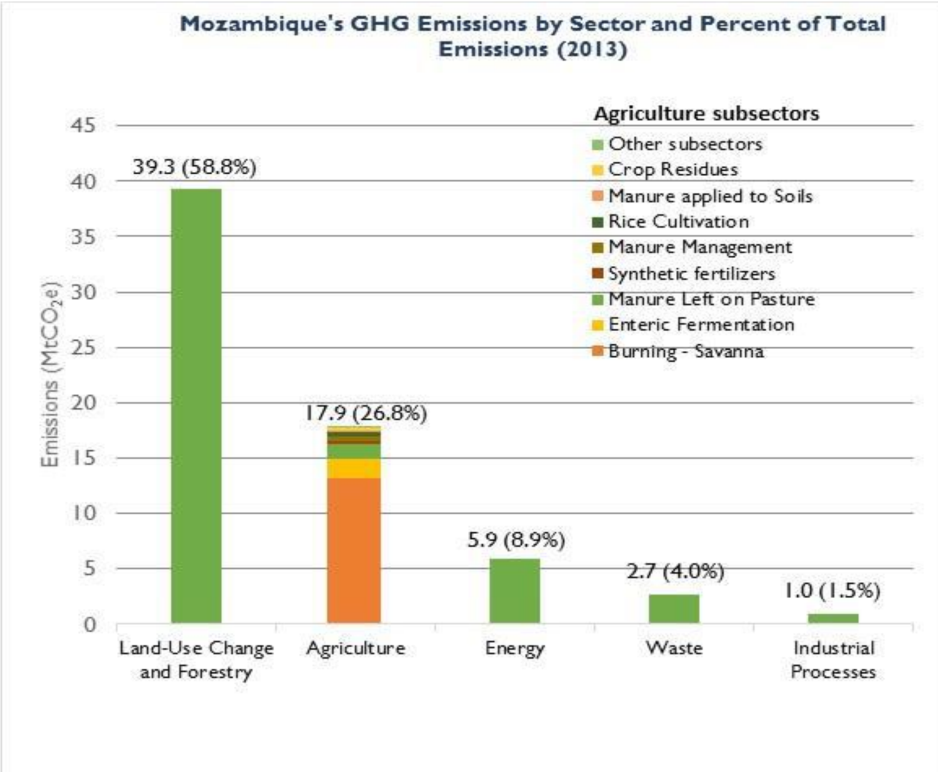

Figure 25: The country's GHG emissions by sector (Source: USAID, 2017).

Outdoor air pollution, mainly from the automotive industry (estimated at 350.000 vehicles, 57% of which are in the City of Maputo), manufacturing industry, mainly around the major urban areas of Matola, Maputo and Beira, and open mining, especially in the provinces of Tete, Manica and Zambézia, result in pollutants emissions (carbon, sulphides, sulphur and dust) (MITADER, 2015). There are no records of the resulting air pollution levels of the industry and manufacturing, but it is estimated to be, sufficiently high to interfere not only with human health, but also with biodiversity conservation (MITADER, 2015).

Mozambique's GHG emissions increased by 11.7 $MtCO_2$ from 1990 to 2013 (USAID, 2017). The annual change in total emissions during this period was 1%, with sector-specific average annual changes as follows: LUCF (0.5%), agriculture (1.5%), energy (2.2%), waste (7.9%), and IP (26%) (USAID, 2017). The rising emissions in the two highest emitting sectors, from 1990 to 2013 were driven by changes in forest lands: agricultural expansion, wildfires and excessive harvesting for wood fuel including for firewood and charcoal (USAID, 2017).

While the GHG emissions increased 21%, averaging 1% annually from 1990 to 2013, the GDP grew 445%, about 7.8% per year (USAID, 2017). However, as of 2013, the Mozambican economy emitted approximately 8 times more GHG emissions relative to GDP than the world average, indicating significant potential for improvement (USAID, 2017). The average GDP and GHG emissions changes are shown below (Figure: 26).

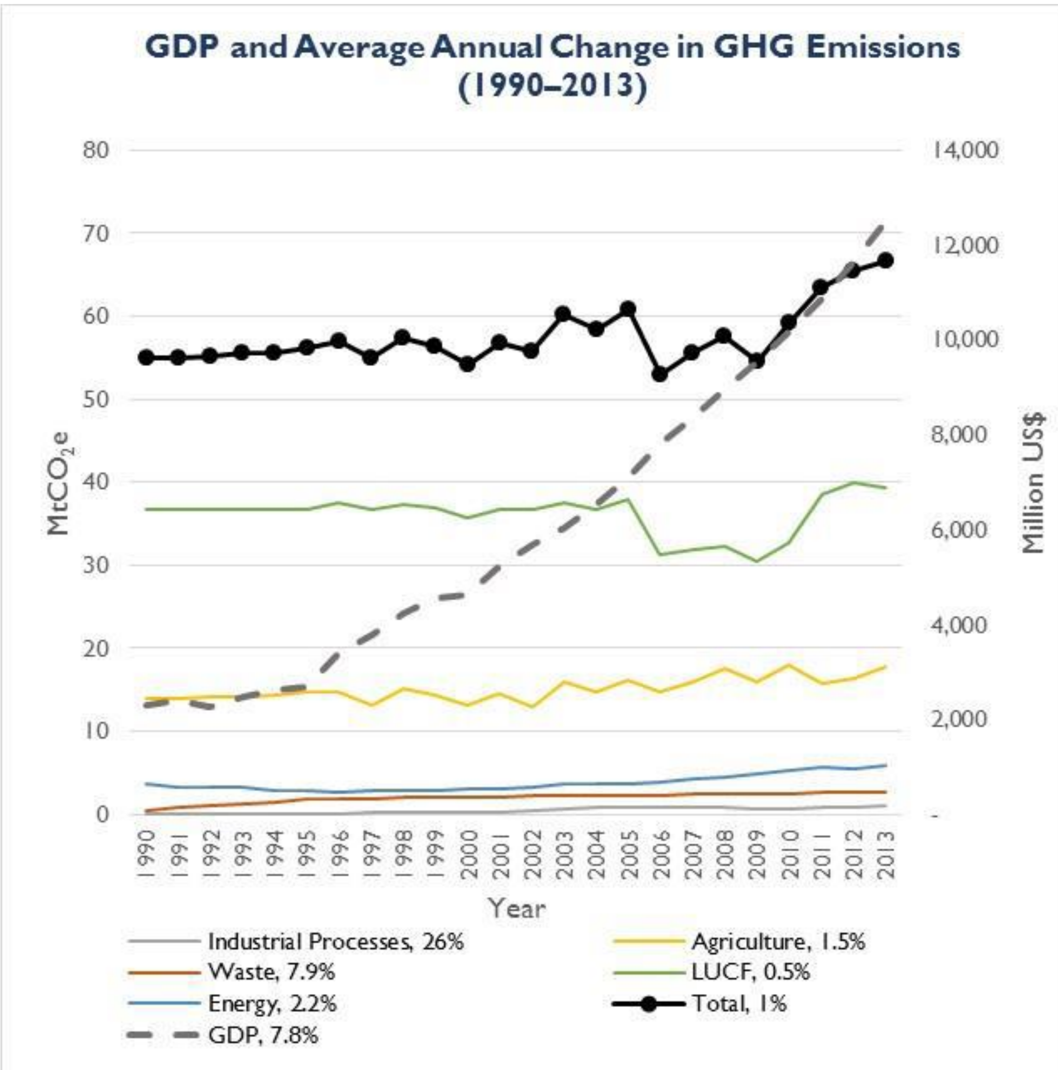

Figure 26: GDP and Average Change in GHG Emissions from 1990 to 2013 (Source: USAID, 2017).

Other important sources of GHG emissions in the agricultural sector include the increasing use of fertilizers, some management practices of soil, and agricultural cultivation practices; for example, the cultivation of rice has the greatest potential emissions of these gases (MITADER, 2015). Another important source of emissions of GHG gases is livestock production, from the production of manure, which has been showing an increasing trend, despite being far from the levels of production of the region (MITADER, 2015). Bellow, Figures 27 and 28, show the increasing trends regarding GHG emissions that are produced in the agricultural sector, including livestock production.

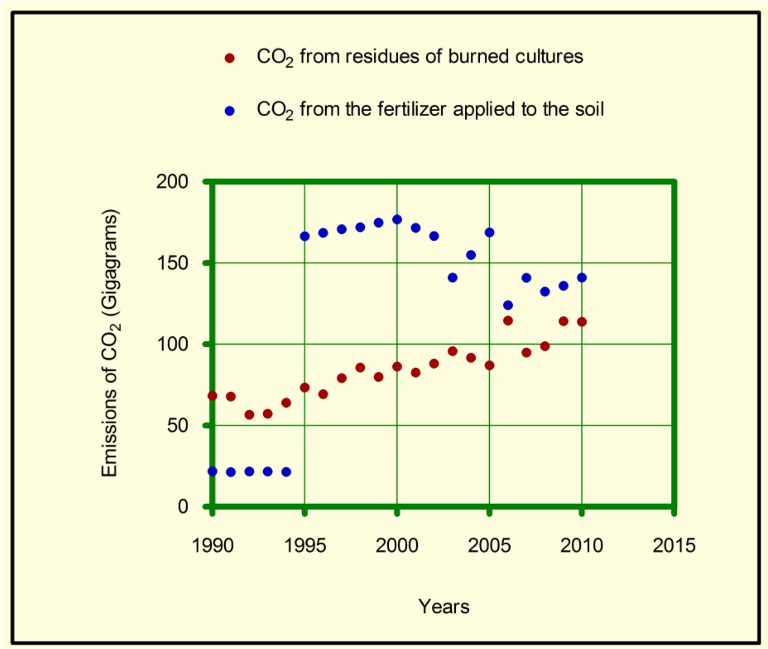

Figure 27: CO2 emissions due to burning of crop residues and forest conversion in Mozambique (source: MITADER, 2015).

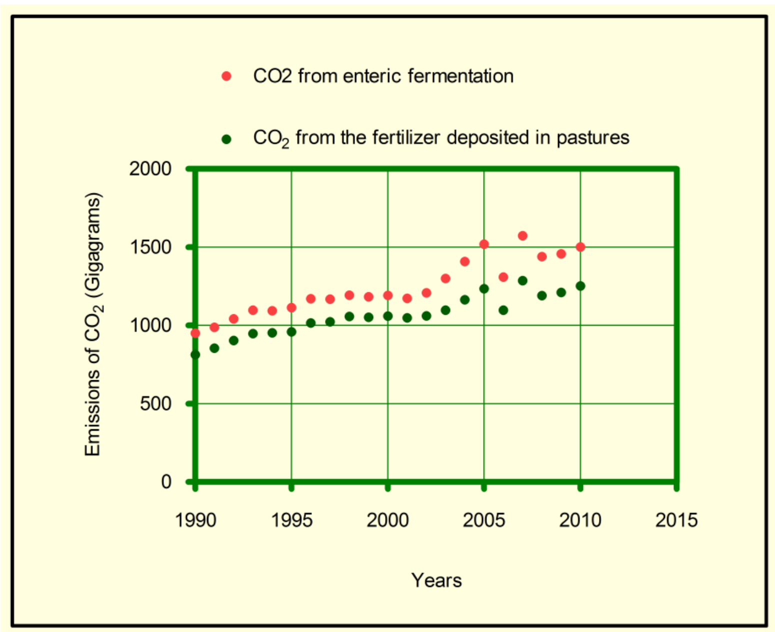

Figure 28: Trends of CO2 equivalent emissions from livestock, application of livestock manure in Mozambique (Source: MITADER, 2015).

5.3. Particulate Matter (PM) Hotspot

Ambient PM2.5 concentrations are relatively low across Mozambique (ranging from 4 mg m3 to 17–18 mg m^3; Figure 29), extremely high values during cooking times averaged with ambient PM2.5 levels for the remainder of the day's exposure result in substantially lower daily exposure estimates. This value is slightly higher than hazardous air pollutants (HAP) exposure measurements from urban charcoal use in Ghana (van Vliet et al 2013) and slightly less than half of kitchen area concentrations measured in rural homes in Malawi (Fullerton et al 2009) cited by (Anemberg *et al*., 2017).

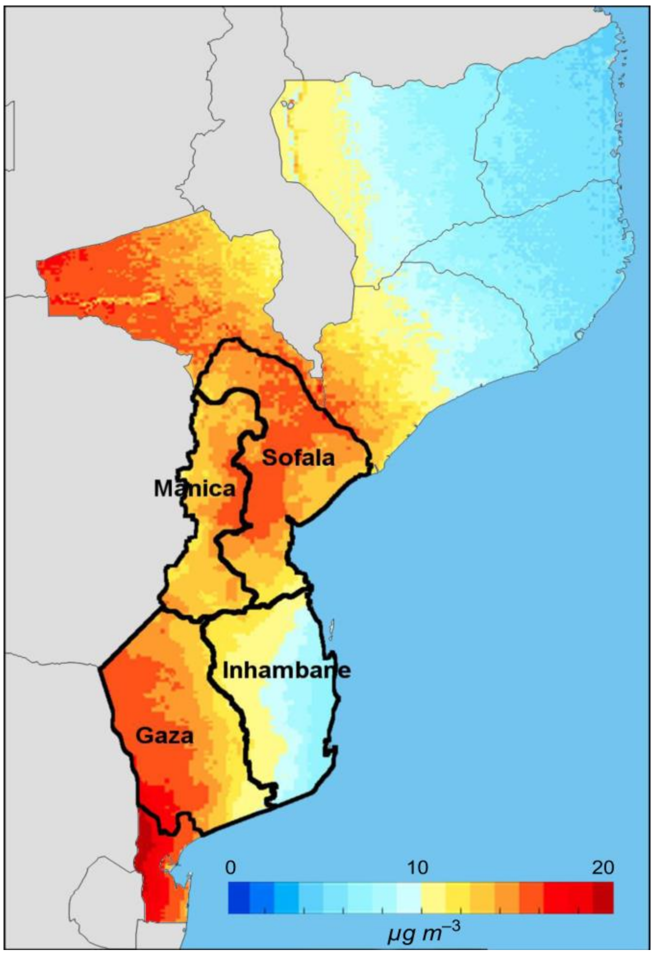

Figure 29: Satellite-derived annual average $PM_{2.5}$ concentrations in 2010 used for ambient $PM_{2.5}$ exposures, from van Donkelaar et al (2016) published in Annenberg et al (2017).

6. Impacts of Pollution in Mozambique

Research in pollution and its impact on biodiversity are still scarce in Mozambique. The existing research studies are localized and do not allow to generalize for the whole country (Ministry of Coordination of Environmental Affairs, 2014). One of the most harmful impacts of pollution is the loss of biodiversity and ecosystem services. Ecosystem services are degraded in some areas, such as Gaza, Manica, Nampula, Sofala and Tete and human well-being is threatened (Wingqvist, 2011). According to MITADER (2015), the estimates of the costs of water and air pollution represent about 260 million USD per year (or 70% of the total cost of pollution in Mozambique), representing a strong impact on depreciation of human capital in the country, in addition to the direct implications for biological diversity.

In Mozambique, the artisanal mining began secretly in 80s (with the mining company Manica Gold Mines) and then spread to the provinces of Tete, Niassa, Sofala, Zambézia and Nampula (MITADER, 2015). In Manica province, artisanal mining is causing serious environmental and health problems to miners and local communities, resulting from mishandling of mercury that is carried out during the process of amalgamation of gold and spreading it throughout the community. The average level of mercury exhaled by miner is 8.23 $\mu g/m^3$ (MITADER, 2015). Some miners have mercury levels above 50 $\mu g/m^3$ (50 times higher than the acceptable levels) (MITADER, 2015).

Besides harming human health, mercury contaminates watercourses, siltation from mining activities, what increases the presence of sold particles in the water during the operation phase (MITADER, 2015). The exploitation of gas in northern Mozambique caused the death of fish and harmful algal blooms, affecting the catching of fish by local communities. In the south, especially in Maputo province, industrial activities cause increased contaminants in watercourses, such as fluoride, which are five times above the recommended concentrations, endangering human health and environment (MITADER, 2015).

Due to burning fossil fuels during the combustion for electricity, the amount of CO_2 is rising in the atmosphere, guiding the country to the context of climate changes. In the country, regarding climate change, it is expected that the weather becomes more extreme, with periods of warmer and longer droughts and more unpredictable rainfall, increasing the risk of crop failures and droughts, floods and wildfires and causing significant changes at the level of ecosystems and species. The consequences of the increase, both in the intensity and the frequency, of extreme events (such as floods, droughts and cyclones) are themselves highly visible, resulting each year, in Mozambique, in the loss of human lives and considerable socio-economic impacts, environmental degradation including loss of natural heritage. The table below (Table 9) shows the impacts of the extreme events from 2016 to 2020.

Nevertheless, there is also a set of equally important gradual impacts of pollution, as sea level rising, coastal erosion, saline intrusion and acidification of the marine environment. Climate scenarios developed by The National Institute of Disaster Management (INGC) for Mozambique indicate that by 2075, it will register an increasing in average temperature between 1.8º C to 3.2º C, reduced precipitation between 2% to 9%, increase solar radiation between 2% to 3%, increase evapotranspiration 9% to 13% (MITADER, 2015). These changes will result in changes in terrestrial and marine biodiversity, as it can be observed in the recovering coral reefs due to bleaching phenomenon induced by the El Nino Southern Oscillation (MITADER, 2015).

Table 9: Impacts of the Extreme Weather Events during Rainy Seasons from 2016 to 2020 at Human Level (Source: Government of Mozambique, 2021).

Season	Event	Affected People	Affected Families	Injured	Deaths	Destroyed houses		Flooded Houses	Worship Locations	Health Units	Destroyed Classrooms		Affected Schools	Affected Students
						Partially	Totally				Totally	Partially		
2016-17	---	1,054,707	216,319	379	73	83,500	43,781	89,078	26	108	486	2,413	693	184,507
2017-18	Heavy rains and winds, strong winds, rains with lightning and gales	152,246	31,146	51	61	14,461	7,313	9,099	44	18	463	201	42	10,088
2018-19	Drought, rain and strong winds, sometimes accompanied by lightning. Intense Tropical Cyclones Desmond, Idai and Kenneth	2,855,417	574,361	1,872	714	153,274	146,482	30,125	1,144	138	1,801	3,109	699	445,404
2018-19	Heavy rains, strong winds, lightning and floods	195,449	40,892	68	57	11,864	6,221	44,809	89	8	---	---	---	---
	Total	4,257,819	862,718	2,370	905	263,099	203,797	173,111	1,303	272	2,750	5,723	1,434	639,999

7. Challenges and Gap Analysis

Information about environmental pollution and pollutants in Mozambique is scarce. Table 10 summarizes some data gaps verified in this report. Academic institutions usually hold published papers on pollution, whereas national government institutions and NGOs with reports may have their own repository.

Given scarcity of updated information in Mozambique, it is therefore urgent to establish a more comprehensive program for information building on pollution, so that Mozambique can have a deeper understanding of the pollutants, sources and impacts of pollution. Such information will support a more faithful and robust management plan for both species and habitats.
Mozambique has made efforts through legal and institutional reform undertaken with a view to improving the country's ability to manage the environment and control pollutants and pollution. For example, prior to installation of an industry, environmental impact assessment should be conducted, and all negative impacts should be previewed and monitored (Regulation for Environmental Impact Assessment - ESIA (Decree No. 54/2015).

Some effort to control pollution by hazardous materials is done by an industrial landfill located near the industrial area in Matola, Maputo Province (this, being the only such landfill existing in the entire Mozambique). The enforcement of the legal framework, control and inspections to verify compliance with environmental pollutants policies and legislation and site management instruments, are some challenges or barriers does the country face in controlling pollutants.
Pollutant control requires a very strict monitoring system. In Mozambique, the capacity for conducting chemical analysis is very low and there is not a strict protocol for checking the different ecosystems to verify health condition, which limit the application of the laws.

In order to increase the management and control of environmental pollutants, the country needs to increase the capacity for testing as well as on lab and technical conditions, including financial capacity. On the other hand, poor environmental literacy is one of the factors that contribute collectively to a behaviour less conducive to tackling emerging issues such as massification of waste segregation, circular economy, ocean acidification and others. Thus, there is a need to introduce environmental education from schools to communities, highlighting best practices and the need for a network/forum building to tackle pollution across Mozambique.

Table 10: Gap analysis of environmental pollution and pollutants in Mozambique.

Pollution types	**Data**		**Legislation**			
	Articles	**Reports**	**Laws**	**Regulations and Decrees**	**Monitory**	**Execution**
Air Pollution	Insufficient	Insufficient	Good	Good	Insufficient	Insufficient
Solid Waste Pollution	Insufficient	Insufficient	Good	Good	Insufficient	Insufficient
Plastic Pollution	Sufficient	Sufficient	Good	Good	Insufficient	Insufficient
Agrochemical Pollution	Insufficient	Bad	Good	Good	Insufficient	Insufficient
Mining Pollution	Insufficient	Bad	Good	Good	Insufficient	Insufficient
Sewage Pollution	Insufficient	Bad	Sufficient	Sufficient	Insufficient	Insufficient
Fuel products Pollution	Insufficient	Insufficient	Good	Good	Insufficient	Insufficient

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9. Appendices

9.1. Appendix 1: Main National Guide Instruments

Legal framework	Descriptions
Environmental Assessment	
Environmental Assessment National Environmental Policy (Resolution No. 5/95)	Provides the basis for various other environmental legislation. The instrument has been enacted to ensure sustainable development while maintaining an acceptable balance between socio-economic development and environmental protection. It stipulates that the integration of environmental considerations in socio-economic planning, the management of the country's natural resources and the protection of ecosystems are essential ecological processes.
Environmental Law (Law No. 20/97)	Establishes the basis for environmental management as a prerequisite for a country's sustainable development. In terms of scope, this applies to public and private activities directly or indirectly affecting the environment.
Regulation on the Environmental Audit Process (Decree No. 25/2011)	Relates to the need and process for an environmental audit. It indicates that an environmental audit is a documented and objective instrument for management and systematic assessment of the management system and relevant documentation implemented to ensure the protection of the environment. Its objective is to assess compliance of work and operational processes with the environmental management plan, including the environmental legal requirements in force, as approved for a particular project.
Regulation for Environmental Inspections (Decree No. 11/2006)	It governs the supervision, control, and verification of compliance with environmental protection rules in the country. It may happen that, during project implementation, MITADER carries out inspections to verify compliance with environmental legislation and site management instruments (Environmental and Social Management Plan- ESMP).

Legal framework	Descriptions
Procedures on environmental licensing (Ministerial Diploma No. 129/2006)	Stipulates the environmental license procedures, its format, and outline and contents of an environmental impact assessment report. The ministerial diploma aims to standardize the process and the procedures followed by various players in the environmental impact assessment process.
Regulation for Environmental Impact Assessment - ESIA (Decree No. 54/2015)	It defines the fundamental instruments for environmental management, the Environmental and Social Impact Assessment (ESIA), which aims at mitigating the negative impacts that certain projects, in the public and private sectors, may cause to the natural and socio-economic environment, through the undertaking of environmental studies prior to commencement of the projects. This also sets out the environmental impact assessment process, required environmental studies, public participation process, the studies review process, project environmental viability decision process, and environmental license emission.
Public Participation methodologies and procedures (Ministerial Diploma No. 130/2006)	Establishes the basic principles related to public participation, methodologies, and procedures. Considers public participation as an interactive process that initiates at the design stage and continues through the lifetime of the project. It defines that Public Participation Process (PPP) for ESIA must conform with the guidelines provided in this Ministerial Diploma.
Air quality	
Environmental law (Law No. 20/97)	Define the maximum standard of toxic substances allowed for discharge into the air. The emissions are further stipulated in Decree No. 18/2004. This law is relevant for the project given the permitted level of emissions by law, so as not to harm the environment.
Regulation for Environmental Standards and Effluent Emission (Decree No. 18/2004 (as amended by Decree No.67/2010).	Establishes parameters for the maintenance of air quality; patterns of emission of gaseous pollutants for various industries; and standards for emission of gaseous pollutants from mobile sources - including light and heavy vehicles.
Water quality	

Legal framework	Descriptions
Water quality for human consumption (Ministerial Diploma n. º180 / 2004)	Define water quality standards for human consumption and define measures for its control, to protect public health. Any project must meet water quality standards for human consumption.
Water Policy (Resolution No. 46/2007).	It provides aspects of sanitation in urban areas, peri-urban and rural areas, hydrologic networks, development of new hydraulic infrastructure, and integrated management of water resources with the participation of interested parties
Water user use (Law No. 16/91)	The policy seeks to protect ecological balance and environment.
Environmental Quality Standards and Effluent Emissions Decree No. 18/2004	Defines that when an industrial effluent is discharged into the environment, the final effluent must comply with discharge standards established. The law also incorporates the discharge of domestic effluents.
Waste management	
Pollution (Law No. 20/97)	Forbids the production and deposition of any toxic or polluting substances on soils, sub-soils, water, or the atmosphere, as well as forbidding any activities which are likely to accelerate any form of environmental degradation beyond the legally established limits.
Regulation on urban solid waste management (Decree No. 94/2014).	Establishes the legal framework for the management of municipal solid waste. The key objective is to establish rules for the production, collection, or disposal of municipal solid waste to minimize their negative impacts on health and the environment.
Regulation of Hazardous Waste management (Decree No. 83/2014)	Establishes the legal framework for hazardous waste management. The key objective is to lay down rules for the production, collection, or disposal of hazardous waste to minimize the negative impacts on health and the environment. The Regulation does not apply to (i) biomedical waste, (ii) radioactive waste, (iii) emissions and discharges of effluents, except for those containing the hazardous characteristics foreseen in Annex III of

Legal framework	**Descriptions**
	the Regulation (iv) wastewater, except for those containing the risk characteristics set forth in Annex III of the Regulation, and (v) other hazardous waste subject to specific regulations.
Land Use and Rights	
Land Policy (Resolution No. 10/95)	It sets out that the State must provide the land for each family to build or possess their habitation, and is responsible for land use and physical planning, although plans can be made by the private sector.
Land use rights (Law No. 19/1997)	Establishes the rights of land use, including details on customary rights and procedures for acquisition and use of land titles by communities and individuals. The law recognizes and protects the rights acquired through inheritance and occupation (customary rights and duties of good faith), except for legally defined reserves or areas where land has been legally transferred to another person or institution. It provides that the 15m corridor surrounding secondary and tertiary roads, and the 30m corridor for primary roads, is defined as public domain. The land use in this corridor is thus reserved for the road infrastructure.
Protection Zones (Decree No. 66/98)	It is a regulation that defines total protection areas, set aside for nature conservation and State defence, as well as partial protection areas, where land-use titles may not be granted, and where activities cannot be implemented without a license. Partial protection areas, which include, amongst others: 50m strip of land along lakes and rivers, 250m strip of land surrounding dams and reservoirs, 100m strip of land along the seafront and estuaries, a strip of 2km along the terrestrial border, applicable for the component 1, the proposed buildings can be accommodated within this particular zone. A 15m corridor surrounding secondary and tertiary roads (applicable for road construction sub-projects), and 30m corridor for primary roads, is also considered a partial protection zone and the land use in this corridor is thus reserved for the road infrastructure. There is also a 50m corridor protection for the railway lines. This regulation defines total and partial protection zones. In these zones, land use is restricted.
Territorial Planning (Decree No. 23/2008).	It establishes regulatory territorial planning measures and procedures, to ensure the rational and sustainable use of natural resources, regional potentials, infrastructure and urban centres, and to promote

Legal framework	Descriptions
	national cohesion and safety of the population. It deals with issues of procedures for expropriation of private property for national public interest reasons. The regulation provides that expropriation for territorial planning is considered to be of public interest if it aims to acquire areas to build economic or social infrastructure with great social positive impacts. Additionally, it states that expropriation should be preceded by just compensation
Cultural Heritage	
Cultural Heritage (Law No. 10/88)	This seeks to protect material and non-material assets of the Mozambican cultural heritage. Material cultural assets include monuments, groups of buildings with historic, artistic or scientific importance, places or locations (with archaeological, historic, aesthetic, ethnologic or anthropologic interest) and natural elements (physical and biological formations with particular interest from an aesthetic or scientific point of view).
Biodiversity	
Biodiversity protection (Law No. 20/97)	Covers aspects of guaranteeing the protection of biological resources, particularly of plant or animal species threatened with extinction or any similar issue, by their genetic value, ecological, cultural, or scientific, require special attention. Protection is extended to their habitats, especially those built in areas of environmental protection.
Conservation areas (Law No. 16/2014)	Stipulates that all activities that could result in changes to land and vegetation cover, or that could disturb flora, fauna, and ecological processes up to the point of compromising their maintenance, are forbidden within national parks, except if required for scientific reasons or management needs. It also indicates that activities can be approved within conservation areas, provided that a management plan is developed and approved.

Legal framework	Descriptions
Labour Safety	
The Labour Law (23/2007)	Is the main statute governing all aspects of the employment relationship?
Labour inspection (Decree nº 45/2009)	This regulation lays down the rules on inspections, under the control of the legality of work It states the employer's responsibility for the prevention of occupational health and safety risks of the employee.
Labour relations (Law Nº 23 /2007)	This law governs work relations between employers and domestic and foreign workers in all industries. The law includes principles of safety and hygiene at work.
National Climate Change Adaptation and Mitigation Strategy (NCCAMS), 2010	Establishes a clear set of strategic actions to be implemented to ensure a more prosperous, resilient and sustainable future.

9.2. Appendix 2: Pollution Case Studies

Publication Year	Number of articles/ reports	Author/s	Topic	Publisher	DOI
1995	1	Nussey, G., J. van Vuren & H. Preez	Effect of copper on the differential white blood cell counts of the Mozambique Tilapia (*Oreochromis mossambicus*)	Comparative Biochemistry and Physiology	**DOI**:10.1016/07428413(95)00064-X
2001	1	Pereira, M, D. de Abreu, A. da Costa & C. Louro	Preliminary survey of solid waste in Beaches of Southern Mozambique: Ponta Malongane	Centro de Desenvolvimento Sustentável-Ministério para a Coordenação da Acção Ambiental (CDS-MICOA)	
2004	1	Louro, C. & M. Pereira	Microbial Pollution in Maputo Bay	Centro Terra Viva	
2005	1	Godfrey, S., F. Timo & M. Smith	Relationship between rainfall and microbiological contamination of shallow groundwater in Northern Mozambique	African Journals Online	**DOI:** 10.4314/wsa.v31i4.5152
2009	1	Cannicci, S., F. Bartolini, F. Dahdouh-Guebas, S. Fratini, C. Litulo, A. Macia,	Effects of urban wastewater on crab and mollusc assemblages in equatorial	Estuarine, Coastal and Shelf Science	**DOI**:10.1016/j.ecss.2009.04.021

Publication Year	Number of articles/ reports	Author/s	Topic	Publisher	DOI
		E. Mrabu., G. Penha-Lopes, & J. Paula	and subtropical mangroves of East Africa		
2010	1	Penha-Lopes, G., S. Xavier, J. Okondo, S. Cannicci, E. Fondo, S. Ferreira, C. Macamo, A. Macia, S. Mwangi & J. Paula	Effects of Urban Wastewater Loading on Macro and Meio-infauna Assemblages in Subtropical and Equatorial East African mangroves	Western Indian Ocean Journal of Marine Science	
2011	1	Mingion, P A. Macia, A. Rosário, J. Machiwa, S. Mwangi & F. Dehairs	Tracing the fate and impact of anthropogenic pollution on epibenthic communities in East Africa mangroves: Evidence from stable isotope signatures	University of Brussels (PhD thesis)	
		Sumalgy, D.	Estimation of risks from toxic waste in the Matola Industrial Park	Master Thesis-Universidade de Coimbra	
2012	2	Fernandes, R., Chemane, A. & M. Louro	International Coastal Zone Cleaning Program 2011- Marine waste on the beaches of southern Mozambique: Miramar, Triunfo, Costa do Sol,	Report by Centro Terra Viva (CTV)	

Publication Year	Number of articles/ reports	Author/s	Topic	Publisher	DOI
			Catembe, Ponta do Ouro and Inhassoro beaches		
		Fernando, A. & S. Lima	Urban solid waste characterization in the municipality of Maxixe, Mozambique	Caminhos da Geografia	
2013	2	Nhantumbo, C.	Evaluation of Long-term Impact of Coal Mining in Zambezi River Basin in Mozambique	Lund University	**DOI:** http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=3809325&fileOId=3809328
		Penha-Lopes G., P. Fidalgo e Costa, J. Gil, M. Leal, S. Cannicci, A. Macia, S. Mwangi & J. Paula.	Effects of Sewage Discharge on Polychaete Communities in Esat African Peri-urban Equatorial and Subtropical Mangroves	Western Indian Ocean Journal of Marine Science	
2014	3	Adddo-Bediako, A., S. Marr, A. Jooste & W. Luus-Powell	Are metals in the muscle tissue of Mozambique tilapia a threat to human health? A case study of two impoundments in	International Journal of Limnology	**DOI:** 10.1051/limn/2014091

Publication Year	Number of articles/ reports	Author/s	Topic	Publisher	DOI
			the Olifants River, Limpopo province, South Africa		
		Tas, A. & A. Belon	A Comprehensive Review of the Municipal Solid Waste Sector in Mozambique	Carbon Africa Limited	
		Langa, J.	Solid waste management in Mozambique, responsibility to whom?	Revista Nacional de Gerenciamento de Cidades	https://doi.org/10.17271/231884722102014747
2015	4	Cavalcanti, W. & M. Fernandes	Comparative analysis of municipal solid waste management between the cities of Belo Horizonte (Brazil) and Maputo (Mozambique)- A documentary survey	Universidade Federal de Minas Gerais-UFMG	
		Kamau, J. P. Kuschk, J. Machiwa, A. Macia, S. Mothes, S. Mwangi, D. Munga & U. Kappelmeyer	Investigating the distribution and fate of Al, Cd, Cr, Cu, Mn, Ni, Pb and Zn in sewage-impacted mangrove-fringed creeks of Kenya, Tanzania and Mozambique.	Journal of Soils and Sediments	**DOI:** 101007s11368-015-1214-3

Publication Year	Number of articles/ reports	Author/s	Topic	Publisher	DOI
		Nhantumbo, C., R. Larsson, M. Larson & D. Juizo	Key Issues for Water Quality Monitoring in the Zambezi River Basin in Mozambique in the Context of Mining Development	Journal of Water Resource and Protection	**DOI:** 10.4236/jwarp.2015.75035
		Nhantumbo, C., R. Larsson, M. Larson, D. Juizo & K. Persson	Simplified Model to estimate the concentration of inorganic ions and heavy metals in Rivers	Water Journal	**DOI:** 10.3390/w8100453
2016	2	Sturve, J., P. Scarlet, H. Maja, K. Jenny & A. Macia	Environmental monitoring of Pesticides exposures and effects on mangrove aquatic organisms of Mozambique.	Marine Environmental Research	
		Nhantumbo, C., R. Larsson, M. Larson, D. Juizo & K. Persson	Applicability of water quality monitoring systems and models in developing countries in the context of mining development	5th International Conference on Environmental Science and Development	**DOI:** IJMAS-IRAJ-DOI-3873
		Nhantumbo, C., R. Larsson, M. Larson, D. Juizo & K. Persson	Modelling pH and alkalinity in rivers impacted by acid mine drainage	IMWA conference 2016	**DOI:** https://www.imwa.info/docs/imwa_2016/IMWA2016_Nhantumbo_167.pdf;

Publication Year	Number of articles/ reports	Author/s	Topic	Publisher	DOI
2017	6	Anenberg, D. Henze, F. Lacey, A. Irfan, P. Kinney, G. Kleiman & A. Pillarisetti	Air pollution-related health and climate benefits of clean cook stove programs in Mozambique	Environmental Research Letters	**DOI:** 10.1088/1748-9326/aa5557
		Ferrari, K., R. Gamberini, B. Rimini & H. Abacassamo	Key strategic actions to improve the challenge of hazardous waste management in Mozambique	International Journal of Sustainable Development and Planning	**DOI:** 10.2495/SDP-V11-N6-1044-1054
		Jane, A.	Wastewater Treatment and Management of Faecal Sludge in Mozambique: Current Situation, Challenges and Perspectives	Master Thesis- Instituto Supperior Técnico de Lisboa	
		Jambeck, J., B. Hardesty, A. Brooks, T. Friend, K. Teleki, J. Fabres, Y. Beaudoin, A. Bamba, J. Francis, A. Ribbink, T. Baleta, H. Bouwman, J. Knox e C. Wilcox	Challenges and emerging solutions to the land-based plastic waste issue in Africa	Marine Policy	https://doi.org/10.1016/j.marpol.2017.10.041

Publication Year	Number of articles/ reports	Author/s	Topic	Publisher	DOI
		Nhantumbo, C.	Sustainable Water Quality Monitoring for Developing Countries in the Context of Mining	Monitoring systems and modelling	**DOI:** http://lup.lub.lu.se/search/ws/files/25112810/Thesis_Clemencio_Nhantumbo.pdf
		Sallwey, J., H. Hettiarachchi & S. Hulsmann	Challenges and opportunities in municipal solid waste management in Mozambique: a review in the light of nexus thinking	Environmental Science	**DOI:** 10.3934/environsci.2017.5.621
		USAID- United States Agency International Development	Greenhouse Gas Emissions in Mozambique	USAID	
2018	5	Arsenio, A., I. Salim, M. Hu, N. Matsinhe, R. Scheidegger, L. Rietveld	Mitigation Potential of Sanitation Infrastructure on Groundwater Contamination by Nitrate in Maputo	Sustainability	**DOI:**10.3390/su10030858
		Genthe, B., T. Kapwata, W. Roux & J. Chamier	The reach of human health risks associated with metals/metalloids in water and vegetables along a	Chemosphere	https://doi.org/10.1016/j.chemosphere.2018.01.160

Publication Year	Number of articles/ reports	Author/s	Topic	Publisher	DOI
			contaminated river catchment: South Africa and Mozambique		
		Mafavisse, I.	Mapping and control strategy of potentially polluting anthropic loads from coal mining in Moatize, Mozambique	PhD Thesis- Universidade Estadual Paulista	
		Nhantumbo, C., R. Larsson, M. Larson, D. Juizo & K. Persson	A Simplified Model to Simulate pH and Alkalinity in the Mixing Zone Downstream of an Acidic Discharge	Mine Water and the Environment	https://doi.org/10.1007/s10230-018-0515-3
		Tvedten, I. &S. Candiracci	Flooding our eyes with rubbish: urban waste management in Maputo, Mozambique	Environmental & Urbanization	https://doi.org/10.1177/0956247818780090
2019	3	Capone, D., Z. Adriano, D. Berendes, O. Cumming, R. Dreibelbis, D. Holcomb, J. Knee, I. Ross & J. Brown	A localized sanitation status index as proxy for faecal contamination urban Maputo, Mozambique	PLoS One	**DOI:** 10.1371/journal.pone.0224333
		Innocent, S. & G. Thomas	Pollution status of Incomati River Estuary Based on Meiofauna Analyses (Free-living Nematodes) in Maputo, Mozambique	Journal of Water Resources and Ocean Science	**DOI:** 10.11648/j.wros.20190805.12

Publication Year	Number of articles/ reports	Author/s	Topic	Publisher	DOI
		Weststrate, J., A. Gianoli, J. Eshuis, G. Dilkstra, I. Cossa & M. Rusca	The regulation of onsite sanitation in Maputo, Mozambique	Utility Policies	https://doi.org/10.1016/j.jup.2019.100968
2020	5	Dos Muchangos, L. & A. Tokai	Greenhouse gas emission analysis of upgrading from an open dump to a semi-aerobic landfill in Mozambique- the case of Hulene dumpsite	Scientific African	https://doi.org/10.1016/j.sciaf.2020.e00638
		Gani, A., O. Aderoju, A. Dias &A. Monjane	Improving the attitude and reaction towards municipal solid waste management in Mozambique	Waste Management and the Environment	**DOI:** 10.2495/WM200051
		Holcomb, D., J. Knee, T. Sumner, Z. Adriano, E. de Bruijn, R. Nalá, O. Cumming, J. Brown & J. Stewart	Human faecal contamination of water, soil and surfaces in households sharing poor-quality sanitation facilities in Maputo, Mozambique	International Journal of Hygiene and Environmental Health	https://doi.org/10.1016/j.ijheh.2020.113496
		Nhantumbo, C., E. Pondja, D. Juizo, A. Cumbane, N. Matsinhe, B. Paqueleque, M. Uamusse, G. França & P. Paron	Effect of Mining to Water Quality in Chua and Revué Rivers, Mozambique	IMWA	**DOI:** **https://www.imwa.info/docs/imwa_2020/IMWA2020_Nhantumbo_57.pdf**

Publication Year	Number of articles/ reports	Author/s	Topic	Publisher	DOI
		Pucino, M., J. Boucher, A. Bouchet, P. Paruta & M. Zgola	Plastic Pollution Hotspotting and Shaping Action: Regional Results from Eastern and Southern Africa, the Mediterranean, and Southeast Asia	IUCN	
		Ricolfi, L., M. Barbieri, P. Muteto, A. Nigro, G. Sappa & S. Vitale	Potential toxic elements in groundwater and their health risk assessment in drinking water of Limpopo National Park, Gaza Province, Southern Mozambique	Environ Geochem Health	https://doi.org/10.1007/s10653-019-00507-z(0123456789().,-volV()0123456789().,-volV)
		Sumbana, J., J. Sacarlal & S. Rubino	Air pollution and other risk factors might buffer COVID-19 severity in Mozambique	The Journal of Infection in Developing Countries	**DOI:**10.3855/jidc.13057
		Tamele, I. & V. Vasconcelos	Microcystin incidence in the drinking water of Mozambique: Challenges for public health protection	Toxins	**DOI:** 10.3390/toxins12060368
2021	8	Castigo, P., F. Costa-Nobre & E. Welengane	Evaluation of the effectiveness of the application of *Ochroma pyramidae*	Research, Society and Development	http://dx.doi.org/10.33448/rsd-v10i16.23211

Publication Year	Number of articles/ reports	Author/s	Topic	Publisher	DOI
			leaves in the gravity concentration of gold in the Alto Revué sub-basin		
		Capone, D., A. Bivins, J. Knee, O. Cumming, R. Nalá & J. Brown	Quantitative Microbial Risk Assessment of Paediatric Infections Attributable to Ingestion of Faecally Contaminated Domestic Soils in Low-Income Urban Maputo, Mozambique	Environmental Science & Technology	https://doi.org/10.1021/acs.est.0c06972
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			Reduction factor analysis of plastic waste in aquatic environment- National analysis of marine litter in Mozambique		
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9.3. Appendix 3: Abbreviations and Acronyms

Al- Aluminum

ANAC- National Administration of Conservation Areas

ARA- Regional Water Administration

As- Arsenic

ASCLME-

BIOFUND- Foundation for the Conservation of Biodiversity

Cd- Cadmium

CH_4- Methane

Co- Cobalt

CO- Carbon Monoxide

CO_2- Carbon Dioxide

Cr- Chromium

Cu- Cooper

DDT- Dichloro-diphenyl-trichloroethane

ESIA- Environmental and Social Impact Assessment

EMODRAGA- Empresa Moçambicana de Dragagens

Fe- Iron

FRELIMO- Frente de Libertação de Moçambique

JNCC- Joint Nature Conservation Committee

GDP- Gross Domestic Product

GHG- Greenhouse Gases

Ha- Hectares

HAP- Hazardous Air Pollutants

HDPE- High-density Polyethylene

IBA- Important Bird Areas

INE- Instituto Nacional de Estatística

INGC- National Institute of Disaster Management

IP- Industrial Process

IPCC- Intergovernmental Panel on Climate Change

IUCN- International Union for Conservation of Nature

LDPE- Low-density Polyethylene

LUCF- Land Use Change Forest

MICOA- Ministry of Co- Ordination of Environmental Affairs

MIMAIP- Ministry of Sea, Interior Waters and Fisheries

MoA - Memorandum of Agreement

MSW- Municipal Solid Waste

MTA- Ministry of Land and Environment (ex- MITADER)

$MtCO_2$- Metric tons of carbon dioxide

MWI- Mismanaged Waste Index

NE- Northeast

NGOs- Non-Governmental Organizations

Ni- Nickel

NMVOC- Volatile Organic Compounds

NO_x- Nitrogen Oxides

N_20- Nitrous Oxides

ODA - Development Assistance Countries

Pb- Lead

PET- Polyethylene Terephthalate

PM- Particulate Matter

PP- Polypropylene

PS- Polystyrene

PVC- Polyvinyl Chloride

SDG's- Sustainable Development Goals

SE- Southeast

SO_2- Sulphur Dioxide

Sr- Strontium

SW- Southwest

UEM - Eduardo Mondlane University

UN- United Nations

UNEP- United Nations Environment Programme

USAID- United States Agency International Development

WCS- Wildlife Conservation Society

WRI CAIT- World Resources Institute Climate Analysis Indicators Tool

Zn- Zinc

Zr- Zirconium