GIS AND REMOTE SENSING FOR THE STUDY OF INTERACTIONS BETWEEN NATURAL AND INDUSTRIAL HAZARDS

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ABSTRACT:

In the Italian territory about 1/3 of municipalities are located in areas exposed to seismic hazard. At the same time most of the Italian territory is subject to hydrogeologic events (i.e. landslides and floods). The area object of this study, Sulmona Basin and upper Pescara Valley, is characterized by potential exposition to these hazards, with a particular attention to seismic hazard and landslide hazard. Furthermore the area is characterized by the presence of major hazard industrial plants.
For this paper a dedicated GIS database has been built in order to evaluate the interactions between specific natural hazards and industrial hazard and the related vulnerability of territory and population. For this research MIVIS hyperspectral (at a 1500 and 3000 m elevation) images have been used. The obtained images have been georeferenced. From the processing and classification of these images some information layer have been obtained: thematic maps of land-use (industrial areas identification), vegetation conditions, thermal pollution, quality parameters (temperature, organic matter, chlorophyll, sediments) for river waters. Thematic maps obtained from remote sensing have been inserted in a GIS, that means a system to insert, store, integrate, extract, retrieve, manipulate and analyze georeferenced data layers in order to produce interpretable information. Then the data base has been integrated with further information inserted as continuous layers; thematic layers; vector layers; punctual data; attributes. Among inserted layers: location and information regarding industrial plants, seismic classification, landslides and landsliding hazard maps. Some specific operators (overlaying, proximity analysis, recoding, matrix analysis) have been applied that allowed to integrate the information contents and therefore to obtain final thematic maps (hazard maps, vulnerability maps, events scenarios). The innovative technologies proposed facilitate and optimize the management of data and information obtained from different methodologies. Therefore it is useful to develop innovative methodologies in order to support industry and Competent Authorities in disaster management and land use planning.

1. INTRODUCTION

Urban and land context in which is located a major hazard industrial plant is recalled more than once in D.Lgs 334/99, the Italian implementation of European Community directive 96/82/CE on "the control of major accident hazards involving dangerous substances". In particular the operator, in the within his major accidents prevention policy aimed to the safety of workers, of population and of environment should provide a information file that includes the description of territory surrounding the establishment, with the individuation of possible sensitive targets in a 5 km range.
The document ("notification") should include information regarding surrounding environment and, in particular, the individuation of elements that could induce a major accident or increase the consequences.
Art. 14 ("Land-use planning") is focused on the territory surrounding the establishment, highlighting the importance of land-use on a major accident.
The specific Ministerial Decree D.M. of 9 may 2001, implementation of that provided for in above mentioned D.Lgs 334/99 defines the "Minimum safety requirements in urban and land-use planning for areas concerned by major hazard industrial plants".
The aim of the implementation of the Decree is the verification (through the analysis of land vulnerability related to major accidents) and the research (through the adoption of planning tools variances) of compatibility of major hazard industrial plants with land-use and environment.

Remote sensing and GIS techniques are efficient tools for the evaluation of vulnerability and for the verification of compatibility with land-use (guarantee of minimum safety requirements for population and infrastructures) and compatibility with environment (protection of natural sensitive elements). Therefore the tasks required from above mentioned D.M. 5/9/2001 could be facilitated and optimized by this methodologies both in the description of updated actual situation and in planning, and in particular for the drawing up and evaluation of the document "Technical Document on Major Accident Hazard" (RIR).

Figure 1. An area of study with major hazard industrial plants (black dots)

The proposed methodologies have been applied to the study of the area of Pescara (Fig.1). This area can be considered as appropriate land coverage in order to define the environmental conditions that interfere with industrial area of Pescara. The area of study, being located on the coast, is characterized by the presence of industrial plants, urban settlements and recreational facilities.

2. METHODOLOGIES

Hyperspectral remote sensing provide noticeable advantages: the capacity of representing synthetically different landscape elements (synoptic vision); the association of multiple data from different regions or bands in the electromagnetic spectrum (multi-spectral vision); the possibility to carry out survey through time (multi-temporal vision). Anyway it is important to select the kind of remote sensing data to use according to basic requirements like desired results scale. In order to obtain an appropriate scale hyperspectral images took the 30 September 1999 by MIVIS (Multispectral Infrared and Visible Imaging Spectrometer) at elevations of about 1500 and 3000 m a.s.l. have been used. MIVIS has 20 channels in visible (0.43-0.83 цm), 8 channels in near infra-red (1.150-1.55 цm), 64 channels in middle infra-red (2.0-2.5 цm), 10 channels in thermal infra-red (8.02-12.7 цm)
The obtained images have been adequately georeferenced . From image processing and classification some information layers (maps) have been obtained: land-use (industrial area identification), vegetations conditions, thermal pollution, environmental quality parameters (like temperature, organic matter, chlorophyll, sediments in sea and river waters).
Thematic maps obtained from remote sensing have been included in a dedicated GIS, that means a easy to update system to input, store, integrate, retrieve, process and analyze georeferenced layers in order to produce interpretable information. The database has been integrated by further information input like continuous layers (aerial photos, hyperspectral images), thematic layers (land-use, vegetation, geology, hydrogeology, seismic classification, landslides and landsliding hazard maps), vector layer (road maps, rivers), point data (industrial plants location, strategic sites), attributes (population, dangerous substances). Some specific operators (proximity analysis, overlaying, matrix analysis, recoding) have been applied and allowed to merge of different information content and to obtain finale thematic maps (environmental quality maps, vulnerability and hazard maps, display of accident models, event scenarios).

3. RESULTS

For the study of Pescara area the following information have been used:

- Orthophotos AIMA (Italian Agricultural Market Authority);
- IGM (Military Geographical Institute) cartography (scale 1:25000);
- Hyperspectral MIVIS images;
- Thematic maps (geology, hydrogeology, geomorphology.

For this purpose a flight has been realized on 30 September 1999, at elevations of 1500 m and 2900 m a.s.l. For the survey a MIVIS sensor has been used, that collected information in 102 spectral channel between 0.43 and 12.7 μm. The images, radiometrically calibrated, have been georeferenced using AIMA orthophotos. This process was performed through and algorithm based on ground control points, with a linear spatial interpolation and a 0 order intensity.
Hyperpectral images have been processed in order to obtain accurate and upgraded information on water quality, vegetation condition and thermal pollution.
For that concern river and sea waters, studied quality parameters are: temperature, sedimentary load, turbidity, organic matter content, eutrophication, chlorophyll content, possible algal blooms, thermal chemical and organic pollution phenomena; furthermore from image processing has been obtained important information on bathymetry, sea bottom features, hydrodynamic circulation.
In order to obtain information regarding vegetation (environment quality indicator) surrounding industrial areas, NDVI (normalized difference Vegetation Indexes) has been computed.
The application of the visualization technique density slice in far (thermal) infrared allowed to investigate and evaluate possible anomalies related to thermal pollution near studied industrial plants.
The classification of Pescara area has been performed using different algorithms unsupervised (Isodata, K-means, Fuzzy K-means) and supervised (Maximum likelihood and Neural Net).
Intuitively it should seems that the more bands are used for the classification the best could be the results. As a matter of fact there is a relatively small number of optimal bands, because the information content of a relevant band can be "contaminated" by non significant data from other reciprocally correlated bands, decreasing the accuracy. This probable is particularly noticeable with hyperspectral images. The decision regarding which, original or synthetic, bands to use involved the study of histograms and bands separability. Principal Component Analysis allowed to overcome the problem represented by high level of correlation among bands, defining a new coordinates projected on principal components, that means the maximum range of dispersion. The product represented by a few synthetic bands having an elevated information content. The application of this techniques allowed to create 13 synthetic bands with an elevated information content, that have been used for classification.
The unsupervised (traditional and innovative) classification provide information that integrated by visual interpretation, thematic maps, and direct knowledge of the area, allowed to identify the samples for supervised classification.
Among the three applied unsupervised classifications the best results, in terms of separability, has been ISODATA algorithm. ISODATA classification identified 16 classes, then aggregated in 14 classes.
"Maximum likelihood" algorithm has been applied in order to obtain a supervised classification of land-use.
A further element of interest of the research is constituted by the comparison between the results obtained applying traditional classification techniques (MLC) and those obtained from different approaches (neural net).
For the neural net classification a perceptron net has been used, with a back propagation training, 13 input channels (2 units each channel), 2 hidden layers, and 16 classes in output. Anyway the neural net classification did not provided a better information than traditional classification, like it happens in the analysis of morphologically rough with many shadows.
Then the land-use maps have been input in a GIS and integrated with other information like hydrogeology, geomorphology, lithology, geologic structure, stratigraphy, orthophotos, industrial plants location, major hazard plants features, urban settlements as information layers.
The software EASI-PACE (PCI) allowed to take into account and process layer both in raster (land-use maps) and vector (industrial plants) format. The processing has been performed through typical GIS operators like indexing, recoding, matrix analysis, and proximity analysis. The matrix analysis assigns a different output value each combination of input values. Proximity analysis creates a layer that shows the different proximity (distance) zones from an element or a group of elements. The choice of indexes, of recoding values, of weights

and matrices has been based on references, personal experience and knowledge of the area.
The possible interactions between industrial facilities, urban areas and other environment components have been studied. This allowed to obtain different thematic layers showing environment quality, hazard, impact. The vulnerability of the possible sensitive targets located in the areas surrounding the major hazard plants has been analyzed (Fig. 2 , Fig. 3 and Fig.4).

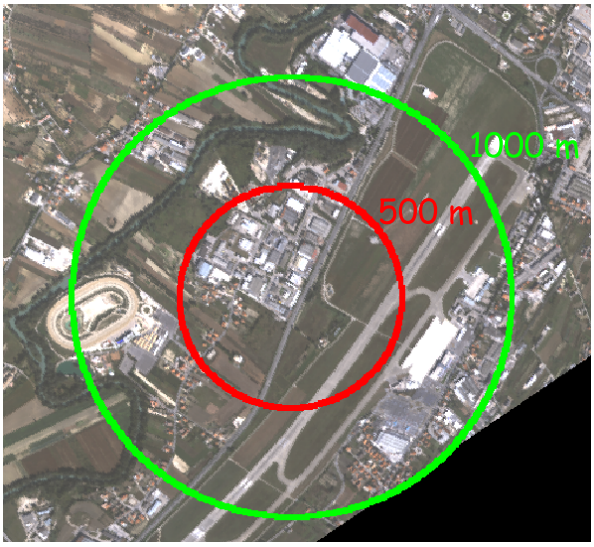


Figure 2. Identification of the vulnerable elements in the environment surrounding a major hazard industrial installation (stadium, shopping mall, airport, highway, urban and industrial settlements)

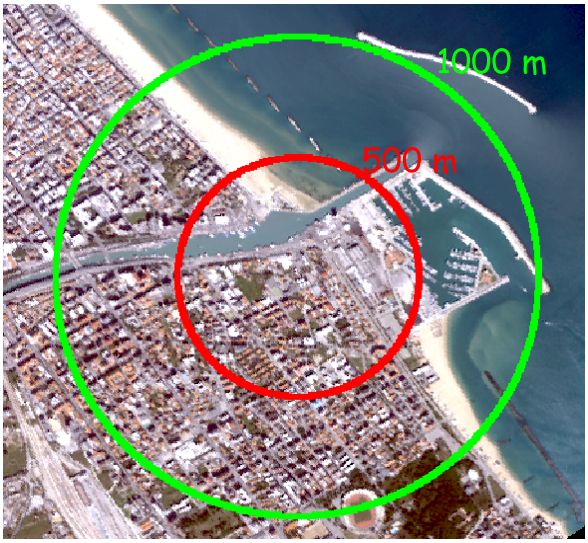
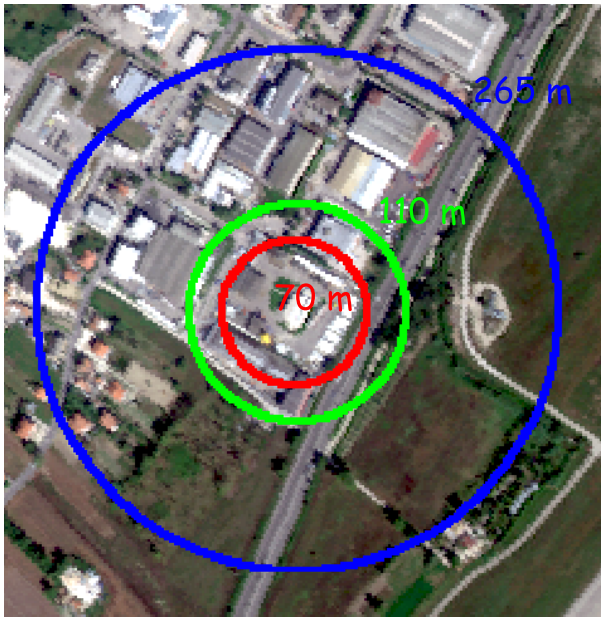


Figure 3. Identification of the vulnerable elements in the environment surrounding a major hazard industrial installation (market, marina, urban settlement, stadium)

Figure 4. Identification of the vulnerable elements in the environment surrounding a major hazard industrial installation (railway, highway, urban and industrial settlements) and natural hazards (1965 lanslide)



Furthermore the visualization of damage models (provided according to regulation by plant operator) related to accidents has been obtained (Fig. 5 and Fig. 6), constituting a valid support for land-use planning and natural and industrial hazard management.

Figure 5. Visualization of the area of possible damage for Flash-fire (instantaneous thermal radiation): Zone I high lethality; Zone II lethality; Zone III irreversible injuries

Figure 6. Visualization of the area of possible damage for Flash-fire (instantaneous thermal radiation): Zone I high lethality; Zone II lethality.

4. CONCLUSIONS

In complex and vulnerable environments it is basic to find ways to convert data into information. Remote sensing and GIS represent useful methodology aimed to that, and at the same time can play an important function in monitoring and management. These methodologies facilitate ad optimize the performance of tasks required by current regulations, as for the recent D.M. of 9 may 2001, aimed to the verification and the research of compatibility of major hazard industrial plants with land-use and environment.
Then it is useful to develop methodologies to support all parties involved, in particular industry and Competent Authorities.

5. REFERENCES

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