Characterizing *Sargassum* Accumulations along the Coastline using Satellite Data and Google Earth Engine

Categorización espacial de acumulaciones de sargazo a lo largo del litoral utilizado datos satelitales y Google Earth Engine

Catégorisation spatiale des accumulations de sargasses le long du littoral à l'aide de données satellitaires et de Google Earth Engine

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EXTENDED ABSTRACT

Massive quantities of pelagic Sargassum spp. have accumulated along the Wider Caribbean Region and West African coast as a result of a new Sargassum source region in the Equatorial Atlantic (Gower et al. 2013). Sargassum blooms have been recurrent since 2011 and reached their biggest spatial extent in 2018 when more than 20 million metric tons of biomass was reported in the Caribbean Sea and Central Atlantic Ocean (Wang et al. 2019). Given the persistent favorable environmental conditions for the flourishment of these species, Sargassum blooms has become the new norm (Wang et al. 2019).

Severe impacts of Sargassum beaching events occurred in both ecological and human systems. Observations of Sargassum accumulations on the coast impact the physiochemical characteristics of the water column and the benthic and neritic organisms nearby. The deterioration of the water quality caused by Sargassum decomposition is known as Sargassum brown tide (van Tussenbroek et al. 2017) and can extend more than 480 m from shore (Rodríguez-Martínez et al. 2019). Mortality of seagrass beds and corals have been documented (van Tussenbroek et al. 2017), as well as fauna mortality (Rodríguez-Martínez et al. 2019). Impacts to the social system include the tourism sector (CAST-CHTA 2015), fisheries (CRFM 2016), and human health (Hinds et al. 2016, Nature Foundation St Maarten 2019).

Pelagic Sargassum distribution and abundance have been monitored throughout the Greater Caribbean and Atlantic region using satellite remote sensing (Gower et al. 2006, Hu et al. 2016, Wang and Hu 2016, Webster and Linton 2013). These products are focused on the detection and monitoring of floating Sargassum masses in the open ocean environment (Wang and Hu 2016) but are not suitable to quantify Sargassum accumulations along the coast. There are challenges associated with using remote sensing for Sargassum detection in coastal environments including (1) spatial resolution that could influence how well Sargassum can be detected or differentiated from other land and coastal features, (2) potential contamination of the spectral signature with bottom and land reflectance, (3) presence of other floating aquatic vegetation, and (4) different spectral signatures associated with decomposition stages that happens when Sargassum accumulates on the shoreline.

To better understand the impacts of Sargassum accumulations in both human and ecological systems, we designed a study to assess the social-ecological vulnerability of a coastal community in Puerto Rico to Sargassum influxes. This abstract focusses on the exposure component of this vulnerability assessment. We define ecological exposure as the extent and duration to which habitats experience the presence of Sargassum in one of its forms (fresh, decomposed or Sargassum brown tide). Recognizing the need for Sargassum detection in coastal areas and the challenges associated with it, we undertook the task of developing a method to characterize Sargassum accumulations along the coastline and to understand their spatial and temporal dynamics.

This study takes place in La Parguera Nature Reserve located southwest of Puerto Rico. The reserve encompasses a variety of coastal and marine ecosystems such as mangroves, seagrass beds, coral reefs, emergent keys, and bioluminescent bays. La Parguera is an important tourist destination in Puerto Rico where most of the uses are related to nautical activities such as boating, snorkeling, SCUBA diving, fishing, kayaking and wind and kite surfing (Valdés-Pizzini and Schärer-Umpierre 2014).

The identification of Sargassum accumulations was conducted using data from the MultiSpectral Instrument (MSI) on the Copernicus Sentinel-2 satellite mission. This mission encompasses two polar-orbiting satellites that provide a revisit time of 5 days at the equator and 2-3 days at mid-latitudes under cloud-free conditions (ESA 2019). The data consist of thirteen bands, nine in the visible and near infrared spectrum, ranging from 10 to 60 meters of spatial resolution (ESA 2019). We analyzed MSI satellite imagery for Sargassum occurrence from 2015 to 2021 for a region of interest within La Parguera Nature Reserve. A combination of MSI reflectance bands and several vegetation and water quality indexes were used with a Random Forest supervised classification algorithm. Field data was collected during 2019, 2020 and 2021 to calibrate and validate the classification product. An accuracy assessment was conducted to determine how well the classification model represents reality. The final classification product has a spatial resolution of 10 meters.

The classification scheme consisted of three Sargassum related classes and four additional classes. Our classification model can identify both fresh and decomposing Sargassum, as well as the brown tide generated from decomposing Sargassum. Six independent Sentinel-2 scenes were used for model validation, achieving ≥ 97% overall accuracy. We are currently working on incorporating more field data to strengthen the assessment of the accuracy of the classification model.

Two hotspots of Sargassum accumulations were identified in Isla Guayacan and Isla Cueva in La Parguera. Their spatial and temporal dynamics were assessed from December 2015 to September 2021. All three Sargassum classes were present throughout the study period, however, the largest area of accumulation occurred in 2018. This coincides with satellite observations of Wang et al. (2019) who reported 2018 as the year with the biggest spatial extent of Sargassum in the Caribbean Sea and Central Atlantic Ocean.

Both hotspots experienced annual seasonality for fresh and decomposed Sargassum and for Sargassum brown tide. Maximum areas of fresh and decomposed Sargassum occurred during the wet season (May to October) and had little to no presence during the dry season. Contrastingly, Sargassum brown tide maximums occurred during the dry season a few months after the fresh and decomposed maximum. Similar to observations in other Caribbean coastlines (van Tussenbroek et al. 2017), the impacts of Sargassum in these two accumulation hotspots do not only occur during summer months but throughout the rest of the year as Sargassum brown tide. This finding has important implications when assessing the social-ecological vulnerability of this coastal community to Sargassum influxes.

The method developed in this research provides a tool to assess the spatial and temporal dynamics of Sargassum influxes in coastal areas. This high spatial resolution product will help resource managers and researchers understand the impacts of these ongoing events and identify areas where mitigation efforts are needed the most.

KEYWORDS: monitoring, spatial-temporal dynamics, Sargassum hotspots, Sentinel-2, Puerto Rico

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