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Report

Integration of climate variability and change into national ICZM strategies

Contribution to the updating of the integrated management plan for coastal zones of the Kerkennah archipelago

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Limit of responsibility

Table of Contents

Acronyms and abbreviations

MPA	Marine Protected Area
APAL	The Agency of Protection and Coastal Management
APIP	Agency of Ports and Fisheries Facilities
DPM	Maritime Public Domain
GDA	Grouping of Agricultural Development
INS	National Statistics Institute (Tunisia)
DTM	Digital Terrain Model
UNEP	United Nations Environment Programme
RiVAMP	Risk and Vulnerability Assessment Methodology Development Project
GIS	Geographic Information System

1. Introduction

1.1 Reducing locally induced environmental threats for a climate change adaptation

The populations of small islands, especially those in developing countries, have no possibility to influence the reduction of CO_2 emissions in a significant way. These populations suffer the impacts of global change even though they have marginally contributed to. Their only possibility for adaptation (to climate change) consists of reducing locally induced impacts through better management and conservation of natural resources.

This study is based on two approaches. On one hand, the data analysis and field validation in order to identify the status of the environment and, on the other, a consultation of national experts, civil society and other local stakeholders to understand the processes that led to this situation and to identify threats weighing on the ecosystems and the potential solutions for their preservation.

In addition, the ecosystems provide multiple services such as carbon storage, coastal protection against erosion, water filtration, and contribute to the quality of the landscape and recreational areas.

In order to identify and quantify the role of the quality of ecosystems in climate change adaptation, the project approach is based on a collection of the finest data possible. These allow seeing the evolution of certain phenomena, but also the realization of a cadastre of ecosystems allowing better consideration of the latter in planning and in regional developments as well as their monitoring.

This concept is based on a methodology called "Risk and Vulnerability Assessment Methodology Development Project (RiVAMP)" that allows decision makers to take informed decisions supporting sustainable development through a better ecosystem management. In this regard, the targeted end users of RiVAMP are the national and local government policy makers, and key stakeholders in the management of natural resources and disaster management.

The concept of RiVAMP was developed by UNEP GRID-Geneva and tested successfully in a context of eroding beaches in Negril region of Jamaica (UNEP, PIOJ 2010; Peduzzi et al 2013.). The purpose of this study is to try to adapt this process to the context of the Kerkennah archipelago by combining it with the *Climagine* participatory approach that ensures a structured involvement of all stakeholders.

1.2 Project demonstration in Tunisia

The Gulf of Gabes by its geographical, morphological, biological and climatic characteristics is mentioned in the scientific literature as a "scale model of the Mediterranean" and a living laboratory for climate change impacts in the Mediterranean. It also contains the biocenosis *Posidonia Oceanica* most extensive in the world.

It is in the Kerkennah archipelago, which is located in the Gulf of Gabes that we find tiger structure of Posidonia Oceanica; a fragile and unique ecosystem to be preserved. In a context of climate change and rising sea levels, taking account of the risks incurred by the archipelago is a leading emergency.

The role of ecosystems in reducing the risks generated by extreme events is one of the most undervalued ecosystem services. However, it is the subject of increasing interest especially since the earthquake and tsunami in South Asia in 2004, which gave rise to an international awareness of the importance of ecosystem management to protect communities and infrastructure against disasters caused by extreme events. Ecosystems can serve as natural buffers or protective barriers, including the reduction of floods, slope stabilization and coastal protection against storms. Furthermore, they increase the adaptive capacity of communities to these events by serving them as means of subsistence. For example, Posidonia meadows can reduce the impact of storm surges by dissipating wave energy; protect the beaches from erosion due to the accumulation of plant debris (benches) on the shore, quickly decreasing water turbidity through the rapid sedimentation of suspended particles, while providing natural habitats for the reconstitution of fish stocks.

On the Kerkennah archipelago, the fisheries resource is one of the ecosystem services that matter most to the local economy. It is, however, the one that is the subject of a greater threat due to illegal and unsustainable fishing practices. *Posidonia* herbarium is the predominant marine ecosystem, its ecological role is considerable (oxygenation, stabilization funds, production of organic matter, source of food, shelter and spawning ground for many organisms). Terrestrial vegetation also plays an important role for the reduction of erosion and against soil salinization.

One of the major concerns in the context of climate change is increasing the frequency and intensity of extreme hydrometeorological events that will result in a corresponding increase in the number or magnitude of catastrophic events. Over the last two decades (1988-2007), 76% of global disasters were hydrometeorological, representing 45% of all deaths and 79% of total economic losses from natural disasters.

Furthermore, climate change will affect the underlying factors of vulnerability, such as food security, ecosystem services and migration phenomena, and therefore increase the risk. With the rise of sea level, climate change will intensify the impact of storm surges, increase coastal erosion, as well as the salinization of soil and groundwater; phenomena already observed on the archipelago of Kerkennah.

Three components have helped contribute to the results presented in this report.

1. The collection and centralization of data on the Kerkennah archipelago, and the collection and extraction of information from existing studies and reports.
2. The consultation of national experts, local, civil society and other local stakeholders (policy makers, representatives of fishermen...).
3. A field campaign for the observation of impacts.

The combination of these three approaches has helped highlight the importance and the role of some ecosystems, threats facing them, and the identification of possible solutions for their preservation and restoration. These observations allow giving recommendations for the implementation of actions to reduce local threats, and thus, enhance the potential for adaptation to climate change. The gathering of data and reports will allow their access facilitated by all sorts of actors and will participate in capacity building for the implementation of public policies and spatial planning, protective of ecosystems.

1.3 Kerkennah as a study area

The Kerkennah archipelago, located in the Gulf of Gabes, was selected for its vulnerability to variations and climate change, its ecological richness has got a significant number of data including environmental one.

The Kerkennah archipelago consists of two main islands, the island Chargui (or greater Kerkennah) and Gharbi island (or Mellita), and a set of twelve islands. The coastal areas of the islands consist of "shores" rather than beaches that are characterized by very limited spaces.

The physical marine environment of the archipelago is very dynamic and multifaceted. It is characterized by the importance of the tidal phenomenon which can be a major handicap in setting the shore and setting isobaths around the archipelago. The archipelago has many underwater channels that give it a specific topographic landscape. These channels have a considerable effect on marine dynamics and are among the explanatory mechanisms of the development of the coast.

The presence of some ecosystems like coral or seagrass *Posidonia* releases material that can be either pushed off seaward, or pushed toward the shore causing a sedimentary abundance at this level[1].

[1] This phenomenon is observed in the Jamaican case investigated by UNEP GRID-Geneva, where the debris produced by the destruction of corals are driven towards the lower area of the underwater beach by gravity and accumulate there.

The hydrodynamics at the Kerkennah archipelago is not favourable to the shores reconstruction phenomenon that can assist in remedying the anthropogenic erosion.

Some areas of the archipelago, El Attaya and El Krakna, often record flooding which would be due to the elevation of groundwater level and lack of infrastructure for the disposal of rainwater.

The population of the archipelago is estimated at about 15 000 inhabitants in winter and up to 200 000 people during the summer season especially with the return of the natives of the Kerkennah archipelago for the holidays and the arrival of tourists. This seasonal population pressure is a major challenge for planning in the archipelago.

The main economic activity in the archipelago is fishing which is characterized by the use of ancient techniques of trapping and capture. The *chrafis* coastal fisheries are fixed in the shape of a maze and used in areas with high sediments and large tidal range. These old traditional techniques once respectable of the environment see today their biodegradable building materials increasingly replaced by synthetic products.

Another characteristic fishing technique of the archipelago is fishing with *gargoulettes* for catching octopus. Today, this technique is used intensively.

There is no agricultural tradition rooted in the archipelago. However, certain characteristic crops are threatened because of anthropic pressure and the abandonment of the activity; like the date palm which is a genetic heritage of great importance.

The Kerkennah archipelago has numerous archaeological sites that testify to the important role played by this region throughout history. This cultural heritage is also threatened by the erosion phenomenon coupled with anthropogenic activities.

The archipelago also knows a major waste management problem. Indeed, much of solid waste ends up in the archipelago *sebkhas* (low and salty Arid Zones), vacant land or waters of the Mediterranean.

The wastewater is collected in the island only at a rate of 20%. In addition, the treated water is discharged too close to the shore.

Oil and gas extraction concessions near the coasts of the archipelago have also been granted in recent years.

1.4 Applied methodology

The regional project entitled "Integration of climate variability and change (CVC) into national strategies for integrated coastal zone management (ICZM)" (ClimVar) is a complementary project of the MedPartnership project. One of the project activities focuses on the assessment of environmental and socio-economic costs of climate variability and climate change in coastal areas in an effort to contribute to the development or updating of integrated coastal zone management plans.

The analysis is based on the RiVAMP model that bases its results simultaneously on scientific models and qualitative consultations in order to demonstrate the role of ecosystems in reducing disaster risk and reduction of impacts related to climate change. However, in the ClimVar project, consultations are based on the participatory approach *Climagine* to provide a structured stakeholder involvement in planning for the future of the coastal area in the archipelago of Kerkennah.

The *Climagine* method stems from the Imagine method, a participatory method based on sustainable development indicators, the scenario method and the shared expertise of local actors. The Blue Plan uses this method (in partnership with PAP/RAC) since the 2000s in various projects for ICZM in Algeria, Lebanon, France, Slovenia and Spain. Each time its implementation is different because it must adapt to the local context, but it has met great interest in all the projects, in order to become the backbone of integrated coastal management.

The involvement of stakeholders is a prerequisite for the success of ICZM. In the case of our study in Kerkennah, we are interested, as described previously, in quantifying the role played by ecosystems in reducing disaster risk and the reduction of impacts related to climate change. Given that this is an area with a certain degree of scientific uncertainty, the role of local actors, as experts at their level, in the process of proposals of strategic actions to adapt to climate change impacts is even more important.

Climagine was structured around three participatory workshops. The first, a national consultation was held in June 19, 2014 in Tunis, the second local consultation, held in Kerkennah in January 2015, while the third was the subject of a double restitution in July 2015 in Tunis (National restoration) and Kerkennah (local restitution).

The purpose of the work envisaged in the context of this participation activity is (i) to identify vulnerable coastal sites with environmental and socio-economic change and climate variability of the archipelago, (ii) to propose measures to mitigate and adapt to the consequences of the expected changes and (iii) to formulate strategic guidelines to be included in the update of the management plan. This participation activity was based on the work of collective expertise and results of Tunisian coastal vulnerability study facing rising sea levels due to climate change conducted by the Agency of Protection and Coastal Management (APAL), the adaptations to climate change impacts would significantly reduce economic, social and potential environmental damage. The proposed adaptation measures should be incorporated into a strategic plans and documents of development and management that are appropriate both locally and nationally.

As this is a pioneering experience in Tunisia in terms of integration of climate considerations in coastal planning, we expect that this significant experience serve to national coastal zone management, and that it will be useful for other coastal areas. We also expect that some of the proposed measures are taken into account by both national and regional bodies for the management of coastal areas.

In this perspective, the first consultation workshop aimed at:

• Building a common understanding of eco-socio-system of the Kerkennah archipelago and make an inventory of APAL data already acquired and also seek other useful data providers for the study.

• Identify the predominant factors of coastal erosion and associated risks for the socio-economic development of the archipelago.

• Identify potentially useful and available data.

The overall objective of the second consultation workshop was, after a phase of analytical work with the leaders of APAL, to go in situ and mobilize the expertise and local knowledge to further refine the assessment of ecosystem roles and to better understand local organizational dynamics.

The second workshop *Climagine* main objectives:

• Identification of the main livelihoods and ecosystems of the archipelago;

• The highlighting of the degradation processes in the archipelago;

• conducting a "Threat-Service-Solution" analysis to highlight:

  - the roles played by the different ecosystems and the services they offer to reduce vulnerability to variability and climate change,
  - the identification of threats facing ecosystems
  - and potential solutions to these threats;

• reviewing the pre-selection of potential areas of study.

The third workshop was an opportunity to present the results of work as well as strategic recommendations for the revision of the integrated management plan for coastal areas of Kerkennah.

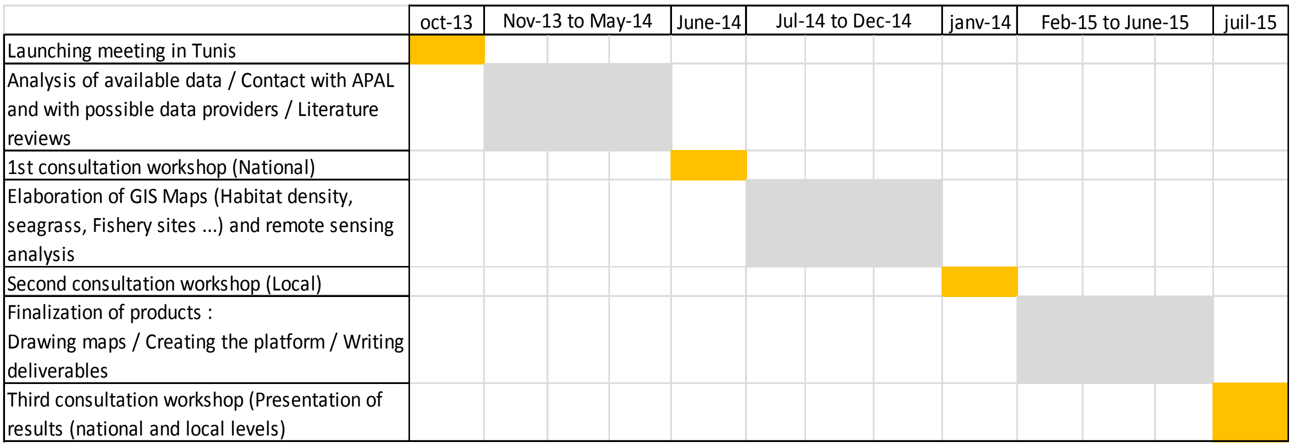

Figure 1 Calendar of project activities

1.5 Reports and products

In addition to this document, a summary document and the reports of participatory consultation workshops and a geographic database (GIS QGIS project) have been created and are available for download at **http://kerkennah.grid.unep.ch/** associated with a set of documents related to the issues addressed in this project.

1.6 Partners involved

The study was implemented through collaboration between the following partners:

• APAL: Mr. Chihaoui Mahmoud, Mr. Adel Abdouli, Ms. Ben Khaouter Houidi, Mr. Morsi Feki;

• GRID-Geneva: Mr. Bruno Chatenoux, Ms Karin Allenbach, Mr. Pascal Peduzzi & Mr. Jean-Philippe Richard;

• Global Water Partnership Mediterranean (GWP-Med): Ms. Sarra Touzi, Ms. Meriam Ben Zakour;

• Plan Bleu/RAC: Mr. Antoine Lafitte.

Several other partners have been consulted and have contributed to the development of the study through the provision of expertise and the provision of information. The full list of partners consulted is given in Appendix.

2. Context

2.1 Regional (the gulf of Gabes)

The Gulf of Gabes has regional specificity (in the Mediterranean context) by its geomorphology and its ecosystem ranking it among the most significant primary production seas (Barale, 1994), with great socio-economic importance since ancient times, making it a model of the Mediterranean Sea.

The unique configuration of the Gulf of Gabes has enabled the establishment of a remarkable natural seacoast system such as the development of the most extensive biocenosis *Posidonia Oceanica* in the world (which extends to the Gulf of Sirte in Libya) (Ben Mustapha and Alfi, 2007). These vast areas of seagrass beds favour the reproduction and development of many marine species.

However the expansion of seagrass *Posidonia* is declining, as are *Cymodocea* meadows that have even disappeared in some areas. Only seagrass *Posidonia* located off the archipelago of Kerkennah that does not exhibit a regressive trend. However, their striped structure makes them very vulnerable to any aggression by the reduced width (1 to 2 m) structural elements (Hamza et al., 2000). Because of their scarcity and incurred pressures, tiger structure is large heritage buildings requiring urgent and efficient conservation policy (Pergent et al., 2010)

The concomitance of the following physical and hydrological characteristics; very shallow depth, large amplitude waves and the presence of channels and throttle has characterized this area as the place where we find the most important currents of the Mediterranean (Abdouli A. Internal communication).

Unlike most of the Mediterranean coasts where the tide is imperceptible, the amplitude of the tide is high and maximal south of the Gulf of Gabes (2 m during spring tides) (Serbaji, 2000) with current speeds up to 2 m / s in the pass of El Kantara.

Tidal currents generally vary based on current swells and winds. The currents generated by winds that can be 2 to 5 times stronger than the tidal currents. They play a major role in the transport and dispersion of pollutants and sediments along the coastline (Drira, 2009). The complex interactions between the tide, wind and water mass movements create ocean currents and therefore unpredictable and highly variable sedimentary dynamics.

Fishery resources are very important in the Gulf of Gabes due to favourable climatic, geomorphological, oceanic and environmental conditions. However this region also concentrates various socio-economic activities (urbanization, agriculture, industries, oil exploration, fishing ...) that have negative impacts on ecosystems and therefore on natural resources that depend on it. Drira (2009) mentions an increase in the frequency of eutrophication phenomena, and the degradation and loss of large areas of vegetation cover over the last decades.

Two thirds of Tunisia's fish production comes from the Gulf of Gabes (CGP, 1996) that concentrates approximately 75% of trawlers, two-thirds of the national fleet and 62% of the Tunisian maritime population (Missaoui et al., 2000). 29% of fishery products of the governorate of Sfax come from the coastal waters of the Kerkennah archipelago (Munir, 2004).

2.2 Local (Kerkennah Archipelago)

The Kerkennah archipelago is located 20km offshore from Sfax in the Gulf of Gabes, it is composed of two main islands Gharbi and Chergui and twelve islets: Charmandia, Sefnou, Roummadia, Gremdi, Lazdad, Er Rakadia plus the six islets of Haj Hmida. It is prolonged according to a Southwest Northeast direction measuring about 35km long and 11km wide and an area of 160 km² and includes 162km of coastline.

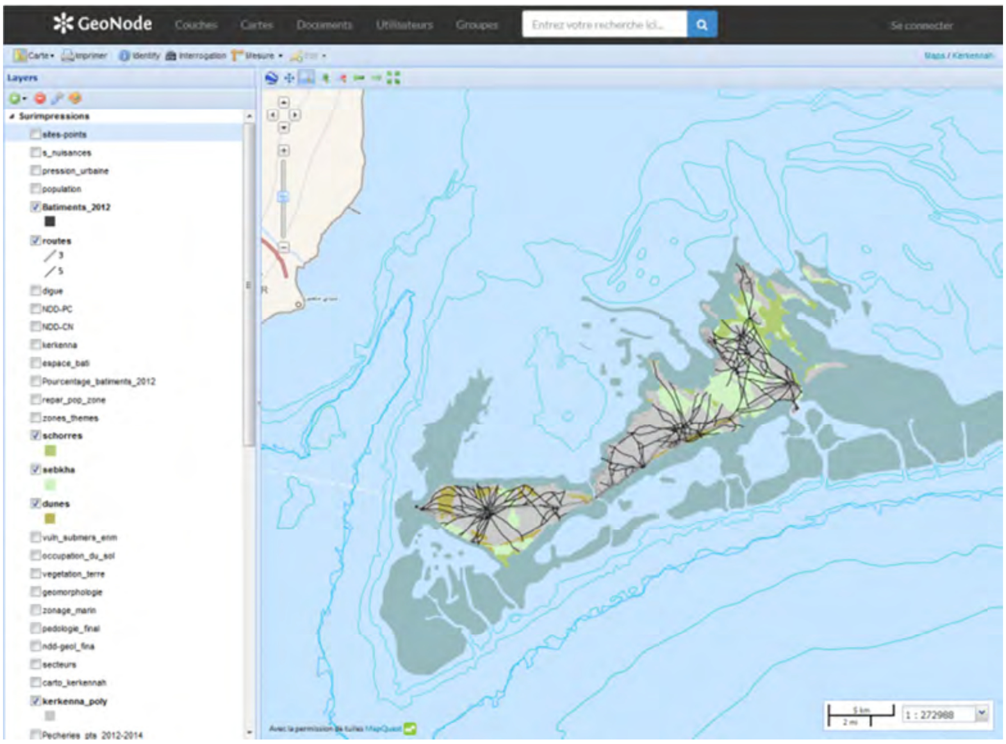

Figure 2 General map of the Kerkennah archipelago

Source http://kerkennah.grid.unep.ch/maps/59/view

The Kerkennah archipelago is the tip part of a vast underwater plateau that extends from 9-50 km around the islands. Its average depth is 2m, and varies between 0 and 5m, the plateau is interspersed with channels that can reach 20m and pits up to 30m (Amari, 1984).

2.1.1 Climate

Although there is no official permanent meteorological station on the Kerkennah archipelago, the comparison of point data coming from various studies (APAL, 2001; Fehri, 2011) with official data from the weather station of Sfax concludes that the archipelago receives the same amount of rainfall but with slightly different temperatures. The presence of moisture in the sea around the archipelago increases humidity and decreases the temperature difference between the land and the sea (Etienne, 2014).

The amount of annual precipitation greatly varies from one year to another, and generally varies between 100 and 400mm (Dahech, 2007).

	J	F	M	A	M	J	J	A	S	O	N	D	Total
P (mm)	23,7	14	27	17	4,9	0,9	0,5	1,1	21,5	44	33,7	35,7	223,6
ETP (mm)	37,4	49,6	77,5	107,7	152,2	184,4	199,6	170,2	116,2	80,3	48,5	36,4	1260,0
ETP-P (mm)	13,7	35,6	50,5	90,7	147,7	183,5	199,1	169,1	94,7	36,3	14,8	0,7	1036,4
P/ETP	0,63	0,28	0,35	0,16	0,03	0,00	0,00	0,01	0,19	0,55	0,69	0,98	0,18

Table 1 Elements of water balance in the Kerkennah islands in the period 1965-2009 (from Fehri, 2011)

The calculation of the water balance in Table 1 shows the water deficit in which the Kerkennah archipelago is subject, resulting in soil salinization caused by the capillary rise of the water table (usually composed of brackish water).

A weather station was commissioned in late 2014 on the roof of the residence Ennakhla (Dahech, personal communication, February 2015).

2.2.2 Population

Year	Population
1890	8'671
1925	13'000
1936	15'130
1946	14'535
1956	13'704
1966	12'587
1975	14'500
1984	14'151
1994	14'062
2004	14'400
2014	15'501

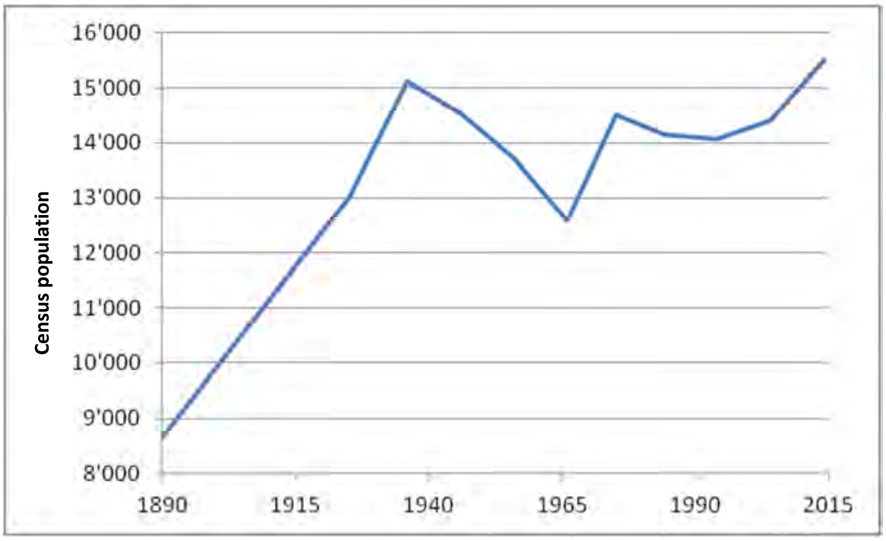

Figure 3 Population of the Kerkennah archipelago recorded by the INS (Louis 1961, Etienne 2014, INS 2014)

The number of residents identified on the archipelago remains stable for several decades (Figure 3) with a resident population estimated by the Tunisian National Institute of Statistic (INS) to 15'501 (100% urban) in

2014, an increase (since 2004) of 7.7% of the population (10.8% national value) in a context of diminishing size of households (-1.6%) and increase in housing (3.6%) (Table2).

Sector	**Men**	**Women**	**Total**	**Household**	**Housing**
El Ataya	1'548	1'529	3'077	828	1'282
El Ramla	1'067	1'019	2'086	655	1'132
Sidi Frej	313	256	569	207	610
Melita	1'849	1'707	3'556	862	1'265
El Kalabine	393	370	763	226	567
En-Najet	480	762	1'242	276	440
El Chargui	183	170	353	121	548
El Kantra	434	226	660	168	549
El Kraten	568	585	1'153	300	429
Ouled Kacem	492	449	941	290	675
Total 2004	7'327	7'073	14'400	3'933	7'497
Total 2014	7'733	7'768	15'501	3'869	7'770

Table 4 Census 2004 and 2014 (INS)

The Kerkennah archipelago faces an aging population demonstrated by this inverted pyramid of ages (Figure 4).

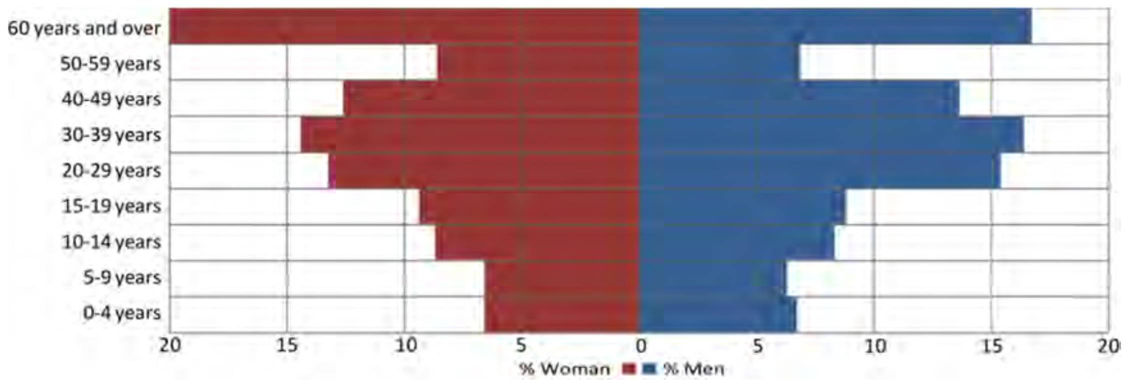

Figure 4 : Age pyramid 2014 for the Kerkennah archipelago (INS)

While the number of residents remains well known and relatively stable, the visitors' number (mainly during the tourist season) is subject to speculation. Rhouma et al. (2005) estimate the number of visitors to be between 40,000 and 50,000 per year. Moreover, the figure of 240,000 visitors was mentioned during the meeting of experts in Tunis in June 2014. However, this value appears to represent the number of passenger boats connecting the islands to the mainland, but the nature and the length of stay are unknown. In order to get a better idea of the pressure generated by the population of visitors, it would be appropriate to calculate the amount of nights in a hotel and the occupancy rate of second homes.

Although the rate of increase of housing is lower than that of the population (Table 2), the intensive construction of new buildings is clearly visible (field mission UNEP/GRID-Geneva, January 2015), which further amplifies human pressure on local resources for construction materials, such as sand or rocks. As the import of building materials from the mainland triple their costs, a significant amount of sand and rock unlawfully levied on the spot or by drawing on the meager resources of the islands beaches, or digging illegal quarries. The illegal extraction of building materials has consequences for the reduction of tourist attractiveness, the acceleration of coastal erosion rate and the acceleration of soil salinization of surface and groundwater.

In her thesis work, Etienne (2014) mapped the evolution of surfaces built between 1963 (119 ha), 1984 (168 ha) and 2010 (719 ha), indicating that the expansion of built areas has mainly taken place since 1984.

Kebaïli Tarchouna (2013) indicates that since the Tunisian revolution in 2011, the construction of buildings without building permits which do not respect the law of development of the territory has become more frequent. Notably, near the coast (requiring the work of setting up coastal defenses) or around *sebkhas*.

2.2.3 Water resources

The Kerkennah archipelago is located on two aquifers. The first is shallow flush in low natural or artificial areas (quarries of sand or rocks); it is brackish and only used for irrigation, thus contributing to soil salinization when excess water is not drained by a drainage system. The second is deep (350 m) and it is part of the confined aquifer of the Sahel; it is used for fresh water supply of the population.

A reverse osmosis desalination plant (the first in Tunisia) is in operation since 1983 in Kerkennah and produces 3,300 m^3/day. However, when high demand (during the tourist season), saline water is added to the fresh water to produce up to 6000 m^3 of water, but in this case the salt concentration reaches 1.5g per liter (maximum level permitted by international standards). Due to the low quality and quantity of water in the distribution network and a low connection rates, the vast majority of the archipelago's buildings have a recovery tank of rainwater.

Discards of water loaded with salt - 25% of the quantity of water produced with a salt content of 14 g/L (Malek, 2007) - is now carried out directly on the shore.

Figure 5 Water treatment plant using reverse osmosis (photo UNEP/GRID-Geneva, 2015)

2.2.4 Waste Management

There is a waste treatment plant in Kerkennah. However, due to disagreements about issues of land ownership, it was closed by court order pending resolution of the legal dispute.

In the meantime, the waste is centralized at the exit of the villages (usually within *sebkhas*) or simply dumped outside properties.

These open dumps are a source of pollution for coastal waters and shallow groundwater and degradation of the landscape by the dispersion of waste by the wind in the archipelago.

Figure 6 Wild waste disposal (photo UNEP/GRID-Geneva, 2015)

The management of waste construction is also problematic, insofar as they are commonly used as embankments or protection against coastal erosion. These protection structures are easily eroded. This, therefore results in a quick remobilization of sediments by ocean currents and their scattering along the coast.

Figure 7 backfill made with waste (photo UNEP/GRID-Geneva, 2015)

2.2.5 Fishing

Maritime activities are dominant in the archipelago of Kerkennah. It is that they revolve around the economic activities and the social and institutional relations. Appropriate traditional fishing techniques (transmitted from generation to generation), scheduled in time and space, are managed by an accepted social rules and respected by the community (and Rhouma Labidi, 2006).

Figure 8 The archipelago boasts impressive fleet of fishing boats (photo UNEP/GRID-Geneva, 2015)

The coastal waters of the Kerkennah archipelago are the main concentration area of *chrafis* (traditional artisanal fishing) that capture the coastal species, sometimes immature or protected shallow depths

(Romdhane and Missaoui, 2002). Traditionally *chrafis* were built mainly with products of date palm, installed and operated in the autumn (September-October) in early summer (June-July) and then dismantled for a period of biological recovery. Nowadays fishing nets, PVC pipes and ferrous materials have replaced the products from the date palm, and are left in place for several years; they no longer respect the biological rest.

The "loud", a sailing vessel with a low draft characteristic of the archipelago, has been replaced by motor boats since the 1970s, which were encouraged by the granting of loans to fishermen (Rhouma and Labidi, 2006).

Traditionally, the Kerkennah archipelago also has a strong octopus fishing activity called fishing jug ("Karour") or hollow stones and sponge fishing, although the latter activity has fallen sharply over the past decade (COMETE Engineering , 2001).

The analysis of fisheries statistics in the waters of the Kerkennah archipelago remains complex and uncertain for the following reasons: some fishermen of the archipelago prefer to sell their produce on the mainland, also an important part of the catch is auto consumed. The catches are landing without control outside the "official" ports and finally the continent fishermen operating in the coastal waters of Kerkennah. APAL (2001) estimated that 60% of fisheries production is not surveyed (30% according to Rhouma and Labidi, 2006).

Although official figures are subject to wide fluctuations, the unanimous opinion of those interviewed, as well as all publications relating to fisheries, show a consistent decline in fisheries resources of the Kerkennah archipelago, particularly octopus (which remains the emblem of the archipelago).

Figure 9 extracted from Rhouma and Labidi (2006) used to display the opposite trend between production and the importance of the fishing fleet (minimum production in 1995, while the fleet was at its maximum).

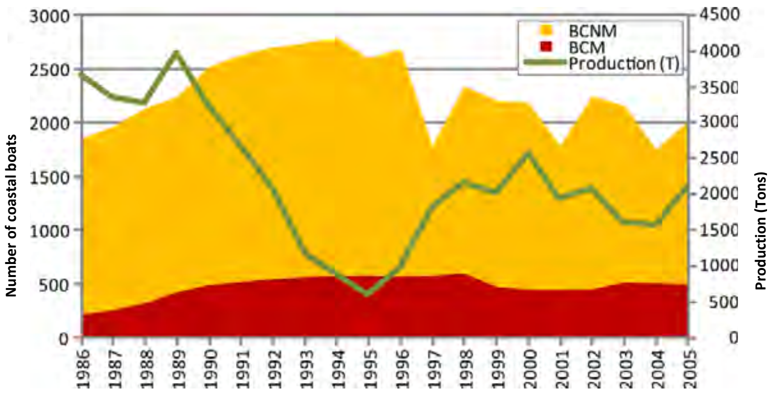

Figure 9 Evolution of the fleet and fishing production in the Kerkennah archipelago (BCM: Motorized Boat Coast, BCNM: Seaside Boat Non Motorized, source: APD extract of Rhouma and Labidi, 2006)

Figure 10 clearly shows the negative relationship between production and coastal fleet motorized boats (BCM), this negative trend having the double of the tendency with non-motorized coastal boats. Although these figures are not recent, they are the only ones available.

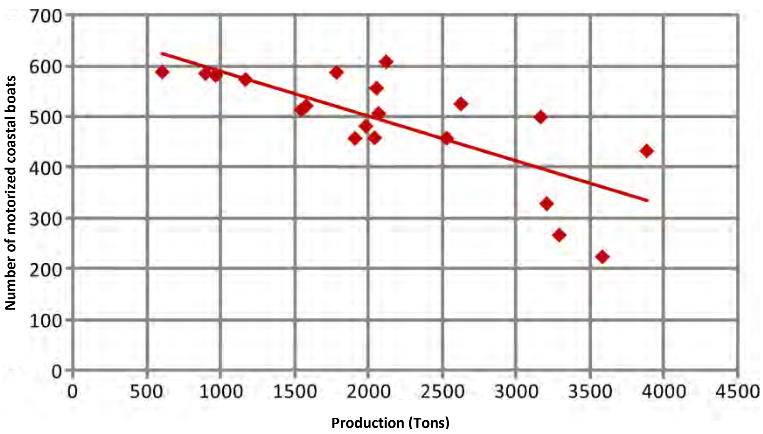

Figure 10 Correlation between production and the fleet of motorized coastal fishing boats in the Kerkennah archipelago (from Rhouma and Labidi, 2006)

Although the available statistics do not take into account the fishing activities of the fleet based outside of the archipelago and that their reliability is a matter of debate, they clearly demonstrate that any additional effort (motorized or not) has a negative and immediate effect on the production in the waters of the archipelago. Several causes can be invoked:

• The proliferation of motor boats - of which over 90% have no license (Rhouma and Labidi, 2006)

• The use of nets of all sizes leading to the capture of juveniles,

• Trawling activities are becoming more intense, including the 'kiss'[2] in shallow areas,

• The illegal exploitation, unregulated and uncontrolled fishery resources,

• Non-compliance and lack of mutual tolerance between fishermen of different types of fishing.

The 'Gacharas' (speculators)

The degradation of fishing conditions is also related to the pressure exercised on fishermen by gacharas; they are speculators who provide 'kiss' practitioners with the necessary funds for their businesses (including costs and running expenses) against the exclusivity of their products. Rhouma and Labidi (2006) we list the consequences as follow:

• Complex and devious marketing channels usually carried out without any control,

• Rapid and unregulated growth of the fleet,

• Submission of fishermen to the commercial conditions imposed by gacharas,

• Failure to comply with the regulations in force (no fishing season mainly for shrimp and octopus)

• The development of the Agricultural Development Group "GDA El Arkhabil" is hampered by debt and submission of fishermen to the gacharas,

• Lack of mobilization of fishermen to defend their interests,

• Almost a complete rupture between the fishermen and their administrative and organizational environment, the distribution network is mainly dominated by gacharas.

2.2.6 Agriculture

Agriculture and orchards were gradually abandoned as a food crop. Rhouma et al. (2005) estimate the area of fruit trees at 923 hectares in 2000, while Louis (1961) estimated that at 6'190 hectares 4 decades ago. The reasons are the growing phenomenon of drought, the exodus of the workforce and the high cost of plowing. However, a number of short-term olive producers replanting projects have been put in place to reverse that trend.

Figure 11 Irrigated agriculture (photo UNEP/GRID-Geneva, 2015)

[2] Mini benthic trawl

Etienne (2014) mapped the agricultural plots (Figure 12) and estimates the irrigated surface area of 178 ha in 1984 and 662 ha in 2011, an increase of 272% related to artesian wells construction in the 1990s. These constructions make available to farmers brackish water requiring the construction of drainage infrastructure to minimize the phenomenon of soil salinization.

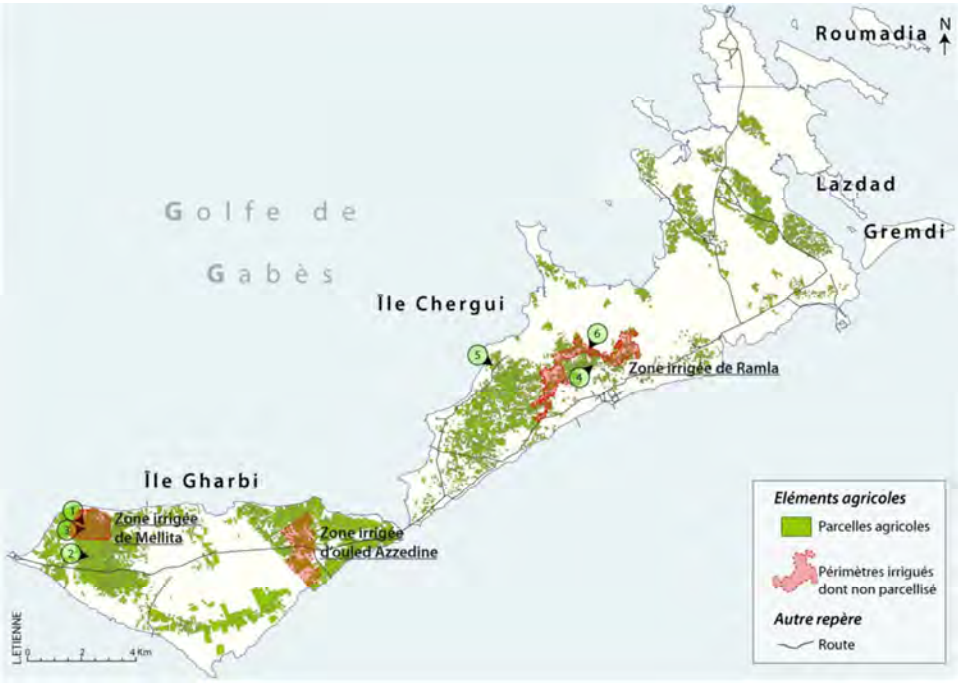

Figure 12 Mapping of agricultural activities in the Kerkennah archipelago
(Extract from Etienne, 2014, Figure 44, p. 96)

The irrigated areas were perpetrated in the spaces located "at altitude" (maximum 13 m) which limits soil salinization phenomena by raising the level of the water table. However, locally gypsum soils are then dissolved and can equally participate in a significant way in this phenomenon.

Opinions differ regarding the irrigated areas and the creation of new perimeters. Indeed, some inhabitants partly associate them to salinization and advancing *Sebkhas*.

2.2.7 Tourism

Despite the existence of tourism infrastructure (six hotels with a capacity of 1,000 beds in the area of Sidi Fredj), this activity barely grow with only 30% occupancy rate during a restricted period of operation. APAL (2001) invokes the following reasons:

• Lack of real beaches and limited bathing potential,

• Difficult access to the archipelago (for boats and remote airports)

• Poor infrastructure,

• Lack of tourism strategy.

Despite these difficulties, two other tourism development projects are under consideration in the areas of Founkhal and Ouled Ezzedine.

2.2.8 Petroleum Activities

Oil exploitation adds offshore pollution problems near tourist sites, often mentioned during the visit of the GRID-Geneva team over the archipelago, and COMETE Engineering (2001).

The risk of pollution of the coast of the archipelago by the oil operations at sea remains a reality all the more worrying that the boreholes are located only a short distance from the coast and are directly exposed to prevailing winds. In case of incident, pollution would be quickly transported to the shore, driven by the characteristics of shallow marine and crossed by tidal channels. Moreover, this environmental disaster would impact directly the only existing official tourist area of the archipelago, generating likewise an economic catastrophe (COMETE Engineering, 2001).

2.2.9 Bathymetry

The reef flat of the Kerkennah archipelago is a large platform located at depths ranging from 0 to 5 m. The morphology is divided into:

• "bhiras" mudflats of 2 to 3m deep (that can even exceed 5m), surrounded by *Posidonia* cords and carpeted with *Cymodocea,*

• "tsirs" (or benches): barrier beaches, made up of biogenic debris shellfish whose top are populated by meadows of *Caulerpa* sometimes emerging at low water

• "wadis" (or tidal channels): narrow winding depressions, of 5 to 12 meters deep by which circulate tidal waters (it can reach a speed of 1.5 m / s).

Although the tidal channels are located in soft and loose sediments and therefore potentially mobile, Etienne (2014) points out that the position of main channels has not changed compared to 1884 cartographic surveys.

2.2.10 Biodiversity

The seagrass *Posidonia* and *Cymodocea* once very widespread on the coasts of the Gulf of Gabes currently no longer exist on the shallows of the archipelago of Kerkennah (Romdhane and Missaoui, 2002). However, the high islands are home to the capital of the most remarkable Posidonia and Cymodocea seagrass beds in the Mediterranean Sea with a unique morphology of tiger structure beds (Boudouresque et al. 2006).

These seagrass have great heritage value and constitute the major ecosystems of the Mediterranean. It is a biodiversity center providing refuge to a quarter of species, Mediterranean (fauna and flora), and playing a significant role in coastal protection against erosion.

The islands of the Kerkennah archipelago are also an important wintering grounds (Romdhane Missaoui and 2002) for shoreline seabirds and other water birds; it is also an important crossing site for passerine birds during migration. The islets located northeast of the archipelago exhibit remarkable biological richness, with many rare or endangered endemic animal and plant species, (APAL, 2001). Moreover, part of the island of Chergui is listed as a Ramsar site since November 2010.

2.2.11 Governance

Administratively, Kerkennah delegation is attached to the governorate of Sfax. Founded in 1964, it is divided into ten imadas[3] (El Ataya El Chargui, El Kallabine El Kantra, El Kraten El Ramla, Ennajet, Melita, Ouled Kacem and Sidi Frej).

Kerkennah also counts a municipality that was created in January 1974. Following the revolution and like many other communes across the country, a special delegation was introduced pending the municipal elections. The means and resources of the municipality have become limited and constituted an issue as crucial as the difficulties encountered by the municipality to assert its authority after the revolution. Registered overruns are so numerous that they could be visually perceptible (building on the edge of the coast, dumping of waste in *sebkhas*, etc.)

[3]Imada is the smallest administrative division of Tunisia.

The network of associations in the archipelago was animated in its majority by the will of the original inhabitants of the islands in large cities (Tunis, Sfax, etc.) to contribute to the improvement of living conditions in the archipelago. This has experienced a revitalization in recent years with the creation of new associations and diversification of activities ranging from environmental awareness to improving scientific knowledge without neglecting of course the actions of development and promotion of exploitation of local heritage (cultural, culinary, etc.)

Concerning the socio-economic activities, the main source of income of the inhabitants comes from seafood. One of the singularities of the archipelago is that fishermen own an offshore parcel which gives them the right to enjoy marine resources but also to maintain these spaces. Property deeds have existed since the 17th century.

Agricultural development groups (GDAs) are established at the level of irrigated areas and record variable performance from one GDA to another.

The integrated management plan for the Kerkennah islands developed in 2008 called for the establishment of an integrated management unit of the Islands (UGIK) bringing together all the stakeholders (administrations of various sectors, local authorities, associations, socio-professional organizations representing various interest groups) and equipped with sufficient human, regulatory and financing resources to be able to implement the necessary management decisions. This unit has not been established yet.

3. Local vulnerability to natural hazards

The estimate of the speed of current sea level rise in the Mediterranean basin remains uncertain. The projections of the IPCC report in 2013 predict a global sea level rise of 26 cm and 82 cm (extreme values according to the four modeled scenarios) by the end of the 21st century.

The estimate of the variation in sea level in the Gulf of Gabes in particular, gives varying trends depending on the method of used analysis (tide gauge, satellite measure, or terrain indicators and modeling). Etienne (2014) presents a good summary of the different used methods and their respective results. It concludes that, although the rise in sea level in the Gulf of Gabes is probably minimal compared with the general rise of the waters of the Mediterranean, the area will be affected by high relative sea level rise resulting from generalized subsidence of the area.

Burollet (1979) estimated a three-meter submersion of the archipelago over the last 2400 years based on the flooding of coastal archaeological sites. This subsidence is also confirmed by the writings of Pliny the Elder, which indicate that the archipelago back then measured 37 km long and 18.5 km wide, while today it measures no more than 30 km to 14 km. Slim et al. (2004) also identified the remains of ancient roads between the island of Gremdi and the island of Chergui, confirming that at that time they were a single land entity.

As part of the project, Climate Change and Impact Research: the Mediterranean Environment (CIRCE), Harzallah et al. (2010) have made an estimate of future trends in the Gulf of Gabes:

• Increase in average daily temperature: ~ 0.5 ° C / decade

• Increase in daily maximum temperature: ~ 0.6 ° C / decade

• Increased frequency of very hot days: 0.7 days / month / decade

• Increased water temperature: ~ 0.12 ° C / decade

• Increase of the maximum height of wave: 1m / decade

• Sea level rise: ~ 2.6 cm / decade,

• Expansion of the tourist season: ~ 8 days / decade

• Decrease in days favorable to tourism: ~ 12 days / decade.

They mention that the tendency to the rise in air temperature is accelerating (the trend from 1973 to 2008 being double the trend from 1950 to 2008).

The relative rise in sea level in the islands of Kerkennah (due to subsidence) (Slim et al., 2004; Saidani, 2007) will further amplify the phenomena of marine water intrusion into groundwater , causing a rise in the roof of the water table, increased coastal erosion, as well as soil salinization and consequently the extension of *sebkhas*.

4. Coastal erosion and vulnerability of means of subsistence

The sustainability of the Kerkennah archipelago and its development are threatened by three major factors; coastal erosion, salinization and the exhaustion of fishery resources which all have a significant and lasting impact on the activities of the archipelago that are fishing, tourism and agriculture.

4.1 Coastal Erosion

Coastal erosion, accentuated by the construction of maladjusted protection works of (Etienne, 2014 COMETE Engineering, 2001), mainly due to several natural phenomena (APAL, 2001):

• Mechanical and chemical action of the waves,

• Rising sea levels,

• Subsidence of the archipelago,

• Lack of sediment supply carried by rivers,

• Fragility of rocks constituting the coast; friable, slightly consolidated or sensitive to chemical dissolution phenomenon.

Subsidence is clearly visible by the Roman remains that can be found two meters deep, or to a much greater depth than other archaeological remains of equivalent period on the rest of the Tunisian coast. The Sfax port tide gauge measurements indicate a rise in sea levels four to five times faster than the global average (COMETE Engineering, 2001).

Figure 13 Illustration of the importance of coastal erosion.

Etienne (2014) studied this issue in depth by performing diachronic studies for the period 1963-2010, using photo interpretation, remote sensing, land surveys, allowing it to precisely quantify the coastal erosion trends (more details on the methodology used in the Appendix).

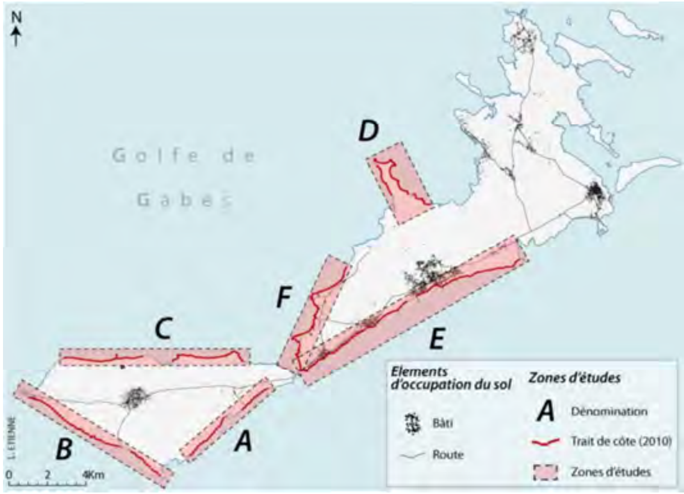

Figure 14 Areas of coastline studied by Etienne (2014) (from Etienne, 2014, Figure 59, p. 155

This study concludes that «field observations have been absolutely essential for all cases", and specifies that the diachronic analysis of the images, is only valid for the coastal zone of the archipelago with more precision of more or less 6 meters.

Table 3 summarizes the erosion speeds of each study area. As reminded by Etienne during a discussion via email the generalization of these values is dangerous insofar as even within the same site the conditions of erosion can be totally different (we may as well find an accreting zone close to areas of strong erosion). We must therefore take these values as a guide only and refer to detailed data available in the thesis manuscript.

Zone	**Site**	**Max (m)**	**m/an**	**Significant average**	**m/an**
A	Southwest coast of the island Gharbi	-14.3	-0.30	-8.6	-0.18
B	Southeast coast of the island Gharbi	-32.2	-0.69	-11.8	-0.25
C	Northern coast of the island Gharbi	-27.6	-0.59	-11.3	-0.24
D	zone of Sidi Fonkhal of the island Chergui	-40.7	-0.87	-12.7	-0.27
E	Southern coast of the island Chergui	-32.0	-0.68	-12.5	-0.27
F	touristic zone of Sidi Frej	-41.2	-0.88	-16.6	-0.35

Table 3 Summary of maximum and average values of each zone

(Etienne, 2014, personal communication)

Apart from natural causes such as the relative sea level rise and slightly consolidated coastal sedimentology, Etienne (2014) and COMETE Engineering (2001) invoking non concerted construction and unstudied protection works as an anthropic cause of coastal erosion. These works have as short-term effect to cause a disturbance of littoral drift and sediment redistribution along the coast with consequent acceleration of erosion in areas without protection, and in the long-term to increase the erosive power of water by the remobilization of degraded protective elements. For these reasons, Etienne (2014) found, in her vulnerability study, than the protective elements increased the vulnerability of the coast instead of decreasing it.

The illegal extraction of sand on the few beaches of the archipelago is also difficult matter to quantify, but probably not inconsiderable, of the coastal erosion.

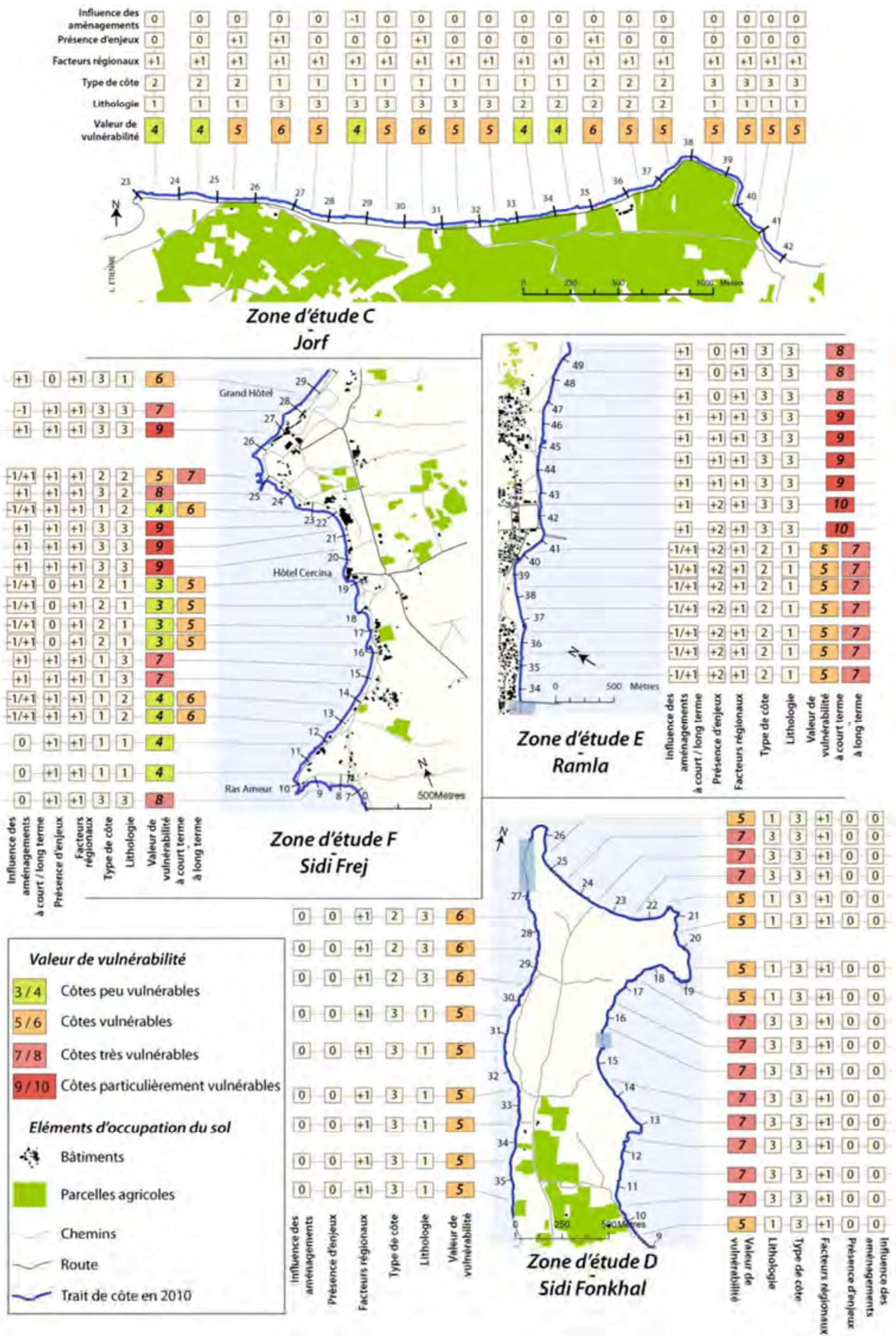

Figure 15 Typology of coasts according to their vulnerability
(From Etienne, 2014, Figure 82, p. 207)

4.2 Tourism

In spite of its potential landscape, and considerable climate, environment and culture, and increasing the length of the tourist season, the development and sustainability of tourism in the Kerkennah archipelago face many threats:

• Limited water resources (quantity and quality).

• Erosion of the coast.

• Low sand resources (urban development or the creation / preservation of beaches).

• Ecosystems threatened by water pollution, soil salinization, or lack of maintenance of palm groves.

• The absence of a waste management program.

• Limited access to the archipelago.

4.3 Agriculture and the risks of soil salinization

Although the volume of agricultural activities has decreased significantly for several decades, a number of revitalization projects of these activities are in progress.

The use of water for irrigated perimeters poses a soil salinization problem when dispersed outside the drained areas.

Planting varieties of olive producers in the short run is positive, though it raises the problem of the long-term vision of this activity.

The soil salinization by raising the roof of the water table or dissolution of gypsum naturally contained in the subsoil of the archipelago is also an important factor to take into account.

As a matter of fact, the salinization phenomena has a double impact; First on freshwater resources in the Kerkennah archipelago, and second on soil quality and consequently on the vegetation that covers it, decimating a non-halophytic vegetation (e.g. palm).

In addition to climatic and natural factors (negative water balance, subsidence, sea level rise, dissolution of gypsum), several practices employed on the archipelago promote soil salinization. It is about the anthropization of *sebkhas*, the use of brackish irrigation water (drawn from the surface of water) in non-irrigated perimeters and finally the illegal extraction of sand and rock.

Generally, although the soil salinization is favourable to the expansion of artificial *sebkhas*, this phenomenon is a threat to the archipelago for which several solutions should be considered.

Fehri (1998) mentions the practice of plowing, which involves plowing in summer from 15 to 20 centimeters of soil before amending it into manure and to sow it with barley (grains tolerating some degree of salinity) during the first autumn rains. This technique, abandoned since the early 1970s, due to a very weak performance, has the double advantage of limiting the capillary rise through soil aeration and to provide a potentially significant farm income.

Irrigated areas must be observed, since they have a drainage system for excess brackish water.

Sebkhas must be preserved in their natural state, and existing dams should be amended to allow the flow of flood waters.

Finally, it is equally urgent to encourage the stopping of wild collection activities of building materials (sand or rocks) which have the effect of bringing the ground / air interface of the roof of the water table and facilitate the rise of brackish water by capillary action (Figure 16).

Figure 16 Roof groundwater exposed by the illegal activities of sand collecting

Figure 17 Consequence of wild collection of sand bordering *sebkha*

4.4 Fishery resources

As described above, a decline in fish stocks has been observed in the Gulf of Gabes. Whether during previous consultations or during the framework of this project. One of the most frequently mentioned solutions is the application of the current legislation. To do this, Rhouma and Labidi mention the following:

• Equip the local services of fisheries, as well as safety services and control of logistics necessary for the implementation of the current legislation,

• Assist and strengthen Groupings for Agricultural Development (GDA)

• Strengthen and multiply controls on illicit channels of marketing of fishery products and confiscate products not complying with the prescribed size or caught by non-regulatory machinery,

• Control of gear fishing and ban on the manufacture of nets and unauthorized by law,

• Update the study of biological cycles of octopuses and their migration to plan the proper capture period,

• Activate the role of the Agency for Ports and Fisheries Facilities (APIP) to develop the structures made for the promotion of fishing (fishing ports, ice plant, spaces for product sales ...) and the exploitation in a rational way,

• Regular monitoring of the fishing boats and to ban illegal boats leaving port without having regularized their situation,

• Confiscation of boats without apparent identification and penalization of owners

• Laying of artificial reefs in sensitive areas known for their importance for the reproduction of marine species,

• Set the number of rooms for the capture of *chrafis* in the terms of references of the public tender and ensure a control in this direction,

• Seek opportunities for diversification of activities between land and sea to reduce the fishing effort,

• Study the possibilities to extend the period of biological recovery.

5. Use of ecosystems to protect the territory

As mentioned above, the role of ecosystems in reducing the risks generated by extreme events is one of the most undervalued ecosystem services.

International efforts, guided by the Hyogo Framework for Action (HFA), strive to reduce vulnerability to natural disasters through a wide range of interventions, including among others the early warning systems, public awareness, regional planning and better management of ecosystems. Most of these efforts are guided by identifying potential risks and estimating the vulnerability of populations and infrastructure. Although many risk assessment methods are available, efforts to develop guidelines and common standards have only begun recently.

Furthermore, the valuation methods do not take into account the changes in risk and vulnerability attributed to environmental change, including ecosystem degradation and climate change. As such, these assessments fail to identify the critical aspects of risk and vulnerability, and therefore do not provide enough information to develop risk reduction actions based on ecosystems.

The question, however, is whether the ecosystems can provide effective protection against extreme events and adaptation to climate change. The scientific research for linking the ecosystem services with risk reduction and adaptation actions remain limited. Yet this information is vital to inform the policy and decision makers.

6. Ecosystems and priority threats identified during consultation workshops

A consultative process accompanied the analytical work and consisted of three consultation workshops. The first consultation workshop was conducted in June 2014 and at the national level in order to mobilize national expertise to highlight the main challenges that the archipelago is exposed to. The discussions helped build a consensus on the seriousness of the problem of coastal erosion and the possible contribution of herbarium to its mitigation.

The second workshop that was held in January 2015 in Kerkennah helped mobilize local expertise to identify what stakeholders consider as key ecosystems in the archipelago and their perception of threats to the ecosystem and the recommended possible solutions. Thus, an exercise to identify the ecosystems and classification of these (+/- 50) by priority action order was made. Table 4 details the ranking assigned by all the participating representatives of the local community.

Local participatory Climagine workshop, Kerkannah, January 2015.

The column "assigned number" indicates the number that was assigned to threats and that will be used on the graphic visualization of priorities. The numbers in the columns "high priority, medium priority and low priority" indicate the number of participants who chose to classify the threat in one of these columns.

Assigned number	Threats identified	High priority	Medium priority	Low priority	Classification weighted by order of priority
1	overfishing	23	4	2	1
2	Replacing fisheries materials	10	11	4	10
3	Little control fishermen	14	7	5	7
4	No respect for biological rest	11	8	5	9
5	Maintenance of port infrastructure	3	10	10	16
6	coastal erosion	22	4	0	2
7	Contamination and overexploitation of aquifers	12	14	0	8
8	Neglect of public cisterns	3	7	12	16
9	Loss of wetlands	9	8	10	11
10	Population migration	6	6	13	13
11	No management of rainwater	5	13	10	14
12	Trawling (uprooting seagrass)	21	3	3	3
13	Absence of waste management	9	13	3	11
14	Uprooting of palm trees	10	8	5	10
15	Increase in built-up areas	4	13	8	15
16	Illegal fishing: Lack of regulation, control and law enforcement	18	9	1	4
17	Oil pollution	10	9	6	10
18	Picking of materials: sand and stone	10	8	5	10
19	Salinization, and rising of the water table	16	4	5	6
20	Advancement of Sebkhas	17	8	2	5
21	Fragmentation of the territory	4	9	8	15
22	Emissaries of the wastewater treatment plant of the National Sanitation Office	7	13	2	12
23	Ballasting and drainage of boats	5	5	11	14
24	Invasive species	6	13	7	13

Table 4 Results of voting on threats identified in order of priority for action

The graph below shows the results of the weighted ranking assigned for each threat, and allows comparing for each the values allocated on their distribution between "high, medium and low" priorities.

This graphic shows that the threats 1 (overfishing), 6 (coastal erosion), 16 (Illegal fishing), 12 (Trawling / pulling grass beds), 20 (Advancement of *Sebkhas)* correspond to the four most threats of "high priority "over the total of twenty-four reported by the audience.

To classify threats taking into account all levels of priority, a weighted sum was calculated by applying a factor "3" to the threats identified as "high priority", a factor "2" to the threats identified as "medium priority" and a factor "1" to the threats identified as "low priority".

As an example, the weighted sum of threat 1 (overfishing) is calculated as follows:

[3 (the weighting factor corresponding to "high priority") x 23 (the number of votes collected)] + [2 (the weighting factor corresponding to "medium priority") x 4 (the number of votes collected)] + [2 (the weighting factor corresponding to "low priority") x 1 (the number of votes collected)] = 79. 79 was the highest score so the threat is considered the highest priority.

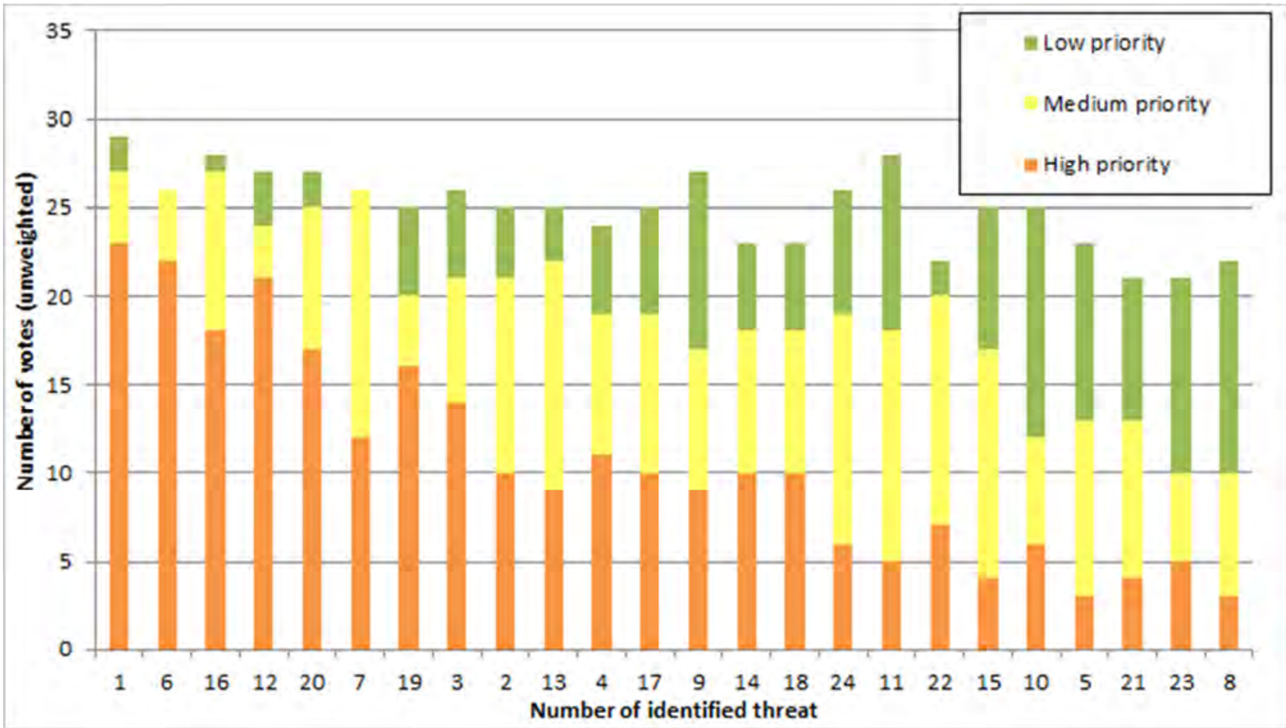

Figure 18 Number of votes identified threats (weighted ranking)

The results of the ranking exercise allows to state the broad consensus reached at the plenary meeting of restitution of group work on the vulnerability accentuated by the rich ecosystem of the Kerkennah archipelago to the various forms of degradation of natural and anthropogenic origins.

According to participants, the most increased threat consists in over-fishing. In fact, although the gear and traditional fishing techniques (and often ingenious) allowed for a long time an efficient and sustainable use suited to the specific nature of the environment, the situation of fishing in the islands is under considerable fishing pressure and is dominated by irregularities and non-compliance of regulations in force. Similarly, certain fishing activities such as trawling in shallow waters are particularly destructive; eroding and damaging the funds and seagrasses.

In the second place comes the phenomenon of coastal erosion of the archipelago which was revealed at several sites and seems to be reinforced by the works and infrastructure carried over the coast.

As mentioned several times during the discussions, progress *sebkhas* appears among the most striking threats in the carried out ranking. The problem of soil salinization, due in part to the continuous extension of these depressions already constitute a significant part of the total area of the archipelago, and threatens the sustainability of some other ecosystems. Salinization and the rise of tablecloths are also among the most pressing issues.

The results of the consultation workshop are consistent with the ones of the investigation developed in the thesis of Stephen (2014) through a questionnaire distributed to 150 persons (~ 1% of the population of the archipelago) to determine among others the perception of the public about the major problems that the Kerkennah archipelago is subject to (Figure 19).

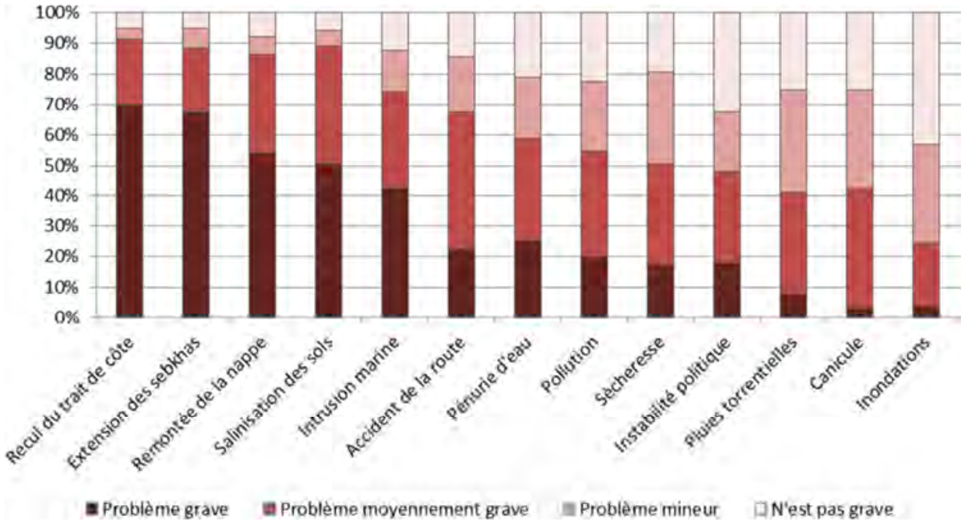

Figure 19 Ranking of major problems (from Etienne, 2014, Figure 101, p. 266)

In fact, the first two issues of the ranking (coastal erosion and extension sebkhas) coincide with the results of the workshop that included local stakeholders, with the exception of the issue of fisheries resources, a theme which was not proposed in the questionnaire of Etienne.

7. Threats Analysis Services Solutions for priority ecosystems

7.1 Vegetation submarine

The reef of the Kerkennah archipelago houses one of the most remarkable *Posidonia* meadows in the Mediterranean stretching over 15 km from the coast because of the low slope of funds (Pergent et al., 2008). It is mainly occupied by several types of marine seagrass (Posidonia oceanica, Cymodocea nodosa) and several varieties of green and brown algae (Padina pavonia, Halimeda tuna and Cystoseira, Caulerpa prolifera) (COMETE Engineering, 2001). These slow-growing plants form large seagrass meadows but also large vertical edifices, playing a vital role in the marine ecosystem (Boudouresque et al., 2006) as well as for coastal protection. Moreover, it is in this region that the morphology tiger herbarium was described for the first time (Blanpied et al., 1979).

Posidonia, have the ability to adapt to a gradual accumulation of sediment through the vertical rhizome growth, developing elevated structures whose end leaves flush with the surface in times of low sea.

The tiger herbarium grows to a maximum depth of 10 meters and is characterized by alternating *Posidonia* seagrass bands more or less parallel surrounded by "dead matte" occupied by a stand with *Cymodocea nodosa* and / or *Caulerpa prolifera*. At the same barrier reef development occurs over several millennia making their irreversible destruction to human scale.

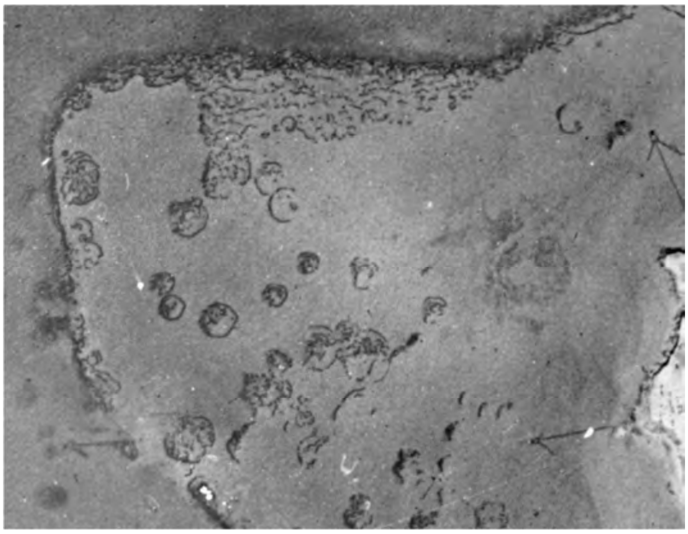
Figure 18 striped meadows, cords and micro-atolls of *Posidonia* in Kerkennah

Mounir (2004) sampled and analyzed colonies of *Posidonia* situated on the platform of the Kerkennah archipelago . The findings of the study indicate that "seagrass *Posidonia* around the Kerkennah islands has very good signs of vitality" with the widespread presence of the most advanced type of development. However, damage due to anchors or dredging actions was identified promptly.

7.1.1 Services

Seagrass provides many ecosystem services that contribute to local economic development. These services are:

• Biodiversity reservoir providing refuge to a quarter of Mediterranean species (flora and fauna) (for coverage below 1% of the surface of the Mediterranean seabed)

• Source of plant debris transported to other types of substrate and used by living organisms beyond 50-100 m depth or accumulated as benches on the beaches acting as a natural protection against beach erosion,

• Spawning ground and nursery for many species of fish and shellfish,

• Production of oxygen (up to 14 l. of oxygen produced per m² per day at 10 m. deep)

• Stabilization of the seabed by trapping sediments, improving the transparency of the water,

• Amortization of wave power and decreased rates of coastal erosion,

• Excellent indicator of the quality of the coastal environment,

• Carbon sequestration.

7.1.2 Threats

Posidonia Seagrass are vulnerable to many anthropic or climatic factors. However, the regression is mainly due to the accumulation and frequency disturbances (Boudouresque, 2006). Moreover, rising sea levels, increasing temperatures and rainfall could embrittled or totally destroy this ecosystem. Generally, the resilience of *Posidonia Oceanica* is raised to temperature variations and all kinds of contamination and invasive species. However, it is low in case of variation of salinity, turbidity, significant sedimentation or grubbing (anchor or trawl) (Pergent et al., 2012).

In addition, the unique morphology of the *Posidonia* tiger structure to the Kerkennah archipelago increases their vulnerability. Their characteristics; shallow depth reduced extension (width of 1 to 2 m) and low migration speed (10 cm / year), which make them particularly vulnerable.

Anthropogenic threats to Submarine vegetation are:

• Recovery by coastal development

• Modification of the sedimentary flows

• Discharge of liquid effluents (emissary):

    o decrease in water transparency (sediment or plankton)

    o Intake of chemical contaminants -Decrease localized salinity.

• Frequent anchors

• Trawling activities

• Pollution

• Competition with introduced species

• Overgrazing by sea urchins and herbivorous fish

• Fish farms.

Equally the activities of the gas exploitation "Cercina field", operated by British Gas in the offshore of Sidi Frej, are a constant and significant threat.

To ensure the quality and preservation of meadows, it is necessary to establish a cartographic monitoring system.

Monitoring systems generally combine tracking tools to three spatial scales:

• Across the entire herbarium: mapping, as receipts, permanent transects,

• Locally: tags at the upper or / and lower limit permanent squares

• A microscale: measuring the density of the sheet bundle, relative importance of crawling and upstanding beams beams, receding rhizomes*, lepidochronology*, and the length of leaves etc.

The Seagrass of the archipelago of Kerkennah is part of a MedPosidonia Program initiated by RAC/SPA network - Regional Activity Centre for Specially Protected Areas (UNEP, MAP, RAC/SPA). The region has benefited from training and field missions in order to develop this ecosystem conservation programs. Part of the herbarium is also a candidate for a marine protected area (MPA) mainly to protect trawling activities (Mustapha and Afli, 2007).

For effective monitoring of seagrass, it is important to combine the cartographic monitoring tools. As part of this study, mapping tests using aerial photographs and high-resolution satellite imagery (QuickBird, WorldView) have shown promising results for a surface monitoring shallow seagrass (flush). However, this tool alone cannot guarantee the accuracy of results (type and condition of mapped Submarine vegetation) nor monitor the deeply-located seagrass. It must be imperatively supplemented by field surveys combined with the use of acoustic mapping methods (sonar).

The main limitations of satellite imagery (or aerial) reside in image quality (they must be cloud and wind-free) and in the interpretation of results (possibility of confusion between close-toned stands, misinterpretation related to bathymetric variations and the state of the tide when taking the picture).

7.1.3 Solutions

Various means can be implemented to ensure the protection of Submarine vegetation. Direct measures of protection are ensured by international and / or national laws and regulations (Europe-wide: Bern Convention on the Conservation of European Wildlife and Natural Habitats of Europe, and the European Habitats Directive (Natura 2000), on a Mediterranean scale: the Barcelona Convention, notably the Protocol Concerning specially Protected Areas and Biological diversity in the Mediterranean whose implementation is coordinated by the Regional Action Centre for Specially protected Areas (RAC / SPA).

However indirect protection measures can also effectively protect seagrass beds, notably through the establishment of MPAs, the inception of regulations aiming to restrict pollutant emissions, encouraging traditional fishing techniques, limiting certain techniques of fishing such as trawling and the application of the requirement for an impact study before any project authorization request having environmental consequences and especially the implementation of the resulting recommendations.

Although the seagrass in coastal waters of the Kerkennah archipelago seem relatively preserved, except for occasional uprooting by anchors or trawling actions, they require the establishment of a cartographic monitoring system. In addition, surveillance systems not only enable early detection of further degradation of seagrass or modification of their distribution, they also aim to measure the effectiveness of environmental local policies, using seagrass as an indicator of the quality of waters and coastal areas, and finally to control the environmental impact of development.

7.2 Sebkhas

A *sebkha* is a flat-bottomed depression in close proximity with the sea level. It is more or less connected to the marine environment that temporarily inundates. The high temperatures and the presence of salt water lead to increased soil salinity with consequent installation of a halophyte vegetation and specific fauna supporting the environmental conditions or high humidity variability (alternately flood-desert) as well as a high temperature and salinity.

7.2.1 Services

Wetland areas such as *sebkha*s exhibit vegetation and a niche for many migratory birds, and as such are worth preserving (COMETE Engineering, 2001). In addition, the specific nature of this medium makes a high-value ecotourism and educational sites.

7.2.2 Threats

Most of the *sebkhas* of the archipelago is anthropized, either by tracks, saline exploitation or through dikes and roads without discharge nozzles. Accordingly, the medium is disturbed and weakened. In addition, water (precipitation or sea in the case of storms) can't be evacuated and evaporated on the spot concentrating significantly soil salinization. The negative water balance of the Kerkennah archipelago also increases soil salinization by groundwater level rising. In dry periods, the salt is then remobilized by winds and moved along *sebkha*, decimating non-halophilic vegetation (e.g. Palm groves) and allowing the advance of *sebkha* at the expense of neighboring ecosystems. Pending a solution for waste management, *sebkhas* also represent privileged places by residents for illegal damping.

Etienne (2014) studied the evolution of extending *sebkha*s between 1963 and 2010, using the boundary formed by the palm trees along the *sebkhas*. The total area covered by *sebkhas* rose from 2'583 ha in 1963 (28% of the study area) to 3'047 ha in 2010 (33% of the study area). Although evolutionary profiles are completely different between the island of Gharbi (24%) and the island of Chergui (9%). In general, it indicates that the extension of *sebkhas* was very limited before 1984 and then exploded. The author hasn't invoked the reason for this acceleration.

7.2.3 Solutions

The proposed solutions consist of updating the Master Plan development with a clear specification for the protection of wetlands, the prohibition of building in wetlands and law enforcement. It has also been recommended to create and maintain networks of drainage in irrigated areas aiming improving the hydraulic operation perimeters in connection with wetlands.

8. Centralization and sharing of data

In order to understand the risks of extreme events and climate change in full background knowledge, we must identify and accurately quantify risk, vulnerability and exposure. The data required for risk assessment and therefore for the proposition of quantified recommendations were not available for the study area, or only to an inappropriate level. Much of the effort put into this project was to collect, standardize, sort and centralize the available data and documents, and to finally make available to the public via Internet at the address **http://kerkennah.grid.unep.ch/**, the geographical data as well as documents pertaining to the Kerkennah archipelago. This website was created and populated by UNEP/GRID-Geneva, in a second time, it will be forwarded to the APAL to be maintained and updated. The aim is to make the data available and documented in order to minimize the laborious phase of data collection for future projects.

A lot of data was provided by the APAL through Mr. Adel Abdouli (focal point of the project). Table 5 in the Appendix summarizes the GIS data that has been selected. The Metadata of these layers were provided by the APAL.

The UNEP/GRID-Geneva has generated multiple data layers necessary for a proper understanding of the study area. They are briefly presented in this chapter just as the data provided by the APAL.

A large number of data probably available in vector format but not accessible was identified during the work of documentation, notably the excellent thesis of Stephen (2014). Therefore, in order to prevent important data from disappearing in a more or less distant future, and in order to optimize their visibility and use, it would be appropriate to contact the author to make available these layers (for viewing and / or download).

8.1 Digital cartography of urban cores of Kerkennah

During a visit to the municipality of Kerkennah, a copy of data CD "digital cartography of urban cores of Kerkennah" was conducted by the UNEP/GRID-Geneva team. The data in AutoCAD format were converted, formatted and reorganized in a GIS format before being incorporated into the geographic database available on the Internet. The original spatial reference system being Carthage / northern Tunisia (epsg: 22391).

8.2 Data collected as part of KfW activities

The APAL, through the focal point of the project (Mr. Adel Abdouli) also transmitted the data collected in the framework of coastal management activities funded by KfW. As previously, an AutoCAD data format conversion attempt to integrate the geographic database project was made. Unfortunately, given the magnitude of the task of standardizing layer names, lack of projection, and due to time constraints, this task could not be brought to completion.

8.3 1939 Aerial images

Thanks to the contacts of Mr. Antoine Lafitte (Plan Bleu/RAC) with Ifremer, we have acquired aerial images from 1939 to an effective resolution of about 1 meter for almost the entire archipelago of Kerkennah (Figure 21). The images were prepared by Ifremer and financed by UNEP / GRID-Geneva. They are distributed under open license and will be available to the public soon **http://sextant.ifremer.fr/fr/**

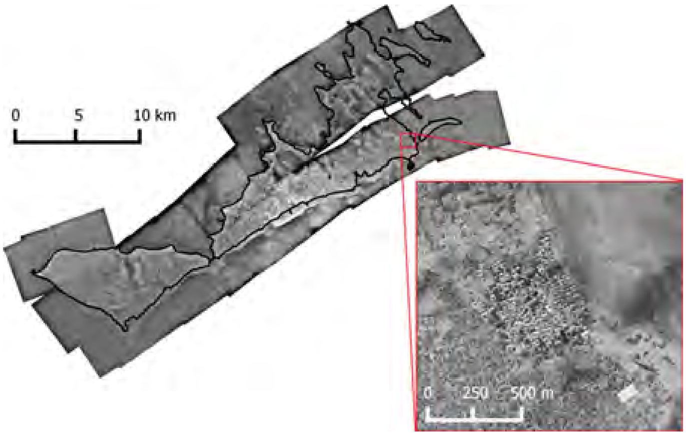

Figure 19 Mosaic of aerial imagery coverage of 1939 (supplier: Ifremer)

8.4 Collection of recent high-resolution satellite images

The access to high resolution satellite images has been possible in the framework of the network of UNEP / GRID in general and the GRID-Sioux Falls **http://na.unep.net/** in particular, which has provided us with QuickBird and WorldView images taken between June 2012 and May 2014 (Figure 22 covering almost the entire Kerkennah archipelago).

It is important to note that because of these images licenses, only the derived data processing (mapping of underwater vegetation and built-up areas) will be shared with project partners.

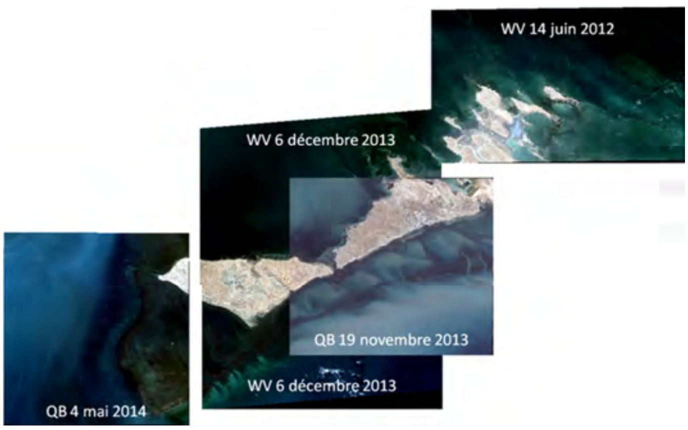

Figure 20 Mosaic of recent coverage of satellite images (supplier : GRID-Sioux Falls)

8.5 Detection hedging changes of underwater vegetation

The quality of the 1939 aerial images allows the mapping of underwater vegetation with the help of oriented classification functions, object of (segmentation) Owner software *eCognition*

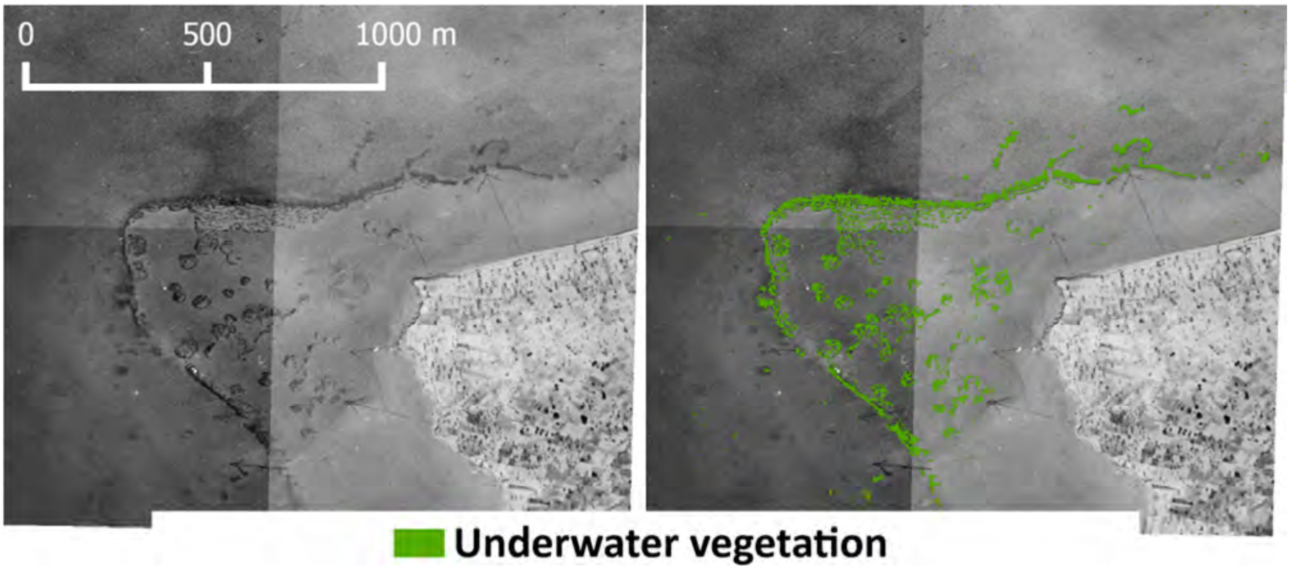

Figure 21 Classification example of underwater vegetation through the use of aerial imagery dating from 1939 of the Sidi Fredj coast

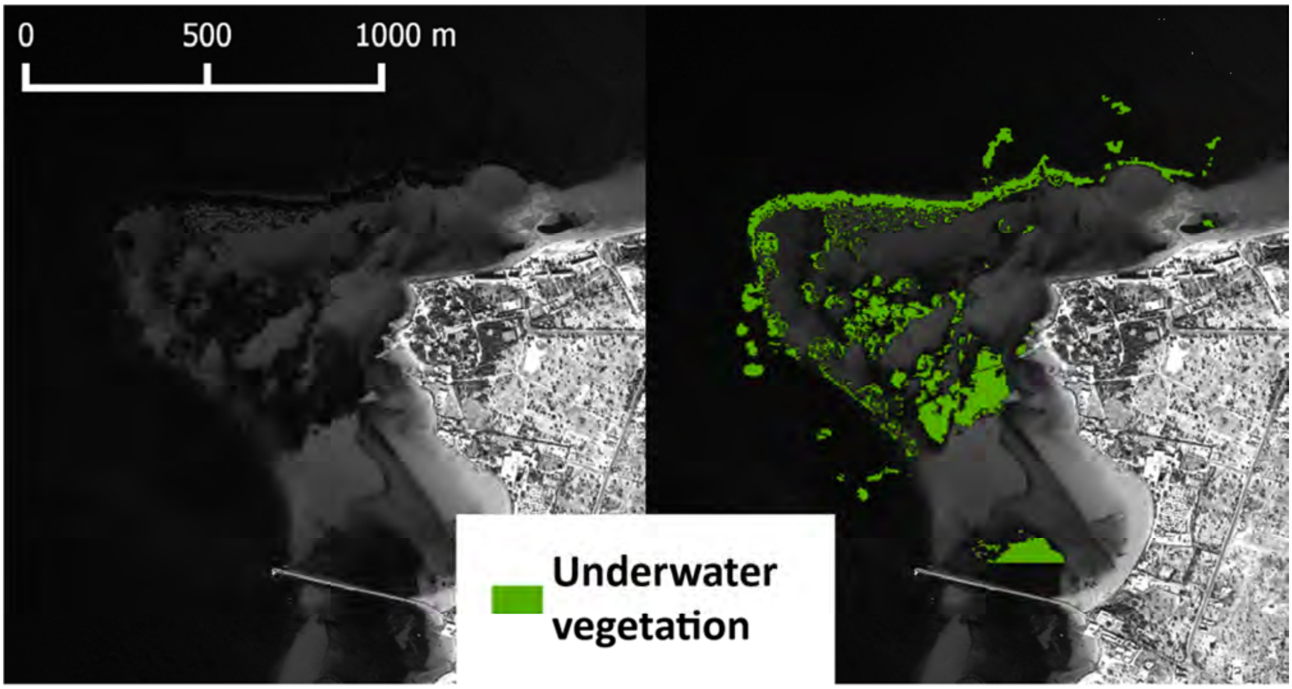

Figure 22 Classification example of underwater vegetation with a Worldview picture dating from 2013 of the Sidi Fredj coast

Although the quality of these classifications has not been evaluated on the field or validated by an expert, we can therefore estimate that the vegetation detected in 2013 (Figure 24) seems overestimated compared to 1939 (Figure 23). These differences are explained by the use of different resolutions (~1 m against ~2 m respectively) and the possible presence of plant debris and algae (*Caulerpa prolifera*). The comparison of the recent coverage with the one of Rais et al. (2009) shows the boundaries of a non-field validation classification. Indeed, the remote sensing alone does not correct any possible classification errors or distinguish different plant associations, which demonstrate the need for access to validation data obtained during field campaign and / or validation or correction of results by experts.

8.6 Distribution of the population

In order to distribute the population of the Kerkennah archipelago and the lack of detailed census data and the high seasonal variations in terms of residents and visitors (14,400 and 200,000, respectively), the building coverage was mapped using panchromatic bands of available high resolution satellite images using the classification functionality object of free software Spring. **http://www.dpi.inpe.br/spring/francais/index.html**

Secondly, the percentage of surface relative to the total constructed surface of the archipelago (1'458'866 m²) was calculated for each cell of a virtual grid of 250 meter resolution.

Figure 25 shows a zoom on the village of Alataya with the coverage of buildings in gray and in degraded orange to red the area percentage of constructed buildings in the archipelago contained in each cell of a virtual grid (e.g. a value of 1 means that the cell 250 m x 250 m contains 1% of the built area of the Kerkennah archipelago). This layer of percentage allows a representation of the distribution of built areas that we can then use to distribute the population living or visiting the archipelago.

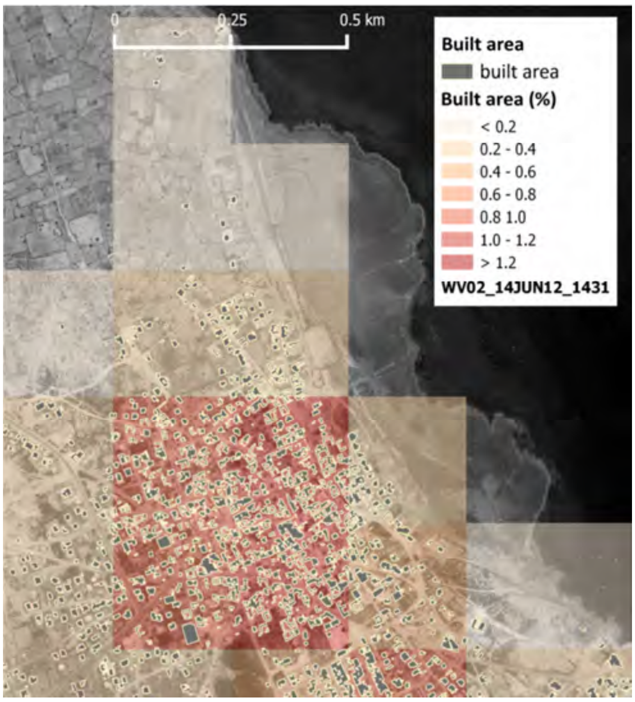

Figure 23 Zoom (Altaya village) on the buildings distribution on the Kerkennah islands

By overlapping this layer with the layer of submersible surfaces provided by APAL (Figure 26), it is possible to estimate that 4.7% of the built areas of the archipelago are located in flood zones (defined by the Tunisian government as any surface at an altitude less than 2m).

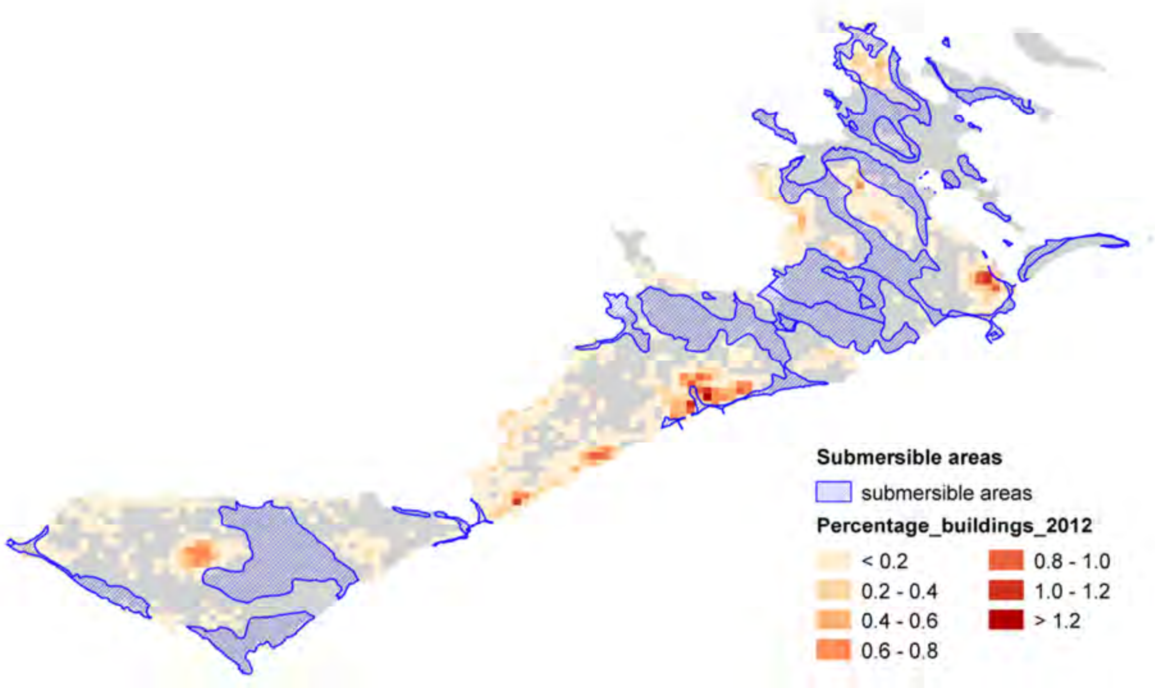

Figure 26 Overlapping built-up areas with submersible areas

Etienne (2014) carried out an equivalent work through mapping the entire urban areas (including hard surfaces adjacent to buildings, roads and gardens). This explains the most important values indicated; 719 ha in 2010, against the 145 hectares of the present study (which measures only building surfaces).

8.7 Location of chrafi traps

The location of the traps (points of collections, Figure 27) of *chrafis* was digitized. Two layers were generated, one for 1939 based on aerial imagery by the IFREMER; the second period is representative of the "current" period and is based on the recent high-resolution satellite images collected for this project. It is noteworthy that the acquisition dates of these images extend over the period June 2012 - May 2014, and that while "fixed" the location of a fishery can be displaced, deleted or created year in and year out. All traps were digitized in order to be representative of the fishing effort in the whole.

Figure 27 Model of a collection point of *chrafi* (created by the youth and science Association, Kerkennah)

Figure 24 Model of a collection point of *chrafi* (created by the youth and science Association, Kerkennah)

A total of 160 traps were identified on aerial photographs from 1939 and 1061 traps on recent satellite images (2012-2014) (Figure 28). However, the area covered by the imagery available for the current period is much larger than that covered in 1939 and these figures are not comparable. The number of “current” traps in the area covered by the 1939 Aerial Imaging amounted to 468; we can conclude that the number of traps has been multiplied by about 3 between 1939 and today.

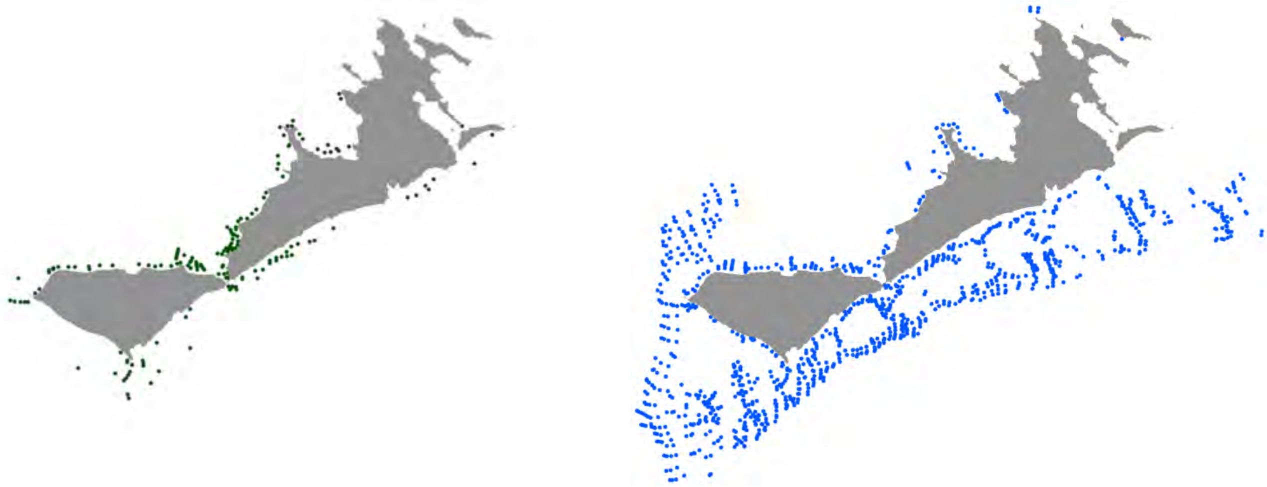

Figure 25 Location of traps *chrafis* (1939 left, "current" right)

8.8 Digital Elevation Models (DEM)

Two different sources of DEM were evaluated as part of this project (SRTM and Aster GDEM both at 30 m resolution), but none has been retained for failing to significantly correlate with vector topographical data available.

Topographic and bathymetric vector data available are too coarse; they unfortunately do not allow generating DEM representative to a fairly accurate scale to accommodate sea level elevations of decimeter. This problem is also noted by Etienne (2014).

The creation and provision of such data should be one of the priorities in the collection of future data. Precise elevations data are necessary to understand in a reliable and accurate way the risk of flooding and erosion. Accurate bathymetry data are also essential to model sedimentary currents and dynamics for building efficient coastal protection works. Accurate data are already available and have been integrated into the geographic database generated by this project. However, their geographical coverage is at for the moment too small to allow the creation of accurate DEM representative of the whole platform containing the Kerkennah archipelago.

9. Recommendations and conclusions

The study concerning the values and services provided by the ecosystems in the Kerkennah archipelago in mitigating physical and socioeconomic impacts of the variability and climate change lasted two years, and confirmed the unique potential of this space, but also to note again that the anthropogenic and climatic pressures exert and induce considerable impacts.

However, it is essential to emphasize that awareness is there. The involvement and constant level of interest from various local and national stakeholders in participatory workshops is irrefutable evidence. The dynamism is born of these consultations and the products of the study (implementation recommendations for concrete actions and maintenance and use of GeoNode) encourage us to think that this work will stimulate the Tunisian national authorities and local actors to make progress in the sustainable management of resources of the archipelago.

Although it has been shown through this study and by all the discussions that emerged during the participatory workshops that the means of action against global climate change effects are limited to the scale of the archipelago, it is possible to act and to undertake local actions for sustainable management of resources and ecosystems.

9.1 General recommendations

The Kerkennah archipelago is subjected to high pressures and severe degradation of its natural resources. The analysis conducted in this work through the mobilization of knowledge generated through previous projects and studies and the mobilization of national and local expertise highlighted priority issues requiring urgent action. The three priority factors that the sustainability and development of the Kerkennah archipelago depend on are the degradation of fishery resources, coastal erosion and soil salinization. All these factors have a significant and lasting impact on the activities of the archipelago that are fishing, agriculture and tourism.

Moreover, the main problem recurring in all areas of activity is the non-compliance with the legislation in force, impacting significantly on quality of life and potential for sustainable development of the archipelago. Concrete steps have already been proposed by Rhouma and Labidi (2006) concerning fishing activities, however they still do not seem to be applied (e.g. strengthening of controls on illegal marketing channels, confiscation of boats and / or non-compliant products , control of fishing gear and prohibition on manufacture of non-conforming nets etc.).

Therefore, the necessary means to compliance with the regulations must always be unlocked. These measures must also be accompanied by awareness programs for local actors on fishing practices and sustainable agriculture, as well as assistance and strengthening of Agricultural Development Group (GDA). Regarding the illegal extraction of building materials, a supply and monitoring system should be in place.

The present infrastructure on the archipelago should be improved through concrete measures and must also be supplemented by regular monitoring of the quality of coastal waters. The waste treatment plant should be commissioned as soon as possible, followed by a collection of old and new waste campaign and public awareness to the wild dumping of waste. The wastewater treatment plant is also to be maintained and repaired, and the sea outfall should be extended. An assessment of potential impacts of petroleum activities offshore and land drilling is necessary to develop a backup plan in case of accident. Finally, it is essential to effectively implement the rules of the Maritime Public Domain (DPM) to prohibit the isolated and uncoordinated activities of inappropriate coastal development. Also, a comprehensive study of the impact of the creation of new irrigation on soil salinization and advancing *sebkhas* is essential.

On another level, the archipelago boasts remarkable ecosystems (palm groves, wetlands, seagrass meadows) that deserve to be restored and / or maintained in order to contribute to the mitigation of the above pressures. The means to provisions are:

• Establishing awareness programs of the population and local authorities on the use and preservation of ecosystems,

• The establishment of cartographic monitoring activities and the extension of the state of ecosystems (including herbals)

• The creation of protected marine areas (MPAs) and protection perimeters,

• The laying of artificial reefs in sensitive areas, to ensure the reproduction of marine species and to protect seagrass from trawling activities

• Supporting local NGOs active in the preservation of the environment (e.g., Youth and science Kerkennah El Majarra)

• The creation of an institute of marine and / or farm research to value local good practices and their generalization,

• The establishment of measures to protect the archaeological heritage from natural and anthropogenic impacts,

• The repair of damaged reefs in place and to replace the protective structures installed by the inhabitants.

Many studies have been conducted on the archipelago for over a decade, generating extensive knowledge on all issues of the archipelago and a considerable number of spatial data. The problem lies in the lack of centralization and sharing of information, urging to the replica of studies and data.

The next actions (or projects) must be centered in the implementation of the recommendations called for in this report and / or in previous studies, as well as the maintenance and provision of centralized information.

The web platform advanced during this project is an application allowing developing Geographic Information Systems (GIS) and deploying spatial data infrastructures.

The creation of a geographic database and a website for viewing and easy access to information within the framework of this project will save time in future studies and avoid duplication. This technology will be transferred to the APAL so it could keep the database updated and populate with new information.

The missing data that should be generated first in future projects are:

• The creation of Digital Elevation Models (topography and bathymetry) at a resolution allowing risk modeling related to climate change and the implementation of coastal protection works. To make this elevation data available on the CD "digital mapping of urban cores of Kerkennah" integrated GIS and data collection activities undertaken in the context of KfW's activities should greatly facilitate these tasks,

• Accurate and localized fishery statistics,

• Identify the number of visitors (e.g., by using a form distributed in the tray)

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National Institute of Statistics (Census of 2014):
http://www.ins.nat.tn/fr/rgph2.1ens.php?Code_indicateur=0301001
National Institute of Statistics (age pyramid2004):

http://www.ins.nat.tn/fr/district_rgph1.php?Code_indicateur=0316002

List of Contributors

Cartography

• The APAL has data on vegetation cover for two campaign periods in 2009 and 2010.

• Additional mapping data on vegetation cover can be obtained from INSTM (The identified resource person Mr. Karim Ben Mustapha).

• In addition, the Ministry of Agriculture, Water Resources and Fisheries has conducted cartography as part of the study with the support of Geomatics Office on the islands of Kerkennah (The identified resource person Mr. Mohamed Salah Ben Romdhane).

Aerial photos

• Ifremer Institute has aerial photos of the islands of Kerkennah dating from 1939 but that are not geo-referenced.

• The National Mapping and Remote Sensing Center (CNCT) has partial aerial photos of 1973 and 1980 that allow visualizing changes in the shore to four time periods for four sites.

• Pictures of 1973 clearly allow viewing the location of fixed fisheries. The team of APAL in charge of the project KfW took steps with the CNCT for obtaining these data (The identified resource person Mr. Bechir Med Nasra).

Fauna and Flora

• An inventory of the fauna and flora of the islands of Kerkennah was conducted by the National Institute of Sciences and Technologies of the Sea (INSTM) as part a project concerning the Gulf of Gabes. The inventory is available at APAL.

Oceanography

• Bathymetric data is available INSTM. However, it should be noted that the measures are not made for the weak bathymetries (before isobath -20m). (The identified resource person is Mr. Cherif Sameri).

Hydrodynamics / Currentology

• All studies of hydrodynamics refer to the old data of Ameri (1982).

• New simulations are performed by the National Engineering School of Tunis (ENIT), these simulations have set two or three levels of swells and helped map the circulation around the Kerkennah Islands (Identified resources, Bashir bejaoui and Mahmoud Moussa).

• The currentmeters have been implanted by INSTM. The number and position of the various currentmeters can be provided by Ms. Oula Amrouni. A tide gauge was immersed in Kerkennah for a period of three months as part of collaboration between the Youth and Science Association (AJS) and INSTM. The data are available in the AJS.

• The tide gauge data recorded in 2007/2008 were published by Mr. Jamel Hatour of INSTM.

• Furthermore, the winds must be considered in the study. Nevertheless, the data available concerns Sfax and not the Kerkennah archipelago; whereas the wind conditions between the archipelago and Sfax are different. Mr. Bashir Bejaoui mentioned that he performed wind / currents marine simulations. On the contrary these simulations are not yet validated.

Meteorological data

• The APAL has meteorological data for the years 2007 and 2008.

• It is useful to note that weather data were collected as part of a study conducted on behalf of the Ministry of Industry and on the Gulf of Gabes. These data can be used for the study.

Economic data

• Economic data, including GDP, etc ... are available either by sector or region. The General Commission for Regional Development (CGDR) has region economic data (Economic Planning Document). An appreciation of Kerkennah GDP can be advanced by crossing the economic data by region and by sector of activity (fishing and oil).

• A report «Governorates in figures " is available at the CGDR and contains economic data that can also be used in the study.

• Mr. Ben Lahbib Chikha, in his capacity as head of the Territorial Agricultural Extension Unit of the Kerkennah archipelago, is informed of various projects in the archipelago and would also be custodians of some useful data.

Existing development plans

• The Ministry of Public Works, Spatial Planning and Sustainable Development commissioned a consulting firm to review urban development plans of 2005, the management plan should be updated in July 2015.

• In 2014, the National Office of Tunisian Tourism (ONTT) published the list of touristic areas.

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Annex

Quantification of coastal erosion by Etienne (2014)

Etienne (2014) quantified coastal erosion of the archipelago for the period from 1963 to 2010. To achieve this, she scanned and geo-referenced (by applying a second degree polynomial transformation to minimize strains) 59 Aerial photographs from 1963 based on a SPOT-5 satellite image of 2010 to compare the shorelines during a diachronic analysis.

Etienne (2014) was faced with several challenges:

• Aerial images deformed on their margins, only their center has been preserved,

• Existence of some hard spots (points of timings such as buildings or crossroads), so she had to use large number (average 110 per image) soft spots (with remained palm trees)

• Lack of knowledge of the right timing to take pictures (again, there is no tidal datum for the islands of Kerkennah)

• Various types of ribs, complicating the accurate detection of the coastline (the position of the coastal vegetation has been used in some sites)

• Different type of image (black and white against multi-spectral), aerial images that can be saturated by location.

The low declivity of the bathymetry and small width of beaches, combined with a large tidal range, varies the position of the coastline by several meters between low and high water, greatly complicating the quantification of the movement of the coastline.

Data provided by the partners

APAL (via the focal point Mr. Adel Abdouli)

Type	Year	Name_layer	format	Description
Vectorial Data		bathyme.shp	ligne	Courbes bathymétriques
Vectorial Data		bathymetrie.shp	ligne	Bathymétries
Vectorial Data		caulepe.shp	polygone	Couverture Caulerpa
Vectorial Data		cymodocea.shp	polygone	Couverture Cymodocea
Vectorial Data		cos.shp	polygone	Occupation du sol
Vectorial Data		couraant_final.shp	point	Bouée
Vectorial Data		digue.shp	ligne	Digues et canaux
Vectorial Data		dunes.shp	polygone	Dunes
Vectorial Data		espace_bati.shp	polygone	Zones urbaines
Vectorial Data		estran.shp	polygone	Estran
Vectorial Data		geomorphologie.shp	polygone	geomorphologie
Vectorial Data		Hauts-fonds.shp	polygone	Hauts fonds
Vectorial Data		kerkenna.shp	ligne	Etat de la ligne de côte
Vectorial Data		NDD-CN.shp	ligne	Courbes de niveau

Vectorial Data		ndd-geol_fina.shp	polygone	Carte géologique
Vectorial Data		NDD-houle.shp	point	Bouée
Vectorial Data		NDD-maree.shp	point	Bouée
Vectorial Data		NDD-PC.shp	point	Points d'altitude
Vectorial Data		pedologie_final.shp	polygone	Carte pédologique
Vectorial Data		point_bathy.shp	point	Bathymétries
Vectorial Data		population.shp	polygone	Principaux centres urbains
Vectorial Data		posidonie.shp	polygone	Couverture Posidonia
Vectorial Data		pression_urbaine.shp	ligne	Zones d'extension urbaine
Vectorial Data		repar_pop_zone.shp	polygone	Répartition de la population
Vectorial Data		route.shp	ligne	Voies de communications
Vectorial Data		s_nuisances.shp	point	Sites de nuisance
Vectorial Data		schorres.shp	polygone	Schorres
Vectorial Data		sebkha.shp	polygone	Sebkhas
Vectorial Data		secteurs.shp	polygone	Secteurs
Vectorial Data		sites-points.shp	point	Points d'intérêt
Vectorial Data		vegetation_terre.shp	polygone	Carte des sols
Vectorial Data		vuln_submers_enm.shp	polygone	Zones submersibles
Vectorial Data		zonage_marin.shp	polygone	Zones marines
Vectorial Data		zones_themes.shp	polygone	Zones d'activités
Satelite_Images		bounoma_1.jpg	raster	
Satelite_Images		bounoma_2.jpg	raster	
Satelite_Images		ouled_bou_ali.jpg	raster	
Satelite_Images		ouled_bou_ali_2.jpg	raster	
Satelite_Images		ouled_gacem.jpg	raster	
Satelite_Images		ouled_yaneg.jpg	raster	
Satelite_Images		sidi_fraj.jpg	raster	
Aerial Photos	1939	Image09_Geo.jpg	raster	
Aerial Photos	1939	Image11_Geo.jpg	raster	
Aerial Photos	1939	Image13_Geo.jpg	raster	
Aerial Photos	1939	Image15_Geo.jpg	raster	
Aerial Photos	1939	Image16_Geo.jpg	raster	
Aerial Photos	1939	Image37_Geo.jpg	raster	
Aerial Photos	1939	Image38_Geo.jpg	raster	
Aerial Photos	1939	Image44_Geo.jpg	raster	
Aerial Photos	1939	Image51_Geo.jpg	raster	
Aerial Photos	1974	image_160_geo.jpg	raster	

Aerial Photos	1974	image_161_geo.jpg	raster	
Aerial Photos	1974	image_183_geo.jpg	raster	
Aerial Photos	1974	image_230_geo.jpg	raster	
Aerial Photos	1992	Image52_Geo.jpg	raster	
Aerial Photos	2002	image_100_geo.jpg	raster	
Aerial Photos	2002	image_101_geo.jpg	raster	
Aerial Photos	2002	image_25_geo.jpg	raster	
Aerial Photos	2002	image_50_geo.jpg	raster	
Aerial Photos	2002	image_51_geo.jpg	raster	
Aerial Photos	2002	image_75_geo.jpg	raster	
Aerial Photos	2002	image_76_geo.jpg	raster	
Aerial Photos	2002	image_78_geo.jpg	raster	
Aerial Photos	2002	image_80_geo.jpg	raster	
Aerial Photos	2002	image_82_geo.jpg	raster	
Aerial Photos	2002	image_83_geo.jpg	raster	
Aerial Photos	2002	image_84_geo.jpg	raster	
Aerial Photos	2002	image_94_geo.jpg	raster	
Aerial Photos	2002	image_96_geo.jpg	raster	
Aerial Photos	2002	image_98_geo.jpg	raster	

Table 5 Summary of data submitted by the APAL

UNEP/GRID-Geneva

Aerial Imaging 1939

Title: Aerial Imaging 1939
Summary: Aerial photographs from 1939 of an effective resolution of about 1 meter for almost the entire archipelago of Kerkennah (Figure 21). The images were prepared by Ifremer and financed by UNEP / GRID-Geneva. They are distributed under open license http://wiki.data.gouv.fr/wiki/Licence_Ouverte_/_Open_Licence and soon will be available to the public at http://sextant.ifremer.fr/fr/

Coordinate System: Carthage / UTM zone 32N (epsg: 22332)

Reference date: 1939

Designer: Bruno Chatenoux (UNEP / GRID-Geneva) bruno.chatenoux@unepgrid.ch

Status: The timing of these images is not precise enough to estimate the movement of visible objects over time.

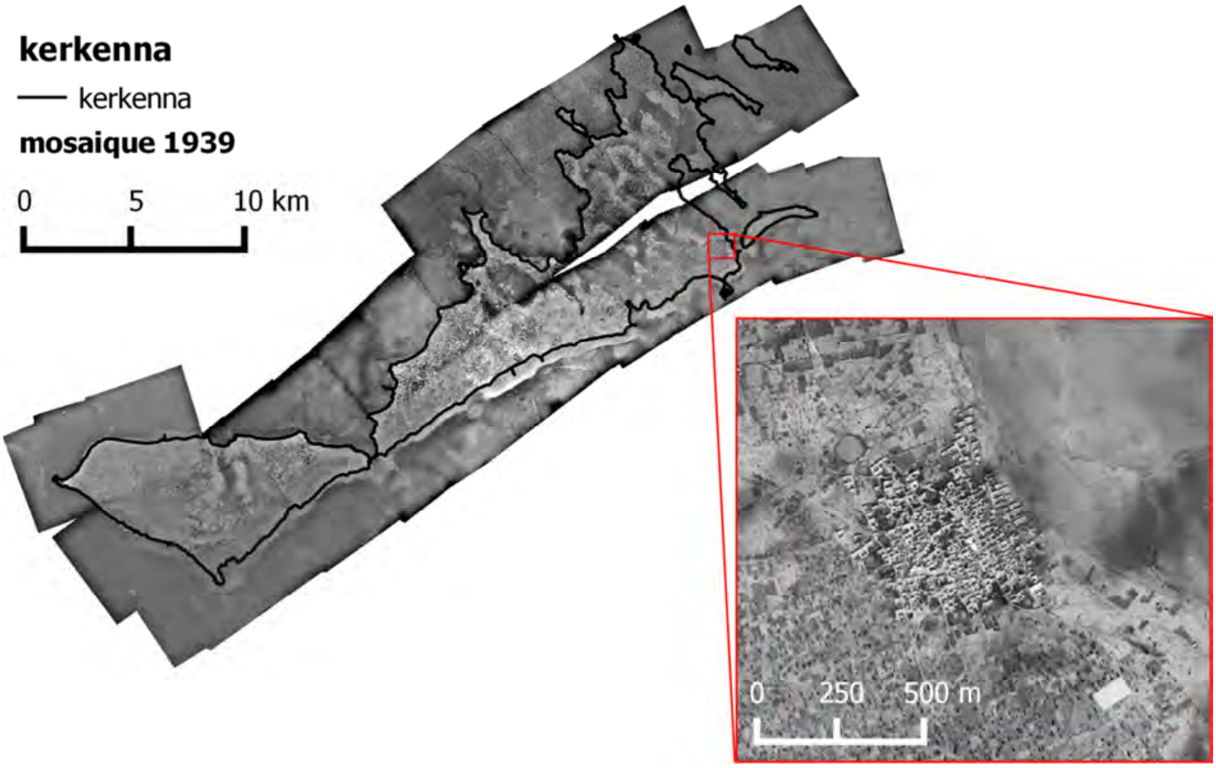

Figure 29 Mosaic of aerial imagery coverage of 1939 (supplier: IFREMER)

Buildings 2012-2014

Title: Influence of buildings on the Kerkennah Archipelago (2012-2014).

Summary: Influence of buildings on the Kerkennah archipelago mapped using oriented classification functions (segmentation) object of free software Spring http://www.dpi.inpe.br/spring/francais/index.html on satellite images Quickbird and WorldView 2 taken between 14 June 2012 and May 4th 2014. The coverage of unhedged areas by satellite images were digitized manually using Google Earth and Bing Map images.

Coordinate System: Carthage / UTM zone 32N (epsg: 22332)

Reference date: June 14, 2012 and May 4, 2014

Attributes:

Cat: unique identifier used during the preparation the data.

Creator: Bruno Chatenoux (UNEP / GRID-Geneva) bruno.chatenoux@unepgrid.ch

Status: Data not validated 22503546 24,069,930

In order to distribute the population of the archipelago of Kerkennah and due to the lack of detailed census data as well as the high seasonal variations in terms of residents and visitors (14,400 and 200,000, respectively), the building coverage was mapped using the panchromatic band providing high resolution satellite images by using the object classification capabilities of free software Spring (http://www.dpi.inpe.br/spring/francais/index.html).

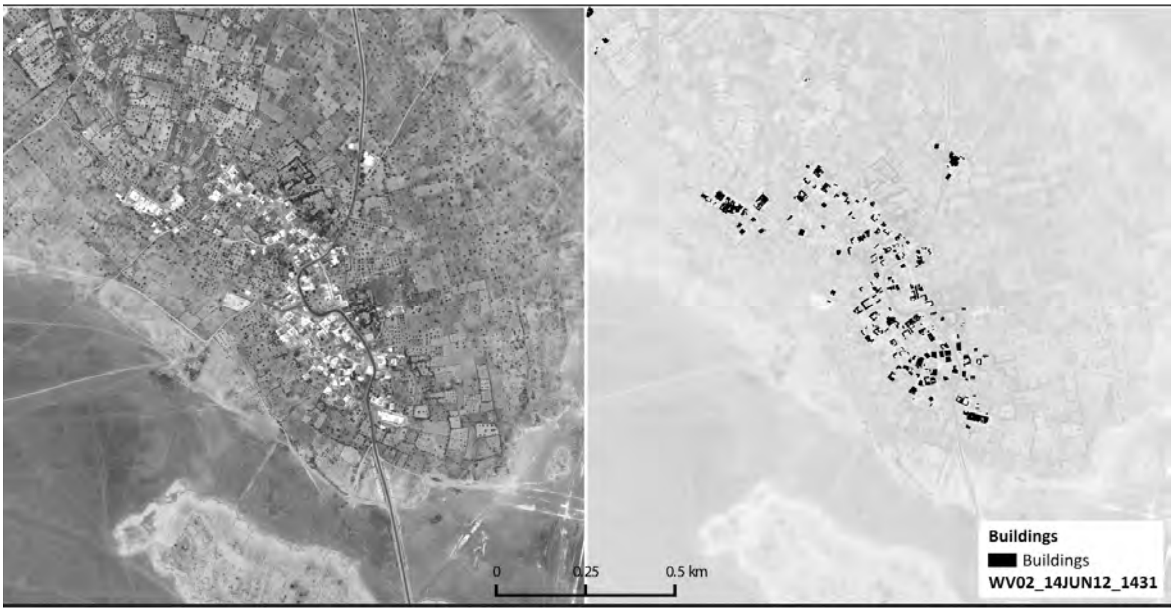

Figure 30 Extraction of buildings in the village of Echargui

Percentage of buildings 2012-2014

Title: Virtual Grid 250 meter resolution representing the percentage of the influence of buildings on the Kerkennah Archipelago (2012-2014).

Summary: Virtual Grid 250 meter resolution representing the percentage of the influence of buildings on the Kerkennah Archipelago (2012-2014).

Coordinate System: Carthage / UTM zone 32N (epsg: 22332)

Reference date: June 14, 2012 and May 4, 2014

Attributes:

ID: A unique identifier for each cell of the virtual grid.

Build_area: Sum of the building surface (in square meters) for each cell of the virtual grid

pc Build Surface Percentage built by cell (= build_area / sum (build_area of the archipelago) * 100

Designer: Bruno Chatenoux (UNEP / GRID-Geneva) bruno.chatenoux@unepgrid.ch

Status: Data not validated

Starting from the layer of the above buildings, the surface percentage with respect to the total built-up surface of the archipelago (1'458'866 m²) was calculated for each cell of a virtual grid of 250 meter resolution.

Figure 31 shows a zoom on the village of Alataya with gray the coverage of buildings and degraded orange-red the percentage of built-up area of the archipelago contained in each cell of a virtual grid (e.g. a value of 1 means that the cell 250 m x 250 m contains 1% of the built-up area of the archipelago of Kerkennah). This layer allows a representation of the percentage of distribution of built-up areas that we can then use to distribute the population living or visiting the archipelago.

Figure 31 Zoom (village Alataya) on the distribution of the buildings on the islands of Kerkennah

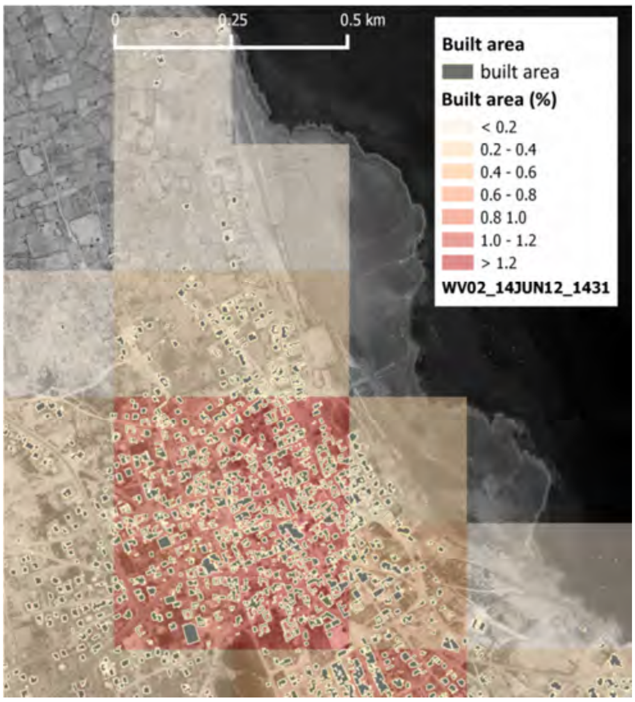

Figure 26 Zoom (Altaya village) on the buildings distribution on the islands of Kerkennah

Subaquatic vegetation in 1939

Title: Partial mapping of subaquatic vegetation (seagrass) Archipelago of Kerkennah (1939)

Summary: Partial mapping of underwater vegetation in the archipelago of Kerkennah based on aerial photographs from 1939 (Source IFREMER). The seagrass beds are composed of Posidonia Oceanica species, Cymodocea nodosa, Caulerpa prolifera, and Halmeda tuna.

List of aerial photographs used:

694_3840.tif, 694_3841.tif, 695_3840.tif, 695_3841.tif, 696_3841.tif, 696_3842.tif, 697_3841.tif, 697_3842.tif, 696_3843.tif, 696_3844.tif, 696_3845.tif, 697_3843.tif, 697_3844.tif, 697_3845.tif, 698_3844.tif, 698_3845.tif, 696_3846.tif, 696_3847.tif, 697_3846.tif, 697_3847.tif, 698_3846.tif, 698_3847.tif, 696_3848.tif, 696_3849.tif, 697_3848.tif, 697_3849.tif, 698_3848.tif, 698_3849.tif, 698_3850.tif, 699_3850.tif, 699_3851.tif, 700_3850.tif, 700_3851.tif, 699_3847.tif, 699_3848.tif, 699_3849.tif, 700_3847.tif, 700_3848.tif, 700_3849.tif, 701_3847.tif, 701_3848.tif, 701_3849.tif, 702_3847.tif, 702_3848.tif, 702_3849.tif, 700_3846.tif, 701_3846.tif, 702_3846.tif, 703_3847.tif, 703_3848.tif, 702_3852.tif, 702_3853.tif, 703_3852.tif, 703_3853.tif, 704_3853.tif, 693_3837.tif, 693_3838.tif, 694_3838.tif, 694_3839.tif, 695_3839.tif, 690_3838.tif, 691_3838.tif, 692_3837.tif, 692_3838.tif, 690_3839.tif, 691_3839.tif, 701_3850.tif, 702_3850.tif, 706_3854.tif, 706_3855.tif, 707_3854.tif, 707_3855.tif, 708_3854.tif, 708_3855.tif, 707_3856.tif, 708_3856.tif

Coordinate System: Carthage / UTM zone 32N (epsg: 22332)

Reference date: 1939 (aerial photography mosaic)

Attributes:

FID: Unique identifier of each polygon resulting from the segmentation.

Class-name: vegetation (single class because the species are indistinguishable with remote sensing)

Designer: Karin Allenbach (UNEP / GRID-Geneva) karin.allenbach@unepgrid.ch

Status: Data not validated

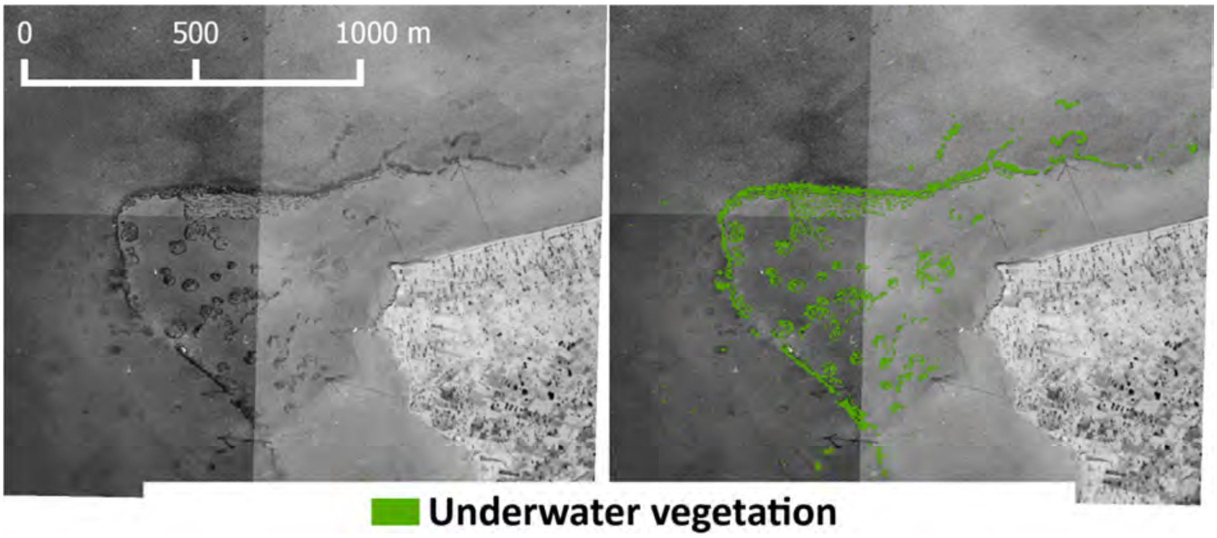

Figure 32 Example of classification of underwater vegetation through the use of aerial imagery dating from 1939 in the Sidi Fredj offshore

2013 Subaquatic vegetation

Title: Partial mapping of underwater vegetation (seagrass beds) Archipelago of Kerkennah Sidi Fredj off (2013)

Summary: Partial mapping of underwater vegetation (seagrass beds) Archipelago of Kerkennah, in the offshore of Sidi Fredj using the object-oriented classification functions (segmentation) of the proprietary software eCognition on a WorldView image 2 of 6 December 2013.

Coordinate System: Carthage / UTM zone 32N (epsg: 22332)

Reference date: December 6, 2013

Attributes:

FID: Unique identifier of each polygon resulting from the segmentation.

Class_name: vegetation (nb single class because the species are indistinguishable with remote sensing)

Designer: Karin Allenbach (UNEP / GRID-Geneva) karin.allenbach@unepgrid.ch

Status: Data not validated

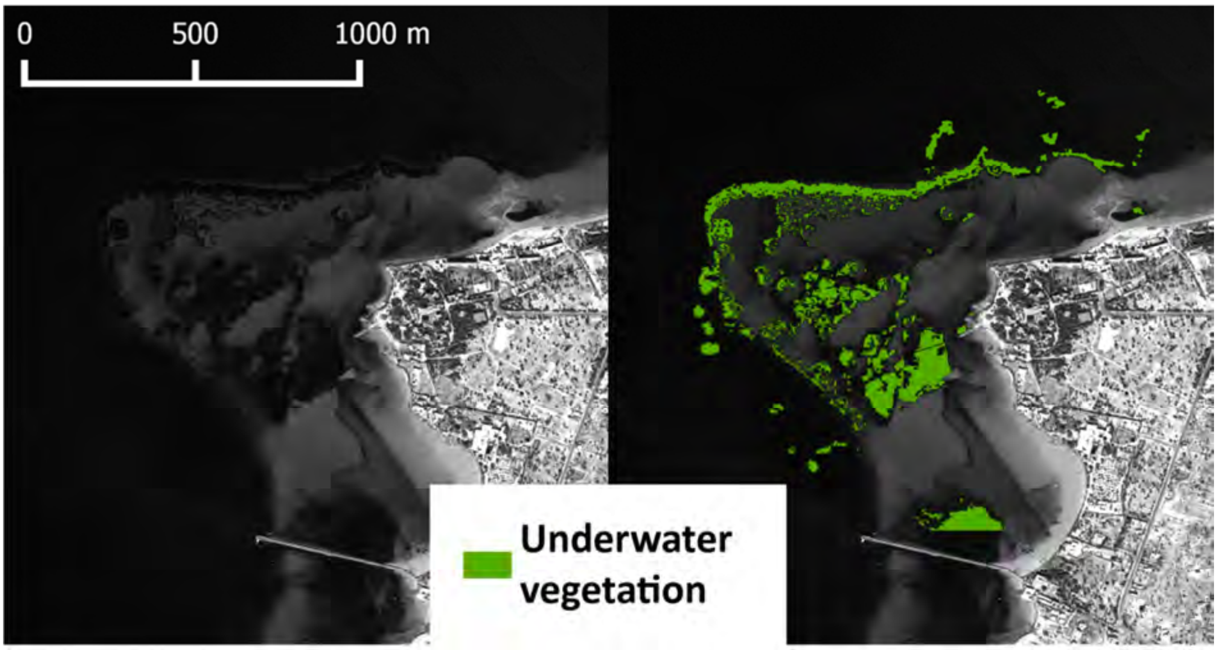

Figure 33 Example of classification of underwater vegetation using a Worldview picture dating from 2013 in the Sidi Fredj offshore

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Collection points of cherfia 1939

Title: Location of "traps" of traditional fisheries in 1939.

Summary: Location of "traps" of traditional fishery in 1939, digitized by using 1939 aerial photographs prepared by IFREMER.

Coordinate System: Carthage / UTM zone 32N (epsg: 22332)

Reference date: 1939

Designer: Bruno Chatenoux (UNEP / GRID-Geneva) bruno.chatenoux@unepgrid.ch

Status: data not validated

The location of the traps (collection points) of cherfias was digitized based on the 1939 aerial imagery provided by the IFREMER.

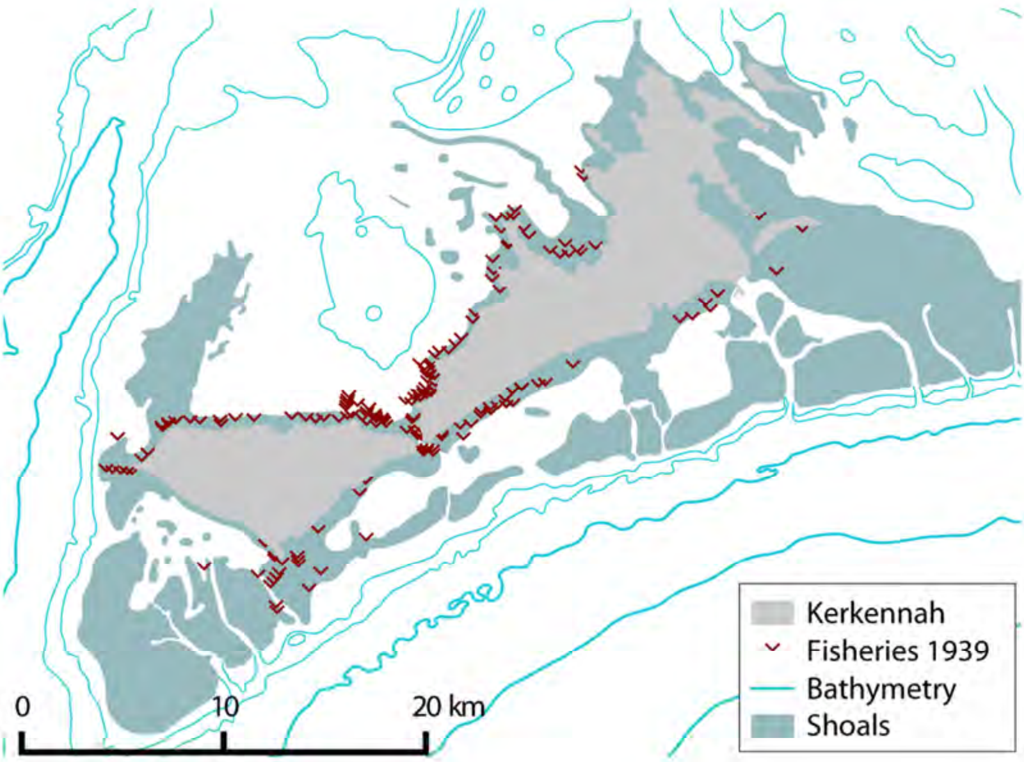


Figure 34 Location of traps of cherfias in 1939

Title: Location of "traps" of traditional fisheries between 2012 and 2014.

Summary: Location of "traps" of traditional fisheries between 2012 and 2014, digitized by using high-resolution satellite imagery:

04MAY14QB020700014MAY04092824, 04MAY14QB020700014MAY04092824, 19NOV13QB020700013NOV19092345, 19NOV13QB020700013NOV19092346, 06DEC13WV020700013DEC06101653, 06DEC13WV020700013DEC06101653, 06DEC13WV020700013DEC06101654, 06DEC13WV020700013DEC06101654, 14JUN12WV020700012JUN14101430, 14JUN12WV020700012JUN14101430, 14JUN12WV020700012JUN14101431, 14JUN12WV020700012JUN14101431

The images have been taken at different times (2012-2014), some fisheries have been displaced or disappeared and others created. This layer contains all listed traps during this period. The areas not covered by the available images were processed by using Google map images and bing map.

Coordinate System: Carthage / UTM zone 32N (epsg: 22332)

Reference date: 2012-2014

Designer: Bruno Chatenoux (UNEP / GRID-Geneva) bruno.chatenoux@unepgrid.ch

Status: data not validated

The location of the traps (collection points) of cherfias was digitized based on the latest high-resolution satellite imagery collected for this project.

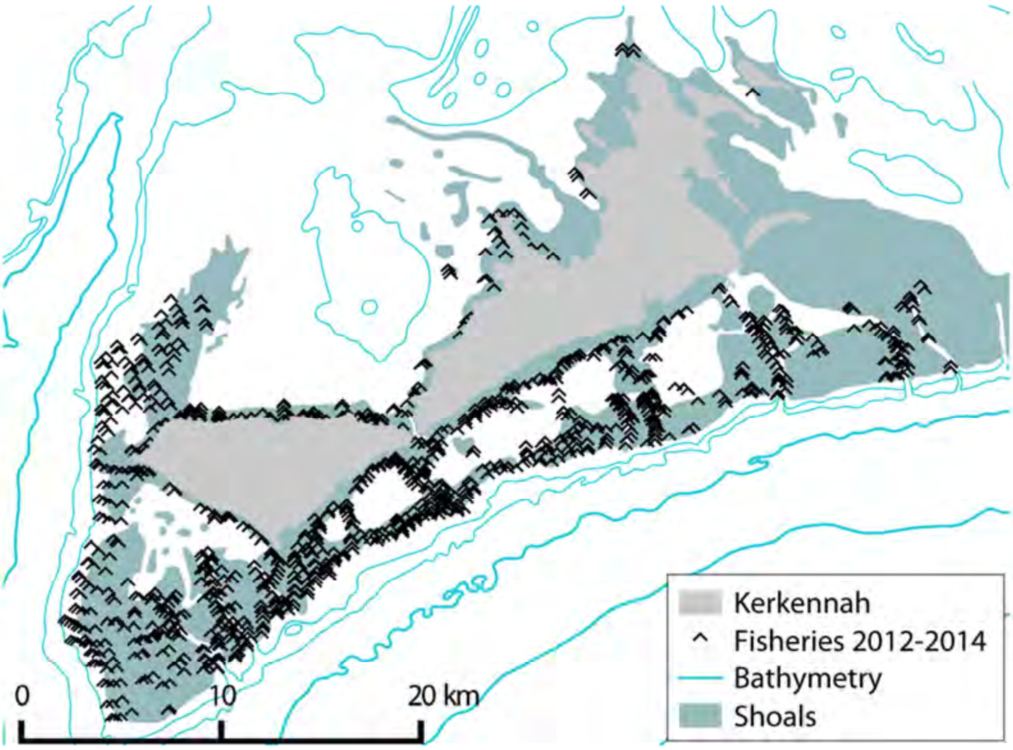
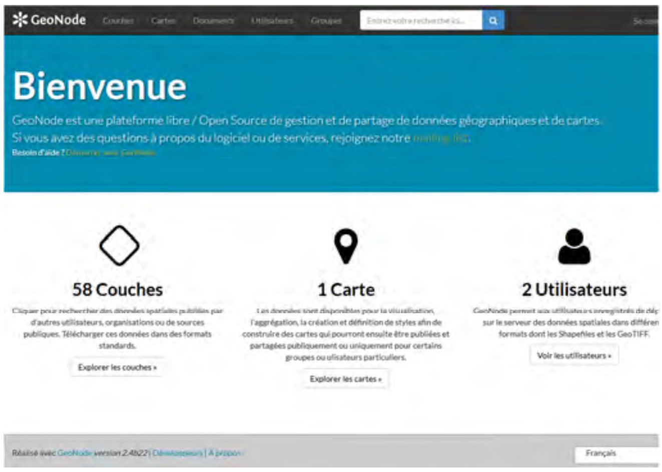


Figure 27 Location of fish traps of cherfias in 2012-2014

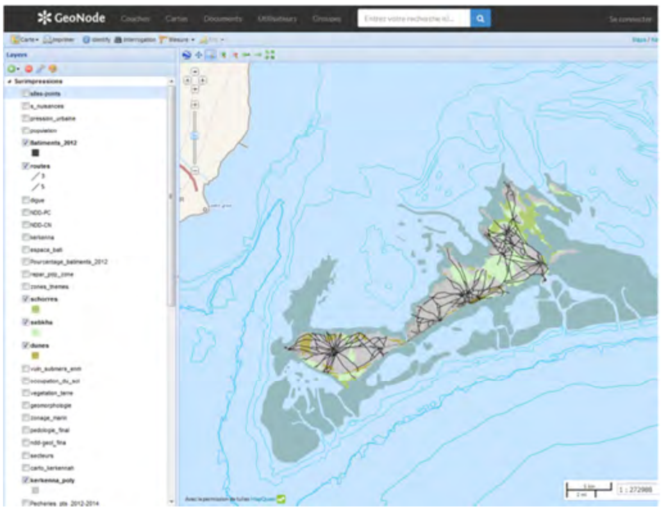
Access to the data centralized by the project

All data mentioned in the above annexes were centralized in a geographic database QGIS http://qgis.org/en/site/ provision of the APAL.

The vast majority of these data (except for aerial and satellite images) are also visible and accessible on condition via a web mapping application.http://kerkennah.grid.unep.ch/



Via this interface, users can freely view the available layers in a mapping project.



http://kerkennah.grid.unep.ch/maps/59/view

Users can also search and view each layer individually and consult its metadata (if indicated).http://kerkennah.grid.unep.ch/layers/