OLIVE OIL MILL WASTES:

A MONITORING APPROACH THROUGH SPACE TECHNOLOGIES

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Introduction

There are approximately 750 million productive olive trees worldwide, 98% of which located in the Mediterranean region. Olive oil industry is very important in Mediterranean countries, both in terms of wealth and tradition. Olive oil industry is considered to be as one of the driving sectors of the agricultural economy of the Mediterranean basin. Olive-mill wastewater (OMWW) which is produced during olive milling and olive oil extraction is the most critical waste emitted by olive-mills in terms of quantity and quality. OMWW uncontrolled disposal areas in aquatic and terrestrial receptors is associated with detrimental effects because of their high content in phenols and in organic matter. OMWW are difficult to be documented due to their seasonal operation as well their high territorial scattering. Remote sensing images may provide a systematic and cost-effective methodology in order to identify as well to monitor open air OMWW disposal areas. The distribution of freely available satellite images can be used in order to support such actions in order to control OMWW disposal areas. This paper investigates the contribution of freely available satellite images such as GeoEye OrbView-3, Landsat 5 TM, Landsat 7 ETM+, Landsat 8 LDCM and images from Google Earth platform, in order to detect and monitor OMWW areas in the island of Crete.

Fig 1: Olive tress and OMWW areas

Case Study Area

The area of olive groves in Greece has increased constantly during the last quarter of the century, as a result of the planting of new high-density groves, reaching an area of about 8.336 km2 in 2007 (+120.000 ha since 1991). For the aims of this paper, two areas of interest have been selected (Figure 1). The first area (case study area 1: *Mesaras inlet*) is located in the southern-central part of Crete where a high resolution GeoEye OrbView-3 image has been acquired. The second case area (case study 2: *Mironikitas area*) is focused in the northern western part of Crete where Google Earth (GE) images have been exploited.

Fig. 2: Case studies areas in the island of Crete

Methodology

The methodology followed in this area was focused to the semi-automatic identification of OMW disposal areas based on seven (7) steps as shown below (for GeoEye OrbView-3):

Step 1: Orthorectification. The GeoEye OrbView-3 image was initially orthorectified using Rational Polynomial Coefficients (RPC) and ASTER Global Digital Elevation Model (ASTER GDEM) data. RPC file was generated from ephemeris data while the ASTER GDEM data was downloaded from ERSDAC website.

Step 2: Resolution Merge. This step was applied in order to improve the spatial resolution of the multispectral bands of the OrbView-3 image. The PAN band of the GeoEye OrbView-3 with spatial resolution of 1m was merged with the multispectral bands of the same sensor with 4m spatial resolution.

Step 3: SAM target detection. The next step was the application of the Spectral Angle Mapper (SAM) for OMW target detection. A small sample (Region Of Interest-ROI) was selected from a known OMW disposal site while other not-OMW ROIs have been also selected to improve the quality of the results.

Step 4: Filtering (Sieving & Clumping). A threshold and filtering of the image was necessary. Sieving filtering was applied to solve the problem of isolated pixels occurring in classification images (i.e. less than 2 pixels), after the SAM target detection, while with clumping filtering similar classified areas were adjusted together using morphological operators.

Step 5: Masking using topographical parameters. Using the ASTER GDEM dataset the slope of the case study area was calculated in a GIS environment. Then areas with slope more than 20% (hilly areas) were excluded (masked) from the analysis since OMW disposal areas are located in flat or almost flat regions.

Step 6: Querying image using geometric properties. Area and length properties of the remaining candidate pixels have been calculated in the GIS environment. Then SQL query has been applied based on specific geometric and shape properties in order to further exclude the remaining areas.

Step 7: Accuracy assessment. The final step for this semi-automatic approach was the accuracy assessment of the results. For this reason the detected OMW disposal areas have been compared with known OMW areas of the region.

Results

The semi-automatic identification of OMW disposal areas in the area of *Mesaras* inlet for the different steps of the applied methodology: Initially the orthorectification of the image was performed, and then the SAM detection algorithm was applied. Yellow pixels indicate the candidate areas as OMW disposal areas. Then the results were masked based on topographic parameters (slope >20%) while the final stage involved the extraction of OMW sites based on geometric properties.

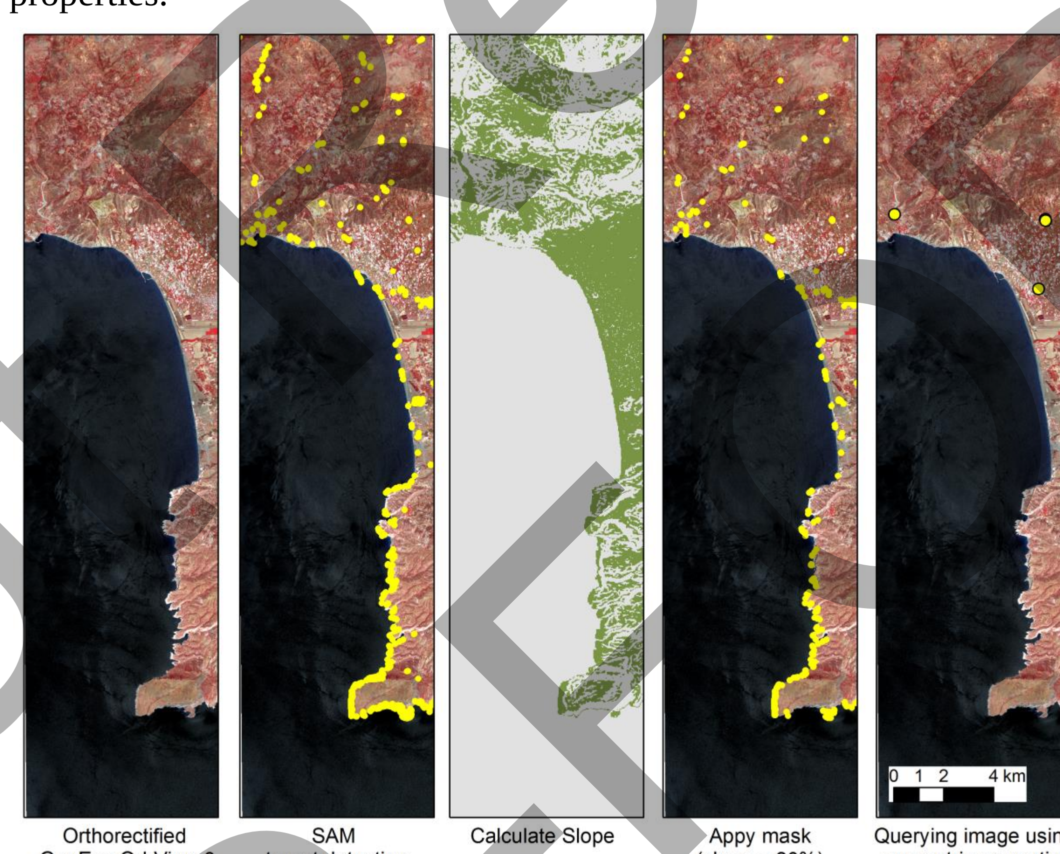

Fig. 3: The semi-automatic identification of OMW disposal areas in the area of *Mesaras* inlet for the different steps of the applied methodology: Initially the orthorectification of the image was performed, and then the SAM detection algorithm was applied. Yellow pixels indicate the candidate areas as OMW disposal areas. Then the results were masked based on topographic parameters (slope >20%) while the final stage involved the extraction of OMW sites based on geometric properties.

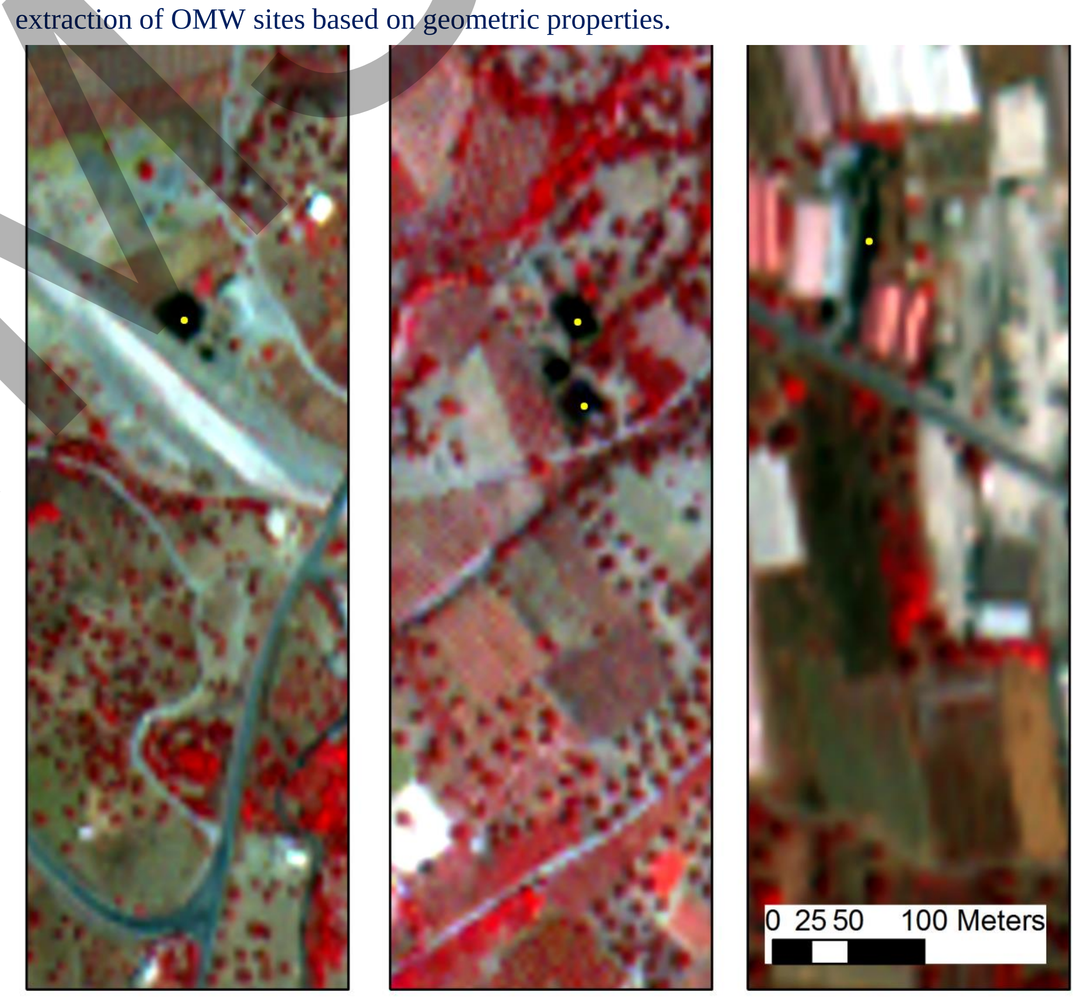

Fig. 4: The final three areas as detected from the methodology applied in the Mesaras area.

For the second case study area in the region of *Mironikita* GE high resolution images have been used. The purpose for this case study was to evaluate the potential use of detection of OMW areas using the RGB images from Google Earth engine. Several classification techniques have been evaluated for the purpose of this study. Four different scales have been selected in this area as shown in the following figures. Red colour indicates the OMW areas; brown and blue colour for the soil areas while green areas for vegetated regions.

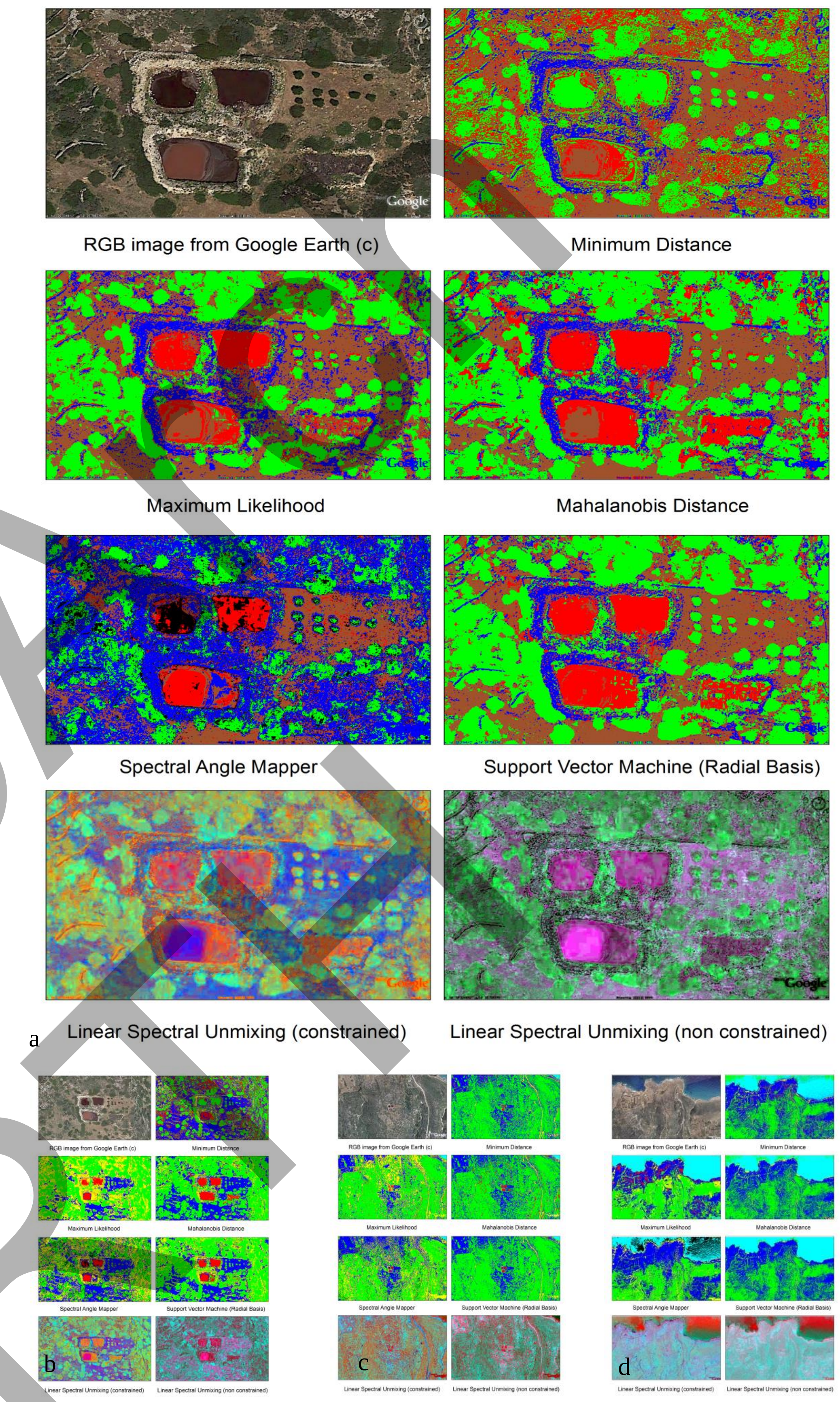

Fig. 5: Classification results for the *Mironikita* area in four different scales (a-d). Figure a was captured from a height of approximately 100 meters above the OMW area, Figure b was captured from a height of 250 meters above the OMW area; Figure c from a height of 850 meters above the OMW area while Figure d from a height of 2000 meter above the OMW area. Red colour indicates the OMW areas; brown and blue colour for the soil areas while green areas for vegetated regions.

Conclusions

Olive oil industry is very important in Mediterranean countries. Greece is the 3rd major olive oil producers worldwide. However the extraction of olive oil generates huge quantities of wastes which can be harmful for the environment. OMW disposal areas are scattered all over the island while their identification might be difficult and time consuming if this is based only from in –situ observations.

For this reason alternative ways to detect as well to monitor OMW areas should be studied. In this direction, remote sensing techniques may be used as an essential and economic tool for detection of OMW disposal areas. In this paper freely distributed satellite images have been explored in two different cases studies. The results were found very promising since 4 OMW areas were detected in this region with coverage of approximately 240 square kilometres. In the second case study the Google Earth engine was used to examine if such RGB freely distributed images can be used to detect disposal areas. Several classification algorithms have been applied in different scales. The results indicated that complicated classifiers such as SVM can be sufficiently used to extract OMW areas from a height of 2000 meters from the GE digital images. Although training areas (ROIs) are needed for both methodologies, the unique spectral profile of OMW areas can be sufficiently used in conjunction with GIS spatial analysis and SQL queries to identify OMW areas.

Acknowledgments

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