Safeguard of Historical and Cultural Values in the Teramo Area: From Hazard Integrated Analysis to Urban Vulnerability

An integrated analysis of spatial and satellite data has been applied on an area of the province of Teramo in Abruzzo region, Italy. Two case studies are presented: one on the gullies of Montefino, as an example of natural heritage at risk, whilst the second case concerns the municipality of Bisenti, as an example of historic centre at risk.
Geomatic methodologies have been used for a preliminary analysis of the study area. In fact, based on the cartographic data, hazard maps were overlaid to high-resolution satellite images, showing a high risk for cultural heritage. The integrated analysis is therefore proposed as a monitoring tool to safeguard the territory and the historical and natural heritage by providing knowledge of both their conservation status and relations

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Introduction

In Italy there is no certain data on the historical, architectural and landscape heritage exposed to natural hazards. This systemic approach requires the study and assessment of the effects of some factors of degradation (hydrogeological, seismic, meteo-climate, etc.) on the state of conservation of cultural heritage, such as historic centres or landscape.
And not as single monument.

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To this end, a spatial approach is proposed using geomatic methodologies for the assessment, monitoring, and hence prevention of the natural and anthropic risks for the preservation of the historical and architectural heritage and landscape.

Geographical and Geomorphological Features

The study area includes the municipalities of Bisenti, Castiglione Messer Raimondo and Montefino, located on the hills of the province of Teramo (Abruzzo region) between 250 and 350 meters above the sea level (Figure 1).
The landscape is characterized by smoothed hills eroded by streams arising from the Gran Sasso massif and reaching the Adriatic Sea. The urban centres of medieval age are arranged on top of the ridges. The

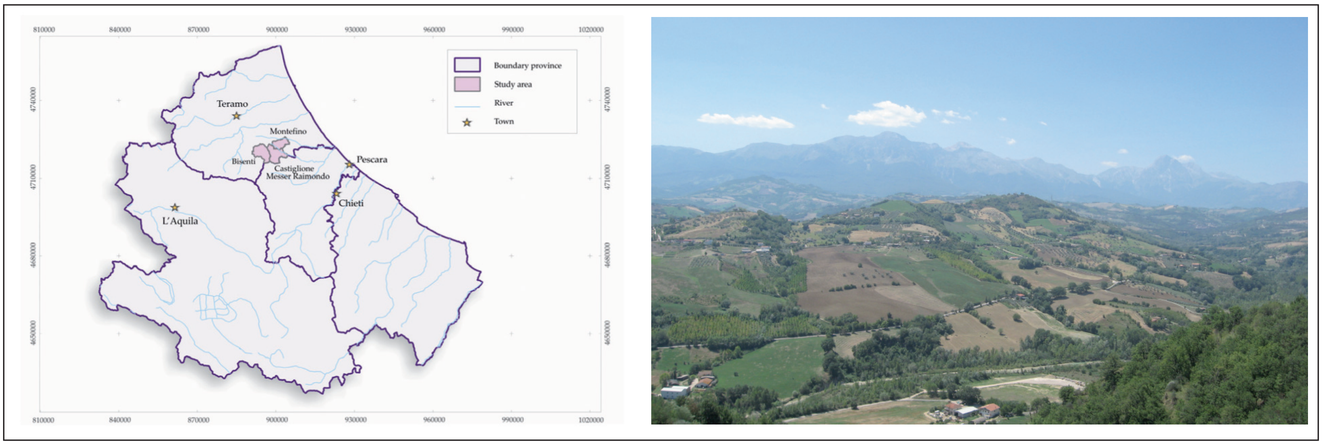

FIGURE 1 Localization and a view of the study area
Source: ENEA

hilly landscape is also characterized by small scattered settlements among the green patches of woods, olive-grove fields and vineyards, and areas planted with crops, the uncultivated fields and grazing.
The morphology of this area is closely linked to its lithology, the study area is characterized by three lithological classes: the first consists of sandstones with intercalations of marl sandstone called "Formazione della Laga", the second from marl and gray-blue clays, and the third from sands and clayed molasse.

The main morphological processes that occur in the area are represented by gravitational phenomena, such as landslides and erosion, affecting gullies and the landslide and slope edges. Landslides, in the literature, are defined as a "movement of rock, debris and / or earth along a slope, under the influence of gravity" [1]. Landslides in this area are of five types: for falling; for Toppling; for rotational slide (slump); for translational sliding (slide); for dripping (flow).
The combination of two or more landslides gives rise to

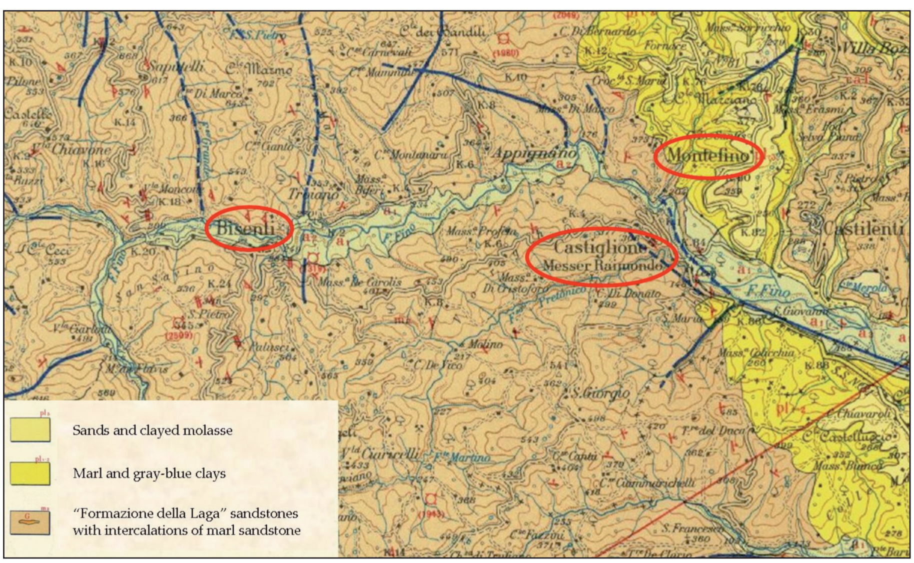

FIGURE 2 The geology of the study area
Source: from Geological Map of Italy scale 1.100:000 sh.140, Servizio Geologico d'Italia

the so-called complex landslides, whereas the erosion processes affect all the surfaces with forms of run-off, gullies surfaces and similar forms. If there is a high concentration of instability, the possibility that other events occur, or that phenomena already present will reactivate is higher, resulting in an increased hazard. The instability phenomena taking place in this region, affecting the urban centers and the surrounding landscape, result in an increase in the risk for historical, archaeological and landscape heritage.

Integrated Analysis of the Study Area: Spatial and Satellite Data

The following work has been accomplished through the use of cartographic data taken from the PAI, Hydrogeological Plan, of the Basin Plan for the Hydrogeological "landslides and erosion", drawn up by the Abruzzo Region. The Plan is a cognitive tool to manage the territory and its natural dynamics through the analysis, validation and updating of existing data [2]. Within the Plan, to complete the geological framework, a series of cartographic maps have been made, as the Geomorphologic Map, and the Hazard and Risk Maps. The data used for this study are those relating to hazard; the data is obtained by overlapping data on steepness, geo-litology, geomorphology and inventory of landslides and erosion.

Figure 3 shows the study area between the municipalities of Bisenti, Castiglione Messer Raimondo and Montefino, which overlapped data by PAI on landslide hazard (polygons with different green tones), gullies (blue polygons) and slopes (red lines), unique instability phenomena on the study area.

Hazard is defined as the probability that a danger of instability phenomenon occurs on a specific area. For each category of hazard the PAI has assigned four classes: P3, P2, P1 and Ps. In hazard P3 (very high hazard), all the areas affected by active or seasonally reactivated instability are taken into account, including active landslides (active), i.e. those that at the time of observation appear to be in motion. In hazard P2 (high hazard), the areas affected by landslides with a high possibility of reactivation are included, whereas P1 (moderate hazard) includes areas affected by landslides with low possibility of reactivation. Hazards

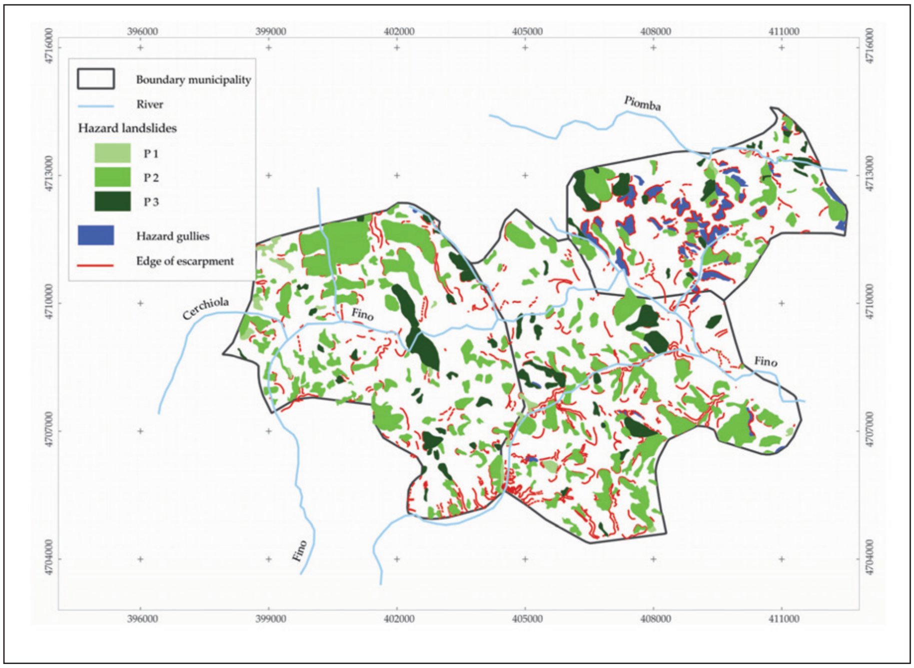

FIGURE 3 Instability phenomena in the study area
Source: ENEA

P2 and P1 include quiescent landslides, in which the movement can be reactivated by the causes which gave rise to it, and inactive landslides, those that have moved the last time before the last seasonal cycle. Instead, Ps hazard includes all slopes regardless of their state of activity.
With regard to the erosion processes, i.e. the gullies surfaces and similar forms are included in hazard P3, regardless of their state of activity, because once these phenomena are activated, they usually continue to move.
The processing of the map data was aimed at a preliminary analysis of the study area through an integrated analysis of spatial data with satellite data. In fact, the cartographic data considered were overlaid on a high-resolution satellite GeoEye image [3]. GeoEye-1 is the commercial satellite with high-resolution optical technology to capture images of the earth, which was launched in September 2008. The satellite is able to capture images with a resolution of 0.41 meters in panchromatic (gray) and 1.65 meters in the four multispectral bands (red, green, blue and near infrared).

A Natural Heritage at Risk: the Gullies of Montefino

An example of the integrated analysis concerned the territory of Montefino municipality. In Figure 4, the boundaries of Montefino municipality and the polygons of the gullies hazard were superimposed on a GeoEye satellite image.
This territory has geomorphological, lithological and climatic features favorable to the gullies morphogenesis. The gullies can be defined as dense and hierarchical drainage, consisting of deep incisions on clay substrates with narrow and sharp ridges [4]. The presence of clayey slopes, with increased steepness and devoid of vegetation, is a prerequisite for gullies setting. The steepness and the impermeability of the slope, in fact, reduce the infiltration of water into the soil and favor the fast runoff into streams (rills), with the subsequent etching of a dense drainage network; the evolution of the latter gives rise to gullies.
In addition, human activities, especially the removal of the vegetation cover and the consequent denudation of the slopes, can heavily affect the gullies

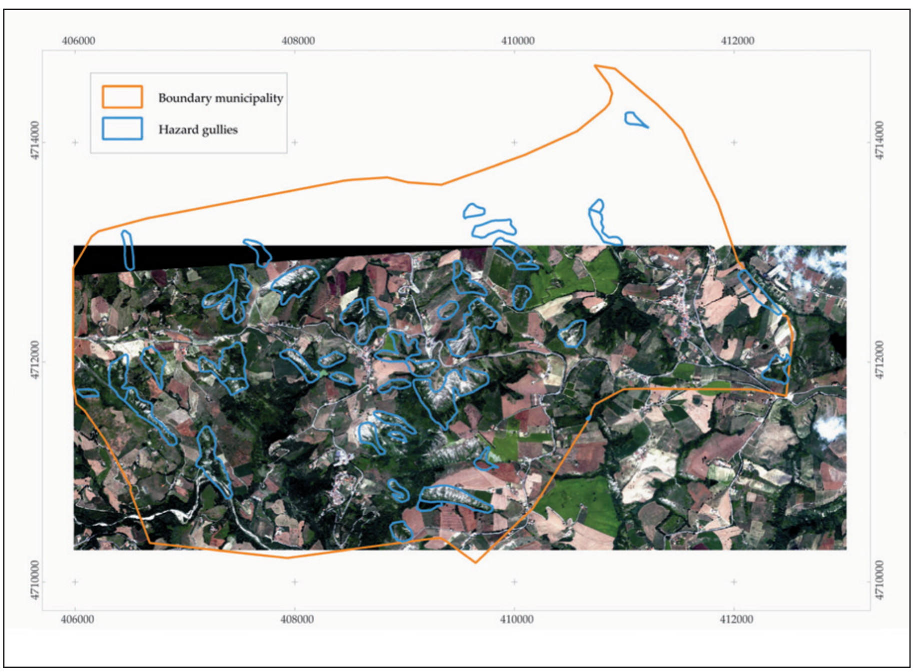

FIGURE 4 The gullies of Montefino
Source: ENEA on E-geos image

FIGURE 5 Landscape and geomorphological features of the study area of Montefino
Source: ENEA

morphogenesis, promoting the accelerated erosion on the slopes. Ultimately, the lithological and structural features of clay, allowing the persistence of steep slopes for various reasons, curb the effects of weather and control the genesis and the form distribution of gullies. Identifying the factors that determine the gullies formation is very difficult, because they are often linked to factors which can prevail one over the other. These factors can be summarized in this way:

- Presence of a layer of clay with a discrete sandy component and geotechnical and mineralogical features
- Steepness of the slope, which promotes rapid drainage of rainwater and the consequent development of the drainage network
- Arrangement of the layers "reggipoggio"
- The aspect towards the sunniest southern sectors
- Erosion at the foot of the slopes by fluvial courses
- Steepness of a slope which may be genetically linked to a geodynamic phenomenon, with the presence of a tectonic dislocation, or a landslide, or that can be connected to a rapid depth of linear erosion by tectonic or climatic causes;
- Climate regime, characterized by dry and long summers and intense rainfall concentrated in certain periods of the year;
- Existence of less erodible layers at the top of the slope; the human activity, in particular farming and pastoral activities (especially poaching of animals) that tend to diminish the vegetation cover and encourage the triggering of erosion processes.
- These instability phenomena lead to the landscape change and degradation; since it is a territory merely characterized by gullies, the hazard is very high. The aggravation of this phenomenon is mainly due to deforestation and the agricultural practices that leave the soil exposed to rain action [5]. With accommodation and terracing of slopes, channeling water runoff, and the environmental engineering techniques, it is possible to reduce runoff and keep it within tolerable limits.

Historic Centers at Risk: the Case of Bisenti

Another example of integrated analysis is the study area shown in the satellite image of the Bisenti municipality, where its boundaries have been superimposed on the slope hazard data (Fig. 6).
The slopes are a particularly important type of instability in the Abruzzo region. These are the linear elements divided into five categories in the Geomorphologic PAI Map: Edge of the fault scarp; Edge of the escarpment of fluvial erosion or torrential; Edge of the escarpment of marine erosion; Edge of the escarpment of glacial erosion; Edge of escarpment degradation and landslide.
In the municipality of Bisenti, slopes fall within just two types of those listed above: the edge of the escarpment and the edge river degradation and landslide (Figure 7); it was possible to zoom on the Bisenti historic center and see the behavior of the slope edges and the urban pattern (Figure 8).
The map shows the edges of slope around most of the town, especially the part of the historic centre (the eastern part): they are slope edges of fluvial erosion in a quiescent state. This means that in the event of heavy rainfall these slopes can reactivate with erosion on the slope base and the formation of degradation phenomena or landslide.

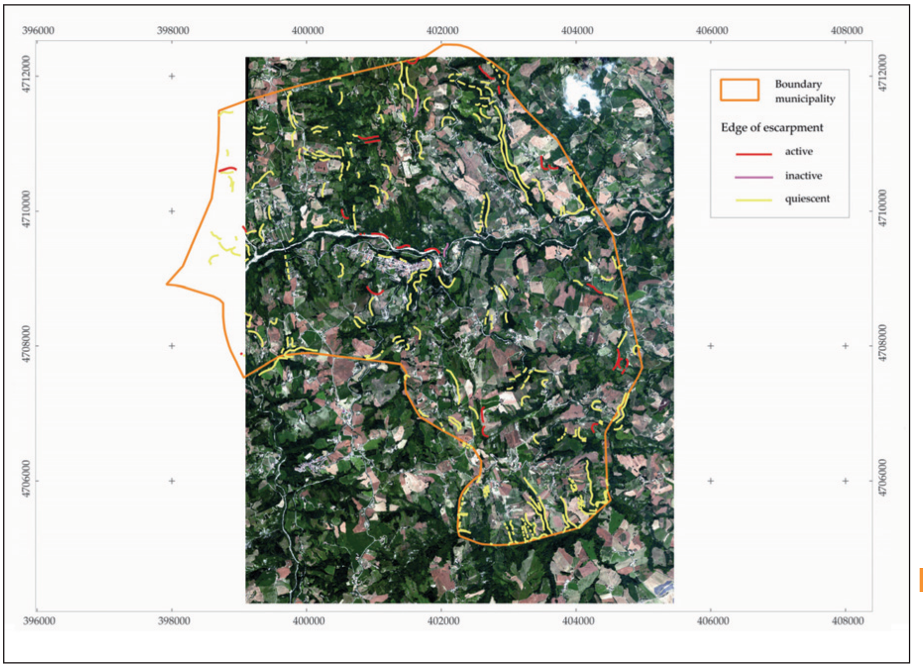

FIGURE 6 Bisenti municipality: satellite image with the data of slope hazard
Source: ENEA on E-geos image

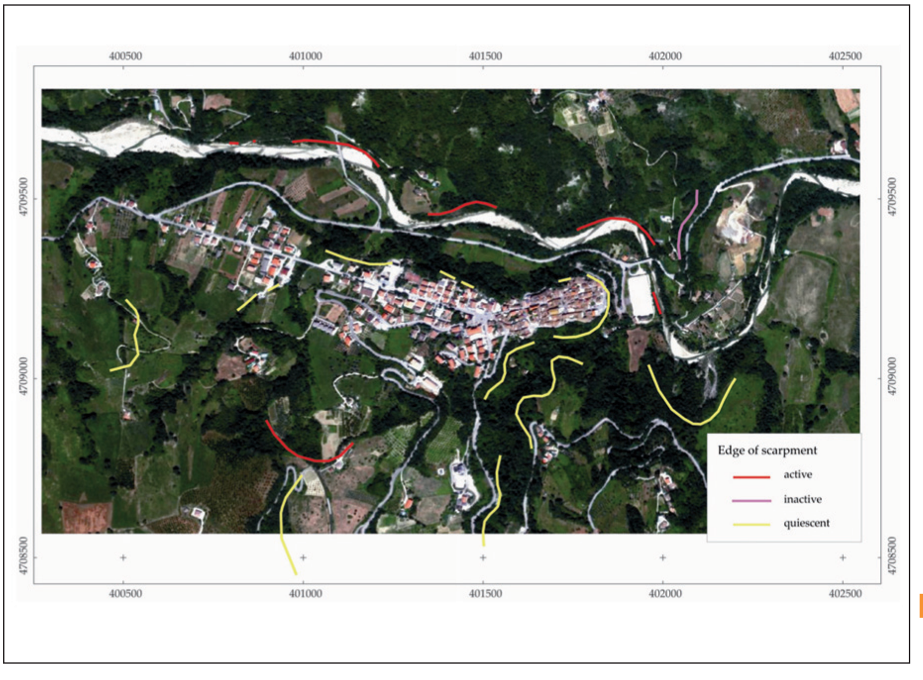

FIGURE 7 Slope hazard in the historic center of Bisenti
Source: ENEA on E-geos image

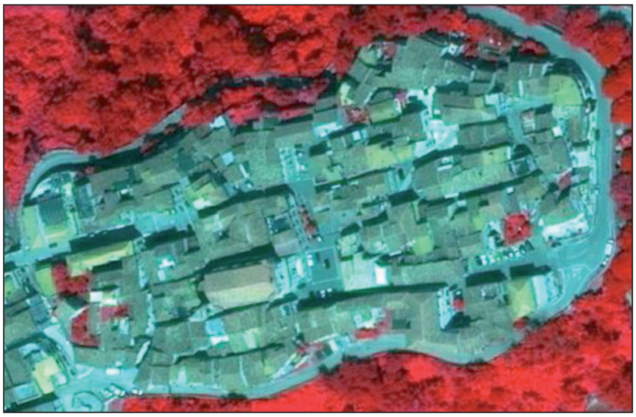

FIGURE 8 Historic centre of Bisenti
Source: E-geos, Geo-Eye high resolution image [3], false colour, RGB 432

These phenomena result in an increase of the hazard, so they should be supervised and monitored continuously. The edges of the active escarpment, instead, are mainly along the river bed (north of the city center), that, being in constant motion, tends to remove material at the base of the escarpment.
Once identified, the hazard on the urban center of Bisenti is shown as the buildings are subject to a greater risk, which is the product of the hazard with the vulnerability and exposure (R = P x V x E). Specifically, the integrated analysis of hazard and urban vulnerability allows to extract risk factors, which can be classified according to severity indexes.
The vulnerability assessment started from the analysis of the conservation state of buildings through the processing of satellite images. Figure 8 has been processed in false colour so as to make evident the contrast between old and new, restored and not in order to get a preliminary analysis.
The investigation will continue through vulnerability assessments of towns; expeditious surveys are ongoing in order to correlate all the data collected. The investigations do not concern the individual buildings but the historic centre as a whole (Figure 9).

Conclusions

In areas, subject to continuous natural phenomena as landslides, floods, earthquakes, there is the need to protect the cultural heritage at risk. Therefore, an integrated analysis control tool for the safeguard of our heritage was proposed.
To this purpose, in the study geomatic techniques have been applied, which enabled the overlaying of spatial data interpreting high-definition satellite images and vector data from local archives (PAI, IFFI, Corine Land Cover). The data processing allowed to create new thematic layers, and especially to query a spatial data in connection with others.

FIGURE 9 Views of Bisenti historic center
Source: Photo1 from the official website of Bisenti Municipality[6], Photos 2-3 ENEA

The integrated analysis of spatial data therefore allowed for the knowledge of several variables that persist in an area and their interdependencies. In this case study the knowledge of land degradation and morphogenesis phenomena is possible, in relation to the stability and preservation of the historic centres that lie on the morphological structures analysed.
The integrated analysis is then a safeguard tool for monitoring the conservation status of the territory and getting knowledge of its relations with cultural heritage, landscape and historic centre seen as a whole and not as a set of individual monuments.

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