RISK ASSESSMENT FOR ENVIRONMENTAL APPLICATIONS: INTEGRATED ANALYSIS OF SPATIAL DATA USING MULTI-TEMPORAL DIGITAL ORTHOPHOTOS AND REMOTE-SENSING SATELLITE IMAGES.

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ABSTRACT:
A recently instituted National Park, in Southern Italy, is offering a wide experience in landscape knowledge and planning from multiple sources finalized to the environmental analysis. The study is conducted, in conjunction with the Italian Ministry of Environmental Affairs, to construct a large multi-disciplinary data-base for monitoring environmental risk and a GIS based management tool.
The full integration of multi temporal digital orthophotos, on a scale of 1:10.000 and 1m ground resolution, with historical and actual vector and raster maps, GPS ground acquisition and Landsat and Ikonos rectified satellite images, was made possible by geometric transformation in the same cartographic projection and datum.
The risk assessment is actually analyzed, using multi-temporal land covers, about the vegetation, forestry, hydrogeology and quarries topics. The paper, concerning the hydro-geological order, describes the linkage between spectral analysis through satellite images and aerial photo coverage on the “stone grinding”: this change of soil composition, executed for agricultural improvements, provides an high increase of terrain permeability.
The area of the National Park, about 1.500 Km^2, has given the possibility to test advanced GIS procedures upon a very large region with a high number of correlated information levels.

INTRODUCTION

The construction of a detailed knowledge base, specialised in environmental analyses, emerges always as preliminary to any territorial planning and management operation. During the last few years there has been an exponential increase in the number of information levels both purposely built or acquired from external sources; a catalyst for this trend has been the digitalization of both graphical and alpha-numerical data, and the relative easiness in the exchange and acquisition of data-bases of large dimension. A drawback of this increase in the quantity of information available is the inability to filter, order and, in the cartographic field, overlay in a usable way representations often inhomogeneous in terms of structure, orientation and measures tolerance.

Fig.1. Aerial photography of “stone grinding”

Pressure on natural resources, the progressive increase in soil consumption and the changes caused by the mechanised transformation of agricultural land, require a territorial and environmental knowledge oriented to the present as well as to the dynamics of historical transformations.
This knowledge includes both the spatial and temporal understanding of the environmental phenomena and of the processes that govern real land use.
These considerations, and others, have led and oriented the methodologies elaborated for the construction of the basic instruments for the understanding and monitoring of the territory included in the proposed National Park of “Alta Murgia”. The absence, within the perimeter under investigation and within the official one, of urban areas of high settlement density has created the conditions to orient the study more toward the analysis of agrarian and forested territory than to the examination of invasive anthropic transformations.

Fig.2. “Murgia” landscape.

History has many times demonstrated that a low cognitive level, the consequent reduction of renewable resources, and the consequent decrease in the quality of life, may produce tensions in the resident population with adverse effects on the growing level of civilization.
Among anthropic transformation the latter it is worth mentioning the "stone grinding operations" which have interested to a significant degree the south-eastern area of existing grassland and which have reached a peak of transformation activity precisely during the central phase of the present study.
The temporal reliability of the information levels provided is therefore tightly bounded to such activities that have caused, briefly speaking and from a cartographic point of view, transformations in the land use representation, the demolition of dry-stone wall boundaries, the flattening of small irregularities in altimetry, the destruction of significant parts of the secondary road network. Different evaluations of such radical interventions of agricultural transformation could be made from a morphological, agronomical and hydraulic point of view.

THE CARTOGRAPHIC BASE

An in-depth analysis of the territorial survey methodologies has allowed to chose those techniques that appear to be more mature and diffuse in such field and that have been applied in conjunction with modern digital technology and with structures and formats widely used at the regional and national level, despite the various obstacles encountered.

HISTORICAL DATA

The geographic Databases used for multitemporal analyses are are essentially:

- Digital orthophotos, nominal scale of 1:10.000, produced for Italian Ministry of Agricultural Affair, from the 1997 and 2001 aerial photo coverages.
- Digital cartography on a scale of 1:25.000 produced in 1999/2000 from the aerial photo coverage of July 1999;
- Ikonos High resolution panchromatic image of May 2000.

The abovementioned cartographic levels, vectorial as well as raster, are analysable, being univocally referenced, in a hybrid CAD environment as well as in a GIS one. An accurate analysis of metadata (which include useful information particularly in order to assess the cartographic tolerances) will always be necessary to evaluate in a correct way the geometrical variations arising form maps of different periods and with considerably different scale of representation.

1:10.000 DIGITAL ORTHOPHOTOS

After an initial phase, based on the historical (1976) raster mosaic of 1:50.000 I.G.M. cartography, the working group, since august 1999, started to operate on the digital orthophotos acquired from the Ministry of Agricultural Affairs and produced for the AIMA and AGEA (technical partners of the Ministry). The cartographic product, supplied on digital support in *.TIFF and *.SID raster format, is associated with numerical data (World file) necessary for the geo-referencing to the National Cartographic System "Gauss-Boaga". The production technique of the 1:10.000 digital orthophoto-map (based, as far as Puglia is concerned, on the aerial-photo coverage of July 1997and 2001) follows the more updated production procedures currently available:

- B/W aerial-photo coverage , nominal photo-scale 1:40.000, acquired on high-resolution film and FMC cameras, in order to compensate the photographic effect of forward motion.
- Photograph digitalization by a photogrammetric scanner, of adequate radiometric resolution, with a pixel dimension of 25µm (1000dpi) at a photo-scale corresponding to a 1m ground resolution.
- Adjustment of an aerotriangulated block oriented on the Italian National Trigonometric and GPS IGM95 networks.
- Creation of a automatically correlated DEM of images with a variable dimension grid, with regard to the uneven altimetry of the terrain (always lower than 100x100m and up to 20x20m).
- Orthoprojection and digital mosaicking of images with equalization of grey tones, to conceal the seaming zones.

The files produced in such a way, used alone or after resampling and mosaicking at smaller scales, formed an indispensable base for the numeric photo-interpretation of some important themes of analysis:

- Woodlands subdivided by typology, density homogeneous sections, etc.;
- Agricultural areas used as pasture;
- Zones for extensive and semi-extensive agriculture;
- Extension, positioning and dynamics of the quarryng industry;
- Localisation of territorial transformations such as surfaces subject to "stone grinding operations", cultivation in the flood-bed of "lame" (typical karstic fissure of Apulia), etc.;
- Outlining of the perimeter of military areas (concealed according to the law n.1732/1939 and liberalized since February 2000) and assessment of existing military servitudes.
- Detailed analysis of proposed boundaries within a evolving territorial situation.

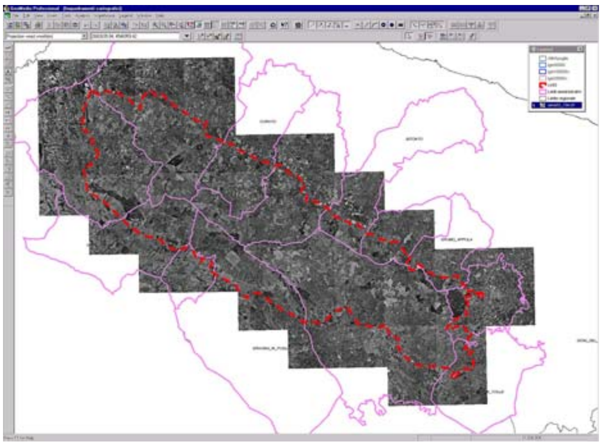

Fig.3. 1999 orthophoto coverage of National Park.

The great usefulness of the used product, characterised by high legibility and capable of a plotting up to a scale of 1:5.000, has been confirmed by the simple photo-interpretative overlay operations, conducted by specialised consultants, by mean of digital monoscopy in a general-purpose CAD environment and subsequently imported in a GIS environment. The simultaneous production of the corresponding raster plotting allowed the same experts to perform a sample-test, with annotations taken on the field, directly on the prints.

1999 DIGITAL CARTOGRAPHY

The construction of a geometrical data-base, updated and structured in conformity to recent methodologies, appears indispensable right from the first design anticipations of the present study. Indeed the mentioned material, even if extremely interesting for comparative historical studies and analyses, seems insufficient as a base for a study concerning such a huge territory, composed of large areas undergoing profound transformations.

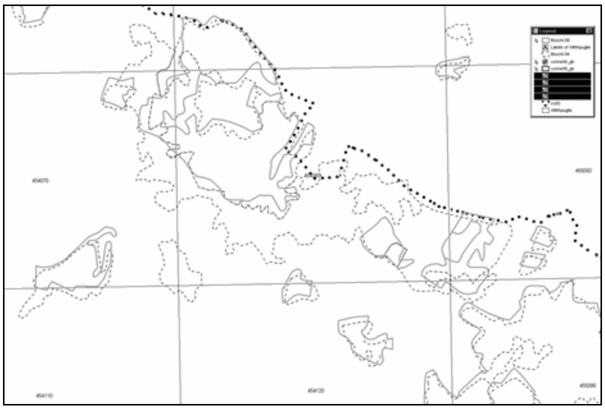

Fig.4. Overlay of Corine LC 1991 and 2001 forest data set.

It proved necessary to build a data structure compatible with the operations of a GIS environment, suitable both for interrogations formulated during the production of the Territorial Plan and for the management of those same areas in subsequent times (i.e. production of the National Park plan).
The choice of the representation scale, expression erroneously flexible in the face of digital geometrical data-bases, was done as the right compromise between the level of detail required for metrical and photo-interpretative analysis and the cost deriving from the requirements expressed from the client public Agencies.
The photo coverage, photo-scale of 1:22.000 on B/W film, was made in August 1999.

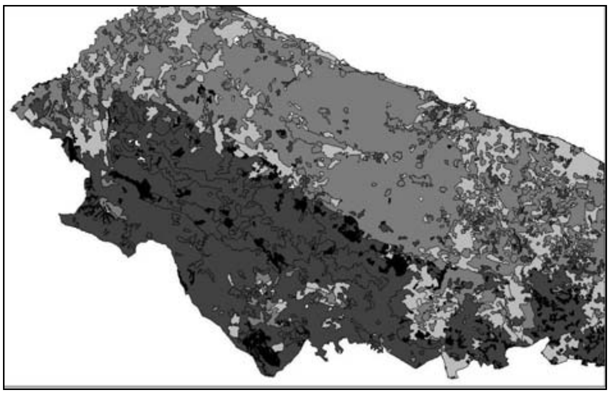

Fig.5. Land Use coverage in province of Bari.

It was also produced a complete digitalization of the acquired aerial photos by mean of a photogrammetric scanner, directly from the B/W negative film, with a resolution of 1270dpi (equal to a pixel dimension of 20 μm). Such files can be utilised for the production of digital orthophotos up to a scale of 1:5.000, with the ground resolution of about 0.40m.

MAP THEMATIC LAYERS

The adopted methodologies and procedures refer to the detailed field survey, consisting of paper drawing and GPS positioning, as well as the indoor digitalisation of information.
The data elaborations realised and organised have been mainly those of the forests, geo-pedological and land use study-groups, and have provided a thematic cartographic base of remarkable value for the subsequent investigations.

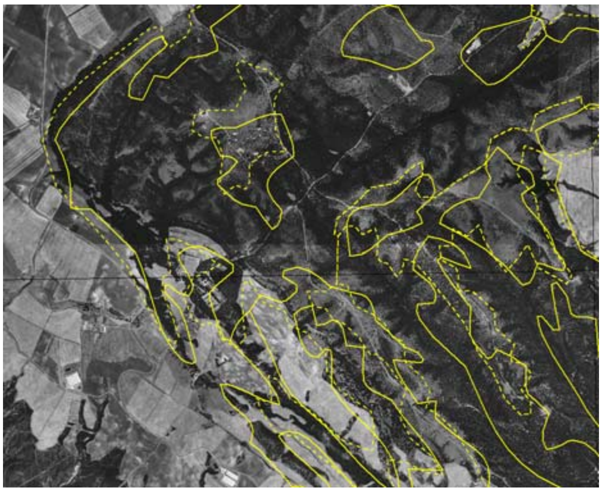

Fig.6. Multi-temporal spatial analysis on forest data set in overlay on 1997 digital orthophoto. The solid line area refers to Corine LC 1991, the dashed refers to 1997 orthophoto.

SPATIAL ANALYSIS IN LAND USE AND AGRICULTURAL TRANSFORMATIONS

The present land-use analyses, traditionally divided in the study of land-cover and land-use, are strongly influenced by the requirements of the storage of digital data, and often show the inability of being temporally and geometrically correlated, together with the scarce temporal reliability of such topographical data-bases.
The classification and the preservation of natural resources, however, requires an information detail which is only attainable with a resolving power below 1 metre and the demand of cartographic bases with such a resolution is steadily growing among the experts of the sector which are not satisfied with the interpretations produced by the photogrammetrist or the "cartographer".
On the basis of such considerations the construction of the polygons relating to land-use was the responsibility of two groups of experts, one concentrated on the use for farming, the other on the use as pasture. The proposed methodology consisted of the photo-interpretation on a ortho-photographical base, validated by a large series of field investigations.
The results of the two groups show a small percentage of overlapping of the evaluations, as evidence of the fact that the refining of survey methods always leads to the variability of the interpretative estimate. It is indeed not possible to assert that the real-world phenomena are precisely definable from a geographical as well as a qualitative point of view; to geometrically define a polygon may be possible, within

cartographic tolerances, only when the aim is to represent something which is univocally marked on the territory. Also in this sector is nowadays emerging the possibility that some feature classes might have overlapping edges whose evaluation lies outside statistical methods typical of the measurement methodologies, and verges on the incertitude peculiar to the fuzzy theories.

A different evaluation can be made of the existing data set, as for example the Corinne LC 1994 and 1999; in such a case is a matter of exceptionally complete classifications, capable of extremely detailed sub-coding, but produced by means of cheaper methodologies and lacking serious controls during the implementation phase (manual and automatic photo-interpretation derived from low resolution remote-sensing images). Specifically the first one, completed in 1994, shows an inaccuracy which is far from the tolerance assured by the 1:100.000 scale and with a percentage of errors and omissions such as to make it unsuitable for an environmental analysis as detailed as the one proposed in the present study. Sample comparisons, carried out in the Park area and in the bordering zones have strengthen our decision of proceeding to the definition of polygons on an evaluation scale aiming at a greater detail and a much lower incertitude.

GIS IMPLEMENTATION

The preliminary phase of data input, both geometrical and alphanumerical, for the implementation of a G.I.S. is inevitably a most critical and delicate one, as it constitute the metric base of the whole system. In this particular case the data deriving from the CAD environment required an additional editing and control phase, which sometime proved to be complex and lengthy, in order to validate their topology and geometrical structure.

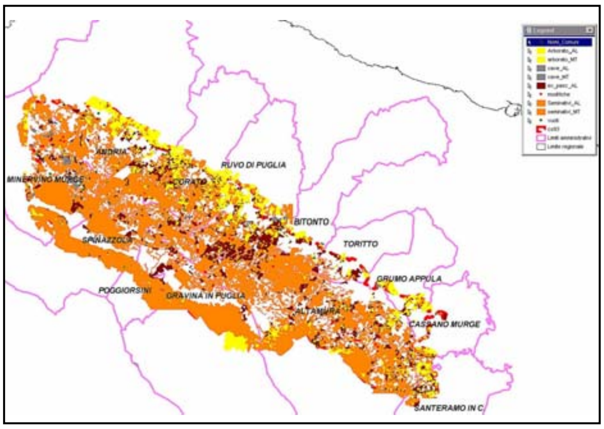

Fig.7. Farming land use.

A graphical entity, depending on the nature and meaning of what it represents, may constitute a spatial punctual, linear or areal information: the necessity to clearly know the functioning of a GIS device is a prerequisite for the implementation of subsequent elaborations on a right structured Data set. Forests data for example, deriving from CAD environment digitalization and including also the alphanumerical value, required, as those on land use for framing or pasture, a detailed control on possible topological inconsistency, in order to be used as information level on which to implement the first queries.
The geometrical analysis verified the closing of single entities from an spatial point of view, as the surface of single sections needed to be calculated; furthermore a precise topological analysis was carried out, with the gradual elimination of redundant or incorrect data as for example overlapping zones (an area for reforestation cannot be also an area for another type of forest), duplicate zones, etc.: such a control is necessary in order to guarantee the reliability of data (within established tolerances). Before proceeding to the connection of the alphanumerical data-base, the correct input of such data was verified: if a field is for numeric values (area, perimeter, etc.) it cannot be contained in an alphanumerical record and vice-versa; if a numeric record as a length of *n* characters, also the other records must be consistent with it, etc. When for each class of entities the consistency of the data was verified, the alphanumerical data-base has been imported in one of the utilized GIS environment (Intergraph Geomedia®), and by means of the correlation of a common field the geometrical and alphanumerical data-bases were linked. Once the starting database was completely built, some spatial data were automatically calculated (surface, perimeter), and some sub-classes were extracted by use of interrogation keys. Both the preliminary cleaning operations and the subsequent queries were produced in collaboration with the G.I.S. experts that activated the procedures, working with the same people that processed the data, allowing in such a way not only a rapid extraction from the G.I.S. of the information required, but also a further control on the content and nature of the same information: in some cases only after a query of qualitative type some gross digitalization mistakes, that could only be spotted by a specialist, were identified (e.g. in the forests data-warehouse were incorrect 2 on 178x58 fields).

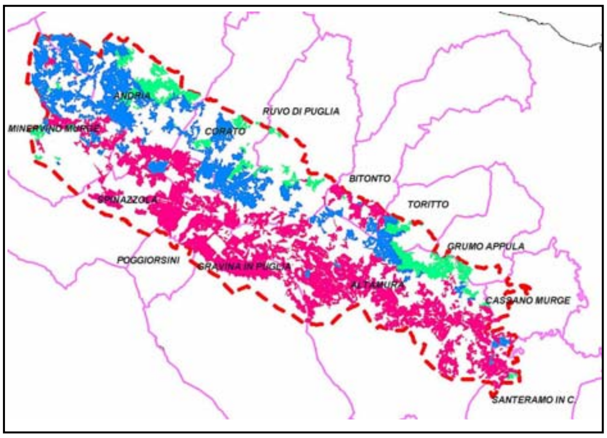

Fig.8. Pasture land use.

The final phases of the study was characterised by the implementation of a Geographical Information System that will allow, using suitable visualisation devices (Viewers), the complete analysis of the data and information levels available through the use of complex query based on the use of common logical operators.
The task of connecting all the basic devices for the understanding and monitoring of the territory will rely on the GIS elaborations, just as described above, with the ability to offer advanced performances in the fields of decision-making, planning and territorial management.
The main feature of the structured System will be:

- Analysis, also on overlaying levels, of all the acquired and univocally referenced cartographic material (current vectorial data, historical and current raster data, remote-sensed images);
- Accessibility to all the analyses and studies, with areal, linear and punctual reference to the territory, memorised

in the alphanumerical data-base and production of thematic maps satisfying specific requirements;
- Building of queries, simple as well as complex, linking the alphanumerical data with the positional information;
- Support in the management of specific areas, according to their peculiarity, and production of printed maps for local use;
- Data exchange capacity with comparable data-bases held by international, national or local territorial Agencies.
- System architecture with client/server accessibility at the local level (National Park administration) or by means of the Internet (queries from remote PC units).
- User friendly interface and minimal staff training requirements, mainly based on self-learning techniques.
- Usability on widespread average speed H/W machines with low-cost easy-maintenance O.S.
- Widely used interchange data format (of both alphanumerical and graphical data), which allows large portability on systems operating with different S/W.

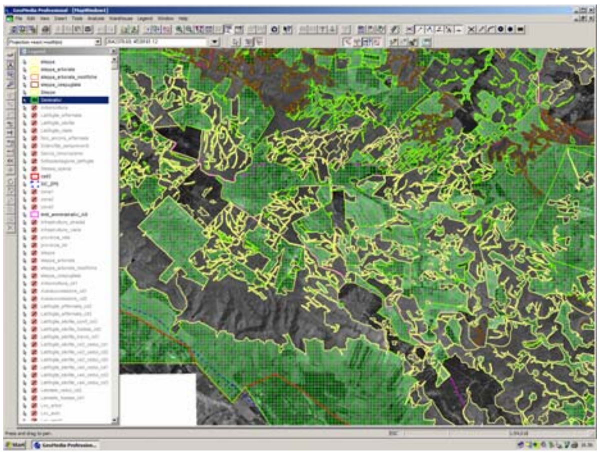

Fig.9. Spatial analysis on land use.

CONCLUSIONS

The use of computer technology is fundamental with the advantage that information in a GIS can be updated and modified very quickly in comparison with the traditional cartography. In this contest we can understand as the traditional 2D maps are often restrictive and overcome by more complete products, very descriptive, witch permit a three-dimensional and realistic representation. Today GIS, managed and completed by modelling instruments, is going to open a new age of Decision Support System in every contest as the environmental analysis mentioned. Real-time representations, DSS and dynamism are only components of the actual GIS application.

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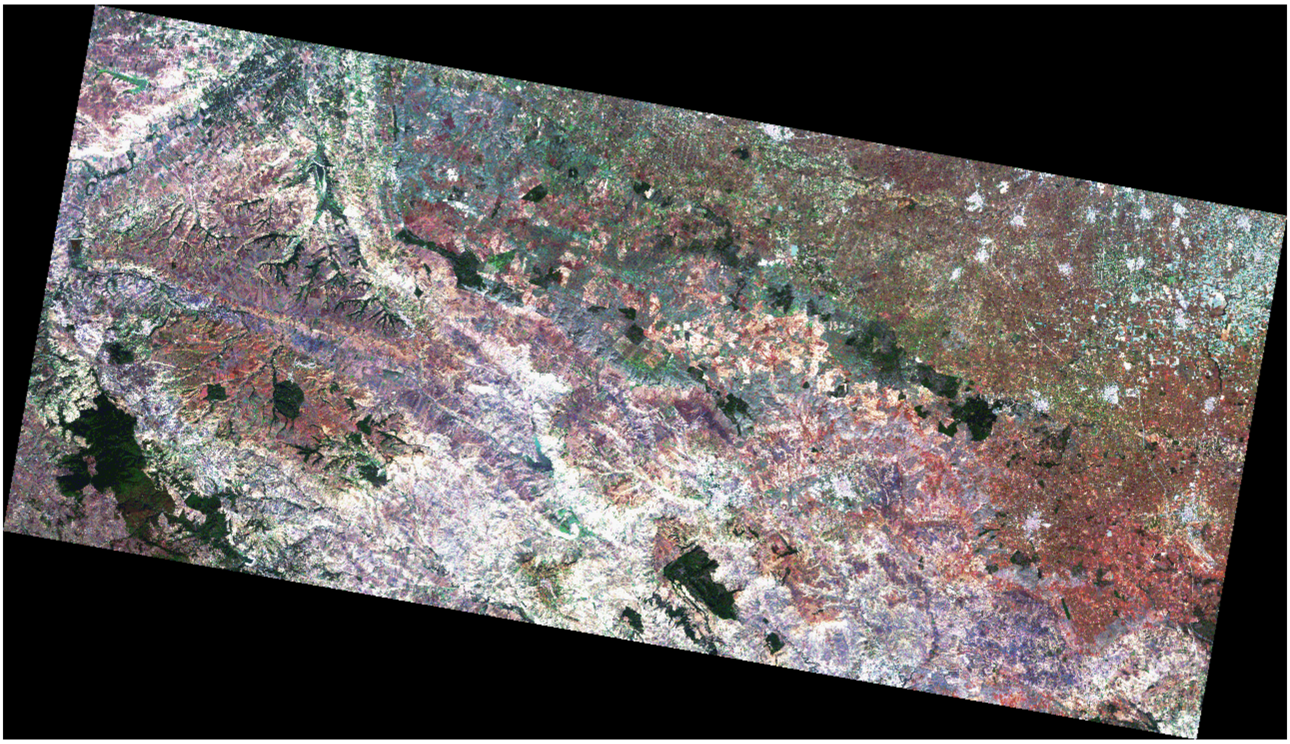

Fig.10. Color composite Landsat TM image (1996).

Fig.11. Multi-temporal spatial analysis on “Stone grinding” in overlay on Ikonos image. The solid line area refers to May 2000, the dashed refers to July 1997.