

Habitat types mapping using remote sensing techniques in Cyprus

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ABSTRACT

Oceans cover 75% of the Earth's surface and account for 99% of the planet's living space by volume. They are home to around 200,000 known species, with *Posidonia oceanica* meadows being among the oldest. These habitats are very important coastal ecosystems, providing vital services such as habitat for marine life, coastal protection, and oxygen generation. Despite their importance, seagrass meadows, including *Posidonia oceanica*, face significant threats, including degradation and loss, with slow regeneration rates. As a result, their monitoring and conservation are essential for maintaining biodiversity and the health of marine ecosystems. This study presents an innovative approach for mapping and monitoring seagrass meadows in western Cyprus using the Google Earth Engine (GEE) platform. Leveraging freely available satellite data from the Copernicus Program, we demonstrate how Earth observation tools can be utilized to map the spatial extent of seagrass meadows and other significant habitat types. This approach supports the monitoring efforts of the European Union's conservation frameworks and aligns with the United Nations' Sustainable Development Goal (SDG) 14, focusing on the conservation of marine life. The integration of GEE for seagrass mapping offers a scalable and efficient method to track habitat changes, contributing to more effective conservation strategies and ensuring the sustainable use of coastal ecosystems.

Keywords: remote sensing, seagrass, habitat mapping, google earth engine

1. INTRODUCTION

Seagrass is one of the most valuable ecosystems and species on planet earth. They enhance biodiversity by providing a plethora of ecosystem services which include oxygen generation, the protection not only of the coastal areas from the wave energy (erosion), but also the protection of young juvenile fishes from the predators¹. These productive ecosystems provide food, shelter, protection, and oxygen (ten liters of oxygen per square meter of seagrass area). Anthropogenic disturbances and climate change started affecting these ecosystems and related services. There have been large losses recorded over the past decades as a result of human activity and climate change. As a result, since 2013, it has been included in the IUCN Red List of Threatened Species. For the useful ecosystem services it provides, there is a framework of protection and conservation governed by several European Union (EU) laws and directives, i.e., the Barcelona Convention, the Bern Convention, Council Directive 92/43/EEC, European Network of protected areas-NATURA 2000- type 1120, council regulation 1626/94, 2000/60/EC, and 2008/56/EC². Seagrass species protection and conservation, also, aligns with the United Nations' Sustainable Development Goal (SDG) 14, which concerns Life Below Water.

Little is known about the total spread and extent of the seagrass species in Cyprus, until 2013, the spread was known to be 30% of the total area of the *Posidonia oceanica* meadows. For *Cymodocea nodosa* the percentage reaches 50%, the spread of the foreign species (invasive) *Halophila stipulacea* was fully known³. Through this research, we can see the necessity to record and map the presence of the *Posidonia oceanica* meadows, and other seagrass species. Knowing seagrass distribution will lead to protection and conversation, from the interested stakeholders and decision making. Remote sensing is a key factor in gathering information from a distance, even in the most unreachable places on Earth. It provided many applications such as bathymetry estimation, ocean and coastal monitoring, land use mapping, weather forecast, natural hazards monitoring in many sectors, such as geography, chemistry, geomorphology, oceanography, agriculture, topography, and many other sectors. Earth Observation (EO) can provide monitoring, protection and conservation in the different seagrass species and habitat types.

In this study, an Earth observation-based approach is applied to map and monitor seagrass beds, with a focus on Cypriot features. The Google Earth Engine platform was used, taking advantage of free and open satellite imagery provided by the Copernicus program in the wider Paphos district area to map the extent of seagrass beds and other habitat types important for local biodiversity.

2. METHODOLOGY

This study gave us the opportunity to learn the skills and capabilities of the Google Earth Engine Platform. We provided an estimation based on the methodology of Traganos et al., 2018⁴ and Poursanidis et al., 2024⁵ with simple steps and time-efficient process. The methodological framework we used is the following:



Figure 1: Methodological Framework applied for the seagrass distribution estimation.

We used the Google Earth Engine platform to provide an estimation of the presence of seagrass and other habitat types. The first part of our algorithm is to filter our data out by selecting the date range, and the cloud coverage to the desired extent (area of interest the wider area of Paphos district). The images which satisfy these criteria are in total 206 images for the time period 2022- 07-01 to 2023- 05-25, and the algorithm provides the first image for further analysis, which is the following: COPERNICUS/S2_SR_HARMONIZED/20220702T082609_20220702T082835_T36SVD. When we use the Sentinel-2 satellite data in a software, the first part of our analysis is to resample our data. This processing step in the Google Earth Engine platform is omitted because it is done automatically. The second step of our analysis is the Land masking. First, we calculate the Normalized Difference Water Index, to discriminate land and water, and finally, we extract the land in our analysis, and we proceed with the masked image to finalize our seagrass mapping.

3. DATA

Satellite Sentinel-2A is a key component for the monitoring of inland waters and coastal areas as it provides high spatial resolution data for three critical bands (B2,B3,B4). Other bands are the following:

- 4 bands in 10m: B2 (490 nm), B3 (560 nm), B4 (665 nm) and B8 (842 nm);
- 6 bands in 20m: B5 (705 nm), B6 (740 nm), B7 (783 nm), B8a (865 nm), B11 (1610 nm) and B12 (2190 nm);
- 3 bands in 60m: B1 (443 nm), B9 (940 nm) and B10 (1375 nm);

It is also provided a high temporal resolution (every 10 days for single Sentinel-2 or every 5 days for combined constellation revisit). For the Google Earth Engine platform, the Level – 2A Sentinal -2 data are downloaded from scihub and they are processed with the sen2cor.



Figure 2: The study site of Cyprus

The island country of Cyprus can be found in the southern Anatolian Peninsula. It is the third largest island of the eastern Mediterranean, in a critical geostrategic location of the Levantine basin and the EMMENA region. Cyprus is bordered on north of Egypt, east of Greece, south of Turkey, and west of Lebanon and Syria. In general, the climate of Cyprus is influenced by the adjacent countries, and the climate is characterized as mild Mediterranean, with dry summers and plenty of sunshine, and short periods of wet winters with little rainfall. Summer is hot and dry. In winter, the climate is mild (not too cold) and rainy. The island suffers from severe water scarcity, along with other countries such as Bahrain, Kuwait, Lebanon, Oman, and Qatar⁶.

In this case study, we will provide a cloud-based estimation of the presence of seagrass and other habitat types important for local biodiversity with the Google Earth Platform, in the wider area of Paphos district with the use of free and open satellite imagery provided by the Copernicus program. Here, we provided a single-image seagrass mapping classification with the satellite data of Sentinel-2A, Level-2A with the MSI (Multispectral Instrument)⁷.

3.1. Training data

Our training dataset is designed with photointerpretation to this specific image we processed. The photointerpretation keys we used to extract our dataset are the color, pattern, and shape to examine the presence or absence of seagrass species and other habitat types⁸. We extracted in total 110 points for the presence of four classes: seagrass, sand, reefs, and deep water. Moreover, the Random Forest classifier was used for the detection of our classes. Our processing steps led to the seagrass species and other habitat types mapping in the in the wider area of Paphos district.

3.2. Validation data

The validation dataset was provided by the Department of Lands and Surveys (DLS) through the DLS portal. The data was obtained by creating a query on the platform ([DLS Portal](#)) and downloaded for further analysis. For protection reasons, the data is aggregated and provided as polygons in a canvas format with 100x100 meters resolution. Since we need to align it with Sentinel-2 data, which is with 10m spatial resolution, we transformed the information into points.

The validation was created with an equal distribution of 10 points per class (40 in total). Finally, we have 150 points for reference dataset.

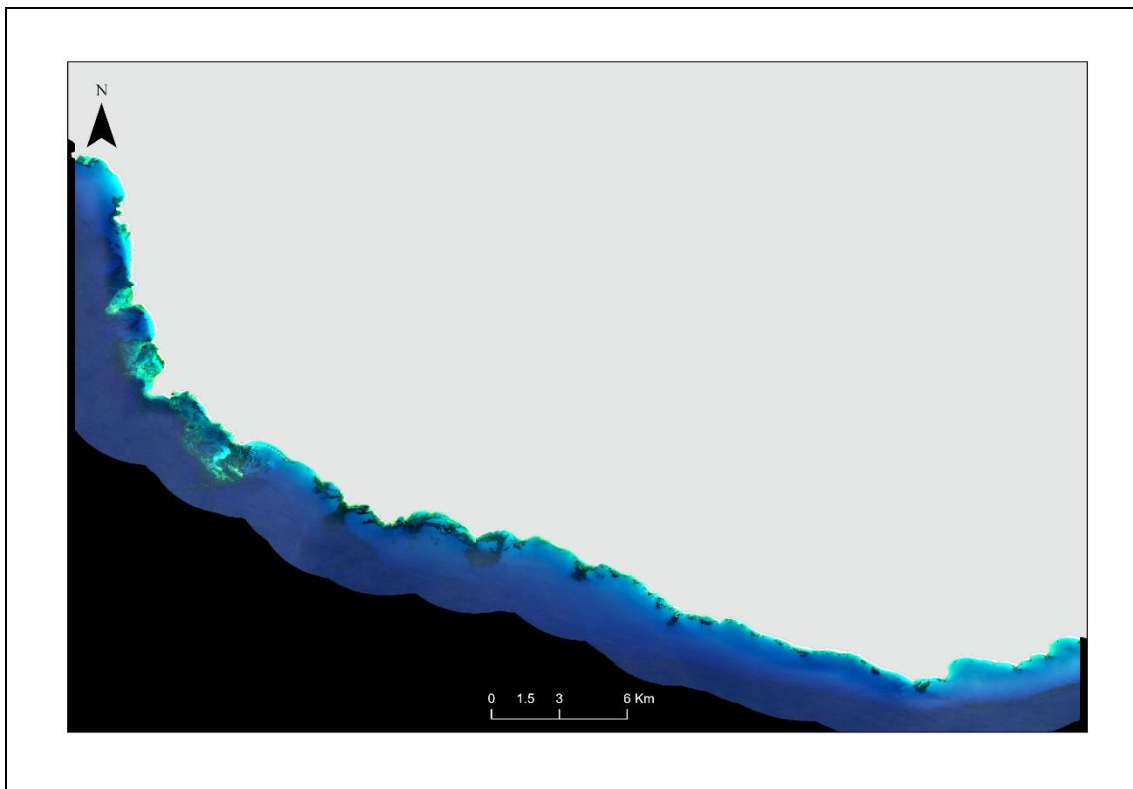
4. RESULTS

Here we provided a single-image Earth observation-based automated approach through Google earth Engine platform, in the wider Paphos district area. We used the Google Earth and the free and open satellite images provided by the Copernicus program to map the extent of seagrass beds and other habitat types important for local biodiversity.

The classification result has been produced with the photointerpretation in the three desired classes, seagrass, sand and reefs. The class seagrass is 10.31%, the class sand 35.6%, the class reefs 8.94% and the biggest classified area in the class Deep_water with 45.15%. Further analysis and in-situ data and measurements are crucial for the accuracy assessment of seagrass species extraction and other habitats and to validate our algorithm.

Table 1: Results produced after the classification for the classes utilized in the analysis

Habitat type	Percentage (%)	Km ²
Seagrass	10.31	20.11
Sand	35.60	69.42
Reefs	8.94	17.43
Deep_water	45.15	88.03
Sum	194.98	



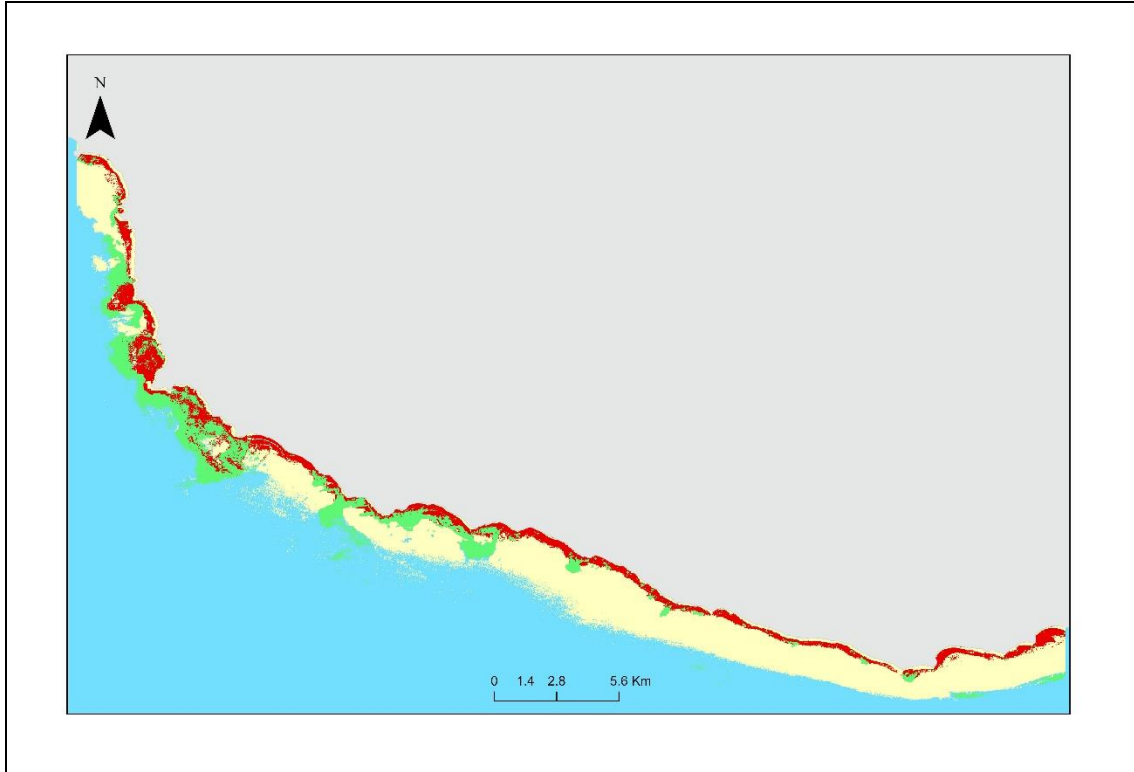


Figure 3: Estimated seagrass distribution; the results were produced with the RF Classification

4.1. Accuracy assessment

Table 2: Accuracy assessment results

Accuracy Assessment RF (100 trees)					
	Seagrass (Class 1)	Soft Bottoms (Class 2)	Hard bottoms (Class 3)	Deep (Class 4)	Producer's Accuracy (%)
Seagrass (Class 1)	7	0	0	1	87.5
Soft Bottoms (Class 2)	0	7	0	2	77
Hard bottoms (Class 3)	0	4	3	1	37.5
Deep water (Class 4)	2	0	0	9	81.8
User's Accuracy (%)	77.7	63.6	100	69.2	
Overall Accuracy 72.2 (%)					
F1-score (%)	82.3	69.7	54.5	75	

The accuracy assessment of the Random Forest classification, using 50 trees, reveals a moderate overall accuracy, with varying performance across different classes. Seagrass (87.5%: PA, 77.7%: UA) and deep water (81.8%: PA, 69.2%:

UA) show strong classification results, while soft bottoms (77%:PA, 63.6%:UA) exhibit moderate performance. However, hard bottoms class (37.5%:PA, 100%:UA, 54.5%:F1-score) is misclassified, mainly as soft bottoms, highlighting the challenge in distinguishing this class. The accuracy assessment results indicate an overestimation of seagrass, soft bottoms and deep water, while hard bottoms are underestimated. Despite these challenges, the classification results are accepted given the complexity of the marine environment.

5. CONCLUSIONS

We provided for the first time a single image classification, with a cloud-based technique with Google Earth engine platform in Cyprus. We mapped in total 20.11 km² seagrass, 69.42 km² Soft substrate, 17.43 km² reefs and 88.03 km² Deep_water. Here, we not only used the advantages of the Earth Observation, but also the cloud-computing which is very promising for regional- to- global scale mapping.

The main issue in marine remote sensing arises mainly due to the water column and the bathymetry and the biases can bring to our result. There is a big issue to discriminate our classes, seagrass, sand and Deep_water, because the seagrass beds in shallow areas have similar spectral characteristics with the soft substrate in deeper areas and the seagrass beds in deep areas have similar spectral characteristics with the Deep_water. We need to find a further step in our analysis in order to extract information from deep water areas, and to process only the desired regions. It is known that the seagrass spreads up to 40m depth maximum, depending on the clarity and the quality of the water column.

It is very important to provide useful tools for the interested stakeholders in order to map the extent of seagrass beds, sandbanks and reefs, due to the importance to the ecosystem and biodiversity. Also, climate change is here, and we need to see how much those habitats have been affected.

There is a big need to find the optimal way to monitor, protect and conserve the valuable species of seagrass, reefs, and soft substrate in Cyprus. There will be a combination of methods, with satellite remote sensing and in-situ measurements. We need to check the suitability of different approaches, methods, and spatial resolutions, taking into consideration the characteristics of Cyprus and cost. The Google Earth Engine platform proves that is a valuable tool for this purpose. It is very important to understand the dynamics of those ecosystems in time and space, and how climate change affects their growth or life cycle.

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