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Remote sensing in the study of the contaminated areas

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Introduction

The study area is mining area of Niccioleta – Val d'Aspra located about 6 km NE of town of Massa Marittima, near Grosseto, South Tuscany. It is an abandoned mine where pyrite and Pb-Zn (Ag) mineral ores with Fe oxdes and hydroxides were mined. The polymetallic mineralizations have been the subject of mining activity, albeit with ups and downs, from the Etruscan period until the mid-twentieth century. Until 1992, the year of closure, mining activity was concerned exclusively to the pyrite mineralizations. This mineral was used for the production of sulfuric acid and iron pellets, in an industrial process which also provided for recovery of heat produced for energy purposes (Lattanzi et al., 1985). In this mine site there are four main landfill, in which fine-grained materials prevail from treatment for ore flotation. The maximum development of the mine is about three kilometers in the sense N-S and about 500 - 600 m in the sense E-O (Tesser E., 2012). Currently, the Niccioletta mining area is part of the Parco Nazionale delle Colline Metallifere Grossetane – Tuscan Mining Geopark, and it is the subject of reclamation with permanent safety (the process is still active).

This study has objective to identify, by means of remote sensing techniques, the presence of minerals that determine the dispersion of toxic ele ments such as heavy metals.

The work intends to characterize in an alternative and effective these polluted areas, supporting the characterization and remediation of contaminated mining sites, with an approach that increases the efficiency of the process of restoration of the site, saving valuable time and resources.

Study areas

The study area is the mining area of Niccioleta - Val d'Aspra located about 6 km NE of the town of Massa Marittima, near Grosseto, South Tuscany. It is an abandoned mine where pyrite and Pb-Zn(Ag) mineral ores with Fe oxides and hydroxides were mined. The polymetallic mineralizations have been the subject of mining activity, albeit with ups and downs, from the Etruscan period until the mid-twentieth century. Until 1992, the year of closure, mining activity was concerned exclusively to the pyrite mineralizations. This mineral was used for the production of sulfuric acid and iron pellets, in an industrial process which also provided for the recovery of heat produced for energy purposes. Currently, the Niccioleta mining area is part of the Parco Nazionale delle Colline Metallifere Grossetane - Tuscan Mining Geopark, and is the subject of reclamation with permanent safety.

Materials and methods

The images used for the study of the Niccioletta mining area, are those of the sensor RapidEy, of 10 June 2012. RapidEy is a costellation of five heliosynchronous satellites aligned on the same orbit and perfectly identical that allow the acquisition of images at a resolution of 5 meter and 5 multispectral bands of large areas, whit a time of revisiting very short (even daily). The bands used in this work are those of the visible, the near and mid-infrared spectral ranges, that are used, in geological and mineralogical studies. This spectral range of VNIR, 0,440-0,850 µm (bands 1-5), allows the identification of minerals in which are present the transition metal, in particular iron. The RapidEye images were analyzed by the algorihm Vegetation Delineation that, after atmosferic correction, allows to quickly identify the presence and/or absence of vegetation and calculates NDVI. This procedure allows to identify in an immediate the areas without vegetation and concentrate the analysis only in those areas. For the classification algorithnm was used SAM Spectral Angle Mapper associated with the "Niccioleta Library", with score of 0.5. The spectral library was built starting from the USGS spectral library Mineral Spectral Library (splib04), it were selected minerals that literature is known for sure, be present in the investigated area. The "Niccioleta Library" was resampled on RapidEy data.

Results and discussion

The processed images show that the landfill areas have been subject to reclamtion; in fact, they are partially vegetated, despite this fact it was possible to point out, in areas without vegetation, the presence of certain minerals that are formed by the oxidation of pyrite. The minerals, certainly present in the area, are also those that are more easily dected in the bands of RapidEye sensor. Amog the transition metals iron is one of the most important sice it is presenta as ferrosus (Fe2+) and as ferric ion (Fe3+), and this feature allows a good spectral characterization of mafic minerals. Indeed, the presence of iron in minerals and in the rocks is highlighted in the respective spectral signatures from different absorption bands each linked to a specific type of transition. For the ferrous ion (Fe2+) bound to oxygen ions the absorption band is more intense than 1,1 µm, while the ferric ion (Fe3+) has little intense absorption bands at 0,40, 0,45, 0,49, 0,70 e 0,87 µm. The minerals that contain iron can bedistinguished because of these bands absorpition.

The analysis of RapidEye images showed the presence of pyrite and chalcopyrite followed by arsenopyrite. The results obtained in these study, point out potentialities of remote sensing applied to the study of these mining areas, indicating the possible advantages of both time and costs, which could be obtained using these techniques.

Conclusions

The results obtained in these two case studies, point out the potentialities of the remote sensing applied to the study of these mining areas, indicating the possible advantages of both time and costs, which could be obtained using these techniques. Better results could be obtained with an increase in spectral ground reflectance data, with high-resolution satellite images (such as RapidEye data), and a refinement of the analysis algorithms, all supported by mineralogical and geochemical analysis. This will make it possible to have a complete mapping of abandoned mining areas and their environmental status.

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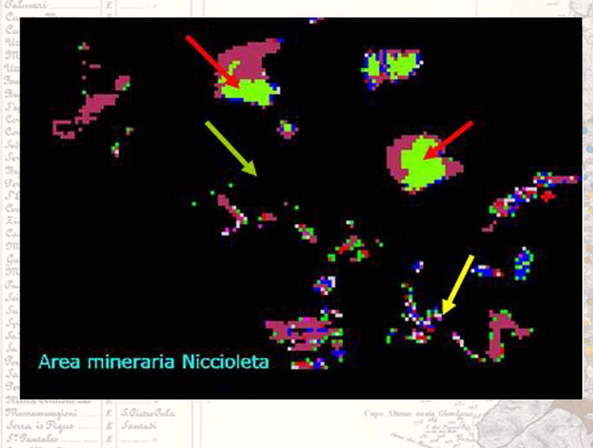
Mining area of Niccioleta (estrapolated from http://it.bing.com/maps/).

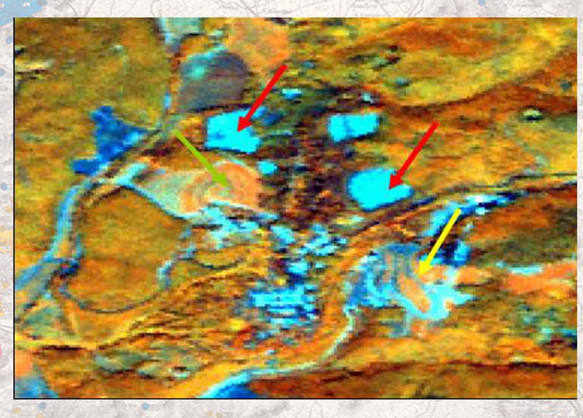
Caratteristiche principali del sensore RapidEye			
Numero banda	Bande spettrali	Intervalli spettrali delle bande	Risoluzione spaziale
1	Blue	440 - 510 nm	5 m
2	Green	520 - 590 nm	
3	Red	630 - 685 nm	
4	Red Edge	690 - 730 nm	
5	Near Infrared	760 - 850 nm	

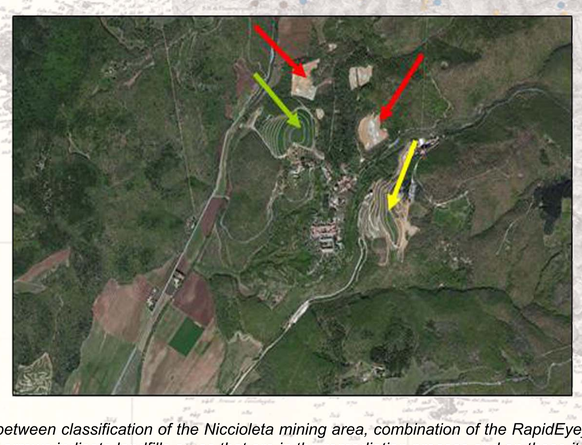
Mining area of Niccioleta: Pozzo Rostan with reclaimed landfill below

Mining area of Niccioleta near Pozzo Rostan with underlying reclaimed landfill but not completely vegetated: particular.

Mining area of Niccioleta: near Pozzo Rostan with underlying landfill reclaimed but not fully vegetated.







Comparison between classification of the Niccioleta mining area, combination of the RapidEye_543 image and the orthophoto: red arrows indicate landfills areas that are in the remediation process and on these it can still identify present minerals; green arrows indicate the already remediation areas, largely covered with vegetation; in this case it is not possible to identify any mineral; finally, yellow arrows indicate the remediation areas but not completely vegetated.

The Geo-mining Park was established with Ministerial Decree 16 October 2001. The law establishing, inserted into the State Budget Law L.388/2001, represents a particular innovation in the field of legislation on Parks. In fact, as manager identifies a consortium similar to organizations and research institutes referred to L.168/89 and does not use the framework law on protected areas n.394/91.

The areas were chosen and numbered progressively in a logic based on the history of mining in Sardinia.

These areas contain an extraordinary heritage of mining archeology which together with the natural and cultural ones make the Mining Geopark unique in the world.

Area Monte Arci - 271 sq km;
Area Orani - 130 sq km;
Area Funtana Raminosa - 145 sq km;
Area Gallura - localised sites;
Area Argentiera-Nurra - 61 sq km;
Area Guzzurra-Sos Enattos - 134 sq km;
Area Sarrabus-Gerrei - 575 sq km;
Area Sulcis Iglesiente Guspinese - 2455 sq km;
Total Area 3771 sq km