OPTIMIZATION OF SENTINEL 2 DATA FOR SUPPORTING GEOLOGICAL MAPPING AND MONITORING OF MINING AREAS

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ABSTRACT

Sentinel-2 is ESA's medium spatial resolution super-spectral instrument aimed at ensuring data continuity for global land surface monitoring of Landsat and SPOT. This paper aims at evaluating Sentinel-2 image products that are relevant to the geologic and mining science community. Different mining and post mining areas have been chosen as pilot test sites in the Mediterranean countries of Greece, Cyprus and Morocco. The methodology has been developed within the EU GeoCradle project and it is used to define the roadmap that facilitates the use of Sentinel 2 data in issues related to mining. Iintegrated identification, collection, assessment and use of available EO - Sentinel 2 data, along with in-situ products and relevant monitoring information are included during the analysis for all the test sites. The evaluated image products of Sentinel-2 VNIR and SWIR bands demonstrate the capacity in mapping features of interest to geologic community and the mining sector. It is also shown that the development of a Monitoring System can be supported for the mitigation of illegal quarrying activities along with the long-term monitoring, mapping, and management of abandoned mining sites. It is expected that the methodologies elaborated on the pilot sites will have a universal character and could be applied on other mining areas too.

1. INTRODUCTION

The life cycle of a mine includes different stages like Prospecting and Exploration, Development, Extraction, and Closure/Rehabilitation. Prospecting and exploration are precursors to mining and often occur simultaneously, while they can take several years to complete, and may be quite costly. Different environmental problems occur during mining. One of the major outstanding environmental problems related to mining is that of abandoned mine sites. Land degradation from mine operations is well known in almost all countries. It is also well documented that illegal quarrying activities are related to severe economic, social and environmental impacts affecting not only the restricted area where such activities take place, but also wider areas.

Earth Observation data can be used in all phases of the mining life cycle, within prospecting, exploration, mineral extraction as well as mine closure and rehabilitation. Environmental monitoring is now an integral part of mining operations. Remote sensing enables the identification, delineation, and monitoring of mining areas, including derelict land, and changes in surface land use, (Stefouli et al.,2004, Charou et al., 2010). Prospection can also make use of medium resolution to perform geological and mineral exploration interpretation, while the derived geological maps can be used to assess the location of potential mineral deposits, (Stefouli 1999, Stefouli 2001, Ferrier et al., 2002, Charou et.al., 2007). The aim of study is to evaluate the use of Earth Observation data and in particular of the multi-temporal Sentinel 2 data to prospecting and monitoring of mining / quarry areas or abandoned mines on regional and local scales. Three different pilot project areas, Figure 1A, are used in order to assess prospecting, quarrying and rehabilitation activities. The selected test sites represent different problems that accrue in the mineral resources sector. The general Plan of the methodology applied and the data used for the Pilot Sites is shown in Figure 1B.

S/W & DATA

TNTgis Integrated application of raster/vector techniques

http://www.microimages.com/products

Sentinel 2
https://cophub.copernicus.eu/dhus/#/home

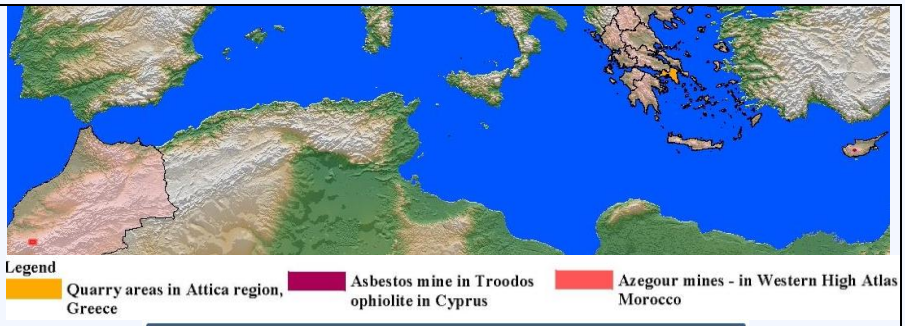
The pan-European component of Copernicus

https://land.copernicus.eu/pan-european

Greek quarry data
http://www.latomet.gr/ypan/default.aspx

Aster DEM
https://earthexplorer.usgs.gov

Geologic maps available in Geological Surveys of Greece, Cyprus



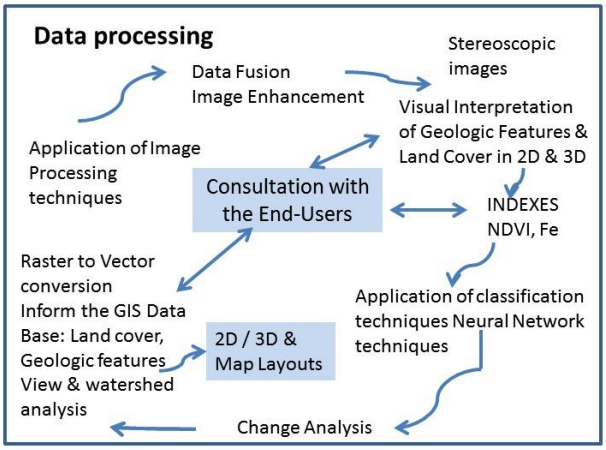


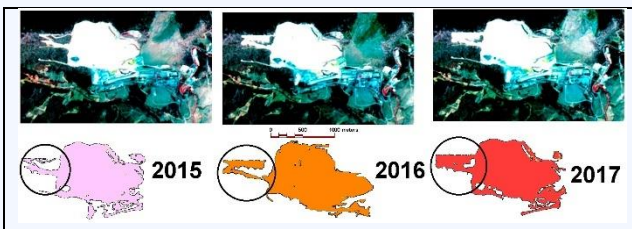
Figure 1. Pilot project areas and overview of data and methods of analysis.

Multitemporal Sentinel 2 data for the time interval of 2015 to 2017 have been collected for each site along with ancillary information, Figure 1. Research has been accomplished following step by step analysis including (1) Pre-processing of EO data, (2) Image processing, (3) Application of neural network classification techniques, (4) Application of GIS techniques, Figure 1. Consultation with End Users has been carried out and this has been integrated in the various stages of analysis.

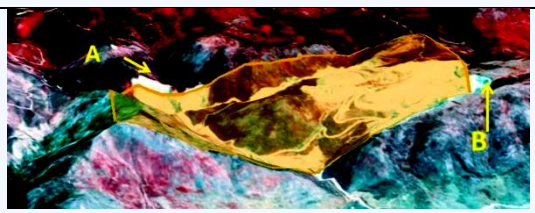
2. PROCESSING OF THE PILOT STUDY AREAS

2.1 Greece

The pilot application in Greece refers to the use of processed Sentinel 2 data for the mapping/monitoring of surface changes attributed to quarrying activities (legal and/or illegal). Several pilot sites with quarries have been identified in Attica region. The application of the methodology shows that Earth Observation techniques can support the monitoring of quarrying activities like: (a) Potential illegal activities taking place in active quarries with a valid permit, and (b) extraction activities in unpermitted sites Figure 2 A, B. Monitoring is supported through change analysis Figure 2A.



A



B

Figure 2. A: Monitoring quarry activity without valid permit. Surface works have been extended by 10212 m^2 for the time interval of 2015 to 2017. B: Quarry area with activity outside valid permit.

The methodology can support field inspections of quarries to ensure national regulations are met. Regular updates can be obtained (Seasonal / monthly / bi-monthly or even more frequently). EO tools assist in mapping & monitoring surface activity –Aspects of the activities have to field verified by the End User.

2.2 Cyprus

Past operation of the Asbestos mine on the Troodos Ophiolite in Cyprus has as result different environmental problems. Therefore, following the termination of the mining activities in 1992, the Cyprus Government undertook the rehabilitation works. The application of the developed methodology can be used for the determination of the land use changes and monitoring progress of restoration works, along with the identification of the local pollution related to former mining activities, Figure 3A. Watershed analysis shows the direction of surface water flows which can be used for risk assessment as it might affect population living in the surrounding areas (Kato Amiantos village), Figure 3B. The rehabilitation works which are taking place in Asbestos mine can be monitored. Rehabilitation through reforestation on part of the quarry area has taken place and this can be mapped and monitored quite accurately, Figure 3C. Monitoring of "reforestation" is particularly important to be carried out on Asbestos mine and this of special interest to the Forestry Department.

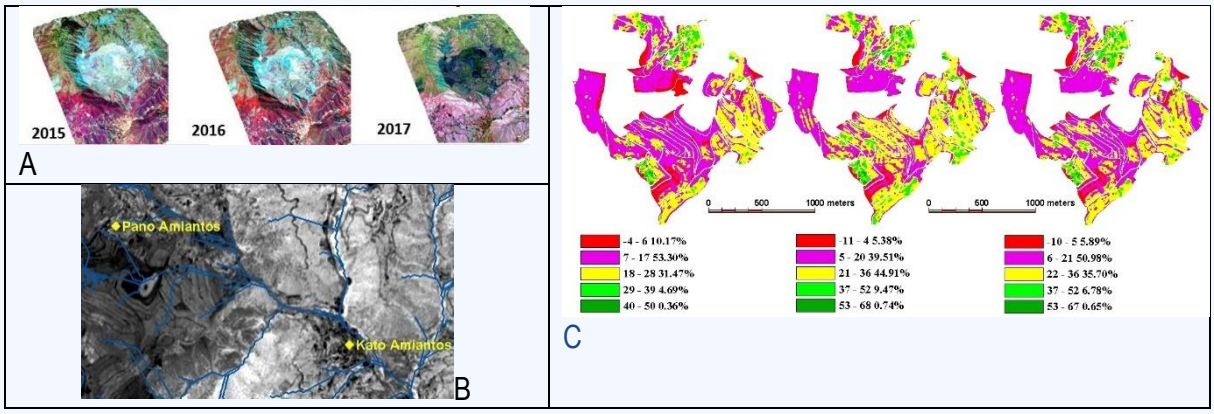


Figure 3. A: Monitoring of Asbestos mine in 2915,2016 &2017. B. Watershed analysis with surface flows directed towards Kato Amiantos village. C. NDVI for reforested areas of the mine.

2.3 Morocco

Azegour is a skarn deposit which was most intensively mined between 1931 and 1947. The assessment of the contribution of Sentinel 2 data on mapping geologic features on local scales is included.

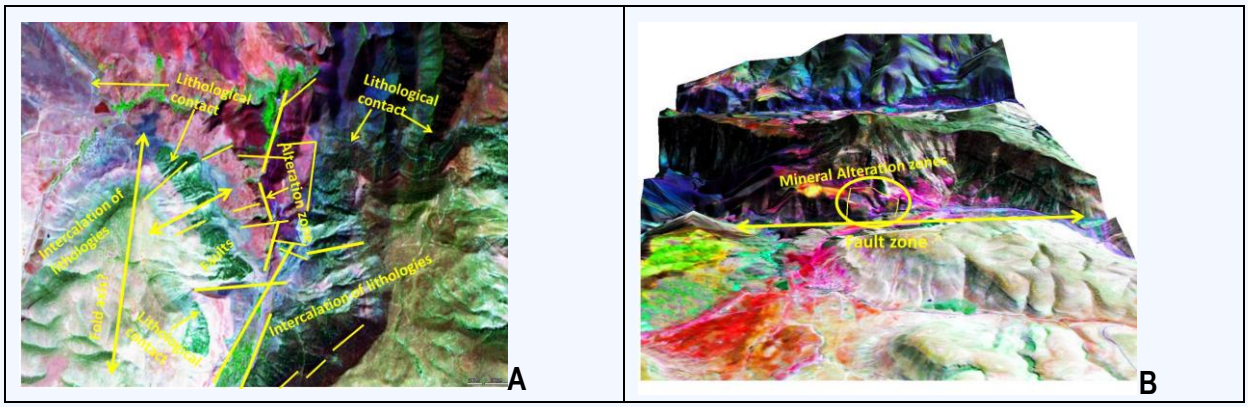


Figure 4. Sentinel 2 processed satellite image of 70 km^2. (A) Enhanced and annotated (B) 3D annotated representation. An area of 0.4 km^2 (ELLIPSE) is under detailed investigation.

As it is shown on the Figure 4 information concerning the general tectonic outline of the area along with the mapping of different lithology and mineral alteration patterns can be accomplished. In particular when investigating the spatial patterns, it is revealed that there is a good capacity of the proposed Sentinel-2 image products to map the geological structure, lithology, mineral alterations and environmental setting at scales up to 1: 20,000.

3. DISCUSSION OF RESULTS

The immediate benefits of the developed methodology can be summarized as following:

- Discrimination of geologic setting - Geologic feature extraction to optimize field reconnaissance. This is of particular interest during the initial planning of exploration activities. Supporting spectral analysis for the detection of "specific target mineral types" that are suspected to be present within Target Areas of Interest in High Concentration.
- Mapping disturbed / undisturbed land. Map land cover changes Identification and characterization of the nature of the changes observed – Identify compliance with permitting regulations.
- Rehabilitation monitoring of the conditions of lands related to mining areas. Delineation of areas where potential restoration activities may take place can be proposed.
- Other types of satellite data (i.e Pléiades, RapidEye, WorldView Images with 0.5 meter resolution**)** can also be included for an improved mining exploration, Mining Site mapping and monitoring.

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