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The Role of Knowledge in the prevention of natural hazards and related risks.

Enrico Miccadei, Tommaso Piacentini
Laboratory of tectonic geomorphology and GIS
Dipartimento di Ingegneria e Geologia INGEO - Università degli Studi *G. D'Annunzio* Chieti - Pescara
miccadei@unich.it – tpiacentini@unich.it

ABSTRACT

Human activities, especially over the last two centuries, have had a huge impact on the environment and the landscape. Mankind is able to control and induce landscape changes but is subject to natural processes and hazards due to severe and extreme events (particularly earthquakes but also landslides and flooding) and related risks. Risks are the result of hazards, exposed elements and vulnerability and they are consequently not only an expression of the natural environment, but also related to human interaction with nature. Risks need to be addressed regularly by means of a high level of knowledge in order to provide most up-to-date information for any decision which needs to be taken by any party involved.
A high level of knowledge concerning natural hazards and related risks stems from the geological and geomorphological history and from the historical records of the natural processes and grows with multi-scale, multi-temporal and multidisciplinary studies and investigations, which include land management, economic and social issues.

A strong effort has to be made in this way to improve risk assessment and the enforcement of existing laws and - if necessary - new laws, really stem from recent disasters. This will help to achieve improved and effective land management, based on an interdisciplinary approach in which expert geologists and land managers will play a role, because of the importance of natural processes in inducing risks.

Introduction

Human activities, especially over the last two centuries, have had a huge impact on the environment and the landscape due to industrialization and land-use changes, which lead to climate change, deforestation, desertification, land degradation, and air and water pollution[1]. These impacts are strongly linked to the occurrence of natural disasters and to related geological and geomorphological hazards, such as earthquakes, floods, mudflows, landslides, snow avalanches, soil erosion, but also subsidence, volcanic eruptions and other phenomena[2].

The whole of Italy, and particularly the Central Apennines, are geologically recent and active and are affected by most natural hazards (seismic, volcanic, landslides, floods, soil and coastal erosion). Concerning seismic risks, recent earthquakes (Friuli, 1976; Irpina, 1980; Umbria-Marche, 1997; San Giuliano di Puglia, 2002; L'Aquila, 2009, Emilia, 2012) show that the damages due to side-effects could in some cases exceed the economic and social losses directly connected to the seismic shaking. Flooding induced by heavy rainfall, as well as landslides, has affected several areas of Italy from south to north in the last decades and particularly over the last ten years as a direct effect of geomorphological processes (i.e. Vayont, 1963; Florence, 1966; Valtellina, 1987; Crotone, 1996; Soverato, 2000; Abruzzo coastal and hilly area, 2003,

1 The Abbot Stoppani in the 19th century already defined the 'debut' of humankind in geological history as the emergence of a new "global geological agent" able to induce morphogenetic processes unknown in previous eras, and named the present one as the Anthropozoic era, now Anthropocene.

2 Alcántara-Ayala & Goudie, 2010.

2007, 2011, 2012; Messina, 2009; Maierato, 2010; Liguria, 2011; etc.). Scientists come from all over the world willing to exchange views and tackle the problems of a geologically evolving landscape. Our peninsula started being studied several centuries ago, when geology, and particularly geomorphology and Quaternary geology, were considered pioneering sciences studied and taught by scientists who strongly believed in knowledge as the basis for human development and civilization. Recent studies have focused on different issues: defining the age of rocks and their formation; understanding slope, fluvial, lacustrine and marsh systems and their evolution and interaction in time (at time scales from seconds and minutes to thousands or millions of years); understanding the interaction of marine and continental processes; basically understanding the interaction between the processes that developed under the earth surface and those taking place over it, whose balance defines the landscape and its evolution. Natural severe events which occurred in the last 5 or 10 years in Italy and induced disasters (Fig. 1 shows some cases in the Abruzzo region) will provide data for several scientific publications, but all these studies must become the subject of environmental and geological education and must be understood and acknowledged by governmental bodies and lawmakers.

Figure 1 – Natural severe events that affected the Abruzzo region in the last 5 years: a) Soil erosion and landslides (northern Abruzzo, 2007); b) earthquake (L'Aquila, 2009); c) flood (northern Abruzzo, 2011).

Scientists and social scientists study risks on a statistical and/or historical basis, analyzing chronicles and cases and performing direct observations of recent severe natural events. The knowledge of hazards and risks grows by analyzing every new event and its direct and indirect effects, opening up new perspectives and interpretations. The work undertaken by geologists and geomorphologists includes not only the understanding, but also the mapping and modelling of the Earth's surface processes, and many of these processes directly affect human activities and societies. In addition, they are now increasingly related to the extent of societal problem-solving, which can be expressed through vulnerability analyses, along with hazard and risk assessment[3].

It is now completely clear – and perhaps it was from the beginning – that most natural disasters are actually severe or extreme natural processes which become "disasters" because of human activities and unsustainable land management (i.e. urban areas, industrial areas, roads and other infrastructures built on river valleys, coastal plains, seismic areas, without correct planning). A disaster occurs when an anthropic system experiences a natural event and is not able to withstand and absorb the energy produced by the event without damages and losses.

This paper aims to outline and highlight how the knowledge of natural processes and their interaction with human activities provides the most effective tools and methods to prevent natural risks and ensure a safer human environment. This can only be achieved through complete multidisciplinary, multi-scale and multi-temporal studies based on geological and geomorphological investigation and mapping, but also by integrating engineering, architectural, economic and social issues. In this perspective, boundaries between professional and academic disciplines should be effectively overcome, as they hinder the knowledge process or even prevent the search for causes, effects, impacts, vulnerability and other issues connected with natural disasters[4].

3 Alcántara-Ayala & Goudie, 2010.

4 Alcántara-Ayala, 2002; Crozier & Glade, 2010.

FUNDAMENTALS

In the broad non-technical sense 'hazards' are defined as those processes and situations, actions or non-actions that have the potential to bring about damage, loss or other adverse effects to those attributes valued by mankind. Thus, in common usage, the term 'hazard' has two different meanings: first, the physical process or activity that is potentially damaging and second, the threatening state or condition, indicated by likelihood of occurrence. The concept of 'risk' can thus be seen as having two components: the likelihood of something adverse happening and the consequences if it happens[5].
The risks due to natural processes depend on the relationship between the natural state of the earth system (geosphere, hydrosphere, atmosphere and biosphere) and the ability of the socio-economic system to adapt to the earth system. Risk (R) is calculated by multiplying the three factors, natural hazard (H), elements at risk (E) and vulnerability (V): R = H x E x V[6] (Fig. 2).

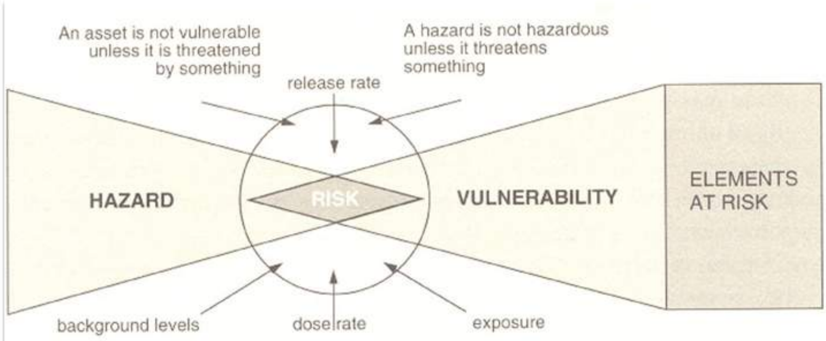

Figure 2 – Conceptual relationship between hazard, elements at risk, vulnerability and risk (Alexander, 2002).

Natural hazards are natural events that can cause loss of life or damage to property. A severe or extreme event is any event affecting a geosystem that remarkably differs from the average values measured for the phenomenon concerned (e.g. seismic shaking, rainfall, wind, river discharge, sea waves,

5 Bell, 1999; Crozier & Glade, 2005.

6 Alexander, 2002.

etc.). Vulnerability is defined as the inability of an element or system to maintain its structure and pattern of behaviour in the presence of a geomorphologic hazard; it is given in a scale from 0 (no loss) to 1 (total loss).
This means that the level of a disaster is due to the level of damages and losses to the anthropic system that is affected by a severe/extreme natural event being not able to sustain its energy. This definition shows that geologic and geomorphologic hazards are only a problem when they interfere with anthropic systems. Risk can increase due to an increase of the hazard (change in the geologic and geomorphologic systems) or due to an increase of the vulnerability and/or value of the exposed elements (change in the socio-economic environment and or land use). In this context, value not only implies economic value but can also include intrinsic, scientific, sentimental or ecological values.
Parameters reflecting the sensitivity of the geosystem (natural hazard) and the social system (vulnerability and element at risk) can be identified and extracted from accessible databases and from multi-scale, multi-temporal and multidisciplinary studies[7]. However, investigation of natural hazards and risks is a diverse and complex undertaking and may include geotechnical and engineering assessments, geomorphological and geographical analysis, political and management perspectives, as well as economic and social considerations[8]. It also includes susceptibility zoning which refers to the likelihood of a process occurring in an area on the basis of local terrain conditions; it is the degree to which an area can be affected by future natural events; for instance, an estimate of ‘where’ landslides are likely to occur. More generally, susceptibility consists of the assessment of what has happened in the past, and hazard evaluation consists in the prediction of what will happen in the future[9].
In Italy these issues, and particularly geology and geomorphology for the prevention of natural risks, starting from Law No. 183/89, are only partially included in existing laws:

7 Alexander, 2002; Fabietti, 2002; Crozier & Glade, 2005; Glade & Crozier, 2005; Lupia Palmieri & Parotto, 2008.

8 Crozier & Glade, 2005.

9 Soeters & Westen, 1996; Guzzetti et alii, 2006; Fell et alii, 2008; Rossi et alii, 2010.

a. environmental and land protection - landslides (Law No.267/98; PAI, IFFI), flooding (PSDA), water resources and waste management and reclamation (PTA; Italian Legislative Decree No.152/2006), recently included in the EU flood directive 2007/60/CE an in the Italian Environment Code;
b. general land management (PRG; Italian Legislative Decree No. 42/2004);
c. seismicity (recent MZS guidelines and NTC 2008 and updates);
d. public works and buildings referable to Italian Presidential Decree No. 207/2010, implementation of the Public contract code (Italian Presidential Decree No.163/06) and Building technical rules (Italian Ministerial Decree dd.14 January 2008).

However, there is an important need, at technical and legislative levels for a new law on land management which should update, integrate, and harmonize the studies and investigations required for the understanding of natural hazards and risks defining the significant geological areas, starting from drainage basin as the main terrain units. Since extreme natural events are connected to processes at variable space and time scales, it is not possible to analyze a single site concerning hazards and risks, but it is necessary to analyze the whole significant area including underground, surface and above-the-ground features.

CASE STUDIES

In the following cases (Fig. 3) we highlight three basic aspects of the knowledge process concerning hazards and risks (particularly seismic, but also landslides and flooding) which should contribute to prevention strategies since they are based on methodologies that take into account the main rules of natural processes and their space-time distribution: a) multiscalarity; b) multitemporality; c) multidisciplinarity.

Figure 3 – Location map (a) and main physiographic domains of the Abruzzo region (b). Red boxes locate the case studies discussed in this work. 1) L'aquila area; 2) Pineto hilly coastal area; 3) Tortoreto hilly coastal area.

Seismic Micro-zonal Mapping in the L'Aquila area

Space scale and multiscalarity

Analyzing and mapping natural processes and related hazards depends on their magnitude, scale of investigation and mapping criteria. A certain area may be mapped at different scales with different results according to the detail of investigation. Some processes should be investigated on a regional scale (smaller than 1:50.000), such as seismic hazard or flooding; some processes should be analyzed at an intermediate scale (1:50.000 to 1:10.000), such as landslide inventories; others, finally, require a detailed scale (larger than 1:10.000), such as landslide evolution, soil erosion, seismic site amplification. In this perspective, we maintain the basic rule that the resulting map cannot be at a scale higher than that applied in the investigation stage.

The assessment of seismic hazard is composed of a systems of investigation at different levels, from regional scale to intermediate to local scale[10]:

- Seismic hazard map of Italy[11] - national scale <1:250.000 (mapping the ground peak acceleration expected on a 50-yr time span on rigid bedrock) (Fig. 4);

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10 See also GRUPPO DI LAVORO MS–AQ (2010), Pizzo and Fabietti (2013) in this volume.

11 INGV, 2004.

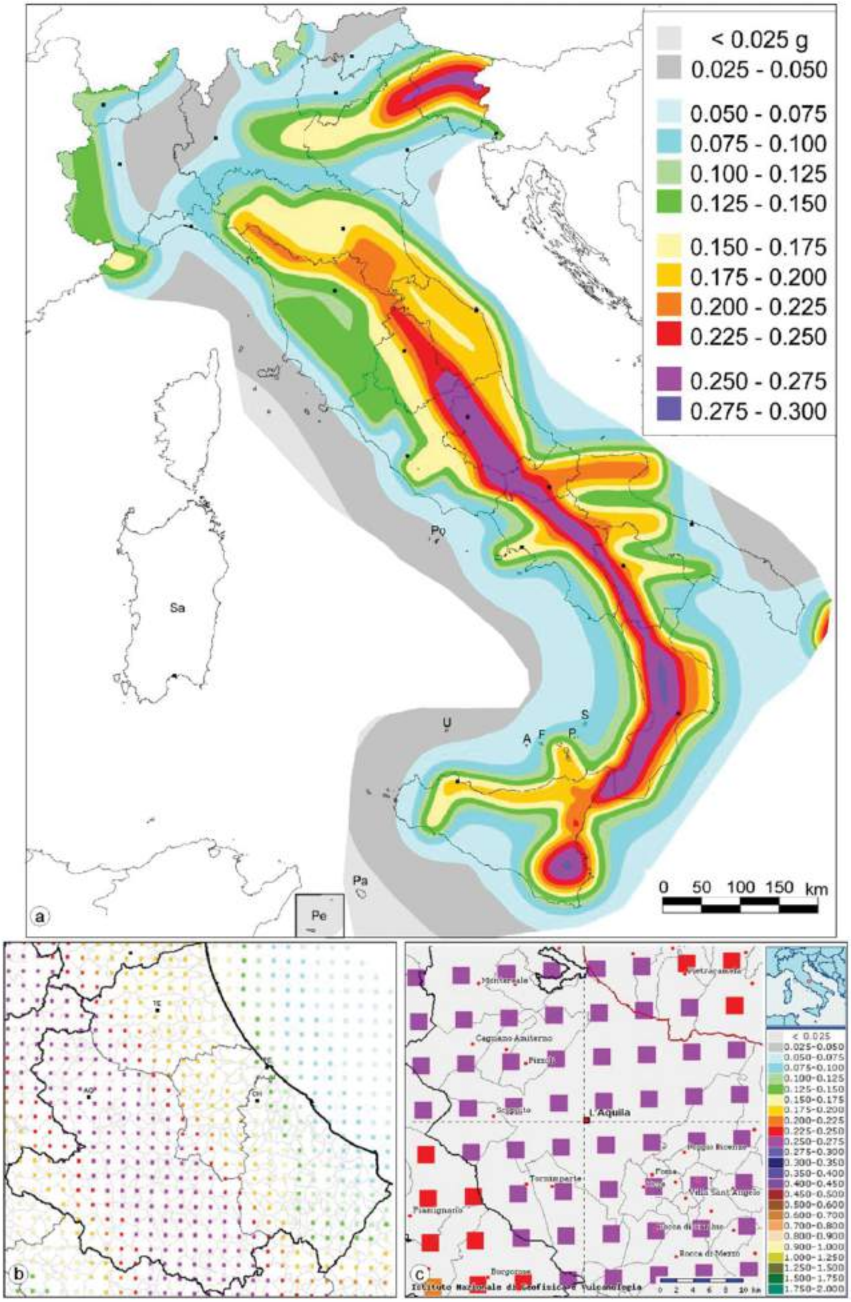

Figure 4 – Seismic Hazard Map of (a) Italy, (b) Abruzzo region and (c) L'Aquila area (c) (from INGV, 2004), in terms of ground peak acceleration with 10% excess probability in 50 years, referred to rigid bedrock (Vs30>800 m/s).

- Geological maps of Italy[12] - intermediate scale 1:50.000-1:100.000 (mapping geological features of surface deposits and bedrock) (Fig. 5, 6).
- Seismic micro-zonal maps[13] - local municipality or site scale>1:5.000 (mapping geological and geomorphological features particularly focusing on superficial deposits and site amplification effects due to stratigraphy or morphology) (Fig. 7).

Figure 5 – Extract from Foglio 139 "L'Aquila" of the Geological Map of Italy 1:100.000 scale (SGI, 1955) in which three units are mapped. The red box mark the L'Aquila east area.

Figure 6 – Extract from Foglio 359 L'Aquila of the Geological Map of Italy 1:50.000 scale (Progetto CARG, APAT, 2006) in which four lithological units are mapped. Red box mark L'Aquila east area.

12 ISPRA, 2013b.

13 GRUPPO DI LAVORO MS–AQ (2010) and updates.

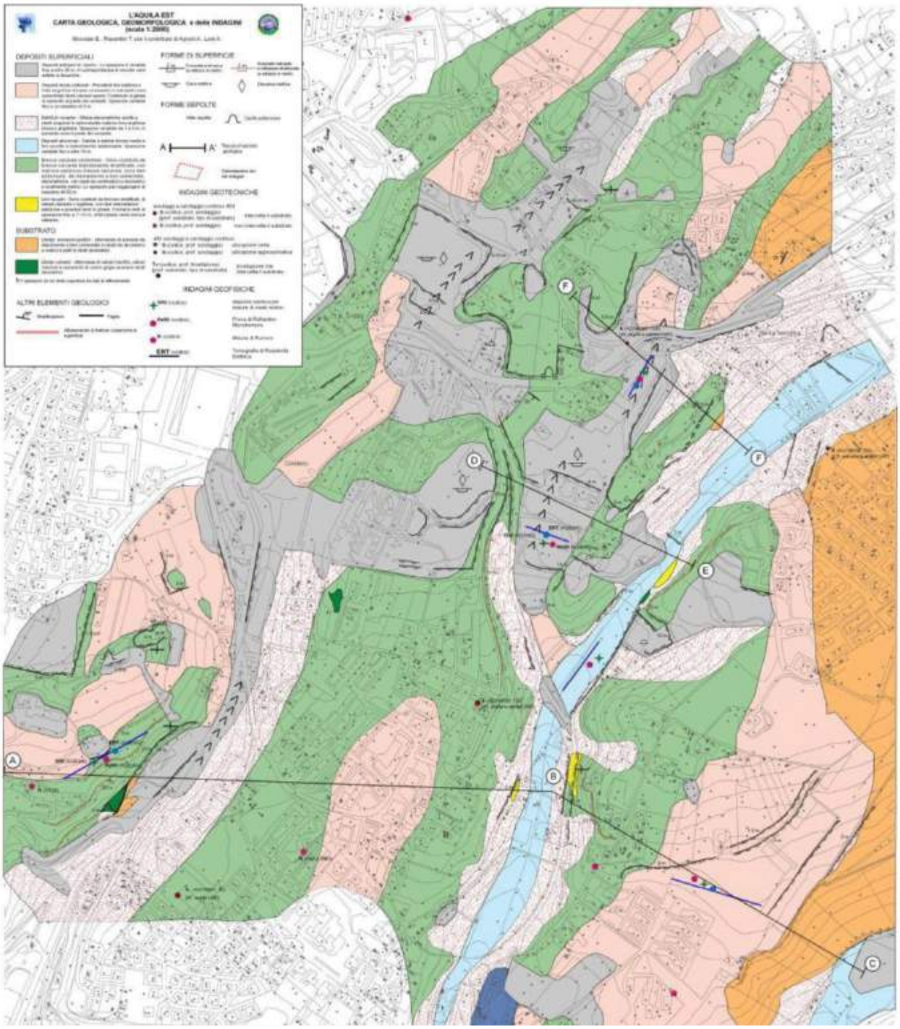

Figure 7 – Geological and geomorphological map 1:2.000 scale for the Seismic microzonation of the L'Aquila area (Miccadei & Piacentini, 2010, Gruppo di Lavoro MS-AQ, 2010) in which eight different lithological units are mapped.

This system results as a synthesis of data obtained from in-situ tests, detailed surveys, hystorical data of the damages, etc., incorporating investigations at different scales, from national to regional to local, but also multitemporal, from the analysis of Quaternary tectonics and paleoseismicity (hundreds of thousands of years) to the study of historical earthquakes (thousands of years) to the instrumental record of seismicity (decades).

The scale ranges of the different study levels have a strong impact on the results in terms of hazard assessment particularly concerning the local and site investigations for a seismic micro-zonal mapping that has to be based on geological and geomorphological field surveys at scale <1:5.000 carried on according to specific and consistent methods[14] and not simply on pre-existing maps.

In the following example, the geological and geomorphological mapping resulting from the micro-zonal studies in the L'Aquila area after the April 2009 earthquake, particularly in the eastern part of L'Aquila, are compared with previous geological mapping carried out at different times and with seismic hazard maps, in order to outline scale and mapping methods for seismic hazard and micro-zonal investigations.

The national hazard map (Fig. 4; INGV, 2004) provides the expected ground peak acceleration for the whole Italian territory. However, moving from national, to regional and local scale (Fig. 4b,c) the map obviously provides rough data. Moreover, the ground acceleration data is only referred to rigid bedrock and do not account for surface cover and soft deposits, on which most of the urban and industrial areas are built.

These data come only from geological and geomorphological maps at the appropriate scale. On the extract from Foglio 139 "L'Aquila" of the Geological Map of Italy 1:100,000 scale (Fig. 5[15]) three lithological units are mapped in the L'Aquila eastern area; on the extract from Foglio 359 "L'Aquila" of the Geological Map of Italy 1:50,000 scale, obtained several years later applying a modern approach (Fig. 6[16]), four lithological units are mapped. After the L'Aquila earthquake, in the geological and geomorphological map 1:2,000 scale for the Seismic micro-zoning of the L'Aquila area (Fig. 7[17]), eight different lithological units are mapped. The detailed mapping (1:2,000 scale) allowed for the definition of the thickness and geometry of superficial continental de-posits and their relationship with the bedrock, thus contributing to determining the seismic behaviour of the area

14 GRUPPO DI LAVORO MS–AQ (2010) and updates.

15 SGI, 1955.

16 Progetto CARG, APAT, 2006.

17 Gruppo di Lavoro MS-AQ, 2010; Miccadei & Piacentini, 2010.

and possible site amplification effects.
This case outlines the role of the scale in mapping geology and landforms for seismic and, more in general, natural hazard assessment. Every type of hazard has its own suitable scale of investigation and mapping.

Flooding and mass movements induced by heavy rainfall in the last decade in the Abruzzo region

Time scale and multitemporality

Natural processes induce progressive changes in landscape and landforms. These changes occur within different time scales and frequency depending on the type of process: from a few seconds in the event of an earthquake (that may, however, have recurrence times of hundreds or thousands of years), to a few hours or days in the event of a flood (with recurrence times from decades to hundreds of years), to hours or days or months in the event of a landslide (with recurrence times from years to decades), etc. Heavy rainfall is one of the most important causes triggering landslides, particularly in Mediterranean areas which are characterised by moderate to low annual precipitations and, occasionally, by a high precipitation intensity. In this case, we compare the landforms triggered by heavy rainfall (daily rainfall ~ 200 mm) in three case studies from the Abruzzo region in Central Italy which occurred in the last decade[18]:

1. on 6-7 October 2007 (hilly - coastal Teramo area),
2. on 1-2 March 2011 (hilly - coastal Teramo and Pescara area),
3. on 5 and 13-14 September 2012 (hilly - coastal Teramo and Pescara area).

These events have triggered different types of geomorphological instability: landslides, soil erosion and flooding.
Each event was characterised by very high rainfall intensity (up to>40 mm/h and >200 mm/d; Fig. 8) that, according to the time series data correspond to a recurrence time of at least 100-200 years. In fact, in the same places of the hilly and coastal Teramo and Pescara area two events took place in 2 years!

18 Miccadei et alii, 2012; Piacentini et alii, 2012; Rainfall data from Servizio Idrografico e Mareografico, Regione Abruzzo

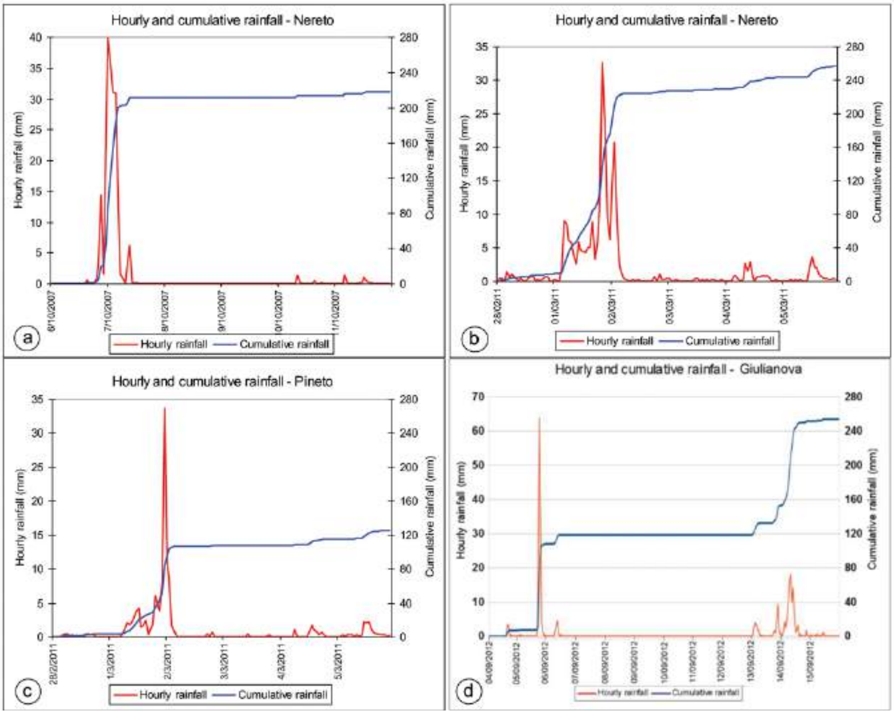

Figure 8 – The hourly and cumulative rainfall occurring during the heavy rainfall events: a) on 7 October 2007 at the Nereto (TE) station; b) on 2 March 2011 at the Nereto (TE) station; c) on 2 March 2011 at the Pineto (TE) station; d) on 6 and 13-14 October 2012 at the giulianova (TE) station.

The geomorphological effects of heavy rainfall were analysed through field surveys or an analysis of aerial photos taken 1-3 days after the event, mapping the distribution of landslides, soil erosion or flooding (Fig. 9,10,11[19]). Histograms and maps outline that the distribution of geomorphological effects, in the same area or in similar geological contexts, is related to rainfall intensity but also to land use and the seasonal state of the agricultural land. The first and third events occurred in September or October on widely ploughed, clayey hills that were affected by heavy soil erosion (gully, rill, sheet) and mud flows, as well as by flooding. The second event occurred in March on land covered with crops on the same clayey

19 Topographic data provided from Cartographic office of Regione Abruzzo (http://www.regione.abruzzo.it/xcartografia/).

hills. As a result the hills were affected by heavy flooding and slight soil erosion or landslides.

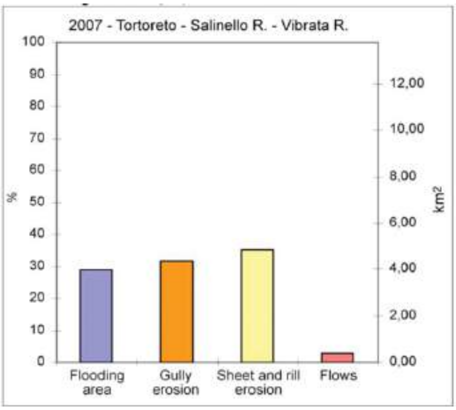

Figure 9 – Percentage and surface distribution of the geomorphological instabilities triggered by the 2007 heavy rainfall event in the Tortoreto hilly and coastal area between the lower T. Vibrata valley and lower F. Salinello valley.

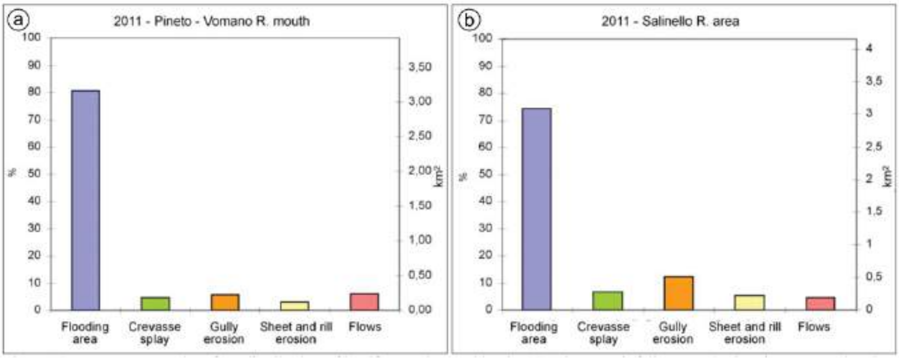

Figure 10 – Percentage and surface distribution of landforms triggered by the 2011 heavy rainfall event: a) The Pineto coastal and hilly area; b) The lower F. Salinello valley and the hilly and coastal slopes of the Tortoreto area.

These simple considerations[20] outline how the temporal scale of a process such as heavy rainfall and related geomorphological effects has to be taken into great account, from a hourly temporal scale (rainfall distribution) to a seasonal one (land use and agricultural yard management cycle), all the way to a decadal-century one (recurrence time of heavy rainfall events).

20 For more details, see Miccadei et alii, 2012 and Piacentini et alii, 2012.

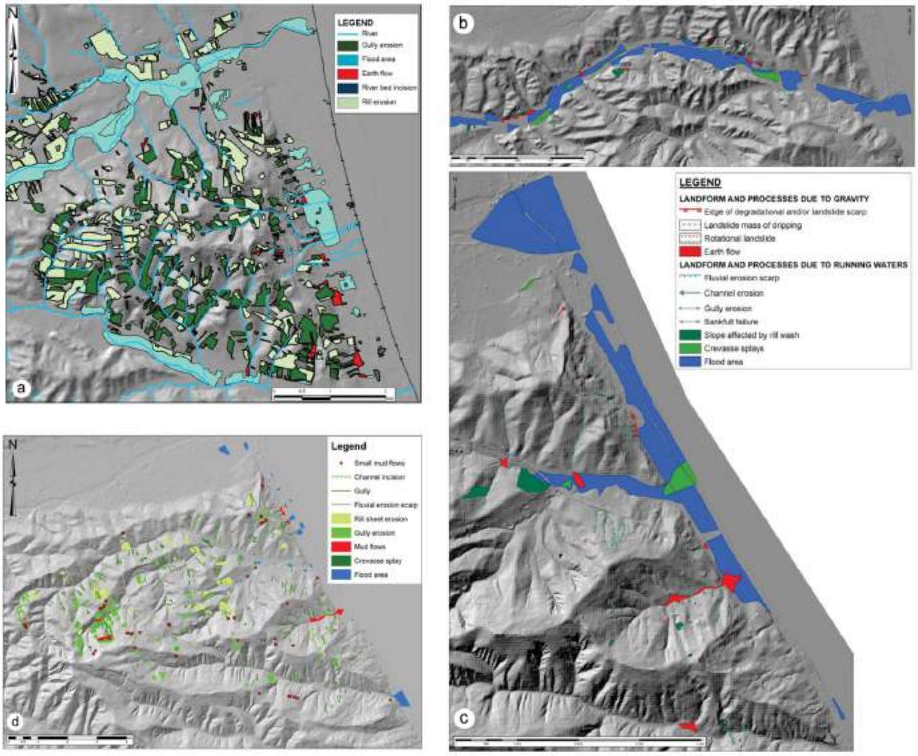

Figure 11 – Geomorphological effects of heavy rainfalls iin the abruzzo region (from Miccadei et alii 2012): a) 7-8 October 2007 Tortoreto area; b) 1-2 March 2011 Salinello river; c) 1-2 March 2011 Silvi-Pineto area; d) 13-14 September 2012 Silvi-Pineto area.

Only knowledge and understanding of these temporal scales (meteorological-climatic analysis) and their interrelation with the geological and geomorphological features (multi-temporal survey and mapping) of the affected landscape allow the analysis of the geomorphological effects and the hazards due to heavy rainfalls.

Landslide and flooding hazard assessment in the northern Abruzzo Region

Multidisciplinary approach

The third case outlines the basic role of multidisciplinary studies in the knowledge process for the prevention of natural hazards. The landscape, its evolution at different spatial and time scales, and the hazards connected to the natural processes acting on it, are related to different underground,

ground and above-ground features. Only multidisciplinary studies allow for a full understanding of the landscape's underground features (geology and tectonics, superficial deposits type and thickness, bedrock lithology), ground features (geomorphology, land use and land use change, particularly urban areas), and above-ground ones (climate, meteorology), as well as for the understanding of natural processes (heavy rainfall, landslides, earthquakes, etc.) and related effects and hazards (soil erosion, mass movement, surface fault and shaking, etc.). The overlay of hazards and land use, vulnerability and exposure led to the definition of risk distribution.

In this case, the methodological scheme of a study carried out in the northern Abruzzo region (coastal hills and plain) after heavy damage following heavy rainfalls (7 October 2007) is presented. The study shows the overlay of different methods of investigations (Fig. 12) based on a robust bibliographic and cartographic study and including orography, hydrography, hydrology, geology, photogeology, geomorphology, land use change, geognostic investigations, which allow the identification of critical drainage sites along main and secondary streams and an estimate of sediment volume transport from the main and secondary basins to the coastal plain.

Conclusions: open problems

Mankind is able to control and induce landscape changes but is subject to natural processes, hazards due to extreme events and related risks. Risks are the result of hazards, exposed elements and vulnerability, and they are consequently not only an expression of the natural environment, but also related to human interaction with nature. Therefore risks need to be addressed regularly by means of a high level of knowledge in order to provide the most up-to-date information for any decision which needs to be taken by any party involved.

A high level of knowledge concerning natural hazards and related risks stems from the geological and geomorphological history and from the historical records of the natural processes, and grows with complete multi-scale, multi temporal and multidisciplinary studies and investigations, which include land management, economic and social issues – with approaches appropriate to the scale (Fig. 13). Causes, correlations and interactions

STEPS OF THE STUDY

METHODOLOGY

METHODOLOGY	DATA and SCALE	PROCESSING and GIS	PRODUCTS
Bibliography	Scientific and technical papers Geologic, geomorphologic, land use, land management and other thematic mapping Topographic data and maps Scales 1:1,000 - 1:100,000	Digitization of papers and maps in GIS and Geodatabase	Geodatabase of papers and maps Geological-geomorphologica setting Highlights of open problems
Cartographic analysis and morphometry	DEM and Vector topography Scale 1:5.000-1:10.000	Orography Slope analysis Energy of relief Hypsometry analysis Digitalization into the geodatabase	Digital Elevation Model Energy relief map Slope map Aspect map
	DEM and Vector topography Scale 1:5.000-1:10.000 Digital drainage network Scale 1:25.000 - 1:10.000	Hydrography Drainage basins and drainage network extraction Longitudinal profiles Drainage network morphometric parameters Drainage basins morphometric parameters Digitalization into the geodatabase	Drainage network - basins map Drainage pattern map Drainage density map Morphometric parameters table
Meteorology and climate analysis	Temperature and rainfall data of the official meteorological stations	Climate charts Heavy rainfall event charts Annual rainfall analysis Maximum rainfall intensity analysis	Climate map Isohyet map Rainfall intensity map
Photogeology analysis	Aerial photos Scale 1:5.000-1:33.000	Photogeology analysis Drainage network; structural landforms; fluvial landforms; slope related landform, etc. Integration and support to field geomorphological mapping. Digitalization into the geodatabase	
Geological and geomorphological mapping	Multiscale geological and geomorphological field mapping Scale 1:25.000 - 1:5,000 Details at scale 1:1,000	Bedrock lithology analysis Quaternary continental surface deposits analysis Geomorphology analysis Digitalization into the geodatabase (Guidelines ISPRA-CARG)	Bedrock lithology map Quaternary continental surface deposits map Geomorphology map
	Inventory and analysis of bore hole and geognostic investigation	Digitization of bore hole and geognostic into the geodatabase (Guidelines ISPRA-CARG)	Geomorphological profiles Quaternary continental surface deposits thickness map
Geomorphological profiles 3D analysis	Correlation of geological, geomorphological and subsurface investigations Scale 1:25.000 - 1:5,000 Details at scale 1:1,000	Analysis of thickness of Quaternary continental surface deposits Analysis of depth of geological and lithological boundaries Hazard mapping	Geomorphological profiles Quaternary continental surface deposits thickness map 3D geological and geomorphological map Hazard map
Vulnerability analysis	Land use maps Multitemporal aerial photo investigations Scale 1:25.000 - 1:5,000	Land use change Distribution of urban areas, industrial areas, structures and infrastructures, road and rail network	Vulnerability map
RESULTS AND FINAL PRODUCTS	Hazard and risk assessment	Overlay of main terrain parameters for hazard assessment Overlay of hazard and vulnerability for risk assessment	HAZARD AND RISK MAPS

Figure 12 – Possible scheme of methods of investigations for a multidisciplinary approach to the study of landslides and flooding triggered by heavy rainfalls. The scheme includes multitemporal investigations and multi scale investigations, from 1:25,000 for general preliminary analysis, to 1:5,000 for main investigations, to 1:1,000 or more for detail analysis of critical sites.

between the factors determining risks can be identified and analysed. However, knowledge does not mean the ability to forecast natural severe events. In most cases this is not possible or it is possible only by applying a statistical approach, while it is possible to prevent or mitigate the effects of natural events by defining their damaging power and possible recurrence time, understanding their magnitude and frequency: we know they will happen and where they will happen, although not exactly when. And knowledge also means evaluating the exposed elements and their ability to withstand a certain expected event without damages or losses: without any disasters occurring. This approach helps to indicate future trends resulting

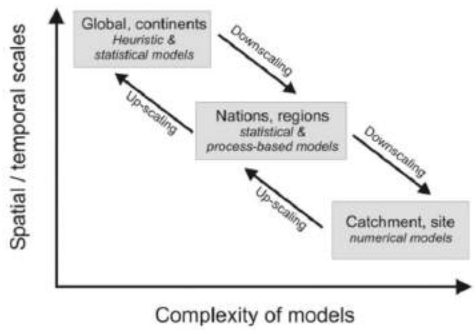

Figure 13 – Relationship between spatial/temporal and complexity of models, defining different type of approaches for analysis of landslides and related hazard and risk, suitable also for natural risks in general (from Glade and Crozier, 2005b).

This approach helps to indicate future trends resulting from human landscape changes[21]. The results support risk management and serve as a tool to optimise future strategies for damage reduction.

In conclusion, the most effective studies on risks are focused on "prevention", rather than on "forecasting", setting up actions capable of reducing losses. These types of studies are crucial to defining future scenarios - which sustainable land planning and management should be based on - by taking into account the specific future uses of different areas and contributing to the identification of proper sites for quarries, dumps and purification plants, or proper areas for industry, urban expansion, thereby generally supporting the process of creating an urban plan.

The dynamics and processes controlling the geological and landscape evolution of planet Earth are well known and scientists make continuous efforts for their study. Natural disasters have always provided new data, more effective intervention models, and land management plans more respectful of the environment. Consequently, improving our ability to face natural severe and extreme events without being subject to disasters is both advisable and necessary. Therefore, the crux is that prevention stems from the community's awareness that natural hazards exist, can be quantified and mapped. In this view, scientists, professionals and technicians working on landscape management have the duty of knowledge transfer, since this is

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21 Grozier & Glade, 2005.

needed, particularly by the civil society. Understanding natural processes is part of a people's environmental sensitivity and culture, which are not innate but requires a slow and progressive process, starting from children's education. The civilization level of a people can, indeed, also be assessed by its awareness of hazards and risks and its ability to set up actions and policies aimed at the protection of property and goods from natural disasters. Only in this way, according to the 2007-2009 "International Year of Planet Earth" Decalogue (whose first article is "Reduce natural and anthropic risks for the society") can a true knowledge and enforcement of existing laws and - if necessary - new laws really stem from recent disasters. This will help to achieve a proper and effective land management, based on an interdisciplinary approach in which expert geologists and land managers will play a role, in the light of the importance of natural processes in inducing risks.

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