Building spectral libraries for monitoring olive mill wastewater (OMW) disposal areas

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Introduction

Olive Mill's Wastewater (OMW) uncontrolled disposal areas in aquatic and terrestrial receptors is associated with detrimental effects because of their high content in phenols and in organic matter. As a consequence, OMW can inhibit plant and microbial growth, alter soil fungal and bacterial communities' structure as well as soil physicochemical properties. The seasonal operation and the high territorial scattering of OMW makes their documentation quite difficult. Remote sensing technology may provide a systematic and cost-effective methodology in order to identify as well to monitor open air OMW disposal areas. An assessment of OMW areas in satellite image classifications is challenging due to the various transition stages the OMW areas.

In order to support satellite image processing for the detection of OMW areas, ground spectroradiometric truth data may be used. Spectral signatures profiles of different targets related with OMW areas are necessary for post-processing of satellite imagery such as classification while ground "truth" data collected during satellite overpass can verify the at-satellite results.

This paper aims to present a preliminary study focused on the development of spectral libraries for monitoring OMW areas. To this direction the ground spectroradiometer GER 1500, with spectral range of 350 - 1050 nm and sampling interval 1.5 nm, has been used in order to record several spectral signatures from a variety of samples. Such signatures can be used for a variety of image post-processing such as to train feature extraction and classification algorithms, un-mixing techniques applied to imagery, for comparison with unlabeled spectra etc. The results have revealed the optimum spectral regions where olive waste can be distinguished in different classes. Moreover, Relative Spectral Response (RSR) filters of high resolution satellite images have been used to simulate the narrow band spectral signatures to the multispectral bands of satellite images. Based on these bands, vegetation indices have been calculated and compared in order to examine the potential use of such equations.

Methodology

For the aims of the study laboratory spectroradiometric measurements were taken over the following samples: (a) fresh olive waste (same day production); (b) dry olive waste; (c) olive waste mixed with water (25%); (d) olive waste mixed with water (50%); (e) olive waste mixed with soil (25%); (f) olive waste mixed with water (50%) and soil (50%) and (g) soil. For each one of these samples 50 spectroradiometric measurements were taken using the GER 1500 spectroradiometer.

Then these narrowband measurements were simulated with the high resolution sensor GeoEye-1 using the appropriate Relative Spectral Response (RSR) filter. Based on these broadband reflectance values several vegetation indices as shown in table 1 were calculated. In detail the Normalized Difference Vegetation Index (NDVI); Simple Ratio (SR); Perpendicular Vegetation Index (PVI); Ratio Vegetation Index (RVI); Transformed Soil Adjusted Vegetation Index (TSAVI); Modified Soil Adjusted Vegetation Index (MSAVI); Soil and Atmospherically Resistant Vegetation Index (SARVI); DVI (Difference Vegetation Index) and Green Normalized Difference Vegetation Index (Green NDVI) were examined. In parallel, the authors examined the spectral similarity of the samples in the range of 450-900 nm. The similarity was initially examined through the correlation coefficient (R^2) of all samples in this spectral range.

$$r = r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

….in brief ("word clouds")

Results

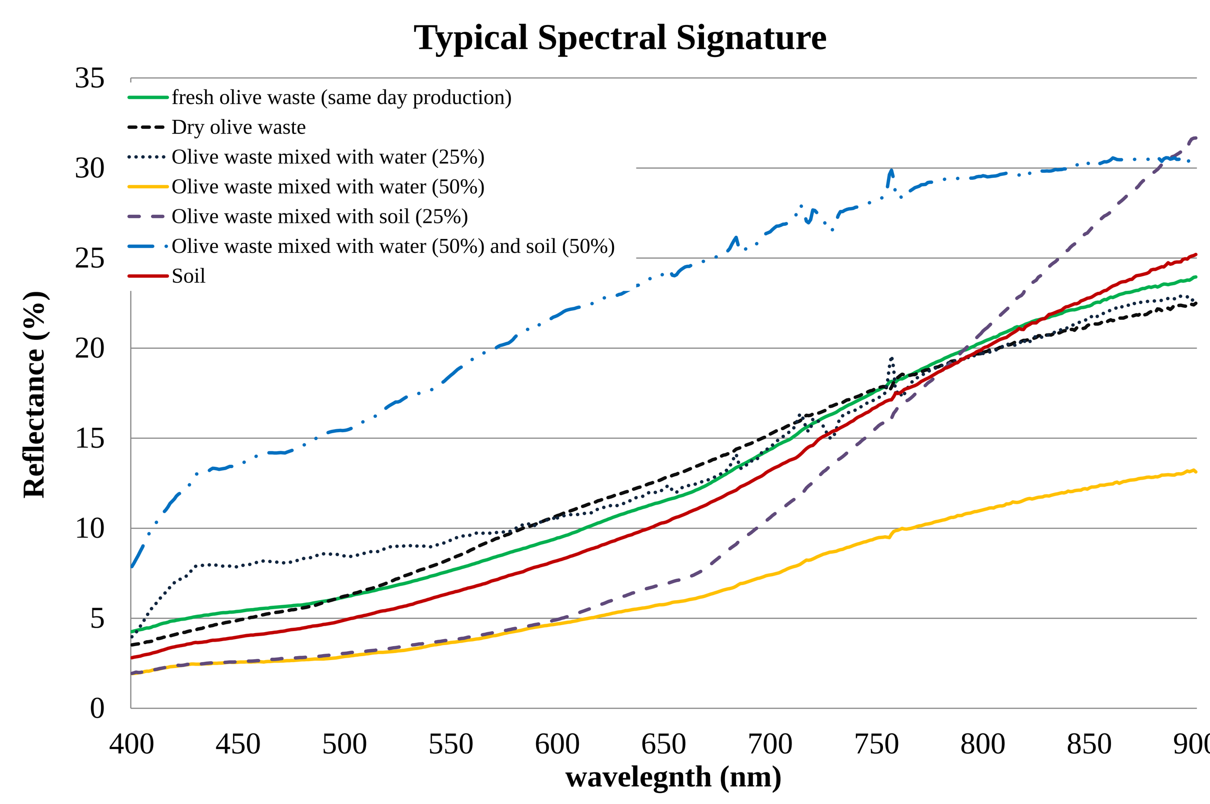

Fig. 1: Typical spectral signatures of OMW targets

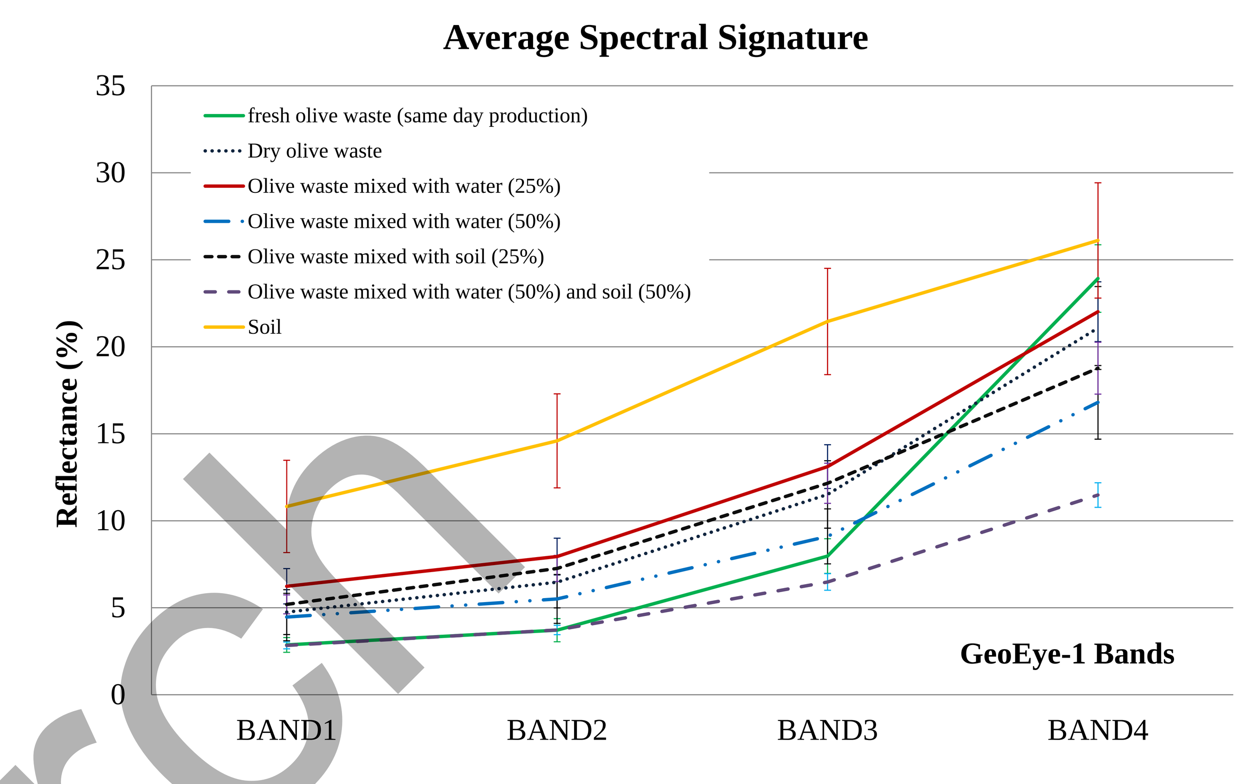

Fig. 2: Simulated spectral signatures of OMW targets to the GeoEye-1 sensor

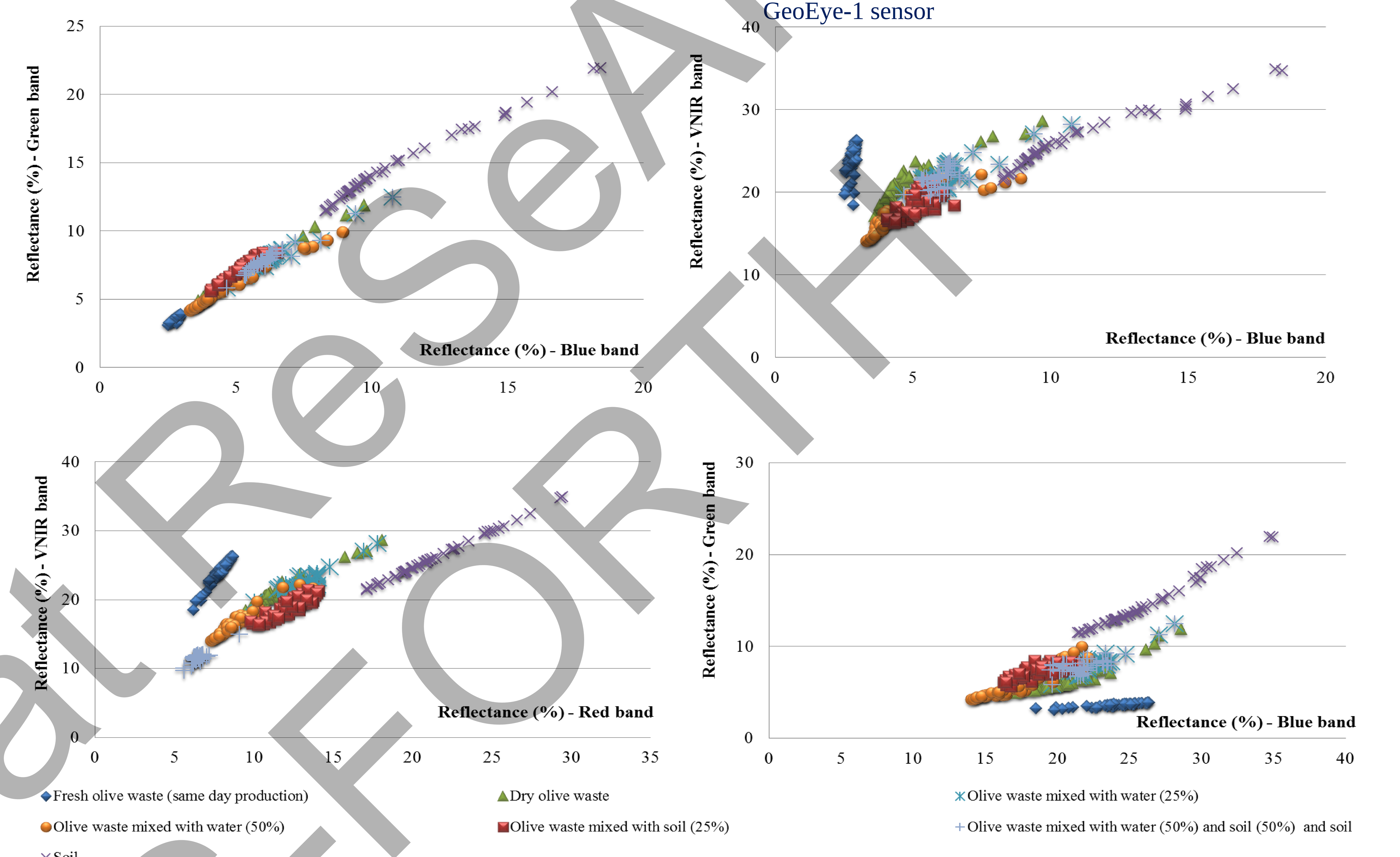

Fig. 3 : Scatter plot of the different targets in the 4-D spectral space

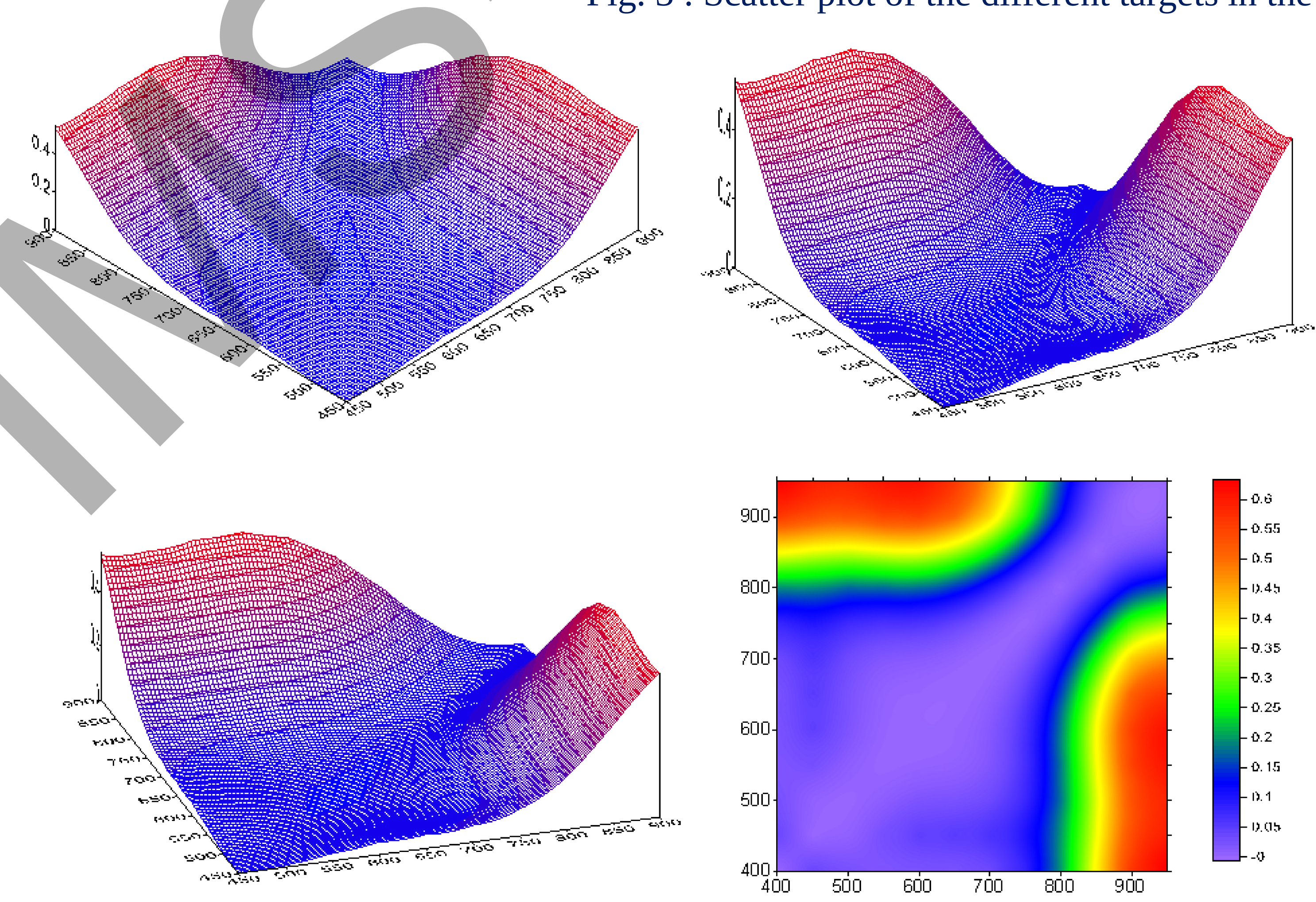

Fig. 4: One minus ccorrelation coefficient between all samples in the range of 450–900nm.

Figure 4 indicates the one minus the sample correlation ($1-R^2$). As shown in the figure higher values, indicated with red colour, are observed in the two edges of the spectrum examined in this study (450 nm and 900 nm). These wavelengths corresponds to the blue and VNIR bands of the GeoEye-1 sensor. For the rest of wavelengths a strong correlation is visible (< 0.3 in Figure 3). This conclusion is also in line with the results of Figures 1 and 2 where visible bands tend to give similar reflectance values while the VNIR band seems to be more appropriated for detection of OMW areas in satellite imagery.

The overall results from this study were applied using a GeoEye-1 pan sharpen image taken over the island of Crete in 16 of June 2013. As it is indicated in Figure 5 (top) some OMW disposal areas can be spotted using interpretation of the image. Figure 5 (bottom) is the same area after the application of the normalized OMW index (shown in equation below). The results shows that OMW disposal areas can be enhanced after the application of the proposed index.

$$\text{Normalized Index}_{OMW} = (\rho_{VNIR} - \rho_{Blue}) / (\rho_{VNIR} + \rho_{Blue})$$

Conclusions

Olive production industry is of great importance for Mediterranean countries. Therefore a sustainable management of the whole cycle of olive production needs to be taken into consideration so as to minimize and eliminate the environmental problems related with the OMWW disposal areas.

As it was found Remote Sensing can be used as an alternative tool for systematic monitoring of OMW areas.

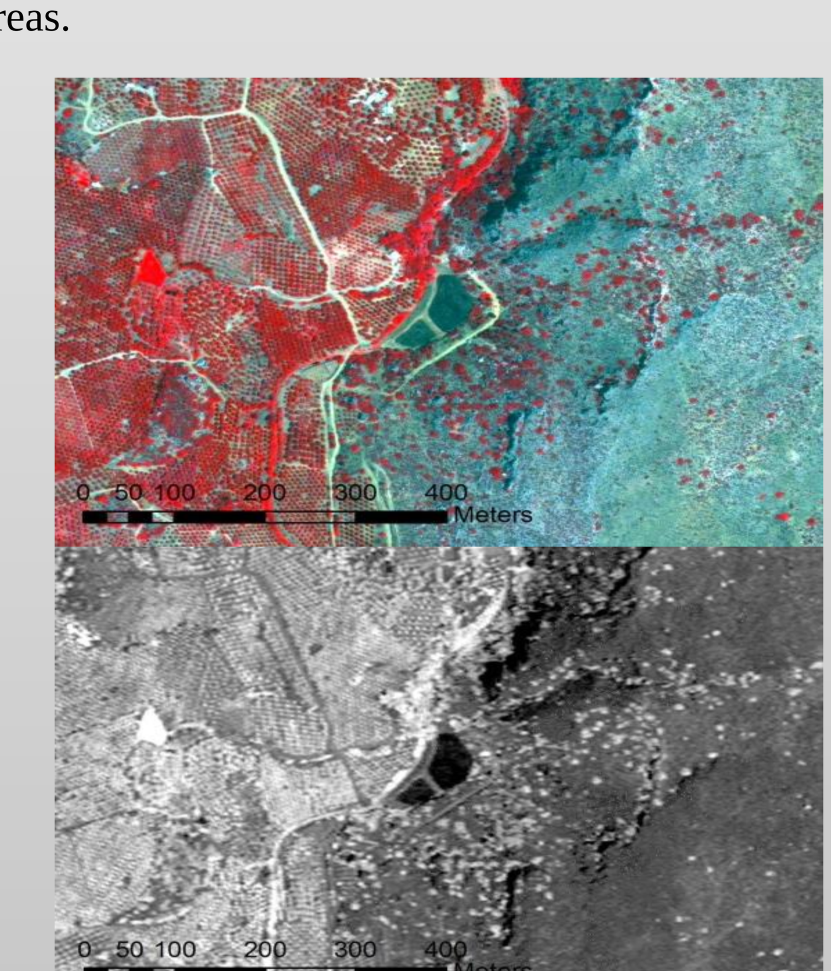

Fig. 5: Example from OMW disposal area in Crete from GeoEye-1 image (top) in the VNIR-R-G pseudo color composite. In the bottom the same area after the application of the normalized VNIR – Blue band. The OMW disposal area is highlighted as dark object in the scene.

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