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Combination of Very High Resoloution (VHR) satellite imagery and side scan data for low cost seagrass mapping

A. Tsokos[1], V. Tsoukala[1], C. Petropoulos[2], P. Sartampakos[3], Emm. Vassilakis[4*]

[1]Department of Civil Engineering, National Technical University of Athens, Athens
[2]Lykofronos 6, Chalkida
[3]Nireas Engineering LTD, Skra 1-3, Kallithea
[4]Faculty of Geology and Geo-environment, National & Kapodistrian University of Athens, Athens
[*]Corresponding author: evasilak@geol.uoa.gr

Abstract

The use of techniques of two different origin were compared and combined aiming to map the seagrass meadows at shallow waters of South Evoikos Gulf, in central Greece. The high spatial and spectral resolution of WorldView-2 satellite images and its ability of water penetration, offers a positive approach for sea bottom mapping, in a relatively high resolution. In addition, the ground truth fieldwork survey with side scan data acquisition revealed that it was in impressively high agreement with the outcomes from the remote sensing data interpretation.

Keywords WorldView-2, South Evoikos Gulf, sea bottom classification.

1 INTRODUCTION

The use of Very High Resolution (VHR) satellite imagery at various applications is gaining more and more popularity due to the growing number of offered data and the increasing spectral properties. WorldView-2 is the first commercial VHR multi-spectral satellite providing imagery in eight different sensors having bands that range from the visible to near-infrared (0.40-1.04 μm). The integration of the “Coastal” band (0.40-0.45 μm) in the 8-band WorldView series of satellite imagery data, which was followed by the addition of the similar wavelength band 1 (0.43 - 0.45 μm) in the Landsat-8 Operational Land Imager (OLI), gave a great boost to applications related to shallow water depths. The fundamental principle underlying the methods used to study the sea bottom from remotely sensed imagery is that different wavelengths of the solar light penetrate the water body to different depths (Phinn et al. 2008).

The ability to accurately determine the seagrass at underwater regions is of great importance for the biodiversity of the submarine environment (Schmidt and Skidmore 2003). The use of certain spectral wavelength data tends to be the most cost-effective way of monitoring the marine habitats by mapping the sea bottom type along with several other jobs like modeling coastlines or even navigating through shallow aquatic areas by studying the bathymetry (Lyzeng 1978; Fornes et al. 2006).

2 DATA AND METHODS

The northern part of South Evoikos Gulf was chosen as a test site for this research work, due to its sea bottom morphology as shallow depths extend at a wide area and the frequent presence of Posidonia oceanica species (Figure 1).

WorldView-2 scene acquired on January 11, 2014 was used, after careful search at DigitalGlobe’s Image Finder quick look archives, as a number of conditions should have been fulfilled (Figure 2). Initially, the sea surface should have been calm enough and the solar angle should have been as much vertical as possible at the time of acquisition (Mean Sun Elevation 59.1^{o}). Accordingly, the satellite sensors should also be in a relatively small angle across the nadir track (Off Nadir View Angle = 10.1^{o}).

Figure 1 Field photograph of seagrass as seen from the beach

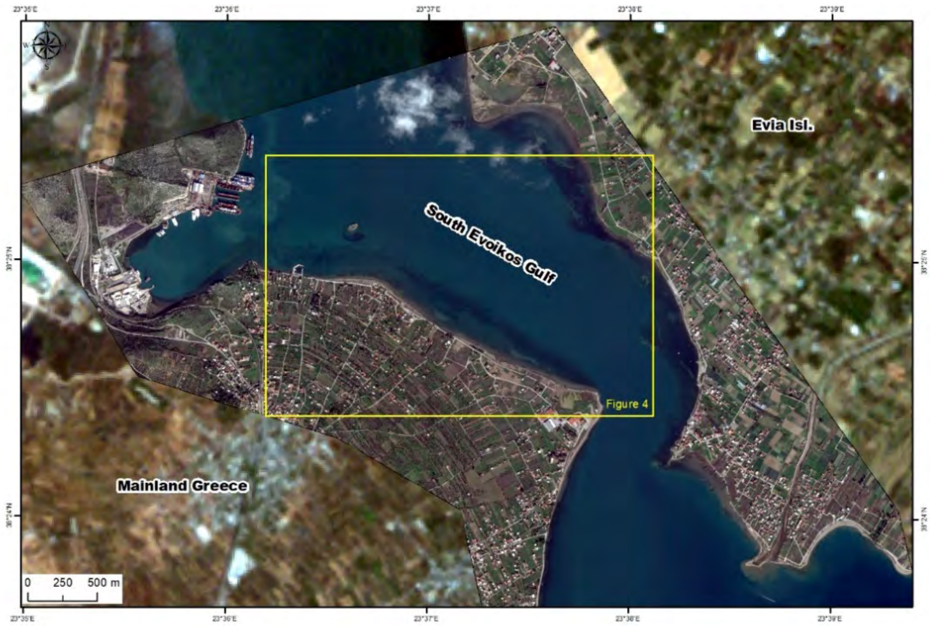

Figure 2 Index map of the area of interest at South Evoikos Gulf, between Mainland Greece and the island of Evia, comprised by two separate satellite images with natural color band combination. The VHR WorldView-2 image in the middle of the figure is in contrast with the medium resolution Landsat-8 OLI, which completers the map figure. The yellow rectangle delineates the study area represented in Figure 4

The dataset was pre-processed before ortho-rectification procedure (Deida and Sanna 2012), including pan-sharpening for increasing the spatial resolution by using the Hyperspherical Color sharpening algorithm (Padwick, et al, 2010), which is specially designed for the WorldView- 2 sensor multi-band data and seems to work efficiently also with other multispectral data containing at least 3 bands. According to the workflow of this algorithm the imagery data are transformed from native color space to hyperspherical color space, in order to replace the multispectral intensity component with an intensity matched version of the panchromatic band.

The satellite image processing part of the methodology was followed by the classification of the Coastal band. Supervised classification was used to cluster the pixels of the image into classes corresponding to user-defined object/areas including the seagrass, based on training classes which consist of groups of pixels representing individual spectra (Phinn et al. 2008).

Several routes were carried out, with a vessel carrying side scan equipment, for mapping large areas of sea bottom, primarily for locating the presence of seagrass meadows (Figure 3). The collected data were registered and geo-rectified for constructing a map representing the seagrass distribution around the test site. The extensive seagrass deployments at the clayey sea bottom of the study area at Avlida, consists of *Cymodocea* along with *Cystoseira crinite* (at shallower areas closer to the coastline). Moreover, sparse developments of *Ulva Enteromorpha* and *Colpomenia* were also located during the fieldwork, which are indicators of organic pollution.

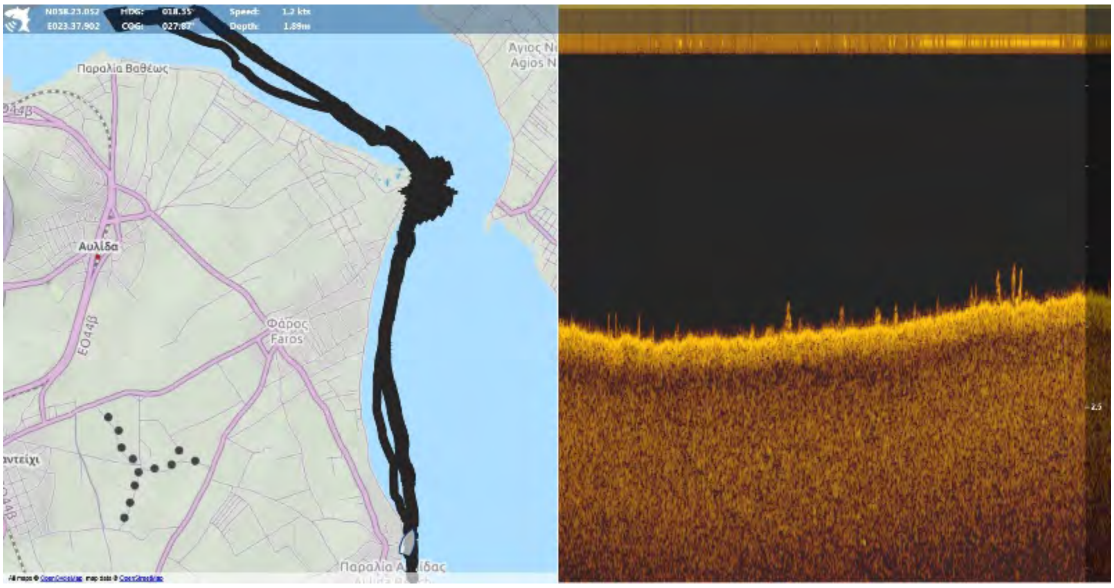

Figure 3 The vessel's routes are displayed at the map on the left and sample of the capture images is displayed at the right

3 RESULTS AND DISCUSSION

The classified images of the Coastal band appeared to have very accurate depictions of the shallow water regions covered by seagrass in the original radiance images, based on visual comparisons with the side scan data interpretation (Figure 4).

The spectral reflectance pattern as revealed by remote sensing spectral measurements shows subtle differences between various sea bottom coverages. The difference is quite evident between submerged seagrass and the other types of sediments.

The cost of providing a VHR satellite image is highly competitive comparing to a marine survey, especially when the pricey side scan equipment along with its maintenance is included in the investigation budget. On top of that the possibility of automating this technique for being efficient at large areas is quite promising. However, the possibility of coupling remote sensing techniques with other ancillary data such as side scanning, would be the best combination for obtaining even more reliable results.

Minor issues concerning the accurate geo-rectification of the satellite imagery can be overruled since a fair geographic placement of the datasets can be applied by using the geo-location information of the satellite, mentioned in the metadata files. Nevertheless, a serious objection could be the effective penetration depth of the Coastal band wavelength spectral radiance, which cannot exceed the 30 meters at clear and moderate turbid water bodies (Stumpf 2003), bearing in mind that several species of seagrass can be found at much deeper sea bottoms.

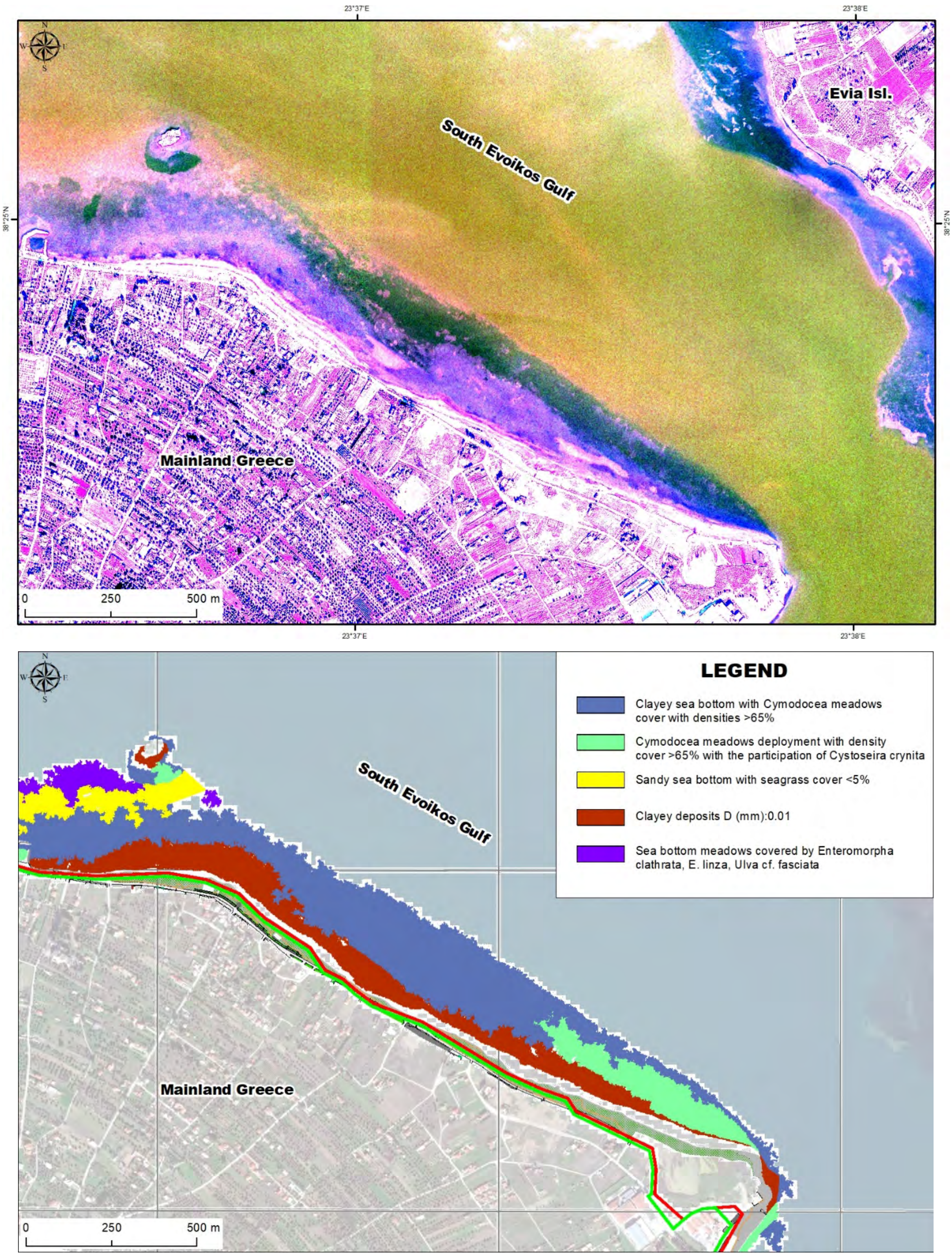

Figure 4 Processed pseudo color WorldView-2 satellite image of the area of interest (band combination 314/RGB), showing the seagrass development at the sea bottom between mainland Greece and Evia island (upper image). At the bottom image, the fieldwork seagrass mapping results are displayed

The additional spectral bands of the VHR images acquired by WorldView series of satellites, especially the use of red-edge, improved the separability of the different Aquatic Macrophyte species. Additionally, multi-band operations such as the Normalized Differential Vegetation Index (NDVI) using the new red-edge band yielded good result. Specifically, NDVI of red-edge (instead of

NearInfraRed1) to red showed better variability and separability of seagrass communities than the NDVI of using the classic NearInfraRed1 and red normalization ratio, even though higher values were obtained in the latter case. Other applied ratios were generated but didn't yield any use for the discrimination of seagrass.

The remote sensing spectral measurements added value to the use and interpretation of WorldView-2 images. The increased spatial resolution after the pan-sharpening procedure improved the visual interpretability to a great extent. More studies are required to prove the use of the additional bands for biomass estimation from satellite images and further to know about the vegetation carbon pool.

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