Title:
Seagrass and invasive algae mapping: An Earth Observation approach to support European blue carbon strategies

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Information about you: Currently, I am a 3rd year PhD student in Aquatic Remote Sensing in the ICMAN-CSIC and University of Cádiz (Spain). I have a BSc in Marine Sciences, as well as two MSc: one in GIS and Data Science and another one in Integrated Coastal Zone Management. Since 2021 I am mostly working with optical satellites, ocean colour and machine learning methods to monitor marine macrophytes and water quality. I've been a Guest Researcher in the German Aerospace Center (DLR, Germany) (6 months), enhancing the marine habitat mapping skills using Earth Observation; and at the Universidade Federal de Santa Catarina (UFSC, Brazil) (3 months) working with blue carbon measurements in coastal lagoons and estuaries. All the results obtained during my career have been presented in 13 conferences, including Esri (San Diego, California) and Google (Silicon Valley, California), as well as transferred to Q1 peer reviewed scientific publications. I've been awarded through the Esri Young Scholar Award 2019 and 3 more academic awards. I define myself as a map, data visualization and scientific illustration enthusiast of the marine environment, where I believe geography has the power not only to generate consciousness about the climate change crisis, but to efficiently report the monitoring statistics coastal managers and policy-makers need to evolve in a new paradigm.

Area of interest

The 83% of the total global carbon cycle is regulated by the oceans, where half of this carbon is sequestered in the sediment through coastal habitats, only covering a 2% of the ocean. Those ecosystems, including seagrass and macroalgae, play an outsized role by burying organic carbon in the long term, not only mitigating climate change through future carbon sequestration, but also in terms of avoided emissions. The global seagrass loss since initial records in 1879 is estimated in a 29%, a 1/3 in the European seagrasses, related to water quality, recreational boating and invasive alien species. Only in the EU, 40% of all invasive alien species are macroalgae, where *Rugulopteryx okamurae*, is generating a decline of seagrass meadows in the Mediterranean Sea (Fig. 1).

Figure 1. R. okamurae affecting a seagrass meadow.

In this context, the EU is planning to quantify the blue carbon stored by each European Member State. However, mapping this ecosystem in such a large area is very expensive to accomplish by only using *in situ* methods, as well as to standardize the methodology between Member States. For this reason, I believe that the development of Earth Observations scalable solutions combined with limited *in situ* measurements can contribute to standardize the report of blue carbon storage to the EU in different environmental conditions and reaching regional to national areas.

Approach to the problem

Within this framework, first we accomplished a study of the invasive alien species *R. okamurae* to test if we could monitor it through different sensors and how this information was correlated at different scales (Fig. 2).

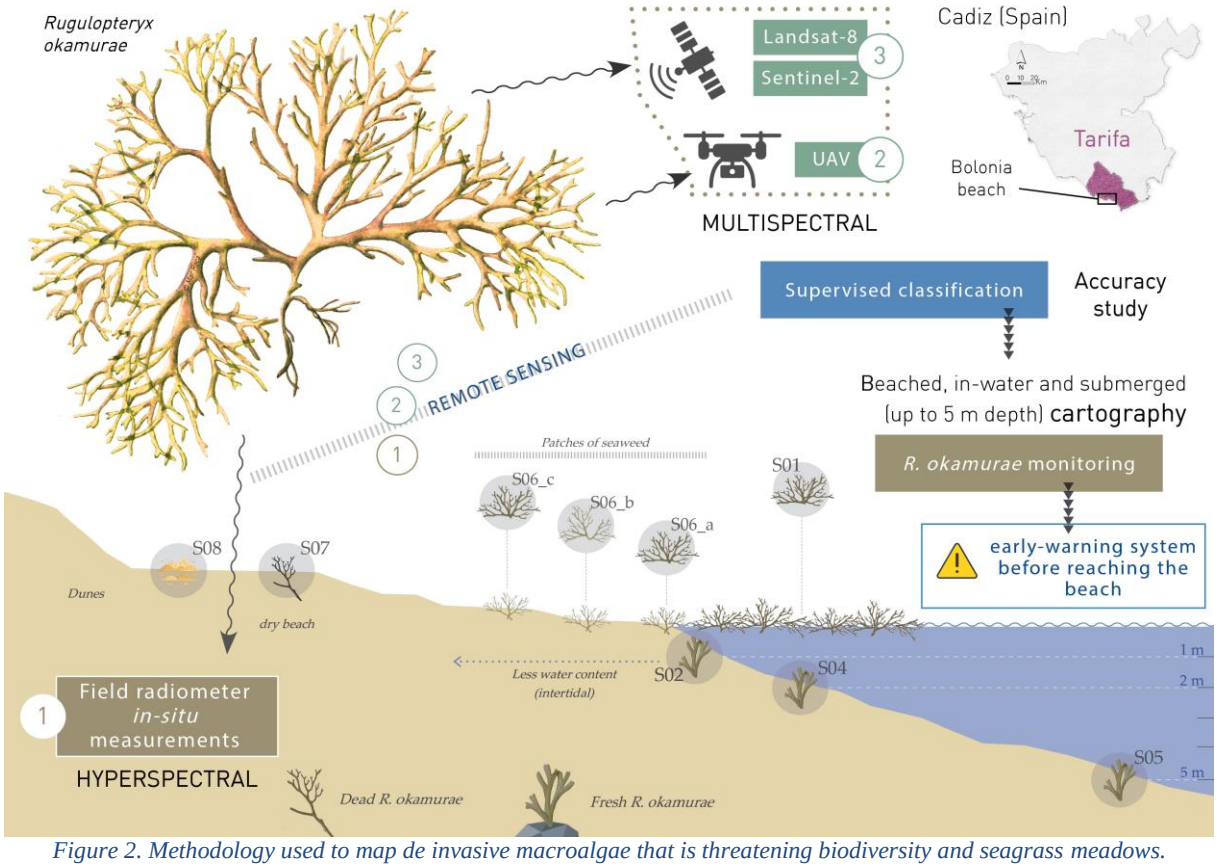

Figure 2. Methodology used to map de invasive macroalgae that is threatening biodiversity and seagrass meadows.

To accomplish this, we used a field radiometer, a multispectral sensor on-board a drone (8 cm pixel resolution) and two different satellites: Sentinel-2 and Landsat-8, at 10- and 30-meter pixel resolution, respectively. We co-related the spectral signatures from all sensors and mapped the macroalgae bloom using the Super Vector Machine Machine Learning (ML) algorithm. With this approach we could detect and quantify the beached, floating macroalgae and submerged macroalgae down to 5-meter depth, also considered as blue carbon, but not at higher depths (Roca *et al*., 2022).

As a second step, we wanted to check the viability of using Sentinel-2 data to reach higher depths mapping existing seagrass meadows in the Mediterranean Sea potentially threatened by this macroalgae. For this, we used a different method that enabled a better result, which is the use of massive amounts of imagery in the cloud computing platform Google Earth Engine to generate a multi-temporal composite, and from that using accurate bathymetric datasets to derive the seagrass cartography using a Random Forest ML algorithm (Fig. 3).

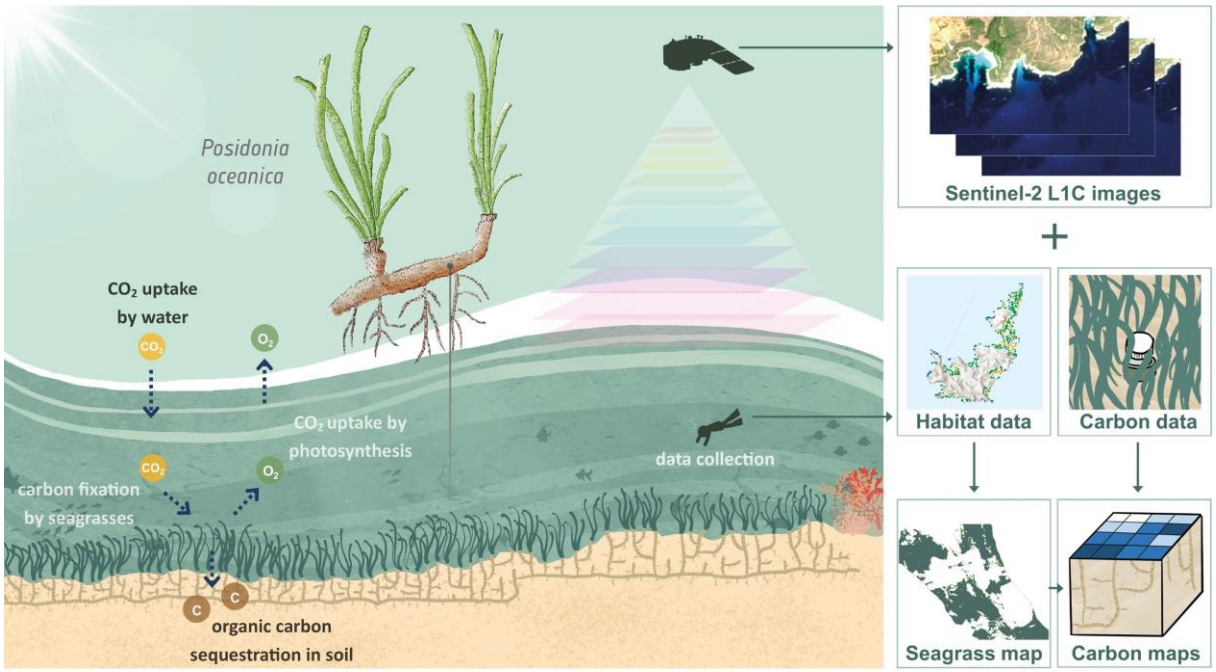

Figure 3. Methodology used to map seagrass meadows and to assess blue carbon storage, sequestration and fixation rates.

Results, conclusions and next steps

First of all, Figure 4 shows how could we quantify the invasion of the invasive macroalgae both through drones and satellites, a method already being used in the southern coast of Spain to monitor the status of the invasion. For mid-term studies, we are monitoring an area with both the invasive macroalgae and seagrass meadows to study the interaction between both species and test if we are able to detect spatial changes.

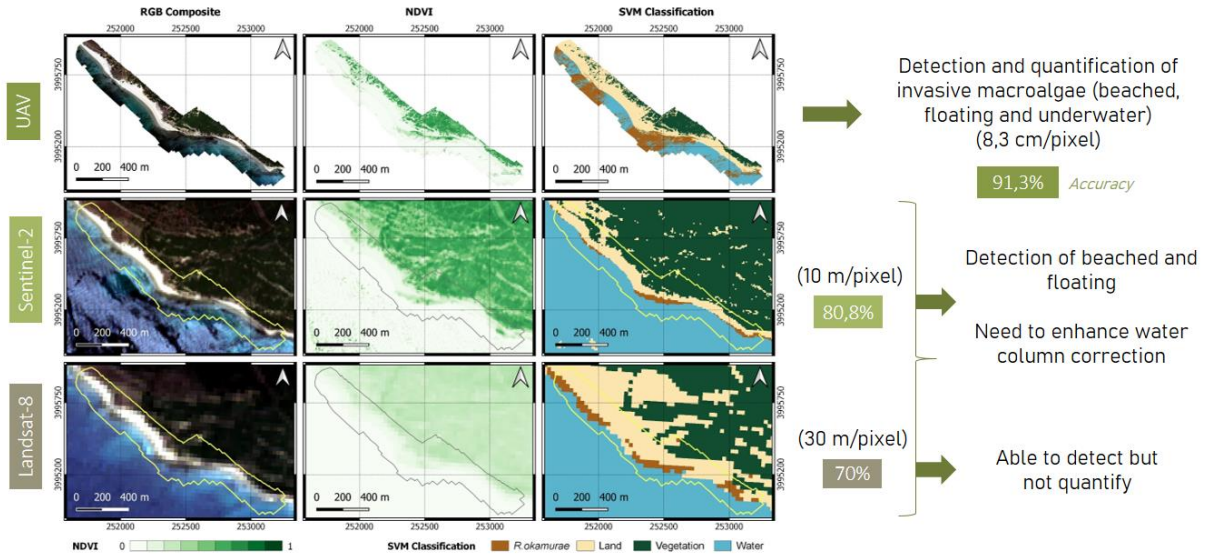

Figure 4. Results of mapping the invasive macroalgae through drones and satellites in the Spanish coast.

The results of the seagrass mapping study (currently under 2nd review in a Q1 peer reviewed journal) had a 92.5% of overall accuracy, enhancing any other published results in the field and reaching down to 30-meter depth in the Mediterranean Sea. Moreover, we included the spatial explicit estimation of carbon sequestration and fixations rates across depth (Fig. 5), an innovative approach and crucial information for policy-makers in successfully implementing European blue carbon strategies.

Within the next steps, I'll be working in blending this remote sensing approach with numerical modelling to better account the carbon estimation under different climate scenarios in the Joint Research Center (Ispra, Italy), within an **Exploratory Blue Carbon Research Project of the European Commission**. This award would be used to partially fund this last step to successfully accomplish my PhD.

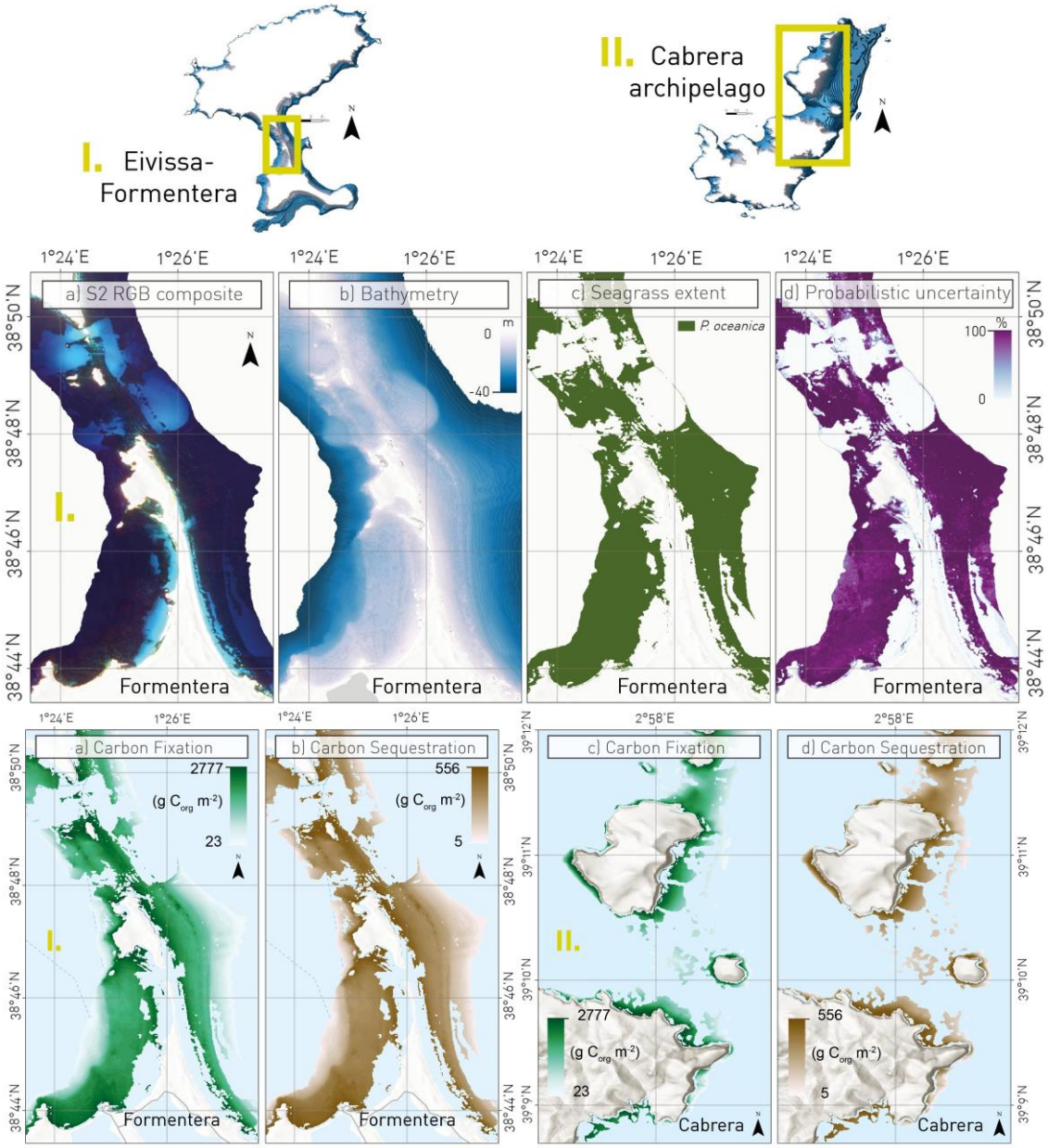

Figure 5. Results under review of the seagrass mapping study and blue carbon estimation.

References

Roca M, Dunbar MB, Román A, Caballero I, Zoffoli ML, Gernez P and Navarro G (**2022**) Monitoring the marine invasive alien species Rugulopteryx okamurae using unmanned aerial vehicles and satellites. Front. Mar. Sci. 9:1004012. doi: 10.3389/fmars.2022.1004012