Sentinel-2 images for the monitoring of dissolved contaminants on Sicily's south-east coast

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1. Introduction

Coastal environments are facing numerous challenges due to urban development, anthropic activities, seas level rise, Population growth, marine pollution, among others. These problems affect not only economic development but also marine ecosystem functioning, Devlin 2015. During the period of high precipitation the coast of Sicily receives amount of sediments reaching near shore water from the land through river runoffs. These sediments are the results of erosion of agricultural fields or high Slope bare land and they are one of main sources of pollutants and contaminants entering in marine ecosystem, Catania 2015, Devlin 2015. Recent studies conducted in coastal areas showed that the influx of sediments from river runoff contain harmful substances, Waterhouse 2012, adsorbed, dissolved or suspended in water. These sediment-plumes can be monitored in coastal waters using satellite image and determine the origin and their destination by observing their dispersion in two dimensions on the sea surface. As traditional accurate water quality monitoring requires intensive field water, Liu 2017, Sentinel-2 has an advantage of providing multi-temporal water quality information on large area at very low coast, Caballero 2018. The aim of this paper is to use various indices algorithms (colored dissolved organic matter (CDOM), normalized difference chlorophyll index (NDCI), normalized suspended material index (NSMI) and land cover/ land use techniques to estimate the composition, the shapes and the destination of sediments- plume observed in the water of the South-east coast of Sicily. The proposed procedure is the combination of qualitative and quantitative interpretation for the dynamics of sediments from the land to the deep sea. Due to the high dynamics of Ionian Sea, this work contribute to the effort of monitoring marine pollution where freely available satellite images can be used to identify marine sites for in-situ measurements..

We intend to provide answers regarding the fate and the origin of dissolved pollutants introduced in coastal environment such as these pollutants destined to remain in one location or spread far away and their impact on coastal environment inhabitants.

2. Material and methods

2.1. Area of study

The area of study is located on the South-east coast of Sicily, Figure 1, stretching from Taormina in the North to Syracuse in the South by passing on the coast of Catania. It is an important touristic site destination with antique theatre and monuments, Etna Mountain and beautiful beaches. Economically this region relies mainly on tourism and agricultural activities.Two main rivers Alcantara near Taormina and Simeto near Catania, the amount of sediments brought by these rivers from land to the sea play a big role in beach nourishment, Lanza 2011, but also contaminate coastal environment by bringing pollutants from industries and agricultural activities all along their courses, Guglielmo, 2013. The area is the site of high Dynamic currents shown in Figure 2, characteristic of wave-dominated Mediterranean Sea, Longhitano 2007, which influence the distribution of these sediments

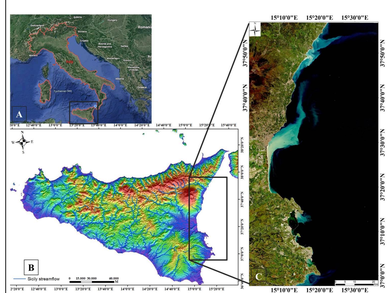


Fig 1. (A) Location of Sicily island in Mediterranean sea, Google image (B) surface stream flow on Sicily island extracted on EU-DEM of 25 m spatial resolution. (C) Sentinel-2 acquired 30 October 2018 on East cost of Sicily .

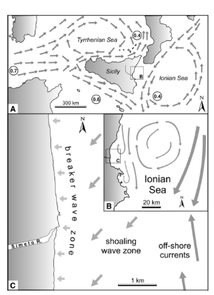


Fig 2. (A) Distribution and direction of the main sea-currents in the central Mediterranean (the numbers express velocity in knots). (B) Clockwise circulation and S-directed offshore currents along the Sicilian eastern coast. (C) Offshore currents and wave motion, Longhitano, 2007.

Table 1. Sentinel-2 images used

Acquisition Time	Acquisition date	Sen2Cor atmospheric correction	Cloud cover %	Spatial resolution of the bands used	Spectral bands used
09:40:19	12-09-2018	Yes	0.29	10 meters	Blue (B2), Green (B3), Red (B4), Red edge (B5), Near-infrared (B8),
09:50:31	30-09-2018	Yes	2.42		
09:40:31	07-10-2018	Yes	1.67		
09:50:31	20-10-2018	Yes	31.92		
09:50:59	25-10-2018	Yes	1.01		
09:51:21	30-10-2018	Yes	0.51		
09:52:21	09-11-2018	Yes	2.46		
09:43:09	21-11-2018	Yes	0.12		
09:43:51	06-12-2018	Yes	0.09		
52:21.02	09-11-2018	Yes	2.46		
09:44:01	16-12-2018	Yes	15.25		
09:54:19	24-12-2018	yes	0.33		

2.2 Data used

High resolution Sentinel-2 images, Table 1, acquired in the area have spectral bands capable of providing information on the quality of water. In ENVI software these images were processed specially by analyzing spectral indices on offshore, Table 2, and supervised classification on the land to determine the land cover.

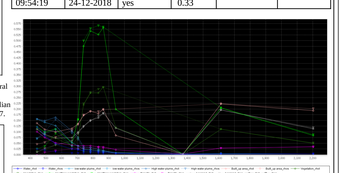
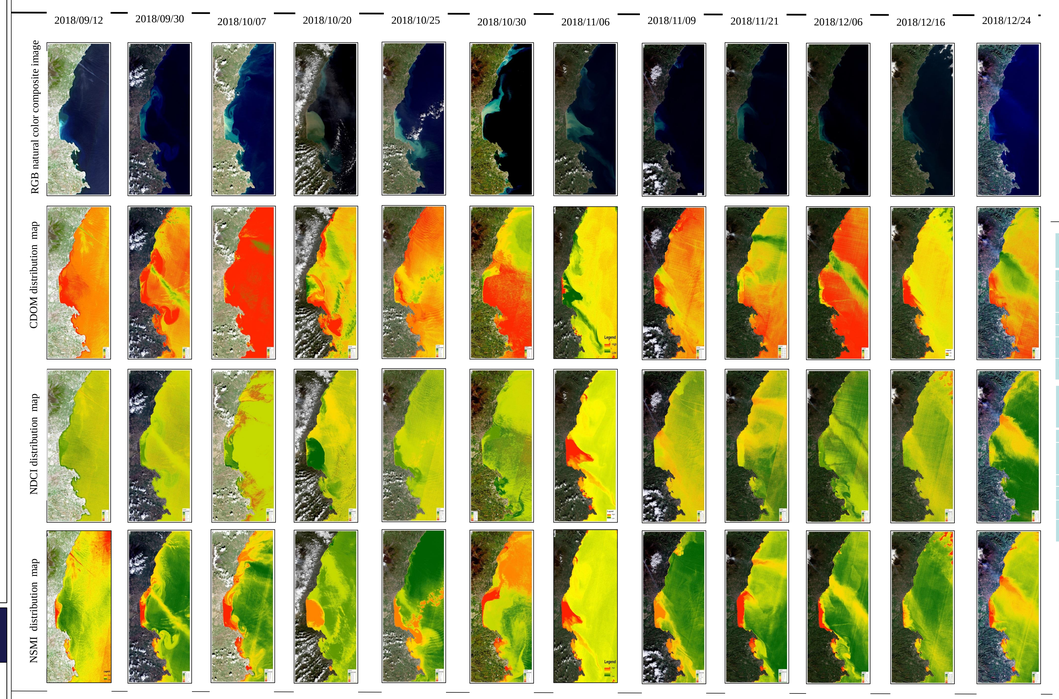


Table 2 : Spectral indices

Spectral indices	Bands and mathematical equation used
Colored dissolved organic matter (CDOM)	CDOM = (B3-B4)/(B3+B4)
Normalized suspended material index (NSMI)	NSMI = (B4+B3-B2)/ (B4+B3+B2)
Normalized difference chlorophyll index (NDCI)	NDCI = (B5-B4)/(B5+B4)

3. Results



Figures 4. RGB natural color composite Sentinel-2 images and maps of different water indices

2018/12/24 classification

Land cover	Percentage
Built-up area	14 %
Vegetation	62 %
Bare land	8 %
water	1
Snow	2

Qualitative and quantitative results interpretation

Types of extracted information	Extracted information description		
	Min	Max	Average
Estimated reached distance	1 km	15 km	8 km
Estimated offshore taken direction	high concentration of colored dissolved organic matter was observed near shoreline spread in SE direction		
Estimated covered area	10 sq km	420 sq km	
Estimated remaining time	5 days	15 days	
Estimated impact on ecosystem	organic carbonate sequestration , algae bloom, reduced light penetration in ocean, growth of aquatic organisms		
Estimated onshore origin	Dead photosynthetic agricultural and bare land organisms brought by runoff river		

Types of extracted information	Extracted information description		
	Min	Max	Average
Estimated reached distance	0.5 km	20 km	10 km
Estimated offshore taken direction	Chlorophyll response was observed over the sea water spread in SE direction		
Estimated remaining time	5 days	15 days	
Estimated impact on ecosystem	growth of aquatic organisms		
Estimated onshore origin	agricultural and bare land organisms brought by runoff river		

Types of extracted information	Extracted information description		
	Min	Max	Average
Estimated reached distance	1 km	60 km	30 km
Estimated offshore taken direction	high concentration of suspended material was observed near shoreline spread in E to NE direction		
Estimated covered area	2 sq km	340 sq km	
Estimated remaining time	5 days	10 days	
Estimated impact on ecosystem	ocean light penetration, coastal pollution, modification in coastal geomorphology		
Estimated onshore origin	Erosional products from agricultural and bare land		

4.Conclusion

This study demonstrates the potential of Sentinel-2 images in monitoring and managing the quality of water in coastal environment. By analyzing sediments plumes brought in sea water by Simeto and Alcantara rivers we were able to estimate the destination of dissolved organic matter, suspended material and some bounded nutrients (such as Nitrogen or Phosphorus) leaving terrestrial environment especially in agricultural and industrial areas. When arrived in the sea their fate is influenced by sea currents and waves.

The influx of pollutant sediments in coastal area is still the major problem threatening marine ecosystem habits and its socio-economic development. In coastal environment such as East-coast of Sicily with economic benefits rely on tourism and agricultural activities, this problem has to be studied and addressed accordingly.

5. References

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