Remote sensing of areas at high environmental risk

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Summary
Regional Agency for Environmental Protection of Campania (ARPAC) with the agreement entitled "Creation of a structure for the management and processing of remote sensing data for environmental protection," contracted with the Institute for Atmospheric Pollution, National Research Center (CNR-IIA), Monterotondo (Rome), has developed a remote sensing laboratory to support the scientific and technical activities for environmental monitoring and environmental information management. The use of remote sensing image processing technologies has given to the Agency a set of analytical methods capable of monitoring the area through the creation of thematic maps about the environmental issues of Campania Region. This paper describes the methodologies used in the search for thermal anomalies by hyperspectral data (Multispectral Infrared and Visible Imaging Spectrometer, MIVIS), with particular attention to the multitemporale analysis of identified sites. The study presented is focused on the territory of the *Regi Lagni*[1] (in Campania), concerned for years by severe environmental change.

Introduction
"*Regions, provinces and municipalities are constantly engaged in an intense monitoring of key environmental compartments such as soil, air and water, detecting possible sources of pollution*" (ARPAC, 2009). Environmental monitoring makes possible not only to detect the current pollution, but also to prevent the causes opposing a strong deterrent to the completion of all the environmental crimes threatening public health and ecosystems. The satellite remote sensing, in this context, is an instrument of integration for monitoring the quality parameters of water and earth on a global up to local scale thanks to the high spatial and spectral resolution of some sensors. MIVIS hyperspectral images used in this work, taken their name from the sensor featured by 102 bands shared between the range of the visible, infrared medium, and the thermal spectra. MIVIS images are characterized by high spectral resolution; they are suitable to local study of the links between different chemical and physical parameters that allow the detection of thermal anomalies in soil and water.

Studied Area
The examinated area is the territory of the Regi Lagni, in Campania, about 65 km long; it originates in the town of Visciano in the province of Naples, through the town of Acerra, Marcianise, Foglianise, Marigliano, San Felice a Cancello, Villa Literno, Santa Maria La Fossa, to the town of Castel Volturno in the province of Caserta (Figure 1).

[1] Regi Lagni are a net of water channels, most of them are artificial. They are classified by Italian Water Law (D. Lgs. 152/99) as superficial water body. They collect rain and well waters.

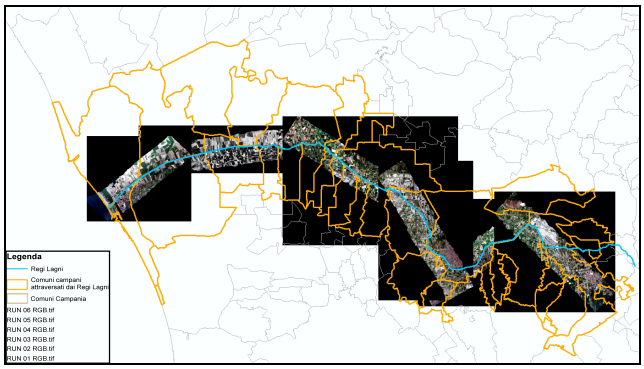

Figure 1 - Mosaic of MIVIS images analyzing and identifying the location of the Regi Lagni in Campania.

Dataset

The dataset used in this study for the detection of thermal anomalies, present both on the surrounding area both in the water, is made up of:

- MIVIS hyperspectral images of Regi Lagni acquired in July 2008 and detected at an altitude of 1500 meters;
- Orthophotos taken in 2006 in the Campania Region;
- Orthophotos taken in 2000 in the Campania Region;
- Black and white orthophotos taken in 1994 in the Campania region acquired by the "Italian Cartography Portal" of the Ministry for the Environment, Land and Sea Protection;
- High-resolution satellite images taken from *Google Earth* website (earth.google.com).

MIVIS data were initially subjected to radiometric and geometric correction, and delivered by the CNR-IIA in the chosen cartographic reference system, in our case UTM-WGS84.

Analysis and extraction of themes

The used methodology has allowed to obtain significant results for the identification, study and mapping of the various types of anomalies in the studied area. The study was divided into four phases:

- the first one, characterized by the display of MIVIS true color images (True Color Composite), has allowed to make a first photo-interpretation of the studied area;
- the second one represented by the study of thermal infrared wavelengths for the detection of thermal anomalies;
- the third one described from the analysis of vegetated areas by studying the Normalized Difference Vegetation Index (NDVI);
- the fourth phase featured by visualized multitemporal analysis, interpretation and comparison of images of the dataset (our study).

The first phase of the analysis has previewed for the photo-interpretation as a first method of observation of the territory, facilitating not only the study and interpretation of the shapes of the land, but also obtaining all the information in the made available ancillary data (orthophotos 1994, 2000 and 2006).

The second phase is marked by the identification of thermal anomalies, has used the compilation of the bands corresponding to the thermal infrared (8.4-12.5 µm spectral range) for the study of surface temperatures through the technique of *Density slicing*.

Through this method it is possible, in fact, to observe the information contained in the image thanks to the representation through a color scale of classes of objects present in the scene analyzed. The outcome is a map of surface temperatures, according to which the differences of temperature are shown with different colors.

The third phase was characterized by the study of vegetation by analyzing the NDVI applied to hyperspectral images (Roettger, 2007), which has allowed to highlight the abnormal growth of vegetation that, in some cases, may be related to soil environmental pollution phenomena. The vegetation index NDVI is one of the indices more used for the analysis of health of the vegetation.

It is based on the normalized difference of the reflectivity values (ρ) in the near infrared band and red; it is defined as the ratio between the difference and the sum of two bands, respectively, the near-infrared (NIR) and Red (R):

$$NDVI = (\rho NIR - \rho R) / (\rho NIR + \rho R).$$

This normalized ratio provides dimensionless numerical values between -1 and +1. These values are closely related to the health of vegetation, the biomass plant, with leaf area index and biochemical processes of plants. Negative values of the index correspond to water, values close to zero but positive (0-0.2) correspond to soils and values from 0.3 to 0.6, indicating the presence of vegetated surfaces with maximum around 0.8 in the case of very dense vegetation.

The fourth and final phase is described by the following study, characterized by the interpretation of the maps of temperature and the comparison of images obtained with those of previous years.

Results of the study

The thermal anomalies detected in the examinated area are different; in the following, we report a study about the analysis carried out on the field.

The considered time period for the comparison of data goes from 1994, with the black and white orthophotos, to 2008, with MIVIS images; this time interval was chosen to reconstruct the evolutionary process of the found anomalies.

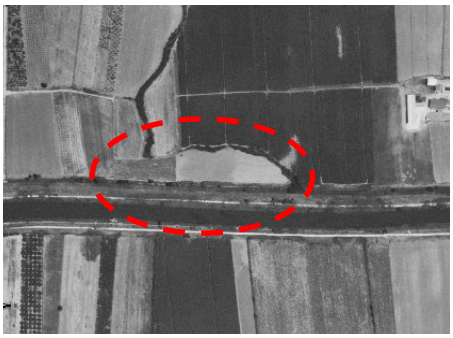

Figure 2 - Detail Orthophoto B / N 1994

Figure 3 - Detail Color Orthophotos 2000

Figure 4 - Special Color Orthophotos 2006

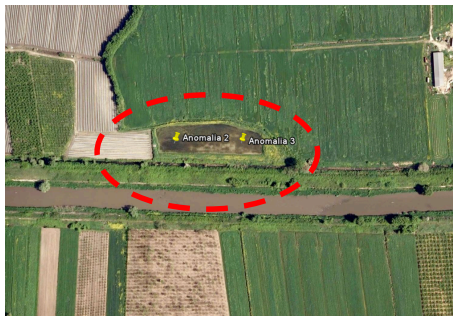

Figure 5 - Detail of the studied area Extracted by Google Earth (2008)

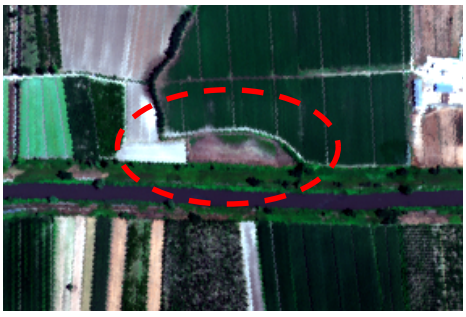

Figure 6 - Detail of the image in RGB MIVIS 2008

From multitemporal analysis of the orthophotos (1994-2000-2006), taken by satellite image *Google Earth* (2004) and the MIVIS image in the visible spectrum (2008) show that the studied area has not undergone any important change, while thermal analysis, performed using the band 94 (Figure 7), have been identified two anomalies that reach approximately temperature of 49 ° C, measured at the sensor.

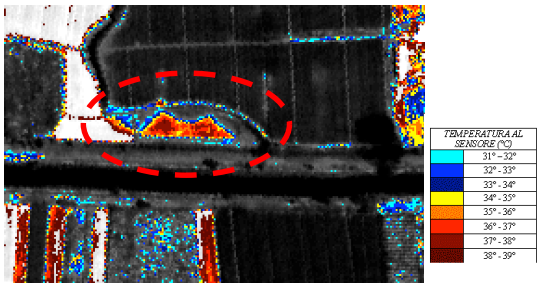

Figure 7 - Detail of the band 94 image MIVIS density slice mode

From the calculation of NDVI (Figure 8) shows that the identified deficiencies are associated with values close to zero; this indicates the absence of vegetation.

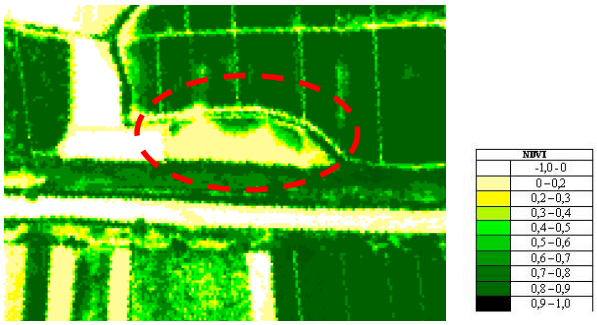

Figure 8 - Detail of the image represented by the NDVI values

Conclusions

The analysis of thermal infrared band MIVIS image has allowed the identification of 26 sites spread across the entire territory, showing abnormalities due to phenomena of temperature increase at some point over the surrounding area.

To find the cause of the detected abnormalities, a campaign of *in situ* observations is under planning for the collection of field data in order to make a qualitative/quantitative assessment of the done surveys.

Among the developments of this study, it is previewed an analysis of high spatial resolution as the data collection exercise; if properly combined with those found in this study and included in a GIS environment, could provide further elements on the proper land use and detection of environmental pollution phenomena.

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