Pollution and Anthropogenic Pressures Affecting Ecosystems

Sousse Scale, Tunisia

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Co-Evolve4BG

Analysis of Threats and Enabling Factors for Sustainable Tourism at Pilot Scale

Pollution and Anthropogenic Pressures Affecting Ecosystems

Sousse scale, Tunisia

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OVERVIEW

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REVIEW

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Abstract

Pollution in Sousse is primarily caused by human activities, including urbanization, industrial processes, and the tourism sector. The rapid expansion of tourist infrastructure has increased pollution concerns, leading to the conversion of natural landscapes and improper waste disposal. Vulnerable coastal areas, such as Oued Hamdoun, are susceptible to thermal, organic, and mineral pollution. Poor waste management practices along rivers and coastlines further exacerbate the issue.

Pollution negatively impacts ecosystems and socio-economic sectors, causing habitat degradation, reduced biodiversity, and declining water quality. The tourism sector, a major economic contributor, faces difficulties due to polluted beaches deterring tourists and affecting local revenue streams and visitor experiences.

Sousse has introduced policies to mitigate pollution, including waste management improvements, sewage treatment enhancements, and stringent environmental regulations. Collaborative efforts and organized clean-up initiatives enhance the tourism experience. The Blue Economy concept, which focuses on waste reduction, clean energy adoption, advanced wastewater treatment, eco-friendly transportation, and circular economy principles, can help minimize pollution and promote sustainable development.

To ensure sustainable development in the Sousse region, a strong coordinating function is needed, including the development of new tools like Integrated Coastal Areas Management, Marine Spatial Planning, Marine Protected Areas, and incorporating blue economy principles into existing regulatory frameworks.

I. Introduction

The coastal ecosystems in tourist zones of Sousse are facing a myriad of pollution and anthropogenic pressures, posing significant challenges to their well-being and long-term sustainability. One of the most pervasive issues is coastal pollution, resulting from the discharge of sewage, industrial waste, and agricultural runoff into the coastal waters. As a consequence, water quality is compromised, adversely affecting marine life and the health of coastal habitats. Moreover, the improper disposal of waste, especially by tourists, contributes to the accumulation of marine litter along the coastline, posing threats to marine organisms through ingestion and entanglement.

Another pressing concern is beach erosion, which is accelerated by coastal development and construction activities associated with the booming tourism industry. The alteration of natural sediment flow disrupts the delicate balance of beach ecosystems, leading to shoreline retreat and habitat loss. Overfishing is yet another anthropogenic pressure, driven by the demand for seafood in tourist hotspots.

Climate change exacerbates these issues, as rising sea levels and ocean acidification further stress the already vulnerable ecosystems. Extreme weather events, attributed to climate change, also take a toll on the coastal habitats in Sousse.

The rapid expansion of tourism infrastructure and coastal development often comes at the expense of critical habitats like mangroves, seagrass beds, and dunes, contributing to habitat destruction and fragmentation. Furthermore, tourism-related activities inadvertently introduce non-native species to the area, causing disturbances and potential harm to native ecosystems.

To safeguard the ecological integrity of the coastal ecosystems in Sousse, it is imperative to address these pollution and anthropogenic pressures comprehensively. Implementing effective management and conservation strategies, as well as promoting sustainable tourism practices, is essential to ensure the preservation of these valuable natural habitats for the benefit of both the environment and the tourism industry.

This report will cover the following parts:

- Main ecosystem coastal services in Sousse .
- Coastal hotspots according to their vulnerability.
- Impact of Coastal/Maritime tourism on environment in Sousse.
- Policies and efforts made to manage pollution in Sousse and their effects on the Coastal/Maritime tourism sector.
- Blue Economy.

II. Ecosystem services in Sousse

II.1. Presentation of Ecosystem services in general

An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit. The conceptual framework for the Millennium Ecosystem Assessment (MA) assumes that people are integral parts of ecosystems and the Report focuses on examining the linkages between ecosystems and human well-being and in particular on 'ecosystem services', which are the benefits that people obtain from ecosystems. (Figure 1)

Ecosystem services include: (UNEP, 2006)

- **Provisioning services** such as food, water, timber, and fiber;
- **Regulating services** such as the regulation of climate, floods, wastes and water quality;
- **Cultural services** such as recreational, aesthetic, and spiritual benefits; and
- **Supporting services** such as soil formation, photosynthesis, and nutrient cycling.

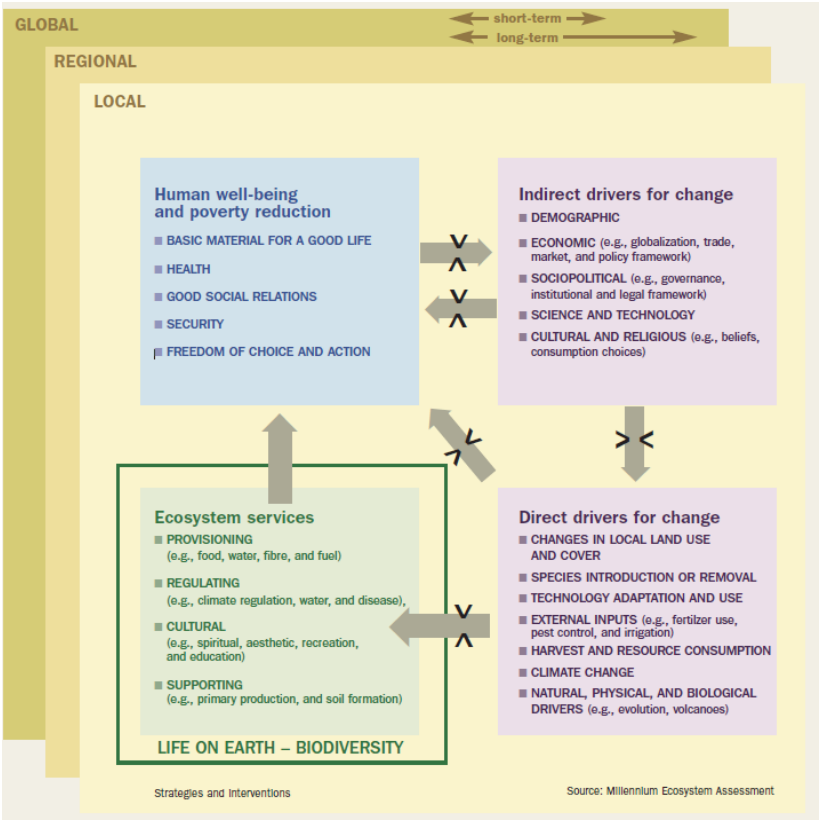

Figure 1. Interaction among biodiversity and ecosystem services (UNEP, 2006)

II.2. Presentation of Coastal Ecosystem services

People are dependent on coasts and their resources for their survival and well-being. Marine and coastal ecosystems provide a wide range of services to human society, including food provision, natural shoreline protection against storms and floods, water quality maintenance, support of tourism and other cultural and spiritual benefits, and maintenance of the basic global life support systems (Figure 2). The effects of coastal degradation and a loss of these services are felt inland and often a long way from the coast.

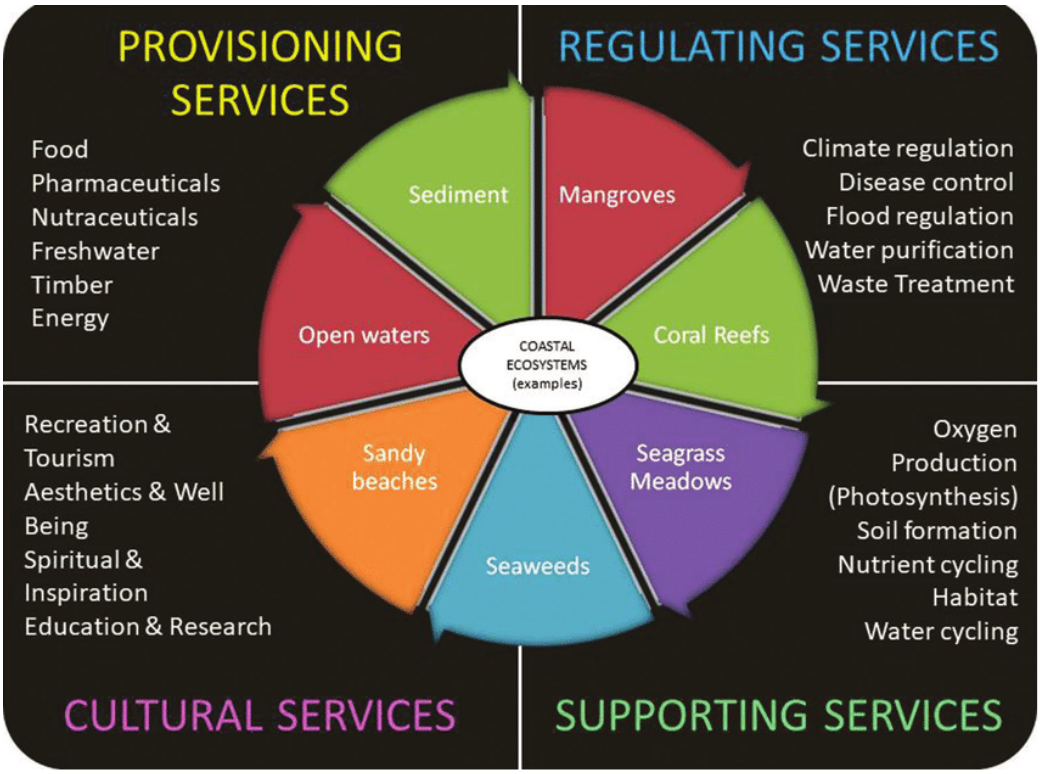

Figure 2. Ecosystem Services provided by Coastal Ecosystems. (Lakshmi Ahana, 2021).

Ecosystem services are the conditions and processes through which natural ecosystems, and the species that form them, sustain and fulfill human life. Globally, coastal and marine natural resource systems are important for delivering various critical provisioning (food…), cultural (spiritual function,..), supporting (pollination,..), and regulatory (carbon sequestration,..) services for human well-being, mostly within one hundred kilometers of the coast (Lakshmi Ahana, 2021). As such, the ecosystem services (ES) concept has become an essential tool for connecting ecosystems to human well-being. To make decisions in a wide range of contexts, understanding this relationship is crucial. Although, the importance of coastal and marine ecosystem services is now well-established, these services and service-producing ecosystems are facing increasing

pressures and threats, mostly due to human activities. For example, about 50% of salt marshes, 35% of mangroves, 29% of seagrasses, and 30% of coral reefs of the world have either been degraded or lost globally.

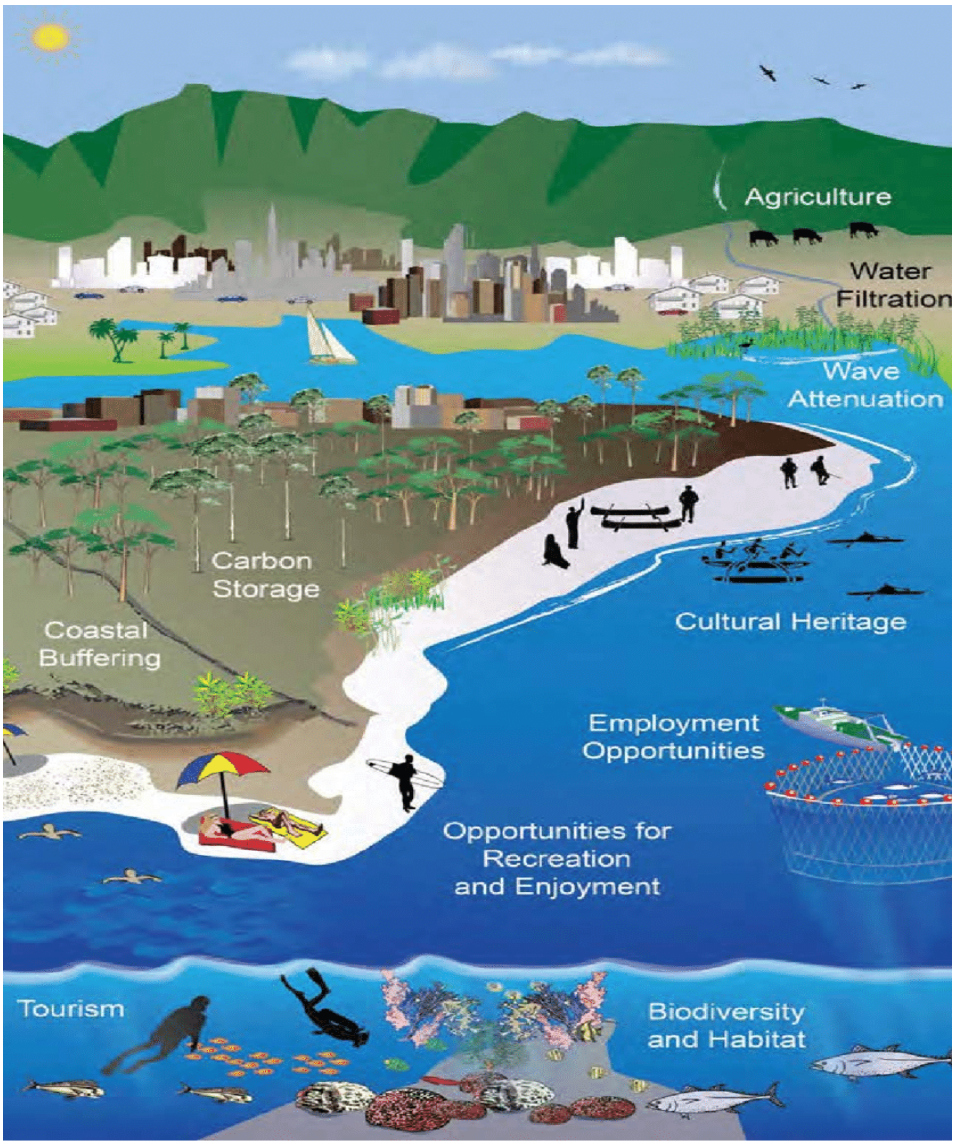

Figure 3. Coastal ecosystem services (Swiderska Krystyna et al., 2018).

II.3. Description of Coastal ecosystem services in Sousse

Sousse is a popular tourist destination known for its beautiful beaches, historical sites, and vibrant culture. The city attracts a significant number of domestic and international tourists each year. The main touristic areas in Sousse include the Medina, a UNESCO World Heritage site, and Port El Kantaoui, a modern resort area with marinas, hotels, and golf courses. These touristic zones are characterized by a mix of urban development and natural landscapes, making them susceptible to environmental challenges.

The touristic areas in Sousse are home to diverse ecosystems services, each contributing to the region's ecological balance and aesthetic appeal. The coastal zones boast sandy beaches, rocky shores, and seagrass meadows, providing habitat for various marine species, including fish, crustaceans, and seabirds. The clear waters also support marine biodiversity, including coral reefs, which are crucial for coastal protection and tourism attractions like snorkeling and diving.

Inland, Sousse features a blend of semi-arid landscapes, agricultural areas, and small pockets of natural vegetation. These ecosystems support a range of flora and fauna, some of which are endemic or endangered species. Additionally, wetland habitats, such as lagoons and estuaries, play a vital role in supporting migratory birds and acting as nurseries for fish species.

The development of touristic infrastructure, however, poses a significant threat to these ecosystems. Unplanned construction and land-use changes can lead to habitat loss and fragmentation, impacting wildlife movement and overall ecological connectivity.

The delicate balance between urbanization and conservation in Sousse necessitates careful environmental management to preserve the region's biodiversity and sustain its appeal as a tourist destination.

The Sousse region is one of the most biodiverse regions in the Tunisian sahel, and its ecosystems provide essential ecological services for human well-being at local, national and global scales. Nevertheless, it is faced to important land cover change over this decade (Boussema & Allouche, 2020).

The region of Sousse is characterized by a Mediterranean climate, belonging to the lower semi-arid bioclimatic stage of the lower steppes of the north. The general average rainfall in Sousse region calculated for the period between 2007 and 2017 is in the order of 258.5 mm and; the annual average temperature is in the order of 18.6 C.

The region of Sousse is known by the diversity of its landscapes: forest, coastline, rural, urban, industrial, and natural, but strongly linked to the variation of the environments that make up it. Indeed, it is marked by natural sites characterized by the striking singularity of their composition and their richness enhanced by the coastal and marine fauna and flora.

II.3.1. Sites of ecological richness in Sousse region

Coastal ecosystems in Sousse, such as wetlands and seagrass beds, help regulate water quality by filtering pollutants and nutrients from runoff and discharges, enhancing the health of coastal waters.

Sousse's picturesque beaches and clear waters attract tourists, providing opportunities for swimming, sunbathing, and beach-related activities. This contributes significantly to the local economy through tourism revenue and job creation. (Figure 4, Boussema et al., 2023)

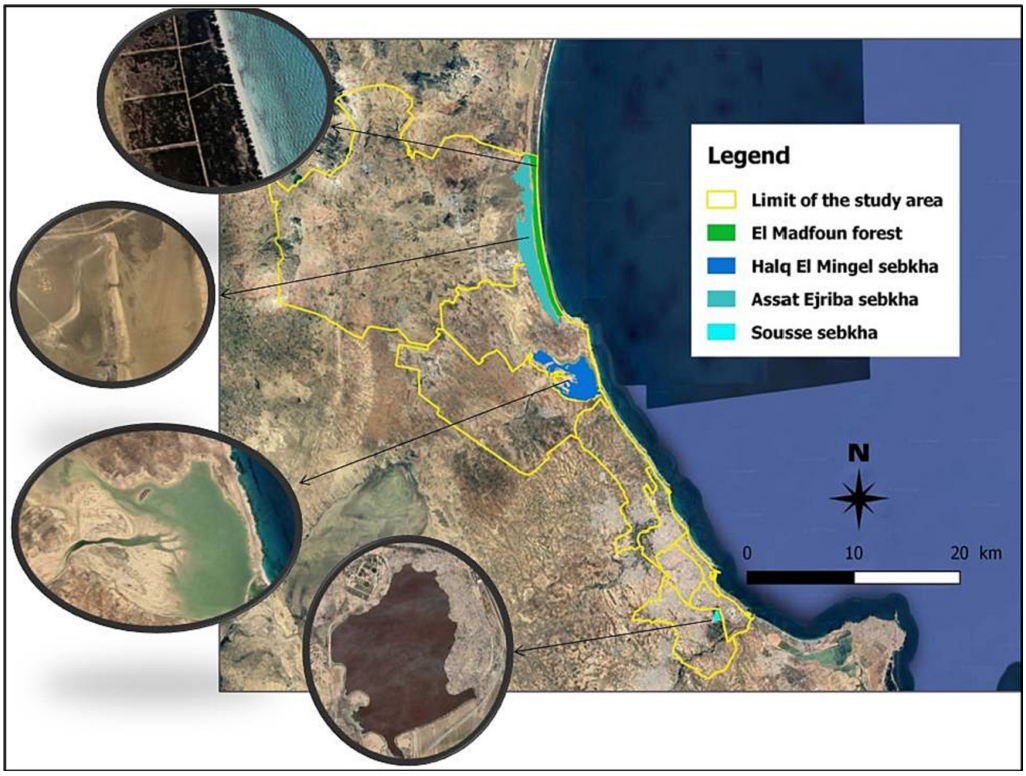

Figure 4. Distribution map of ecological sites in the Sousse region (@Google Earth, 2022).

- **Coastal Area**

This fragile zone faces multiple issues, the most severe of which are the complete destruction of dunes, excessive urban expansion at the expense of the DPM, and the discharge of treated and warm waters. These issues are responsible for the degradation of seawater quality and the destruction of marine ecosystems in several areas. The coastal area stretching between the commercial port and Sidi-Abdelhamid is particularly affected by this problem due to the disposal of solid and liquid waste into the sea.

- **Riverbeds**

The governorate of Sousse is crossed by several riverbeds, the most significant of which are Oued Laya, Oued Blibène, Oued Hamdoun, and Oued Hallouf. The inhabited regions along these riverbeds have been developed into tourist zones and upscale residential areas. However, these riverbeds have now become anarchic dumping grounds and even spaces for discharging treated and untreated wastewater and waste by-products. This has led to the proliferation of insects and the spread of foul odors, particularly in neighborhoods, significantly altering the environment.

- **El Madfoun forest**

The forest extends over 21 km along the coast, between Hergla and Salloum, with a variable width of 50 to 500 m, and occupies an area of about 450 ha (DGF, 2018). According to Hamdaoui (2015), this forest is one of the rare coastal forests in the country and constitutes a regional lung, a reserve of fauna and flora, a fixative element of the coastal dunes, and a distributor of a microclimate by its role of protecting the winds and through its influence on various climatic processes. .(Boussema Safa et al., 2023)

- **Halq El Mingel sebkha**

Since 2006, the site has been classified as a Ramsar site according to the Ramsar Convention' or 'Wetlands Convention' adopted in Ramsar, Iran in February 1971 (Boussema et al., 2020a). This sebkha is located from 25 km northwest of Sousse city, its permanent

surface is 1450 ha and it can reach 2050 ha during wet periods. It is divided into two parts; a northern part where the water is periodic and a southern part where the water is permanent. This segmentation is due to the road linking SidiBou Ali to Hergla which interrupts the exchange of water between the two parts. (Boussema Safa et al., 2023).

- **Assat Ejriba sebkha**

This sebkha is located on the north of the city of Hergla, it is limited to the east by the El Madfoun forest and the Mediterranean Sea, to the west by the Enfidha airport, to the north by the sebkha of Sidi Khalifa. It extends over 25 km from the north of Hergla to Bouficha with a variable width of 1 to 2 m. It is widely filled in rainy season and dry in summer; sheltering a multitude of fauna and flora. (Boussema Safa et al., 2023).

- **Sousse sebkha**

The sebkha is located in the south of Sousse city, and occupies an area of 62 ha. It is well located in an urban environment and close to the industrial area of Sidi Abdelhamid. It is a very fragile ecosystem which has become increasingly degraded, according to Ajimi (2019). Nevertheless, this ecosystem still represents an ecological potential that must be developed in order to restore and preserve the environmental quality of this area and restore the natural

functions of the sebkha. (Boussema Safa et al., 2023).

II.3.2. Urban Environment and green spaces

The governorate of Sousse includes two urban parks developed by the Ministry of Environment:

- **Hamada Douik Park**: Located in the city of Sousse, it covers 10.5 hectares. The project was completed in 2009, but the park is currently neglected.
- **Errihane Park:** Situated in the municipality of Ezzouhour (Sousse Erriadh), it spans 3.5 hectares. The development plan includes children's play areas, two petanque courts, family spaces, and green zones.

In addition to these two parks, most municipalities have established environmentally dedicated avenues. This program involved planting various types of vegetation adapted to the natural characteristics of the governorate along many avenues, as well as setting up urban amenities such as public benches, lighting, and waste bins. The development of urban parks, environmental avenues, gardens, and fitness trails has not only contributed to improving the urban environment of the governorate's municipalities but has also increased the number of green spaces per inhabitant, from 5.7 m² per inhabitant in 1995 to 15.2 m² per inhabitant in 2011 (Table 2). Nevertheless, this indicator varies by municipality. For instance, the two delegations of Sidi El Hani and Enfidha present a high green space indicator (35 m² per inhabitant), although this indicator does not reflect the quality of the development and equipment of these areas. On the other hand, other municipalities with an indicator below 15 m² per inhabitant lack green spaces. This is notably the case for the municipalities of Sousse, Kalaâ Kébira, Sidi Bou Ali, M'Saken, Kalaâ Sghira, Ezzaouia, and Ezzouhour (DGAT, 2011).

Table 1. Indicator of the area of green spaces/inhabitants (Atlas, 2021)

Delegation	m² of space
Sousse	14.33
Hammam Sousse	21.11
Akouda	15.82
Kalaâ Kebira	8.02
Sidi Bou Ali	13.86
Hergla	24.5
Enfidha	35.37
Bouficha	21.38
Kondar	15.11
Sidi El Hèni	35.86
M'saken	14.8
Kalaâ Séghira	14.54
Zaouia Sousse	14.45
Ezzohour	11.63
Messadine	16.23
Kendar	15.11
Ksiba Thrayet	20.52

II.3.3. Protecting Tunisia's coastal landscape

Over the years, the beach in Hammam Sousse had been washing away metre by metre; the waves crept closer all the time. But today, a sandy, white strip of shoreline sprawls along the coast in Hammam Sousse. There are now about 30 metres of land between the "Dreams Beach" hotel and the water again. "The tourists benefit from coastal protection, the beach has been rebuilt in the Tunisian seaside town of Hammam Sousse. The Tunisian coastal protection agency APAL supervises the extensive Tunisian coastal protection project.

APAL rebuilt the beach in Hammam Sousse by creating submarine breakwaters. They prevent coastal erosion and allow more sand to collect on the beach. This is one of the methods that Tunisia is using with KfW's support to stabilise its Mediterranean coastline, which is threatened by erosion. The first three phases of the project have cost close to 38 million euros. It began in 2013 and, thus far, the Tunisian government has financed 25 per cent and KfW has financed 75 per cent with grants and loans on behalf of the German Federal Government. In light of rising sea levels, the programme also has the objective to "increase the adaptability of the Tunisian coastal landscape to climate change.

Tunisia's Mediterranean coastline is around 1,100 kilometres long. Just over ten per cent of the coastline is considered severely threatened by erosion. That could have devastating consequences for Tunisia, as the coastal regions are the demographic and economic backbone of the country. Nine of the country's ten largest cities are on the coast; two thirds of the eleven million Tunisians live here. They are responsible for 90 per cent of the country's total economic output. (Seaside) tourism accounts for around seven per cent of the gross domestic product.

Null Over ten per cent of Tunisia's Mediterranean coastline is under severe threat of erosion.

As part of the Paris Agreement, Tunisia declared coastal protection as one of its focus areas to combat climate change. The government anticipates that the level of the Mediterranean Sea will rise by up to half a metre by 2050, resulting in the loss of half a per cent of the gross domestic product per year if they do not tackle the threat.

Robust shorelines can withstand rising waters and thus protect densely populated areas and economic centres from flooding. Seawater that makes its way further inland also diminishes the drinking water supply, as it increases the salinity of the land and ground water.

In addition to submarine breakwaters like those in Hammam Sousse, APAL is also using other methods to defy the waves. For example, over a stretch of four kilometres so far, they have used fences made from pinewood to stabilise the dunes, which act as a natural protective barrier.

Figure 5. APAL stabilised the dunes with measures such as fences made from pinewood.

II.3.4. Climate Change and carbon sequestration

Climate change is one of the major environmental issues affecting the entire national territory. Most studies on this subject have demonstrated that the Mediterranean South region is the most affected and will become increasingly sensitive. The main effects of these phenomena include rising temperatures, reduced average precipitation, and sea level rise. In this context, the Ministry of Environment has implemented a range of strategies to mitigate the undesirable effects of this phenomenon:

- Adaptation strategy for the agricultural sector and various ecosystems to climate change.
- Strategy and action plan for coastal zone adaptation to rising sea levels.
- Adaptation strategy for the health sector to climate change.
- Adaptation strategy for the tourism sector to climate change.
- Strategy for establishing an alert system for the protection against various natural phenomena.
- Preparation of an action plan and projects that consider the climate change factor.

More important, Coastal vegetation, including mangroves and dunes, contributes to carbon sequestration by capturing and storing carbon dioxide from the atmosphere. This helps mitigate climate change by reducing greenhouse gas concentrations.

II.3.5. Energy and Climate Diagnosis

The energy diagnosis and greenhouse gas emissions assessment of the city of Sousse provide an initial overview of the energy-climate profile of the territory and identify the most emitting sectors. This diagnosis helps pinpoint the most significant energy-saving opportunities and prioritizes sectors (Figure 6).

The inventory reveals that CO_2 emissions within the city's perimeter amount to 492,808 tCO_2, equivalent to 2.2 tCO_2 per inhabitant. The per capita emission in Sousse remains lower than the national average of around 3.6 tCO_2 per inhabitant (the figure of 2.2 tCO_2 per inhabitant, however, represents CO_2 emissions related solely to energy consumption). The transportation sector is the largest emitter, accounting for 34% of emissions in the municipal area. Following that are the residential and industrial sectors, each contributing 25% of the emissions. The following graph illustrates the emission distribution by sector (Commune de Sousse, 2012).

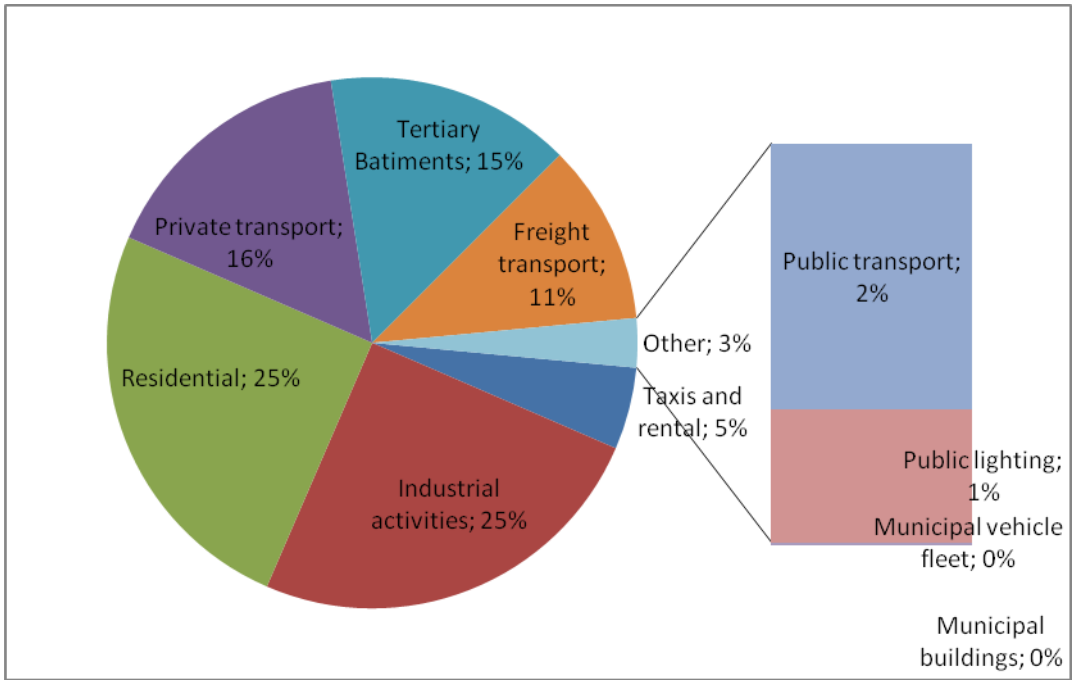

Figure 6. Greenhouse gas emissions distribution by sector in Sousse

Moreover, several programs and projects that have already been implemented help alleviate the adverse effects of this problem, such as protecting coastal zones from marine erosion, safeguarding and managing forest areas, using treated wastewater to ease pressure on water resources, and combating desertification.

II.3.6. Aquaculture

The governorate of Sousse has 5 aquaculture companies: 4 of them use submerged cages in the sea, and only one company operates water basins. Although this sector is important, it presents several environmental problems due to:

- The lack of an evaluative study of aquaculture projects in the governorate of Sousse and the carrying capacity of its coastline.
- The increasing demand in the aquaculture sector, which could significantly affect the marine ecosystem, the socio-economic environment of the governorate, and the activities of small fishermen.
- Fisheries and Livelihoods: The coastal waters of Sousse support local fisheries, providing a source of livelihood for fishing communities. The seafood caught in these waters contributes to the food security and income of local residents.

II.3.7. Solid Waste Management

The governorate of Sousse has only one controlled landfill located in the city of Sousse (Oued Laya) and 4 waste transfer centers. The landfill's capacity is 220 000 tons (Table 2).

Table 2. Evolution of waste flows in urban landfills (by landfill category/size)

Waste (kt)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Sousse	164	139	154	154	164	164	164	164	172	181	189
Total	1 555	1 355	1 407	1 268	1428	1398	1398	1398	1467	1539	1615
Waste (kt)	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	
Sousse	198	206	216	225	235	245	255	265	276	288	
Total	1686	1760	1837	1918	2002	2086	2172	2262	2356	2454	

The quantities managed by recycling companies amount to 191,332 tons. As for the transfer centers, they are situated in the delegations of Ezzouhour, Kalaâ Sghira, Bouficha, and Enfidha. However, the insufficient number of these centers has led to the proliferation of illegal dumping sites, further exacerbating environmental pollution.

II.3.8. Air Quality Monitoring

This issue results from toxic emissions from industrial establishments such as power plants and gas facilities, in addition to carbon dioxide emissions from various means of transportation. In this context, a fixed air quality monitoring station has been installed in Sousse by the National Agency of Environment Protection (ANPE) (Bouchlaghem et al., 2012).

The assessment and monitoring of air quality are carried out by this fixed station located at the Farhat Hached Hospital. In the urban station of Sousse (ANPE), the PM_{10} annual average (58 μg/m^3) and the number of exceedances (188 days per year) of the limit value are higher than those of the European Directive. By looking to the origin of air masses using the aerosol maps, we remark that most of these exceedances may be attributed to Saharan events (Figure 2 and Figure 3).

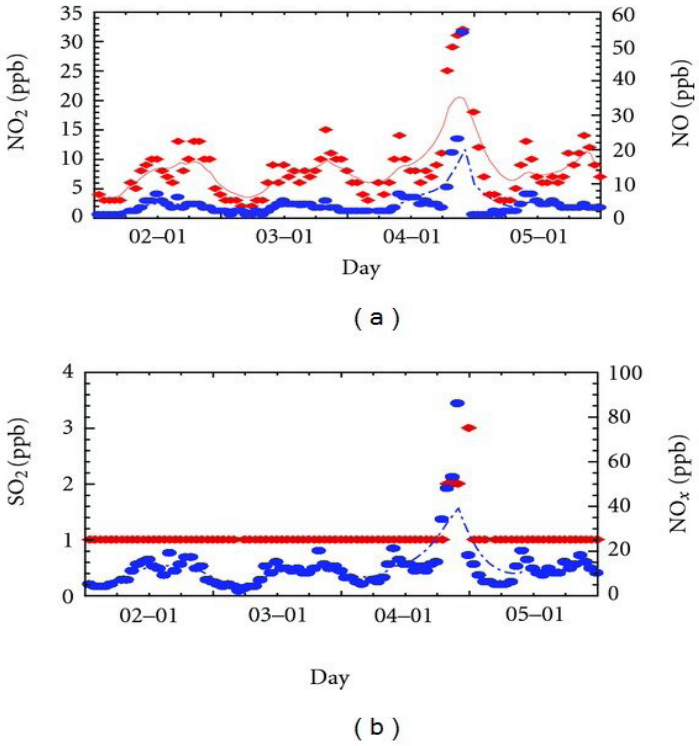

Figure 7. Hourly averaged series of pollutants concentrations during a winter period in Sousse. (Bouchlaghem et al., 2007).

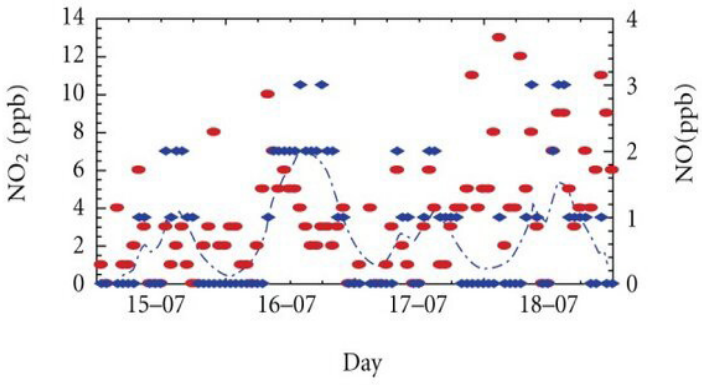

Figure 8. Hourly averaged series of pollutants concentrations during a summer period in Sousse city. (Bouchlaghem et al., 2007).

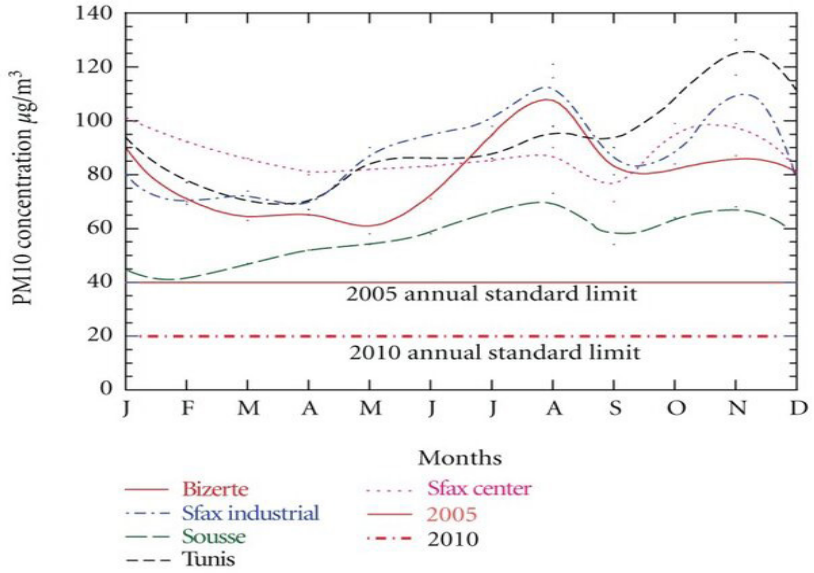

Figure 9. PM_{10} monthly averaged concentration recorded at the selected monitoring stations from January to December (Bouchlaghem et al., 2007).

II.3.9. Sanitation network

The sanitation network in the governorate of Sousse consists of 7 wastewater treatment plants and 79 pumping stations. The connection rate to this network, at the municipal level, stands at 97.4%. The municipalities of Kondar, Sidi El Hani, Chott Mariem, and Grimett Hicher lack sanitation networks, leading residents to resort to individual solutions that are harmful to the environment.

The quantity of collected water amounts to 30.5 million m^3 per day. The tourism sector contribute with 11% of this quantity of water .The treated quantity is estimated at 26.5 million m3 per day. However, the use of these waters in the agricultural sector and for course development remains limited. Some wastewater treatment plants emit foul odors, particularly the Sousse-North treatment plant.

II.3.10. Others ecosystem coastal services

- Cultural and Aesthetic Values: The natural beauty of Sousse's coastal landscapes holds cultural and aesthetic significance for its residents and visitors. These landscapes are often part of the cultural identity and heritage of the region.
- Educational and Research Opportunities: Sousse's coastal ecosystems offer valuable settings for environmental education and research. They provide opportunities to study marine biodiversity, ecosystem dynamics, and the impacts of human activities on coastal environments.

- Educational Tourism: Sousse's coastal ecosystems provide opportunities for educational tourism, allowing visitors to learn about local marine life, conservation efforts, and the importance of protecting these environments.

These examples showcase how Sousse's coastal ecosystems offer a range of valuable ecosystem services that benefit both local communities and the broader economy. It's important to recognize and manage these services sustainably to ensure their continued provision for current and future generations.

II.4. Main threats from tourism affecting the coastal ecosystem

The environmental situation in the governorate of Sousse varies significantly depending on the specific characteristics of each environment. The natural environment, which includes the coastal zones, wetlands, and terrestrial ecosystems, faces distinct alterations and challenges compared to the urban environment.

Pollution of Beaches and Coastal Waters by Waste: Beaches are often subject to pollution caused by irresponsible behavior of beachgoers. Various types of waste are discarded along the coast, including food remnants, cigarette butts, paper, plastic bags, and packaging waste. The annual quantity of waste collected by municipal services amounts to 100 tons. The nuisances and pollution related to beach waste often end up in the sea, with significant repercussions on the marine and coastal ecosystem, water quality, and coastal aesthetics (Ministry of Environment, 2016)

II.4.1. Impact of tourism sector on the ecosystem

While a century ago only 15% of the Earth's surface was modified by the direct effects of human activities, this proportion has now grown to 87% of the ocean and 77% of the land According a recent report from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), human activities threaten around 1 million species with extinction (IPBES, 2019), many others being extinct already (Ganivet, 2020).

The tourism industry does not escape this rule. In fact, tourism has become an increasingly accessible activity and has thus developed over time to become a mass activity. This activity then becomes a threat to fragile environments as it presents too much pressure in relation to the environment's capacity to host. The repeated passage of visitors to host lands, the use of natural resources without concern for the sustainability of this consumer good, the increase of waste generated by consumption, are all negative impacts on ecosystems and can affect local communities in different ways. In fact, tourism is a growing source of disruption to fragile ecosystems. Its social, economic and environmental impacts are considerable and complex, especially because tourism focuses on vulnerable natural and cultural sites. Thus, these sites are weakening from

year to year by mass tourism favouring the overconsumption of natural resources, and by the development of tourist infrastructures responding to an ever-growing demand. Furthermore, short-term gains from tourism may take up long-term environmental considerations, in particular with regard to the conservation and sustainable use of biodiversity. This is important in coastal maritime regions, where tourism is constantly increasing and where biodiversity is the greatest.

In such context, the tourism in the region of Sousse is the first activity, after the fishing industry, benefiting from the sea. More than 80% of the hotels are lying along 13 Km of coastline. It is expected to be the most environmentally friendly, but like any human activity it becomes the biggest environmental problem. (Figure 10) (Khebour et al., 2023)

Figure 10. LULC changes in the Sabkha of Sousse at the northwest side (at left in September 2009, at right in December 2018, @Google Earth)

Beach occupation and sand extraction are the first negative results of hotel building in Sousse. The increasing number of pleasure boats, ports and other pleasure structures; fully occupied during summer time and located in many cases in the coastal areas, is becoming one more source of marine pollution by the amount of wastes they discharge deliberately into the sea (oily water, garbage, sewage) and particularly by the difficulties in handling them.

The impact on ecosystems is really serious through the bacteriological pollution of the sea, and therefore the disturbance caused to marine organisms by the propulsion engines of thousands of pleasure boats having their exhaust pipes under water, releasing a considerable amount of thermal energy and toxic gases into the sea water. These boats represent a real threat to the coral and sea grass.

In the same context, a report was published in 2003 by the Centre of Regional Activities for Specially Protected Areas CAR/ASP under the title: Impact of tourism on the marine and coastal biodiversity of the Mediterranean. The report revealed that the coasts between the Sousse and the Monastir regions constitute a migratory stop for an avifauna

of international importance, such as the railleur goeland, classified as a vulnerable species. These coasts constitute one of the most western nesting sites of the *Caouanne* turtle, this species is unfortunately very threatened by tourism and coastal fishing in the Mediterranean (CAR/ASP, 2003).

To conclude what was discussed previously, the Maritime Tourism constitutes a serious damage to the maritime and coastal ecosystem and environmental quality in Sousse, by:

- Wasting generation and marine littering.
- Overconsumption of scarce natural resources as water.
- Environmental and land degradation and hazards to biodiversity: destruction of ecosystems as a result of complex construction and urbanization in fragile natural spaces.
- Biodiversity losses and decrease of the aesthetic value of landscapes.
- Pollution of soil and water.
- Overconsumption of water.
- Disruption of flora and fauna.
- Emissions of greenhouse gases at a rate of 20% from tourist travel.

The tourism sector can contribute to pollution in Sousse through various activities and practices associated with tourist arrivals, accommodations, transportation, and recreational activities. Some ways in which the tourism sector can contribute to pollution include:

- **Waste Generation:** The increased influx of tourists can lead to higher levels of waste generation, including solid waste and plastic pollution. Improper waste disposal and inadequate waste management infrastructure can result in littering and pollution in coastal areas.
- **Water Pollution:** Tourism facilities such as hotels, resorts, and cruise ships can discharge untreated or inadequately treated wastewater into local water bodies. This can introduce pollutants and contaminants, including nutrients and chemicals, into marine ecosystems.
- **Marine Activities:** Recreational activities like boating, diving, and snorkeling can result in physical damage to coral reefs and other marine habitats. Improper anchoring and contact with sensitive marine life can contribute to habitat degradation.
- **Energy Consumption:** Increased tourism can lead to higher energy consumption for accommodations, transportation, and entertainment facilities. If the energy sources are not renewable, it can result in air pollution and greenhouse gas emissions.
- **Transportation Emissions:** The use of vehicles for tourist transportation, both on land and by sea, can contribute to air pollution through exhaust emissions.

This is particularly relevant for destinations with heavy traffic.

- **Construction and Infrastructure:** The development of new tourism infrastructure, such as hotels and resorts, can result in construction-related pollution, including dust, noise, and soil erosion.
- **Depletion of Resources:** The high demand for resources such as water, energy, and raw materials by the tourism sector can strain local resources, leading to overuse and potential depletion.
- **Tourist Activities:** Tourists engaging in activities like snorkeling, fishing, and collecting souvenirs can inadvertently damage ecosystems and contribute to habitat destruction and pollution.
- **Cultural and Social Impact:** The pressure to cater to tourism demands can lead to a shift in local cultural practices and lifestyle, potentially resulting in unsustainable resource consumption and waste generation.
- **Seasonal Peaks:** During peak tourism seasons, when visitor numbers significantly increase, the stress on local infrastructure and waste management systems can lead to increased pollution levels.

To mitigate the tourism sector's contribution to pollution, destinations like Sousse can implement sustainable tourism practices, including:

- Promoting responsible tourism behavior among visitors.
- Improving waste management infrastructure and recycling programs.
- Encouraging sustainable transportation options such as public transit or cycling.
- Implementing wastewater treatment facilities for tourism facilities.
- Adopting green building and energy-efficient practices for tourism infrastructure.
- Establishing protected marine areas and promoting sustainable marine activities.
- Educating tourists and locals about the importance of preserving the environment.

By adopting such measures, the tourism sector in Sousse can minimize its negative impact on the environment and contribute to the overall sustainability of the region.

- **Threats to Ecosystem Balance**

The consequences of the pollution are diverse. Suspended matter can smother ecosystems of great interest, nutrients lead to the proliferation of opportunistic macroalgae and phytoplankton, macro-waste can harm marine mammals such as turtles or birds, micropollutants disrupt species physiology and accumulate in sediments and food chains up to humans. The increasing urbanization of the waterfront through development of esplanades, buildings, and infrastructure disrupts the land-sea exchange, thereby unbalancing the coast.

- **Eutrophication and Pollution of the Environment**

The macro-faunal distribution in the 'Hamdoun' oued is distinctive; the presence of turtles, snakes, and some fish has been noted. Additionally, insects are abundant in this area, as well as birds (ducks, egrets, etc.). Mollusks generally constitute a significant part of the microfauna, mainly gastropods and bivalves. Crabs are also a prevalent

group in this wadi. Nevertheless, pollution and eutrophication of this ecosystem threaten its ecological balance. Some species of mollusks develop with significant biomasses in association with the proliferation of ulva and heteromorphs, reflecting the polluted state of the site. Moreover, crabs and fish often fall victim to the over-proliferation of algae, getting entangled in discarded fishing nets and decomposing plastic materials. Furthermore, the intense input of micro-nutrients into the oued, sometimes coupled with thermal pollution and weak water circulation, promotes the massive proliferation of macroalgae. The green tide disrupts the natural self-purification cycle due to eutrophication. The high organic matter load limits aerobic degradation due to low available oxygen concentration.

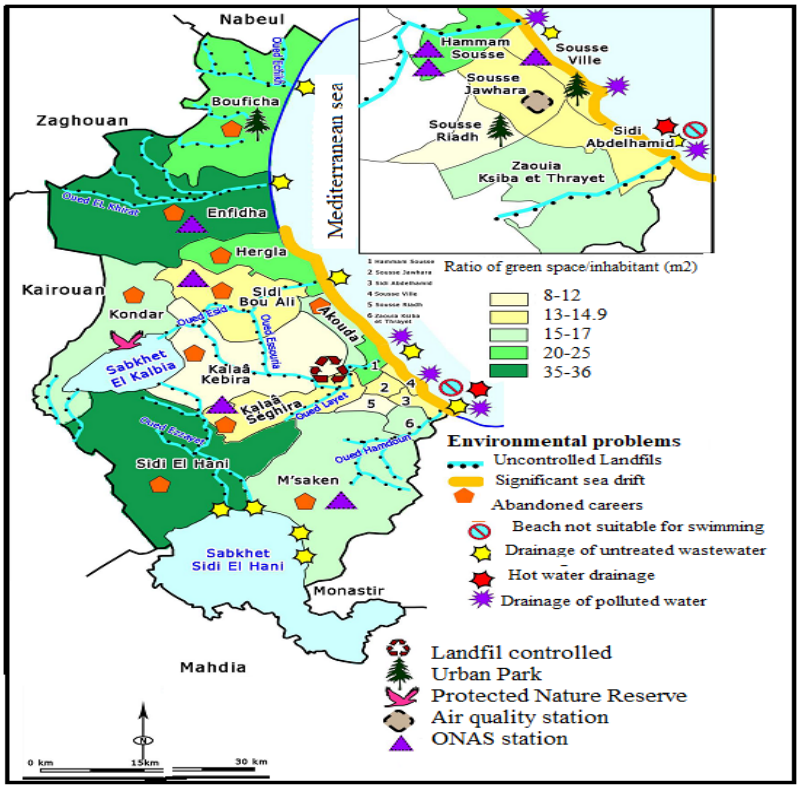

Figure 11. Environmental Situation in the Governorate of Sousse (Atlas, 2021)

III. The coastal hotspots according to their vulnerability

The vulnerable Oued Hamdoun faces combined pollution effects. On one hand, it experiences thermal pollution from the cooling water discharge of the STEG power plant. On the other hand, it suffers from organic and mineral pollution due to rainwater runoff from the power plant, along with urban and industrial discharges. Oued Hamdoun releases its effluents into Sidi Abdelhamid beach. The ecological disturbance caused by this organic and thermal pollution, combined with continuous river flow, often leads to massive jellyfish proliferation in the bay of Sousse.

III.1. Principal polluted area in Sousse

From an ecological perspective, the southern zone appears to be most exposed to environmental problems. This urban space is situated between two rivers: “Hallouf” to the north and “Hamdoun” to the south. These rivers are inadequately managed and act as points of disposal for solid waste, unregulated industrial and urban sewage. This leads to bad odors and insect proliferation, especially in the summer when flow decreases and water stagnates. Furthermore, these rivers directly discharge their pollutants into the sea, contributing to the degradation of coastal water quality. As a result, Sidi Abdelhamid beach has been declared unfit for swimming due to its poor water quality. Additionally, this coastal area has experienced significant dune remobilization and erosion, resulting in the complete disappearance of beaches in several areas due to the effects of the southern jetty of port infrastructure and protective structures.

The lack of green spaces and esplanades, concentrated gardens in the northern half of the city, further exacerbates the situation. The Sebkha of Sousse is also threatened by pollution from municipal services, which dispose of bulky waste and construction debris, as well as untreated wastewater from the Sousse South treatment plant during periods of overuse. The cleanliness of these neighborhoods is often not ensured. Garbage is not properly disposed of in containers when available, and due to limited economic and human resources, the municipality struggles to cover all areas (Jlassi et al., 2020).

Coastal waters are also affected by pollution, primarily caused by effluents entering the sea through rivers or direct discharge via the emission pipe of the Sousse Nord treatment plant, connections of the stormwater drainage network, uncontrolled discharges from primary processing and fish packaging activities, and fuel leaks during refueling and maintenance of small boats at the port of Sousse.

Polluting industries create a concerning environmental situation when industrial units lack pretreatment facilities or possess inadequate treatment equipment. Their highly polluted effluents are usually discharged into the collective network, alongside domestic wastewater **(**Sahtout et al, 2015).

In the Greater Sousse region, the polluting industries span various sectors, including textiles, clothing, agri-food, mechanics, and metallurgy. Most industries are concentrated in the Sidi Abdelhamid industrial zone, while others are scattered in smaller industrial areas across different localities in the Greater Sousse area.

These industries release various types of pollutants that combine with domestic ones. The extent of their impact on natural environment degradation varies across zones. However, the coastal zone of South Sousse and its marine environment seem to be most affected by these pollutants. For instance, high and continuous germ concentrations are observed on Sidi Abdelhamid beach and often on Gaied Souassi beach. This pollution can be attributed to factors such as:

- Direct discharge of raw industrial wastewater, either directly into the sea through canals and outfalls or through various rivers that lead to the sea, resulting in primarily organic pollution. This contaminates the water and exacerbates ecosystem eutrophication.
- The location of effluent discharge from treatment plants. During peak times, these plants work at full capacity and release untreated water. Additionally, these plants often require regular shutdown periods for maintenance.
- Uncontrolled disposal of primary processing and fish packaging waste at the fishing port, where waste from these activities is directly released into the sea.
- Protective structures at Gaied Souassi beach lead to water stagnation and promote the intense growth of algae colonies, a source of pollution and bad odor. Urban Wastewater Pollution:

The high concentration of urbanization on the coastal front, coupled with challenges in establishing sewage treatment facilities and equipment (land availability, etc.), contributes to environmental problems. For example, in the Chott Meriem area, sanitation issues arise due to the significant difference between summer (high beach activity) and winter wastewater volumes, the fragile marine environment, and the difficulty of finding land for potential sewage treatment plants. This leads to considerations for connecting peripheral sites.

- The existence of anarchic settlements in certain neighborhoods.
- Stormwater issues that require a separate, specific, and context-adapted drainage system, which is not the case across the entire territory.
- A significant number of lift stations that need to be managed to address topographical challenges.
- Releasing network points outside the urban perimeter.

Furthermore, ONAS-treated wastewater doesn't always find proper outlets. For example, the Hallouf river currently acts as a conduit for treated wastewater from the Sousse South treatment plant. This same river is subject to overflows of untreated sewage from pumping stations, especially during heavy rainfall periods. It passes

through the El Matar area, receiving large amounts of household and animal waste. The Hallouf river discharges into the sea at Gaied Souassi beach, causing pollution that renders the beach unsuitable for swimming. Water stagnation causing bad odors is observed in the lower course of the river.

Additionally, the stormwater system faces dysfunction challenges in terms of maintenance, cleaning, and upkeep. During rain showers, all pollutants collected in the system are carried to the sea.

III.2. Coastal Impact of Aquaculture Activities

While the fishing sector contributes 4.5% to national fish production and provides over 1000 jobs, it also presents potential sources of pollution, including water, chemical, and solid pollution.

The Grand Sousse region, particularly around Hergla, hosts two aquaculture sites, involving land-based ponds (operational since 1998 on nearly 80 ha) and submersible floating cages (operational since 2006) (Sahtout et al, 2015).

Aquaculture, whether practiced on land or in the sea, generates pollution sources. The fish's feed contains various substances, including food and others, that dilute in water and can contaminate it, affecting human health and environmental cleanliness.

Intensive aquaculture, as currently practiced, is considered a potential pollution source. Close interactions between the farming environment and the ecosystem hosting the fish cages increase pollution risks.

The fastest way to reduce pollution generated by aquaculture seems to be, for now, reducing the quantity of feed dumped by increasing its energy value (which will decrease the suspended matter) and substituting some protein with lipids. However, implementing this type of feed requires high technical expertise.

As a consequence, in recent years, fishermen at the Hergla port have expressed dissatisfaction with the competition from aquaculture companies that occupy significant marine areas (Hellal, 2017).

This has led to a decline in their share of regional fish resources. They lament the lack of control over the increasing environmental pollution caused by plastic waste thrown into the sea after fish feeding. Aquaculture has very different impacts on the natural environment, depending on the animals' feeding mode. In any case, there is nitrogen and phosphorus discharge potential leading to eutrophication. In particular, the Hergla aquaculture farm uses the Halk El Menjel Sebkha as a dumping ground for its waste. According to the same source, the farm releases fish waste and disinfectants, antibiotics against parasites, steroids to produce more females, and medications and hormones to accelerate their growth into the Sebkha. This causes pollution, making the beach unsuitable for swimming, and stagnant water with bad odors is observed in the lower course of the Sebkha.

IV. Impact of Coastal/Maritime tourism on environment in Sousse

The environmental situation in the governorate of Sousse varies depending on the specificity of the environment. Thus, the natural environment faces alterations and problems that are quite different from those affecting the urban environment.

- **Natural Environment**

The natural resources of the governorate of Sousse are highly vulnerable to edaphic conditions, climate, and the type of relief existing in the region. These resources are confronted with numerous problems, such as water erosion, wind erosion, and an increase in salinity levels, which significantly affect various sectors as well as the quality of life in the governorate. Similarly, the intensive development of the industrial and tourism sectors has weakened the various resources of the region.

- **Water Quality for Bathing**

The results obtained from studies conducted by the Ministry of Environment in 2017 indicate that 5 beaches in the Sidi Abdelhamid area are polluted by the waters of the Hallouf and Hamdoun wadis, making them unsuitable for bathing. The situation of these beaches is likely to improve once the wastewater treatment plant and the marine outfall for Oued Hamdoun are established. (Municipality of Sousse, 2020)

- **Water Erosion**

The majority of delegations in the governorate of Sousse suffer from water erosion, which has altered soil quality and fertility. This problem is closely linked to the climatic characteristics of the governorate, including irregular and often torrential rainfall. These natural challenges are exacerbated by the scarcity of vegetation cover and the absence of regional plants capable of stabilizing soils (agricultural land development and cultivation of olive and fruit trees).

- **Salinity**

Poor land drainage in the agricultural areas of the governorate of Sousse has increased the salinity levels of several irrigated areas. Salinity levels ranging from 1.5 to 3 g/l have affected numerous zones, particularly the Sidi El – Hani delegation, where agricultural land has become completely unproductive.

- **Degradation of Agricultural Land**

In addition to these natural challenges (rainfall, wind, soil type, etc.), the activities of the population have considerably exacerbated environmental problems. Indeed, the population density in the governorate of Sousse is high, exceeding 1000 inhabitants/km^2 in several delegations and reaching up to 6000 inhabitants/km^2 in certain cities like Sousse. Urban areas are expanding at the expense of agricultural land.

- **Overexploitation of Aquifers**

The overexploitation of various groundwater aquifers in the Sahel region has led to an increase in water salinity and sometimes intrusion of seawater, making water resources increasingly unusable. This issue particularly affects aquifers near wetland areas (Sidi El - Hani, Kelbia, etc.). Deep aquifers are subject to significant pressure, a problem that has become alarming, especially after 2011, due to the increase in the number of illegal wells (Table 1).

Table 3. UUrban water supply systems in coastal towns in 2004 (Atlas, 2021)

ndicator	Sousse	tverage/
Level of consumer connection lines (%)	96.4	85.2
Network length (km)	1027	9 767
Number of purification stations	5	59
Number of pumping stations	51	463
Number of customers (one thousand inhabitants)	396	3 878
Volume of water collected (million m3)	15.4	139.9
Volume of water treated (million m3)	14.8	135.1
Level of treated water/collected water (%)	96.1	96.6
Number of member municipalities	13	120

- **Poor Use of Soil Resources**

Irrigation water has a very high salinity level, which has significantly damaged land and rendered it unproductive. The imbalance between available water resources and PPI needs has worsened the problem of water overexploitation. Most public dumps occupy fragile soils (sebkhas, riverbanks, agricultural land, etc.) that have become receptacles for domestic waste, wastewater, and margin waste. The Kalaâ Kebira delegation is the most affected by this issue, as most rivers passing through it serve as unregulated dumping sites, similar to abandoned quarries. This puts both the urban and natural environment at risk.

V. Policies and efforts made to manage pollution in Sousse and their effects on the Coastal/Maritime tourism sector

Policies and efforts to manage pollution in Sousse have been crucial in minimizing the negative impacts of pollution on the Coastal/Maritime Tourism sector. These measures aim to maintain the pristine coastal and marine environments while sustaining the tourism industry.

V.1. Examples of policies and efforts implemented

- **Waste Management Initiatives:** Sousse has established waste management systems that include proper waste collection, separation, recycling, and disposal. This reduces the amount of solid waste that ends up in coastal and marine areas, preventing pollution.
- **Sewage Treatment and Infrastructure:** Improved sewage treatment facilities and proper sewage management infrastructure have been developed to ensure that wastewater, including that generated from tourism activities, is treated before being released into the environment.
- **Environmental Regulations:** Regulatory measures and guidelines have been put in place to limit the impact of tourism-related activities on the environment. These regulations cover aspects such as waste disposal, noise pollution, and protection of sensitive areas.
- **Coastal Zoning:** Sousse has implemented coastal zoning plans that define specific areas for tourism development, preservation, and conservation. This helps prevent excessive development that could lead to pollution and degradation of coastal ecosystems.
- **Educational Campaigns:** Public awareness campaigns targeting both tourists and local communities have been conducted to promote responsible tourism practices. These campaigns emphasize the importance of reducing waste, conserving resources, and respecting the environment.
- **Environmental Audits and Certification:** Some tourism establishments in Sousse participate in environmental audits and certification programs, which encourage them to adopt sustainable practices. This includes energy-efficient measures, waste reduction, and water conservation **(**Tunisian National Tourist Office, 2016).
- **Collaboration with Tourism Industry:** Collaboration between local authorities and the tourism industry has resulted in initiatives to reduce pollution. These include beach clean-up campaigns, waste reduction programs, and responsible tourism training.

V.2. Effects on Coastal/Maritime Tourism

These policies and efforts have had positive effects on the Coastal/Maritime Tourism sector in Sousse (Hellal, 2017):

- **Enhanced Tourism Experience:** Clean and well-maintained coastal and marine environments enhance the overall experience for tourists, attracting them to the region and encouraging repeat visits.
- **Sustainable Tourism:** The implementation of sustainable practices has positioned Sousse as a destination that values environmental conservation. This can appeal to eco-conscious travelers who prefer responsible tourism options.
- **Positive Public Perception:** Tourism stakeholders and visitors appreciate the efforts made to protect the environment. This positive perception can contribute to the overall reputation of Sousse as a responsible and eco-friendly destination.
- **Preservation of Natural Assets:** By effectively managing pollution, Sousse ensures the preservation of its natural assets, such as beaches, coral reefs, and marine life, which are critical for tourism activities.
- **Long-Term Viability:** Pollution management measures contribute to the long-term viability of the tourism sector by preventing environmental degradation that could negatively impact the attractiveness of the destination.
- **Economic Resilience:** A healthy coastal environment supports the local economy by sustaining activities like fishing, diving, and water sports that are intertwined with the tourism sector.

Overall, the policies and efforts to manage pollution in Sousse have a positive ripple effect on the Coastal/Maritime Tourism sector, ensuring a sustainable and appealing destination for visitors.

V.3. Environmental practices within the tourism sector in Sousse

These practices play a critical role in reducing pollution and minimizing the negative impact of tourism activities on the coastal and marine environments. These practices are aimed at promoting sustainable tourism and preserving the natural beauty of the region. Here are some key environmental practices adopted by the tourism sector in Sousse to reduce pollution:

- **Waste Reduction and Management**
  - Implementing waste reduction strategies by minimizing single-use plastics and promoting reusable and recyclable materials.
  - Providing designated recycling bins and waste disposal facilities in hotels, resorts, and public areas.
  - Conducting regular beach clean-up campaigns to remove litter and debris from coastal areas.

- **Water Conservation**
  - Promoting water-saving initiatives such as encouraging guests to reuse towels and linens to reduce water consumption in hotels.
  - Installing water-efficient fixtures and appliances in accommodations and tourism facilities.
  - Educating tourists and staff about the importance of conserving water resources.
- **Energy Efficiency**
  - Using energy-efficient lighting, appliances, and HVAC systems in accommodations and tourism establishments.
  - Implementing energy conservation practices and encouraging guests to turn off lights and appliances when not in use.
- **Sustainable Transportation**
  - Promoting eco-friendly transportation options such as cycling, walking, and using public transportation to reduce air pollution.
  - Encouraging the use of electric or hybrid vehicles for airport transfers and tours.
- **Responsible Marine Activities**
  - Enforcing guidelines for responsible diving and snorkeling to prevent damage to coral reefs and marine life.
  - Educating tourists about the importance of not touching or disturbing marine animals and ecosystems.
- **Local Sourcing and Community Engagement**
  - Encouraging tourism establishments to source locally-produced food and products to reduce the carbon footprint of imported goods.
  - Collaborating with local communities for eco-tourism initiatives and cultural experiences that promote environmental awareness.
- **Environmental Education and Awareness**
  - Providing information to tourists about the local environment, including marine life, ecosystems, and conservation efforts.
  - Organizing workshops, seminars, and guided tours to raise awareness about the importance of protecting natural resources.
- **Certifications and Labels**
  - Seeking eco-certifications and labels, such as the Blue Flag certification for beaches and marinas, to demonstrate commitment to environmental standards.
  - Displaying eco-friendly labels in accommodations to inform guests about sustainable practices.

- **Reducing Air Pollution**
  - Encouraging the use of electric or hybrid vehicles for transportation services.
  - Advocating for clean and efficient public transportation options for tourists.
- **Collaboration and Advocacy**
  - Collaborating with local authorities, non-governmental organizations, and other stakeholders to develop and implement sustainable tourism practices.
  - Participating in advocacy efforts to influence policies and regulations that promote sustainable tourism development.

By adopting these environmental practices, the tourism sector in Sousse can contribute to reducing pollution, preserving natural resources, and ensuring the long-term sustainability of the destination. These practices also enhance the overall tourism experience for visitors who are increasingly seeking responsible and eco-friendly travel options.

VI. Blue Economy

The Blue Economy concept, which focuses on sustainable and responsible use of ocean and coastal resources, holds great potential for reducing pollution in the context of sustainable Coastal/Maritime Tourism development in Sousse. By integrating principles of the Blue Economy, Sousse can adopt innovative approaches that promote economic growth while minimizing negative environmental impacts, particularly pollution caused by tourism activities. Here's how applying the Blue Economy concept can help reduce pollution:

- **Waste Management and Recycling**
  - Establishing efficient waste separation and recycling systems in tourism establishments and public areas.
  - Encouraging the use of eco-friendly packaging and materials to minimize plastic waste.
  - Transforming plastic waste into valuable resources through recycling and upcycling initiatives.
- **Clean Energy Adoption**
  - Embracing renewable energy sources such as solar, wind, and hydropower to power tourism facilities and reduce reliance on fossil fuels.
  - Installing energy-efficient lighting and appliances in accommodations and public spaces.
- **Wastewater Treatment and Reuse**
  - Developing and implementing advanced wastewater treatment plants that purify wastewater before discharge into coastal waters.
  - Exploring options for treated wastewater reuse in irrigation or non-potable applications, reducing the demand on freshwater resources.
- **Eco-Friendly Transportation**
  - Promoting sustainable transportation modes such as electric vehicles, bicycles, and low-emission public transport for tourists and locals.
  - Implementing charging infrastructure for electric vehicles and offering incentives for eco-friendly transportation choices.
- **Marine Protection and Conservation**
  - Establishing marine protected areas and adopting responsible tourism practices that prevent damage to sensitive marine ecosystems.
  - Implementing regulations to prevent anchor damage to coral reefs and underwater habitats.

- **Sustainable Coastal Infrastructure**

- Designing coastal infrastructure with minimal environmental impact, including erosion-resistant structures and eco-friendly beach amenities.
- Using sustainable construction materials that reduce pollution and habitat destruction.

- **Eco-Tourism and Education**

- Promoting eco-tourism activities that educate visitors about marine conservation and the importance of minimizing pollution.
- Encouraging tourists to participate in beach clean-up initiatives and environmental awareness campaigns.

- **Circular Economy Practices**

- Implementing circular economy principles by reusing and repurposing materials to minimize waste generation.
- Encouraging businesses to adopt closed-loop systems that reduce the need for new resource extraction.

- **Green Certification and Labels**

- Encouraging tourism establishments to obtain eco-certifications and labels that endorse their commitment to sustainability and pollution reduction.
- Educating tourists about the significance of supporting certified eco-friendly businesses.

- **Community Involvement and Collaboration**

- Engaging local communities, NGOs, and government agencies in the development and implementation of Blue Economy strategies.
- Collaborating to identify pollution sources, develop solutions, and monitor progress.

By integrating Blue Economy principles, Sousse can create a sustainable tourism model that addresses pollution challenges while fostering economic growth, job creation, and improved quality of life for both residents and visitors. This holistic approach ensures that the development of Coastal/Maritime Tourism aligns with long-term environmental and socio-economic goals.

VII. Conclusion

In the governorate of Sousse, one of the main human-induced pressures on ecosystems is urbanization and rapid tourist infrastructure development. The growth of tourism leads to the construction of hotels, resorts, and facilities, causing the conversion of natural areas into built environments. This expansion negatively affects vital ecosystems like coastal dunes and wetlands.

Tourism-driven development disrupts ecosystems, altering hydrological patterns and causing erosion. Coastal habitats like sand dunes and mangroves, important for erosion control and wildlife, suffer. Destroying these habitats weakens their resilience against disasters and leads to biodiversity loss.

Urbanization and other activities fragment habitats. Converting land for tourism disconnects habitats, impacting wildlife movement and genetics, increasing vulnerability to environmental changes.

Wetland degradation from drainage and agriculture reduces essential ecosystem services like water purification and flood control. Tourism strains resources, overfishing and excessive harvesting harm marine ecosystems and local fisheries' sustainability.

The increasing demand for resources driven by tourism places considerable pressure on the region's natural resources. Overfishing and excessive harvesting of marine species can disrupt marine ecosystems and threaten the sustainability of local fisheries. Moreover, the demand for water resources in tourist zones can strain the local water supply.

Climate change is a global challenge impacting the governorate of Sousse and its ecosystems and can have severe consequences for the region's biodiversity and natural resources. Coastal erosion is a significant concern due to sea-level rise and more frequent and intense storms. The loss of beachfront and coastal habitats not only affects tourism but also reduces the natural protection against storm surges and flooding. Addressing the anthropogenic pressures on ecosystems in Sousse requires a comprehensive approach that balances tourism development with environmental conservation. Sustainable land-use planning, responsible resource management, climate adaptation strategies, and community engagement are essential.

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