LAND MODIFICATION MEASUREMENTS USING ERS-2 SATELLITE IMAGES

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Abstract: The aim of this paper is to show an experimental use of satellite images in determining soil quality affected by anthropic activities. We have used ERS-2/SAR images [1] as contribution in the process of soil characterization. The area we have considered is in Puglia (Italy) and is subject to soil transformation due to rocks crushed on land for agricultural facilities. Thus the basic aspect is the contribution of satellite in Environmental impact assessment of some components like soil, subsoil and relative factors, for example morphologic modification. The relationship between image intensity and soil characteristics is an important aspect of this work. The amount of rain in the area helps us to determine water effect in the soil. We have also measured the extension of degraded land.

Keywords: Remote Sensing Measurements, Environmental Management, SAR, Multivariate Analysis, Delphi Method.

1   INTRODUCTION

Since the ground of interest is **" karstic"** , the presence of crushed rocks on the ground, also represents a modification of evapotranspiration conditions. We remember that evapotranspiration is defined as combined evaporation (moisture lost to the atmosphere from soil and open water) and transpiration (moisture lost to the atmosphere by plants) [2]. Evapotranspiration measures the total moisture lost to the atmosphere from the land surface, and as such it (together with other variables) forms an important variable in understanding the local operation of the hydrologic cycle.

2   ERS-2/SAR SATELLITE IMAGES

An imaging radar produces an image in which the digital number at each pixel position is determined by the strength of the radar signal reflected from the corresponding location in the scene. Digital image files usually are created using the square root of power, since less dynamic range is required for data in this form. For technical purposes, radar performance may be analyzed in terms of the power of the reflected signals. The power received from each radar pulse transmitted may be expressed in terms of the physical parameters of the radar and illumination geometry trough the Radar Equation. The received power is a function of radar wavelength and wave polarization, among other variables. Images are built by integrating over many pulses, and the mean power in the image from a terrain patch may be derived from the single pulse radar equation. For users, the important relationship is the SAR Image Radar Equation, which has the form:

$$< P_R >= \frac{C_T G^2 (q_i) \Delta x \Delta R s^0}{R^3 Sin (q_i)} \tag{1}$$

where $<P_i>$ is mean received power, per pixel
q_i is incident angle
$G(q_i)$ is one-way antenna power gain
R is range (distance) between antenna and reflecting terrain patch
C_T is constant of the system, including transmitted power, wavelength, various gains and losses
Dx is pixel spacing in the azimuth direction
DR is pixel spacing in the slant range direction
s^0 is average reflectivity, per unit area, of the scene

This expression includes the most important parameter dependencies of concern to a user, which are incidence angle and range. The signal level is very sensitive to the antenna gain pattern, which often is the limiting factor in system brightness calibration. σ^0 is the radar cross section per surface unit of the target. σ^0 is commonly called the *radar backscattering coefficient* and is a parameter characterizing the target. The σ^0 is dimensionless but, as associated to a very high dynamic range (of the order of 10^5), it is generally expressed in decibels. The radar backscattering coefficient σ^0 provides information about the imaged surface. It is a function of: radar observation parameters (frequency f, polarization p and incidence angle of the electromagnetic waves emitted) and surface parameters (roughness, geometric shape and dielectric properties of the target).

Synthetic Aperture Radars were developed as means of overcoming limitations [3] of RAR (Real Aperture Radars) that are often called SLAR (Side Looking Airbone Radars). SAR systems achieve good azimuth resolution that is independent of the slant range to the target, yet use small antennae and relatively long wavelength to do it. A synthetic aperture is produced by using the forward motion of the radar. As it passes a given scatterer, many pulses are reflected in sequence. By recording and then combining these individuals signals, a "synthetic aperture" is created in the computer providing a much improved azimuth resolution. It is important to note that the detailed structure of the echoes produced by a given target change during the time the radar passes by.

The Objective of SAR processing is to reconstruct the imaged scene from the many pulses reflected by each single target, received by the antenna and registered in memory. SAR processing is a simple process although it requires much computation. It can be considered as a two-dimensional focussing operation. The first of these is the relatively straightforward one of range focussing, requiring the "de-chirping" of the received echoes. Azimuth focussing depends upon the doppler histories produced by each point in the target field and is similar to the de-chirping operation used to focus in the range direction. This is complicated however by the fact that these doppler histories are range dependent, so azimuth compression must have the same range dependancy. It is necessary also to make various corrections to the data for sensor motion and each rotation for example, as well as for the changes in target range as the sensor flies past it.

3   MULTIVARIATE ANALYSIS

The adopted methodology regards multicriteria analysis with matrices of variable correlation levels. It is gives interesting results and allows in the same time to consider also other aspect than environmental ones. As results from the methodology that uses matrix models are conditioned by the operating choice provided by compiler, we have used Delphi method (Air-Force, USA) to find, to choice and to weight meaningful elements to be employed in the estimation of magnitude to be given to factors and to be assign to correlation levels. We have assigned magnitude to factors (minimum, average and maximum magnitude) according to statistic evaluation on the ecosystem and on satellite data acquisition.

Once we have assigned magnitudes and decided on correlation levels, we have developed matrices by software capable of processing elementary impacts through a matrix with seven correlation levels and with variable summing. We have decided to adopt 4 correlation levels :
A= 2B, B=2C, C= 2D, D=1 and the sum of influence values as 10 (A+B+C+D=10).
The Correlation levels are:

A = high; B= average; C= low; D= lowest.
Computing step consists in the development of an equation system for each component, composed of multiplicating factors of correlation levels and of overall value influence.
Elementary impact is given by:

$$I_e = \sum n_i (I_{pi}.P_i) \tag{2}$$

where I_e= elementary impact on any component
I_{pi}= pondered influence of factor on component
P_i= factor magnitude (own)

4   LAND MODIFICATION EVALUATION

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4.1   Area of interest

The present work reports results of an analysis regarding the anthropic phenomenon of "Rock crushing" in the nothern area of Murge - *Alta Murgia* (Italy). The objective of the work is geologic sensing, according to a large scale first and a detailed one on the other hand, for a vast area of Puglia Region called "Murge". Geological sensing has been used to study and to analyse the diffusion of Rock Crushing in the area, since the nature of appearing rock is limestone. The investigated area belongs to Italian geological map of sheet n.176.
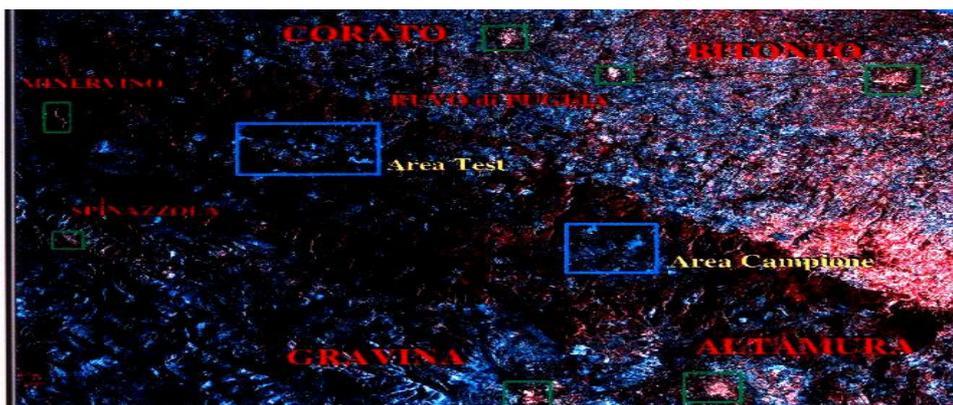

Figure 1. Geographic location of the area

4.2   Data analysis and methodology

We have used ERS-2 images for the area of carbonatic platform of Puglia Region (as illustrated in figure 2). Since it is necessary to perform mutitemporal analysis, we have preselected four digital images for the same scene and referred to the same period of the year. In particular images are relative to the following dates and each frame measures 100 km x 100 km.

The predisposed methodology has been executed according to the following steps: visualization of each frame with the description of spectral signature, filtering operation by putting on the image digital number pixels, selection of best bands and photo interpretation .

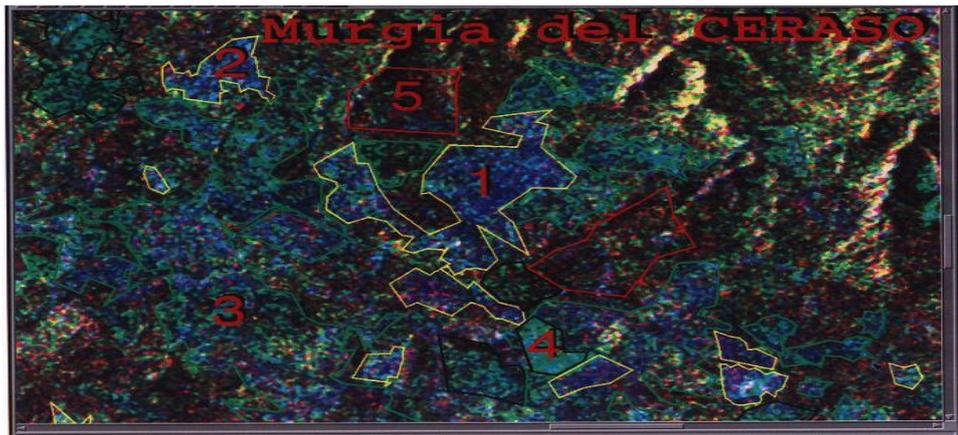**Figure 2.** Geographic frame of the area in a SAR imaging

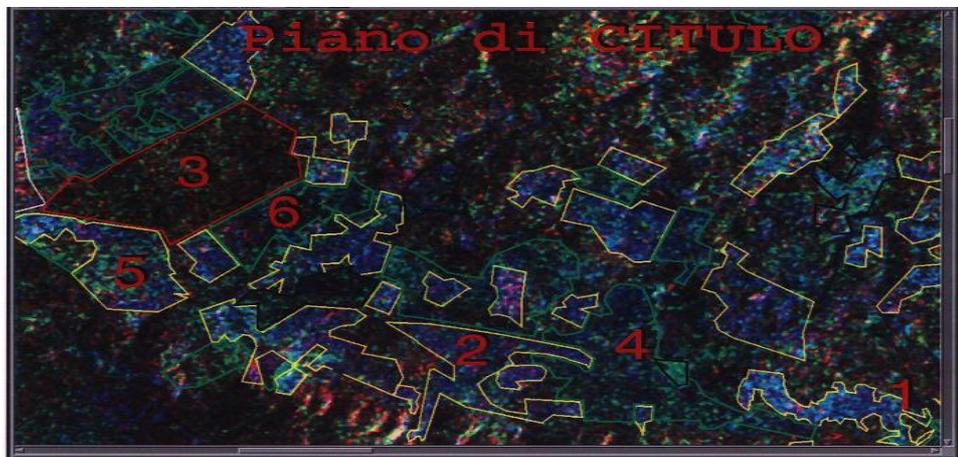**Figure 3**. Sample area - overlaying of April/October/January

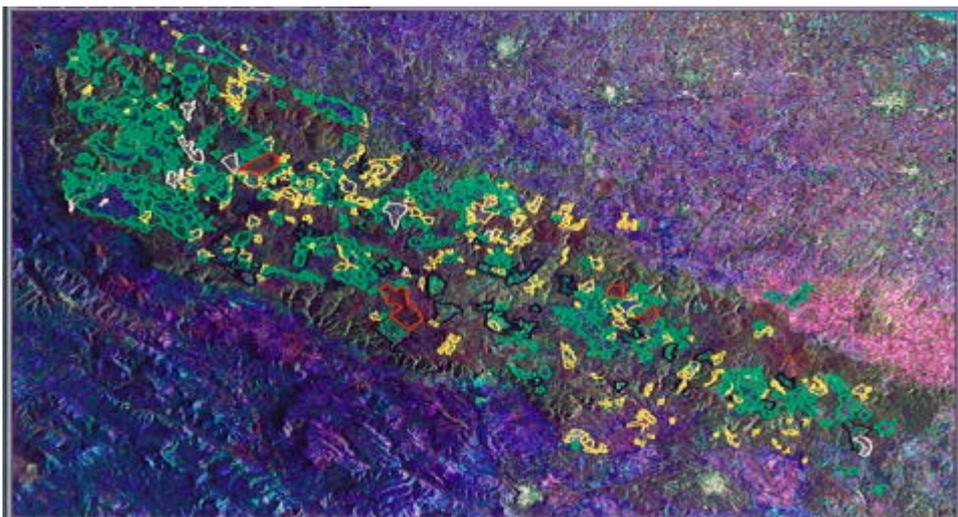**Figure 4.** Test area - overlaying of April/October/January

Figure 5. Overall SAR image of the area

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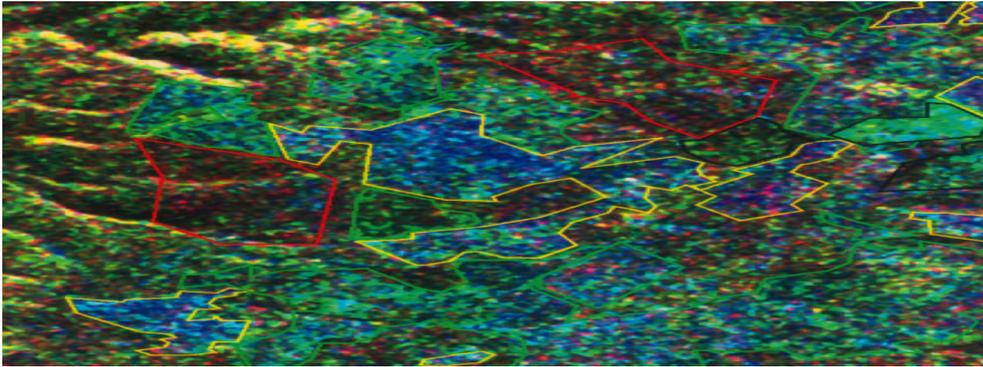Vienna, AUSTRIA, 2000, September 25-28

Figure 6. Area classification

4.3   Matricial evaluation

The role of ERS-2/SAR data has been decisive in impact evaluation. Verifications have been made on the area in order to have a comparison between calculations and ground reality. The results can be considered good. Figure 3 and Figure 4 illustrate the sample area and the test one, from which Air photo interpretation has been performed. In Figure 5, we have an other representation of the area of interest. In Figure 6 we get a classified image according to the SAR reflectivity.

Table 1. Situation before crushing - example of considered components: soil and subsoil.

Example of factor list	Magnitudes		
	min	own	max
Precipitation	1	1	4
Morphologic modification	1	1	3
Flood risk	1	1	2
Vegetation modification	1	1	2

Table 2. Situation after crushing - Example of considered components: soil and subsoil

Example of factor list	Magnitudes		
	min	own	max
Precipitation	1	1	4
Morphologic modification	1	3	6
Flood risk	2	5	6
Vegetation modification	2	5	8

Table 3. Results of multivariate analysis

Component	Before crushing Elementary impact			After crushing Elementary impact		
Soil	10	10	32.5	35	15	57.5
Subsoil	10	10	30	33.3	14.9	53.3

We see first in Table 1 and Table 2 the assignment of magnitudes before and after crushing. Magnitudes have been statistically computed by using Pair Comparison Technique in relationship with

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the   area rate for each classification. All calculations in Table 4 have been executed with an appropriate software of Russi Sofware society [4].

4.4   Susceptibility evaluation

An other way to evaluate the quality of soil and the Environnemental impact of crushing activities on soil, is the use of Erosion - susceptibility index according to image interpretation. We have used the Van Zuidam & Van Zuidam Concelado's model [5]. This kind of model is suitable whether it is possible to get remotly sensed images. Data about crushed soil and uncrushed one of the same area, have been collected. In order to meaure soil modification, the following elements have been taken into account: side morphology, soil, substratum, climate and erosion danger. According to this model, the computed index for the same area before crushing is 21, and after crushing 42, as illustrated in Table 4.

Table 4. Susceptibility evaluation

Type of area	Susceptibility to erosion	Characteristics
Area before crushing	Class III, total index 21	middle
Area after crushing	Class IV, total index 42	high

5   CONCLUSIONS

Simultaneously, using minimun and maximum magnitude of any factor (m, M), we get for each component, relative elementary impact and we measure the area of degraded land, as shown in figure. The role of ERS-2/SAR data [6] has been decisive in impact evaluation. Verifications have been made on the area in order to have a comparison between calculations and ground reality. The results can be considered good. Magnitude computing and susceptibility evaluation have shown the use of satellite images in oder to measure land modification. "On situ" measurements have been performed by means of Global Positioning System (GPS) to compute the extension of areas as confirmation of satellite data.

REFERENCES

[1] J.T. Pulliainem, L. Kurvonem, M.T. Hallikainem, Multitemporal Behavior of L- and C- Band Sar Observations of Boreal Forests, *IEEE Trans on Geoscience and Remote Sensing*, Vol.**37**,No.2, March 1999.

[2] M. Moghaddam, S. S. Saatchi, Monitoring Tree Moisture Using an Estimation Algorithm Applied to Sar data from BOREAS, *IEEE Trans on Geoscience and Remote Sensing*, Vol.**37**,No.2, March 1999.

[3] Goodyear Aerospace Corporation, "Basic concepts of Synthetic Aperture Side-Looking Radar", GIB9167, 1971.

[4] A. Russi, L. Buccino, *Elementary impact calculations with matrix models*, Dario Flaccovio Editor, Palermo, Italy, 1999.

[5] V.R.A. Zuidam, F.I. Zuidam Concelato, *Terrain Analysis and Classification Using Aerial Photographs: a Geomorphological Approach*, ITC Texbook of Photointerpretation, 1978 .

[6] T. Le Toan, Active microwave signatures of soil and crops: Significant results of three years of experiments, *Proceedings of Symp. IGARSS'82*, Munich, Germany, June 1-4, 1982.

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