The Hungarian University of Agriculture and Life Sciences

Institute of Landscape Architecture

Urban Planning and Garden Art of MATE

Site development and enhancement of Sijoumi Lagoon–Tunis

Supervisor: Lina Haddadin

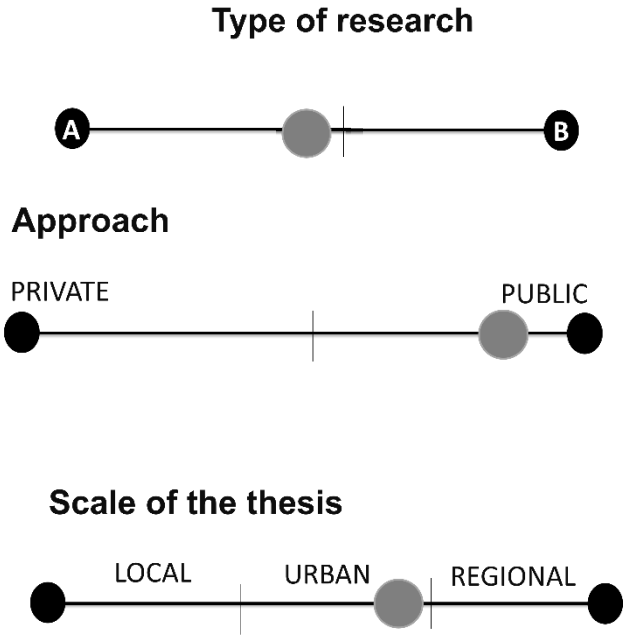
Student: Nermine Mili

Abstract:

S*i*joumi lagoon is a wetland of great ecological value in the heart of an urban environment. Its importance, particularly for migratory waterbirds, has been recognized by the award of several international statuses: 'Wetland of International Importance', 'Important Area for Bird and Nature Conservation and Key Biodiversity Area'. It is also the 4th most important site for wintering waterbirds in North Africa. It is one of the last "large" wetlands in a supposedly still intact and "natural" state in the Greater Tunis region.

Unfortunately, in recent years it has undergone from numerous conversions of natural areas into urban settlement, which has impacted the ecological and environmental situation of the site.

This work aims to contribute to the strengthening and consolidation of knowledge relating to the wet ecosystems of *Sijoumi*, in order to obtain instructions to follow for a **sustainable development of the Lagoon** and for a **prototype design that can be applied across the entire banks.**



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Introduction and objective of the research:

The selection of this subject stems from a personal passion for ecology, specifically, in *Greater Tunis* (encompassing the capital *Tunis* and three other cities *Ben Arous, Ariana,* and *Manouba*), as it presents a complex interplay between urban and natural elements, built structures and the environmental one, the city and its water surfaces. This complexity is evident in the four hydraulic networks comprising the Lake of *Tunis*, the lagoons of *Ariana* and *Sijoumi*, and the *Miliane* valley.

The examination of the wetlands' banks reveals dual dimensions: environmental dimension and an urban one. Consequently, our research centers on the vulnerability of the *Sijoumi* wetland banks in the face of rapid urbanization in the area. Despite being considered the urban extension of Greater Tunis due to its geographical location, land availability, and transportation infrastructure, the *Sijoumi* Lagoon and its surroundings boast significant environmental value. This includes biological richness contributing to biodiversity, vital hydraulic networks, green coverage, and fertile lands.

Throughout this thesis, our objective is to comprehend the interconnected aspects of this ecological, environmental, and urban context. We aim to propose optimal solutions to various challenges and underscore the diverse potentials of the site. Our research takes a "Landscape" perspective on *Sijoumi* Lagoon to ensure sustainable territorial development by integrating the environment, ecological components, and functional features into the project's development vision.

Ultimately, enhancing the landscape in this specific area and alleviating pressures would undoubtedly amplify its attractiveness while preserving its unique attributes as a wetland of local, regional, national, and intercontinental significance.

Methodology:

In order to understand the different issues related to the environmental and ecological context of the site, we will eventually start with an in-depth urban analysis of the entire territory.

The initial phase is dedicated to analyzing the natural, landscape, and ecological aspects of the *Sijoumi* wetland and its functioning. Within this stage, our focus will be specifically on the unique characteristics of the Lagoon, emphasizing primary fauna and flora types, as well as their direct environmental context. This exploration aims to uncover the main potentials of the area.

The next step is mainly analytical, through analyzing two crucial components: the historical urban evolution by understanding the evolution of forms of human occupation along the banks of the *Sijoumi* Lagoon, and their impact on the lagoon's specifications. Commencing with a historical overview, we trace the chronological development of the City of Tunis in relation to its surrounding water surfaces. This part underscores the impact of urban sprawl on the ecological quality of the lagoon, detailing how urbanization introduces vulnerabilities, such as modifications to the water balance, pollution, flooding risks, and various threats to the ecosystem.

After understanding the urban, natural, and ecological context of the site, we will move to the third part, where our focus shifts to design tools aimed at resolving various challenges. This involves an analysis of global authority interventions to discern new strategies applicable to this context. Referencing real situations provides us with instructions and diverse design tools to formulate an effective design, influencing the natural, ecological, and urban context and mitigating the negative impact of urbanization on *Sijoumi*.

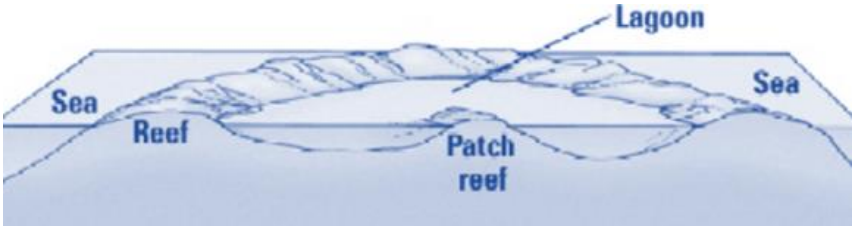
Having comprehended the framework, the urban and environmental context of *Sijoumi,* and the varied challenges encountered, the final part centers on the project design. Here, we assemble the primary intentions and the general intervention concept, subsequently developing different graphic elements. This includes plans, sections, rendering images showcasing key project elements, and technical details, facilitating a comprehensive understanding of the proposed intervention.

Terminologies and definitions:

In order to understand the different concepts related to the ecological and environmental aspects, we present in the following, the definition and terminology of certain terms that we will use throughout our research.

Lagoons are shallow bodies of water protected from a larger body of water (like oceans and seas) by sandbars, barrier islands, or coral reefs. In fact, there are two types of lagoons:

Atoll lagoon "*Is a ring-shaped coral reef, island, or series of islets. The atoll surrounds a body of water called a lagoon.*" Source: oceanservice.noaa.gov



Coastal lagoon: "*Forms along gently sloping coasts. They are generally tending to be separated from the ocean/sea by an island, reef, or sand bank".* Source: oceanservice.noaa.gov

Figure 1: Types of lagoons – Atoll & Coastal-Source: oceanservice.noaa.gov

Intermittent stream: "*A stream that has flowing water during certain times of the year, when groundwater provides water for stream flow. During dry periods, intermittent streams may not have flowing water. Runoff from precipitation is a supplemental source of water for stream flow.*" Source: virginiaplaces.org

Halophilic vegetation: "*A halophyte is a salt-tolerant plant that grows in soil or waters of high salinity, coming into contact with saline water through its roots or by salt spray, such as in saline semi-deserts, mangrove swamps, marshes and sloughs and seashores.*" Source: wikipedia.org

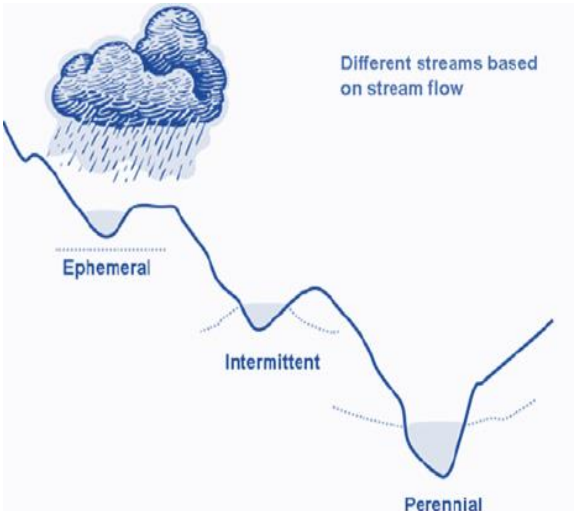
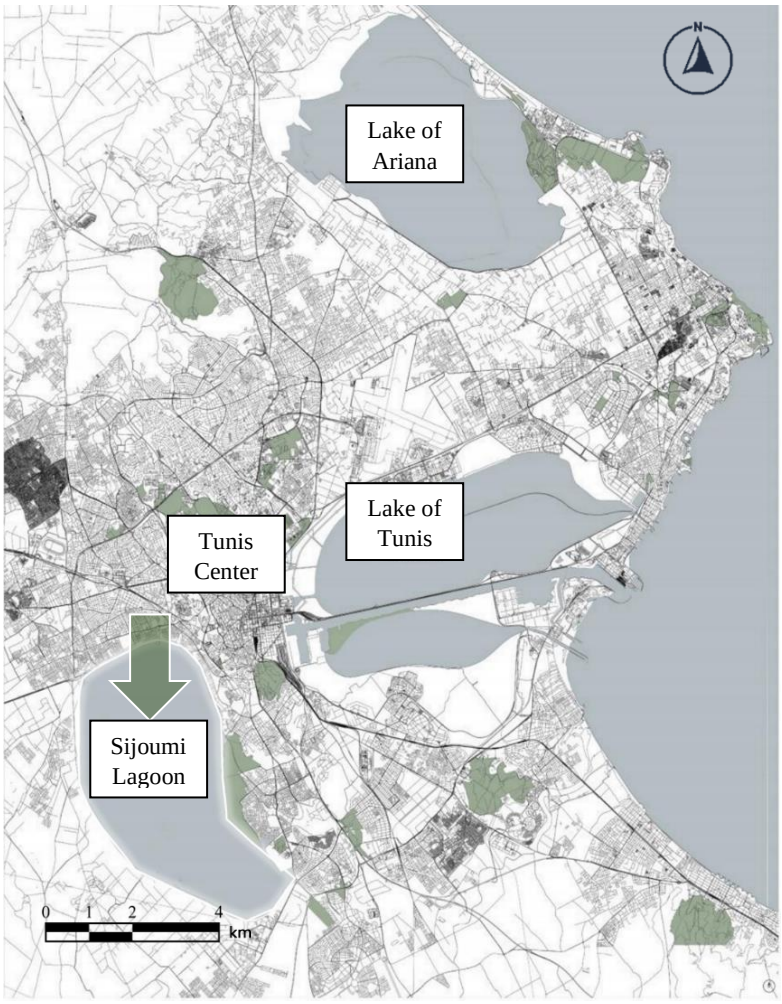


Figure 2: The different types of streams-Souce: virginiaplaces.org

I-GENERAL PREVIEW:



The capital, Tunis, is situated in the northern part of the country, spanning the coastal plain and nearby hills. As of now, Greater Tunis covers an area of 300,000 hectares, with 30,000 hectares urbanized, 20,000 hectares comprising water bodies, and the remaining 250,000 hectares designated as agricultural or natural areas. The ongoing urban expansion, estimated at 500 hectares annually, poses a continual threat to the city's natural environment.

Figure3: Sijoumi lagoon location

I-1- Climate data of the lagoon:

As a country located in North *Africa*, *Tunisia's* climate is *Mediterranean* with mild, rainy winters and hot, sunny summers along the northern coast.

The hot season lasts for 3 months, from mid-June to mid-September, with an average daily high temperature above 31°C .

The cool season lasts for 4 months, from the end of November to the end of March, with an average daily high temperature below 19°C.

Precipitation is moderate, being exposed to the passage of disturbances from the Atlantic or the *Mediterranean*: in *Tunis*, it totals 485 millimeters per year, most of which occurs between September and April, while in summer it hardly ever rains

I-2-Geographical data of the lagoon:

The *Sijoumi* Lagoon has a catchment area of 250 km² and it is located at an altitude between 5 and 7.5 NGT, however during the rainy seasons, its waters can overflow and exceed 10 NGT during floods.

This sub-littoral and peri-urban depression adjoining the capital is an endorheic basin fed by waters generally coming from the *Gueriana* and the *ElMelah* rivers.

Formerly, the majority of its banks presented agricultural land, but today, the surroundings are mostly urbanized, evacuating domestic and industrial waters into the Lagoon that is considered as receptacle. Buffering most of the flows, the waters of the lagoon are fresh to brackish waters.

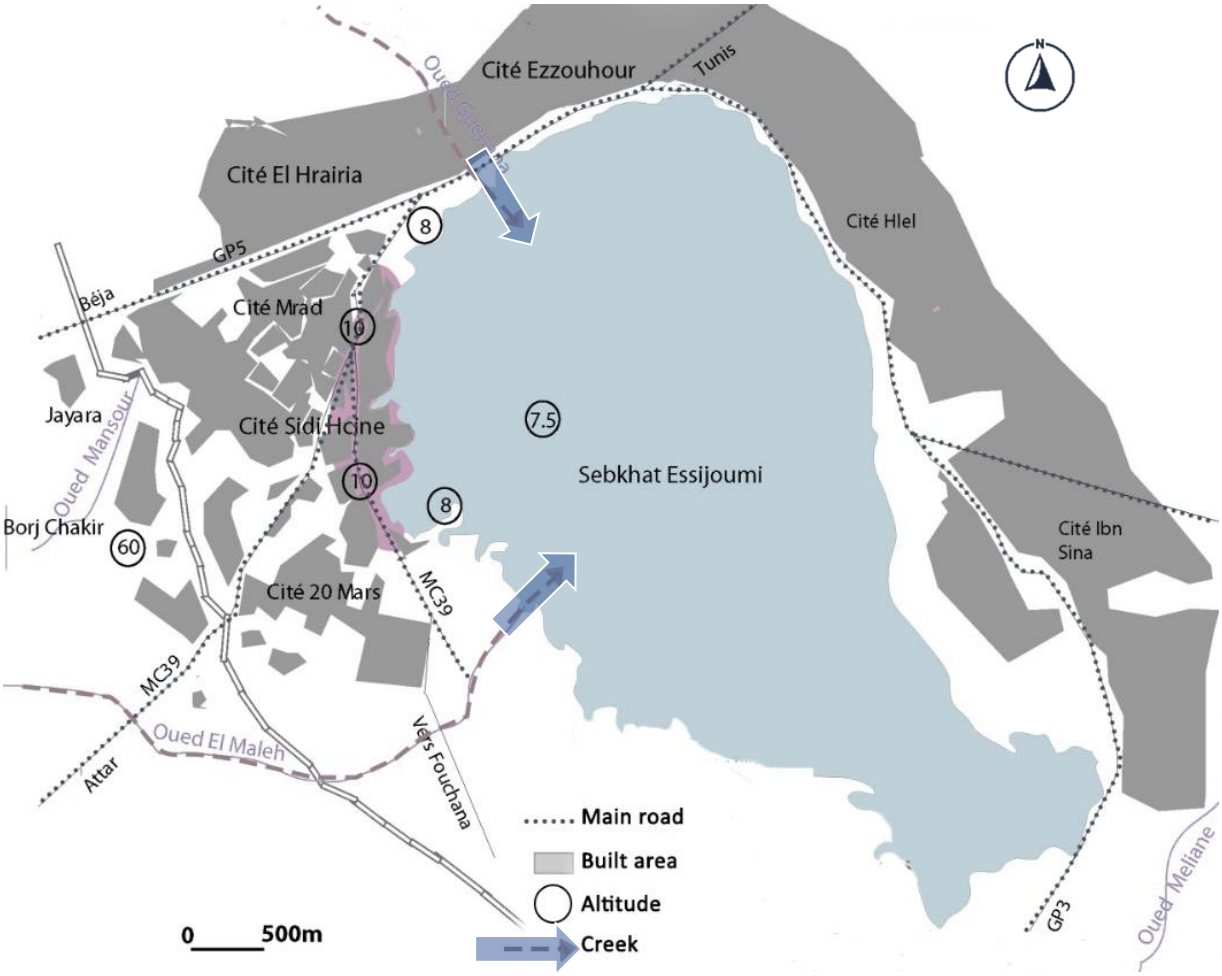


Figure 4: Geographical location of the Lagoon and the supplying water sources

The banks of the lagoon are characterized by a particularly flat topography. It is bordered by the topography of low plains which are connected to low ridges such as *Mount Nahli* (200m) in the northeast and *Mount LAhmar* (329m) in the northwest, the southeast is characterized by slightly overgrown hills dominating the bottom of the Lagoon.

The Lagoon is well surrounded by a road network that ensures its connection through different ways: the so-called *Route X,* running along its entire western and southern part for about 11 km constitutes a particularly long line of sight close to the body of water and facilitating its discovery. On the east side of the lagoon, the southern inter-municipal alternates between an opening zone and a closing zone in relation to the body of water. Indeed, the road crosses the forest and thus offers an opening on a forest landscape unit on both sides and over a length of approximately 1.3 km.

I-3-Lagoon Formation History

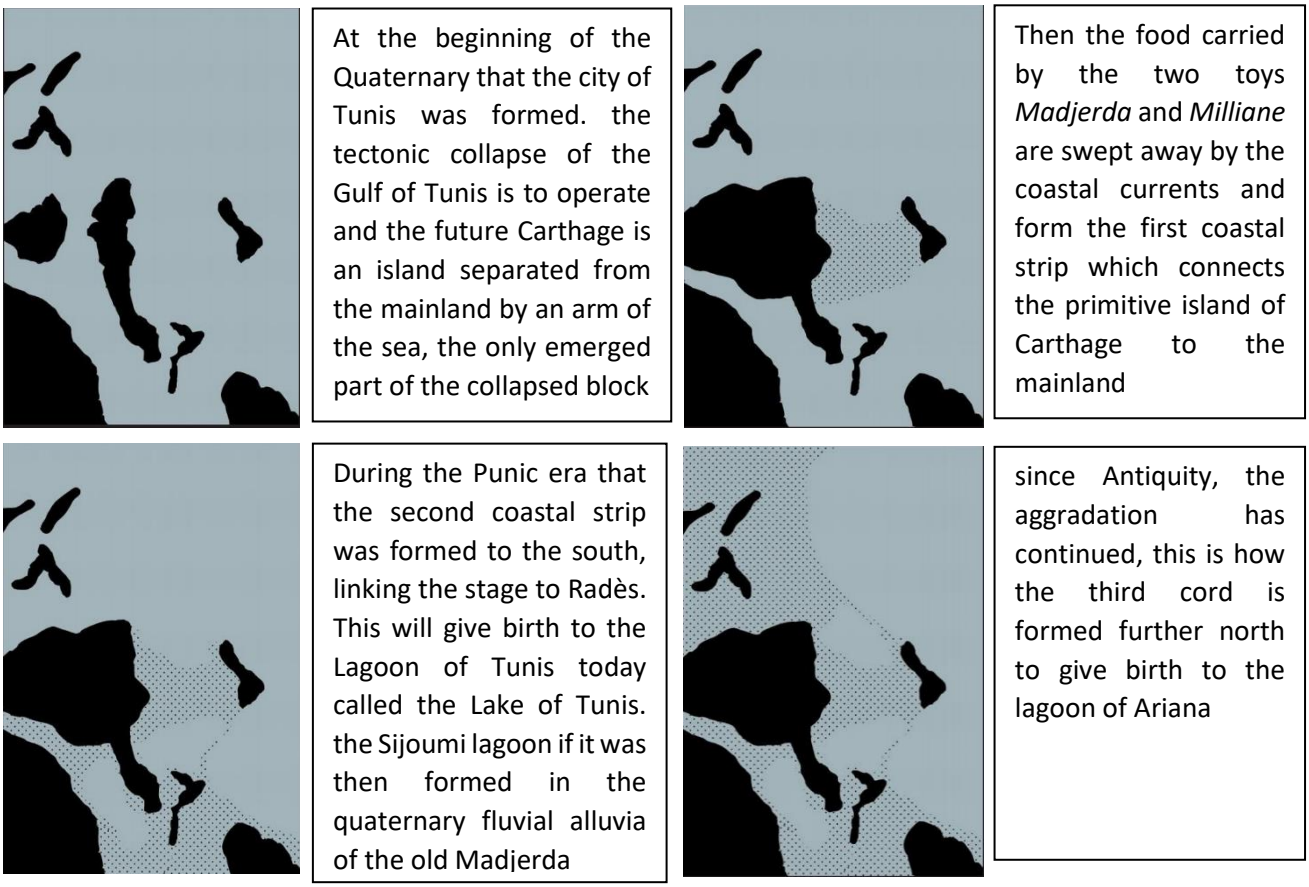


Figure 5: Lagoon formation history-Source: rapport sur La sebkha Sijoumi

II-LANDSCAPE ANALYSIS

II-1-Diversity in Landscape character:

Several elements together contribute to a coherent image of the *Sijoumi lagoon*. Apart from the water, the landscape along the shores is very rich and can be divided into different potential landscape units: the forest and green unit, the agricultural unit, and the road infrastructure unit. Indeed, a wetland cannot be reduced to its water body. It is a more or less complex interface that brings together not only the water on the ground but also the water with the existing flora and fauna.

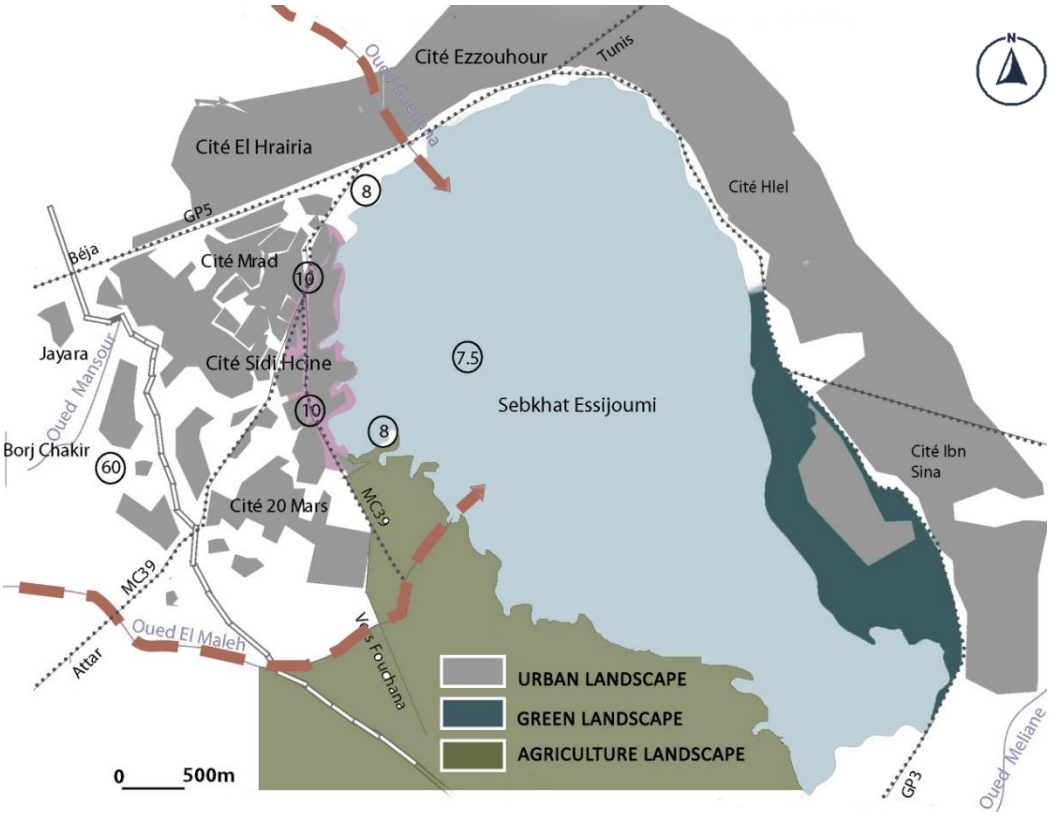


Figure 6: Diversity in Landscape character

The water surface of *Sijoumi* naturally breaks through a landscape characterized by dense urban sprawl and offers relief and panoramic views from certain points and angles. The calm water surface of the lagoon makes it possible to offer a fixed image of the sky and clouds through the mirror effect, thus protecting the aquatic avifauna. For sure, the lagoon of *Sijoumi* is one of the most important centers in *North Africa* for the concentration and reception of pink flamingos.

In summer, the evaporation of the water creates a new landscape in some parts of the lake, which is covered by a white layer of salt crystals that reflect the daylight. The alternating water surface with a salt crust thus offers a changing landscape depending on the rainy and dry seasons. The geographical environment bordering consists of an alternation of hills and plains drained by valleys. This explains the marshy character of part of the region, especially the part bordering the sabkha, where the void is maintained by the weakness of the current sedimentary contributions.

Figure 7: Marshy character of the lagoon bordering

.II-2-Urban landscape character

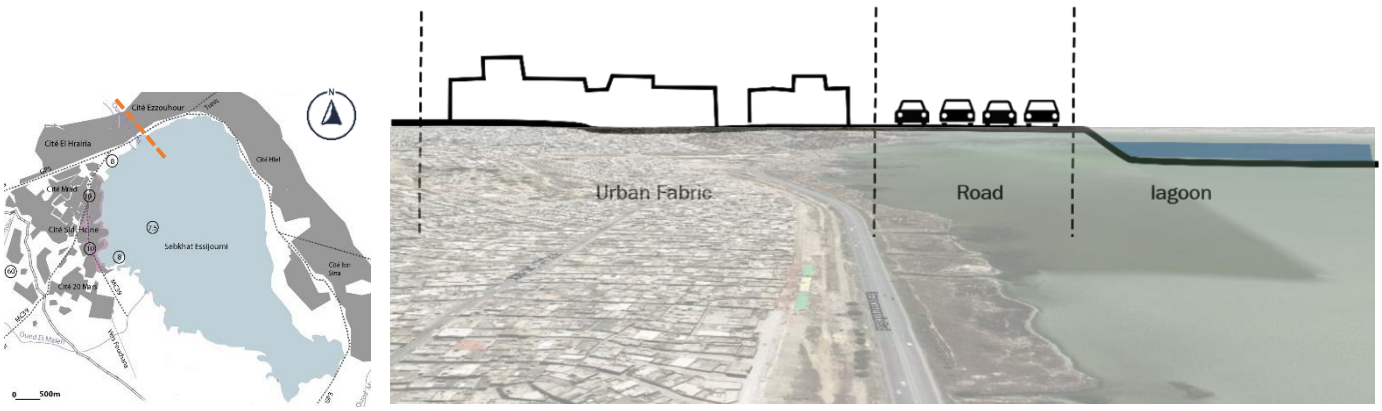


Figure 8: Section on the urban landscape

According to the spatial image, this unit is the most dominant on the overall landscape of the lagoon. to the north, east, and southeast, the urbanization front surrounding the lagoon appears very dense. In the West, the situation is different and urbanization has rather a fragmented character. Except for the districts of El *Mourouj, Ibnou Cina and Ezzouhour* where the constructions are organized and legalized, the urban fabric around the lagoon is generally disorderly and especially unfinished. The cemented brick facades are very close to each other and most of the time follow the type of semi-detached constructions. It should be noted that the inhabitants of these neighborhoods do not really express a strong social link towards the lagoon as a landscape of a natural wetland. Most of the buildings, not having windows on its body of water, signal a devaluation of the lagoon and a disconnect between society and the environment. Parallel to the dense built-up front around the lagoon, another phenomenon is integrated into this unity and contributes to the fragmentation of the landscape.

Figure 9: Urban fabric landscape on the north banks of the lagoon

II-3-Agricultural landscape character

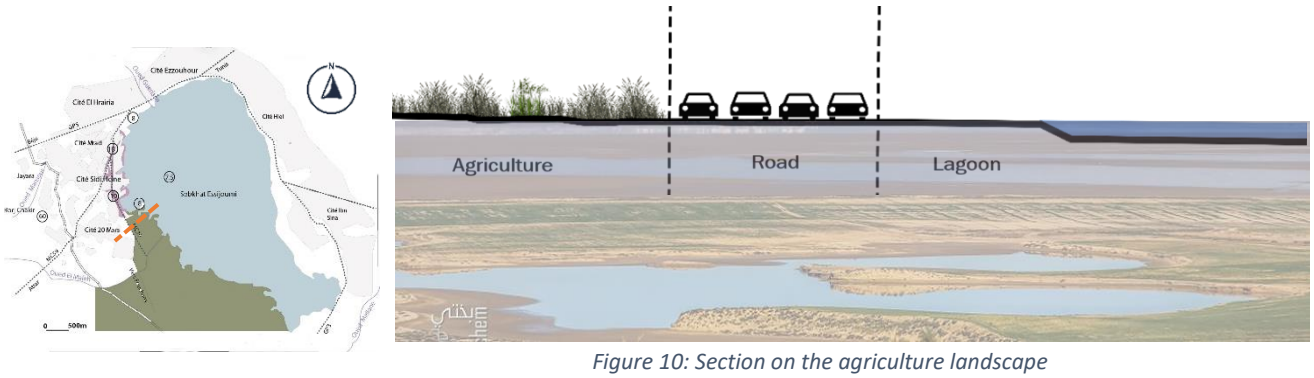


Figure 10: Section on the agriculture landscape

Being inserted between a dense urban area and an industrial area, this unit ensures a restorative effect on the entire landscape of the lagoon. Indeed, natural landscapes are the best from the point of view of restorative and buffering effects (insulation from urban noise, green textures, etc.), followed by public parks in this area, the fields extend to the line of the water body of the lagoon, which further promotes its development. The fields, extending over almost 3000 hectares to the west of the lagoon, host several types of crops such as cereals, olive trees, market gardening and fruit growing. A certain reconciliation of the lagoon with its environment thus arises from the connection between the fields and the body of water on one hand, and from the disconnection from the urban space on the other.

Figure 11: Agricultural area on the southwest banks of the lagoon

II-4-Forest and green landscape unit character:

Figure 12: Section on the green landscape

Most of the area around the lagoon is mainly modified by man either to create urban areas, agricultural fields or exploit it for heavy traffic. The only virgin area is located to the east. This area represents in particular a large area of vegetal cover, a small part is exploited as a natural park near the urban fabric but for the rest it remains virgin until today. It plays the role of a border protecting the lagoon against urban expansion on its banks.

It should be noted that this forest only fulfills its environmental function as an anti-urban sprawl green screen and as an aesthetic marker element of the landscape of the eastern shore of the lake and sheltering a biodiversity, especially floristic, regrouping mainly trees of moderate density and height and dispersed herbaceous agglomerations.

Figure 13: Green environment limiting the lagoon to the South-East

III-ECOLOGICAL ANALYSIS

III-1-Migratory route of water birds through the Mediterranean

Tunisia has long served as a vital sanctuary for water birds, forming a crucial leg of their migratory journey across *Europe*. These avian travelers soar over the continent, traversing *Italy* and crossing the *Strait of Messina* to reach *Sicily*. Opting for the safest route, they bypass the Mediterranean Sea and choose the vast land bridge connecting Africa and Europe. This landmass becomes a preferred pathway for birds seeking suitable nesting grounds.

Tunisia, with its abundant water sources, becomes a winter haven for numerous Eurasian species, welcoming them in autumn and bidding farewell in spring. The remarkable seasonality of these migrations paints a captivating natural spectacle across the landscape.

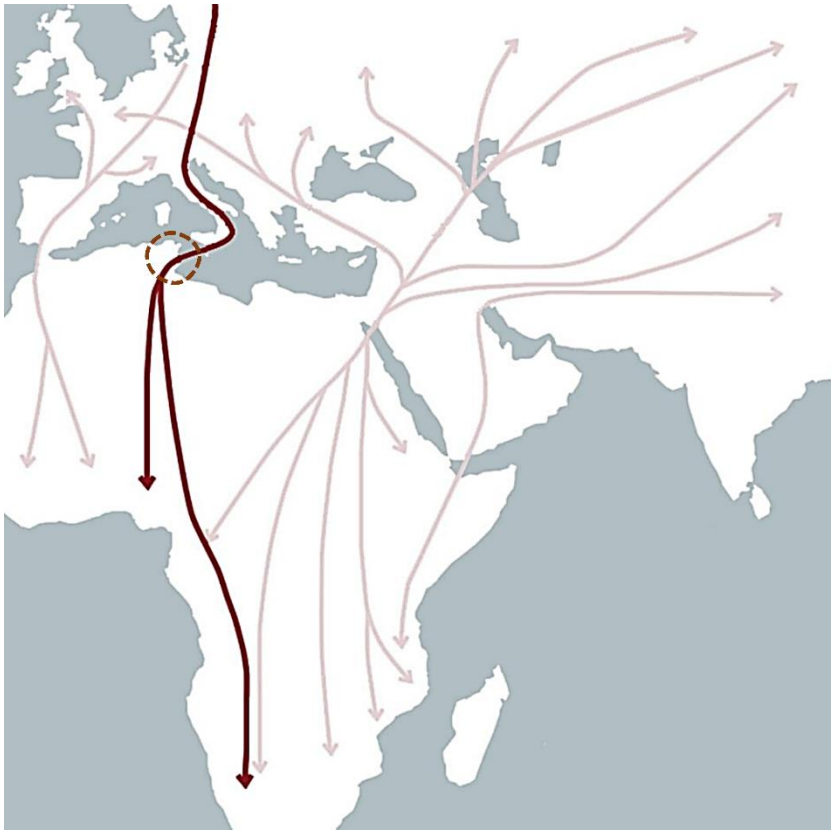


Figure 14: Migratory routes of water birds

Source: *MEDWET – The Mediterranean Wetlands Initiative*

Sijoumi Lagoon attracts a large and diverse aquatic avifauna since it's bordered by regular marshes and is rich in organic matter, a major food source for birds. This then indicates the reason why *Sijoumi* has become an essential stopover for migratory birds, whether they are passing through, wintering, or summering.

almost all wintering migratory species frequent its wetlands (*flamingo duck*) and a series of marine species (*legged gull, little tern, black-headed gull*) and shorebirds nest there (*ringed plovers, black stilts, sandpipers*), this attributes to *Sijoumi* Lagoon an international role in the maintenance of water birds in the Mediterranean

Figure 15: Birds in Sijoumi lagoon

III-2-Dynamics of vegetation and space on the banks of the Essijoumi lagoon

According to the development study of the lagoon of *Sijoumi*, in December 2015 the plant cover that borders the lagoon is influenced by a set of factors including: relief, orientation, climatic data, salinity, hylomorphism, soil texture, etc.

The natural vegetation in the watershed shows a medium to low density and it shows two strata: a tree stratum and an herbaceous stratum.

The lagoon forest formation plays a crucial ecological role in terms of biodiversity conservation and the protection of soil and agricultural land against erosion. It is a ligneous formation whose height of trees often exceeds 7 m and whose density is 100 vines/ha. The tree stratum forms a discontinuous band around the lagoon with 190 ha of Riparian Forest. The herbaceous vegetation observed presents a spatial distribution in belts and is largely controlled by hydrological gradients.

We note that the halophilic and hydromorphic groups (mosaic with halophilic steppe and wet meadows, flooded meadows) are well represented around the lagoon, Following the strong anthropogenic pressure on the environment, a good part of the listed halophilic plants is threatened with extinction.

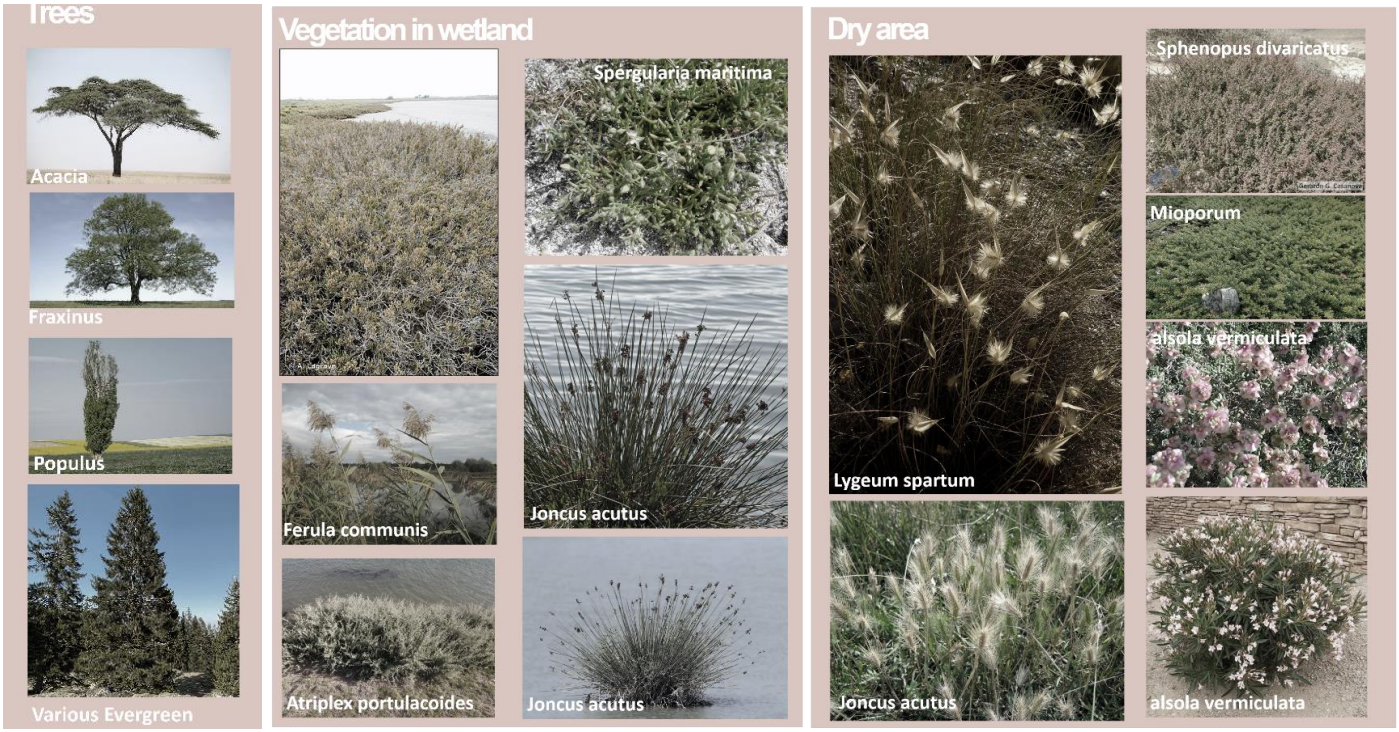


Figure 16: Vegetation species on the bank of the lagoon

IV- URBAN ANALYSIS

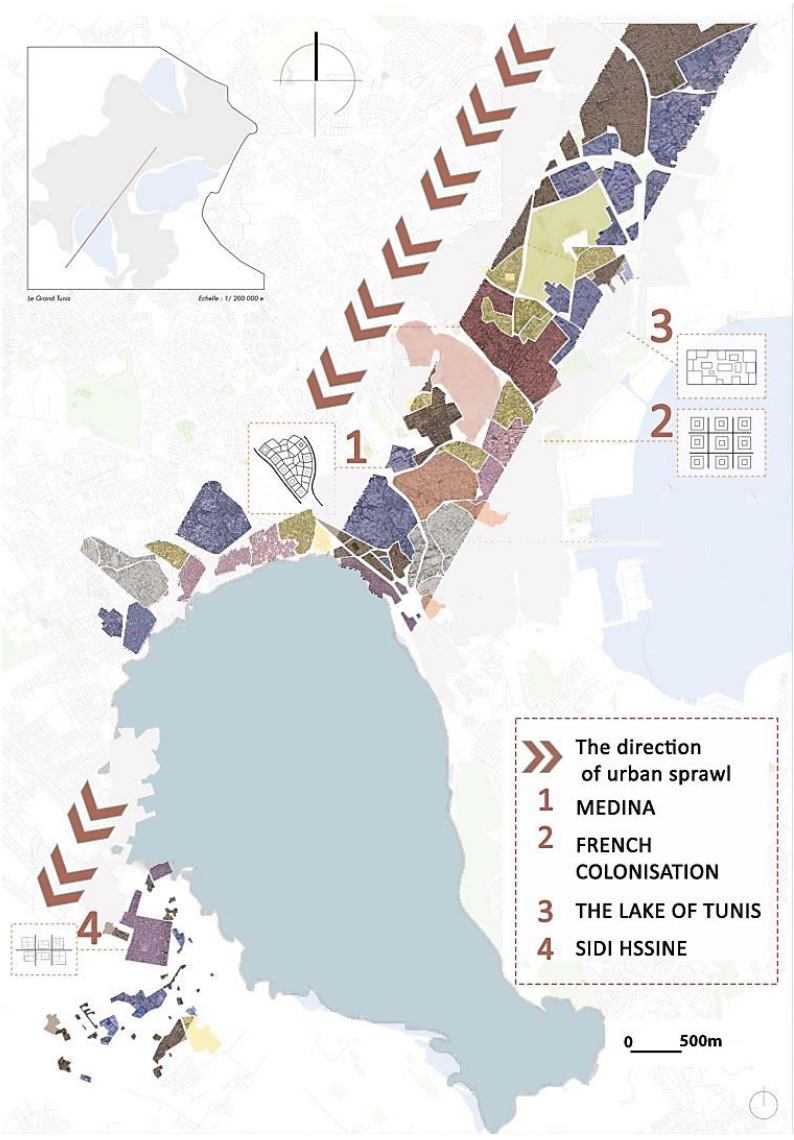
IV-1- General context

1: *The Medina of Tunis fabric* is the *Medina* quarter of *Tunis*, the capital of *Tunisia*. It has been a UNESCO World Heritage Site since 1979. It contains around 700 monuments.

2: *The French colonization fabric* was leading to rapid redevelopment of the city it's divided into a traditional *Arab*-populated old city, and a new city with a different structure.

3: *The Lake of Tunis fabric* is a natural lagoon located between the Tunisian capital city of *Tunis* and the Gulf of *Tunis* (*Mediterranean* Sea)

.**5: *Sidi Hassine fabric*** is a spontaneous urban settlement around the lagoon



Medina

The colonial French city

The Lake of Tunis

Sidi Hassine

IV-2-Forms of human occupation of the banks of the Essijoumi lagoon:

Adjoining the capital, the mode of land use on the banks of the lagoon has undergone profound and rapid changes since the end of the last century.

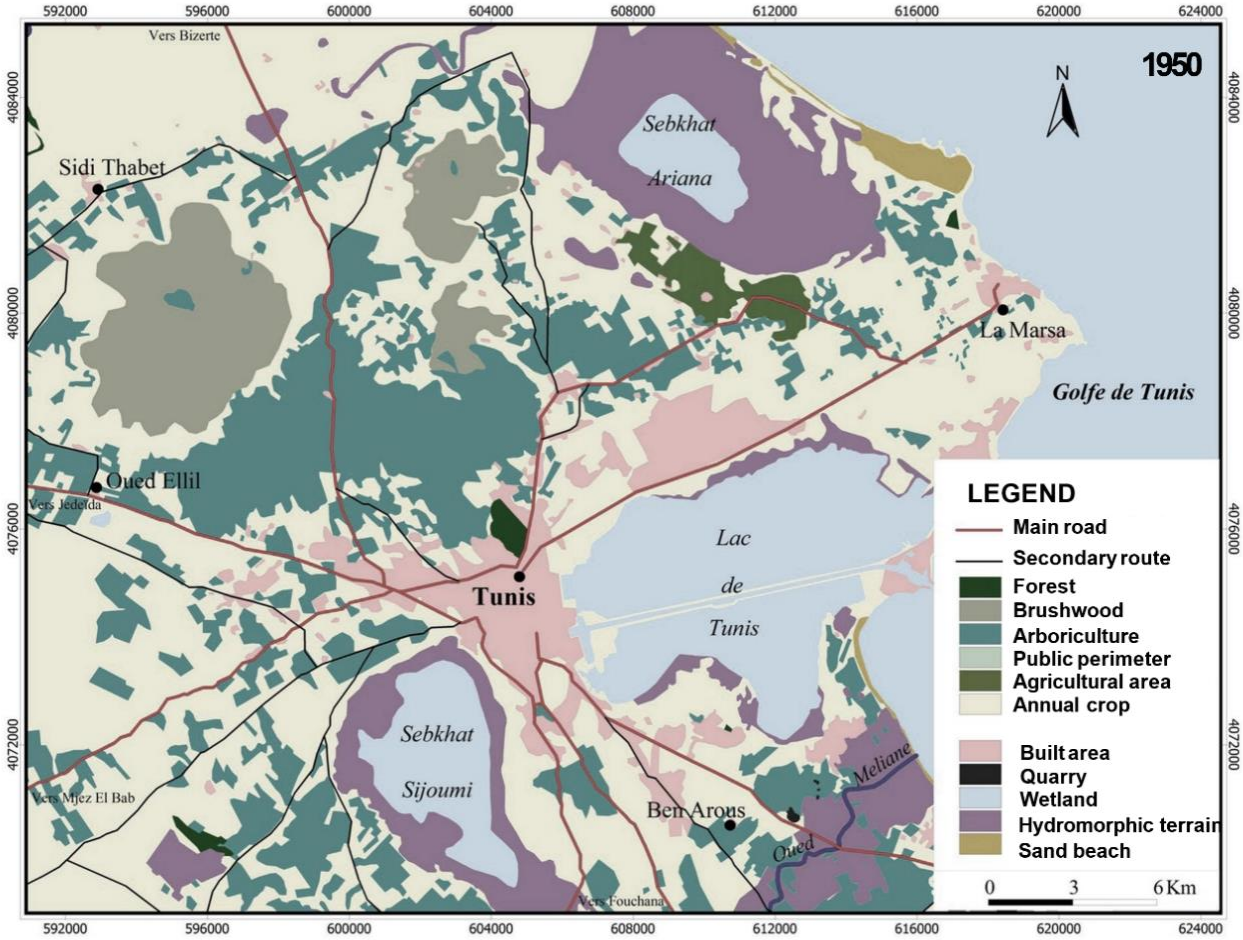


Figure 18: The lands occupation on 1950

Source: *Métropolisation et recomposition territoriale du Nord-Est Tunisien*

It was from the 1940s that the east bank of the lagoon hosted the first populations and the first “gourbis” towns.

During this period, population growth was insignificant, therefore we notice the low rate of urbanization which may explain the exceeded 3% of the total watershed area.

The built-up areas are very small and only a few urban blocks scattered on the north and east banks of the lagoon represented on the topographic map drawn up in 1950 when the suburbs begun to appear, this wave of extension is underpinned by waves of rural exodus.

Figure 19: Agricultural land around the lagoon on 1979

Going back to the history of the appointment of the lagoon, and before the installation of the French settlers, the banks of the lagoon were agricultural lands of wheat and olive trees and meadows ensuring the need of the Medina in market gardening products.

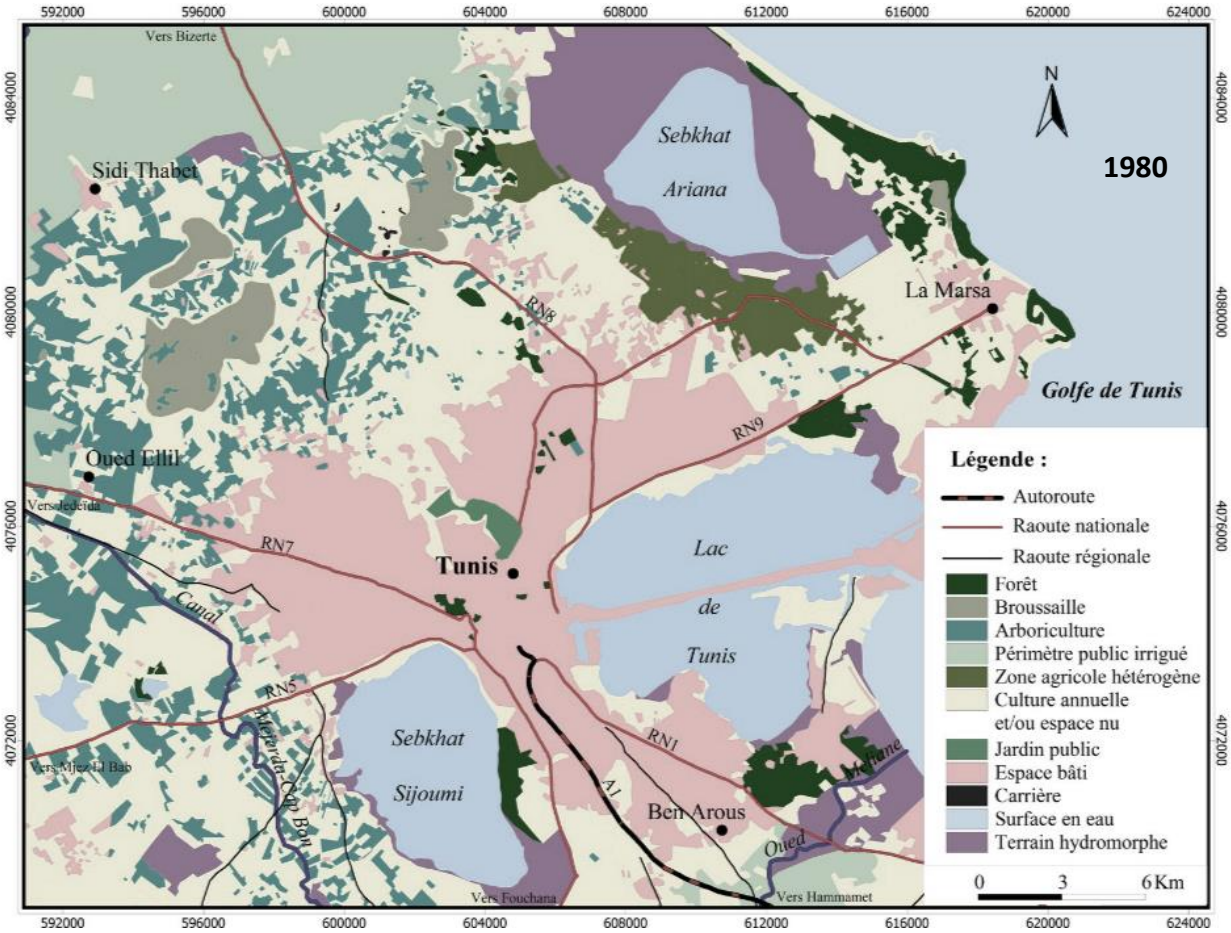


Figure 20: The land occupation in Tunis on 1980

Source: Métropolisation et recomposition territoriale du Nord-Est Tunisien

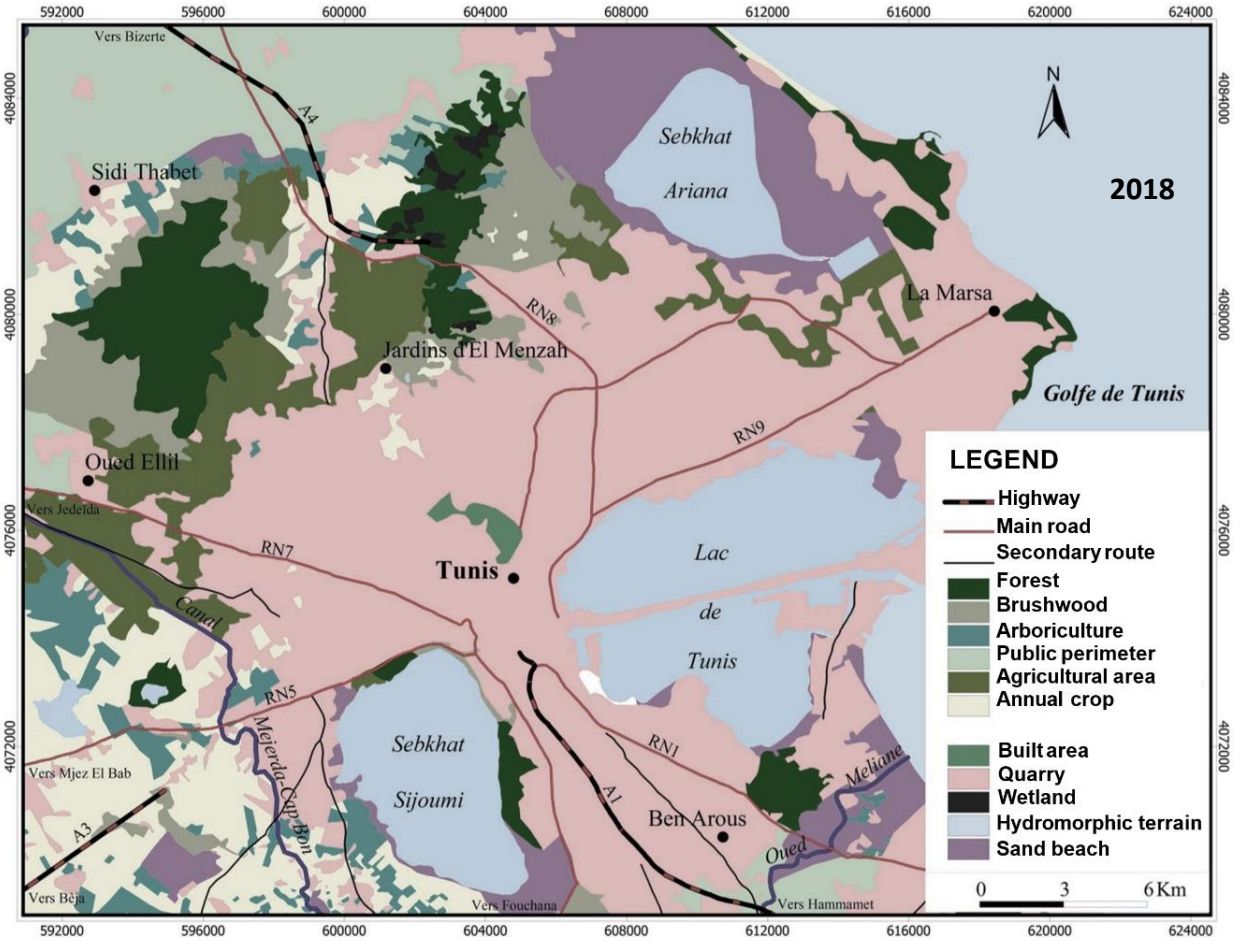


Figure 21: The land occupation on 2018

Source: *Métropolisation et recomposition territoriale du Nord-Est Tunisien*

The monitoring of spatial dynamics of the wetland and its catchment area, using satellites covering the past 30 years, revealed that the surface of green areas around the lagoon has decreased considerably since the late 1980s, due to the new process of land occupation on the plain of *Sijoumi* and the consumption of agricultural spaces.

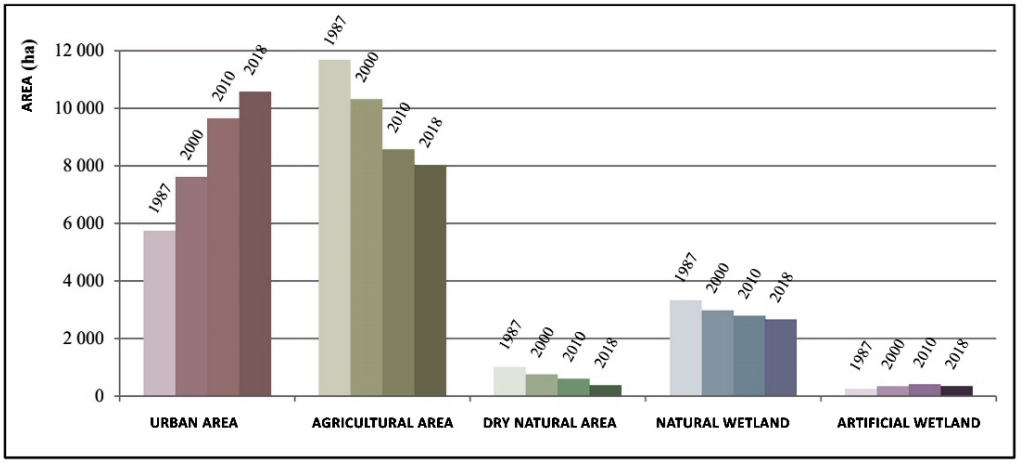


Figure 22: Chronological development of the different types of land use

This diagram shows the chronological development of the different types of land use (urban area, agriculture area, dry natural area, natural wetland, artificial wetland), 65% of the agricultural lands and green spaces are converted into residential, commercial, and industrial areas to accommodate the growing population.

The construction of roads, highways, bridges, and buildings associated with urbanization requires clearing land. These infrastructural developments often result in the loss of green areas and further encroachment upon the lagoon's natural surroundings.

V-IMPACT OF URBAN DEVELOPMENT ON THE LAGOON: AN URBANIZATION GENERATING VULNERABILITIES:

V-1- Fragmentation of Habitats:

The map of the current state shows that all the city of *Greater Tunis*: there is no green space apart from that around the lagoon. This green space is juxtaposed with a dense urban center that lacks green space or any recreational institution.

Urban sprawl fragment natural habitats around the lagoon. The green areas are divided into smaller patches due to urban development; it disrupts the ecosystems and make it challenging for flora and fauna to thrive, leading to a decline in biodiversity.

Figure 23: The green areas location

V-2-threatened birds

Many *Mediterranean* expanses are today considered as "hot spots" areas where biodiversity is threatened. The avifauna of the *Mediterranean* basin presents major conservation challenges because these sensitive areas are their natural habitat.

The water bird totally dependent on these wetlands loses its natural habitat and will seek another until the day when there is no longer a substitute. The bird then appears as a signal of an endangered natural ecosystem.

we can visualize this threat from this map produced according to a study on the "hot spots" in the *Mediterranean* by the *"Mediterranean water bird"* organization which shows that *Tunisia* and more particularly the *Sijoumi* lagoon is one of the threatened areas.

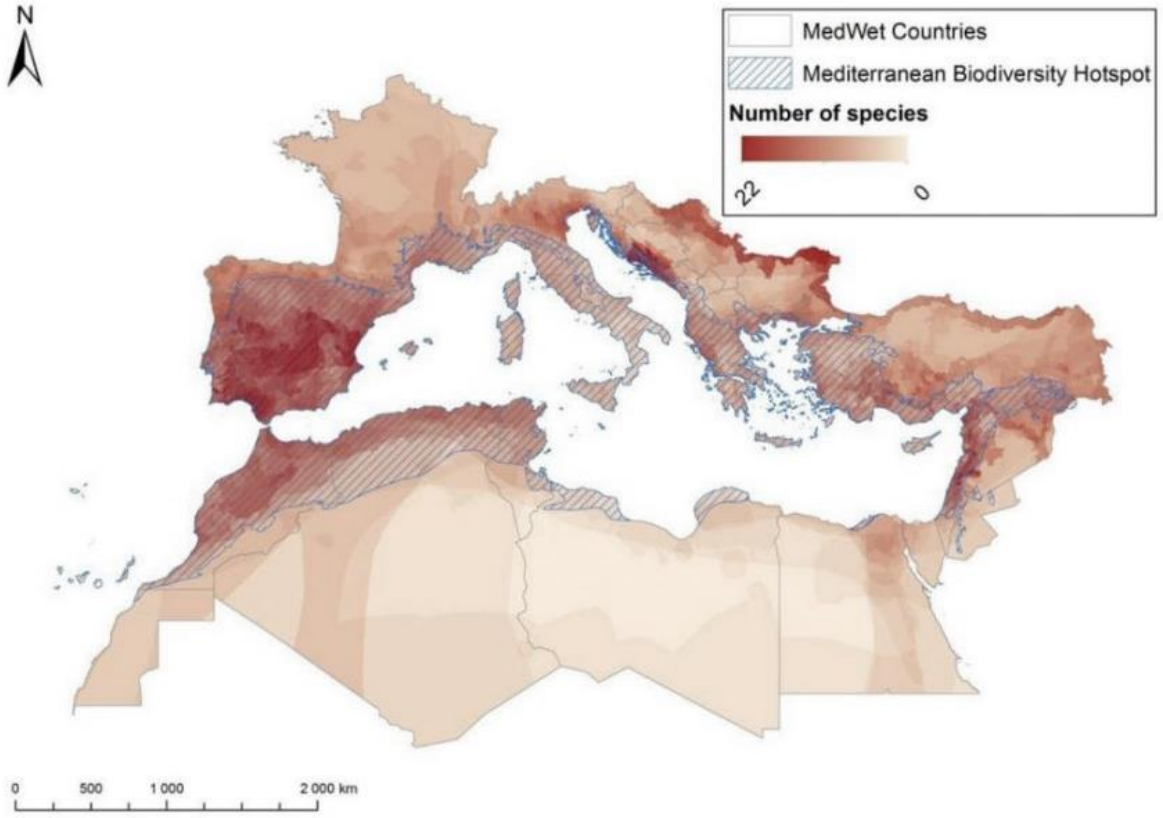


Figure 24: Map of the hot spots' distribution in the Mediterranean region
Source: MEDWET – The Mediterranean Wetlands Initiative

Birds in *Sijoumi*, like in many other wetland areas, face various threats that can impact their populations and habitats. Some common threats to birds in this ecosystem include:

Habitat Loss: Urbanization, agricultural expansion, and infrastructure development lead to the loss of natural habitats, including wetlands. Birds lose nesting sites and feeding grounds, reducing their ability to find food and raise their young.

Pollution: Pollution from urban runoff, industrial discharges, and agricultural chemicals can contaminate the water in the lagoon. This pollution affects the fish and other prey that birds rely on for food, leading to a decline in bird populations.

Disturbance: Human activities disturb nesting birds, causing them to abandon their nests or young. Nesting birds are particularly vulnerable to disturbance, which can disrupt their breeding cycles and decrease their reproductive success.

Altered Water Flow: Changes in the natural flow of water into and out of the lagoon can affect the availability of food and nesting sites for birds. Alterations in water flow patterns can lead to the loss of crucial feeding and breeding grounds.

V-3-Water Quality Degradation

The development of spontaneous neighborhoods and the concentration of polluting industrial companies on the banks of the lagoon is at the origin of a significant production of solid and liquid waste.

The problem of the accumulation of household waste on spontaneous and wild dumpsites is linked to the low rate of collection by the services concerned and the uncontrolled increase in construction by backfilling the banks of the depression. Clearly, uncontrolled and poorly managed landfills create serious environmental and health problems.

The clogging of solid waste in natural and artificial drainage channels causes poor circulation of runoff water, thus promoting a rise in the water table.

Figure 25: Pollutants markers of the lagoon

Figure 26: Industrial discharge

Figure 27: Stormwater runoff

Figure 28: Domestic waste

Figure 29: Oil Spills

Through this map we can notice there are several sources of lagoon pollution:

Industrial Discharges: Industrial facilities and factories sometimes release pollutants, including heavy metals and chemicals.

Agricultural Runoff: Chemical fertilizers, herbicides, and pesticides can be used in agriculture and can be washed into the lagoon by rainwater, especially during winter time. These elements can affect water quality and harm aquatic life.

Stormwater Runoff: Urban areas with impervious surfaces like pavements and roads prevent rainwater from soaking into the ground. Instead, this water, often carrying pollutants like oil and debris will follow other ways, most of the time leading to the lagoon.

Solid Waste: Improper disposal of solid waste, including plastic, can lead to littering in and around the lagoon. Plastics and other non-biodegradable materials not only ruin the visual appeal of the area but can also harm wildlife and degrade water quality as they break down.

Liquid Waste: Accidental spills of oil or other hazardous substances, either from boats or nearby industries, can have severe consequences for the lagoon's ecosystem. Oil pollution can coat plants, animals, and the shoreline, disrupting the balance of the ecosystem.

V-4- Changes in hydrographic dynamics: flooding risk

The rising vulnerability to flooding is closely tied to various factors such as the configuration of the lagoon outlet, inadequate drainage and water disposal systems, unregulated waste dumping, and urbanization. Urban development not only leads to soil sealing but also increases the impermeability of the catchment area, complicating water drainage processes. These factors collectively contribute to the heightened risk of floods in the area.

To understand the flooding risk, we need to analyze the water levels as the relationship between permanent and temporary water levels and flooding risk is crucial in understanding and managing flood-prone areas

Permanent Water Level: also known as the baseline water level, is the average level of water in the lagoon over an extended period, usually years to decades. It represents the typical water height during normal or non-extreme conditions.

Temporary water levels: temporary means variable and means it can fluctuate on a daily, seasonal, or even shorter timescale. These fluctuations can be caused by rainfall, storm surges, and human activities like dam releases or water diversions.

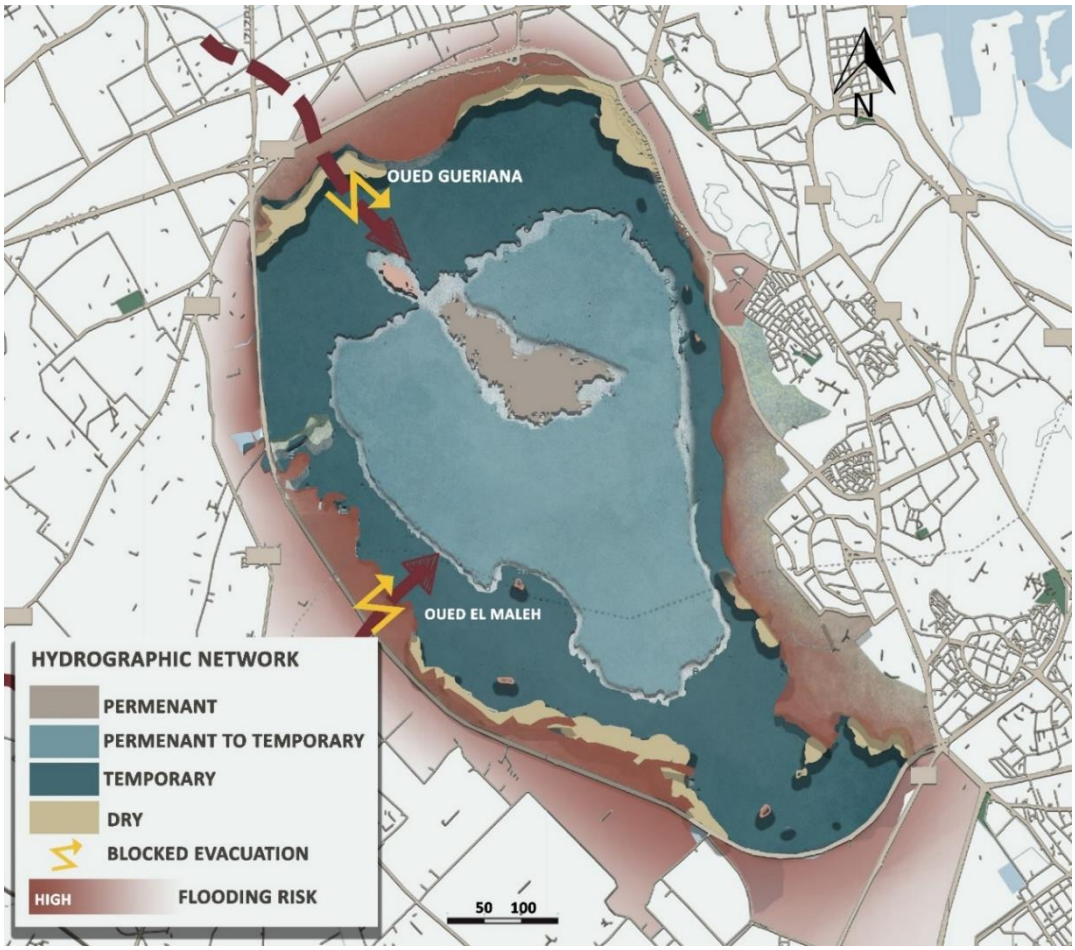


Figure 30: Hydrographic dynamics of the lagoon

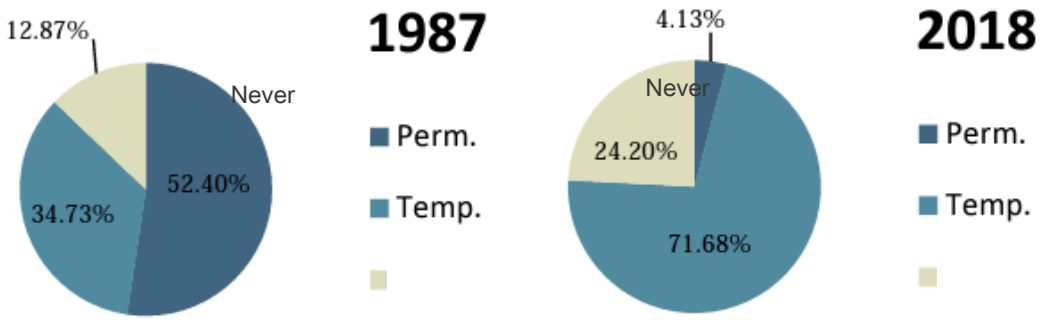


Figure 31: The percentage of permanent and temporary water level between 1987 and 2018

In recent years, the percentage of temporary water level has become continuously higher than the percentage of permanent water level in the lagoon, which indicates several important aspects of the hydrological characteristics of the lagoon and the existence of a serious risk of flooding during the winter.

V-5-Consolidation of banks and impacts on the ecosystem of the lagoon

Between 1987 and 2018, the outer limits of the wetland habitats forming the *Sijoumi* lagoon ecosystem were greatly reduced and the banks of the latter receded up to 500 m to the northwest of it, or even more than 1.5 km to the south. It is expected that the area will shrink more and more in the coming years. On the northeast side, the withdrawals are less marked but can reach up to 200 m in some spots.

Moreover, in the *Mediterranean*, this type of wetland is characterized by a shallow depression containing water for more or less long periods of the year, but rarely permanently over most of its extent, and drying up, generally, during summer seasons, the fact of backfilling the banks will not only reduce the areas of natural wetland habitats by destroying them but also break the gentle slopes that characterize this type of wetland and significantly reduce the areas where Shallow water bodies may vary with the seasons.

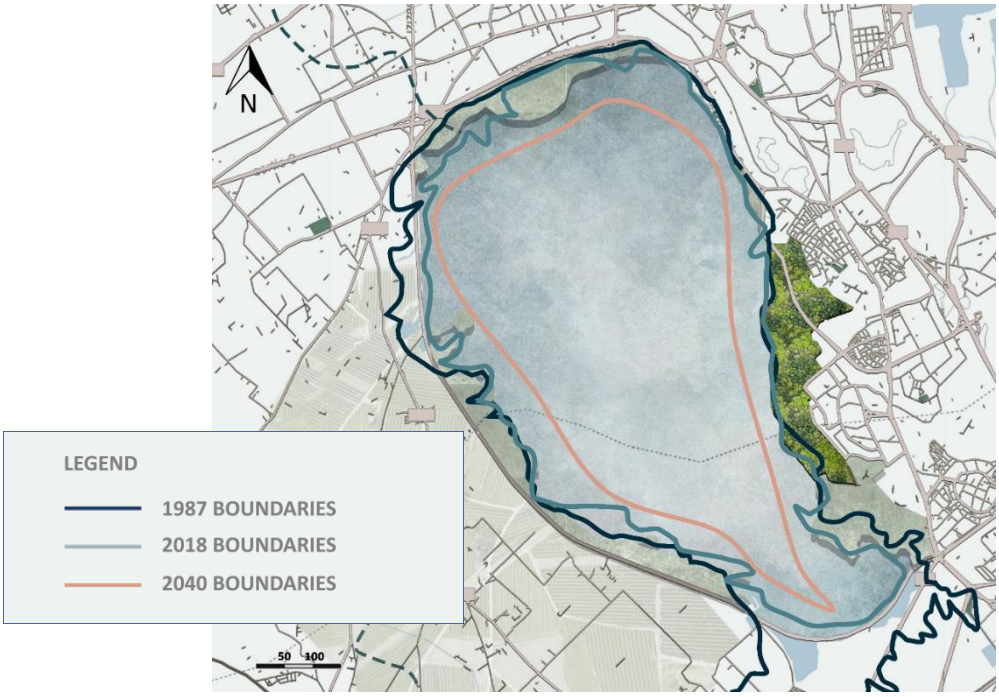


Figure 32: Consolidation of banks

V-6- Sijoumi lagoon: a fragile and vulnerable ecosystem

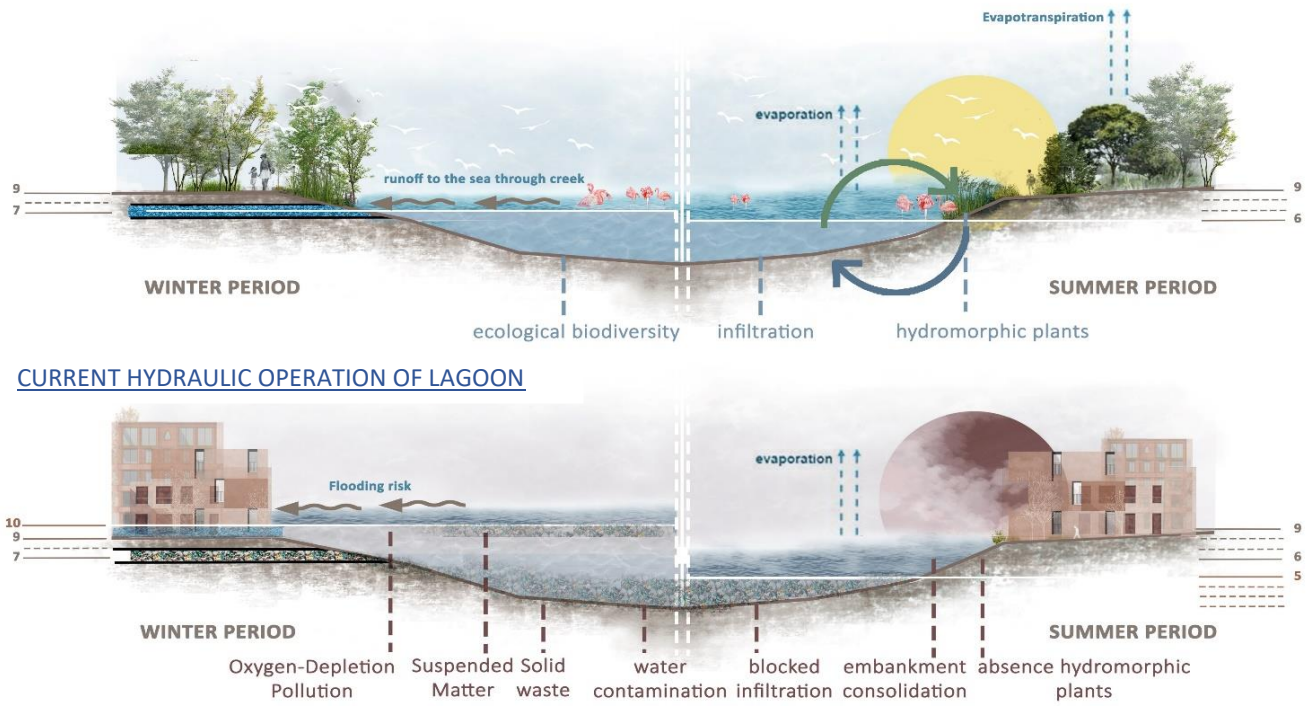


Figure 33: Vulnerability of the Sijoumi lagoon ecosystem

The vulnerability of the *Sijoumi* lagoon ecosystem is caused by various factors, primarily related to natural and anthropogenic changes in the hydrological cycle and land use patterns. Here are some common causes:

Poor Drainage Infrastructure: Inadequate or poorly maintained drainage systems, including canals, and stormwater drains, can impede the efficient flow of water away from the lagoon area.

In the past, the evacuation of the overflow from the lagoon water body seems to be ensured by a natural outlet which connects it to the sea via *Oued Méliane*

Today, the hydrological dynamics have radically changed. The depression works like a confined environment into which the waters of the entire catchment area flow.

As a result, the natural functioning of the lagoon ecosystem is completely disrupted. Such an evolution led to the transformation of the *Sijoumi* lagoon into a true closed depression with an endorheic hydrological regime.

This situation is well illustrated during the rainy season where the body of water not only covers the bottom of the depression but also invades the lowlands located on its banks.

Deforestation and Urbanization: Clearing off natural vegetation, such as forests and green areas can reduce the natural absorption of rainwater. In urbanized areas, impervious surfaces like asphalt, and concrete, etc… prevent water from infiltrating to the ground, leading to increased blocking surface and therefore potential flooding.

Loss of evaporation phenomenon: Plants surrounding the lagoon, including trees, grasses, and wetland vegetation, absorb water through their roots. This water is later released into the atmosphere through the transpiration process. Transpiration is a vital component of evapotranspiration and contributes to the overall water movement within the ecosystem.

Sedimentation and pollution: Over time, channel connected to the lagoon accumulate sediment, reducing their water-holding capacity. When sediment builds up, the lagoon may overflow more easily during heavy rains, leading to flooding in nearby areas.

V-7-Synthesis:

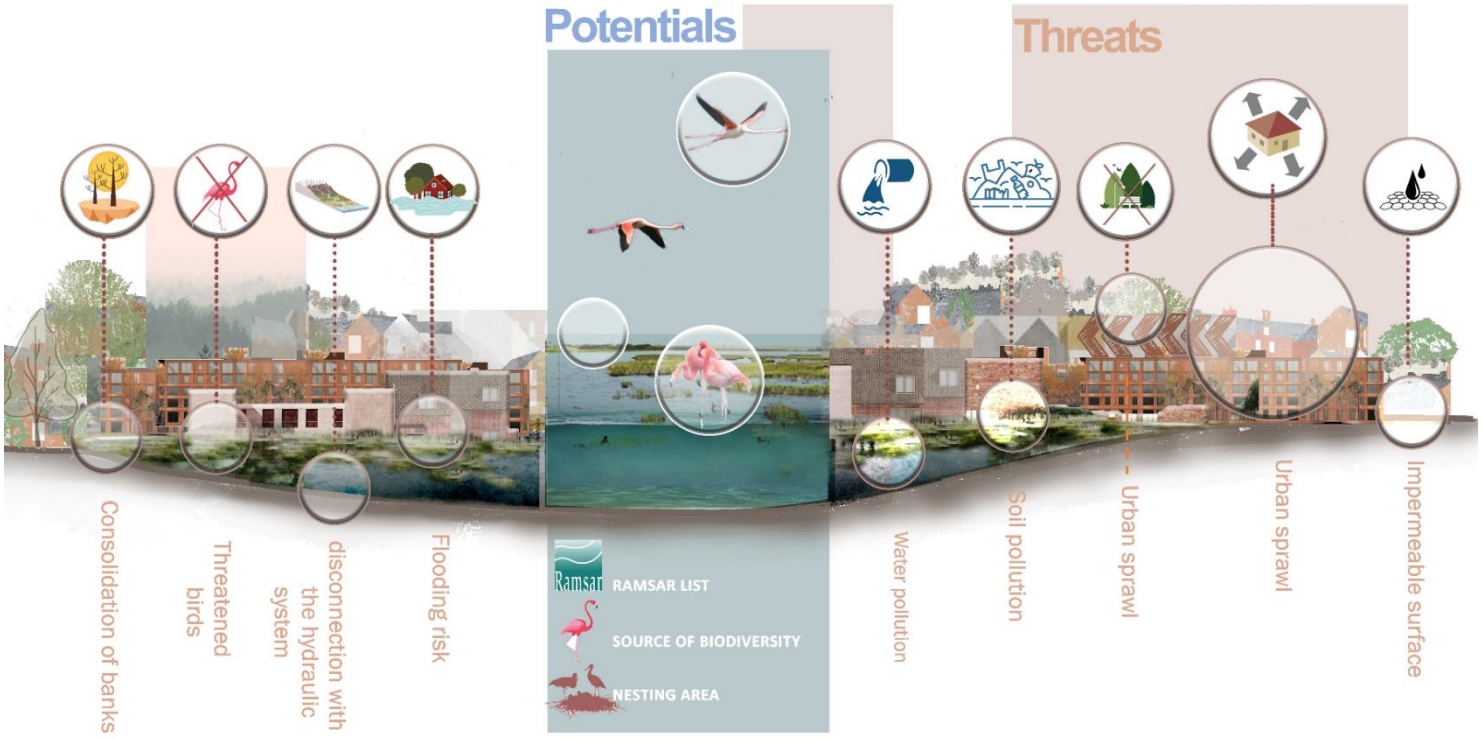


Figure 34: The different potentials & threats of the Sijoumi lagoon

As a conclusion of the analytic reading of the Lagoon's situation, we may extract the following headlines regrouping the main potentials of the area and its threatening factors:

Speaking of Environmental values, one of the substantial particularities of *Sijoumi* Lagoon is its rich and specific biodiversity in terms of fauna and flora, as it represents a major station in the migratory itinerary of many birds being a nesting area that offers optimal natural circumstances for these species: these conditions made from it a part of the ***Ramsar list***.

On the other hand, The location of the Lagoon regarding its direct/regional urban fabric is quite important as it occupies a magnetic environmental and recreational hub for the over-urbanized surrounding agglomerations.

As for the threats, they are mainly related to the excessive urban sprawl, which led to increasing rates of water and soil pollution, the expansion of impermeable surfaces, consolidation of the banks as well as the disconnection with the natural hydraulic system, and therefore the high risks of flooding.

VI- CONCEPTUAL APPROACH & DESIGN DEVELOPMENT

VI-1-The proposed solutions: Tunisian authority intervention plans

After this deep analysis we found that the lagoon of *Sijoumi* suffers from various problems at different scales and the efficient solution of these problems requires a whole global approach and a strategy of development on different sectors.

As a response from the Tunisian state, the authorities launched in 2018 a major project that serves to solve the ecological problems linked to the environmental, urban, hydraulic, and landscape context of the lagoon.

Regarding the global intervention plan that the state has defined to treat the Sijoumi Lagoon's issues, we may classify many strategic steps among the actions that fall within the authority's responsibility, including the Technical engineering phase that treats mainly the hydraulic system remediation of the lagoon, as well as the work on the Ecological aspect via

the study of the *Figure 17: Urban typography-Source: rapport sur La sebkha* essential ways to cease the pollution sources and to maintain the optimal quality of the waters and soil and therefore the adequate environment for the fauna and flora. Nevertheless, In light of the mentioned headlines, the design process will integrate the establishment of a rainwater drainage system to improve the water inflows to the Lagoon. Moreover, in order to contribute to minimizing water pollution, 4 settling ponds will be conceived in the selected site in addition to the improvement of the automatic water pumping.

The urban management solutions of the current pressing situation are considered as a complex long-term file that requires the collaboration of the various intervenients of the state.

The last core of this remediation strategy plan is the Landscape development field, and it's where, as landscape designers, we can intervene to contribute to the conservation and the development of such a sensitive and valuable area according to the deducted assessment.

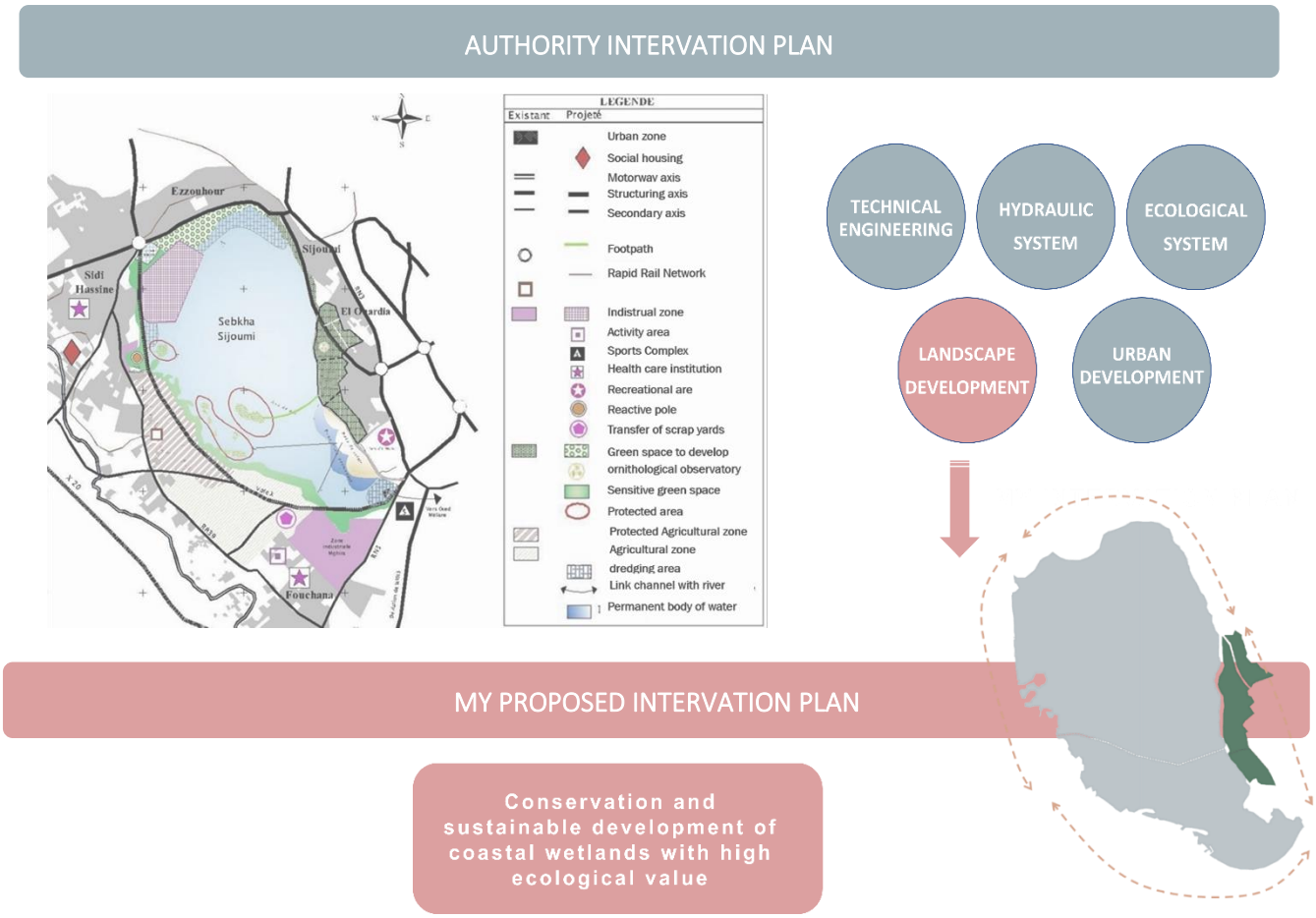


Figure 35: Authority's intervention plan & my proposed intervention plan

VI-2-Conceptual approach: urban level

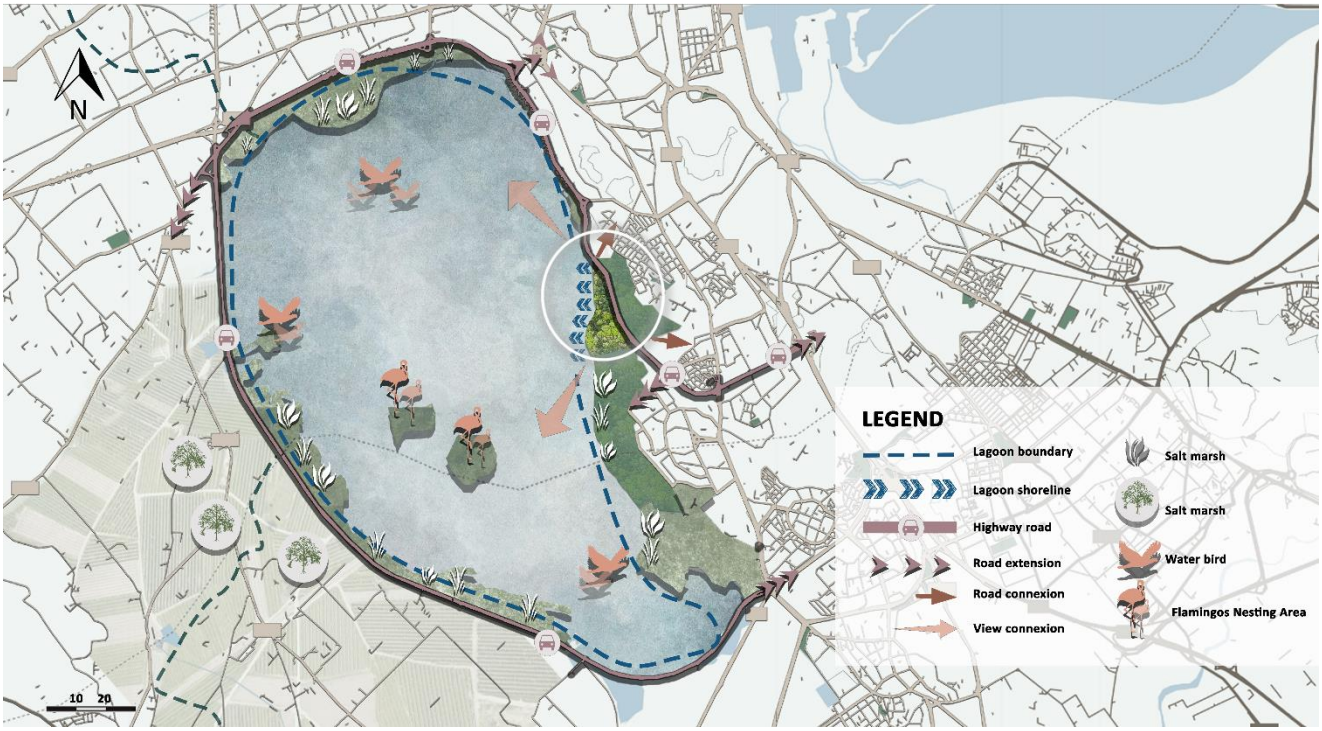


Figure 36: Site selection

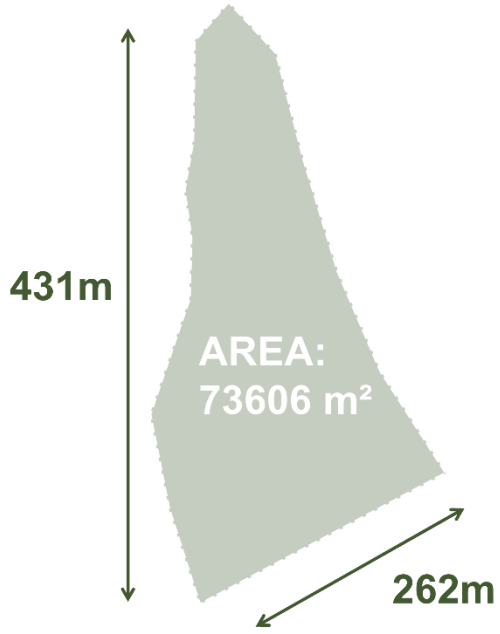


Figure 37: Site dimensions

Among the criteria of the site selection, we can mention that the spot is directly attached to the Lagoon which enables taking advantage of an extraordinary view along the bank. It is also located close to considerable urban agglomerations, granting easy accessibility for pedestrians and vehicles, and connected to the rest of the regional context through an important road axis. In addition to this, the vocation of the site, according to the regulations, allows the intervention by developing environmental projects aiming at the valorization of such a site. As for the dimensions, it covers around 73600m² with a bank spread over 431m.

VI-3-Site analysis:

For years, the site was deprived of appealing functions, except for a small adventure park located on the southeast corner of the terrain, which suffers nowadays from the lack of maintenance. Other than that, only the natural aspect and the special views offered by the green fields, marches, and the Lagoon horizon succeded in attracting some local pedestrians to the area. Consequently, a few spontaneous pathways can be detected along the bank.

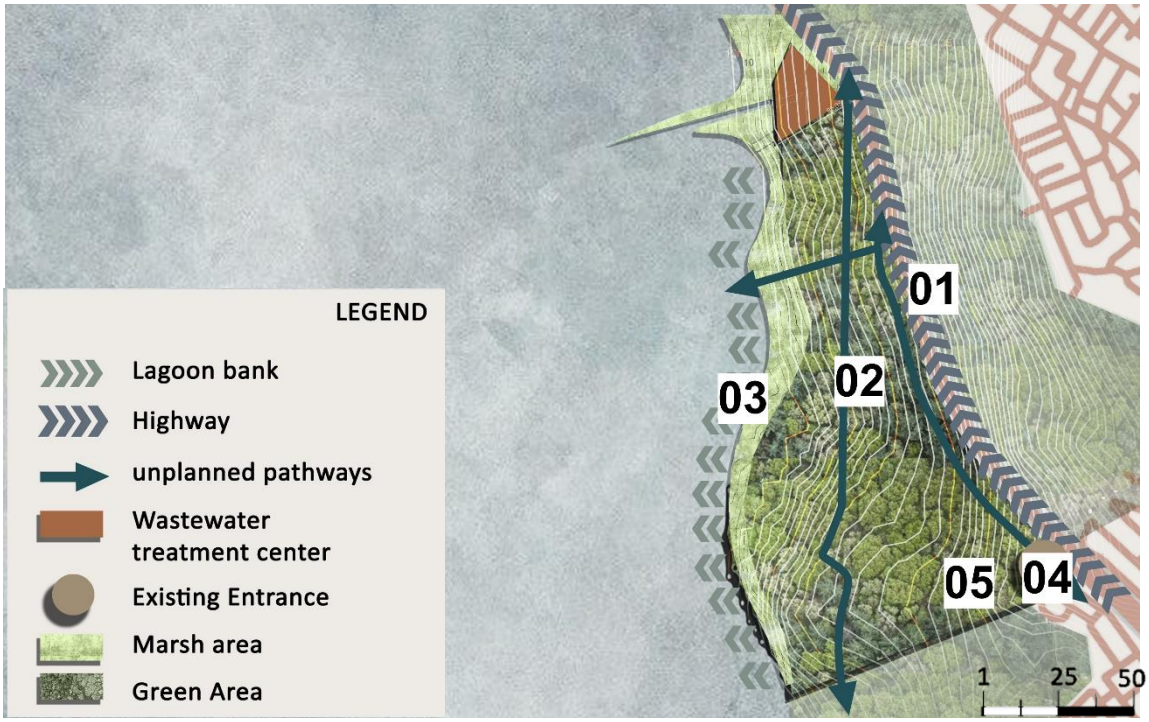


Figure 38: Preliminary data of the site

Figure 39: View from the road (01)

Figure 40: View from the green area (02)

Figure 41: View from the march area (03)

Figure 42: View from the entrance (04)

Figure 43: View from the adventure park (05)

VI-4-Design strategies

The design in such a context requires careful planning and consideration of the lagoon's potential to be highlighted and its ecological sensitivity and threats to be solved.

The adopted design strategy will be based on 2 key perspectives deducted from the study of the issues and potentials:

The first one will be about **Ecology**, it focuses on creating sustainable, resilient, and biodiverse outdoor spaces that harmonize with natural ecosystems. This strategy aims to minimize environmental impact, conserve resources, enhance biodiversity, and provide multifunctional habitats for both wildlife and humans.

Figure 44: Ecological adaptation strategy

Below, we mention the key principles and approaches used in the ecological design strategy :

Phytotechnology : which involves the use of plants to address environmental issues, can play a significant role in the restoration and management of the Sijoumi Lagoon.

Wildlife-Friendly Habitats : Incorporate features like birdhouses, bat boxes, and bee hotels to provide shelter for animals and nesting sites for wildlife.

Biodiversity Enhancement: Use native plants in landscaping to support local wildlife, attract pollinators, and create diverse habitats.

Stormwater Management: Implement rain gardens, bioswales, and permeable pavements to capture and manage rainwater.

On another side, The **Educational and Recreational** aspects will be also present in the establishment of the design strategies.

EDUCATIONAL & RECREATIONAL ADAPTATION STRATEGY

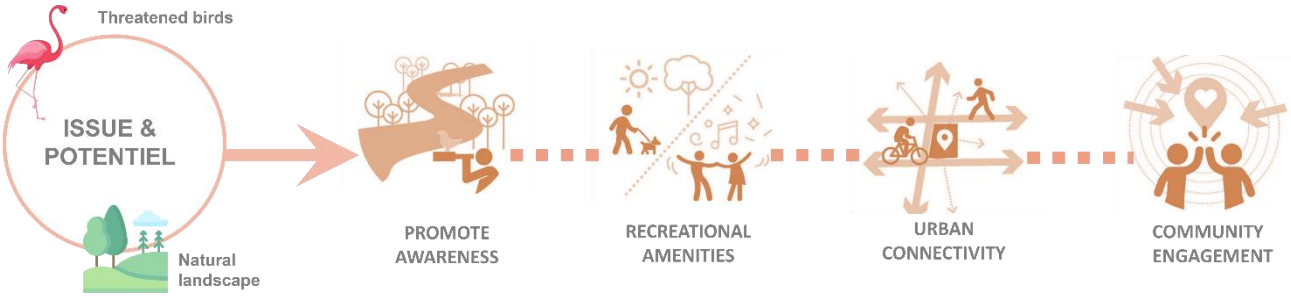


Figure 45: Educational & recreational adaptation strategy

This strategy involves creating spaces that engage all the senses and evoke emotional connections with nature. It goes beyond visual aesthetics, encouraging people to interact, explore, and fully immerse themselves in the environment by :

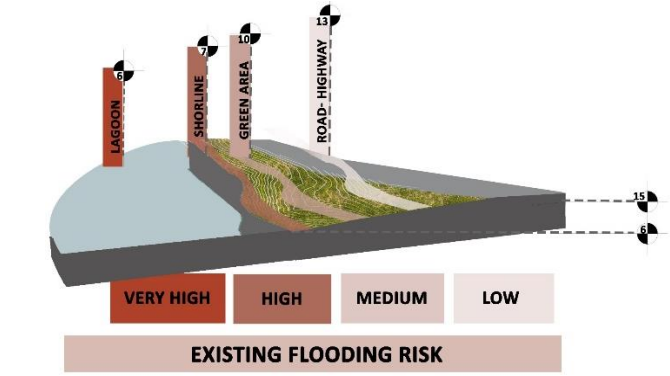
Promote Awareness : Incorporate educational elements within the landscape to inform visitors about local ecology, biodiversity, and sustainable practices. Educate the community about sustainable landscape practices and involve them in conservation efforts.

Recreational Areas: Designate spaces for sports, playgrounds, and other recreational activities. Consider amenities like basketball courts, football fields, and play structures for different age groups.

Urban connectivity: Extend the city's architectural and design elements into the park, creating a seamless transition between the urban environment and the park space.

Community engagement: Engage local schools, community groups, and volunteers in habitat restoration, clean-up events, and educational programs. Community involvement fosters a sense of ownership and pride in the green area.

VI-5- Functions, structure & plantation dispatching



The Logic behind establishing the optimal and convenient distribution of functions will be essentially determined by the relief and the structure of the site. Depending on the typography and structure of the land we developed the functional dispatching.

In the area with a high risk of flooding, we developed the ecological function which serves to stabilize the bank and interact with the water aspect, leisure functions are developed as active urban edges that interact with the surrounding urban environment by integrating cafes, restaurants, and shops facing the park, encouraging social interaction and commercial activity.

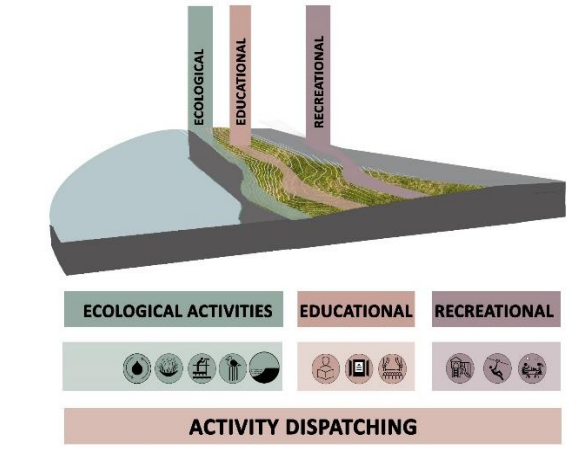
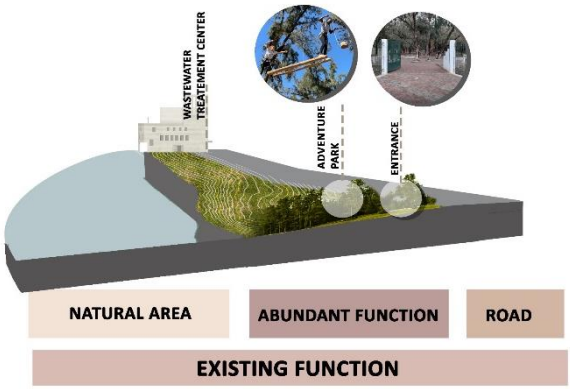


Figure 46: Activity Dispatching



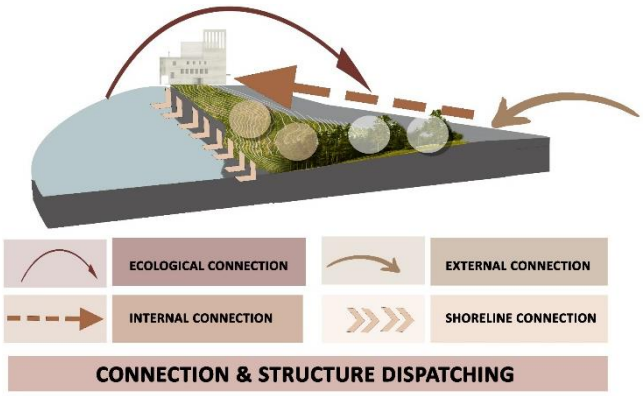


Figure 47: Connection & Structure dispatching

Both internal and external structures play a vital role in sorting out a cohesive and engaging environment via creating paved pedestrian pathways that connect the differet functions and zones in the park to nearby residential areas, schools, and commercial districts.

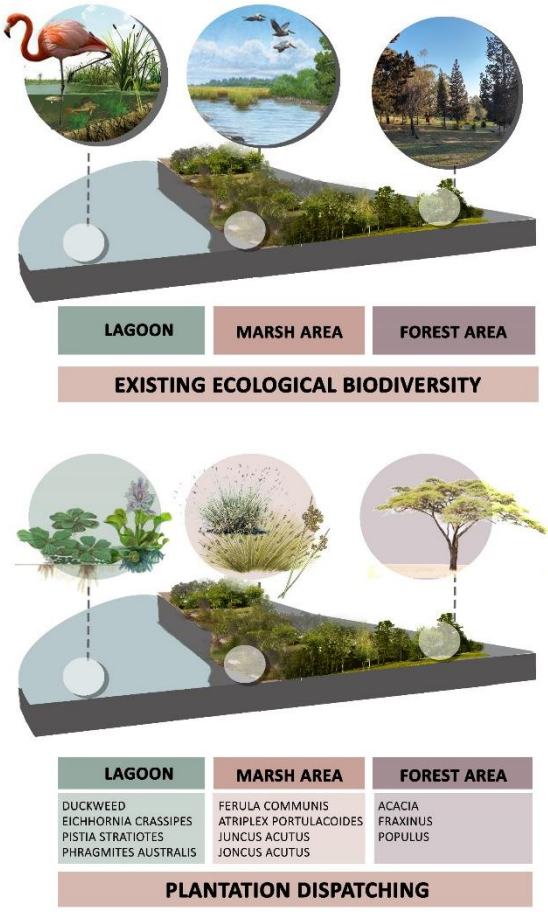


Figure 48: Plantation Dispatching

As we can observe through the figures, the lateral section indicates 3 types of ecosystems: the Lagoon, the marches, and the forest. Each one of them occupies a certain space defined by a specific altitude, a specific relation with water levels in normal states and during floodings, and finally by a specific soil character.

These areas attract a diverse range of bird species, including waterfowl, and migratory birds, it provides essential breeding, nesting, and foraging grounds. Wetland plants, both submerged and emergent contributes to the overall biodiversity and help stabilize the shoreline.

VI-6-Bubble Diagram

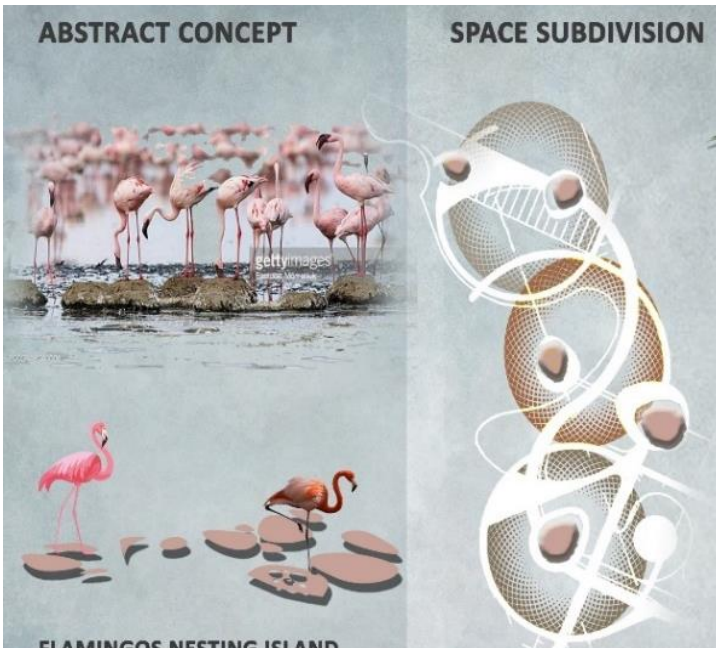


Figure 49: Abstract concept

The concept adopted in the design of the masterplan expresses the natural phenomena, abstractly, of the nesting islands that the Flamingo birds create with mud.

The Ecological, Educational, and Recreational functions will be distributed according to this idea while taking into consideration the previously mentioned natural factors.

These bubbles highlight specific areas such as playgrounds, outdoor exhibitions, adventure park, and many other landscape component :

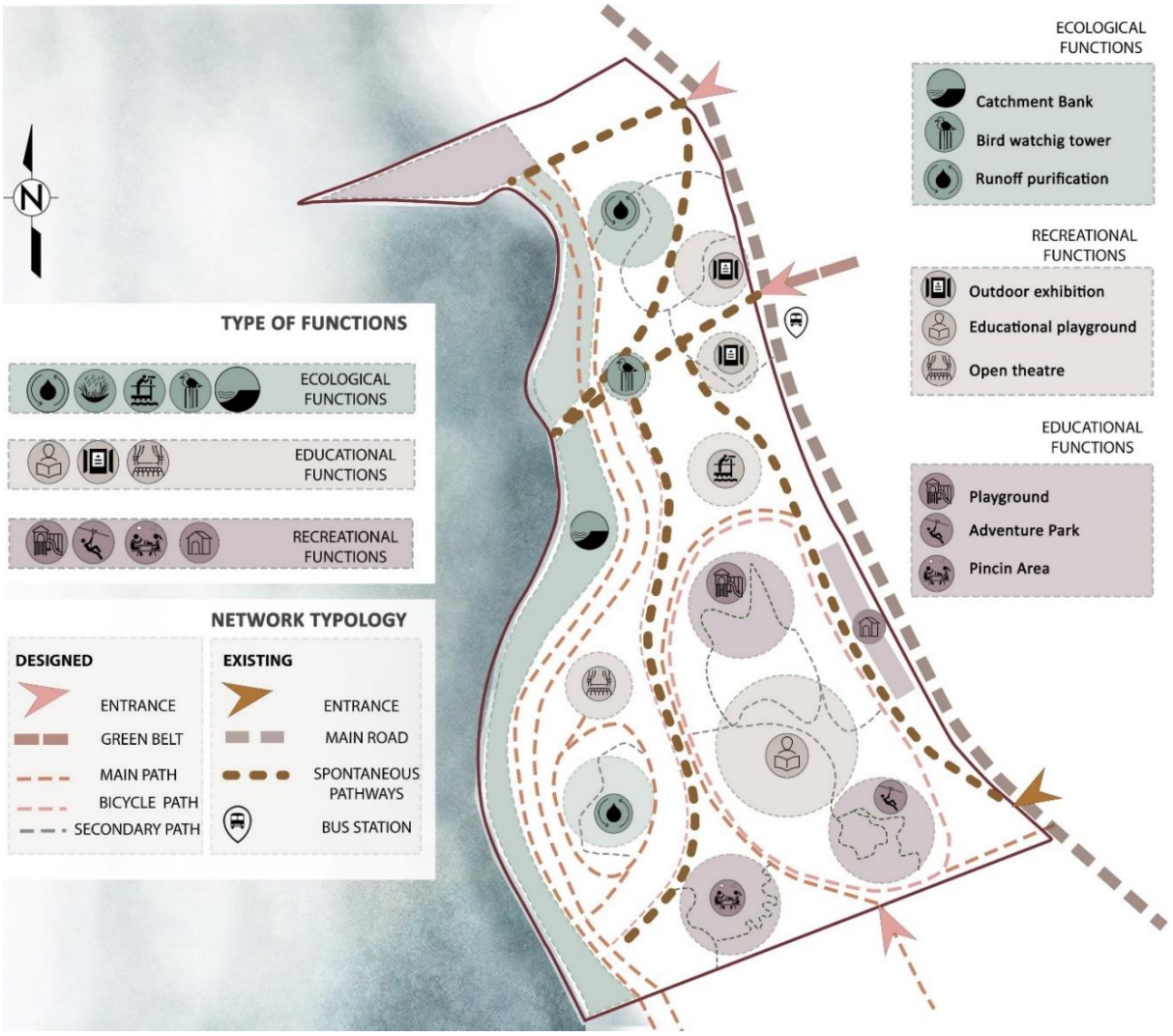


Figure 50: Bubble diagram

Ecological functions: Preserve natural habitats and integrate walking trails, birdwatching tower, wildlife-friendly areas, as well as creating nesting boxes, to attract and support a variety of animal species and include informational signage about the biodiversity, fauna and flora found in the area, conceiving rain gardens to manage stormwater runoff.

Educational functions: Include outdoor theater, outdoor stages for cultural events, concerts, and performances. Create interactive exhibits and displays that allow visitors to explore ecological concepts in an engaging way.

Recreational functions: Designate spaces for gathering, sports, playgrounds, and other recreational activities. Consider elements like adventure park, and play structures for different age groups and shaded picnic areas with seating, encouraging community gatherings.

VI-7- Master plan

Figure 51: Master Plan

Designing a master plan for a park around the *Sijoumi* Lagoon requires a comprehensive approach that considers ecological preservation, community engagement, and educational development. We suggest a design that will highlight the different potentials of the site and at the same time resolve the problems. This design can be considered as a prototype to be redone and reproduced throughout the *sijoumi* lagoon shoreline.

VI-8- Main section

This section shows the accessibility of the site by the integration of a green belt into the design that plays a significant role in creating a seamless connection between the lagoon of Sijoumi and its urban fabric, for pedestrians and cyclists and animals.

we can notice that the elevated pathways span over challenging terrain, such as catchment banks, wetlands, providing a smooth and accessible path, providing a panoramic view of the surrounding, and allowing people to appreciate the natural beauty of the lagoon and the urban landscape.

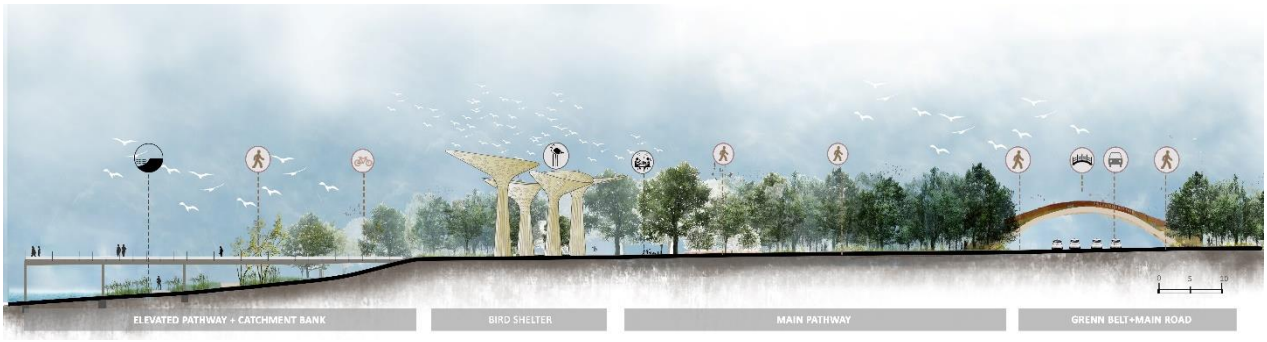


Figure52: Section A-A

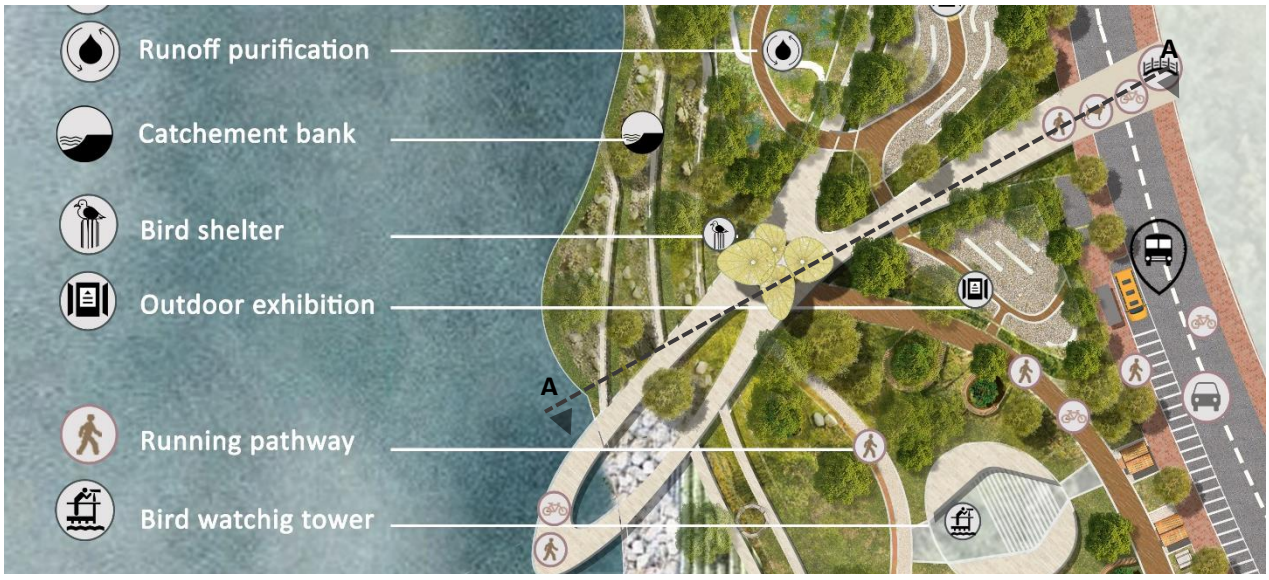


Figure 53: Section Plan A-A

VI-9- Pathway typology

The choice of road types depends on the expected volume of traffic, the park's size, and the design goals. Here are some common road typologies used in the design:

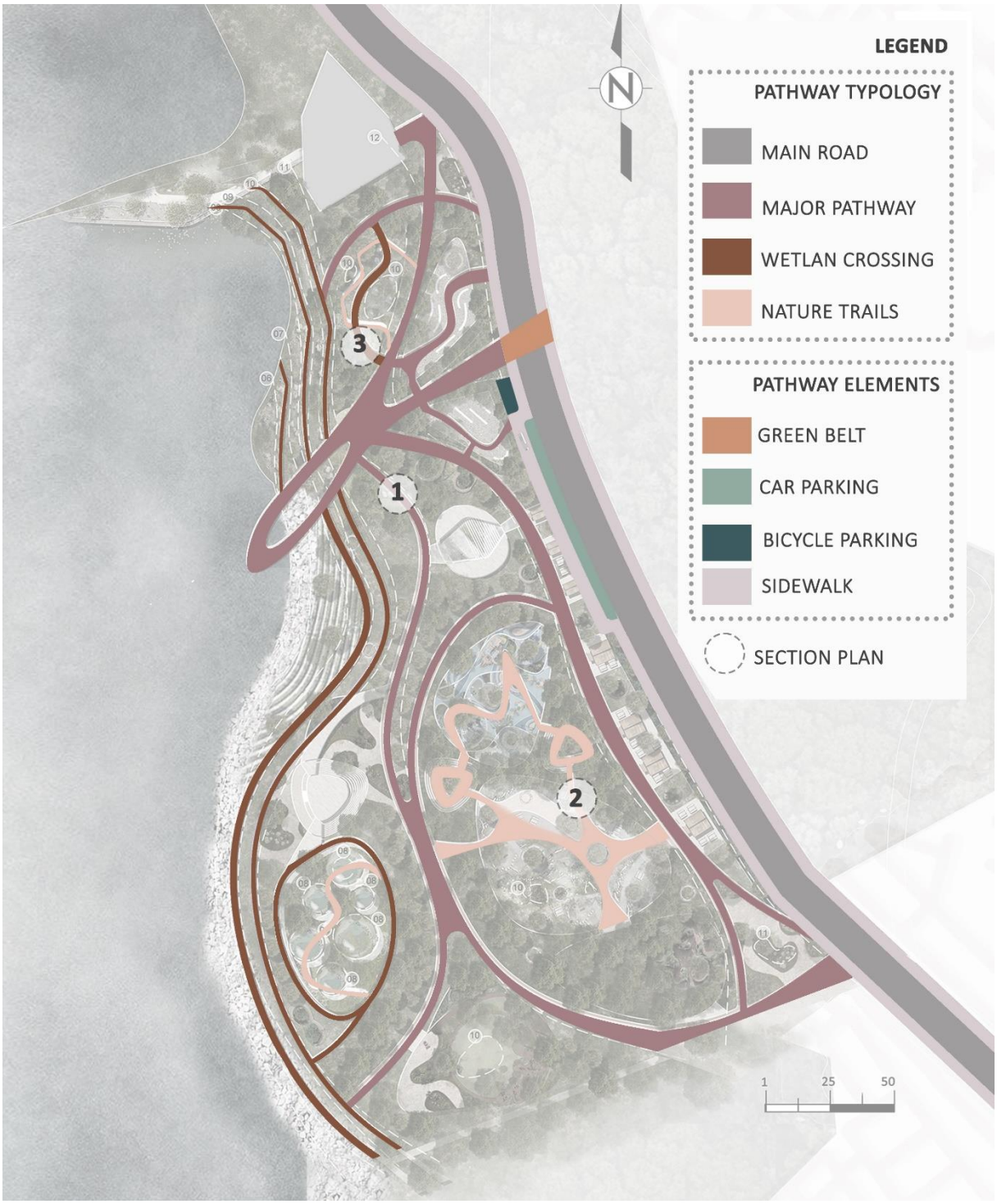


Figure54: Pathways typology

1-Major pathway: larger roads within the park that connect major facilities. They allow efficient circulation and they are designed for higher speeds, they keep the same traces of the existing spontaneous route made by the inhabitants of the region.

2-Nature trail: Intermediate-sized roads connecting various sections of the park. They facilitate movement between different amenities.

3-Wetland crossing: Wooden boardwalks that provide access to wetland areas, these elevated paths include informative signage and places to pause and enjoy the view.

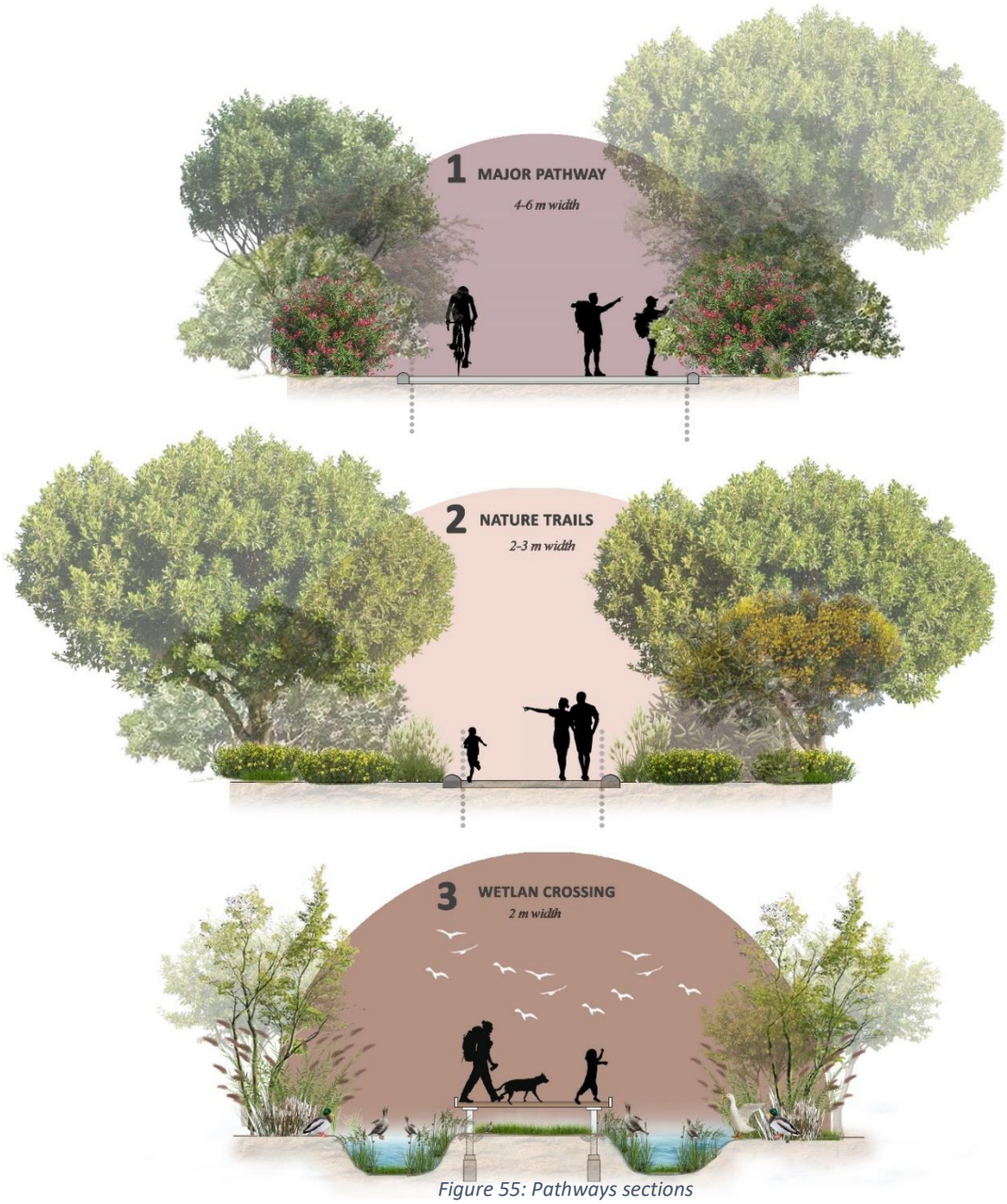


Figure 55: Pathways sections

VI-10- Pavement types

Selecting the pavement type entails taking into account multiple factors such as the intended use, climate, aesthetics, and budget.

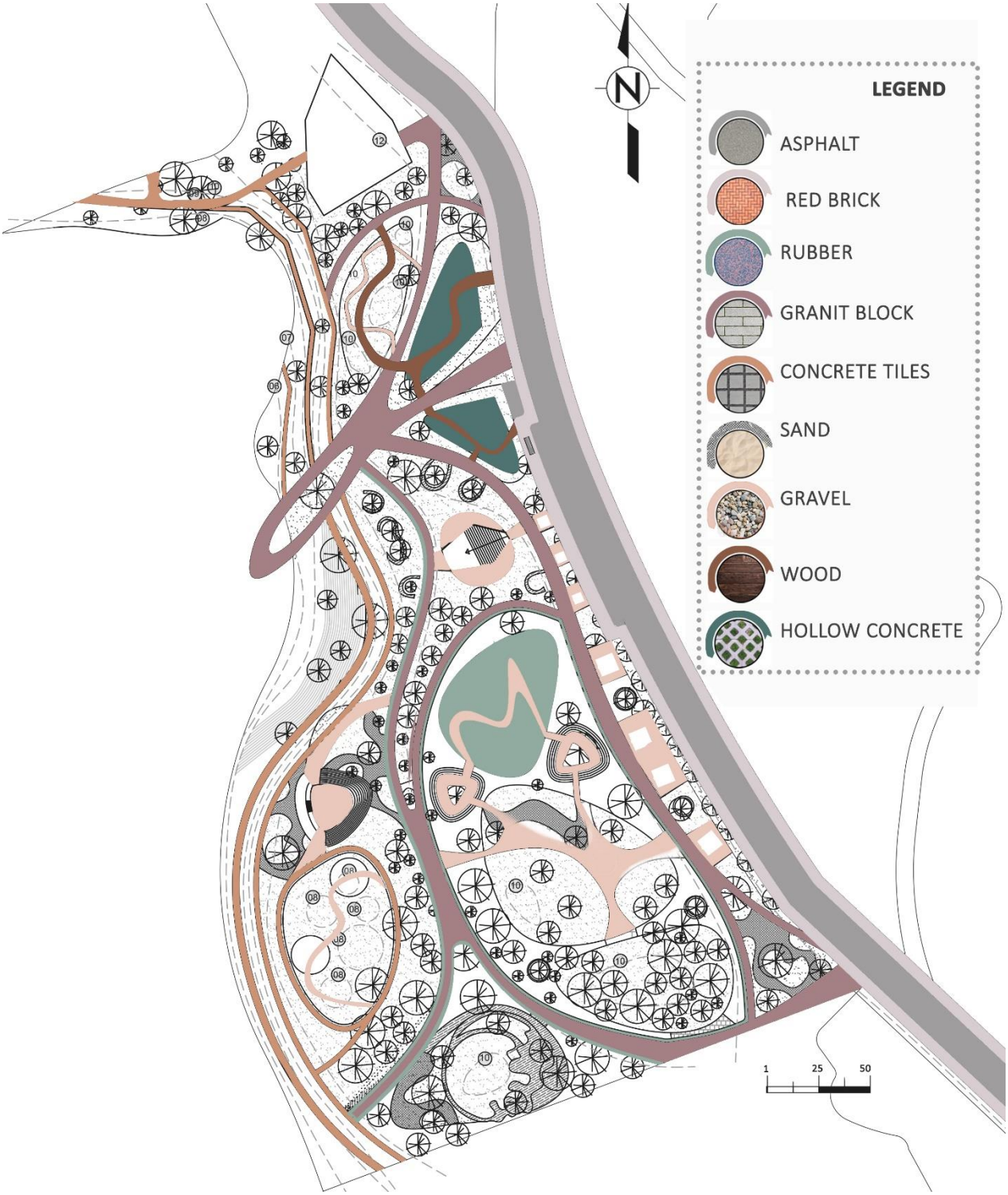


Figure 56: Pavement types

VI-11- Plantation character and species

Planting design involves selecting and arranging plants to create visually appealing, functional, and ecologically balanced outdoor spaces. we can divide the types of plants into 3 categories

Wetland atmosphere: variety of plant species to create diverse habitats and support local wildlife. A mix of trees, shrubs, grasses, and flowering plants that enhance biodiversity.

Structured atmosphere: define spaces, create boundaries, and guide movement within the park; low hedges, ornamental grasses to delineate areas.

Natural atmosphere: Plants that are adapted to the local climate and require minimal irrigation once established. Drought-tolerant species that conserve water resources.

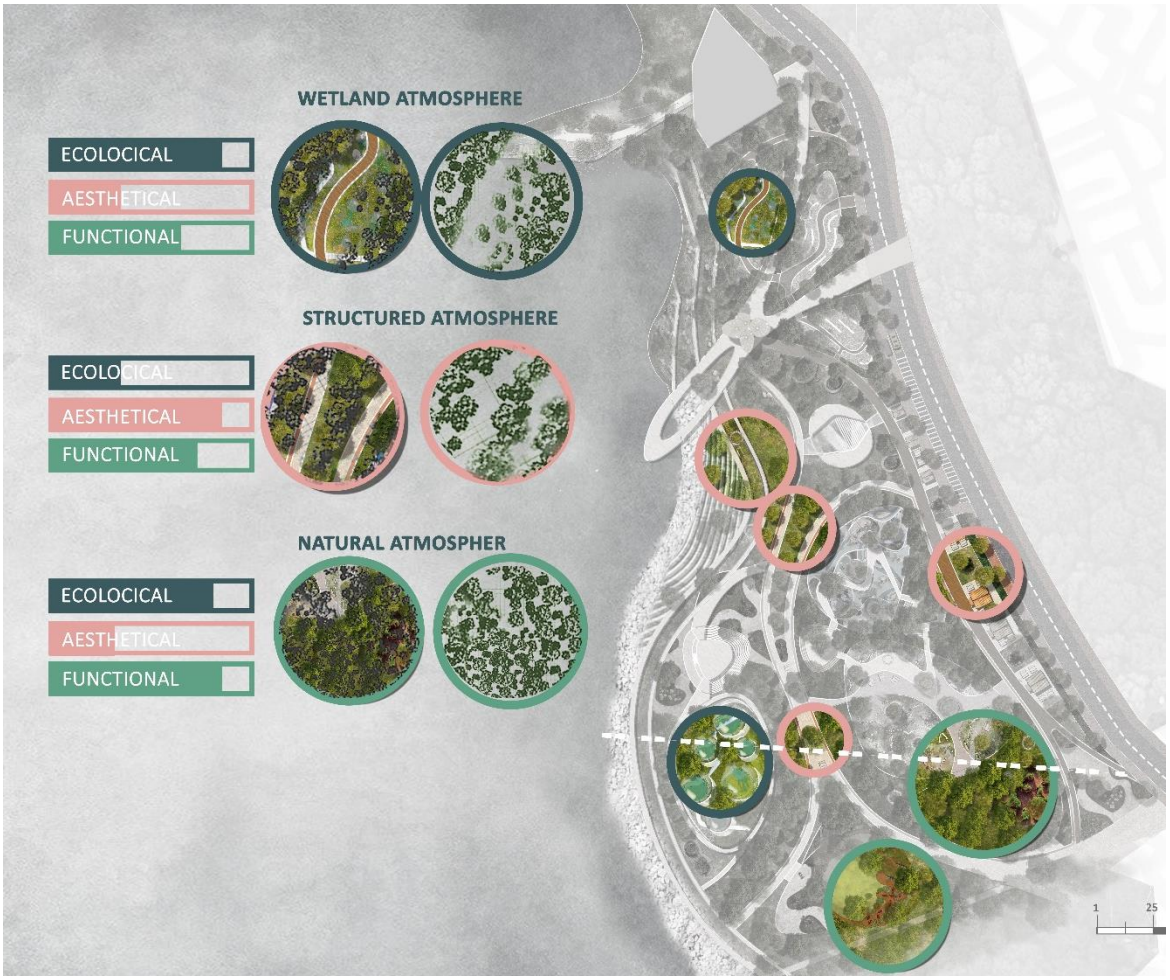


Figure 57: Samples of Plantation characters

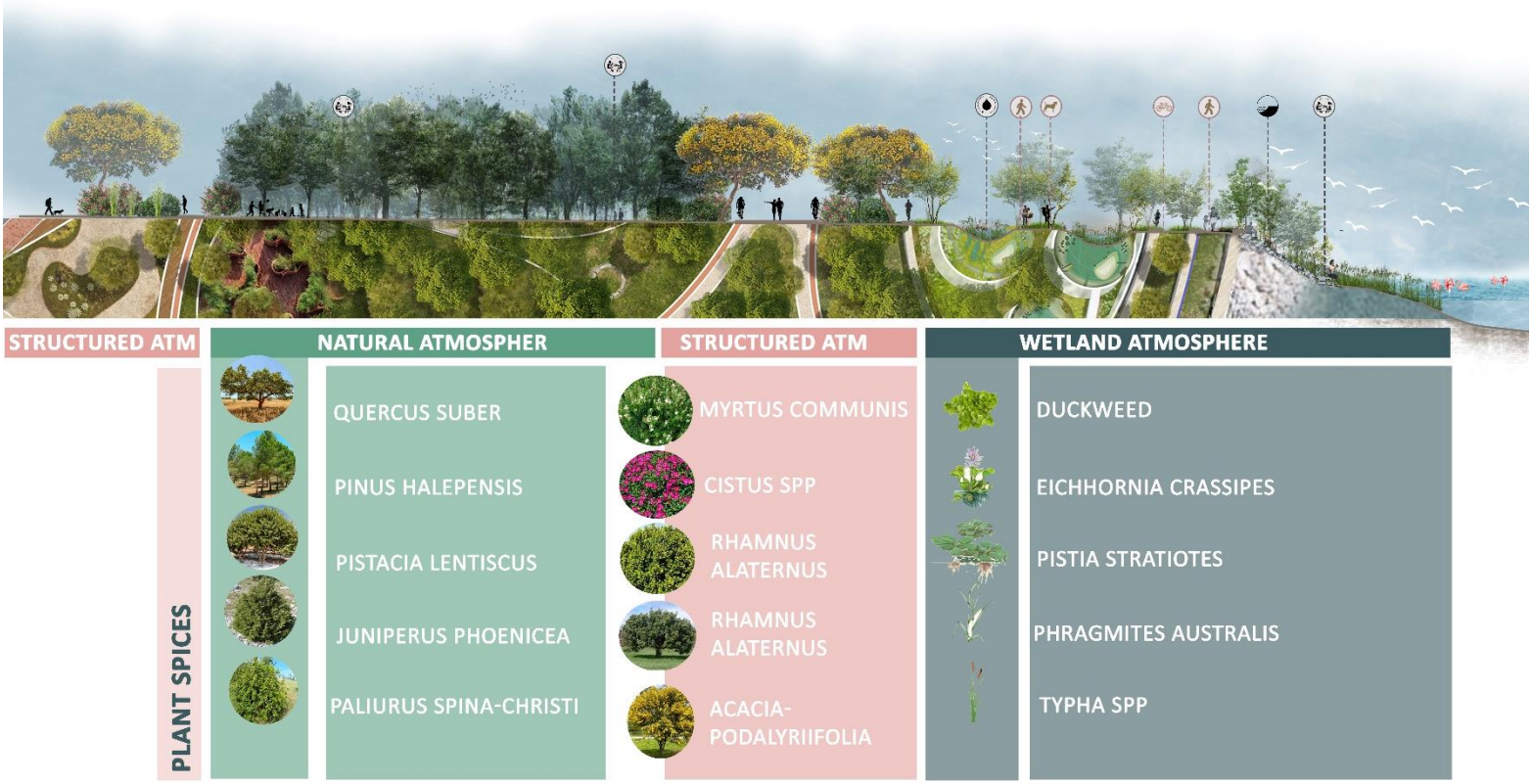


Figure 58: Plantation character according to each atmosphere

NATURAL ATMOSPHERE				
NAME	**DIMENSION**	**FLOWERING PERIOD**	**WATER DEMAND**	**SUN DEMAND**
Quercus suber	**H: 12-21m** **S:12-20m**	**Spring** **Summer**	**low**	**Full sun**
Pinus halepensis	**H:13-15m** **S:10-15m**	**Evergreen**	**low**	**Full sun**
Pistacia lentiscus	**H:4.6-8m** **S: 7-10m**	**Spring** **summer**	**low**	**Full sun**
Juniperus phoenicea	**H:5-7m** **S:3-5m**	**Evergreen**	**low**	**sun**
Paliurus spina-christi	**H:3-5m** **S:4-5m**	**Summer**	**low**	**sun**

STRUCTURED ATMOSPHER				
NAME	**DIMENSION**	**FLOWERING PERIOD**	**WATER DEMAND**	**SUN DEMAND**
Duckweed	**H: 2-3cm S:2-3cm**	**EVERGREEN**	**High**	**Full sun**
Eichhornia crassipes	**H:15-20 cm S:15-20cm**	**Summer**	**High**	**Full sun**
Pistia stratiotes	**H:8-15cm S: 30-60cm**	**Spring Summer**	**High**	**Partial sun**
Phragmites australis	**H:3m S:3.6m**	**Summer**	**High**	**sun**
Typha spp	**H:1-2m S:1-2m**	**Summer**	**High**	**Sun-Partial shade**

WETLAND ATMOSPHER				
NAME	**DIMENSION**	**FLOWERING PERIOD**	**WATER DEMAND**	**SUN DEMAND**
Myrtus communis	**H: 2-3m S:2-3m**	**Spring Summer**	**low**	**Full sun**
Cistus spp	**H:1-1.5m S:0.5-1m**	**Spring Summer**	**low**	**Full sun**
Rhamnus alaternus	**H:1.5m S: 1.5m**	**Spring**	**low**	**Full sun**
Ceratonia siliqua	**H:10-15 S:10-15**	**Evergreen**	**low**	**sun**
Acacia-podalyriifolia	**H:3-6 S:4-5**	**Spring Summer**	**low**	**sun**

Figure 59: Plantation table (Samples)

VI-12- Ecological area

Figure 60: Rain Garden – Focus Plan

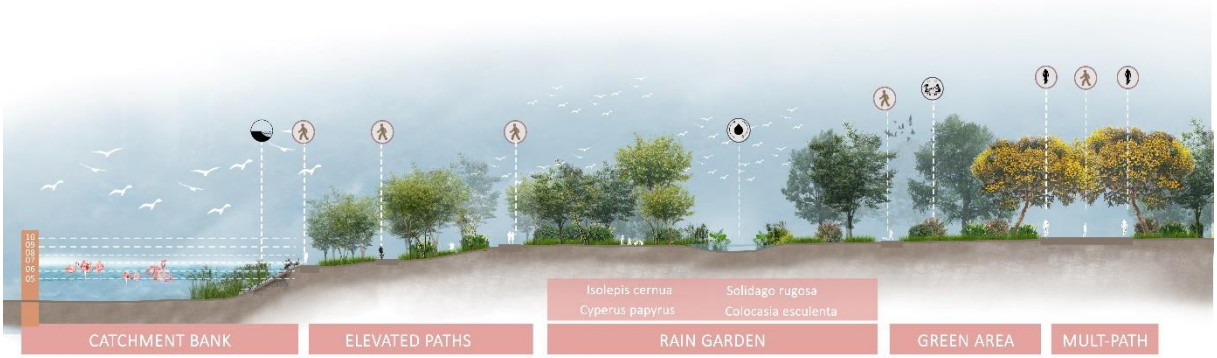
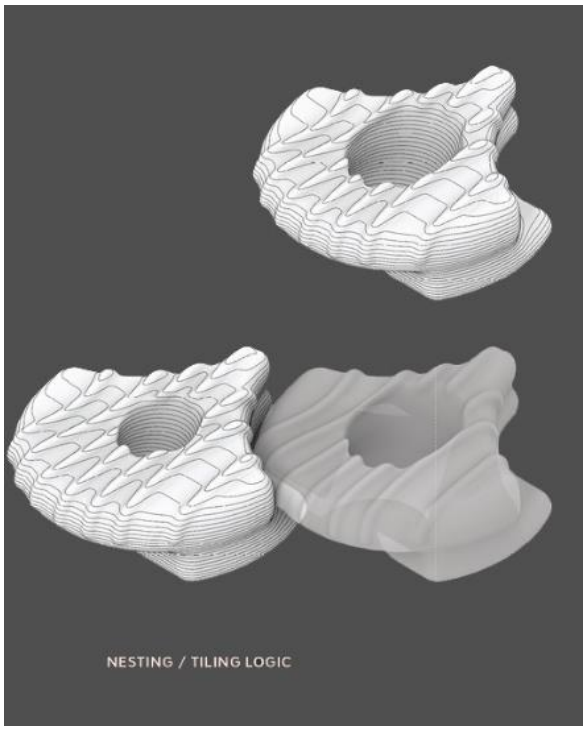


Figure 61: Rain Garden section C-C



This innovative structure serves to mitigate erosion while fostering the growth of vegetation through variable-sized openings. These apertures not only facilitate the establishment of robust root structures but also serve as protective spaces for fish along the lagoon edge. Furthermore, the diverse range of habitats created, spanning various scales, offers valuable environments for both animals and humans. This not only promotes biodiversity but also contributes to the local food web, making the **living levee** a comprehensive and sustainable solution.

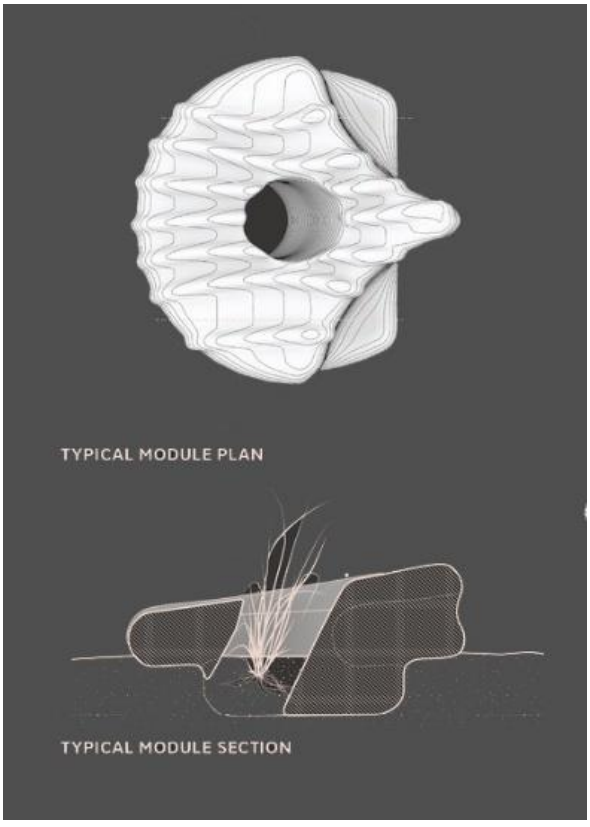


Figure 62: Catchment bank details-Model proposed by "The Architectural Ecologies Lab team"

Figure 63: Catchment bank visualization

Figure 64: Runoff purification wetland visualization

VI-13- Educational area

Figure 65: Educational playground – Focus plan

Figure 66: Educational zone visualization

Figure 67:Open air theatre

Figure 68: outdoor exhibition

VI-14- Recreational area

Figure 69: Playground & Sport area – Focus plan

Figure 70: Playground & Sport area visualization

VI-15- Water management typology

Addressing stormwater management around the *Sijoumi* Lagoon is crucial to minimize flooding risks and ensure the sustainable use of the area. While specific initiatives might vary based on local conditions, here are some common stormwater management strategies that can be employed to mitigate flooding risks around the lagoon:

Figure 71: Types of covers, surfaces and paving

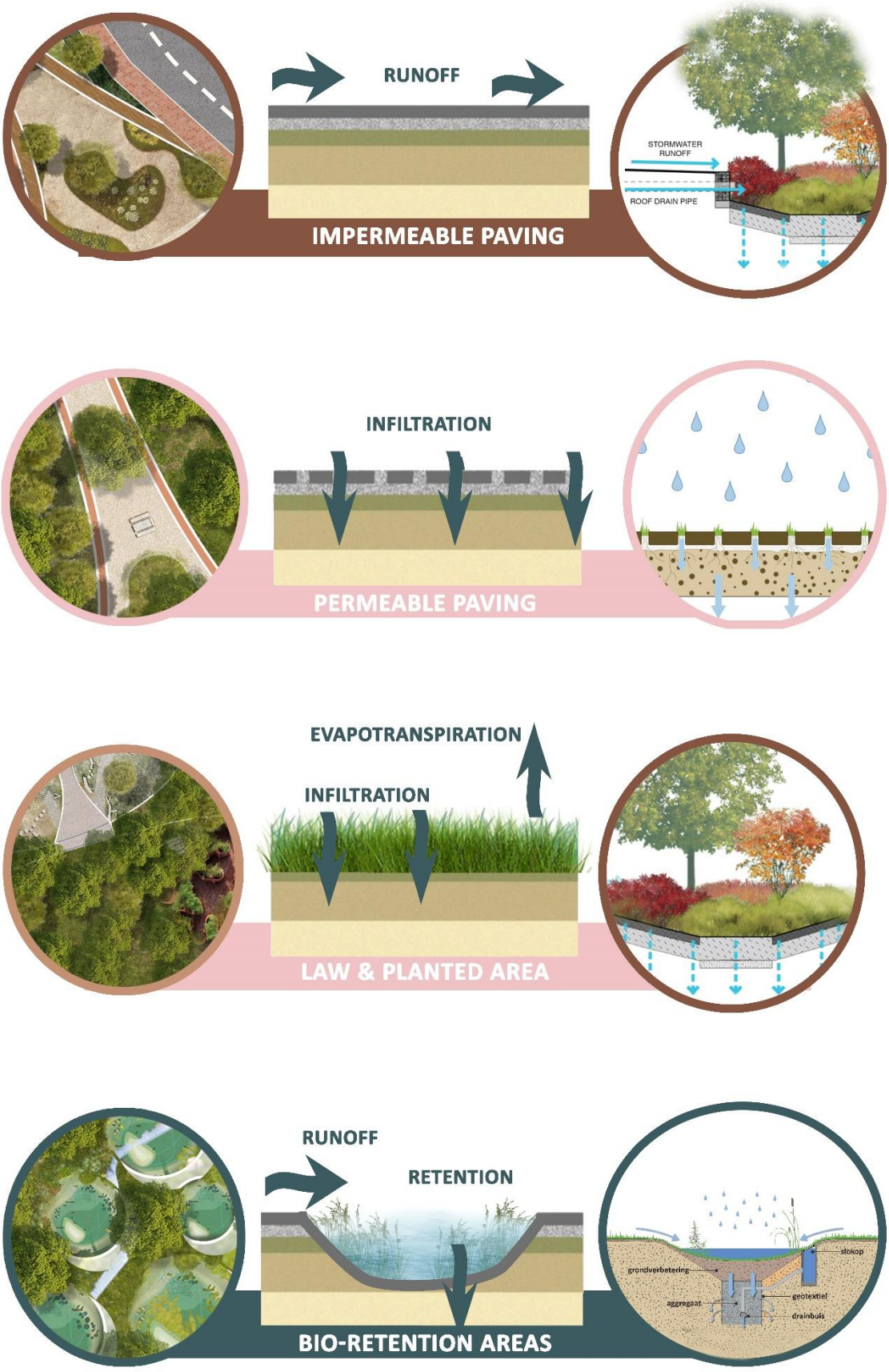
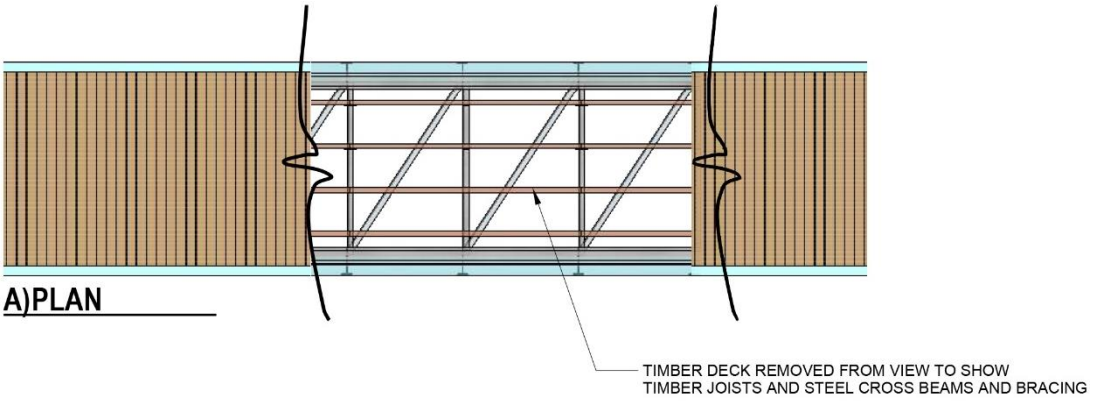


Figure 72: Stormwater management strategies

VI-16-Elevated pathway detail

Figure 71: Elevated pathway – Detailed plan



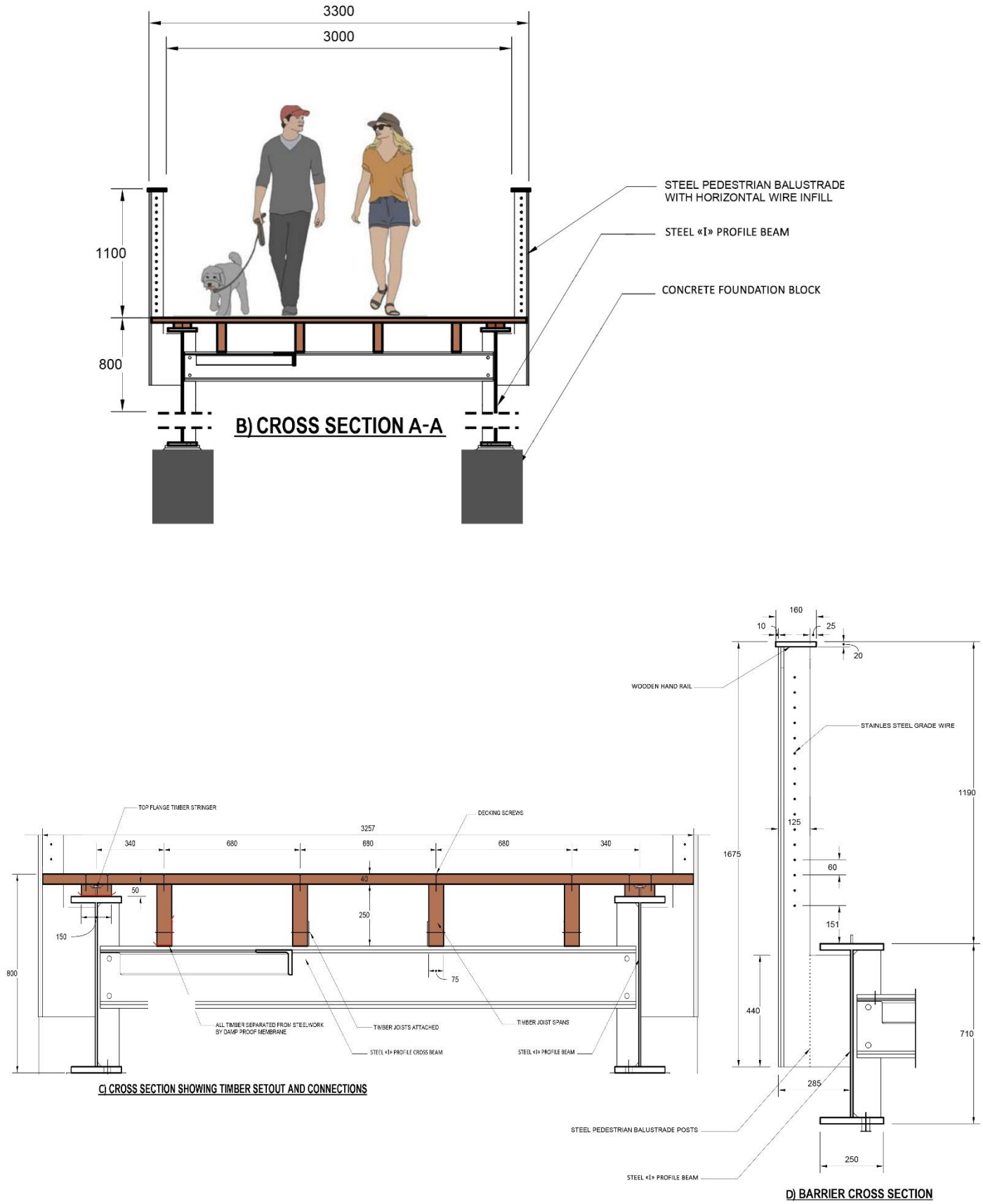


Figure 73: Elevated pathway - Details

VI-17-Conclusion

In summary, this study brought attention to the various disruptions resulting from the territorial changes observed over the past three decades in the *Sijoumi* Lagoon. Additionally, it underscored the diverse challenges associated with planning, conservation, restoration of natural environments, and local development.

The main idea of this design was the promotion of sustainable development for the Lagoon parallelly to conserving its high ecological value. This involved proposing comprehensive solutions with three main objectives:

-The first component emphasized the ecological approach and the enhancement of natural ecosystem functions. This strategy aims to enhance biodiversity ,conserve resources, and provide multifunctional habitats for wildlife. This included creating natural shelters for various species, especially endangered birds, implementing different types of water treatment to minimize water discharge into the lagoon basin and improve water quality, and employing phytotechnology techniques along the lagoon's edge to reduce pollution risks.

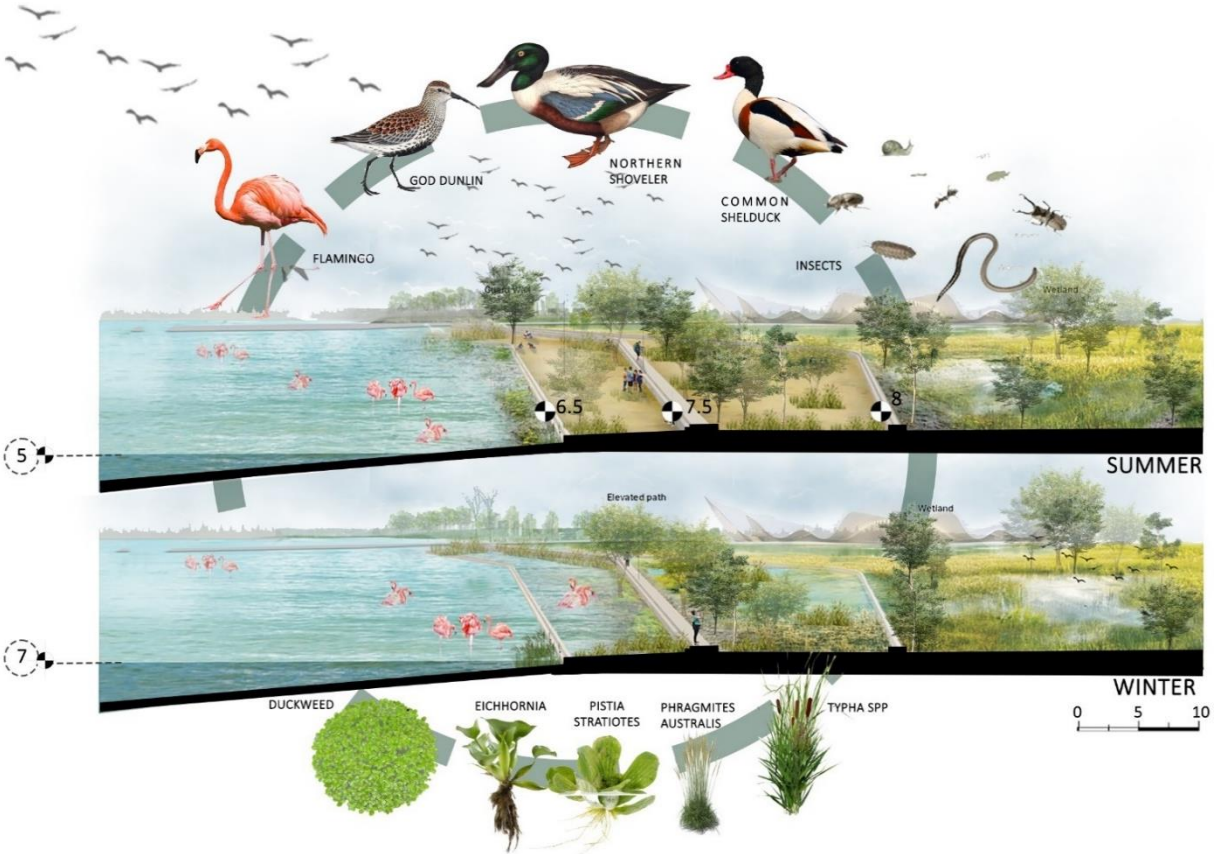


Figure 74: Synthesis illustration

- The second part is Integrating the community through recreational functions appealing to residents and tourists, ensuring direct accessibility for citizens, and providing an exceptional experience in the natural environment. This strategy involves creating spaces that engage all the senses and evoke emotional connections with nature.

-The last part focused on raising awareness among citizens, children, and potentially civil society and associations. This was achieved through the incorporation of educational functions within the landscape to inform visitors about local ecology, biodiversity, and sustainable practices, such as outdoor exhibitions, workshop spaces, and informative panels explaining the ecological values of the site to educate the community about sustainable landscape practices and involve them in protection efforts.

Over the long term, the project, by addressing urbanization pressures through sustainable design, has the potential to establish a precedent for future urban developments in the region. This influence on city planning and development policies can foster a more sustainable and ecologically sensitive approach. The success of this design could serve as a model to be replicated along the entire lagoon, amplifying its impact and contributing significantly to the lagoon's resilience in the face of changing environmental conditions.

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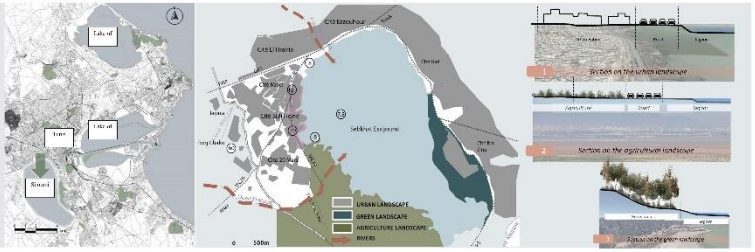
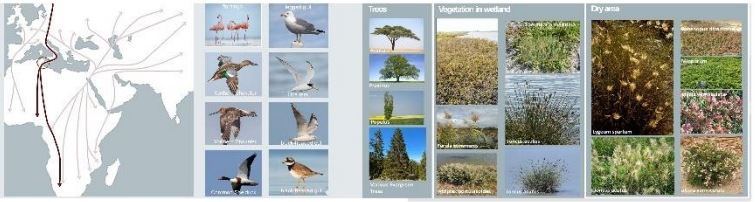
LANDSCAPE ANALYSIS

The capital, Tunis, is situated in the northern part of the country, spanning the coastal plain and nearby hills. As of now, Greater Tunis covers an area of 300,000 hectares, with 20,000 hectares comprising waterbodies. The Sijoumi lagoon has a catchment area of 250 km² and it is located at an altitude between 5 and 7.5 m, however during the rainy seasons, its waters can overflow and exceed 8 during floods. This sub-littoral and peri-urban depression adjoining the capital is an endorheic basin fed by waters generally coming from the Ouest area and the Miliane rivers.



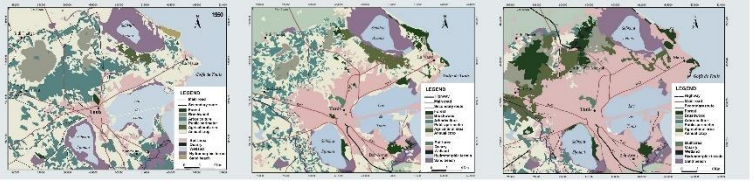
ECOLOGICAL ANALYSIS

Sijoumi lagoon is a wetland of great ecological value in the heart of an urban environment. Its importance, particularly for migratory waterbirds, has been recognized by the award of several international statuses: Wetland of International Importance, Important Area for Bird and Nature Conservation and Key Biodiversity Area. It is also the 4th most important site for wintering waterbirds in North Africa.



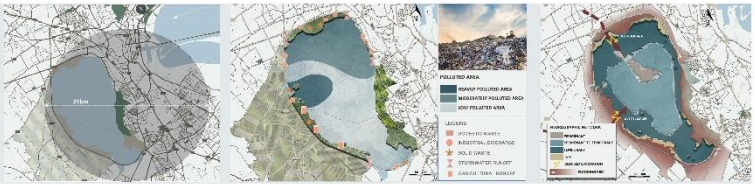
URBAN ANALYSIS

The chronological development of the different types of land use: 65% of the agricultural lands and green spaces are converted into residential, commercial, and industrial areas. The construction of roads, bridges, and buildings associated with urbanization, as well as clearing land, These infrastructure developments often result in the loss of green areas and further encroachment upon the lagoon's natural surroundings.

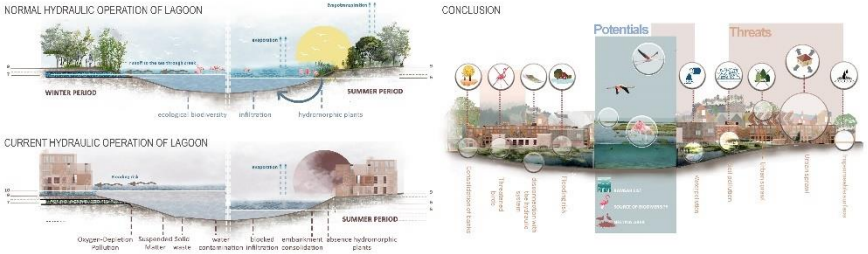


IMPACT OF URBAN DEV

As for the threats, they are mainly related to the excessive urban sprawl, which led to increasing rates of water and soil pollution, the expansion of impermeable surfaces, canalization of the banks as well as the disconnection with the natural hydraulic system, and therefore the risks of flooding.



SUMMARY OF SITE ANALYSIS (LANDSCAPE, ECOLOGICAL, URBAN)

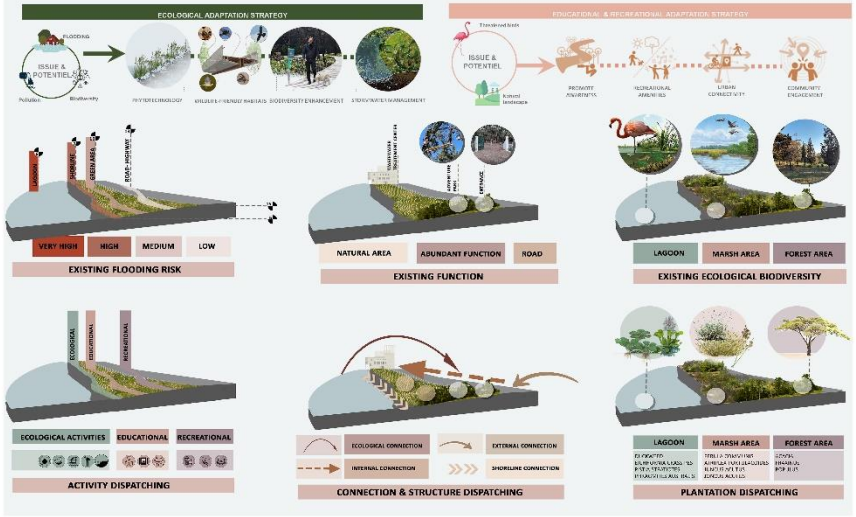


NARMINE MILI
SUPERVISOR: LINA HADDADIN

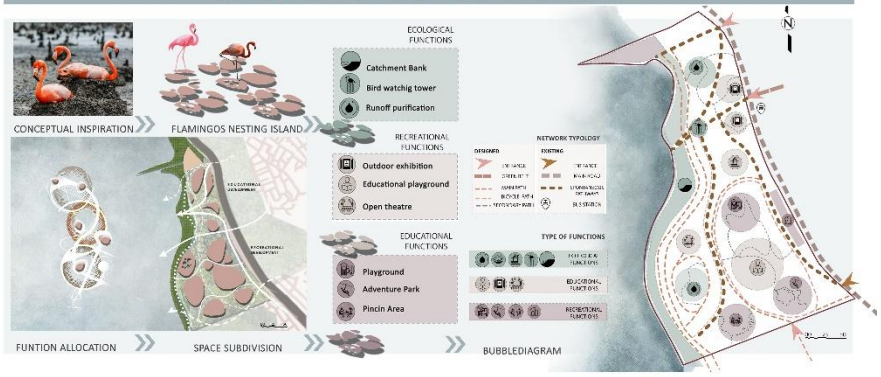
URBAN APPROACH

Designing a park around the Sijoumi Lagoon requires a comprehensive approach that considers ecological preservation, community engagement, and sustainable development. We suggest a design that will highlight the different potentials of the area and at the same time resolve the problems. This design can be considered as a prototype to be redone and reproduced throughout the Sijoumi lagoon shoreline.

DESIGN STRATEGIES & APPROACHES



FROM ABSTRACT CONCEPT TO THE BUBBLE DIAGRAM



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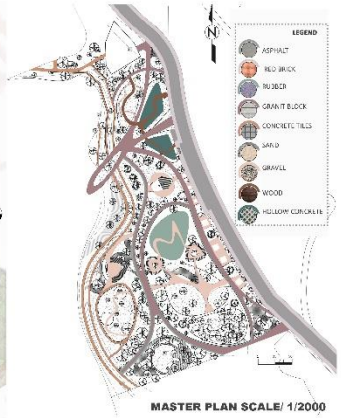
MASTER PLAN SCALE/ 1/1000



MASTER PLAN SCALE/ 1/2000

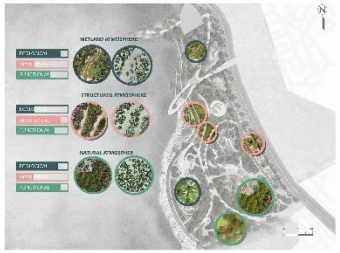
SECTION A-A 1/500

ROAD SECTION

MASTER PLAN SCALE/ 1/2000

PLANTATION CHARACTER AND SPICES

SECTION B-B SCALE 1/250



FOCUS PLAN SCALE/ 1/250

SECTION C-C SCALE/ 1/250

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