

الجمهورية الجزائرية الديمقراطية الشعبية

People's Democratic Republic of Algeria

وزارة التعليم العالي والبحث العلمي

Ministry of Higher Education and Scientific Research

المدرسة الوطنية العليا لعلوم البحر وتهيئة الساحل

National School of Marine Sciences and Coastal Planning



Final dissertation for the Master's degree in Marine Sciences and Coastal Management

**Specialty:** Marine and Coastal Environment Engineering

**Theme:**

**Assessment and quantification of anthropogenic pressures on  
*Posidonia oceanica* (L.) Delile 1883 meadows in the central  
Algerian coast**

Presented by:

**BOUDJADJA Rihem**

Defended on 30/06/2024 in front of the jury composed of:

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Promotion: 2023-2024

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## *DEDICATION*

*To my parents, I dedicate this final project. Your unconditional love, wisdom, and sacrifices have been the foundation upon which I have built this journey. You have always believed in me and supported me at every step, and for that, I will be eternally grateful.*

*To my siblings, thank you for your unwavering support and understanding during moments of doubt and stress. Your warm presence and constant encouragement have been an invaluable source of comfort.*

*To my close friends, your sincere friendship and moral support have been essential pillars throughout this project. Thank you for your invaluable help and encouragement, which have enabled me to overcome the challenges encountered along the way.*

*Finally, to all those who have inspired, motivated, and guided me throughout this academic experience, I express my deepest gratitude. Your influence has been instrumental in the completion of this project.*

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## **ACRONYMS LIST**

**AB:** Ain Benian

**AG:** Aguelli

**AK:** Kouali cove

**APPL:** Agence de Protection et de Promotion du Littoral de la Wilaya d'Alger

**BR:** Berard

**BSM:** Bou Ismail

**CH:** Cap El Hammouche

**CNL:** Commissariat National du Littoral

**CNRDPA:** Centre National de Recherche et de Développement de la Pêche et de l'Aquaculture

**DLS:** Dellys

**DRE:** Direction des Ressources en Eau

**EGPP:** Entreprise de Gestion des Ports de Pêche

**EQR:** Ecological Quality Ratio

**LP:** Le Port de la Madrague

**ONS:** Office National des Statistiques

**PREI:** Posidonia Rapid Easy Index

**PP:** Pointe Pescade

# ***INTRODUCTION***

# INTRODUCTION

## Introduction

The Mediterranean Sea, a semi-enclosed body of water that connects three continents, is known for its rich biodiversity, making it a critical hotspot for conservation efforts (**Boudouresque et al., 2009**). One of the main contributors to this exceptional marine diversity is the presence of *Posidonia oceanica*, a unique seagrass species endemic to the Mediterranean (**Telesca et al., 2015**).

Seagrasses are very sensitive to changes in their environment, and, specifically, to human impacts, to the point that a worldwide decline seems to be taking place (**Short and Wyllie-Echeverria, 1996**). Coastal development, pollution, overfishing, and climate change are exerting substantial pressure on the Mediterranean Sea and its fragile *Posidonia oceanica* meadows (**Montefalcone et al., 2008; Marbà et al., 2014**). Urbanization has led to habitat loss and degradation due to increased sedimentation, turbidity, and nutrient input (**Duarte, 2002**). Agricultural runoff, sewage discharge, and industrial effluents introduce harmful contaminants that adversely impact seagrass health (**Pergent-Martini et al., 2005**). Overfishing disturbs food web dynamics, indirectly affecting these meadows (**Jackson et al., 2001**). The repercussions extend beyond just the *Posidonia oceanica* meadows, threatening the entire Mediterranean marine ecosystem. Loss of these key meadows can trigger cascading impacts like biodiversity loss, food web disruptions, and loss of ecosystem services (**Coll et al., 2010**). As the Mediterranean regulates regional climate patterns and supports coastal economies, preserving its biodiversity is of global significance (**Claudet et al., 2020**).

Assessing the health and extent of *Posidonia oceanica* meadows is vital for the conservation and management of the Mediterranean marine environment, using standard methods for in situ and laboratory measurements, which allow a detailed examination of various parameters and biotic indices. *In situ* assessments enable the monitoring of key parameters such as shoot density, the lower limit depth, and the presence of associated fauna, which serve as indicators of meadow health and environmental quality (**Pergent-Martini et al., 2005**). Complementing field studies, laboratory analyses of collected samples (leaf biometry, epiphyte load, ...) can further elucidate the physiological and biochemical status of *Posidonia oceanica* meadows. Moreover, the use of biotic indices like the *Posidonia oceanica* Multivariate Index (POMI), the *Posidonia* Rapid Easy Index (PREI), and the Biotic Indices for *Posidonia oceanica* (BIPO) that integrate multiple descriptors, provides comprehensive assessments of seagrass ecosystem conditions (**Gobert et al., 2006; Lopez Y Royo et al., 2010**).

## INTRODUCTION

Apart from in situ and laboratory methods, the assessment of *Posidonia oceanica* meadows also involves data census and satellite imagery. These methods allow for large-scale monitoring, simple and cost-effective assessment of human-induced pressures on these ecosystems (**Lopez et al., 2009**).

In this context, the present study aims to define a straightforward and cost-efficient method for evaluating the impact of human activities on the *Posidonia oceanica* meadows at 9 sites along the central Algerian coast. Two complementary approaches are proposed: the first approach is a visual assessment which uses satellite images, this approach was implemented in two distinct methods. The second approach is quantitative, utilizing governmental census data in conjunction with mapping, this approach was implemented in three distinct methods to quantify the exposure of seagrass habitats to anthropogenic pressures. A total of five methods were applied. Finally, the robustness of these methods will be verified by studying their relationship with a ground truth data set represented by an Ecological Quality Ratio (EQR), previously calculated for the same study sites and based on five parameters of vitality of *Posidonia oceanica* meadows. The results of this step will serve to validate the approach that better reflect the ecological status of these meadows.

# ***LITERATURE REVIEW***

## LITERATURE REVIEW

### 1. Literature review

#### 1.1. Biological characteristics of *Posidonia oceanica*

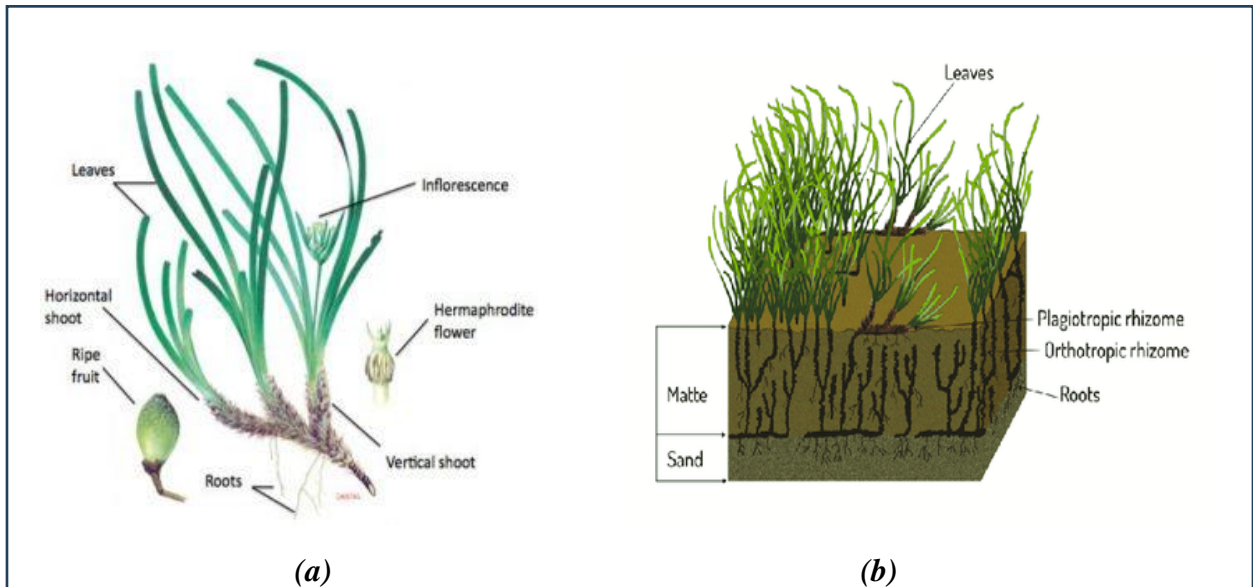
*Posidonia oceanica* (L.) Delile stands out as the predominant endemic seagrass species within the Mediterranean Sea (**Telesca et al., 2015**), it is classified within the Najadales order and the Posidoniaceae family (**Duarte, 1991**). These plants are distinguished by their capability to thrive and propagate entirely submerged in saltwater, firmly attaching themselves to the substrate (**Hartog, 1970**).

*Posidonia oceanica* exhibits a unique structure, featuring leaves, rhizomes, and a root system (Figure 1a) (**Boudouresque et al., 2016**). They expand both vertically (through orthotropic rhizomes competing for light access), and horizontally (with plagiotropic rhizomes vying for space) (**Boudouresque and Meinesz, 1982**). The rhizomes have the capacity to transit between orthotropic and plagiotropic forms, depending on the availability of space and light (**Caye, 1989**). The living and dead rhizomes and roots, with the interstices filled with sediment form a thick belowground formation commonly referred to as a "matte" (Figure 2b) (**Boudouresque and De Grissac, 1983**).

The leaves of *Posidonia oceanica* exhibit a ribbon-shaped structure, spanning from 40 to 140 cm in length and 7 to 12 mm in width (**Pergent-Martini and Le Ravallec, 2007; Semroud, 1993**). They cluster in "shoots" of approximately 4 to 8 leaves. As *Posidonia oceanica* leaves desiccate, the leaf blade disconnects and drops, leaving the base, termed the petiole, affixed to the rhizome; this segment is referred to as the "scale." These "scales" can endure for centuries within the matte, as they are resistant to decay (**Boudouresque et al., 2006**).

*Posidonia oceanica* is a clonal plant for which sexual reproduction is believed to play a modest role, compared to clonal reproduction (**Marbà et al., 1996; Hemminga and Duarte, 2000**); Flowering is an irregular phenomenon both spatially and temporally and depends on environmental parameters (**Boudouresque et al., 2006**).

## LITERATURE REVIEW



**Figure 1. (a):** part of a *Posidonia oceanica* and illustration of orthotropic and plagiotropic growths / **(b):** Structure of *Posidonia oceanica* on mat (Boudouresque and Meinesz, 1982).

### 1.2. Distribution of *Posidonia oceanica* meadows

The area covered by meadows in the Mediterranean is estimated between 2.5 and 4.5 million hectares, representing 23% of the seafloor between 0- and 50-meters depth (Pasqualini *et al.*, 1998). They inhabit the majority of European and North African coastlines, except for the area around Gibraltar, regions affected by significant rivers like the Po, Rhone, and Nile, and the southeastern coast of the Eastern Basin (Figure 2).



**Figure 2.** Geographical distribution (solid green line) of *Posidonia oceanica* in the Mediterranean Sea. R = Rhone estuary, P = Po estuary, N = Nile estuary. Using data from (Boudouresque *et al.*, 2012).

## LITERATURE REVIEW

### 1.3. Economic and ecological roles of *Posidonia oceanica* meadows

*Posidonia oceanica* meadows play an essential role in marine ecosystems, both ecologically and economically. These essential marine habitats are home to a diversity of animal species, they serve as both feeding grounds and breeding grounds (spawning and nursery areas), ( **Templado, 1984; Boudouresque et al., 2006;**).

*Posidonia oceanica* meadows generate significant primary production, comparable to that of tropical forests (**Pergent-Martini et al., 2006**). This abundance of plant matter is consumed within the meadow, but a substantial proportion (30 to 35%) is exported to other ecosystems, where it serves as the foundation of numerous food webs (**Rico-Raimondino, 1995**). The meadows are essential for the production of oxygen and organic matter. The associated leaves and epiphytic algae make a major contribution to this production, making them an important factor in the oxygenation of water and sediments in the infralittoral zone (**Boudouresque et al., 2006**). They also contribute to 12% of the carbon stored in ocean sediments and play a crucial role in regulating the global carbon cycle, (**Marbà et al., 2014**) estimates, *Posidonia oceanica* meadows in the Mediterranean basin sequester approximately 20 to 27Tg of CO<sub>2</sub> annually. Consequently, these meadows serve as natural carbon sinks, contributing to the mitigation of climate change (**Pergent et al., 2014**). If the ongoing decline of *Posidonia oceanica* meadows is not halted, their crucial role could be significantly undermined (**Marbà et al., 2014**). *Posidonia oceanica* meadows serve as a barrier against hydrodynamics, contributing for the retention of suspended particles. and enhancing water clarity. They also provide coastal defense against erosion (**Jeudy de Grissac and Boudouresque, 1985; Terrados and Duarte, 2000**). Underground mat serves to stabilize soft bottoms by functioning as a sediment trap (**Molinier and Picard, 1952**).

Taking into account all these details, *Posidonia oceanica* meadows have a significant economic value, with prices ranging from €1,965 to €2,960 per ton. Nevertheless, their deterioration can result in significant economic losses (an estimation of €58,854,676 based on the quantities harvested from 1990 to 2014 in Gabes Gulf (SE Tunisia) (**El Zrelli et al., 2020**).

In addition, *Posidonia oceanica* serves as a 'Biological Quality Element' in different monitoring programs as those mandated by the EU Water Framework Directive, offering insights into the status of coastal ecosystems (**Rigo et al., 2021**).

## LITERATURE REVIEW

### 1.4. *Posidonia oceanica*: biological status indicators

Within the Mediterranean region, the *Posidonia oceanica* meadow serves as a robust bioindicator for assessing the quality of coastal water due to its sensitivity to human impact (**Pergent-Martini et al., 1995; Pergent et al., 2005**). The presence and vitality of the *Posidonia oceanica* meadow reflect the quality of the waters. Many parameters can be recorded by the meadow ( **Pergent et al., 1995; Pergent-Martini et al., 2005; Boumaza et al., 2022**):

- Water turbidity affects the position of the lower limit of *Posidonia oceanica* meadows and the density of their shoots;
- The presence of erosive formations such as intermats within the meadow indicates the presence of currents;
- Sedimentation rates are indicated by the growth rates of rhizomes;
- Lepidochronology emerges as a valuable tool for conducting temporal pollution studies, enabling comparisons between past and present levels of specific pollutants, such as heavy metals;
- Organic pollution and eutrophication are evidenced by the presence of epiphytes on leaves and the chemical composition of the plant (nutrients, phenolic compounds,);
- The density of tannin cells, which are cells rich in phenolic acid, increases in response to a state of plant stress.

### 1.5. *Posidonia oceanica* meadows in Algeria

A lot of data about the presence of *P. oceanica* in the Algerian coasts were recorded (Table1). Whereas, our bibliographic research did not reveal a precise distribution map on these coasts. In fact, studies have been concentrated in few parts of the Algerian coasts: Tipaza and Algiers in the central coasts (**Semroud et al., 1992; Boumaza and Semroud, 1995; Lamouti, 2010**) Jijel, Bejaia, Annaba, Skikda and Ettaref in the eastern coasts (**PNG/ISMAL. (2004); Semroud et al., 2004; Derbal and Kara, 2010**) and Oran, Mostaghanem and Ain Temouchent in the western coasts. These studies (Table1), aimed to characterize the meadows throughout the morphometry of the species, the demography of the meadows, and the physiological and morphological patterns of *P.oceanica* in response to environmental changes

## LITERATURE REVIEW

**Table 1.** Examples of impacts on *Posidonia oceanica* from studies on the Algerian coast.

<b>Author</b>	<b>Zone</b>	<b>Aspect/ Parameter</b>	<b>The impact on <i>Posidonia oceanica</i></b>
<b>(Saliha <i>et al.</i>, 2015)</b>	Waters of the Gulf of Annaba	The measurement of some element's metallic traces in the marine phanerogam <i>Posidonia oceanica</i> using atomic absorption spectrophotometer	Contamination of <i>Posidonia oceanica</i> with heavy metals in the Gulf of Annaba impairs its health and affects the entire marine ecosystem, highlighting the need for consistent pollution management.
<b>(Hamimeche, 2015)</b>	Jijel	A biometric and phenological characterization	<i>Posidonia oceanica</i> seagrass meadows in the Taza Marine Protected Area are thriving, serving as crucial biodiversity reservoirs.
<b>(Sengouga, <i>et al.</i>, 2019)</b>	Algiers, Tipaza	Application of a multimetric index	<i>Posidonia oceanica</i> meadows along the central Algerian coast show resilience to anthropogenic pressures, maintaining mostly good ecological status from 2011 to 2018, with only localized impacts observed at some sites.

## LITERATURE REVIEW

<p style="text-align: center;"><b>(Zeghdoudi <i>et al.</i>, 2019)</b></p>	<p style="text-align: center;">Skikda Gulf</p>	<p style="text-align: center;">The distribution of trace metals</p>	<p>The distribution of trace metals in sediment and plant showed a significant spatiotemporal fluctuation.</p> <p>The contamination of <i>P. oceanica</i> tissues reflected the contamination of the sites</p> <p>Seasonal variation was related to the physiological state of the plant.</p>
<p style="text-align: center;"><b>(Boumaza <i>et al.</i>, 2022)</b></p>	<p style="text-align: center;">Tipaza Algiers</p>	<p style="text-align: center;">Tannic cell density and leaf characteristics</p>	<p>The density of leaf tannin cells is significantly correlated with the Ecological Quality Ratio corresponding to the ecological status of <i>P. oceanica</i> meadows and reflecting the impact of environmental pressures.</p>
<p style="text-align: center;"><b>(Bentaallah <i>et al.</i>, 2023)</b></p>	<p style="text-align: center;">North-Western coast of Algeria: Chlef, Mostaghanem,</p>	<p style="text-align: center;">Leaf biometry</p>	<p>Heavy metal contamination adversely affects <i>Posidonia oceanica</i> by reducing growth and</p>

## LITERATURE REVIEW

	Oran, Ain Temouchent		photosynthesis, altering physiological processes, and damaging structural integrity, leading to the regression of seagrass meadows.
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### 1.6. Sensitivity of *Posidonia oceanica* meadows to anthropogenic pressures

*Posidonia oceanica* meadows are highly sensitive to anthropogenic pressures that can lead to physiological stress, structural alterations, and even seagrass loss, impacting the biodiversity and ecosystem functioning of these valuable marine habitats (**Christine Pergent-Martini et al., 2005b; Boudouresque et al., 2006; Bidak et al., 2021; Cantasano, 2023**). Monitoring studies have shown that anthropogenic disturbances can stress the meadows, highlighting the importance of *P. oceanica* as a biological indicator of human activities at a local scale. Overall, understanding and mitigating anthropogenic pressures are crucial for the conservation and sustainability of *P. oceanica* meadows. Across multiple sectors of the Mediterranean coast, *P. oceanica* meadows are impacted by diverse human activities:

- Coastal construction projects, including ports, artificial beaches, and groynes, threaten seagrass habitats and result in direct burial, increasing turbidity, decreasing light availability, upstream sedimentation, and downstream erosion, leading to the destruction and alteration of seagrass meadows (**Ruiz and Romero, 2003; Montefalcone et al., 2007; Holon et al., 2015**).
- Sewage and industrial/urban pollution, particularly near urban areas and sewage networks (**Duarte, 2002**), pose significant threats to marine environments.
- The discharge of brine during desalination operations, elevates seawater salinity and disruption of habitats and ecosystems in the discharge zone (**Sandoval-Gil et al., 2010**).
- Unregulated boating activities, particularly anchoring, have caused significant damage to seagrass meadows in bays with heavy shipping traffic (**Okudan et al., 2011**). The anchor type including factors like weight and design, plays critical roles in the extent of damage to *Posidonia oceanica* (**Milazzo et al., 2004**).
- Trawling is likely the most severe and concerning factor contributing to the regression of *P. oceanica* (**Boudouresque et al., 2009**), and it stands out as a primary contributor

## LITERATURE REVIEW

to the extensive degradation witnessed in *Posidonia oceanica* meadows, especially in deep-seated meadows (**Frangoudes et al., 2020**).

- Aquaculture farms contribute to pollution and eutrophication through uneaten feed and fish excretion, while also causing a significant reduction in light intensity (**Pérez et al., 2008**). Research on the impact of fish farms shows significant degradation of *Posidonia oceanica* in all the sectors studied. Generally, when fish cages have been placed over a *P. oceanica* meadow, the meadow is severely degraded or has disappeared, depending on the age of the farm (**Boudouresque et al., 2006**).
- *Posidonia oceanica* meadows adjacent to agricultural hinterland especially plastic greenhouses have been identified as hotspots for microplastic contamination (**Grego et al., 2022**). For other species, they can interfere with seagrass respiration and photosynthesis processes, potentially harming the ecosystem (**Rasyid et al., 2022**).
- Invasive and introduced species as *Caulerpa cylindracea* or *Caulerpa taxifolia* are capable of invading upon sparsely populated *Posidonia oceanica* meadows (**Deudero et al., 2011; Bernardeau-Esteller et al., 2020**). The impact of competition with *Posidonia oceanica* could lead to a reduction in density, as is the case with *Caulerpa taxifolia* (**Molenaar et al., 2009**).
- High herbivory pressure can have negative impacts on *Posidonia oceanica* meadows. The herbivory pressure can lead to reduce primary production, defoliation rates, nutrient content, and canopy structure (**Gera et al., 2013; Buñuel et al., 2023**).

***MATERIALS AND  
METHODS***

## MATERIELS AND METHODS

### 2. Materials And Methods

#### 2.1. Study area

This study was carried out along the middle coast of Algeria, specifically within the three regions (Tipaza, Algiers and, Boumerdes) where *P. oceanica* meadows are present and exposed to different levels and types of anthropogenic pressures (Figure 3).

##### 2.1.1. Tipaza Region

Tipaza region is a coastal area located 70 km west of Algiers (**Ouahchia et al., 2015**), with magnificent beaches along the Mediterranean Sea. This region has tourist and agricultural vocation.

##### 2.1.1.1. Tipaza municipality sites

Tipaza is a popular tourist destination. It has a fishing and recreational port, as well as tourist sites along the coast, such as the tourist complex (ex CET), Corne d'or, and the Roman ruins. Two sites were considered in this area: Cap El Hamouche (CH) and Kouali Cove (AK)

The first site (CH), is located in the western part of the municipality at the western extremity of Bou Ismail Bay, at the base of Mount Chenoua, part of a future marine protected area (**PNUE/PAM/PAP/CAR, 2005**). The area is characterized by agricultural activities and unregulated urbanization. Pressures on the marine environment in this region include discharges into the sea, beach sand extraction, and fishing activities that impact seagrass beds (**PNUE/PAM/CAR PAP, 2006**).

The second site (AK), is located in a beach area frequented by sea users, approximately 70 km west of Algiers (**Boumaza and Semroud, 1995**). This area is considered to be of major strategic interest for the conservation and protection of marine biodiversity ), it is only slightly affected by human activities (**Benali, 2010**), notably overcrowding on summer season . In spite of that, this location is distinguished by the existence of a barrier reef and dense meadow of *P. oceanica*, with a lower boundary reaching a depth of 20 meters (**Boumaza, 2015**). The meadow grows on hard substrate, with a high primary productivity and a good vitality making it as a reference meadow in Bou Ismail Bay (**Boumaza and Semroud, 2000; Boumaza et al., 2014; Sengouga et al., 2019**).

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### **2.1.1.2. Ain Tagourait municipality site**

Ain Tagourait is located in the north-east of the region of Tipaza, about 15 km east of Tipaza. It is a sparsely urbanized agricultural town. One site was considered in this area, which is Berrard (BR).

The meadow in this site is located near of an aquaculture farm with two aquaculture activities: mussel farm producing 50 tonnes of mussels (*Mytilus galloprovincialis*) per year and finfish farm.

### **2.1.1.3. Bou Ismail municipality site**

Bou Ismail is located on the coast, 45 km west of Algiers and 25 km east of the region capital Tipaza. It has a wealth of agricultural, tourist and manufacturing attractions. Bou Ismail stands out as the most important industrial area in the region of Tipaza. Bou Ismail's industrial activities are mainly concentrated in the sectors of metallurgy, textiles, tannery, paper, plastics, and ceramics (UNEP/PAM/CAR PAP, 2005). However, this industrial development is not without its impact on the environment. Moreover, the site is characterized by coastal defense structures which also serve as a shelter for small fishing and recreation boats. In addition, the place receives the impacts of three major discharges (CNL-Tipasa, 2015).

### **2.1.2. Algiers region**

It's the country's capital, a lively, modern city on the Mediterranean coast. The region of Algiers is the most populous in Algeria, with 4 090 (Hab/Km<sup>2</sup>) (Wilaya of Algiers, 2020). It is also the smallest, with a surface area of 809,22 km<sup>2</sup> (Direction Générale des Forêts, 2019).

#### **2.1.2.1. Ain Benian municipality sites**

Aïn Benian is located 16 km from the capital and is one of the most important maritime towns in the Algerian suburbs. The area is characterized by the presence of a fishing and pleasure port, an artificial beach, frequented by summer visitors, and very marked urbanization on the coastline with a very important touristic activity. Two stations were studied in this municipality: La Madrague (LP), it's also known as El Djamilia in the eastern edge of Bou Ismail Bay, in the small cove of El Djamilia, and Aïn Benain (AB) to the east of Ras Acrata, in an exposed sector.

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### **2.1.2.2.Rais Hamidou municipality site**

Rais Hamidou is a coastal town with fishing and recreational port. The selected site in this area is called Pointe Pescade (PP) and is located 600 m from the Rais Hamidou port. The urbanization in this region is concentrated on the coastal fringe. The volume of wastewater discharged into the sea is 4,700 m<sup>3</sup> per day (**MRE/DEAH/ CTB/2012**). There's also a cement plant that contaminates water resources by discharging pollutants (**Origines, 2022**).

### **2.1.2.3.Reghaia municipality site**

Located in the eastern part of Algiers, the region is characterized by an important industrial zone and heavy urbanization. It also boasts a lake that functions as a wetland, This wetland has always been subject to a number of risks, such as pollution, which threaten its terrestrial and aquatic habitats (**Djitli, 2021**). The site is near the Agueli Iselt (AG).

The islet Agueli (AG), also known as Hadjret Bounatah, located 1 km from Réghaïa beach, provides shelter for dominant species (**Ouarab et al., 2021**).

### **2.1.3. Boumerdes region**

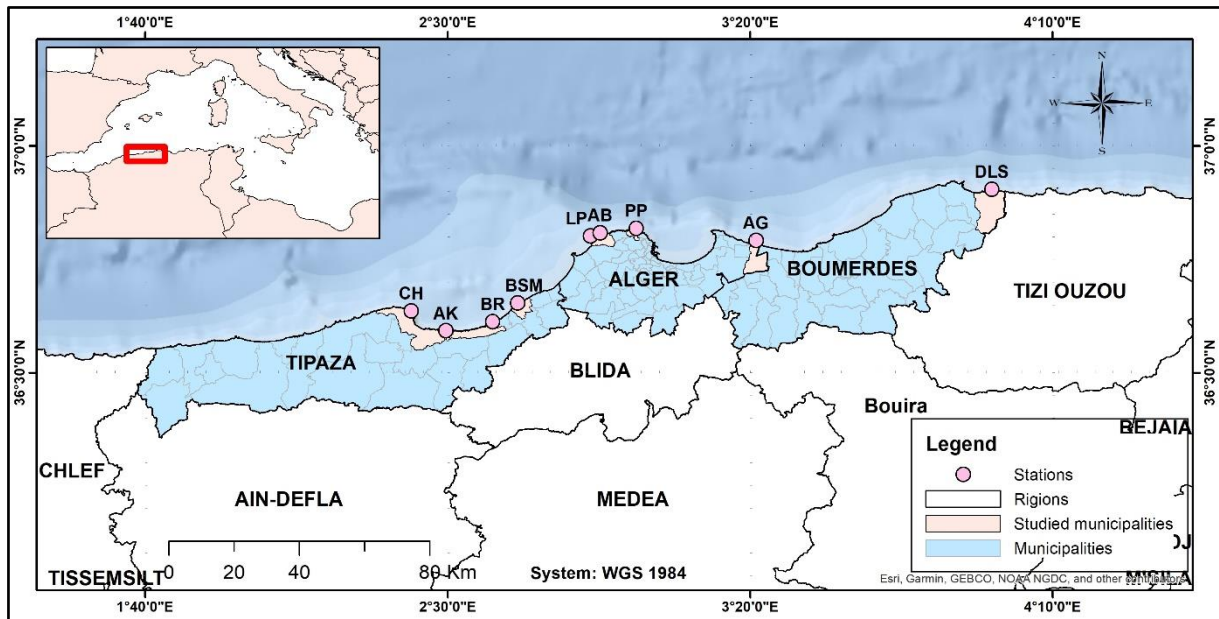
Boumerdes is located at the east of Algiers and offers a natural and a cultural heritage. It is characterized by agricultural, fishing, industry and, touristic activity.

#### **2.1.3.1.Afir municipality site**

It's one of the least populated municipalities of Boumardes (**ONS, 2008**), characterized with agricultural activities and natural landscape.

It is close to the touristic town of Dellys, which has a fishing and pleasure port sheltered by a natural bay that can accommodate about 100 boats. One site was considered (DLS) and is located 500 m from oued Brika.

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**Figure 3.** Localization of studied municipalities and stations.

### 2.2. Anthropogenic pressure assessment

Several approaches were used to assess anthropogenic pressure on *Posidonia oceanica* meadows. First, a qualitative remote sensing method was used to visually assess the potential anthropogenic impact of human activities at different meadow sites. Concurrently, quantitative approaches based on both remote sensing and data census were used to quantify the exposure to various anthropogenic pressures.

For all approaches we used data from around the year 2018 (where available) since the ground truth data of the studied meadows were carried out in 2018 by **Sengouga et al (2019)**. The results of this study will serve to validate the approach that better reflect the ecological status of these meadows.

#### 2.2.1. Anthropogenic pressure assessment using satellite imagery

Anthropogenic pressures are evaluated at different geographic scales using satellite imagery from Google Earth (Ver. 7.3.6.9796) (2018):

A 25km x 25km square study area is delineated around each seagrass meadow station, with the site in the center (Figure 4). Five types of potential coastal pressures are considered: land use, industries, ports, rivers, and artificial structures other than urban areas. These pressures, indicative of urbanization, industrial activities, fishing, maritime transportation, and tourism, can impact the coastal environment.

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For each pressure type, a four-level classification (high, moderate, low, none) is established based on the distance to the site (industries, ports, rivers, and artificial structures) or the percentage of occupation (land use) (Table.2). For ports, the type (industrial, commercial, leisure, fishing) is also noted. If an industrial port is within 10km, it is classified as high pressure. An industrial port more than 10km away or a commercial port within 10km is moderate. A commercial port more than 10km away or a leisure port within 10km is classified as low pressure. In the absence of a port, it is none. When multiple pressures of the same type coexist, the one closest to the station determines the classification. For coastal artificial structures within a 10km radius, they are classified as moderate if present, none if absent.

Land use is an important parameter to assess the anthropogenic pressure in a coastal area, it reflects the urban areas, agricultural lands, forests, and infrastructures. To assess the land use impact, three broad categories are delineated: urban, agricultural, and natural areas. This classification is performed by analyzing the landscape composition using two different methods to verify the best method to assess land use:

- (i) using a 10 km side grid, subdivided into 500 m x 500 m squares (Figure 5). The percentage of land use is calculated on the basis of the number of 0.25 km<sup>2</sup> squares attributed to the type of land use.
- (ii) using a 10km x 10km square with the site in the center, where we considered all the area within that square.

Satellite images with a very high spatial resolution, captured on November 19, 2018, were obtained from Google Earth Pro. The images were projected in the WGS 1984 UTM zone 31N coordinate system. In order to ensure the accurate representation of the spatial data, it was necessary to apply georeferencing to these images in ArcGIS (version 10.4.1). Subsequently, three vector layers were created in shapefile format: urban, agricultural, and natural.

The "Buffer" tool from the ArcGIS toolbox was employed to generate the 10 km x 10 km squares situated around the stations. The identical methodology was utilized to create the 25 km squares. In order to utilize these squares on Google Earth Pro for distance measurements, the squares in shapefile format were converted to KML format (Arc toolbox > Conversion tools > To KML > Layer to KML). The three types of land cover (i.e., urban, agricultural, and natural) were digitalized for land use analysis using the "Editor" tool.

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In the first method (§ 2.2.1.i) a 10 km side grid was applied to the image, subdivided into 500 m x 500 m squares, using the "Create Fishnet" tool from Arctoolbox. This was done by overlaying it directly on the digitalized area within the 10 km squares. In the second method (§ 2.2.1.ii), all the area within this square was considered. The predominant land use type is evaluated in each 0.25 km<sup>2</sup> square along the coastline. The number of squares attributed to the type of land use were then calculated. The percentage of occupation type is determined by the number of squares allocated to each type (urban, agricultural and natural). The percentage of the different types of land use is used to classify this type of pressure: high, moderate, low or no pressure (Figure 8).

The five elements presented in Table 2 are used to assess the total pressure exerted on each of the stations. These different factors allow estimating the overall human pressures that apply to the areas surrounding the study stations.

Then we have considered all the pressure classes assigned to each site in order to characterize each one of them as having high, moderate, low or none pressure (Table3).

For a later correlation with the ground truth data, we need to convert the type of pressure into a numerical value, the value of 3 is attributed for high pressure, 2 for moderate, 1 for low, and 0 for none, (Table 4). Then we calculated a quotation for each site by considering the average of the scores obtained for each of the pressures. Finally, we adopted the approach suggested by **Garcia Marin (2013)** to interpret each quotation.

**Table 2.** Classification of the 5 types of pressure considered (land use, river, industry, ports and artificial structure) (**Lopez Y Royo et al. 2009**).

Type of pressure	High (3)	Moderate (2)	Low (1)	None (0)
Land use (% coastline)	Urban: >90%	Natural: <50%; Urban +agricultural: >50%	Urban + agricultural: 50%; or only agricultural: <90%	Natural: >90%
River (distance from site)	n/a	<10Km (in the same bay)	>10 km	None
Industry (distance from site)	<10Km	Industry: >10 km	n/a	None
Ports (type and distance from site)	Industrial: <10 km	Industrial: >10 km and/or commercial: <10 km	Commercial: >10 km; recreational: <10 km	None
Artificial structures	n/a	Yes	n/a	None

n/a: no answer.

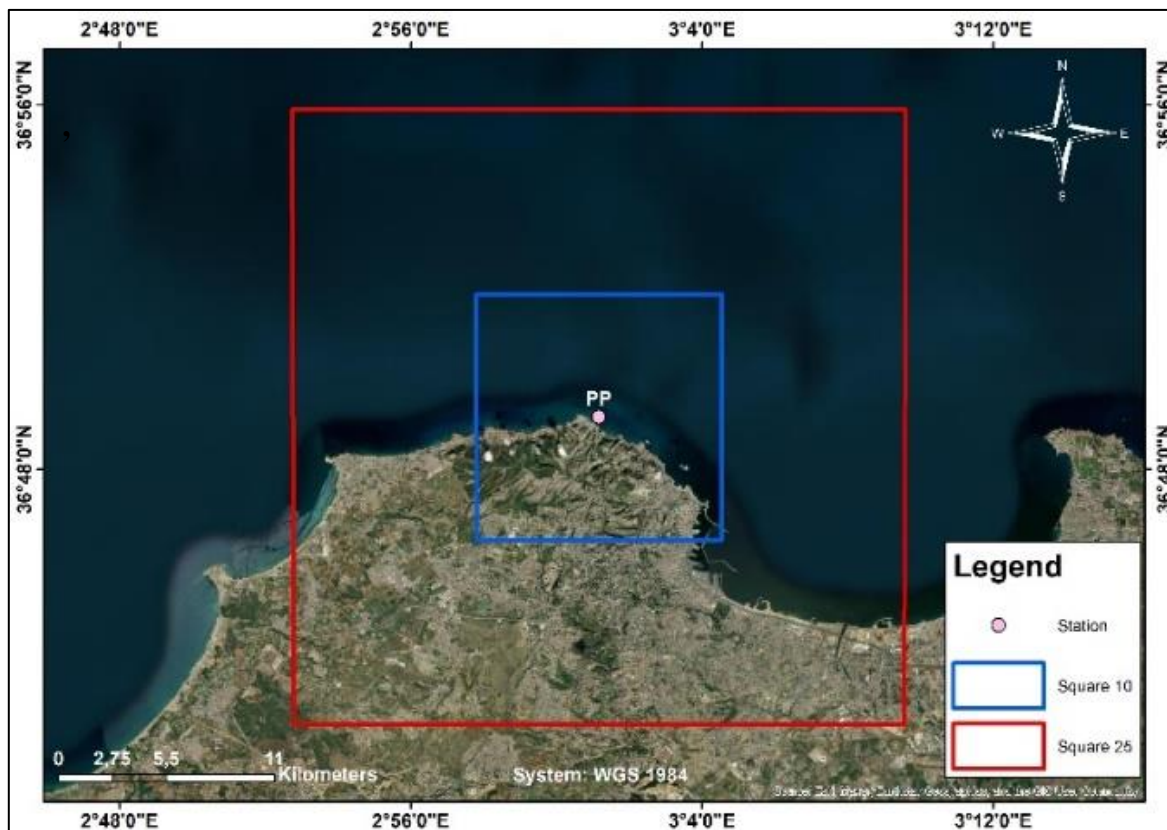
## MATERIELS AND METHODS

**Table 3:** Integration of the five pressure elements classified (classified pressure is relative to the classification of each of the types of pressure in Table 2).

Pressure	Classified pressure
High	At least one High
Moderate	At least 2 Moderate
Low	At least 2 Low

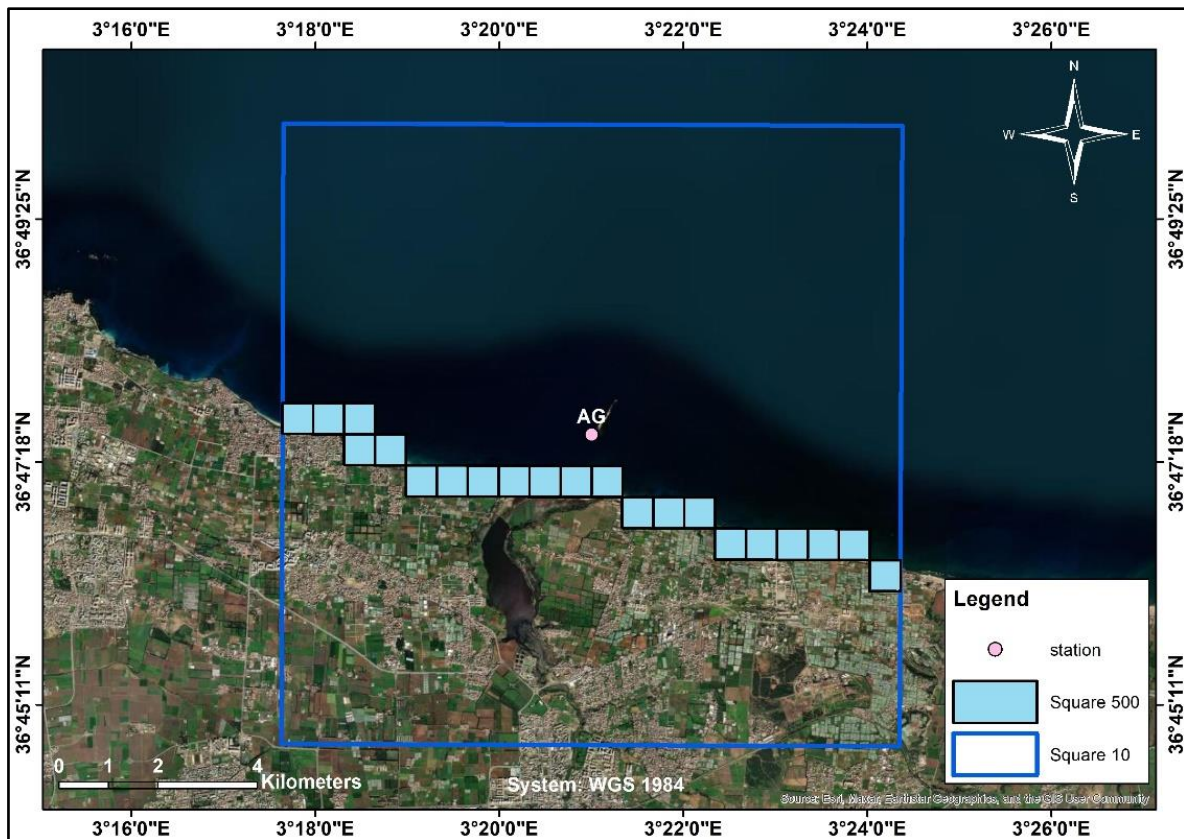
**Table 4:** Interval limits in the assessment of pressure according to Garcia Marin (2013).

Quotation	Categories
2-3	High
1-2	Moderate
0-1	Low



**Figure 4.** Example of the positioning of the 25km and 10km squares.

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**Figure 5.** Example of 10Km side grid subdivided into 500m X 500m squares along the coastline.

### 2.2.2. Anthropogenic pressures assessment supplemented by data census

#### 2.2.2.1. Using the method described by Hu *et al.* (2021) and adjusted

It's a quantitative approach based on data census to assess anthropogenic pressures on seagrass where the human pressure intensity was quantified. This approach was proposed to rapidly estimate the magnitude of quantified pressures. The area considered here is always within the 25Km x 25Km square, and the intensity of human pressure has been quantified considering data collected from different sources.

The pressures included surface urbanization, distance from industry, demography (residents), fishing activity represented by the total number of vessels for each port, aquaculture activity represented by the annual production of the fish farms, the number of wastewater discharge points and the presence or absence of the introduced specie (*Caulerpa cylindracea*). This approach has been applied in two ways on the basis of two urbanization estimation methods:

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- (i) The percentage of urbanization only in the 10km square area.
- (ii) The percentage of urbanization considering the entire municipal area.

The estimation of the urbanization was carried out using satellite imagery from Google Earth pro as described above (§2.2.1).

- Step 1: data collection

Bibliographic research was conducted using governmental websites, Google Scholar, Google Earth pro, Science Direct and Springer Link, ... In addition, we checked several lists of all studies retrieved to identify all relevant primary researches published in other peer reviewed journals, books, reports, and proceedings of international conferences to find numerical values of studied pressures (for 2018).

We also visited various administrative bodies and ministries to request missing data, such as: the Ministry of Fisheries, the Ministry of the Environment, the National Statistics Office, the Water Resources Ministry and its local Directorates and the National Water Resources Agency.

- Step2: Integrated exposure index calculation

An integrated exposure index was calculated to estimate the total exposure to facilitate calculation and comparison.

Firstly, the collected and the measured pressure values were standardized as follows:

$$Z_j = \frac{\max(x) - x_j}{\max(x) - \min(x)} \quad (1)$$

Where:  $Z_j$ : is the standardized value of pressure j

$X_j$ : is the original value of pressure j

$\max(x)$ : is the maximum value of pressure within the study area,

$\min(x)$ : is the minimum value of pressure within the study area.

Only for the distance from industry, we inversed the maximum and the minimum values for the standardization.

Then, the integrated exposure index was calculated as follows:

$$E = \sum_{i=1}^n W_i \times Z_i \quad (2)$$

## MATERIELS AND METHODS

where:

E: is the integrated exposure index,

$Z_i$ : is the value of pressure i,

$W_i$ : is the weight of pressure

i: and n: represents the number of pressures.

Based on a literature review (Maggi, 1972; 1973; Maggi *et al.*, 1977; Picard 1978; Peirano et Bianchi.,1997; Montefalcone *et al* 2007; McDonnell *et al.*, 2009), we attributed a higher weight to urban and demographic pressures, as they have a greater impact on the meadow (Table5):

**Table 5.** The weight of each pressure type.

Pressure	Weight
Urbanization	0.22
Demography	0.22
Fishing activity	0.11
Distance from industry	0.11
Annual production of fish farms	0.11
The number of wastewater discharge points	0.11
The presence or not of <i>Caulerpa cylindracea</i>	0.11

### 2.2.2.2.Using the method described by Larid (2002) and adjusted

As the Hu method, this approach is based on data census, it aims to provide an overview of the current situation in the coastal area, where a series of parameters (Pn) were chosen to qualify the overall condition of the study sites. The first step is to create a matrix with the parameters (Pn) in the rows (urbanized area per municipality (%), fishing activity, distance from industry, the presence or not of *Caulerpa cylindracea*, percentage of municipality demographics in relation to the wilaya population) and the quotations (Cn) in the columns, varying from 1 to 5 (Table 6).

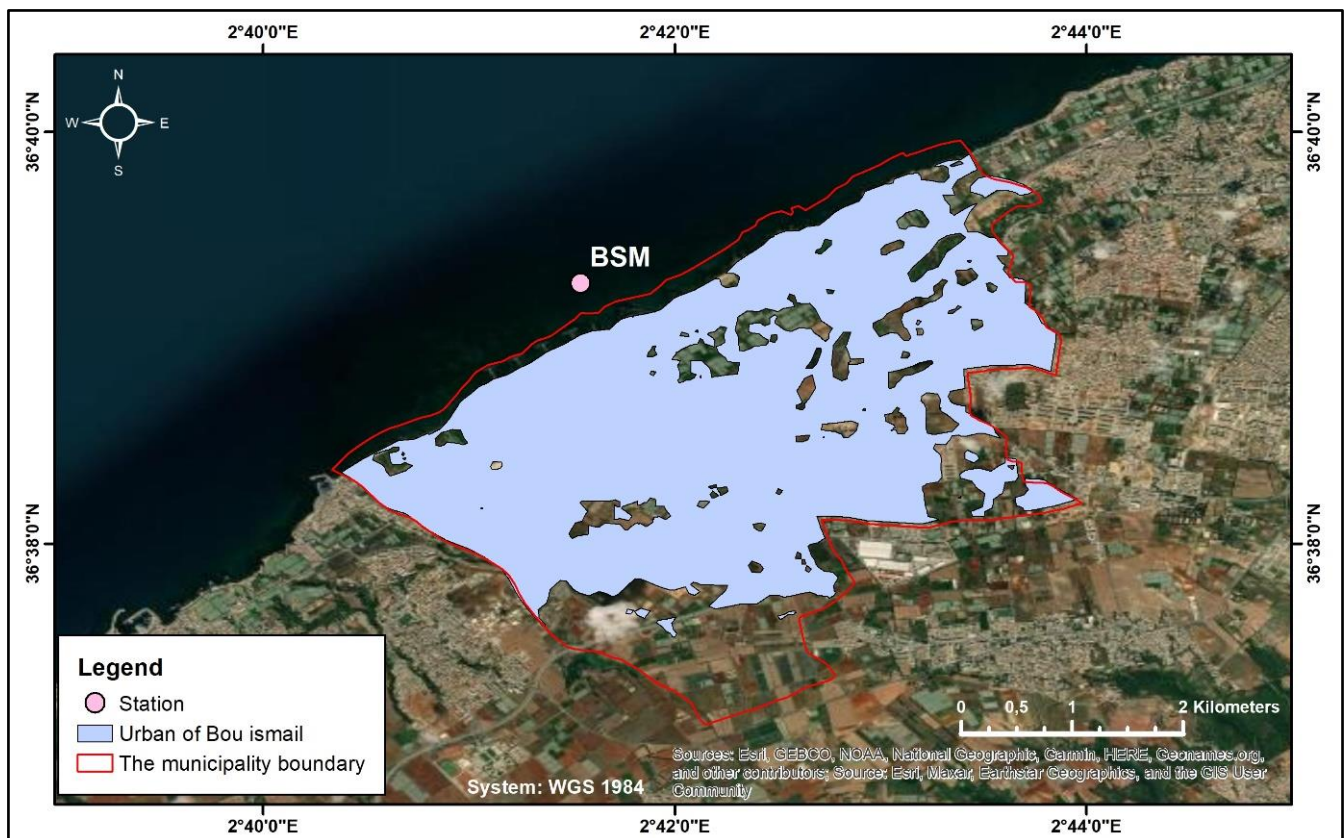
Based on this matrix, we determine the overall assessment (Ck) for each site:

$$Ck = \frac{\sum_1^N Cn}{5 \cdot \sum_1^N Pn} \quad (3)$$

## MATERIELS AND METHODS

**Table 6.** Parameters quotations matrix according to **Larid (2002)**.

Parameters	Quotations				
	1	2	3	4	5
Urbanized area per municipality (%)	<5	5- 28,75	28,76-52,51	52,52-76,27	76,28-100
Fishing activity (number)	0-68	69-137	138-206	207-275	277-340
Distance from industry (km)	9,69-12,05	7,27-9,68	4,84-7,26	2,42-4,83	0-2,41
The presence or not of <i>Caulerpa cylindracea</i>	No		Yes		
Percentage of municipality demographics in relation to the wilaya population	<5	5- 28,75	28,76-52,51	52,52-76,27	76,28-100
$\Sigma$ quotations	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>5</sub>	C <sub>5</sub>



**Figure 6.** Example of the digitalization of the urbanization (Bou Ismail municipality).

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To illustrate and summarize all the methods used, the Figure 7 and Table 7 provide a comprehensive overview and comparison of the various methodologies employed and parameters considered in this study.

### **2.3. Statistical analysis**

To assess the reliability of all studied methods, the results were compared to a truth data ground study conducted at the same studies sites by **Sengouga *et al* (2019)**. Pearson's coefficient was computed at the 95% and 90 % significance levels, between the indexes of the anthropogenic pressures and the EQR values relative to the Posidonia Rapid and Easy Index (PREI).

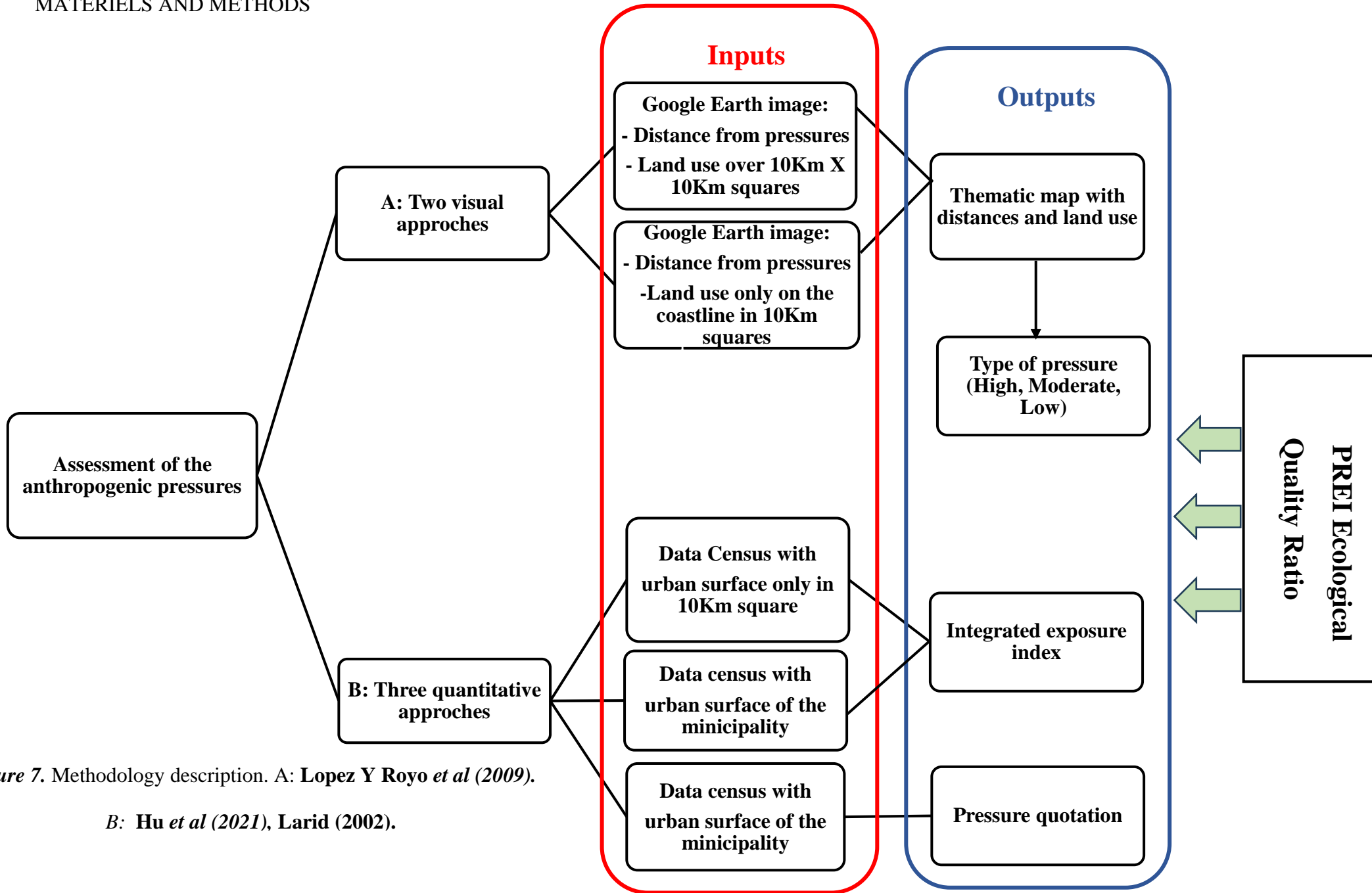


Figure 7. Methodology description. A: Lopez Y Royo et al (2009).

B: Hu et al (2021), Larid (2002).

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**Table 7.** Parameters used for each approach: **Lopez Y Royo et al (2009), Hu et al (2021), Larid (2002)** (adjusted).

Pressure		Type/Zone	Source	Methods				
				Visual approach		Quantitative approach		
				Lopez Y Royo et al (2009)	Lopez Y Royo et al (2009) adjusted	Hu et al (2021) adjusted1	Hu et al (2021) adjusted2	Larid (2002) adjusted
Land use (%)	Urban	The 9 sites or the 8 municipalities	Digitalization	X	X		X	X
	Natural							
	Agricultural							
The urban surface (Km <sup>2</sup> )						X		
Distance from rivers (Km)		Nador, Mazafron, Beni Messous, EL Harrach, the mouth of Reghaia's lake	Mapping	X	X			
Distance from Industry (Km)		Hadjout, Bou ismail, Ain Benian, Rais Hamidou, Reghaia	Mapping+ Ministry of industry	X	X	X	X	X
Distance from Ports (Km)	Commercial	Algiers	Mapping + EGPP	X	X			
	Fishing	Tipaza, Bouharoun, Khemisti, El Djamila, Algiers, Tamentfoust, Dellys						
Fishing activity						X	X	X
Distance from artificial structures		Ain Tagourait, Bou Ismail, Ain Benian, Reghaia	Mapping	X	X			
Introduced specie ( <i>Caulerpa cylindracea</i> ).		Tipaza, Ain Benian, Rais Hamidou, Reghaia	Sengouga A. comm. pers			X	X	X
Fishing farms production (ton/year)		Ain Tagourait	CNRDPA			X	X	X
Wastewater discharge points		9sites	CNL+APPL+DRE Boumerdes			X	X	
Demography (residents)		9sites	ONS 2008			X	X	X

***RESULTS AND  
DISCUSSION***

## RESULTS AND DISCUSSION

### 3. Results and Discussion

#### 3.1. Anthropogenic pressures assessment using satellite imagery

In order to assess the anthropogenic pressures at each studied site, the method suggested by **Lopez Y Royo *et al.* (2009)** was applied and interpreted according to **Garcia Marin (2013)**. We applied two variants for land use estimation:

##### 3.1.1. Lopez Y Royo *et al.* (2009): Land use only in the coastline (0.25km<sup>2</sup>)

The results obtained from this approach reveal that (03) sites are faced to low pressure while the other sites are subject to moderate anthropogenic pressures.

The sites (CH), (AK) and (DLS) are under a low pressure, due to low urbanization over the coastline, the natural aspect is most common in (CH) and agriculture is common in (AK) and (DLS).

The sites (LP), (AB) and (PP) are under moderate pressure due to heavy urbanization along the coastline.

Sites (BR) and (BSM) are under moderate pressure due to the agriculture along the coastline.

##### 3.1.2. Lopez Y Royo *et al.* (2009) and, adjusted in this study: land use over the 10km

The results obtained from this approach reveal that (02) sites (CH and DLS) are faced with low pressure and the other sites are subject to moderate anthropogenic pressures.

The site (CH) is classified as low pressure. The land use is essentially natural, Oued Nador is less than 10 km away and the Hadjout industrial zone is more than 10 km away, which is considered moderate pressure. The fishing port of Tipaza exerts little pressure.

The site (DLS) is under low pressure, despite the proximity of the Oued Brika and the Dellys fishing port, which exert little pressure on the station. Land use is mainly agricultural, there is no industrial zone and no artificial structures on the site.

The site (AK) is under moderate pressure according to the **Lopez Y Royo *et al.* (2009)** classification. The land use is mainly agricultural. As the site (CH) Oued Nador is less than 10km away and the industrial zone Hadjout is more than 10km away, this is considered as moderate pressure. The fishing port of Tipaza exerts low pressure.

## RESULTS AND DISCUSSION

The site (Br) is under moderate pressure. The fishing port of Bouharoun, 3.23km away, has little impact. Agricultural land use also exerts moderate pressure. This site is also affected by the industrial activity of the town of Bou Ismail, 8.77km away. It also faces moderate pressure from artificial structures (a pier, 3.93km away).

Despite the presence of the industrial zone in the town of Bou Ismail, the site (BSM) faces only moderate pressures. It also faces moderate pressure from artificial structures (beach protection works), urban and agricultural land use. The fishing port of Khemisti has a low impact on this site. As for the Oued Mazafran, it exerts a moderate pressure on the site.

The two sites (LP) and (AB) are under moderate pressure from heavy urbanization. They are also under moderate pressure due to their proximity to the Oued Beni Messous, the presence of an industrial zone and the artificial beach at Aïn Benian. The fishing port of El Djamila exerts a low pressure on the sites.

The site (PP) is under moderate pressure due to its proximity to the Raïs Hamidou cement factory. It is also moderately affected by urbanization, its proximity to the commercial port of Algiers and the presence of artificial structures: the El Kettani beach protection structures in Bab El Oued. On the other hand, the Oued El Harrach and the Raïs Hamidou fishing shelter exert a low pressure on the station.

The site (AG) is under moderate pressure, mainly from the Rouiba-Réghaïa industrial zone. It is also subject to moderate pressures caused by: the proximity of the Réghaïa lake mouth, the artificial structures of Aïn Taya coast and the agricultural occupation of the land.

For both variants (according to land use estimation), the sites (LP) and (AB) show the highest pressure index (Tables 8 and 9). In fact, both variants show the same trend for all sites, with a slight increase in the enthronezation index calculated using Lopez's original method (Figure 8).

## RESULTS AND DISCUSSION

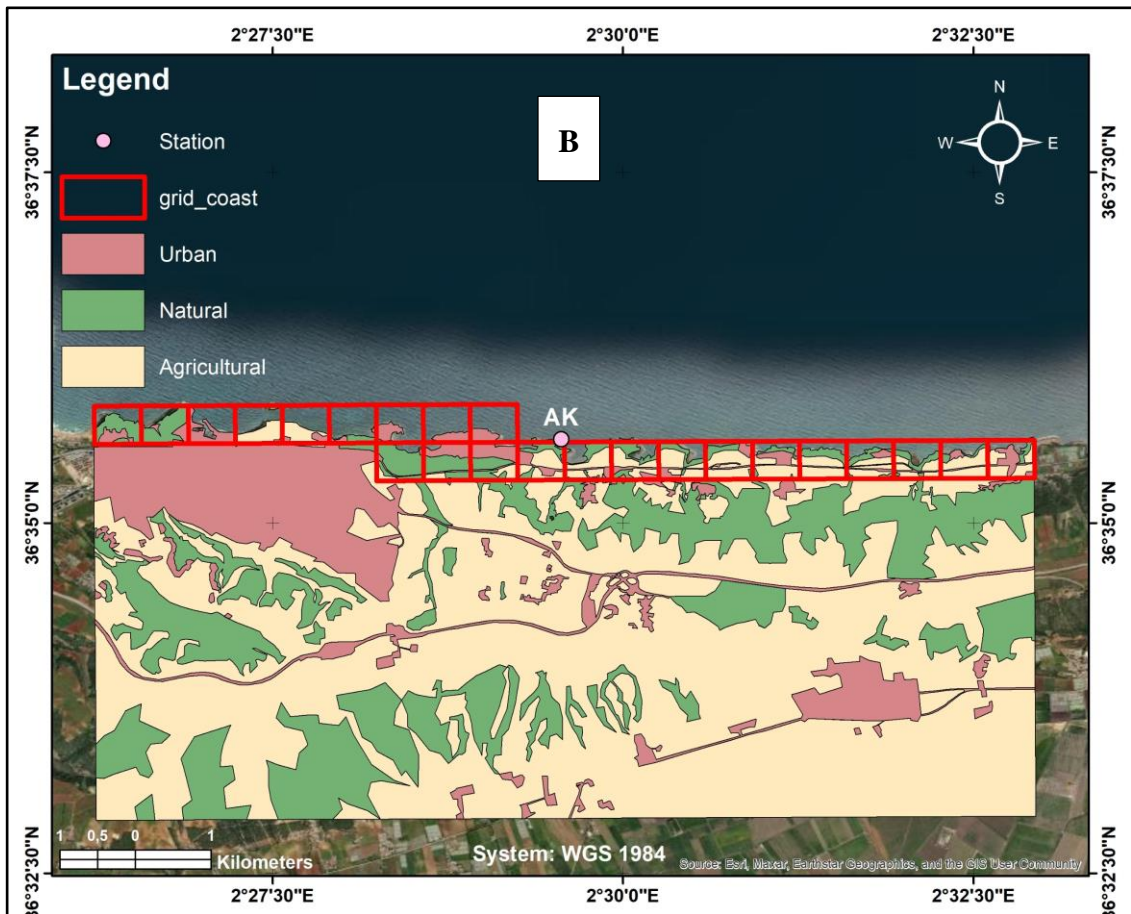
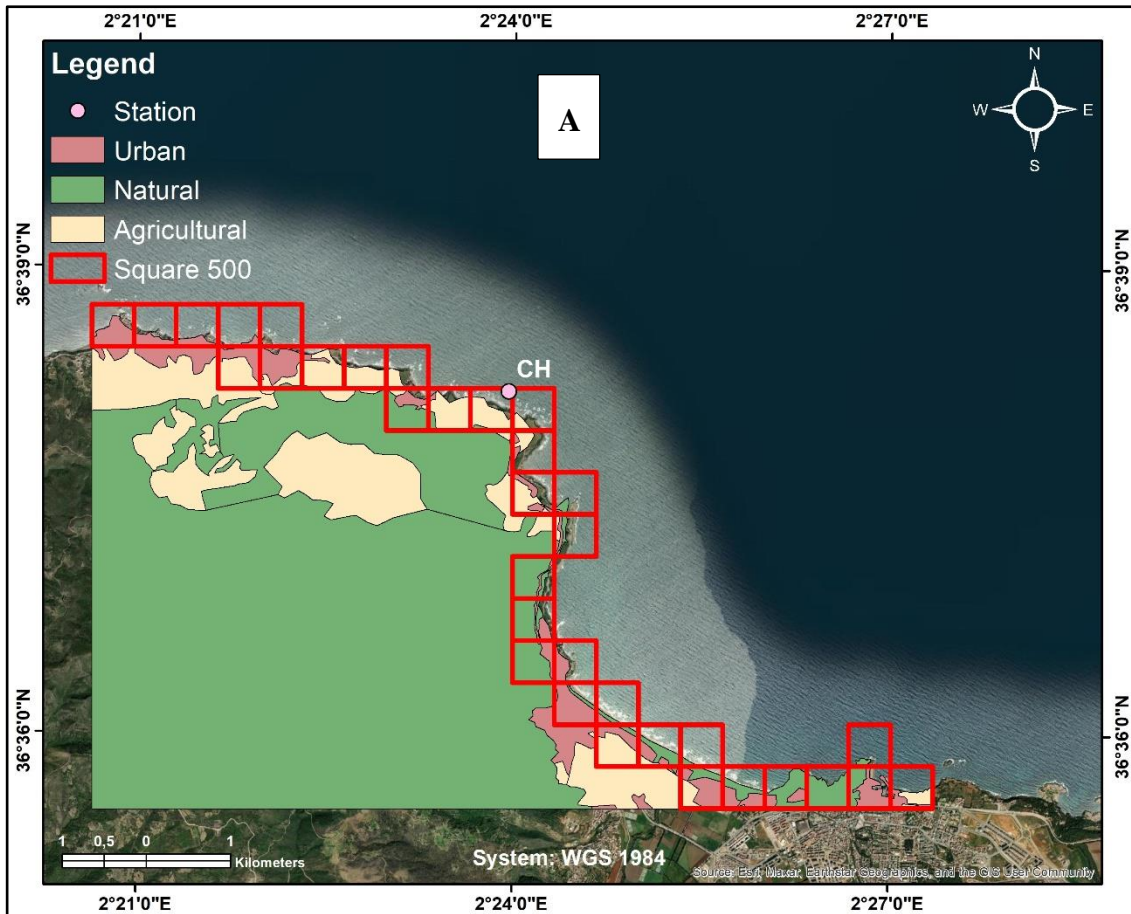
**Table 8.** Percentage of land use (U: urban, A: agricultural, N: natural), distance from rivers, industries and ports (C: commercial, R: recreational), and presence of artificial structures (AS). The average values for the different pressures and the corresponding pressure category are also shown according to the **Lopez Y Royo et al. (2009)**.

Sites	OS %				Rivers (Km)	industry (Km)	Ports (Km)		AS	Pressure	
	U	A	N	A+U			C	R		Value	Category
CH	31.25	28.13	40.63	59.38	5.63	12.05	0.00	6.55	0.00	1.00	Low
AK	21.74	56.52	21.74	78.26	6.59	10.22	0.00	4.10	0.00	1.00	Low
BR	34.62	34.62	30.77	69.24	0.00	8.77	0.00	3.23	3.93	1.14	Moderate
BSM	44.44	48.15	7.41	92.59	11.37	2.63	0.00	3.79	0.38	1.29	Moderate
AB	100.00	0.00	0.00	100.00	3.05	2.59	0.00	2.53	2.31	1.57	Moderate
LP	100.00	0.00	0.00	100.00	3.93	4.79	0.00	0.65	0.19	1.57	Moderate
PP	100.00	0.00	0.00	100.00	15.6	0.51	8.8	5.78	0.00	1.29	Moderate
AG	14.29	4.76	80.95	19.05	2.74	6.27	0.00	8.65	3.53	1.14	Moderate
DLS	20.00	44.00	36.00	64.00	0.52	0.00	0.00	7.24	0.00	0.71	Low

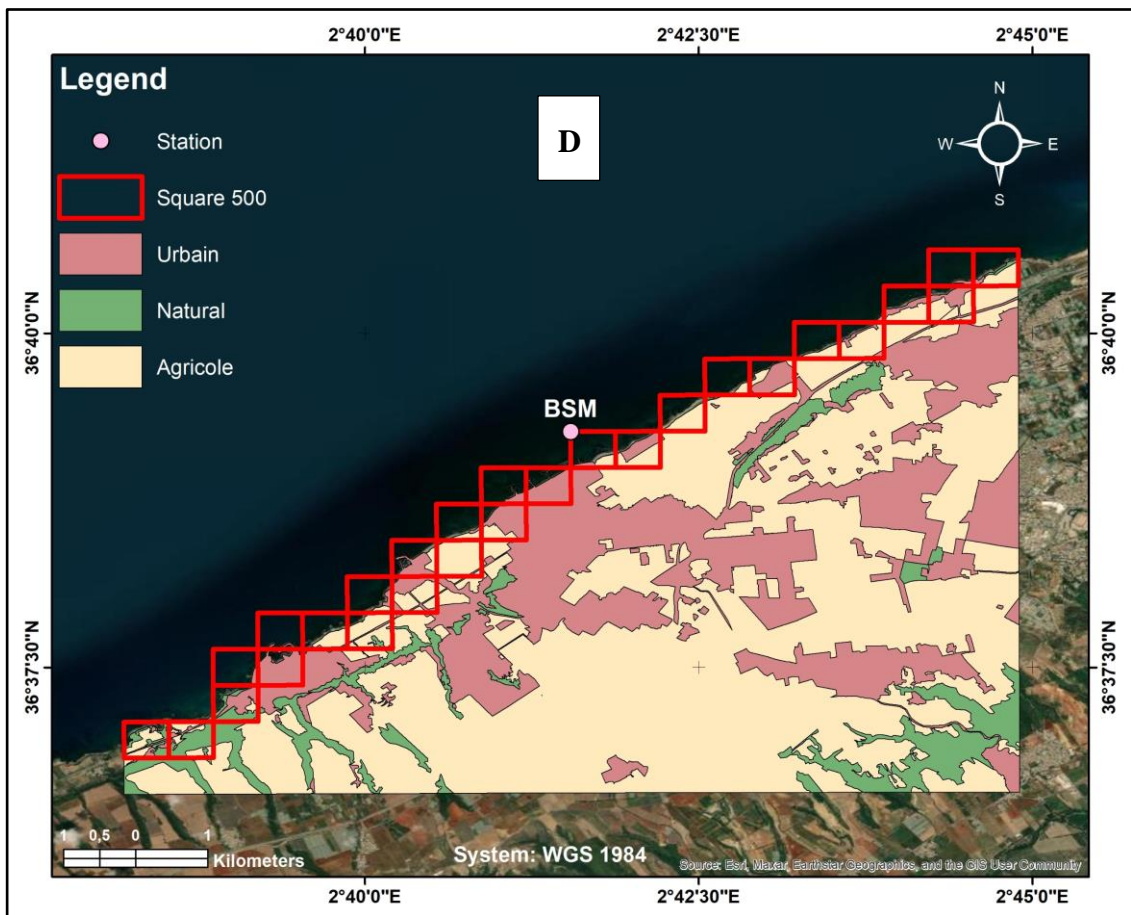
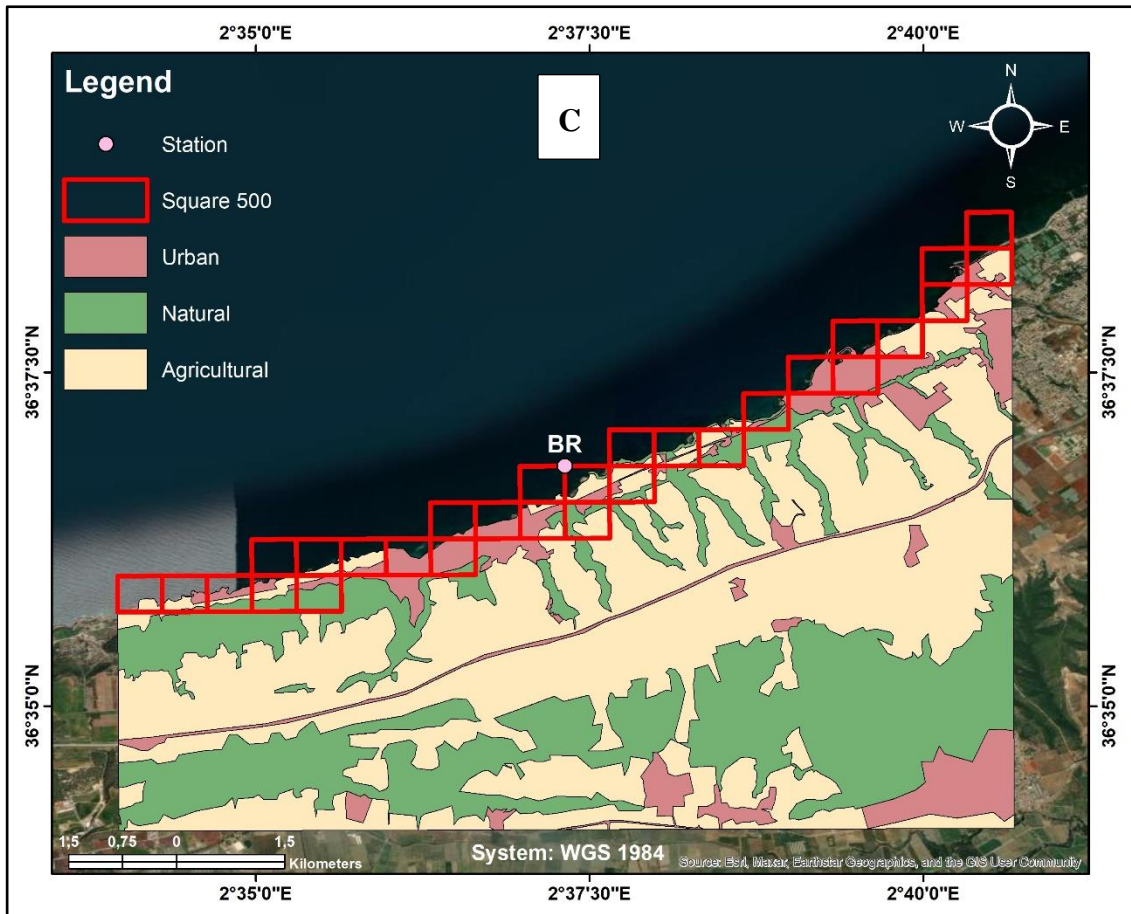
**Table 9.** Percentage of land use (U: urban, A: agricultural, N: natural), distance from rivers, industries and ports (C: commercial, R: recreational), and presence of artificial structures (AS). The average values for the different pressures and the corresponding pressure category are also shown according to **Lopez Y Royo et al. (2009) adjusted**.

Site	OS %				Rivers (Km)	industry (Km)	Ports (Km)		AS	Pressure	
	U	A	N	A+U			C	R		Value	Category
CH	6.57	17.23	76.20	23.80	5.63	12.05	0.00	6.55	0.00	0.86	Low
AK	14.56	61.64	23.80	76.20	6.59	10.22	0.00	4.10	0.00	1.08	Moderate
BR	11.59	54.23	34.18	65.82	0.00	8.77	0.00	3.23	3.93	1.14	Moderate
BSM	29.33	62.66	8.00	92.00	11.37	2.63	0.00	3.79	0.38	1.29	Moderate
AB	49.10	33.96	16.94	83.06	3.05	2.59	0.00	2.53	2.31	1.43	Moderate
LP	54.12	41.49	4.39	95.61	3.93	4.79	0.00	0.65	0.19	1.43	Moderate
PP	65.12	0.92	33.96	66.04	15.6	0.51	8.8	5.78	0.00	1.14	Moderate
AG	33.10	57.56	9.34	90.66	2.74	6.27	0.00	8.65	3.53	1.43	Moderate
DLS	4.82	48.53	46.65	53.35	0.52	0.00	0.00	7.24	0.00	0.71	Low

# RESULTS AND DISCUSSION

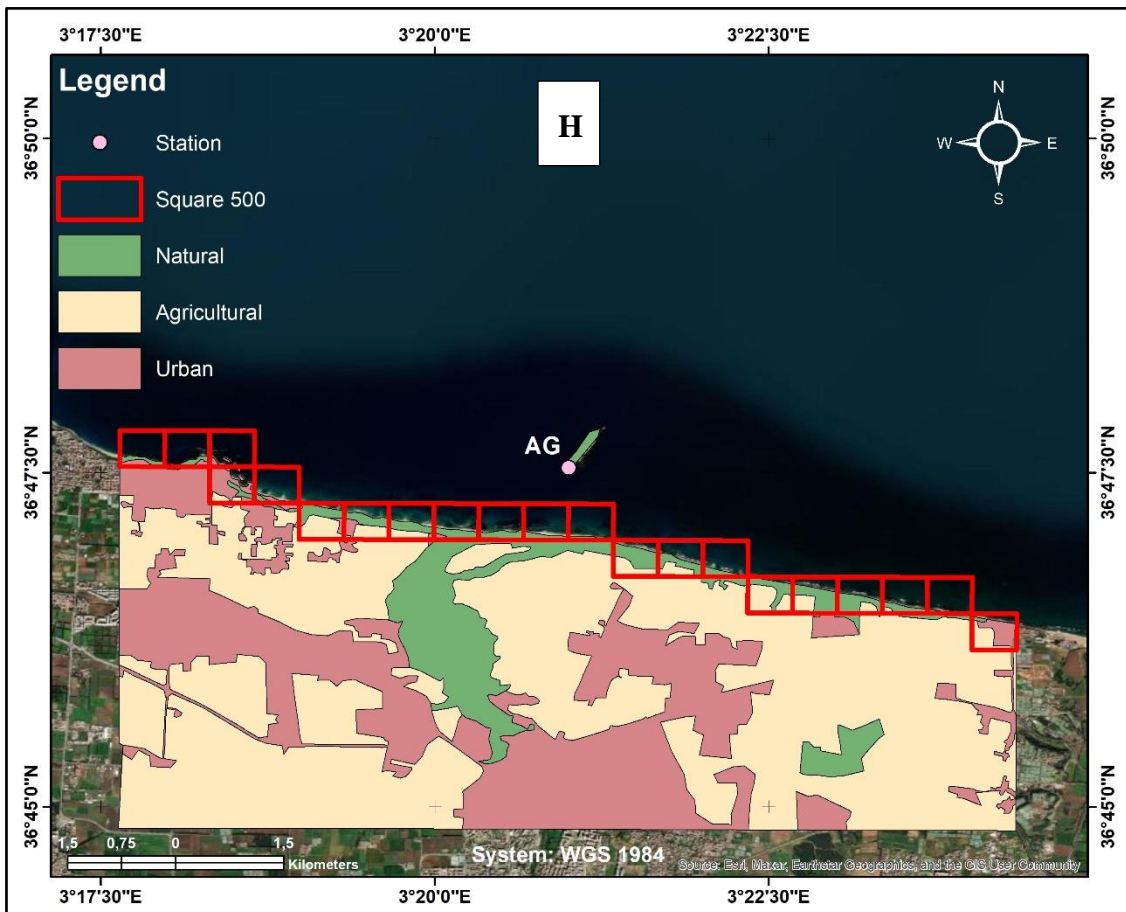
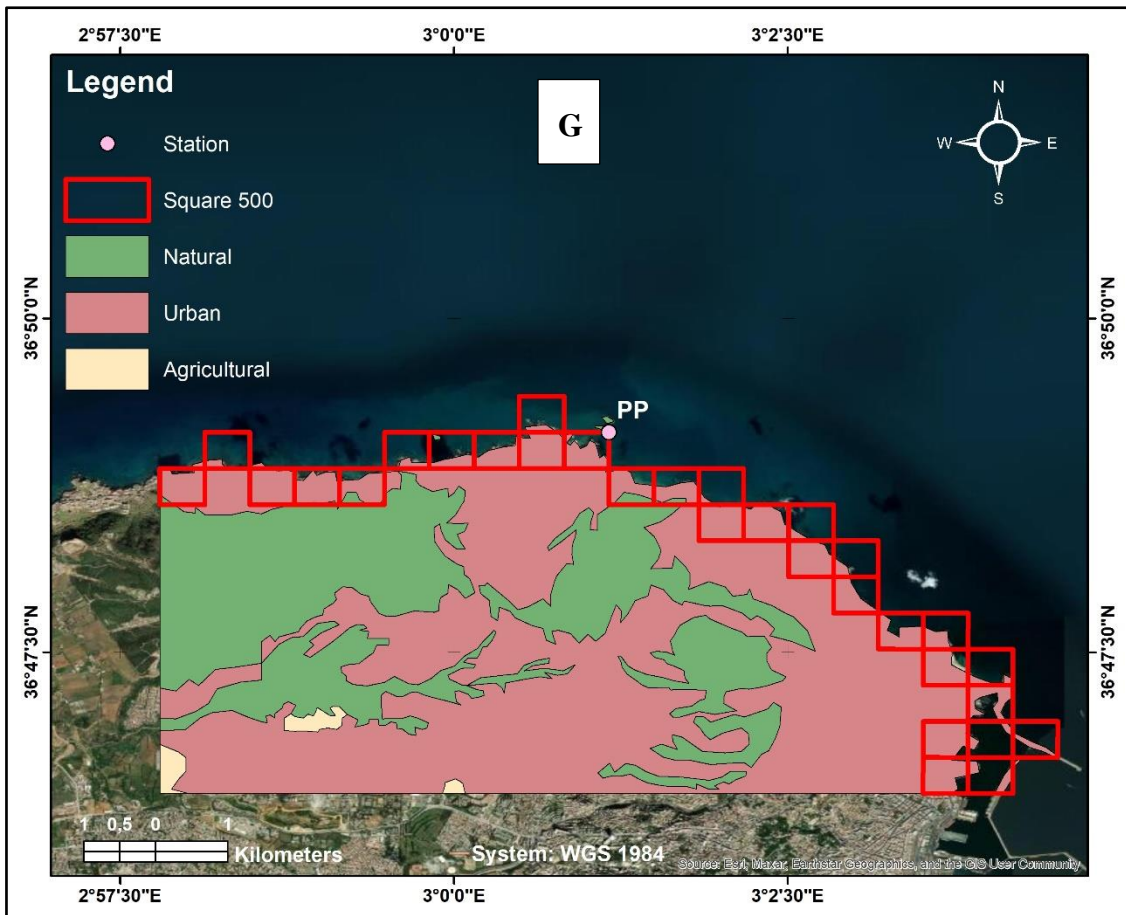


# RESULTS AND DISCUSSION

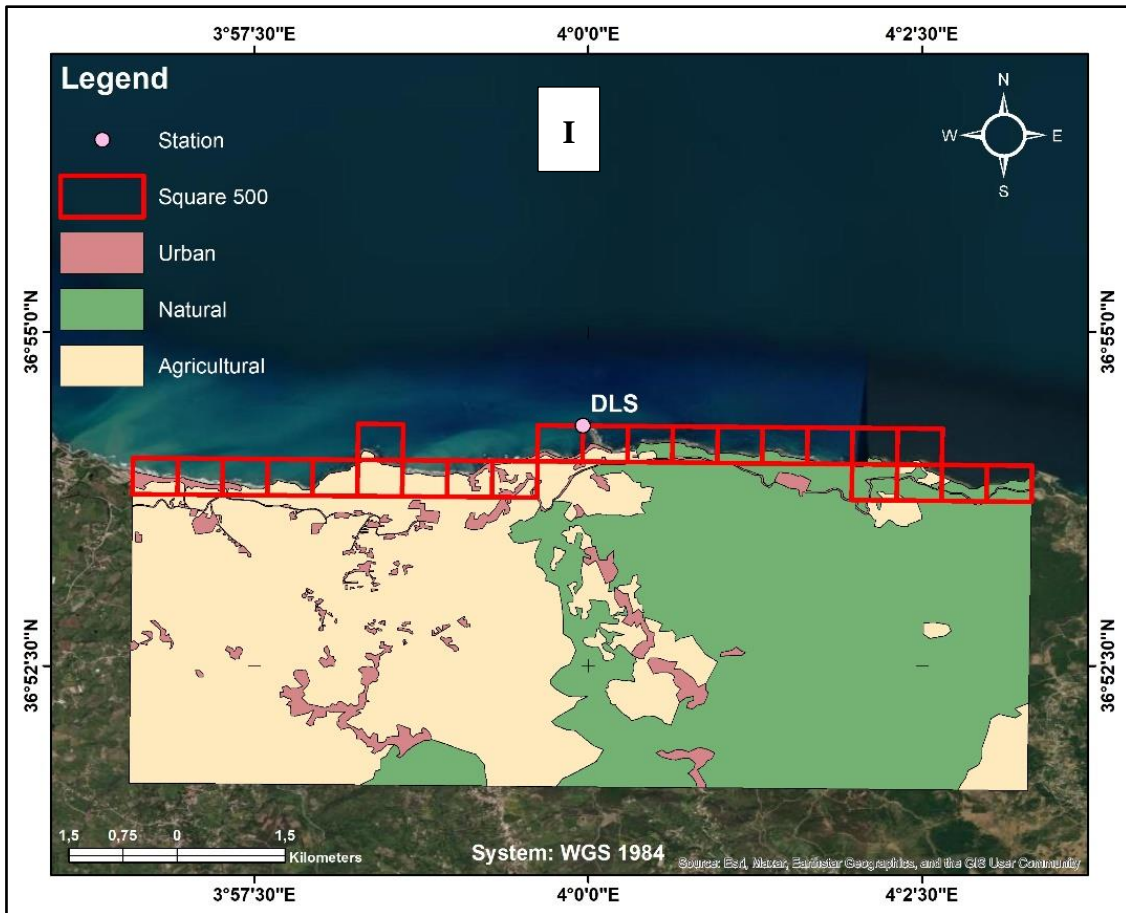




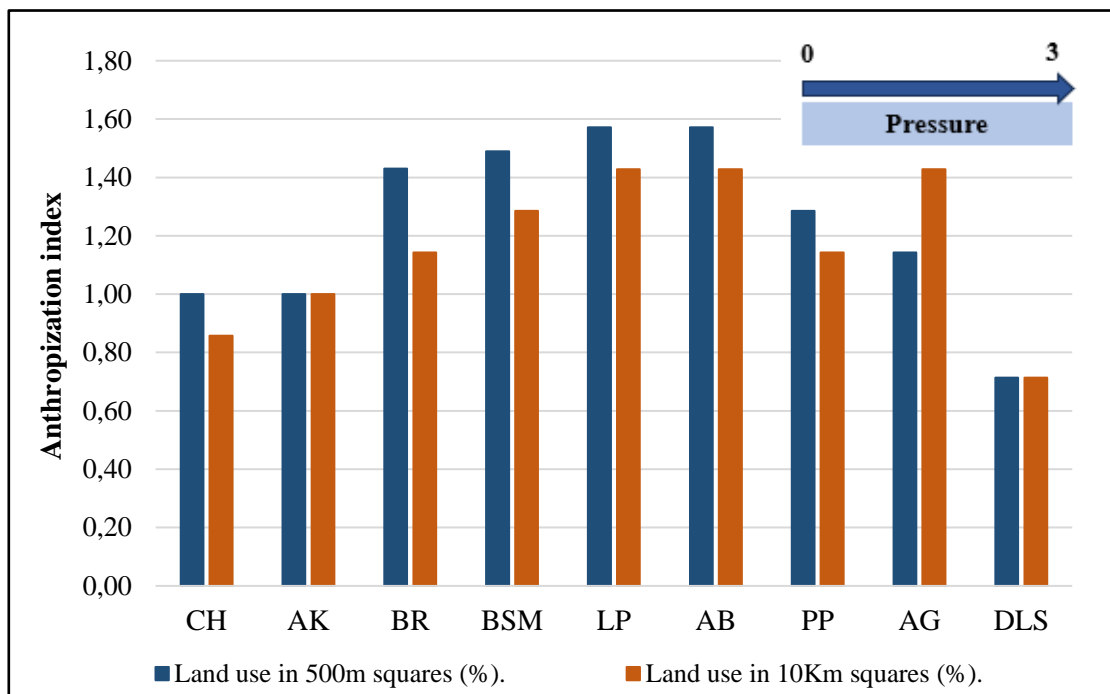
# RESULTS AND DISCUSSION



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**Figure 8.** Land use in the 10Km squares and in the coastline (0.25km<sup>2</sup>).



**Figure 9.** Anthropization index per station according to Garcia 2013 for Lopez 2009 method interpretation.

## RESULTS AND DISCUSSION

### 3.2. Anthropogenic pressures assessment supplemented by data census

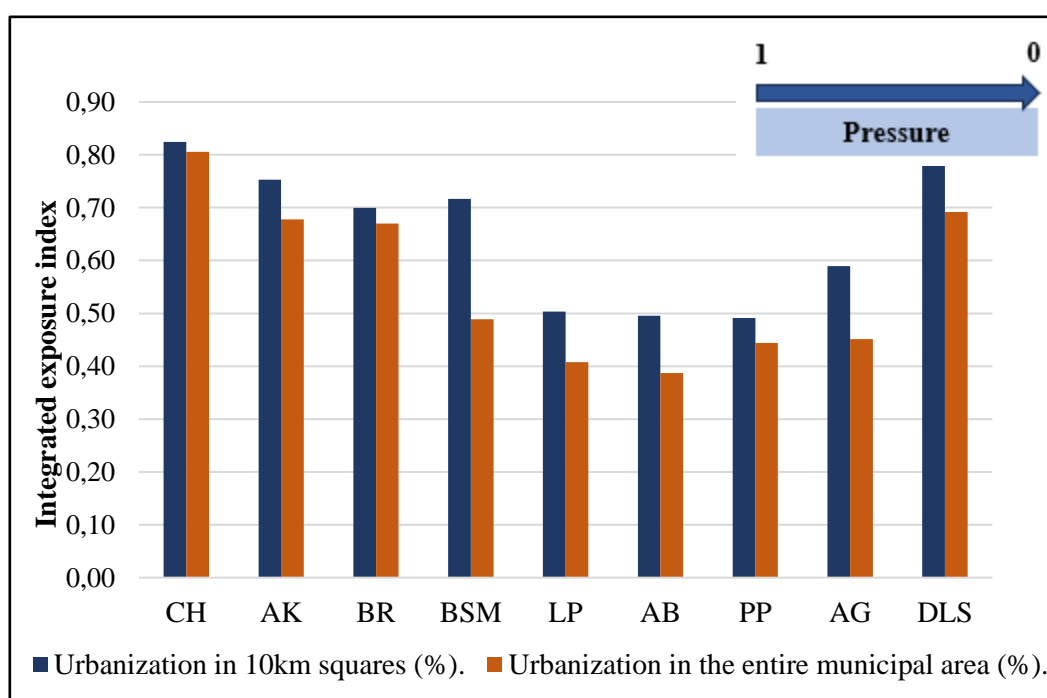
#### 3.2.1. Using the method described by Hu *et al.* (2021) and adjusted

This quantitative approach uses an inverted scale. On this scale, the closer the value of the Integrated Exposure Index is to 1, the less the site is affected by anthropogenic pressures. Conversely, the further the value of the Integrated Exposure Index is from 1, the more the site is affected by anthropogenic pressures.

The site (CH) appears to be the least affected by anthropogenic pressures, as evidenced by its maximum integrated exposure index value in both cases: when considering the percentage of urbanization in the entire municipal area, and when considering the urbanization within a 10km square area surrounding the site.

Considering the urbanization in the 10km square area surrounding the sites, the site (PP) emerges as the one most affected by high anthropogenic pressure, as evidenced by its minimum integrated exposure index value of 0.49.

The site (AB) experiences the highest anthropogenic pressure when the percentage of urbanization is calculated over the entire municipal area, since the site (AB) shows the lowest integrated exposure index value of 0.39.



**Figure 10.** The variation of the integrated exposure index according to **Hu et al (2021)** and adjusted.

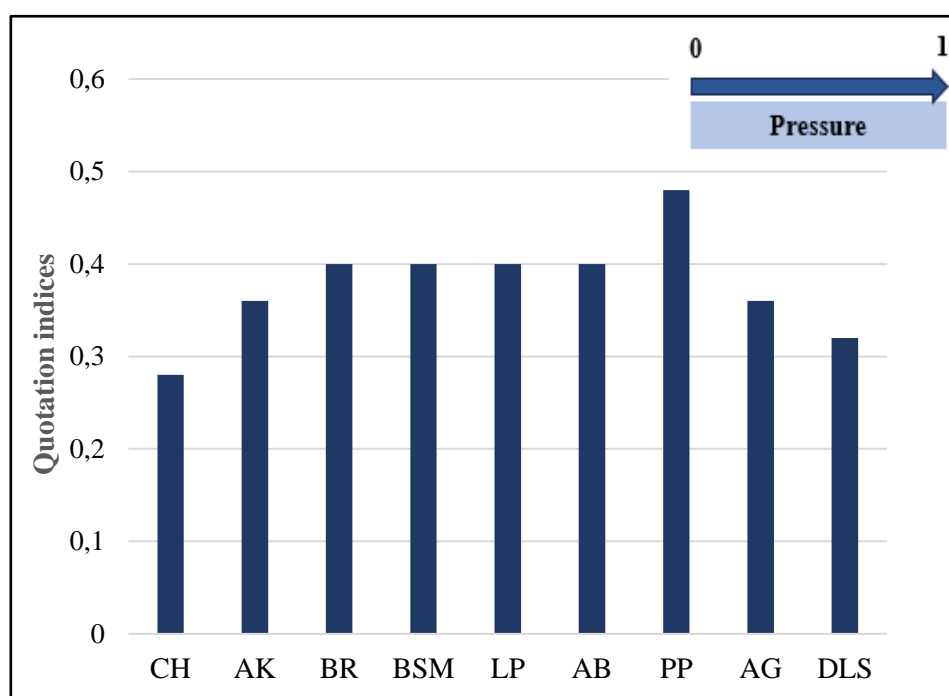
## RESULTS AND DISCUSSION

### 3.2.1. Using the method described by Larid (2002) and adjusted

According to the approach proposed by **Larid (2002)**, the various quotation indices (Table 10) assigned to the sites indicate that:

The proximity of the Rais Hamidou cement plant to the site (PP) gives it a maximum score (Figure 11). Due to the absence of industry and the low impact of the port of Tipaza, site (CH) receives the minimum score.

Sites BR, BSM, AB, and, LP show the same anthropogenic quotations. for AP, LP and AB, it is due to the heavy urbanization and the proximity of the cement plant in Rais Hamidou and for BR and BSM, it due to the presence of the industrial zone of Bou Ismail.



*Figure 11.* Quotation indices according to **Larid (2002)**.

*Table 10.* Results of **Larid (2002)**.

Sites	CH	AK	BR	BSM	LP	AB	PP	AG	DLS
Ck	0.28	0.36	0.4	0.4	0.4	0.4	0.48	0.36	0.32

## RESULTS AND DISCUSSION

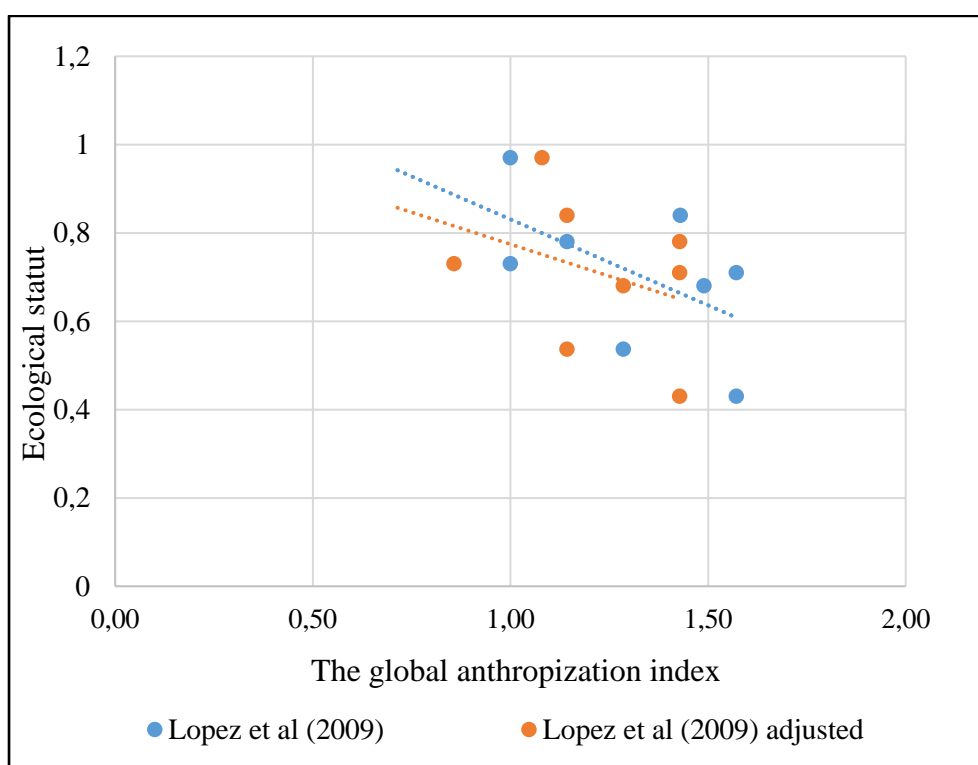
### 3.3. The relationship between anthropogenic pressure assessment and ecological status of *Posidonia oceanica* meadows

The aim of this step is to analyze the relationship between the previously calculated indices of anthropogenic pressures and the ecological status of *Posidonia oceanica* meadows represented by the EQR PREI values obtained by **Sengouga et al. (2019)**.

First, the comparison between the adjusted variants for each approach (**Lopez and Hu**) shows the same trend (Figure 12).

The higher correlation is obtained between the EQR PREI values for each station and the global anthropization index calculated according to **Lopez Y Royo et al. (2009)** when the land use was considered in the 500m X 500m squares (R Pearson = - 0.76; p-value = 0.03).

For the adjusted method of **Lopez Y Royo et al. (2009)** (land use considered in a 10Km x 10Km square), the approach has no significant correlation with the EQR PREI (R Pearson = - 0.42; p-value = 0.3).



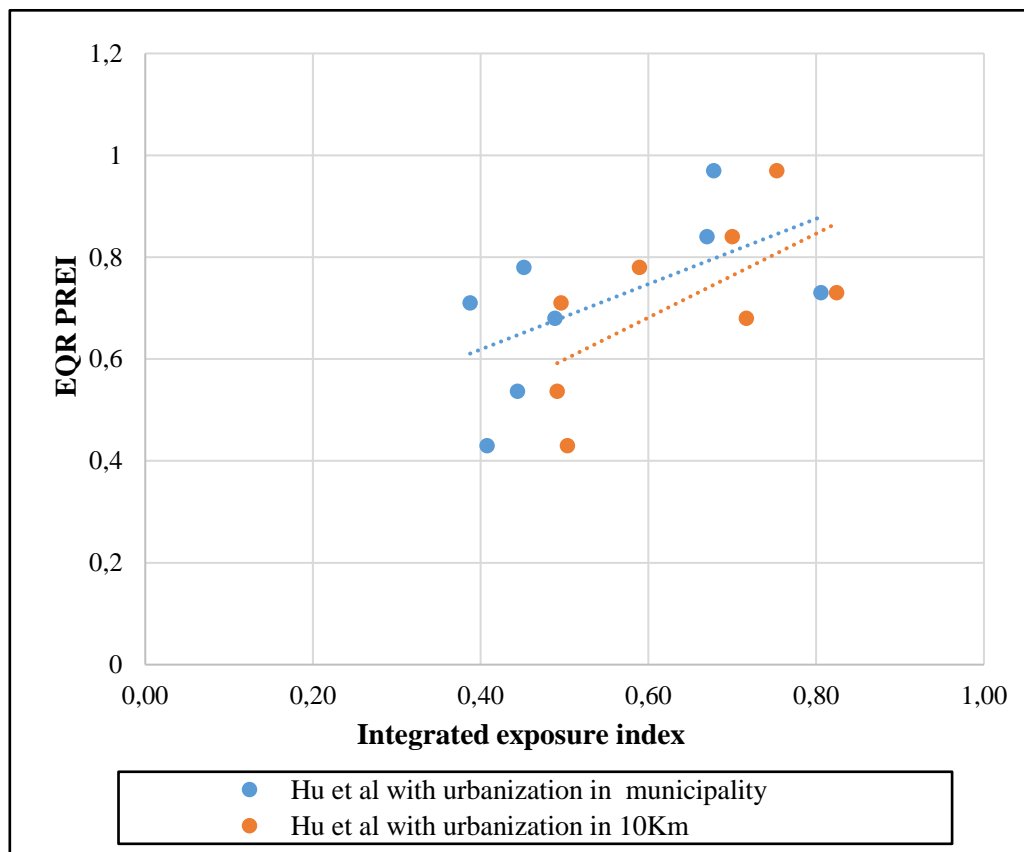
**Figure 12.** Relationship between EQR PREI and the anthropization index calculated according to **Lopez Y Royo et al. (2009)**.

## RESULTS AND DISCUSSION

The correlation tests showed that there is no correlation between the EQR PREI and the approach of **Hu et al. (2021)** when the percentage of urbanization is considered for the entire municipal area (R Pearson = 0.59. P-value= 0.13) (Figure 13).

In contrast, a significant correlation (P-value < 0.1) is recorded between the EQR PREI and the quantitative approach proposed by **Hu et al (2021)** when the percentage of urbanization is considered only in the 10km x 10 km square area (R Pearson = 0.64; p-value=0.08), (Figure 13).

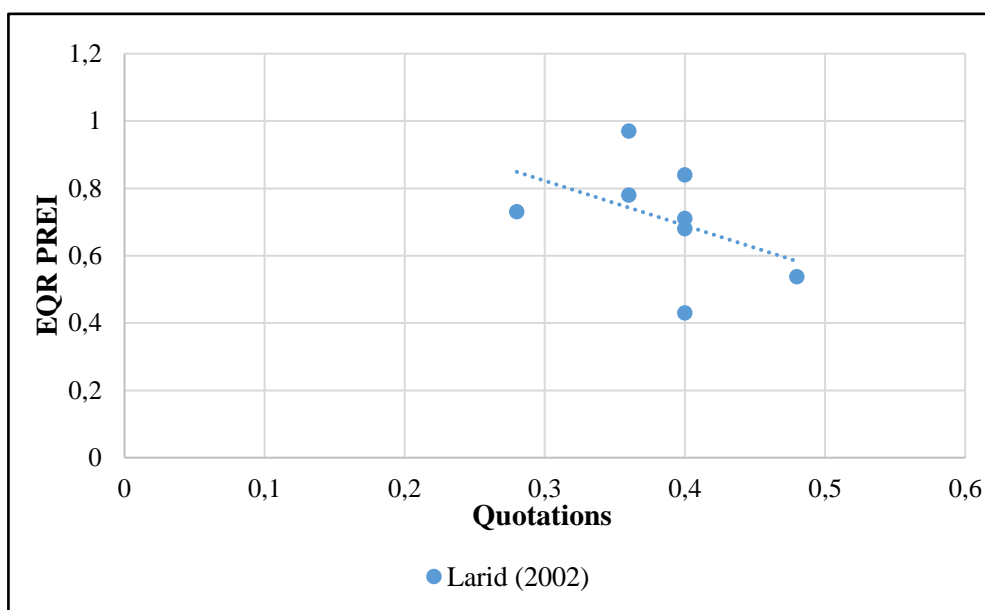
Moreover, this method correlates very well with all the other methods (P-value < 0.05), which may represent a potentiality of its use for the same purpose, i.e. to assess anthropogenic pressures on the *Posidonia oceanica* meadow.



**Figure 13.** Relationship between EQR PREI and the integrated exposure index calculated by **Hu et al. 2021**.

The results of the correlation analysis show that there is no correlation between the EQR PREI and the quotation of anthropization calculated according to **Larid (2002)** and adjusted on the basis of available data (R Pearson = -0.44; p-value= 0.27), (Figure 14).

## RESULTS AND DISCUSSION



**Figure 14.** Relationship between EQR PREI and the anthropization quotation indexes calculated according to **Larid (2002)**.

Consequently, the assessment of anthropogenic pressure using the **Lopez Y Royo et al. (2009)** approach with land use in the 500m X 500m squares shows the maximum of coherence with the ecological status of *Posidonia oceanica* meadows based on the calculation of the PREI index ( $P\text{-value} < 0.05$ ), compared to the other approaches. This visual approach provides a detailed picture of the anthropogenic pressures affecting *Posidonia oceanica* meadows than other approaches due to data availability.

In previous studies (**Boumaza et al. 2015; Sengouga et al. 2017**), the EQR PREI showed a high significant correlation with the **Larid 2002** approach (without adjustment). This discrepancy with our results may be attributed to the change in the parameters used, which may be more descriptive. In particular, the volume of wastewater, which was not available in the present study and may have influenced the results. Based on the results obtained in this study, the approach of **Lopez et al. (2009)** that shows the best correlation with the EQR PREI, can be suggested to rapidly assess human pressure that potentially impact the ecological status of *Posidonia oceanica* meadows in the Algerian coasts. This approach classifies the studied sites as impacted, with low pressure levels observed at three sites and moderate pressure levels observed at six sites, (Figure 15).

## RESULTS AND DISCUSSION

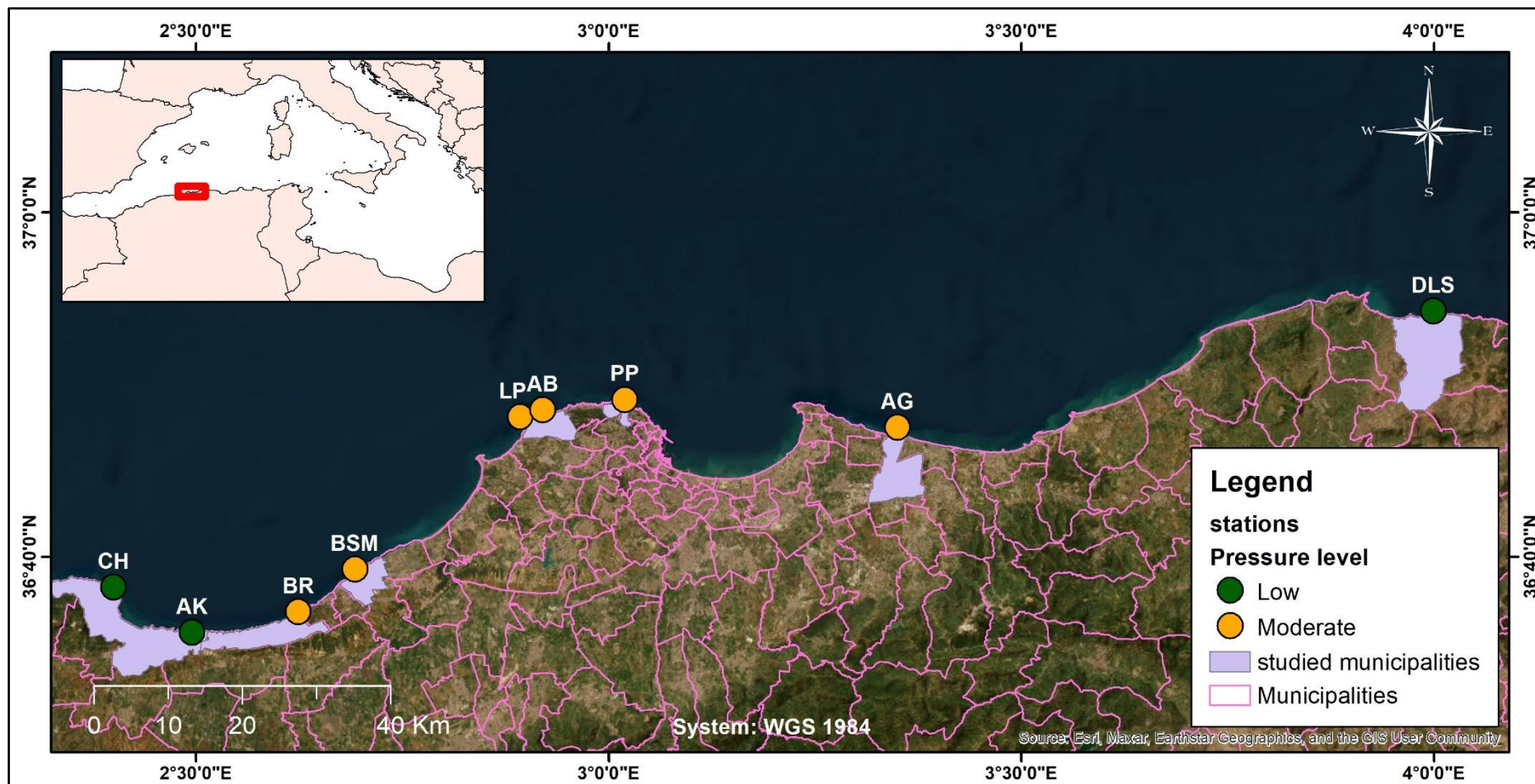


Figure 15. The Anthropogenic level based on Lopez Y Royo *et al.* (2009).

# *CONCLUSION AND OUTLOOK*

## CONCLUSION AND OUTLOOK

### Conclusion and outlook

This study has allowed to assess the anthropogenic pressures on *Posidonia oceanica* meadows along the central Algerian coast, throughout the uses of a total of 5 methods with different approaches and parameters.

The results show that using visual method based on satellite imagery such as the approach of **Lopez Y Royo et al. (2009)**, can provide a significant information about the ecological status of these meadows. The results of this visual approach validated in the present study show that 3 out of 9 stations in the study area were classified as "low pressure" sites. The visual assessment method provided detailed insights into the specific anthropogenic pressures affecting the meadows. The results indicated that regions with higher levels of urbanization and industrial activity exhibited greater ecological degradation.

Furthermore, the study showed that while the quantitative approach of **Larid (2002)** provided descriptive insights, the qualitative approach of **Lopez et al. (2009)** was more effective in capturing the nuances of human impacts on *Posidonia oceanica*. This is not necessarily due to the inefficiency of this quantitative method. Rather, the most probable explanation is the absence of more relevant and updated data that can adequately reflect the human impact on these marine ecosystems.

In order to develop a more effective monitoring system for these meadows, it is essential to identify more relevant indicators that are both readily accessible and capable of accurately reflecting the current state of the meadow. This will enable the establishment of a rapid and reliable monitoring tool for predicting the potential degradation of these fragile and important ecosystems.

Finally, we notice that a part of results obtained in this study was presented in an oral communication at the university of biology of Constantine (Annex1)

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# *ANNEXS*

## Annex 1: Certificate of Attendance at an Oral Communication

Ministère de l'Enseignement Supérieur et de la Recherche Scientifique  
Université Constantine 1 - Frères Mentouri  
Faculté des Sciences de la Nature et de la Vie  
Département d'Ecologie et Environnement, Département de Biologie Végétale, Département de Biologie Animale

SNV  
Société Nationale de Valorisation de la Nature  
UNIVERSITY OF CONSTANTINE 1  
FACULTY OF NATURAL AND LIFE SCIENCES  
DEPARTMENT OF ENVIRONMENTAL BIOLOGY

# ATTESTATION DE COMMUNICATION

3<sup>ème</sup> Journée d'Etude sur la Biodiversité et les Espèces Menacées (JEBEM)  
Constantine le 15 Mai 2024

Je soussigné **Dr ARFA Azzedine Mohamed Touffik**, Président de la 3<sup>ème</sup> Journée d'étude sur la biodiversité et les espèces menacées.

Atteste que **Madame : BOUDJADJA Rihem**  
CO-AUTEURS : SENGOUGA Amina, KERAGHEL Mehdiya Asma  
AFFILIATIONS : École Nationale Supérieure des Sciences de la Mer et de l'Aménagement du Littoral Alger, Algérie.

A présenté une **Communication Orale** intitulée :  
Assessment of anthropogenic pressure on *Posidonia oceanica* (L.) Deille meadows in Algiers region coast.

Président de la JEBEM 2024  
Dr ARFA Azzedine Mohamed Touffik

Thème 3 :  
Protection et sauvegarde des espèces menacées

عز الدين محمد التوفيق عرفة

La présente attestation est délivrée pour servir et faire valoir ce que de droit



## REFERENCES

### ABSTRACT

The present study aims to define a straightforward and cost-efficient method for evaluating the impact of human activities on the *Posidonia oceanica* meadows along the Algerian coast, employing a combination of visual and quantitative methods. The study evaluates multiple pressures including urbanization, industrial activity, port proximity, fishing activity, wastewater discharge and the presence of invasive species. Satellite imagery was used for the visual assessment and quantitative data were collected from various sources such as governmental websites, academic databases, and administrative bodies, for the calculation of an integrated exposure indexes. These indexes standardize the pressure values to facilitate comparison and estimation of total human impact. Pearson's coefficient, were applied to correlate these pressures with the ecological status of *Posidonia oceanica* meadows represented by the ecological quality ratio values of the multiparametric index Posidonia Rapid Easy Index. The findings reveal a high significant correlation between the assessment of anthropogenic pressure using the visual approach and the ecological status of *Posidonia oceanica* meadows. This visual approach provides a detailed picture of the anthropogenic pressures affecting *Posidonia oceanica* meadows than other approaches. The absence of more relevant and updated data that can adequately reflect the human impact on these marine ecosystems can explain the low correlation obtained with the quantitative approach.

**Keywords:** *Posidonia oceanica*, anthropogenic pressures, ecological status, urbanization, Algerian coast.

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### RESUME

Cette étude vise à définir une méthode simple et rentable pour évaluer l'impact des activités anthropiques sur les herbiers de *Posidonia oceanica* le long de la côte algérienne. En utilisant une combinaison de méthodes visuelles et quantitatives. L'étude évalue les pressions multiples. Notamment l'urbanisation. L'activité industrielle. La proximité des ports. L'activité de pêche. les rejets d'eaux usées et la présence d'espèces envahissantes. L'imagerie satellitaire a été utilisée pour l'évaluation visuelle et des données quantitatives ont été collectées à partir de diverses sources telles que des sites web gouvernementaux. Des bases de données universitaires et des organismes administratifs. Ces données ont été utilisées pour le calcul des indices d'exposition. Ces indices normalisent les valeurs de pression afin de faciliter la comparaison et l'estimation de l'impact humain total. Le coefficient de Pearson a été appliqué pour vérifier la corrélation entre ces pressions et l'état écologique des herbiers de *Posidonia oceanica* représenté par les valeurs du ratio de qualité écologique calculé pour l'indice multiparamétrique Posidonia Rapid Easy Index. Les résultats révèlent une corrélation significative entre l'évaluation de la pression anthropique avec l'approche visuelle et l'état écologique des herbiers de *Posidonia oceanica*. Cette approche visuelle fournit une image plus détaillée des pressions anthropiques affectant les herbiers de *Posidonia oceanica* par rapport aux autres approches. L'absence de données plus pertinentes et actualisées pouvant refléter de manière adéquate l'impact humain sur ces écosystèmes marins peut expliquer la faible corrélation obtenue avec l'approche quantitative.

**Mots clés :** *Posidonia oceanica*, pressions anthropiques, état écologique, urbanisation, côte algérienne.

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### المخلص

تهدف هذه الدراسة إلى تحديد طريقة بسيطة وفعالة من حيث التكلفة لتقييم تأثير الأنشطة البشرية المنشأ على مروج *Posidonia oceanica* على طول الساحل الجزائري، باستخدام مزيج من الأساليب البصرية والكمية. تقيّم الدراسة الضغوط المتعددة بما في ذلك التحضر، والنشاط الصناعي، والقرب من الموانئ، ونشاط الصيد، وتصريف مياه الصرف الصحي، ووجود الأنواع الغازية. تم استخدام صور الأقمار الصناعية للتقييم البصري وتم جمع البيانات الكمية من مصادر مختلفة مثل المواقع الإلكترونية الحكومية وقواعد البيانات الأكاديمية والهيئات الإدارية لحساب مؤشرات التعرض المتكاملة. تعمل هذه المؤشرات على توحيد قيم الضغط لتسهيل المقارنة وتقدير التأثير البشري الكلي. تم تطبيق معامل بيرسون، لربط هذه الضغوط مع قيم نسبة الجودة البيئية (EQR) المستمدة من مؤشر *Posidonia* السريع السهل (PREI) كشفت النتائج عن وجود ارتباط كبير بين تقييم الضغط البشري المنشأ باستخدام النهج البصري والحالة البيئية لمروج *Posidonia oceanica*. ويوفر هذا النهج البصري صورة مفصلة للضغوط البشرية المنشأ التي تؤثر على مروج *Posidonia oceanica* أكثر من النهج الأخرى، ويمكن أن يفسر عدم وجود بيانات أكثر ملاءمة وتحديداً يمكن أن تعكس بشكل كافٍ التأثير البشري على هذه النظم الإيكولوجية البحرية انخفاض الارتباط الذي تم الحصول عليه باستخدام النهج الكمي.

**الكلمات المفتاحية:** *Posidonia oceanica* ، الضغوطات البشرية، الحالة البيئية، العمران، الساحل الجزائري.