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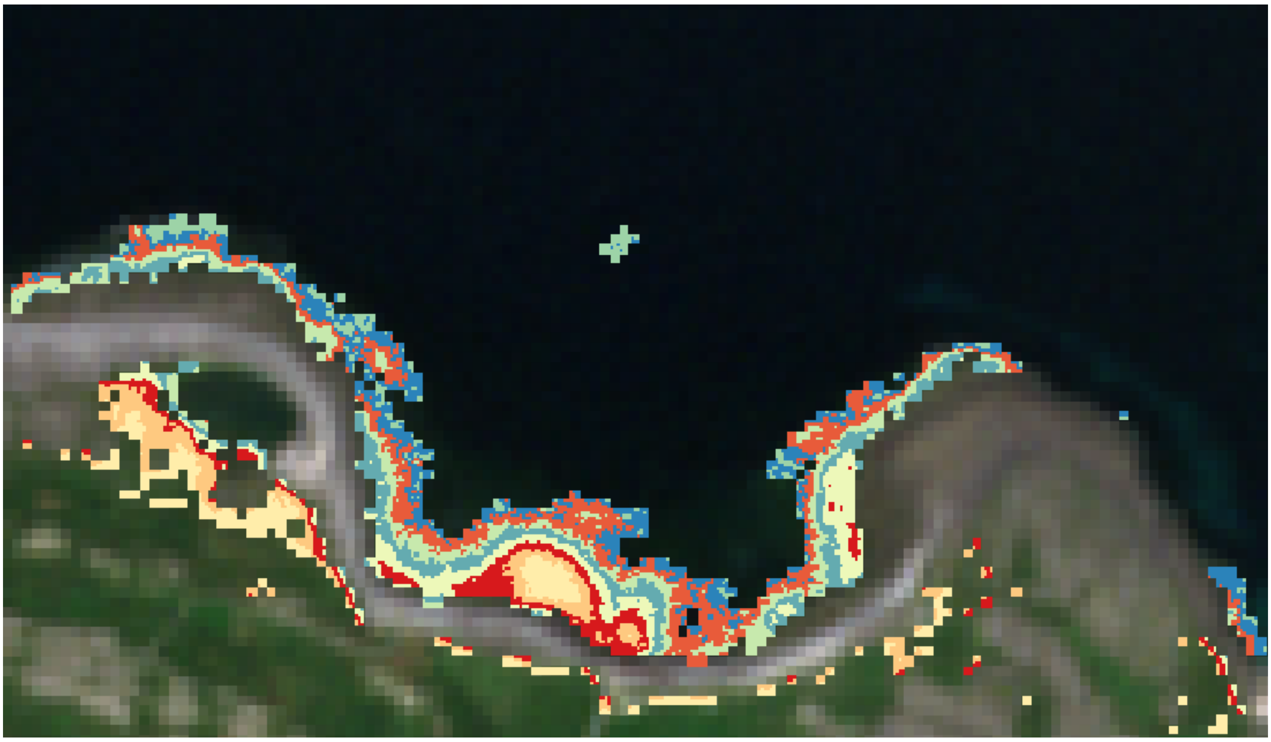

TECHNICAL REPORT OF PHASE 2

Remote Sensing Data Analysis to Classify Different Seaweeds Species

Committee:		**Document developed by:**
____________________		T.E.R.R.A. S.r.l. Dott. Filippo Tonion
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SUMMARY

1. INTRODUCTION

Coastal areas management and monitoring represents a crucial challenge for future, especially considering the effects of climate changes. Coastal areas are fundamental because of the fragility of their ecosystems and because of the high number of human activities within these areas (navigation, urbanisation, fishery…ecc.).

The harvesting of wild seaweeds continues to play an important cultural and socioeconomic role for many coastal communities on Ireland's Atlantic seaboard. Although Irish waters contain a diverse and substantial benthic seaweed flora, only a few species are exploited commercially. Historically in Ireland, seaweed was commercially used as a raw material in the production of high-volume, low-value commodities such as animal feed and raw material for alginate production. Recently, with increasing acceptance of seaweed as a sea vegetable and its ever-increasing role as a raw material in the cosmetic and pharmaceutical industries, there has been a renewed vigour in the Irish seaweed industry particularly with new entrants into the human nutrition and cosmetic markets producing high-quality, high-value products.(Mac Monagail & Morrison, 2020).

In this contest Remote Sensing techniques represents an important support for monitoring activities and to plan a sustainable usage of seaweed resources. In particular Remote Sensing can give support in different aspects, such as increased geographical coverage and repeated measures over time (Vihervaara et al., 2017), that is fundamental also to understand effect of seaweed collection on the coastal ecosystems.

The Remote Sensing approach can be easily implemented considering the rapid development of the last years, that concerned in particular the following aspects:

- Technology development. The quality of satellite data is constantly improved in the last years in term of spatial, temporal and radiometric resolution. This allows end user to plan effective monitoring activities.
- Data Analysis Techniques.The precision of Remote Sensing Based Analysis has been really improved in past years, using advanced data analysis techniques based on Artificial Intelligence (AI); among the most effective models for remote sensing data analysis can be found some Machine Learning algorithms, like Random Forest(Breiman, 2001), Support Vector Machines(Steinwart & Christmann, 2008) and K-Nearest Neighbors(Keller et al., 1985) that are particularly precise both in regression and classification problems.

Considering the extremely positive results of the first phase of the job, during the second phase the aim was to evaluate the potential of remote sensing based classification of seaweeds, using different satellite platforms on a particular area of interest.

The following chapters provide a description of methodology applied, results obtained and future perspective for coast environment monitoring using remote sensing and artificial intelligence.

2. MATERIALS AND METHODS

The analysis of seaweed presence was based on Remote Sensing data analysis and was developed through different main steps, that are:

- Definition of Area of Analysis
- Choice of Satellite Data;
- Satellite Data Processing;

In the following chapters it is provided a description of the mentioned phases of the work.

2.1. DEFINITION OF AREA OF ANALYSIS

The Area of Analysis considered for this phase of the work consisted of a part of the Aran island, considering the availability of ground surveyed data, collected with multispectral drones.

In particular the following map shows the extension of the study area for phase 2.

Figure 1 Boundaries of Study Area

The study area showed in the previous picture is extended approximately 1,814 km^2, distributed along approximately 4 km of shoreline.

2.2. CHOICE OF SATELLITE DATA

Considering the aim of the work it was decided to consider two different kind of satellite data, that are:

- **Sentinel-2**, considering that the algorithm for seaweeds detection built in phase 1 was based on Sentinel-2 data.
- **Planetscope 8**, considering that for this work Planetscope gave the possibility to test some samples of the new 8 band product, the so called Superdove, that consist of a significant update of the existing Dove constellation (4 bands).The Superdove product have a spatial resolution of 3m.

The following picture provides a comparison of spectral resolution of the two platforms considered.

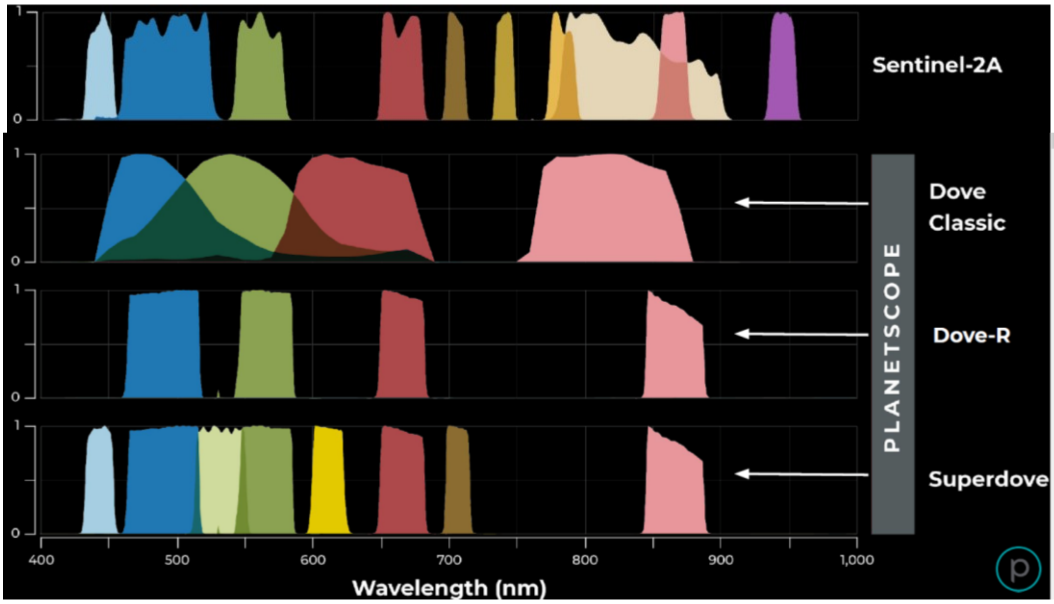

Figure 2 Comparison of Sentinel-2 and Planetscope Superdove Spectral Resolution

Considering the availability of a data from a ground survey collected on 28/05/2021 on the Bantry Bay, it was decided to acquire Sentinel-2 data for that day, in order to have a starting point for classification.

For what concerns Sentinel-2 data it was decided to use the following two products:

- T29UMU_20201017T114359 collected on 17/10/2020, having the availability of ground survey images, acquired on Aran Island on the 16/10/2020.
- T29UMU_20210828T114351 collected on 28/08/2021, in order to compare Sentinel-2 with Planetscope Superdove.

For what concerns Planetscope product the available data for Aran Island were acquired on 28/08/2021 (20210828_105426_06_2436_3B_AnalyticMS_SR_8b).

The following pictures provide a comparison of Sentinel-2 and Planetscope Superdoves true color image for the study area.

Figure 3 Sentinel-2 Data for the Study Area – Date of Acquisition 28-08-2021

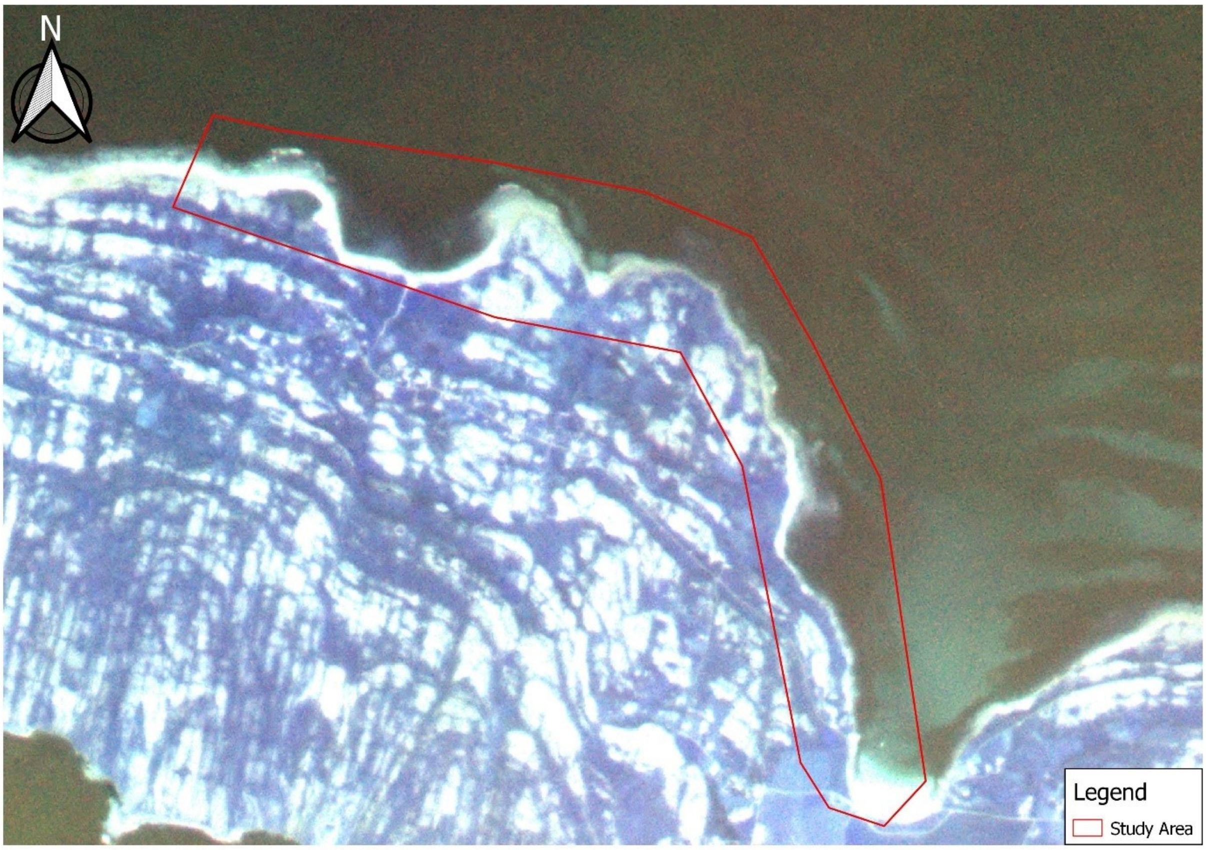

Figure 4 Planetscope Superdove – Date of Acquisition 28-08-2021

2.3. SATELLITE DATA PROCESSING

The processing phase of satellite data started applying the algorithm developed in the first phase of the job; the processing milestone is the innovative Variable Amplification Process (VAP), that lead to significant improvement in the study of Satellite Derived Bathymetry (Tonion et al., 2020). The VAP consist of a processing phase of raw satellite bands in order to create new meaningful variables to be used as predictors in the study of a particular phenomenon. The following picture gives a graphical representation of VAP.

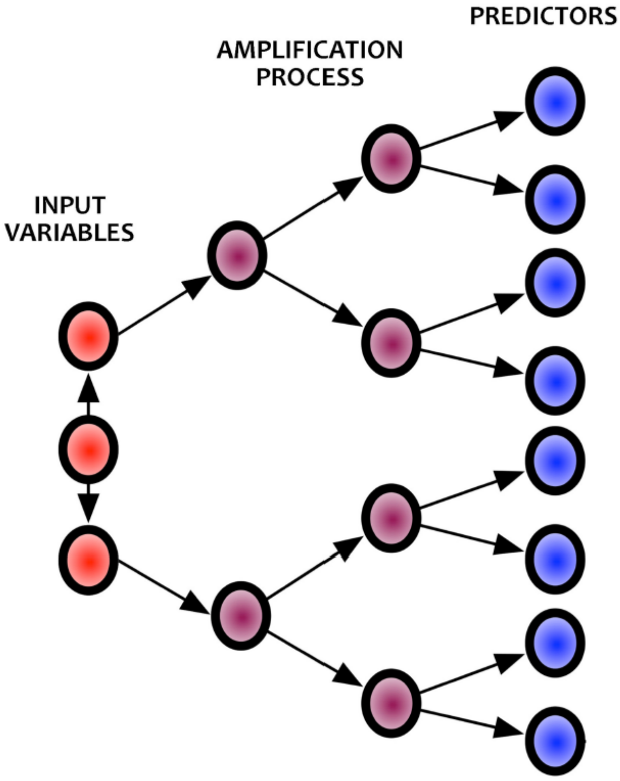

Figure 5 Scheme of Variable Amplification Process

The Sentinel-2 data were processed to obtain the class identified with the trained model developed in the Phase 1, that are:

1) <u>Seaweeds.</u> This is the main target class, and includes different kinds of seaweeds.
2) <u>Water.</u> This class include sea water without the presence of seaweeds.
3) <u>Rock.</u> This class includes rock out of the water.
4) <u>Fine Sediment.</u> This class includes fine sediments out of the water.
5) <u>Vegetation.</u> This class comprehend vegetation element outside sea water.
6) <u>Cloud.</u> This class includes cloud cover areas within the study area; this class helps only in masking cloud covered area in order to don't produce misclassification once the process will be fully automated.

After this processing phase all raster data of predictors were masked and only those area identified as "**<u>Seaweeds</u>**" were maintained for the following analysis.

Considering only the Seaweeds area both Sentinel-2 images were processed with an iterative k-means unsupervised classification algorithm, in order to extract meaningful information from the seaweeds area.

The iterative procedure aimed to identify the best number of centers for the kmeans algorithm.

Planetscope SuperDoves data were processed to extract different predictors, that are:

ID	Index	Description	Formula	Reference

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Table 1 Spectral Index calculated for the Superdove data

Once all predictors were extracted the all rasters were masked, keeping in consideration only those areas identified as "Seaweeds" after the processing phase of Sentinel-2 data. It was not possible to recalibrate the algorithm in order to identify seaweeds on Planetscope Superdove, considering the limited spatial extension of the samples acquired.

After the masking procedure the same iterative procedure applied on Sentinel-2 data was replied on Planetscope ones. The unsupervised kmeans classification procedure was studied to extract meaningful classes within seaweeds areas.

The analysis of results dealt with two different kinds of analysis, that are:

- Comparison of Sentinel-2 Unsupervised Classification with UAV data collected on 16/10/2020.
- Comparison of Sentinel-2 Unsupervised Classification with Planetscope Superdove one, on data collected on 28/08/2021.

The following chapters contains a discussion and an analysis of the results obtained.

3 RESULTS AND DISCUSSION

The following picture shows an extract of the UAV flight over Aran Island, acquired on 16/10/2020.

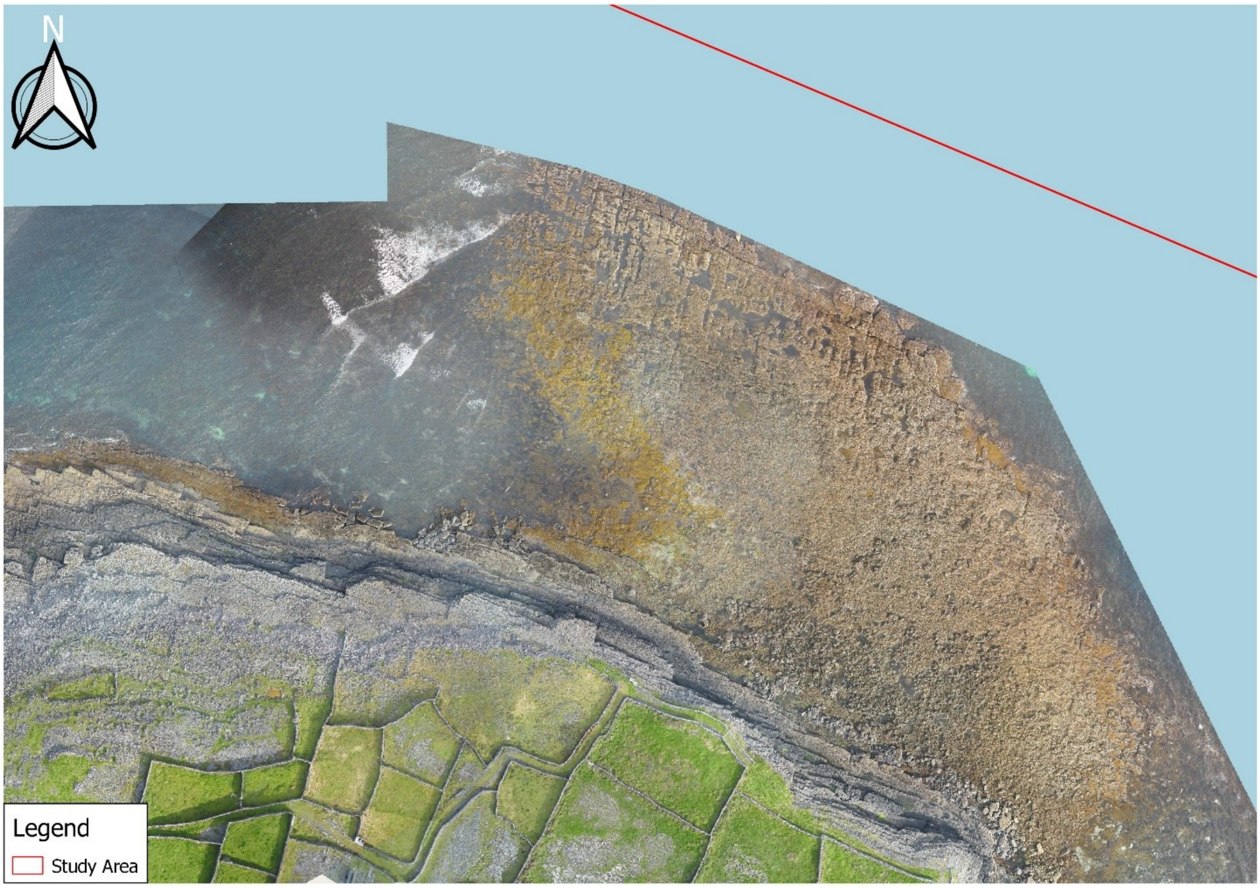

Figure 6 UAV RGB acquisition on Aran Island 16/20/2020

After applying the unsupervised kmeans based classification with Sentinel-2 data, it was obtained the map showed in the following figure.

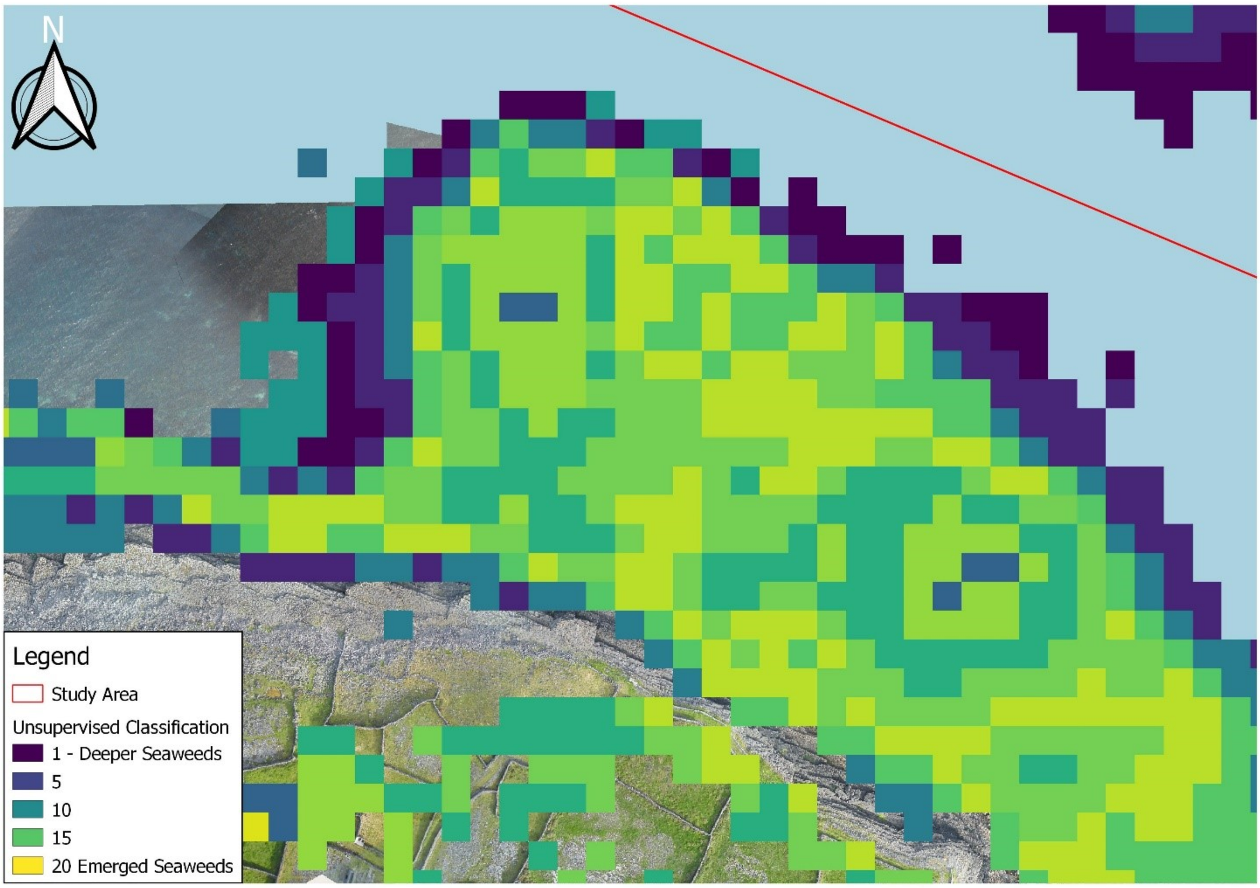

Figure 7 Unsupervised Classification obtained with AI kmeans based algorithm on Sentinel-2 data

As it is possible to notice from the analysis of the previous picture, compared with Figure 6, generally the algorithm is capable to distinguish more and less submerged seaweeds.

Considering the spatial resolution of Sentinel-2 (10 m), the presence of rock or mixed classes within a pixel can affect the result of the classification. The presence of both rocks and emerged seaweed can be observed, by analysing the following figures, which shows the point of photography acquisition on 16/10/2020 and the ground collected photo.

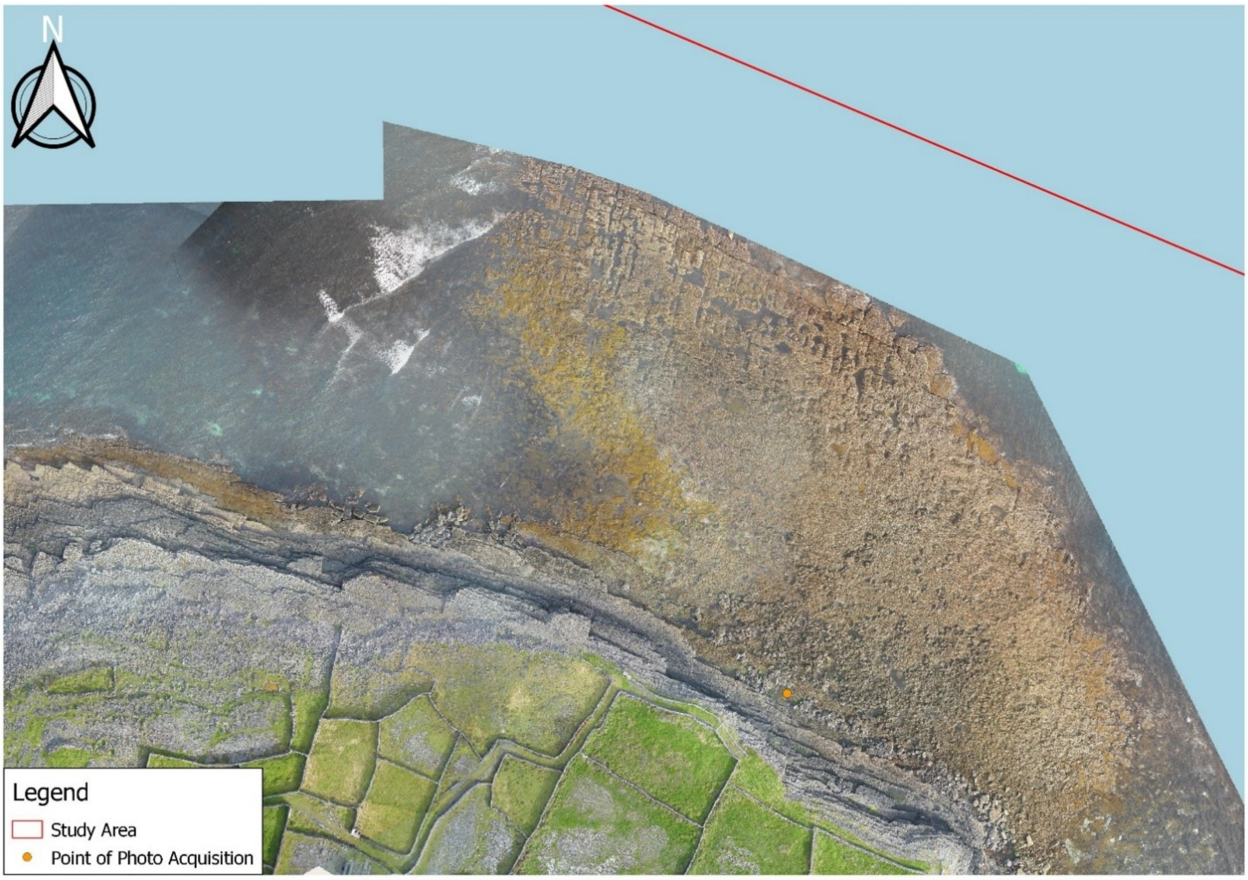

Figure 8 Point of Photo acquisition 16/10/2020

Figure 9 Seaweed Photo 1 – 16/10/2020

Figure 10 Seaweed Photo 2 – 16/10/2020

Considering the pictures collected on 28/08/2021 the unsupervised classification process generated the following two distribution maps, generated with Sentinel-2 and Planetscope.

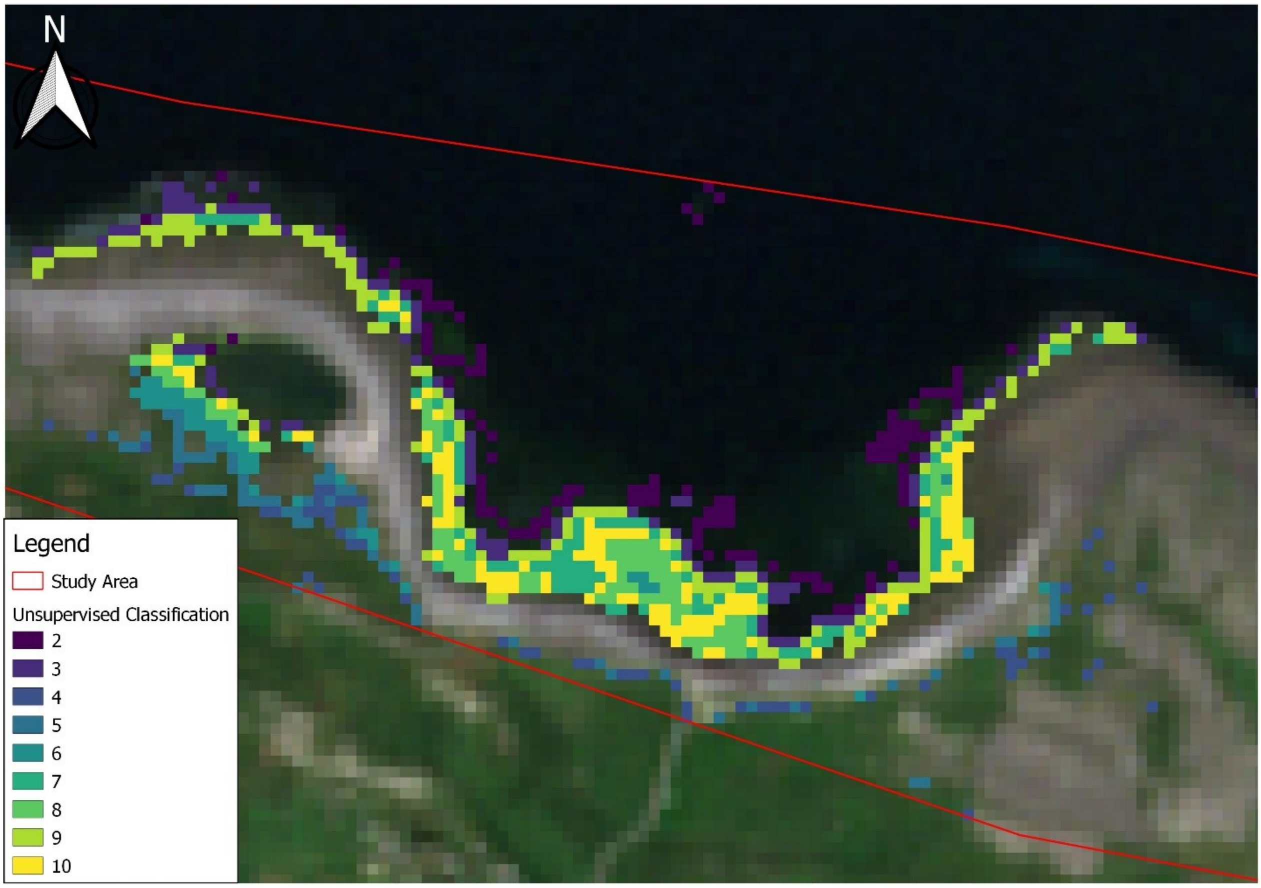

Figure 11 Unsupervised Classification of Sentinel-2 data collected on 28-08-2021

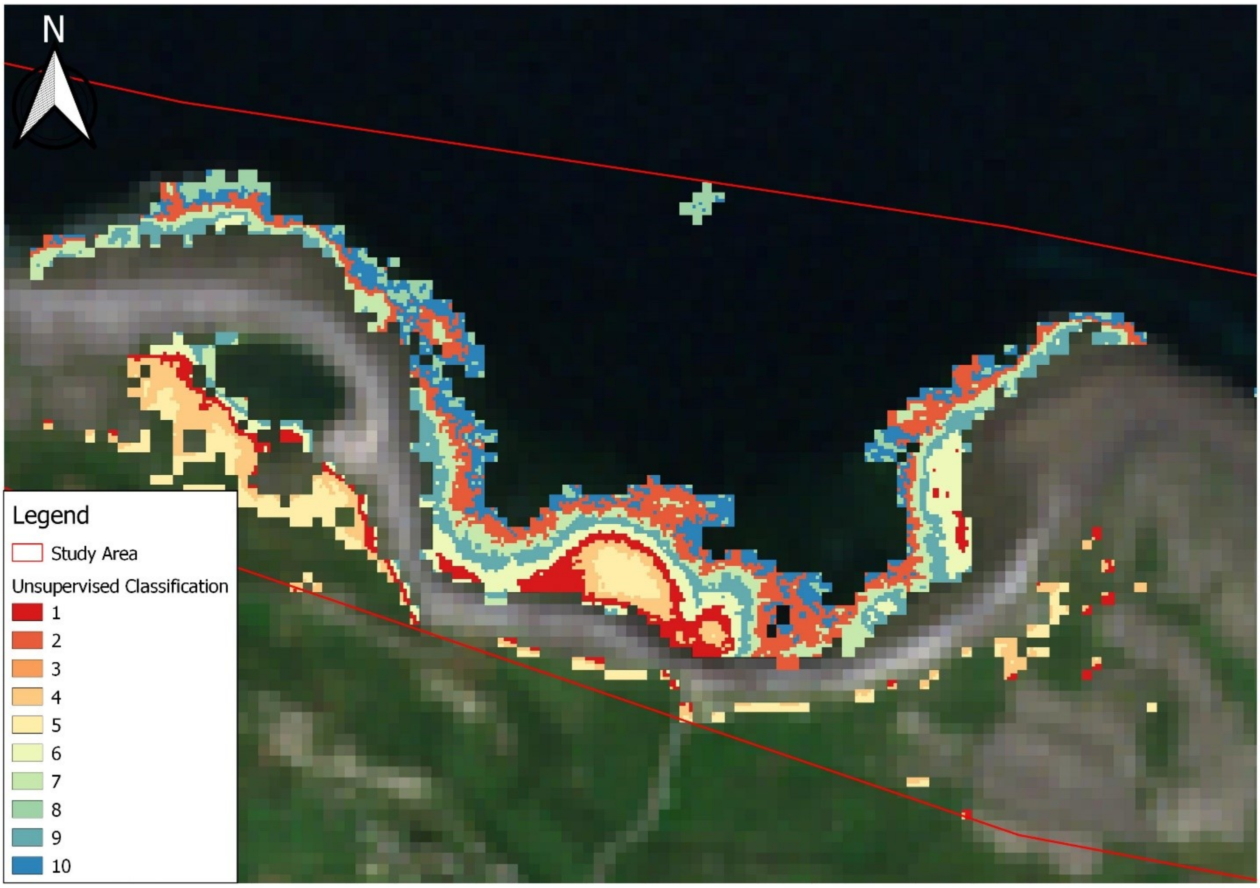

Figure 12 Unsupervised Classification of Planetscope Superdove data acquired on 28/08/2021

As it is possible to notice from the comparison of the previous two images, the unsupervised 10 centres classification gave coherent output with both Sentinel-2 and Planetscope Superdove.

With both platform it is possible to distinguish different species of seaweeds, different positioning and the presence of external element (rocks).

However considering the spatial resolution of Planetscope Superdove the result is extremely less disturbed and more continuos than those obtained with Sentinel-2.

4 CONCLUSIONS

The result obtained showed that the AI based approach is really precise in the autonomous identification of spatial distribution of different species of seaweed and other classes typical of coastal environments (rock, sands…etc.).

Thanks to the higher spatial resolution, the unsupervised classification of seaweeds species gave better results with Planetscope Superdove data.

In general this work shows that is possible to monitor efficiently coastal environment (seaweeds species distribution, rock patterns, shoreline…ecc), with extremely high precision and with high temporal resolution (potentially each day with planetscope and after 3-4 days with Sentinel-2).

However a large scale monitoring of the spatial distribution of seaweeds species along the entire coast of Ireland can be achieved only after a great computational phase in order to find representative computational configuration of the models. A remarkable strength point of the approach studied is the combination of supervised and unsupervised classification, that can lead to incredible results especially for large scale monitoring.

4.1 FUTURE STEPS AND PERSPECTIVES

Thanks to Artificial Intelligence reliability it is extremely real the possibility to create a smart and scalable tool for Irish coasts monitoring.

This tools, once calibrated, will be able to:

1) Identify Seaweed on the entire coast, starting from Sentinel-2 or Planetscope data;
2) Classify different kinds of seaweeds
3) Monitor coastal environment (shoreline, rocks pattern evolution..etc).

The development of such powerful tool can start from the extremely positive and innovative results of the present work, following the following steps:

- Increase the ground survey data collection, in order to provide a stronger calibration to the models.
- Develop the computational structure of the algorithms, in order to reach more precise estimation and to provide multitemporal analysis.

Once a more complete tool has been developed it would be possible to have an automated processing of satellite data, and a comparison of coastal environments evolution; if a strong calibration dataset will be provided to the algorithms, it will be possible to monitor coast from remote and to repeat analysis with high precision without the necessity of ground surveys.

The creation of such a powerful instrument can provide practical advantages to different stakeholders, like for example:

- Public Irish Authorities, responsible of the management of coast. In particular they can acquire environmental and ecological information of the entire coasts, with high temporal frequency and high quality.
- Private Stakeholders involved in seaweeds harvesting or fishery operation, that can use the tools for a more efficient logistic operation planning phase (it will be possible to know precisely where to find a particular species of seaweed or to plan fishery campaign).

Moreover, a complete tools for coast monitoring, can be developed with the same approach used in the present job, including also others fundamental themes that can be monitored with AI+remote sensing, that are:

- **Bathymetric analysis, using satellite data**
- **Carbon Stock estimation along seaweeds formation.**

Both previous themes are crucial if considering the effects of climate changes. For these reasons the study of these phenomena using remote sensing and artificial intelligence is essential for the acquisition of scientific and statistical estimation over large areas and at high temporal resolution and to give real support to sustainable management of coastal areas.

"*If you can not measure, you can not improve it*"

Lord Kelvin