Crowdsourcing for *Sargassum* Monitoring Along the Beaches in Quintana Roo

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Abstract. In recent years, the unusual arrival of *Sargassum* to the coasts of the Caribbean Sea has caused considerable damage, both economic and ecological. The monitoring of this macroalgae is a major challenge for researchers. Historically, satellite remote-sensing has been used for this purpose; however, limitations in the temporal and spatial resolution of available satellite platforms do not allow for the monitoring of *Sargassum* on beach coastlines. The increase in the capacity of communication and the decrease in the costs of technology have enhanced users' access to intelligent mobile devices. Crowdsourcing has proven to be successful in combining informational technology with a collaborative solution to complex problems. This study demonstrates how crowdsourcing and the new technologies, can be used to monitor *Sargassum* on the beaches in Quintana Roo, complementing satellite monitoring.

Keywords: Citizen science · Learning from crowds · Observing network · Coordinated observing system

1 Introduction

Sargassum belongs to the group of brown algae Phaeophyta that inhabit the seas around the world. The pelagic *Sargassum* subgroup, that is, the one that floats freely in the ocean, is composed of two species: *S. natans* and *S. fluitans*, the former being the most abundant in the Atlantic ocean. These species, belonging to the Phaeophyta Division, are typically pale brown-yellowish in color and can measure between 20 and 80 cm in diameter [1]. They have numerous nematocysts, which are small vesicles less than 1 cm in diameter that can float because of their gas composition [2]. Under optimal conditions of light, temperature, and salinity, *Sargassum* can double its mass in only 10 days, especially *S. fluitans* [3]. The recent arrival of *Sargassum* from 2018 to date on the Atlantic coast has quickly become both an environmental and a socio-economical challenge, with multi-factorial causes and leading to several unanswered questions.

Remote-sensing through satellite sensors is considered a powerful tool, it has demonstrated to have been important for Earth observation, and it has

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traditionally been the main technique for observing *Sargassum* in the ocean [4]. *Sargassum* monitoring using satellite imagery has been possible for more than a decade, with the implementation of pelagic algae detection algorithms using a wide range of sensors. Some of these algorithms include: Maximum Chlorophyll Index (MCI) [4], MODIS Red Edge (MRE) [5], Index of floating algae (FAI) [6], alternative floating algae index (AFAI) [7] and ERISNet [8]. Most of these algorithms have essentially been used with low or moderate spatial resolution images (larger pixel size at 1 km). This allows for covering more extensive areas in one image and monitoring them more frequently. More detailed spatial scales have also been used, for example, the Landsat-8 [9] or Sentinel-2 [10]. However, the main disadvantage of these data can be found in the temporal resolution; for instance, the Landsat-8 provides an image of the same site each 16 days, which does not allow a daily monitoring. These approaches are limited by inputs, as some sensors may work well in oceanic environments, yet become saturated in coastal environments.

Due to technical limitations, some natural phenomena – such as *Sargassum* blooms – cannot be studied in detail through the use of traditional remote-sensing techniques. *Sargassum* observation along the beach requires daily images with a spatial resolution of less than one-meter. Nonetheless, the features of open source data satellite platforms do not allow accurate monitoring of *Sargassum* along the beaches. Table 1 shows a summary of the spatial and temporal resolution of four of the most important earth observation platforms which offer open source data: Landsat-8[1], through the sensors Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS); Sentinel-2,[2] through the sensor Multi Spectral Instrument (MSI); and Aqua and Terra,[3] through the sensor Moderate Resolution Imaging Spectroradiometer (MODIS) . Other satellite platforms offer imagery with accurate resolutions, but in most cases, they are not appropriate (i.e., they only offer low temporal resolution or they are not affordable). Due to the natural environment of the Caribbean Sea, the presence of clouds does not allow the optical satellite sensors to receive sufficient information. This causes several reactions, including: a) a drastic decrease in the amount of information available for monitoring the *Sargassum*, b) a challenge for conducting observations over extended periods of time (e.g., during rainy and/or hurricane season); and c) zero visibility of the Earth's surface resulting in the generation of false positives in most of the algorithms known in the literature.

2 State of the Art

The term crowdsourcing was coined by Howe et al., in 2006, to describe "the act of taking a job traditionally performed by a designated agent (usually an employee) and outsourcing it to an undefined, generally large group of people in the form of an open call" [11]. Crowdsourcing has been successfully applied in

[1] https://www.usgs.gov/land-resources/nli/landsat.
[2] https://sentinel.esa.int/web/sentinel/home.
[3] https://modis.gsfc.nasa.gov/about/specifications.php.

Table 1. Summary of the spatial and temporal resolution of four of the most important earth observation platforms which offering open-data: Sentinel-2, Landsat-8 and Aqua-Terra

Satellite platform	Sensor	Resolution	
		Time [days]	Spatial [m]
Sentinel 2	MSI	10 single 5 both	10, 20 & 60
Landsat 8	OLI & TIRS	16	15, 30 & 100
Aqua Terra	MODIS	1 or 2	250, 500 & 1000

numerous areas, including: Image Classification (CellSlider, Galaxy Zoo, Phylo, MOLT, Polyp Classification for Colon Cancer Detection), Character Recognition (ReCAPTCHA), Genome Annotation, Document Translation (DuoLingo), Protein Folding, RNA Structure Design (Foldit, EteRNA), and Algorithm Development (DTRA) [12]. Meteor Counter[4] is a platform launched by NASA for individual citizens to observe meteors. Creek Watch[5] was developed by IBM for monitoring and managing water resources. SciSpy[6] allows users to take screenshots of the plants and animals that are found. Finally, Greenappsandweb[7] is a platform that includes various applications for individual citizens with diverse objectives.

Another highly successful application related to ecology and biodiversity monitoring is iNaturalis, a citizen science project and online social network of naturalists, scientists, and biologists. This application maps and exchanges biodiversity observations around the world. One of the main features of this platform is that the information obtained can be widely accessed and is open-source data [13]. Epicollect, managed by the Big Data Institute of the University of Oxford, is a very robust platform in which, in addition to images, different data can be captured in text format through its user interface. It is designed for an expert user (e.g., scientists, technicians, and students), so it becomes complex for someone who is not familiarized with the topic [14].

In terms of *Sargassum* monitoring, the Marine Macroalgae Research lab at Florida International University (MMRL-FIU) is studying the occurrences of washed-up *Sargassum* landings on South Florida and Caribbean coastal areas, through the project "*Sargassum* Watch". This project is powered by the iNaturalist platform [15]. In early 2020, the *Sargassum* Watch project has 980 observations that have been carried out by 577 people. It contains mostly images related to the object of study since the intention is to taxonomically identify the image in each snapshot; however, there are also panoramic photographs. Additionally, MMRL-FIU linked the "*Sargassum* Watch" project to the "Epicollect" platform. The use of Epicollect allows for downloading the data and metadata

[4] http://ww17.meteorcounter.com.
[5] http://creekwatch.researchlabs.ibm.com.
[6] http://www.sciencechannel.com.
[7] https://www.greenappsandweb.com.

in different formats, enabling the interested community direct access to all of the information available. To date, there are 1,367 photographs in Epicollect [16]. On the other hand, in Mexico, the "National Commission for the Knowledge and Use of Biodiversity" (CONABIO)[8] manages the project "Monitoring pelagic *Sargassum* in the Mexican Atlantic" on the "Naturalista" platform. In early 2020, CONABIO's project has 154 observations which have been carried out by 50 people. Photographs include both close up and panoramic shots of *Sargassum*.

Several studies have demonstrated that crowdsourcing is a useful methodology for collecting and managing data. In the following section, this paper explains how the use of a novel crowdsourcing platform allowed for monitoring *Sargassum* on the beaches in the state of Quintana Roo.

3 Crowdsourcing for Monitoring *Sargassum* Along the Beaches in Quintana Roo

A pilot test was carried out in order to answer the question "Is crowdsourcing a useful technique to monitor *Sargassum* on the coast of Quintana Roo?" This pilot test consisted of creating and testing an infrastructure capable of collecting, processing, and distributing information related to the topic of the study. The platform was tested by dozens of users who participated voluntarily during the testing phase.

In short, the platform created is divided into two components: first, a mobile App that allows users to collect and send information regarding the *Sargassum* on the beaches; second, a central server that concentrates, analyses, and distributes the information collected by the users. In order to create the mobile application, we used the Java programming language and the Android operating system. For the implementation of the platform, we used Google Firebase. To analyze the data, we used the Python programming language with some libraries (e.g., pandas and scikit-learn). Finally, ESRI ArcGIS Online was used for the visualization and creation of the maps.

The process of monitoring *Sargassum* on the beaches in Quintana Roo through the use of crowdsourcing is shown in Fig. 1. The different stages included: data collection, data preprocessing, product generation to support decision making, data visualization and distribution of results as open source data to encourage other researchers to collaborate and extend the scope of the results obtained. The following sections demonstrate how crowdsourcing was used to improve the monitoring of the presence/absence, accumulation, and distribution of *Sargassum* on the beaches in Quintana Roo, complementing the classical satellite remote-sensing techniques currently employed.

[8] https://www.naturalista.mx/projects/monitoreo-de-sargazo-pelagico-en-el-atlantico-mexicano.

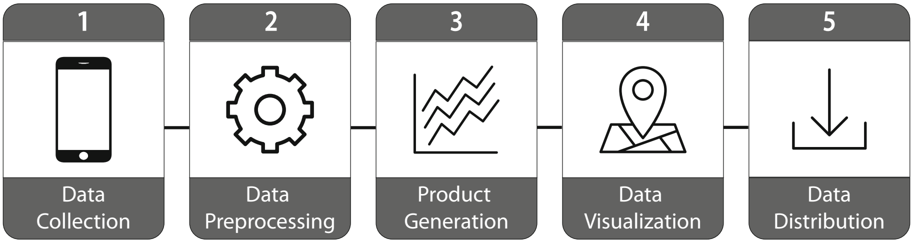

Fig. 1. Data flow of the monitoring process

The first stage in the process of monitoring was the collection of the data. To obtain the data, we developed a mobile application that allowed users to gather information about the condition of the beaches and upload the data to the platform on the cloud. The data collected included: medium-resolution photos (see Fig. 2), time, date, and geographic coordinates that allowed for determining the exact location of each photograph.

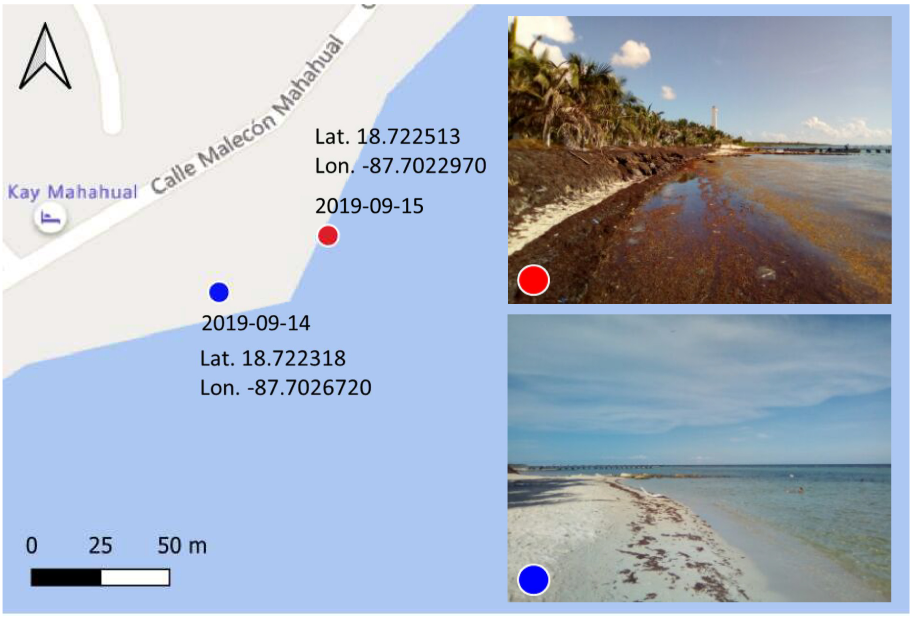

Fig. 2. Geo-located images collected by the users of Mahahual (Quintana Roo, Mexico) from September 14 and 15, 2019.

Since we wanted the system to be adopted by as many users as possible, the proposed model did not require users to have previous experience in monitoring the beaches. Higher volumes of information collected and uploaded by users of the platform resulted in an increased accuracy of the system. Based on the hypothesis that the users were distributed along the beaches, despite having little information, the system was able to determine the condition of nearby areas where the information was originally collected, creating an approximate global image of the condition of the beaches.

Once the data was received, the second step of the process began. The preprocessing stage included all of the necessary preparation for building the data-set that would be used in the next stage. Data preprocessing activities included: data cleansing (i.e., dealing with missing or invalid values, removing duplicates, and formatting appropriately); combining data from multiple sources (e.g., files, tables, platforms); and transforming the data into more useful variables. During this stage, images were also analyzed and classified into two groups: images with and without the presence of *Sargassum*. Furthermore, images with elements that are unrelated to the interest of this study were discarded. When all of the images were classified and the data was prepared, everything was stored in a geospatial database for the product generation.

In order to classify the set of data properly in two groups (i.e., images with the presence of sargassum and images without the presence of this macro-algae), the following strategies were used. First, the original set of images was classified by an expert into the two groups mentioned previously. Then, the new data set was again divided, forming two subsets: a training dataset (80%) and a validation dataset (20%).

Using the knowledge transfer technique, a pre-trained AlexNet neural network (for the ImageNet dataset) was employed. In order to fulfill the purposes of this study, we adapted the network by modifying the last layer. This made the classification of the two groups possible (e.g., presence and absence of sargassum). The technique of augmented data was used due to the small and unbalanced set of images obtained. Additionally, the K-Fold cross-validation test was used to improve and give certainty to the results.

Through Google Colab, Python programming language and the PyTorch library, a GPU was used to perform a 10-hour training process for 1000 epochs. The results demonstrated an accuracy of more than 90%. Considering the data set available, we consider this to be a good result. As part of our future work, we will continue to improve the process of generalizing the network using the images that become available.

Figure 3 shows some examples of images with the presence of *Sargassum*. A great diversity of elements can be observed in each of the photographs (e.g., *Sargassum*, garbage, sand, water, clouds, boats, piers, buildings, and palm trees). In addition, it is possible to see multiple differences between the photographs (i.e., illumination, color, angle, light, type of close-up, and camera position). This represented a big challenge for automatic classification.

At the end of the data preprocessing stage, the information was analyzed, resulting in a set of tools that can be used to inform the condition of the beaches in near real-time. This benefits the population, especially visitors who use the

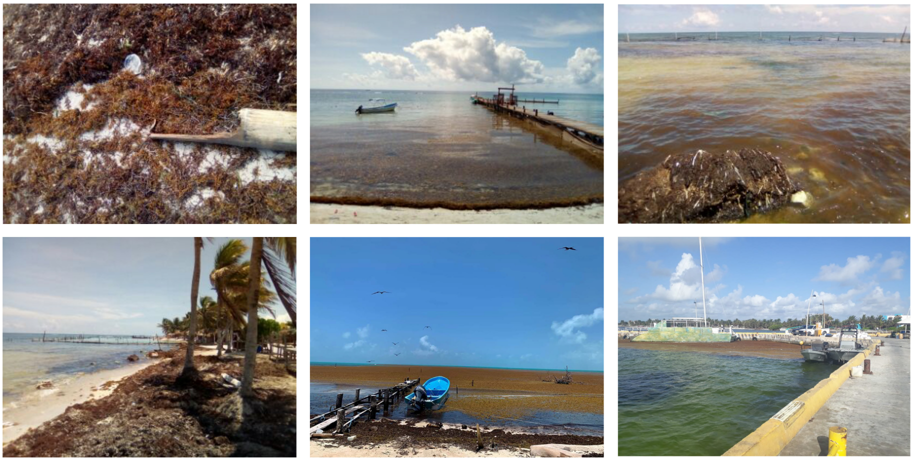

Fig. 3. Some examples of the different types of photographs and the wide diversity of elements in the images obtained through Crowdsourcing.

beaches as recreation and rest areas. Additionally, these tools can serve as support for local authorities responsible for cleaning and conserving the beaches.

As part of the products that are currently being generated in the third step of the process, the following are included:

- Definition of areas with and without the presence of *Sargassum*.
- Creation of heat maps that indicate user activity.
- Analysis of time series to study the behavior of the platform.
- Design of reports that examine the state of the various beaches for which information is available.

The visualization of the collected data is a fundamental step during the monitoring process since it enabled us to observe and identify the current condition of the beaches. Furthermore, it served to identify possible distribution patterns of the accumulated *Sargassum* in defined time intervals. This could be fundamental for the planning and preparation stages before the arrival of these macroalgae.

The use of maps for visualizing the data was indispensable. As shown in Fig. 4, the geolocation of the points on the map allowed for conducting studies using geographic information system tools (e.g., heat maps). In the case of heat zones, each one highlights the areas or beaches with the most activity by users. More data allowed the monitoring system to be more robust from a statistical point of view. The status of the areas that had higher activity allowed to infer the status of nearby areas with high precision, even when there was not sufficient information from such zones directly.

Other methods of visualization of the information included different types of charts and graphs (e.g., pie, bars, and lines). These visual representations helped summarize the data collected in an executive way. Some examples included the

Fig. 4. Data points collected for Mahahual beach.

total points per zone, the zones with more photos that report *Sargassum*, the progression of activity by users over time, among others (see Fig. 5).

It is important to highlight that the proposed system was not only in charge of monitoring the areas with the presence of *Sargassum*. It also highlighted the areas that did not have the presence of this macroalgae. This is useful for tourists because it allows them to make decisions about which beaches they should or should not visit. With a correct classification of the images, the proposed system can automatically generate a status (e.g., green, yellow, red) that indicates the areas that are ideal for their visit and those areas where the authorities should focus their efforts to carry out the cleaning process.

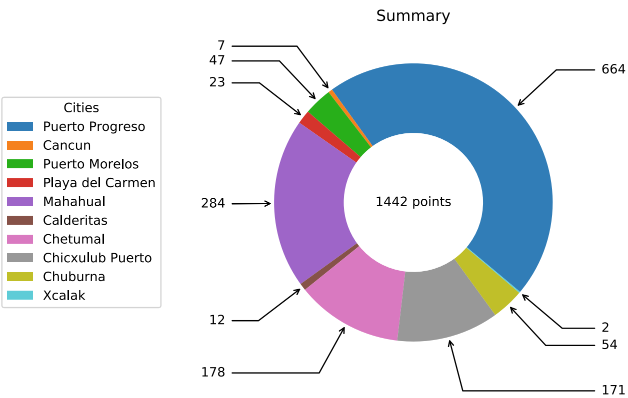

Fig. 5. Point per zone report

The final step in this process was related to data distribution. Due to the origin of the data as well as the impact that the results can have for further research related to the monitoring of *Sargassum*, it is necessary to distribute the data obtained permanently and transparently in the open source data model. The publication of information as Open Source Data is an increasingly common practice that aims to make certain types of data freely available to everyone, without restrictions of copyright, patent, or other control mechanisms. Open source data can come from any source, such as scientific results, governments, private companies, and others.

One of the main reasons why more and more organizations are publishing their data is due to interoperability, which denotes the ability of diverse systems and organizations to work together. In our case, interoperability was defined as the ability to integrate different data-sets for the study of the accumulation, distribution, and behavior of *Sargassum* on the beaches in Quintana Roo. This ability to integrate components is essential for building complex systems. Without interoperability, it is almost impossible to achieve - as demonstrated by the famous myth of the "Babel Tower" where the inability to communicate resulted in the collapse of the entire effort to build the tower.

4 Results

In order to evaluate the sustainability of using crowdsourcing as a method for collecting data related to the presence and absence of *Sargassum* on the beaches in Quintana Roo, the application we designed was distributed and tested with a total of 32 citizens who voluntarily obtained images of the most frequently visited beaches in Quintana Roo. Table 2 shows a list of the beaches and the number of photos obtained.

Table 2. Number of photos obtained for the Quintana Roo state beaches

Location	Data points
Mahahual	**284**
Chetumal	178
Puerto Morelos	47
Playa del Carmen	23
Calderitas	12
Cancún	7
Xcalak	2

At the same time, the same activity was also carried out, with a total of 16 people, in some beaches in the state of Yucatán. The results are shown in Table 3.

The period during which the piloting was carried out took place between July 1, 2019 and October 31, 2019. At the end of the piloting phase, 1442 photos were

Table 3. Number of photos obtained for the Yucatán state beaches

Location	Data points
Puerto Progreso	**664**
Chicxulub Puerto	171
Chuburna	54

obtained from the states of Quintana Roo and Yucatán in Mexico, by a total of 48 participants.

As demonstrated in Fig. 6, at the beginning of the piloting phase, the activity uploaded by participants was very low, almost null. The number of photos during the first month was zero. This could be due to a number of reasons, including the lack of knowledge on how to the use the application, or the lack of awareness on behalf of the participants about the relevance of their participation for monitoring *Sargassum* on the beaches.

Beginning in the second month of the study, a progressive increase in the activity can be observed, which implies an increasingly active participation by the community. Figure 6 shows that, at least for this study, the processes involving crowdsourcing require a minimum time before they are adopted. Thus, this type of projects are not adopted immediately, which leads to very interesting conclusions regarding the minimum average time that must be considered before the information from individuals starts to flow continuously.

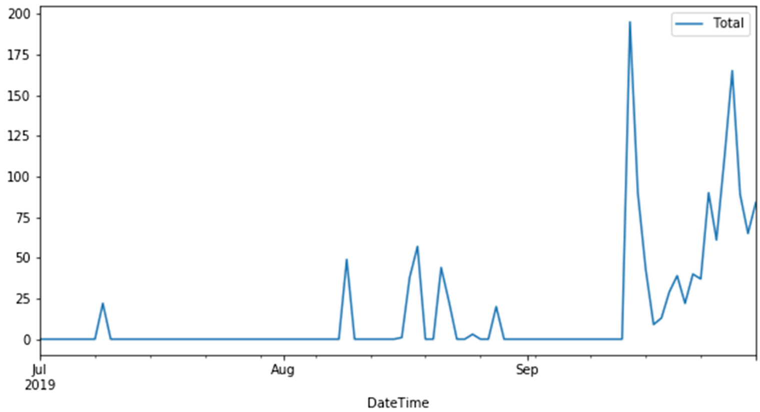

Fig. 6. Application activity

To exemplify the advantages of Crowdsourcing, we can visualize that we are interested in knowing the beach conditions of Mahahual for September 15, 2019. Around that date, the Landsat platform offers two scenes, one for September 9 and 25 (Landsat-8 imagery courtesy of the U.S. Geological Survey). On the other hand, the Sentinel-2 platform offers us 5 scenes: September 9, 12, 14, 24, and 29 (Sentinel-2 imagery courtesy of the European Space Agency). The scene closest to the desired date is that of September 14 from the Sentinel 2 platform; however, due to weather conditions, it is only possible to observe a cloud over the city of Mahahual. The next closest date with images available is September 9. Figure 7 shows the scenes of the Landsat and Sentinel platforms corresponding to September 9, 2019. In Fig. 7a, the image of Landsat 8 is emphasized, and in Fig. 7c the image of Sentinel 2 is emphasized. In both figures, it is possible to appreciate the differences in spatial resolution between the two platforms. Figure 7b is a close-up of the Landsat-8 image with pixels of 30 m per side. Figure 7d is a close-up of the Sentinel-2 image with pixels of 20 m per side. In Figs. 7b and 7d, it is possible to observe that the pixels corresponding to the beach mostly present information on both land and water, so they are not a reliable input to be used in the different algorithms for monitoring *Sargassum* and generally do not offer reliability for any type of analysis.

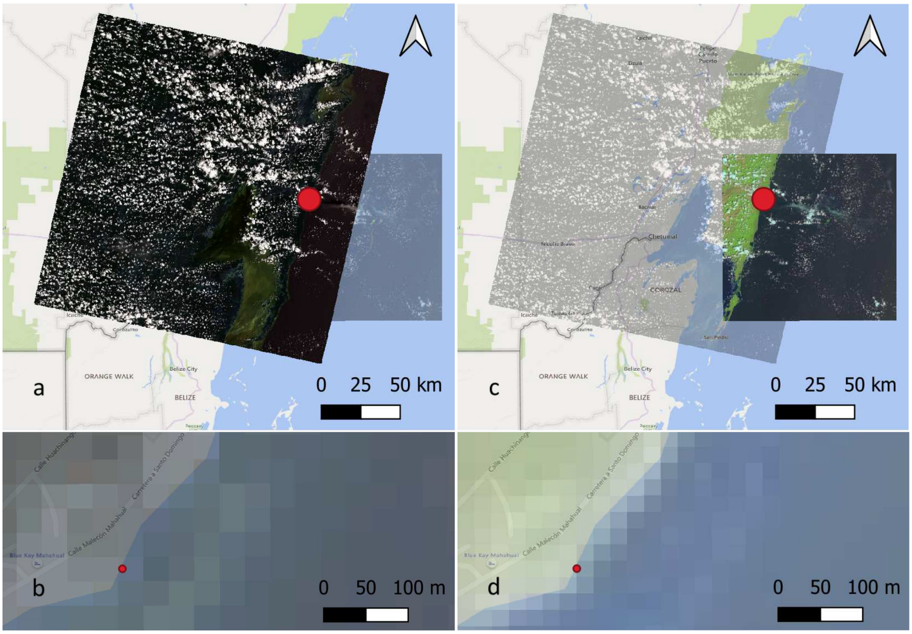

Fig. 7. RGB imagery from the south of Quintana Roo, Mexico, a) Landsat-8, b) Landsat-8 Close-up, c) Sentinel-2, d) Close-up Sentinel-2.

As a summary, there was no information from remote sensors. However, with crowdsourcing, we were able to obtain the imagery to carry out the *Sargassum* monitoring. This exercise exemplifies how, in some cases, the participation of citizens from the community contributes to satellite information and has the potential to become an alternative source of data.

5 Conclusions

The present study demonstrated the sustainability of crowdsourcing as a method that can be useful for monitoring the presence or absence of Sargassum along the beaches in Quintana Roo. However, there are challenges that must be addressed to guarantee the possibility of continuing the monitoring over an extended period of time, which could be months or years. This study found both advantages and challenges to crowdsourcing. In the present study 1142 photographs were uploaded to the platform, from 10 different cities distributed along two states of the Yucatan peninsula, without incurring in any logistical expenses. The pictures obtained allowed for monitoring the beaches. On the other hand, we encountered several challenges as well. Crowdsourcing is well accepted by small ecology-sensitive organizations (e.g., turtle protection groups), as well as by scholars and institutions interested in coastal ecosystems. Nevertheless, the participation of society, in general, was very low despite the dissemination carried out through conferences in different institutions and social networks. We consider that this low participation is because crowdsourcing is not a common habit in society, at least not in the southeast of Mexico. This should be considered in further research when using this method for data collection. In order to ensure higher success rates when using this type of methods, we suggest networking with social sciences experts. Another technological challenge we faced and could be improved is the automatic classification of images. As a positive feature to the study area, in the past few years, the tourism industry has increased the telecommunication infrastructure along the coastline of the state of Quintana Roo, mainly in the northern area, including Benito Juarez, Isla Mujeres, Puerto Morelos, and Solidaridad. Therefore, this study considers that crowdsourcing could be a powerful method to support Sargassum monitoring along the beaches in this geographical area, as long as the participation of society as a whole is guaranteed for the entire study period.

This study demonstrated that crowdsourcing allowed for generating data and information that did not exist previously. This method is potentially useful for other researchers. However, we suggest that for this type of tool to be considered more advantageous, it is necessary for large numbers of people to adopt it and participate in a coordinated way during the different stages of the process. Crowdsourcing brings together society, researchers, industries, and the government, all working collectively for the benefit of the environment. One strategy we recommend to involve more users, is creating synergy among organizations, associations, and companies that coexist along the beaches; for example, turtle protection groups, garbage-monitoring teams, hoteliers, and government institutions are all focused on preserving the beaches along the coasts and could benefit crowdsourcing tremendously.

6 Future Work

The main objective of this study was to show if the use of crowdsourcing could support the monitoring of Sargassum along the beaches in Quintana Roo by complementing traditional satellite remote sensing techniques. Many aspects of this study can be improved (e.g., increasing the neural network accuracy, enhancing the web and mobile platforms, and/or extending the number of users). However, one of the most important aspects that has not yet been achieved, is ensuring the sets of images collected through the platform are available for all the interested parties (researchers and community in general). As part of our future research, we must focus on resolving the legal and logistical aspects related to this matter, so that the information can be accessed freely without incurring in copyright problems.

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