GIS AND GEOMATICS FOR DISASTER MANAGEMENT AND EMERGENCY RELIEF: A PROACTIVE RESPONSE TO NATURAL HAZARDS

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ABSTRACT:

Geo-information and remote sensing are proper tools to enhance functional strategies forincreasing awareness on natural hazardpreventionandfor supporting research and operational activities devoted to disaster reduction.An improvedEarth Sciences knowledgecoupled with Geomatics advanced technologies is here proposed with the goal of reducing human, social, economic and environmental losses due to natural hazards and related disasters. Research activities lead to the collection and evaluation of data from: global and national literature for the definition of predisposing/triggering factors and evolutionary processes of natural instability phenomena (landslides, floods, storms, …) and for the analysis of statistical methods for the prediction of natural disasters;local and regional historical, geological, geomorphological studies of mountain territories of Europe and Developing Countries. Geodatabases, Remote Sensing and Mobile-GIS applications were developed to perform analysis of:1) large, climate-related disaster (Hurricane Mitch, Central America; Zambesi Flood, Mozambique), either for early warning or mitigation measures at the national and international scale; 2) distribution on slope instabilities at the regional scale (Landslide Inventory in the Aosta Valley, NW-Italy), to activate prevention and recovering measures; 3) geological and geomorphological controlling factors of seismicity, to provide microzonation maps and scenarios for co-seismic response of instable zones (Dronero, NW- Italian Alps);4) earthquake effects on ground and infrastructures, in order to register early assessment for awareness situations and for compile damage inventories (Asti-Alessandria seismi events, 2000, 2001, 2003).The research results has been able to substantiate early warning models by structuring geodatabases on natural disasters, and to support humanitarian relief and disaster management activities by creating and testing SRG2, a mobile-GIS application for field-data collection on natural hazards and risks.

1. INTRODUCTION

1.1 Aims

The “GeoSITLab” (GIS and Geomatics Laboratory) was founded at the Department of Earth Sciences of the University of Torino to enhance the application of Geomatics technologies for geothematic mapping and for geological and geomorphological field activities.

The “ITHACA” centre (“Information Technology for Humanitarian Assistance, Cooperation and Action”) was founded by Politecnicodi Torino and SiTI (IstitutoSuperiore sui SistemiTerritoriali per l’Innovazione) in cooperation with the UN-WFP (World Food Programme) to conduct operational and research activities for analysis, evaluation and mitigation of natural and manmade hazards and for emergency management.

At the Doctoral School in Strategic Sciences of the University of Torino (SUISS) a research program has been set up to evaluate the role of Civil Defence in the management and recovery from natural disasters: remote sensing and geo-information are here considered as proper tools to enhance functional strategies, from civil-military cooperation to force integration during search and rescue activities.

Based on these premises, the above-mentioned institutions recognized the proactive response to natural hazards as a common aim, and an agreement between the “GeoSITLab” and the “ITHACA”centres was signed. So far a joint research program has been developed in order: 1) to substantiate early warning models by structuring geodatabases on natural disasters with substantial Earth Sciences-oriented information, and 2) to support emergency relief and disaster management activities by creating a mobile-GIS application for field-data collection on natural hazards and risks.

1.2 Reference Framework and Theory of Emergency Relief and Disaster Management

A disaster is a sudden event bringing great damage (Quarantelli, 1998). Usually disasters are distinguished in natural, as geological, hydrometeorological and biological ones, or induced by human processes, as environmental degradation and technological hazards (UN/ISDR, 2004). Here, the voluntary human-induced disasters (i.e. NBCR-E terrorist attacks) are excluded.

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The natural disasters are generally subdivided into"slow onset ones" (famine, drought, pandemia) and "rapid onset ones" (floods, earthquake, landslide, storms, etc.). A complete list of disaster types and associated death tolls is provided by CRED - Centre for Research on the Epidemiology of Disasters (www.cred.be).

Disaster management is the process that is implemented when any type of catastrophic event takes place to overcome the catastrophe and return to normal life and function as quickly as possible. The disaster management activities are likely to address such as important matters as evacuating people from an impacted region, arranging temporary housing, providing safe water, food and medical care.

The emergency relief focus in apply available resources to urgent problems in the most timely and efficient manner. For this objective command and control (C^2) must be centralized and supported by continuous information awareness (Alexander, 1993).

Real time information from affected areasare provided by personnel operating on site or by satellite imagery. Only after the first rescue, personnel deploy is possible to obtain detailed and technical information provided by trained units and by aerial imagery (such as UAV).

1.3 Geomatics for Human Security

The Human Security approach to humanitarian emergencies focalised relief effort on a people-centred recovery activity that should guarantee not only the lives of affected people but also their social ties and economic capacities (UN/OCHA, 2009).The *Hyogo Declaration* (World Conference on Disaster Reduction, hold during 2005 in Kobe, Hyogo, Japan) stressed that the phases of relief, rehabilitation and reconstruction are windows of opportunity for the rebuilding of livelihoods and for the planning and reconstruction of physical and socio-economic structures, in a way that will build community resilience and reduce vulnerability to future disaster risks (UN/ISDR, 2005).Faster relief will avoid not only an highest toll of death but also the outbreak of famine and disease, the rise of internally displaced persons (IDP), the fall of productive system.It's also to underline that, especially in developing countries, the assistance must be highly impacting and short timed to prevent from creating dependency (USAID, 2002).

Geomatics involves the integrated acquisition, modeling, analysis, presentation and management of spatially referenced data (i.e. any type of data that includes its location on earth), to support decisionmaking(Gomarasca, 2009).Since the mid-1990s Geomaticsplayed an important role in the data acquisition and communication about natural and human-induced disasters around the globe: activities of media and humanitarian agencies have been increasingly dependent on satellite images, maps and three-dimensional terrain visualizations. Almost any report on the Darfur Crisis, Iraq War, or the Indian Ocean Tsunami exploits a host of powerful geospatial technologies. Historically the primary domain of Cold War-era military agencies, geomatics has grown to include a thriving civilian user base, thanks to several key industry trends (Verjee, 2005).

Geomatics should boost relief effort in every field of disaster management: the integration of geospatial databases, global positioning system (GPS) and digital cartography led to a comprehensive view of affected areas from "boots on the ground" perspective. The possibility to link Pocket / Tablet PC to home servers, via mobile or satellite telecommunications, gives also to emergency operations director an immediate impression of situation on the ground.Especially in large disasters, which could evolve to complex emergencies, the knowledge management increase exponentially the success of the emergency relief (von Lubitz et al., 2008).Special attention needs to be devoted to the problems of integrated emergency response for large disasters in the international arena (figure 1). When a major flood or earthquake causes a massive death toll and leaves survivors homeless and hungry, the United Nations organize relief effort that should provide some or all the following actions (figure 1):

1) Search and Rescue teams should be connected each others to exchange information and to provide support to major efforts; in wide urban areas (more and more frequently hits by disasters) communications and movement are strongly disturbed by ruins and aerial survey associated with GPS localizers is the only way to guarantee C^3I (command, control, communications, information).
2) First aid and health care facilities become strategic structures that must be guarantee from new occurrences (i.e. aftershocks), so their right position should studied as soon as possible.
3) Food and drinking water supply chain could be better organized with the location of safe area for storage and distribution; environmental pollution induced by disaster should be analysed and consequences management activated.
4) A safe environment for refugee camps should be provided only by deep analysis of hazards still threating the affected area; adequate access, space for warehouses, easy security are as important as healthy conditions.
5) Finally first rebuilding should start at once, with particularly attentions to local social structure; the strength ties that grow among hit people should be used to avoid IDP.

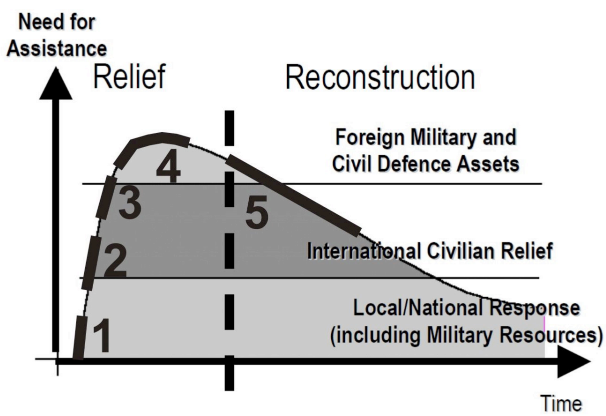

Figure 1. Disaster management timeline in complex emergencies (modified from: UN/OCHA, 2008. United Nations Civil-Military Coordination Officer Field handbook.United Nations, Geneva, Switzerland).

1.4 The Role of Earth Sciences in Geothematic Mapping and Description of Natural Hazards

Geology and Geomorphology support regional or local studies on natural hazards assessment and management through the collection and interpretation of Earth's surface landforms, materials, structures, processes.

Geothematic maps are synthetic ways of showing the above-mentioned information: for example, geomorphological maps (Goudie, 2004) of flood plain are suitable both for natural hazards studies and emergency management activities. As stated by the Working Group on Applied Geomorphological Mapping (AppGeMa) of the International Association of Geomorphologists, geomorphological maps are, in fact, not only important as end products of scientific researches but also as tools for technical applications by professionals dealing with the landscape and landforms (Pain et al., 2008).

In a similar way, regional geological maps can play a strategic role in enhancing natural hazards studies, including assessment, management and planning for remedial measures.

In the case of an earthquake-prone region, useful information can be synthesized by geo-structural maps including highly active faults, as well as maps of historical seismicity (Yeats et Al., 1997). Combination of points, linear and areal georeferenced information from these thematic maps with other parametrical data (e.g.: slope angle, rock strength, sediment granulometry, …) may result in seismic zoning maps in which different degrees of hazards are delineated. Moreover, during emergency activities and specialized early impact studies related to a large earthquake, detailed geological and geomorphological data can offer a precise location of individual local hazards, such as liquefaction, earthquake induced landslides, or tsunami runup.

1.5 Better Knowledge for Faster Relief

In order to improvein our societies the knowledge and capacity related to prevention of natural hazards and risks, a strategic use of geo-information by geomatic techniques is here proposed. Both regional and local data are seen here as necessary components to mitigate damages and human losses by natural disaster and to strengthen effectiveness of risks management.

Amultiscalemethod has been developed and assessed in order to enable administrative bodies and institutions to make proper choices and decisions for the mitigationof natural disaster and adaptation to their effects. Better forecasting and warning of natural hazardsis based on the improved integration of geological knowledge into disaster risk reduction researches.

2. METHODOLOGY

2.1 Developing aMulti-scale Method

Scientific community, decision- and policy-makers can access to a great variety of information on natural hazards. Available data can be of very different types by contents, quality and dimensions, thus causing difficulties of management. Some problems can also arise when original data are collected, either locally or globally, by remote sensing or by field surveys: they have to be interpreted, summarised and redrawn in order to create reports, base maps and/or more elaborated geothematic or statistical representations. Furthermore

In the last 15 years, the use of computers and other electronic devices for collection, analysis and distribution of data had a notable development in the Earth Sciences and their applications to environmental analysis. Based on these effective improvements, a multidisciplinary, multi-scale method for collection, interpretation and representation of data on natural hazards is here proposed, including:

1) a relational geodatabase structure, for standardized collection and storage of literature and remote sensing data on natural hazards;
2) a mobile-GIS technology for geothematic mapping and data implementation in the field.

2.2 Geodatabases Dimensions, GIS and Remote Sensing Solutions

Modern GIS allow easy loading structures and complex data management (Arctur&Zeiler, 2004). Nevertheless, in a complex geodatabase on natural hazards, these important potential capabilities can clash with the difficulty in the operational data insertion. Therefore, a straightforward structure and a rapid access to data must be offered to the users, for easier data loading and consulting: geodatabase has to contain an adjusted number of fields for the specific natural hazard to be identificated and characterized (Antenucciet Al., 1991). Furthermore, a key of the success for natural hazards and risks perception, assessment and management is the appropriate selection ofRemote Sensing techniques and imagery, whose accuracy and effectiveness must correlate to the features included in the geodatabase(Crespi et Al., 2007).

Based on the amount of details derived from field activities and remote sensing investigations and stored in an inventory of data on natural hazards, it is possible to separate four dimensional macro-classes of geodatabases:

A) Local
B) Regional
C) National
D) Global

Their differences essentially consist in the scale of analysis, which has repercussions on the geodatabase structure and on the total number and type of available fields and records.

In case "A", the local geodatabase has to achieve the largest possible amount of georeferenced data (geological and geomorphological mappings, hazard and risk analysis, monitoring systems, …) of a single instability phenomenon or of a small area invoved in a natural hazard event. The main purpose of a local geodatabase consists in the search and storage of all those possible data capable to define the most univocal model of the studied hazard, as well as the realization of a possible zoning of the instability phenomenon or event, such as a landslide or a flood event, either from a geomorphological/structural reconstruction (Giardino et Al., 2004) or from a hazard assessment point of view (Luino et Al., 2009).

Case “B” foresees a lower detail of the data collection, making greater attention to all the useful sources for a regional description, individualization and distribution analysis of several types of natural instability. This type of geodatabase loads data from historical files, newspaper information, technical reports, remote sensing studies. So, regional geodatabases consist of extremely heterogeneous data, from very different sources, often compiled by not-experienced staff. For these reasons, their complicated operation sometimes deals with problems of accuracy and precision (Brunsden and Isben, 1996). Nevertheless, proper regional geodatabases offer a unique possibility of individualizing “characteristic” hazards of specific areas: as an example, the most significant earthquake for a seismic zone, in term of magnitude and frequency (Schwarz and Coppersmith, 1984). Moreover, detailed temporal and spatial analysis of the collected information are possible through regional databases. WebGIS technologiesare sometimes adopted to show the location of the sites historically affected by hazardous phenomena (e.g.: landslides and floods in Umbria Region; Salvati et Al., 2009).

National-scale geodatabases (case “C”) hold natural hazard data characteristic of a whole nation. Usually they are controlled by governmental agencies, which set up common data models addressingspecific aspects for different types of natural hazards.Being their original data captured by different research and territorial institutions, the success of national geodatabases is proportionate to the ability of components of the contributors to work together in a common way by linking data, information and processing tools between different applications, regardless of their underlying software, hardware systems and geographic location. That is the suggested use of a ‘networked service-oriented interoperability’ (Osuchowski& Atkinson, 2008), which is able to connect disparate inventories into a single ‘virtual’ national database; here, custom functions allow the spatial data to be manipulated and queried: for example to find all the residents of an area within an exposure zone for a potential environmental hazard (Trigila et Al., 2007). In short, being national geodatabases addressed to territorial applications, they are the standard reference for developing socioeconomic analysis of natural hazards and risk management policies.

Case “D” includes global geodatabases. These types are generally associated to the Spatial Data Infrastructure (SDI) project developed and managed by United Nations Geospatial Information Working Group (UNGIWG) since 2000. The tipical use is short-term emergency response capacities, long-term risk reduction, development and environmental protection activities. SDI is often used to denote the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data.

Accurate, easily accessible geographic information is crucial to good decision-making in humanitarian operations. The main aim of the SDI project is the development and implementation of a global database, with its related rules and procedures to store, manage and exchange geospatial data for international organizations (e.g. World Food Program). The SDI is an efficient tool for storing, querying and manipulating large amounts of global geographic information and spatial data for analysis and visualization purposes. The database integrates and updates data coming from multiple sources, providing each user with the latest datasets, thus avoiding duplications and mistakes. The data models is shaped according to specific needs and demands of the user groups within the organization. SDI metadata are commonly delivered electronically via internet (Ajmar A., 2008, UNGIWG, 2007).

Recent GIS developments applied to natural hazards and risks assessment and management introduced new possibilities for the interaction of geodatabases from different dimensional classes. Modern relational database management systems make it easier to store geometries, attributes, and behavioral rules for multidimensional data, from A) to D) macro-classes.

The integration of field-based and remote sensing investigation and the use of multi-scale Land Information Systems (GIS devoted to territorial data management) for the development of Decision Support Systems suggest the opportunity to activate stronger links between informative levels for regional-scale files management (geodatabases B) and detail analysis (geodatabase A) .

2.3 Geomatics Supports for Field Activities

Looking for faster and more suitable procedures for mapping and describing natural hazards in the field, applications of Geomaticscan help to share, compare and exchange data between researcher and users in unambiguous and accessible ways, possibly following codified standards for map production and user-friendly technologies for results communication.

Simplicity, precision and rapidity of field survey techniques are some ingredient for achieving better results. In this perspective, a key factor offered by digital techniques is the possibility to organise a complete dataset during field activities, avoiding time-consuming laboratory operations, such as copying data from paper forms and/or repeated drawing of maps.

To develop a digital methodology for mapping and description of natural hazards, different studies on computer applications for field-based geological/geomorphological activities have been compared, conducted by Universities, research centres, and technical institutions (e.g.: Haugerud&Thoms, 1999; Walsh et al., 2000; Clarke et al., 2002). Geomatics support to field surveying was also tested for developing skills at an educational level (e.g.: International conference: “Supporting fieldwork using information technology”, University of Plymouth). As a common conclusion of the above mentioned works, light, easy-to-handle hardware and user-friendly software have been selected, in order to offer a precise, uniform standard technological path to be followed when collecting and processing data in the field.

The geomatics methodology suggested here consists in the integrated use of digital pictures and maps from different sources (topographic maps, hortorectified aerial photographs, other technical geotematic maps), which becomes either a base or an output for data collection and representation of natural hazards, by using dedicated forms for geomorphological descriptions and mapping. The equipment for such activities consists in a pocket PC based on Windows CE, with dedicated GIS software and Bluetooth GPS for ground positioning (figure 2). The use of palm/pocket PC is an innovative solution with respect to the use of tablet PC as a field mapping tool proposed by other research teams. Juxtaposition of the two alternatives revealed that palm computers are more convenient tools for supporting field activities, according to several criteria: size, weight, autonomy power of batteries, rapidity and simplicity of use, overall cost of instrumentation.

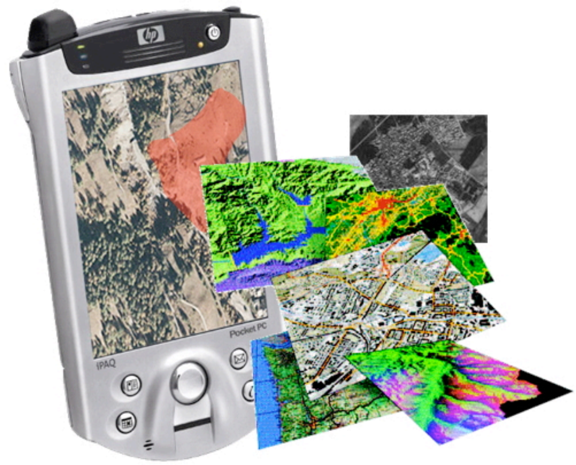

Figure 2. Geomatics supports for digital mapping and description of natural hazards: palm/pocket PC and digital imageries (topographicmaps, ortorectified aerial photographs, other technical geotematic maps).

3. APPLICATIONS AND RESULTS

3.1 Overview on Geodatabases, Remote Sensing and Mobile-GIS Applications

Research activities lead to the collection and evaluation of data on natural hazards and disaster events from different sources:

- historical, geological, geomorphological, hydrogeological data on natural hazards from mountain territories of Europe and Developing Countries;
- reference papers and bibliographic data useful for the definition of predisposing/triggering factors and evolutionary processes of natural instability phenomena (landslides, floods, storms, …) and for the analysis of statistical methods for the prediction of natural disasters;
- remote sensing data for the application of geomatics techniques in the management of emergencies related to geological and geomorphological phenomena.

Geodatabases, Remote Sensing and Mobile-GIS applications were devoted to the analysis of:

- large, climate-related disaster, either for early warning or mitigation measures at the national and international scale;
- distribution on slope instabilities at the regional scale, to activate prevention and recovering measures;
- geological and geomorphological controlling factors of seismicity, to provide microzonation maps and scenarios for co-seismic response of instable zones;
- earthquake effects on ground and infrastructures, in order to register early assessment for awareness situations and for compile damage inventories.

3.2 Application of Remote Sensing to Climate-related Natural Disaster

Two recent examples of applications of remote sensing,devoted to the mitigation of environmental hazards connected to climate-related Disaster, are here summarized.

The first case-study concerns a remote sensing application for processing satellite images performed during the UN-funded project "Rural indigenous communities and mitigation of disasters. - The Polochic Valley of Guatemala" (Perotti, 2002). The project had a pilot site for areas of high vulnerabilityto extreme weather events in the microbasin of Rio Matanzas, central Guatemala, (figure 3), a tributary of the Rio Polochic, a W-E riverflowing to the Gulf of Honduras (Caribbean Sea).

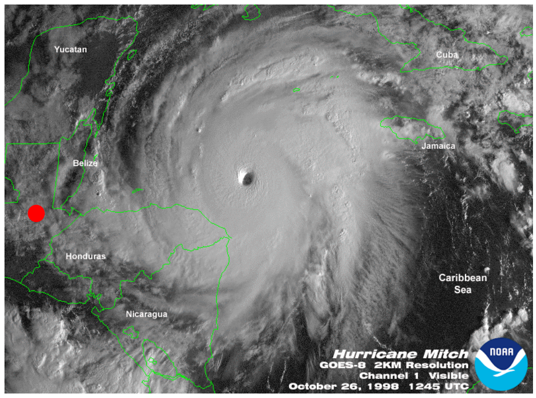

Figure 3. Hurricane Micth 1998 from Remote sensed image GOES-8. In red the Rio Polochic Area.

The aim of the work has beenthe study of the environmental effects ofHurricane Mitch (1998) by multitemporal analysis of satellite images acquired before and after the catastrophic event.Flooding related to Hurricane Mitch, occurred October to November1998. The area of the Rio Polochicconfluence was flooded in several populated places. Comparison of pre- and post-event images with topographic maps (year 1991), showsfluvial diversion downstream of the confluence. General changes in vegetated areas have been also reported. Remote sensing also individualizedclimate-related landslides (triggered by Hurrican Mitch) and othertectonic controls to the stability of slopes by thestructural discontinuities belonging to the regional system Chixoy-Polochic (figures4 and 5), sometimes associated with lower forest cover due to deforestation.

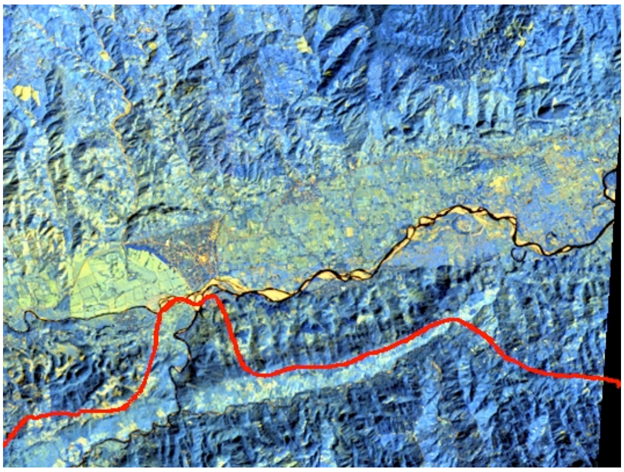

Figure 4. False color RGB 754 from Landsat 7 ETM+ AFTER Hurricane Mitch. In yellow a new meander zone due to the event.

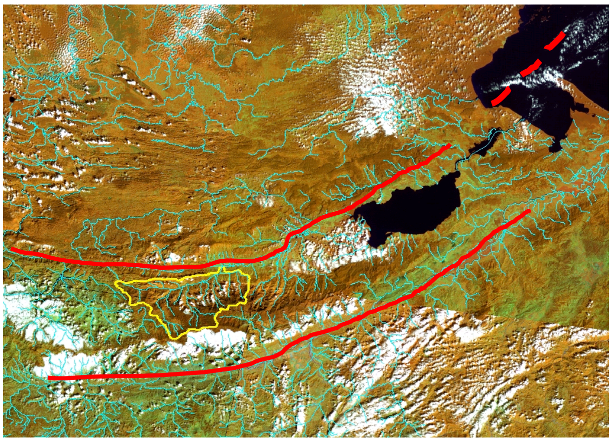

Figure 5. Rio MatenzasMicroBasin (Y). The LandsatMosaik image show the structure of regional cross-junction formed by two major faults: ChixoyPolochicand Motagua fault. The pattern certainly clarifies the evolution of the basin structures.

The second application concerns the development of an Early Warning system for flood events based on precipitation analysis and related historical flooded area detection (figure 6).The methodology is based on the individuation of critical precipitation events in the last ten years on worldwide extent and the evaluation of related fields effects in terms of flooded areas; these are extracted from satellite images using suitable classification procedures and analyzing geomorphologicalfeatures to identify the potential floodable areas (e.g.: application to the Zambesi basin, Mozambique; figure 7). Pluviometric thresholds, determined by different analysis (hydrological and statistical), executed on historical rainfall data, are stored in a database structure where they can be compared with real-time rainfall values.

This Early Warning System allows to monitor near real time rainfall values, creatingan alert for critical values and producing a map with a flood scenario referred to the past event with similar rainfall fields (Albanese et al., 2008).

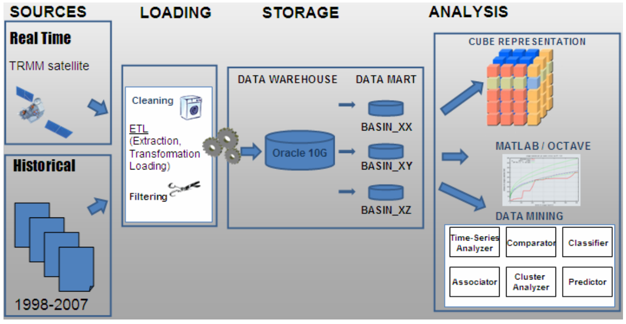

Figure 6. Early Warning Architecture (Albanese et al., 2008).

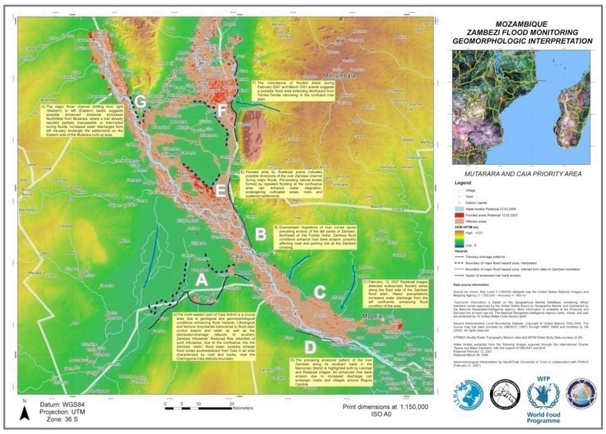

Figure 7. Example of ZambesiGeomorphological interpretation – Mozambique.

3.3 A Regional Geodatabase on Landslides

For a best landslide hazard assessment of the Aosta Valley Region (NW-Italy), a 3-stage program of landslide inventory has been completed in February 2007, combining field and remote-sensing surveys and historical data analysis. The activities are part of the IFFI project (Inventory of Landslide Phenomena in Italy), carried out by ISPRA and the local governments (Regions and Autonomous Provinces).

Here are summerized the activities performed in the Aosta Valley:

- as a first step in defining geometry of landslide areas, multitemporal aerial photointerpretations were conducted over the Region territory, not only for mapping still unknown landslides, but also for verifying other case-history map. The scale used to compare this data has been 1:10.000.
- As a second step, data have been compared to the up to date information from the municipalities' hazard maps conducted over whole Region for land planning restriction. The analysis has been extended also to the other areas classified with theFlood and Landslide Risk Maps (PAI: Hydrogeological Asset Plan) produced by the River Po Basin Authority in 1999.

- More detailed local field studies has been conducted in selected localities to identifying processes and factors related to major present-day natural instability phenomena.
- All data have been finally organized in a GIS and used to improve statistical analysis for understanding how the geological and geomorphological factors can influence on the landslides distribution.

With the aim of homogenizing the classification and glossary (i.e. type of movement, state of activity, intensity, velocity, distribution), at the regional, national and global scale, the methodology of the National Landslide Inventory of Italy (Trigila et Al., 2008) have been applied. The followinginternational classification standards have been adopted: Cruden and Varnes (1996), Recommendations of the International Association of Engineering Geology (IAEG 1990), International Geotechnical Societies UNESCO Working Party on World Landslide Inventory (WP/WLI 1990, 1991, 1993, 1994, 1995).

3.4 SRG2: an Application for Digital Mapping and Description of Areas Affected by Natural Hazards

Looking for faster and more suitable procedures of field mapping and data collection on natural hazards, either for scientific research and technical management, an application called “SRG2” (acronym for the Italian: “Supporto al RilevamentoGeologico / Geomorfologico” - Support to Geological / Geomorphological Surveys) was created, as an extension for ArcPad (GIS-ESRI for palms) developed in Visual Basic. Into the ArcPad environment, the SRG2 application adds a toolbar, vectors and tables made up of several functions for a useful mapping and classification of geological and geomorphological features (Fig. 8). ArcPad software generates vector shapefiles, of large use in GIS project and of great utility in assessments and management of any type of field activities.

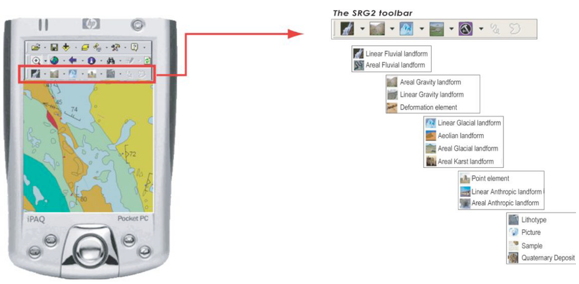

Figure 8. Left) SRG2 shapefiles and toolbar into ArcPad. Right) List of the 16 layers used in test sites. Geometries, legend and visual representations are available for areal, linear and point features.

In order to catalogue geomorphologicalfeatures relevant for early warning analisysof hazardous process (landslides, floods, …) ,the SRG2 application was structured into different layers and with a simple geodatabase structure (figure 9):erosional and depositional landforms and related deposits, characteristic processes of different morphogenetic environments; lithological and structural elements; anthropic features and infrastructures; location points for sampling and picture views.

During field activities, as a first-step, distinct elements are classified by geometry (points, linear, areal features). Drawing elements in the map can be manually operated, through visual recognition in the field, or automatic, by means of GPS tracking option. Then surveyed features are classified by typology: 1) genetic environment and related process, either endogenic or exogenic, are interpreted (“glacial”, “fluvial”, “gravity-induced”, “tectonic”, “complex”, etc.) or left unknown; 2) further alphanumeric data (morphometrical, chronological, lithological, etc.) are requested to complete description and to support interpretations. Each typology of classified elements has a dedicated list of selectable attributes (figure9), useful both for achieving a complete scientific description of the surveyed features and for indicating natural hazards to be considered by technical operators, for planning and management purposes.

As an example, by using SRG2 application, geological and geomorphological features were mapped in seismic areas; their full description allowed not only selection of elements to be considered in the interpretation of processes and extent of natural hazards, but also in a proper management of their effects in a dynamic environment interacting with human activities and infrastructures.

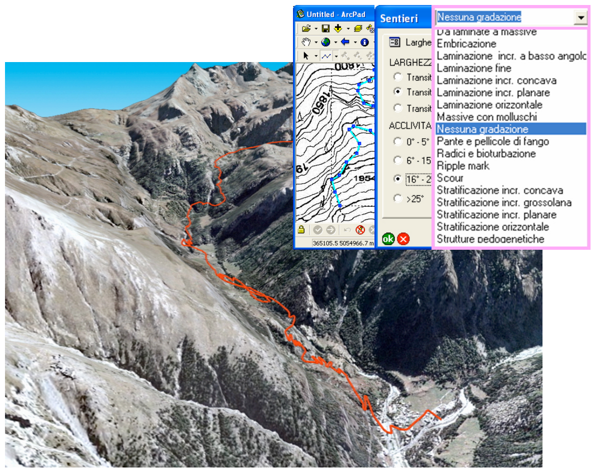

Figure 9. Exampleof forms developed for ArcpPad to check trailsoperability and their characteristics.

3.5 Application of Geomatics to Seismic Microzonation

Seismic microzonation involve a series of studies including geology, geomorphology, geophysics, geotechnics and engineering geology, aimed to the subdivision of an area into zones characterized by an homogeneous seismic shaking during an earthquake. Detailed geological and geomorphological maps are particularly important, especially in areas characterized by high geological and geomorphological complexity, as basic tools for a proper planning of geophysical and geotechnical investigations needed for detailed seismic microzonation (Perrone et al. 2008). Different types of geomorphological and geological features have been considered for the realization of seismic microzonation maps. These features are mainly related to:

- *theamplification phenomena* of seismic waves generated by an earthquake (Idriss& Seed, 1968). This phenomenon,that strongly increase the ground shaking, may occur when seismic waves propagate in scarcely cohesive superficial deposits with limited thickness overlying a rocky substratum. Amplification phenomena may be also induced by particular geomorphological conditions, known as topographic effect, like ridges, crest lines, scarps and fluvial terraces;
- *the liquefaction phenomena*, that may be induced by the sudden shaking of saturated non cohesive deposits like sands and gravels (Perucca L. P. &Moreiras S. M.,2006);
- *the activation or reactivation of landslides*,whichinclude the mapping of trenches, slope-related scarps and landslide deposits (Keefer, 1984);
- the occurrence of *buried landforms*.
- characterization of the *activity of the faults* in the analyzed area; geomorphological indicator of recent activity of faults are therefore particularly important (see McCalpin, 1996 for a detailed description).

In the figure 10 it is shown an example of a detailed geological-geomorphological map of the Dronero village (italian Western Alps), aimed to the seismic microzonation. Geological-geomorphological mapping was carried out at 1:5,000 scale using the *ArcPad* software with the *SRG* extension. The Dronero village is located at the mouth of an Alpine valley (Maira valley) and is characterized by a complex geomorphological geological setting (Perrone, 2008).

The *geological mapping,* was mainly aimed to characterize the superficial Quaternary deposits. Parameters like lithology of the clasts, texture, composition of the matrix and thickness of the deposits were therefore considered. Different superficial deposits were distinguished, including eluvial deposits, recent fluvial deposits, landslide deposits, slope deposits, stream and alluvial fan deposits, ancient fluvial deposits.
Even if the bedrock was constituted by metamorphic rocks, roughly characterized by similar physical-mechanical properties, the different lithologies were differentiated in order to locate the trace of the major faults dissecting this area. Faults and fracture systems were moreover characterized on the basis of their geometry (strike, dip) and sense of movement.

The *geomorphological mapping* was aimed to the characterization of the different landforms characterizing the analyzed area.

Slope-related and fluvial landforms were distinguished. Slope-related geomorphological features include landslides and gravity-scarps; fluvial geomorphological features include fluvial terraces and alluvial fans. Scarps and fluvial terraces were subdivided, on the basis of their height, in two main classes (more and less than 10 metres). Landslide were differentiated on the basis of their activity (stable, quiescent and active).

On the basis of the integration between surface geological-geomorphologicalinformations with stratigraphic borehole and geophysical investigations (electric tomography, seismic refraction, and seismic down-hole) it has been also possible to detect a buried fluvial bed beneath the fluvial deposits of the Mairariver.

The geological, geomorphological and geophysical information were utilized to realize the *homogeneous microzones map*. In this map the investigated area is subdivided in three main classes (see also Gruppodilavoro MS, 2008), qualitatively characterized by a homogeneous seismic behaviour: stable zones, zones susceptible of local amplifications and zones susceptible of instabilities. <u>Stable zones</u> (Zone 1) include the areas where bedrock outcrops, widespread on both the slopes of the valley. <u>Zones susceptible to local amplifications</u> include 5 sub-classes (Zone 2-6) distinguished on the basis of their local stratigraphic characteristics. <u>Zones susceptible to instabilities</u> include areas where potential reactivation of quiescent landslides may occur. Geomorphologial features (fluvial terraces, landslides, gravity-scarps and alluvial fans) where instabilities during the seismic shaking may occur and the trace of major faults were also indicated on this thematic map.
The homogeneous microzones map represents afundamental tool for the understanding of the behaviour during the seismic shaking. This map, integrated with further geophysical and geotechnical investigations that allow to characterize quantitatively the seismic response of these zones, also may allow to forecast the zones affected by the major coseismic damages. Besides speeding up the realization of microzonation maps, the use of a GIS mobile software may also allow a faster and precise location of hazardous situations in areas struck by seismic events.

3.6 Damage Inventory and Management of a Seismic Crisis

The last geomatic application here presented is aimed to improve emergency relief in developing countries. In these areas geomatic for post-seismic disaster management should be tested in early assessment for awareness situation and in damage surveys to check habitability.The application of geomatics to early operations as USAR (Urban Search And Rescue) is excluded due to the long time needed by rescue personnel to reach the affected area; entrapment involve short survival times: most victims will dead within 8-12 hours and the rescuers arrived during a time window from 36 to 72 hours after the main earthquake.

EMS-98 (European Macroseismic Scale – Grünthal, 1998) should provide International Organisations, like UN, EU and large NGO, with a first situation table to activate humanitarian relief. An ArcPad extension was developed on the base of intensity scale guidelines as tested in earthquakes that struck Piedmont (north-western Italy) in recent years (Asti-Alessandria 2000 - 2001 - 2003 events).
As described before the software generates vector shapefiles based on point geometries with associated database positioned by GPS or direct location on orthophotos. Buildings vulnerability classes and the classification of damage suffered by every structure are supported by image abacus and example sketches.

The data collected are suitable to be easily sent via satellite to a Local Emergency Management Authority or to a foreign coordination centre (like MIC at EU in Brussels or to UN/OCHA in Geneva). Here they should be organized to better understand the severity of induced damages and coordinate the relief actions.Digital images help a second level data interpretation and should be used to compare situations in case of aftershocks.

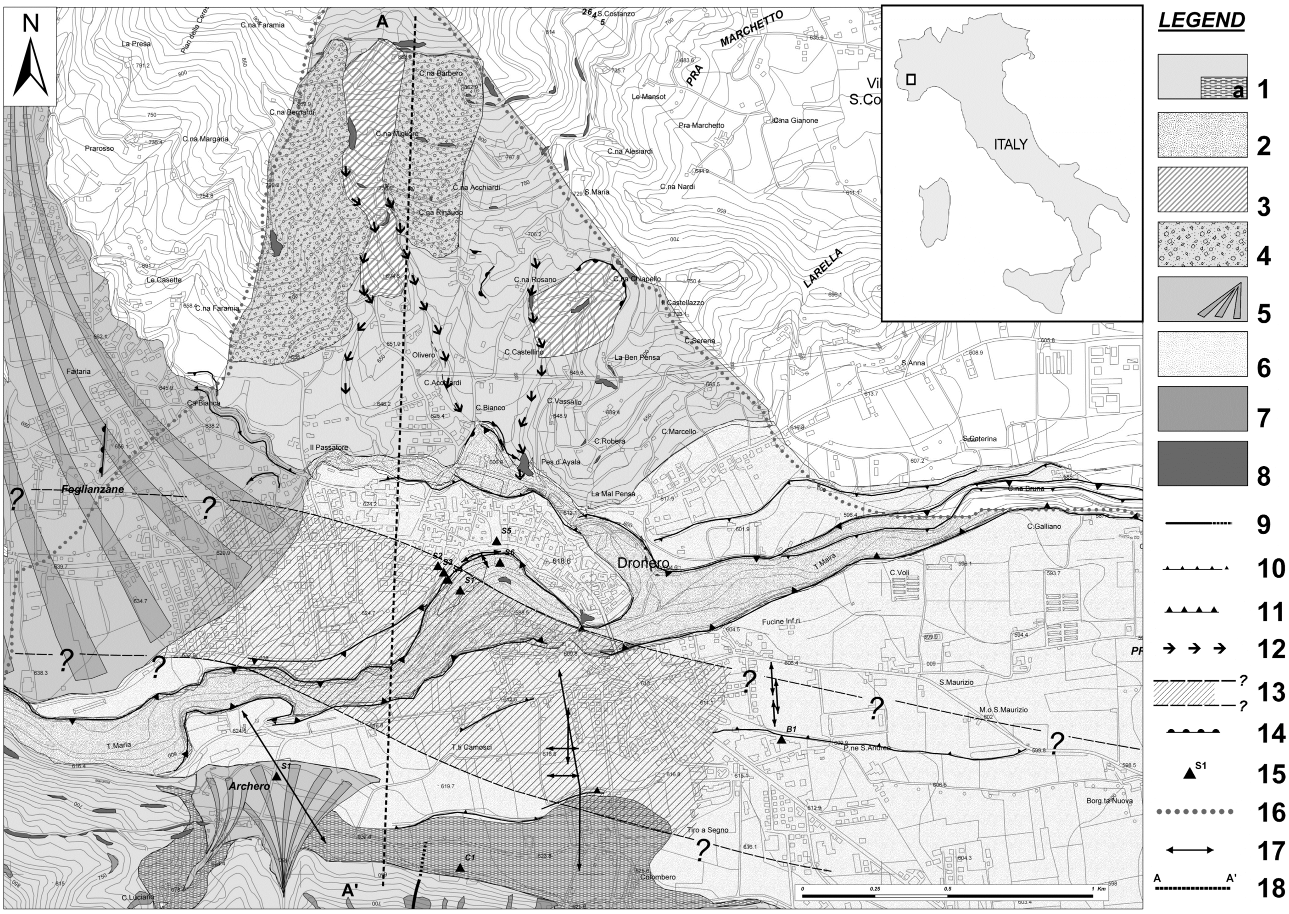

Figure 10 - **Quaternary deposits**: (1) eluvial-colluvial deposits, with thickness ranging on average between 1-2 metres, (a) sometimes strongly alterated in the shallower part (red soils); (2) recent and current bottom valley fluvial deposits constituted by well-rounded gravels, sands and centimetric to metric blocks; (3) landslide deposits constituted by angular blocks with variable dimensions, ranging from decimetric to metric, in a sandy-gravelly matrix; (4) debris and slope-deposits, stable, constituted by decimetric to metric blocks; (5) stream and alluvial fan deposits constituted by polygenic pebbles, sometimes well-rounded, and blocks with dimensions ranging from centimetric to metric, alternated to silty, locally clayey intercalations; (6) ancient fluvial deposits constituted by gravelly-sandy levels alternated by silty-sandy levels, usually these deposits are cemented (conglomerates) in the shallow part. **Pre-Quaternary substratum:** (7) dolomitic marble and dolomites; (8) micascists, sometimes phylladic, with minor metabasities. **Structural elements:** (9) fault. **Hydrography related elements:** (10) fluvial terrace less than 10 metres high; (11) fluvial terrace more than 10 metres high; (12) deeply incised valley; (13) buried river bed and its hypothesized prolongation. **Slope dynamics-related geomorphological elements:** (14) scarp less than 10 metres high. **Other symbols:** (15) borehole; (16) village boundary; (17) geophysical investigation; (18) trace of the geological section.

The Italian National Seismic Survey (SSN) developed in 2000 a first level damage chart (AeDES) utilized with minor revision until the recent "l'Aquila" earthquake (officially edited 07/04/2009 on GazzettaUfficialedellaRepubblicaItaliana).The aim of AeDES is to certify the practicability of building struck by earthquakes, to define the measures to security the building.This chart is composed of 3 paper pages (A4 format) and it was always completed on paper (Asti-Alessandria 2000, Alessandria 2002, Molise 2002, Asti 2003, Desenzano 2004, L'Aquila 2009).Basically the first page identifies exactly the building, the second page reportsoccurred damages and the third page gives the risk situation and the needed assessment.

By using SRG2 for geographic positioning and avoiding to give assessment notices, a really simple geodatabaseis derived,which define the amount of houses suitable for being re-used.The derived inventory, when transmitted as EMS-98 database, offers a better shot of the post-seismicsituation on the ground.

4. CONCLUSIONS

Geodatabasesresearcheslead to the collection and evaluation of global and national literature on natural disaster. Local and regional studies of historical, geological, geomorphologicaldataon natural hazards have been conducted by Mobile-GIS and Remote Sensing applications on mountain territories of Europe and Developing Countries. Information on predisposing/triggering factors and evolutionary processes of natural instability phenomena (landslides, floods, storms, …)have been interpretedfor the analysis of statistical methods for the prediction of natural disasters.

Presented results concerns: large, climate-related disaster (Hurricane Mitch, Central America; Zambesi Flood, Mozambique), either for early warning or mitigation measures at the national and international scale; distribution on slope instabilities at the regional scale (Landslide Inventory in the Aosta Valley, NW-Italy), to activate prevention and recovering measures; geological and geomorphological controlling factors of seismicity, to provide microzonation maps and scenarios for co-seismic response of instable zones (Dronero, NW- Italian Alps); earthquake effects on ground and infrastructures, in order to register early assessment for awareness situations and for compile damage inventories (Asti-Alessandria seismi events, 2000, 2001, 2003).
The research results has been able to substantiate early warning models by structuring geodatabases on natural disasters, and to support humanitarian relief and disaster management activities by creating a mobile-GIS application for field-data collection on natural hazards and risks.The researches accomplished the aims to create a tightened collaboration between research centres (in this case: ITHACA, GeoSITLab, SUISS) and Humanitarian Agencies,as the general request of UN Agencies for a proactive response to natural hazards by changingthe way of approach to disater prevention and the emergency preparedness.

5. REFERENCES

A. Albanese, F. Disabato, O. Terzo, R. Vigna, Giardino M., L. Perotti (2008). A preliminary approach to flood risk mapping and flood forecasting system for the LCDs. *International Archives Of The Photogrammetry, Remote Sensing And Spatial Information Sciences*, vol. XXXVII, T. B4, Commission IV; p. 1537-1542, ISSN: 1682-1750.

Alexander, D.E., 1991. Information technology in real-time for monitoring and managing natural disasters.*Progress in Physical Geography*,15(3), pp. 238-260.

Antenucci, J., C., Brown, K., Croswell, P., L., and Kevany, M., 1991.*Geographic Information Systems: a guide to technology*. Van Nostrand Reinhold, New York, 301.

Arctur, D., Zeiler, M., 2004.*Designing Geodatabases: Case Studies In Gis Data Modeling*. ESRIpress, Redlands, California, 408 pp.

Brunsden, D., and Isben, M., L., 1996. The nature, use and problem of historical archives for the temporal occurrence of landslides, with specific reference to the south coast of Britain, Ventnor, Isle of Wight.*Geomorphology*, 15, pp. 241–258.

Clarke, S., Geenwald, C., and Spalding, V., 2002.*Using ArcPad*. ESRI, 296 pp.

Crespi, M., Giardino, M., Perotti, L., 2007. Recent Develpoments in Remote Sensing For Geological Risks in Mountainous Areas. In: Gomarasca A. (ed.), *EARSel Workshops in the Framework of the 27thEARSel Symposium,* Bolzano, Italy, 7-9 June 2007, pp. 205.

Dikau, R., Cavallin, A., and Jager, S., 1996. Databases and GIS for landslide research in Europe. *Geomorphology*, 15, pp. 227–239,

Embleton, C., 1988. Applied geomorphological mapping: Methodology by example. *ZeitschriftfürGeomorphologie, Supplementbände*, 68, 239 pp.

Giardino, M., Giordan, D., and Ambrogio, S., 2004. GIS technologies for data collection, management and visualization of large slope instabilities: two applications in the Western Italian Alps. *Natural Hazards and Earth System Sciences*, 4, pp. 197–211.

Glass, T.A., 2001. Understanding Public Response to Disasters. *Public Health reports*,116(2), pp. 69-73.

Gomarasca, M.A., 2009. *Basic of Geomatics*.Springer-Verlag New York, 697 pp.

Goudie, A., 2004.*Encyclopedia of Geomorphology*.Routledge, 1156 pp.

Grünthal, G. (ed.), 1998.*European Macroseismic Scale 1998*. Working Group Mascroseismic Scale, Cahiers du Centre Européen de Géodynamiqueet de Séismologie, 15, Luxembourg.

Gruppo di lavoro MS, 2008. *Indirizzi e criteri per la microzonazione sismica*. Conferenza delle Regioni e delle Province autonome - Dipartimento della protezione civile, Roma, Italy, 3 vol. and Dvd.

Haugerud, R., and Thoms, E., 1999. Geologic Data Assistant (GDA): An ArcPad Extension for Geologic Mapping. *U.S. Geological Survey Open-File Report*, pp. 06-450.

Idriss, I.,M., Seed, H.,B., 1968. Seismic response of horizontal soil layers. Journal of Soil Mech. and Found Eng., Proc. of ASCE, 94 (4), pp. 1003-1031.

Jagger, S., and Dikau, R., 1994.The temporal occurrence of landslidesin south Germany. The temporal occurrence and fore- casting of landslides in the European Community, edited by Casale, R. and FantecchiFlageollet, J. C., European Community – Programme EPOCH, Contract 90 0025, Final Report, 1, pp. 509–559.

Keefer, D.,K., 1984. Landslides caused by eartquakes. Geol. Soc. Amer. Bull., 95, pp. 406-421.

Luino, F., Cirio, C., G., Biddoccu, M., Agangi, A., Giulietto, W., Godone, F., and Nigrelli, G., 2009. Application of a model to the evaluation of flood damage.*Geoinformatica*, 13, pp. 339–353.

McCalpin, J.P., 1996. *Paleoseismology*. Academic Press, 588 pp.

Osuchowski, M., and Atkinson, R., 2008. Connecting diverse landslide inventories for improved information in Australia. *Proceedings of the 1st World Landslide Forum*, Tokyo, Japan, 18–21 November 2008, pp. 455-458.

Pain, C., Paron, P., and Smith, M., 2008. Applied geomorphological mapping (AppGeMa): a working group of the International Association of Geomorphologists. *GeophysicalResearchAbstracts*, Vol. 10, EGU2008-A-05888.

Perrone, G., Cadoppi, P., Giardino, M., Conte, R., 2008. La cartografia geologica finalizzata agli studi di microzonazione sismica in ambito alpino: gli esempi di Susa (To) e Dronero (Cn). *Rendiconti online della Società Geologica Italiana*, 3, pp. 633-634.

Perotti, L., 2002. Elaborazionedi immagini da satellite per lo studio geologico-ambientale del bacino del Rio Matanzas (Valle del Polochic – Guatemala), M.Sc. thesis,Universityof Torino, Italy, 173 pp.

Perucca, L., P., Moreiras, S., M., 2006. Liquefaction phenomena associated with historical earthquakes in San

Juan and Mendoza Provinces, Argentina. Quaternary international, 158, pp. 96-109.

Quarantelli, E.L. (ed.), 1998. *What is a Disaster? Perspectives on the Question*.Routledge, London, UK.

Ratto, S., and Bonetto, F., 2003. The October 2000 flood in Valle d'Aosta (Italy): event description and land planning measures for the risk mitigation. *JRBM*, 2, pp. 105–116,

Salvati, P., Balducci, V., Bianchi, C., Guzzetti, F., and Tonelli, G., 2009. A WebGIS for the Dissemination of Information on Historical Landslides and Floods in Umbria, Italy.*Geoinformatica*, 13, pp. 339–353

Schwarz, D., P., and Coppersmith, K., J., 1984. Fault behaviour and characteristic earthquakes: examples from the Wasatch and san Andreas faults. *Jour. Geophys. Res.*, 89, pp. 5681-98.

Trigila, A., Iadanza, C., Spizzichino, D., 2008. - IFFI Project (Italian Landslide Inventory) and Risk Assessment. *Proceedings of the 1st World Landslide Forum*, Tokyo, Japan, 18–21 November 2008, pp. 603-606.

UN/ISDR (United Nations / International Strategy for Disaster Reduction), 2004.*Living with Risk: A Global Review of Disaster Reduction Initiatives.* UN/ISDR, Geneva, Switzerland, Vol 1.

UN/ISDR (United Nations / International Strategy for Disaster Reduction), 2005.*Hyogo Framework for Action 2005-2015: Building the resilience of nations and communities to disasters (HFA).* UN/ISDR, Kobe, Hyogo, Japan.

UN/OCHA (United Nations / Office for the Coordination of Humanitarian Affairs), 2009.*Human Security in Theory and Practice.* UN/OCHA, New York, USA.

UNGIWG, 2007, STRATEGY for developing andimplementing a United Nations Spatial Data Infrastructure insupport of Humanitarian Response, Economic Development,Environmental Protection, Peace and Safety.

http://www.ungiwg.org/docs/unsdi/UNSDI_Strategy_Implementation_Paper.pdf (accessed 24 Dic. 09)

UNGIWG, 2007, UNSDI COMPENDIUM. A UNSDI Vision, Implementation Strategy and Reference Architecture.

http://www.ungiwg.org/docs/unsdi/UNSDI_Compendium_13_02_2007.pdf (accessed 24 Dic 09)

USAID (United States Agency for International Development), 2002.*Disaster Reduction: a Practitioner's Guide.* USAID, Washington, D.C., USA.

Verjee, F., 2005.The Application of Geomatics in Complex Humanitarian Emergencies, *The Journal of Humanitarian Assistance*, 27 pp.

vonLubitz, D.K.J.E., Beakley, J.E. and Patricelli, F., 2008. "All hazards approach" to disaster management: the role of information and knowledge management, Boyd's OODA Loop, and network-centricity.*Disasters*, 32(4), pp. 561−585.

Walsh, G., Reddy, J., and Armstrong, T., 2000. Geologic Mapping and Collection of Geologic Structure Data with a GPS Receiver and a Personal Digital Assistance (PDA) Computer. *U.S. Geological Survey Open-File Report*, pp 00-346.

WP/WLI – UNESCO Working Party on World Landslide Inventory – A suggested method for reporting a landslide, IAEG Bull., 41, 5–12, 1990.

WP/WLI – UNESCO Working Party on World Landslide Inventory: A suggested method for a landslide summary, IAEG Bull., 43, 101–110, 1991.

WP/WLI – UNESCO Working Party on World Landslide Inventory: A suggested method for describing the activity of a landslide, IAEG Bull., 47, 53–57, 1993.

WP/WLI – UNESCO Working Party on World Landslide Inventory: A suggested method for reporting landslides causes, IAEG Bull., 50, 71–74, 1994.

WP/WLI – UNESCO Working Party on World Landslide Inventory: A suggested method for describing the rate of movement of a landslide, IAEG Bull., 52, 75–78, 1995.