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LANDSLIDE RISK: RECENT DEVELOPMENTS FOR THE EMERGENCY MANAGEMENT

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ABSTRACT :
The recent advances in cloud computing have opened new opportunities in disastrous natural early warning and emergency management issues. In the last years, the scientific community has recognized the added value of a geo-analytic approach in complex decision, making processes for critical situations due to natural events such as landslides and earthquake. In this context, the main objective of the research Project CLARA - *CLoud plAtform and smart underground imaging for natural Risk Assessment* - is the acquisition of a local knowledge on issues related to hydro-geological instability and natural risk that may affect urban areas, through the development of smart technologies that allow widespread acquisition, management and sharing of complex information, such as direct observation by remote sensing and field technologies, databases relating to presence and level of hazard posed by hydro-geological phenomena and earthquakes, and vulnerability of the exposed resources.
In the research Project CLARA a procedure, implemented in a WebGIS system, has been developed to assess landslide and seismic risk. With this aim, data available by previous studies and those deduced by the studies carried out within the Project CLARA, have been organized in a database and geo-referenced.
A set of data and information will be available on the Web in the GIS platform, representing an important tool for the prevention and reduction of disastrous natural. In the paper, an early warning system implementation to assess the landslide hazard is described for the test site of Enna area in the south of Italy.

KEYWORDS :
WebGIS, risk assessment, emergency management, landslide, early warning system.

1. INTRODUCTION

The paper focuses on issues related to geotechnical aspects of disasters caused by landslides. Some countries and regions have already progressed in the development of procedures for managing urban and population growth, as well as, for minimizing the associated risks. These procedures are based on hazard and risk zoning which, however, can imply difficulties because of technical and socio-economic contributing factors.
Risk mitigation strategies are discussed, also considering the valuable contribution that can be furnished by the skilful use of new technologies and mathematical modeling. However, improvement of both remote sensing and data treatment techniques should not detract from field work and personal judgment since the current use of landslide inventories, which are the key input parameter for hazard assessment and validation, cannot be prepared in a reliable way with automatic data capture techniques exclusively. Uncertainties and errors in landslide zoning restrict the applicability of the hazard and risk maps for practical purposes and can generate conflicts. The validation of both procedures and maps is, therefore, a necessity especially in urban areas.
Landslide zoning, hazard maps and early warning systems are the approaches to reduce the risks, especially where the infrastructures are not enough to prevent the damage. The design of a complete early warning system, and implementing it, is highly complex and hard to test. Main problems causing this are the numbers of uncertainties about the triggering factors, geotechnical and mechanical parameters, as well as human reactions as emergency protocols and response of people.
Because of its lithological and structural features, Italy is a country in which the landslide risk is particularly

high. On the whole 6.8% of the territory is susceptible to landslide risk and the population concerned is almost 1 million, that is the 1,74% of the whole population. Italy has the highest number of dead and/or missing people among the European countries and it is the second in the ranking for landslide risk among the industrialized countries, after Japan.
In the field of scientific research, an evolution in the managing of problems related to risk management and risk assessment has occurred. At the beginning the idea of scientific knowledge as solely deriving from objective data to be adopted as a basis for decisions and reasonable actions has prevailed. As a consequence of considering risk assessment as perfectly logical, because produced by an examination of objective data, slow learning of low-risk behaviors by population or ineffective public policies are both considered as a side effect of subjective irrationality. Inadequacy in risk governance is not due to limitations of the scientific knowledge but result of failures in communication between researcher and population.
Based on these considerations, one of the main objectives of the research Project CLARA is to acquire a better knowledge of the territory regarding the risk assessment by developing widespread smart technologies which could facilitate managing and sharing complex information. These could be a database concerning the level of landslide (Figure 1a) and vulnerability of resources exposed in urban areas (Figure 1b and 1c), adopting the idea of open data. The contribution that the project can provide, is in terms of methodologies for investigation and monitoring, as well as, for the implementation of the results in the management of natural disasters.

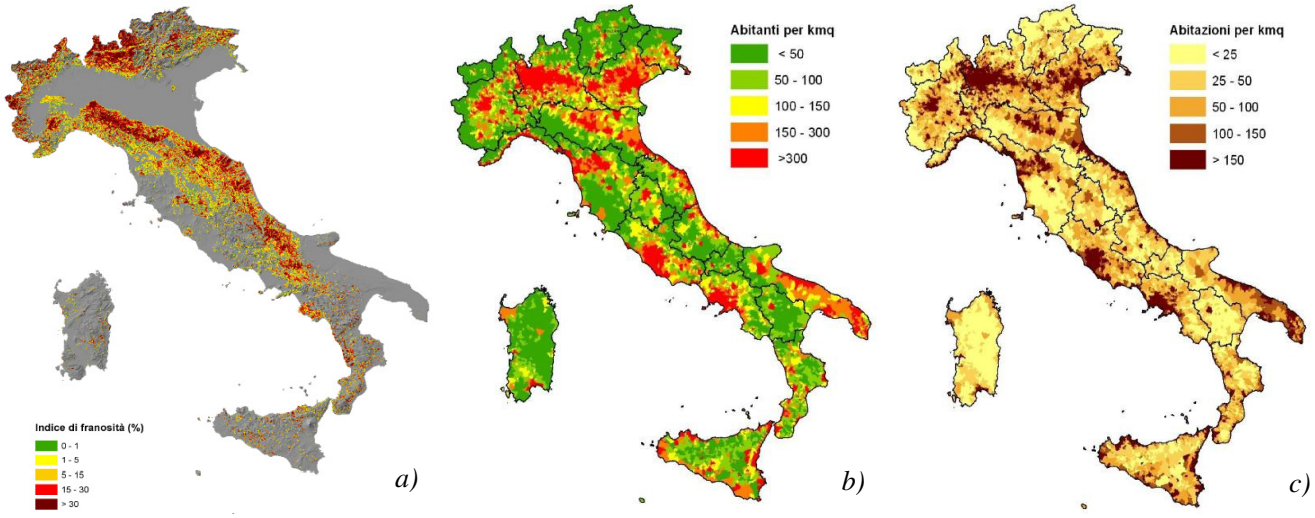


Figure 1 Map of Italy: a) Landslide distribution b) Inhabitants and c) Habitations (APAT, 2007)

With regard to analysis, assessment and mitigation of hydro-geological risk, as well as developing smart technologies in support of these activities, must be accompanied by a careful study of the human factors involved in these processes. The active and aware involvement of population in monitoring and taking care of the territory are necessary conditions in order to achieve any successful intervention. An accurate understanding of the reasons that produce harmful or risky attitudes is necessary to adopt virtuous behaviors. In particular, analyzing perception of hydro-geological hazard by population, the trust among citizens and information or interventions implemented by institutions appear to be the key-issue.
At the same time, participation of citizens in monitoring and taking care of territory brings out a fundamental issue: it is necessary to identify adequate criterions to evaluate trustworthiness of received reports and reliability of behaviors carried out by citizens facing an issue of hydro-geological hazard or emergency.
Institutions must infuse trust in the population by policies activated to prevent and mitigate hydro-geological emergencies. These considerations are not needed for an effective introduction of smart technologies aimed at granting safety in the area: technological systems, distributed for signaling, alerting and interventions, properly work only if citizens perceive them as reliable and useful and thus use them carefully.
In this context, the use of systems for the diagnostics of subsoil, quick damage assessment, and monitoring of urban areas and infrastructure, is a technological option with significant social and economic implications in terms of the protection of society, the reduction in operating costs during the normal lifecycle of the infrastructure and a better ability to manage emergency situations.

To grant the integration of these themes in the Project CLARA and in its applications, the program develop research activities on the themes of trust and risk perception, with particular reference to hydro-geological instability and seismic risk, following three integrated approaches: modeling, simulation and participation.
The operational objectives have been achieved through the experimental development and research activities in three test site of Enna, Ferrara and Matera (Figure 2), through the active involvement of the Department of Civil Protection. The experimental and research activities regard:

- technological systems of data acquisition and transmission through satellite (remote sensing, interferometry, Global Position System, etc..) and terrestrial (surveys) mapping methodologies for the monitoring of the spatio-temporal evolution of landslides and earthquake scenarios, aimed at monitoring high risk areas and populated areas; wireless networks for an "*early warning*" monitoring;
- innovative applications for 2D and 3D tomographic images of the subsurface in urban environment;
- systems for monitoring and damage assessment of critical infrastructure based on the integration of remote sensing technologies and non-invasive methods of structural engineering;
- geographical digital database (GIS) of observed landslides and earthquakes and of their temporal evolution through the technologies for data collection and processing for a continuous updating of information;
- information systems, based on Open Cloud platforms, containing information and tool to support territorial Institutions working on land protection, through the distribution of data relating to geomorphological conditions and vulnerability of populated areas, of strategic structures and of transport infrastructures;
- smart application implementing models of trust dynamics among all the subjects involved in the analysis, evaluation and mitigation of landslide and seismic risk (*modeling approach*);
- smart application implementing methodologies based on social simulations to study the dynamics of prevention and the interaction of the various subjects involved; this will allow not only the validation of the proposed theoretical models, but also the individuation of the technological and social tools that are mainly suitable to reduce the hydro-geological and seismic risk (*simulative approach*);
- smart application implementing techniques to investigate the risk representations and the trust dynamics of all the subjects involved in the safety for the territory (*participative approach*).

Matera	*Ferrara*	*Enna*

Figure 2 Test sites: Matera, Ferrara, Enna (Italy)

1.1. Objectives of the Research Project

CLARA is a highly multidisciplinary project that involves research activities in different applicative contexts ranging from hydro-geological and seismic risk to social-cognitive, to the context of microelectronics, telecommunications technologies, mathematical modeling, to automated reasoning and decision support systems. Throughout this wide variety of research topics, CLARA aims at overcoming the state of art in all the above mentioned contexts offering innovations and contaminations among different disciplines, till to the innovative applications in the fields of interest for the homeland security.
CLARA, within the field of "territorial security", aims to investigate a novel solution that leveraging the cloud platforms, is able to overcome the following limitations:

- early warning systems based on information contained in database exist, but harmonization of these systems is not yet realized;
- the available data by open sources (sensors, radar, satellite) are often rare, delayed and in a insufficient spatial resolution in order to enable fast and precise warning in urban areas;
- decision support system adapted to the specific need of stakeholders are often not realized due to high implementation and maintenance costs;

- the warning information often do not reach the end users in an appropriate way for effective response actions.

In consideration of these limitations, the research project proposes to realize new environmental warning systems by natural risks such as landslides and earthquakes in urban areas based on the following concepts:

- integration of existing simulation models;
- high density sensor networks in order to enhance the date sources for more precise predictions;
- decision support systems built out of existing information systems (GIS, simulations models) that can be adapted to specific need;
- *warning systems* specifically designed for exploiting the active involvement of people on the base of risk perception.

2. ANALYSIS OF MODELS FOR ASSESSMENT OF NATURAL HAZARDS IN URBAN AREAS

The concept of natural hazard is to be understood as the manifestation of the interference between the processes of instability that naturally occur in the territory, in relation to the vulnerability and the value of the assets exposed. The interaction between these natural phenomena and human activities is reciprocal: inappropriate methods of use and management of soil often provide an amplification of instability.
The prevention of natural hazard, therefore, is closely connected to territorial planning that taking into account the geological and geo-morphological conditions and the seismicity of the area.
The consequences of some recent earthquakes (L'Aquila, 2009; Port-au-Prince Haiti, 2011; Tohoku Japan, 2011; Emilia Romagna, 2012) and landslides/flood (Giampilieri (ME), 2009; Genoa, 2011; Barcellona Pozzo di Gotto (ME), 2011), however, show that this challenge is still very far from being won. In fact, despite the progress of scientific and technical knowledge, the victims and the damage caused by natural events in recent times have been substantially increased, partly as a result of the strong anthropic territory.
Different factors may contribute to the achievement of the common aim of human life safety: prevention activities through proper planning policies is certainly a priority. However, the interdisciplinary of the approach necessary to address the study and the qualifications of the technicians responsible for the management of the territory are not minor.
Urban tools, sector rules and usual procedures, often have not be able to assure environmental safety within the urban and territorial size in the Italian territory. Furthermore, the answer to the emergency following catastrophic events has shown a legislative and operative vulnerability. The overlay of urban and environmental tools has not assured safety in terms of prevention and mitigation of risk; actual control and monitoring tools are not able to interact in real time with population and local administrations devoted to control and decision. A standardized model for interaction with population of the territories interested by catastrophic phenomena has not been validated yet.

2.1. Hydrological Risk

For the safety of the territory it is of great importance the study of landslide events triggered by heavy rains, with short duration (Bonnard & Noverraz, 2001), located in areas of medium/large extension (Lentini et al., 2011; Maugeri & Motta, 2011). These events, which often evolve in debris flows and/or mud (Caine, 1980; Cascini et al., 2011; Cascini et al., 2010) require innovative instruments (Frattini et al., 2010; Glade et al., 2000) for the analysis, modeling (Tsai et al., 2008) and the mitigation of the effects.
Italy, and Sicily (Castelli & Lentini, 2011) in particular, are characterized by a complex morphology, a geologic order with a particular heterogenic hydro-geological conditions, that predispose to different kind of instability phenomena such as landslides, geo-hydrological disaster, coasts and soil surface erosion.
In the last century, although the scientific knowledge has been improved, the number of human losses and the economic damages due to landslide events triggered by intense rainfall are increased as a consequence of the strong urbanization of urban areas.
For the evaluation of hazard connected to these events it is necessary to take into account: **i**) the particular characteristics (Calvello et al., 2009) of limited extension areas in terms of the meteorological conditions, such as intense rainfalls in the area (critical rainfall threshold: hazard); **ii**) the vulnerability of the area to intense rainfalls; **iii**) the hazard of the different elements (strategic structures, road infrastructures, etc..).

Between the prevention activities for the reduction of the hazard there are the instruments for the territorial and urban planning (Flentje & Chowdhur, 2002).
Through the territorial planning the evaluation of the hazard (intense rainfall events in medium and small extension areas, vulnerability of the slopes to such events, elements to risk), the prevention and mitigation activities must be regulated in appropriate guidelines (Luzi & Pergalani, 1999).
The evaluation of the landslide hazard in local area is made of three prevention phases:

1. WHERE: forecast of areas susceptible to reactivation and/or new landslide movements. The susceptibility forecast includes: the individuation of the area in which the mass movement can be primed; the propagation of the soil movement after the mobilization of the material; the potential location of the mobilized material.
2. HOW: forecast of the intensity of the expected phenomena. This parameter can be expressed in terms of critical threshold for different scenarios.
3. WHEN: forecast of the return period of the rainfall event. This parameter must be expressed through the definition of rainfall thresholds (Felice & Versace, 1990) being the critical value closely connected to the intensity attended.

Often to evaluate these three phases, the scientific community adopts different methodological approaches for each case. The result is that the Public Administration have not an univocal reference for territorial and emergency planning. This has involved that the accuracy and the affability of the territorial planning on which the policies of management of the territory are based, are different from the area realistic conditions. Another problem is related to the time and the intensity distribution of the precipitations (Sirangelo & Braca, 2004), especially in the Mediterranean regions, in consequence of the climatic changes.
This involves in a variation of the type and the frequency of the soil movements expected that must be take into account in the approaches for the hazard estimation. Starting from the state of the art and according to the necessity to assess the hazard related to fast and slow phenomena evolution, an innovative methodology applicable to the different territorial scenarios, will be developed (Figure 3).

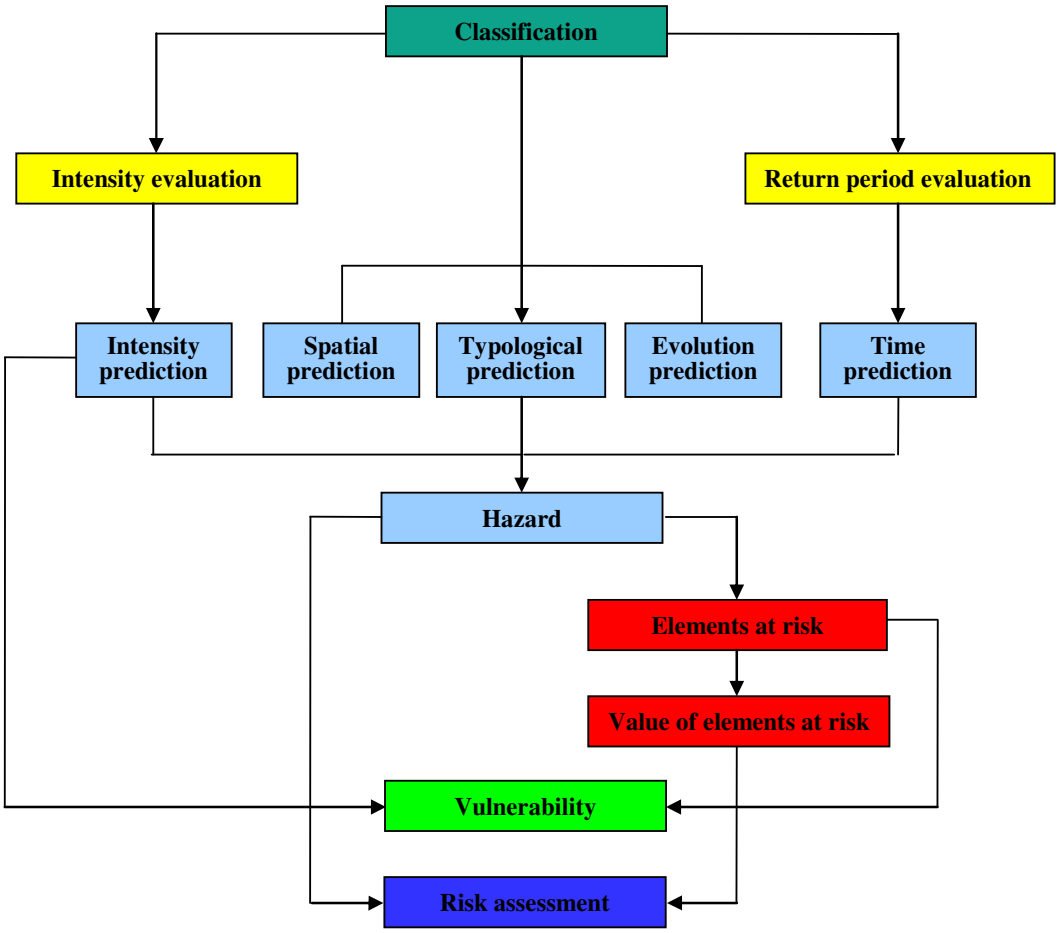


Figure 3 Flow chart of risk assessment

The zonation of the landslide risk is necessary for the management of the natural disasters and for the planning of the prevention activities, mainly for the increased awareness that the landslide events have a remarkable social and economic impact. The available qualitative models (Cascini & Versace, 1988; Glade et al., 2000) estimate when the movement begins only according to the knowledge of soil movements occurred in the past therefore are often useful only for local preview (Crosta, 1998).
To make objective analyses (Chowdhury & Flentje, 2002) it is necessary to employ determinist methods that allow to consider that, every time that the soil movement begins, change of the topographical, geo-mechanical and hydro-geological conditions of the slope occur (D'Amato Avanzi et al., 2004) and a new instability configuration is produced, different from that beginning. The analysis of the time distribution data of the trigger factors (Corominas & Moya, 1999) can be very useful to determine the return period of the landslides in an area. For example, if we consider the landslides triggered by rainfall, it is possible to establish the threshold values (Aleotti, 2004) for which the soil movement begins according to the rainfall data and the landslides occurred in the past, relating to geological and topographical conditions.
Moreover, the type of the soil movement play an important role on the forecast evaluation both of the event intensity and vulnerability of the area. Different type of landslides are characterized by some trigger and propagation factors of the soil movement, and therefore the models used for the prevision must be different relating time or space provision (Campus et al., 2001).
In the field of space analysis of landslide hazard a very important contribution can be given by the employment of the interferometric radars technologies (Cascini et al., 2009; 2010) like instrument for the remote monitoring, by the development of the calculation abilities and by the possibility to use software GIS (Caruso et al., 2008).
Also the prevision of the landslide intensity has a great importance in the risk assessment. The damages caused by a landslide are a function of the velocity, the mass, the characteristics of the soil movement, of the water content, the inclination of slope along which the soil mass moves. The prevision of landslide propagation (Pirulli, 2010) is another important aspect in determining of hazard, because it concurs to individuate the areas in which landslides can occur.

2.2. Earthquake - Induced Landslides

Moderate and strong earthquakes trigger landslides, and these landslides commonly account for a significant portion of total earthquake damage and injuries. Thus, formulating scenarios where earthquake-induced landslides are likely to occur can help local authorities plan emergency response and mitigate landslide risk. We are developing a method to quantify the effects of landslides triggered by earthquakes using both deterministic and probabilistic seismic-hazard scenarios. Seismic shaking and the resulting slope performance are integrated in a capacity-demand analysis that estimates the probability that a specified threshold slope performance will be exceeded. Then, an expected damage distribution is estimated for a set of exposed elements, given the response to the landslide effects (i.e. fragility functions). Finally, the expected losses are estimated by relating the damage distribution to a real-estate inventory.
Data from historical world-wide earthquakes were studied to determine the characteristics, geologic environments, and hazards of landslides caused by seismic events. Threshold magnitudes, minimum shaking intensities, and relations between magnitude and distance from epicenter or fault rupture were used to define relative levels of shaking that trigger landslides in susceptible materials.
In a country with high seismic risk (Figure 4) as Italy, with an urban area characterized by high levels of seismic vulnerability, the implementation of the results of the research project, in terms of seismic zonation, monitoring local networks and security systems, may allow the promotion of appropriate policies for the prevention and mitigation of the earthquakes effects.
However, for the reduction of seismic risk, the development of innovative experimental activities that enable the advancement of knowledge in the field of seismic geotechnical hazard assessment of sites and of the vulnerability of infrastructure and civil and industrial facilities is necessary. Geological and geotechnical aspects related to seismic protection are particularly topical in Italy also in relation to the effects caused by the recent earthquakes in the city of L'Aquila and in the Emilia region.
In the past, the study of these problems was often limited to the geotechnical characterization of the sites and to the analysis of phenomena such as, subsidence or local seismic amplification, not reaching concrete suggestions about the possibility to realize soil remediation to ensure the structures preservation. In contrast, the structural remediation are often separated from the geotechnical characterization of the sites, the geotechnical modeling of the soil foundation and the actions for the improvement of the foundations.

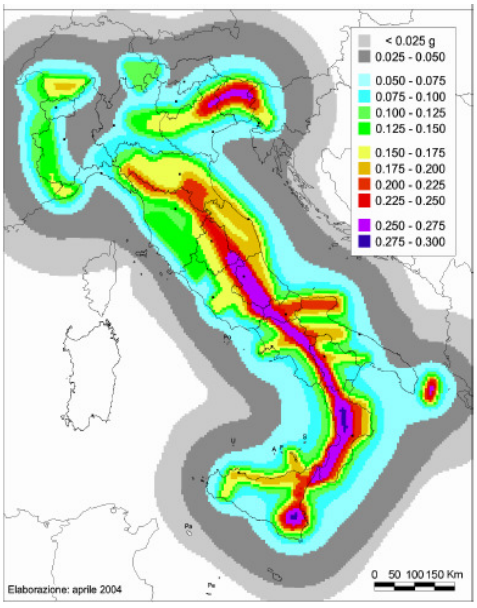


Figure 4 Seismic map of Italy

To overcome the limits of these approaches, the research activity will aim to study the analysis of the phenomena regarding the soil in order to evaluate the influence that they exert on the seismic vulnerability of buildings and systems to secure the achievement of seismic improvement.
These goals can be achieved through an innovative experimentation in the field of evaluation of soil, structures and infrastructure behavior subjected to seismic loads.
Therefore, the establishment of a monitoring network of seismic action for the acquisition of site data and the comparison with seismic amplification factors required by national and international regulations and the procedures for the analysis of the seismic response in the case of difficult soil condition is expected.
For more realistic assessment of the seismic hazard of a test site, it is necessary in addition to geological surveys, to take into account the historical and instrumental seismicity (Figure 5) of the area around the test site in order to better constrain the degree of regional seismicity.
The aim of research activity is to realize a platform open cloud, based on the implementation of smart systems for monitoring characteristics of the environment to allow the construction of seismic damage scenarios, the verification of the structural resistance of strategic buildings and the assessment of seismic vulnerability of the urban area, the verification of the practicability of the road system. The project combines the use of advanced technologies by public administrations, people and enterprises for the processes of emergency management.

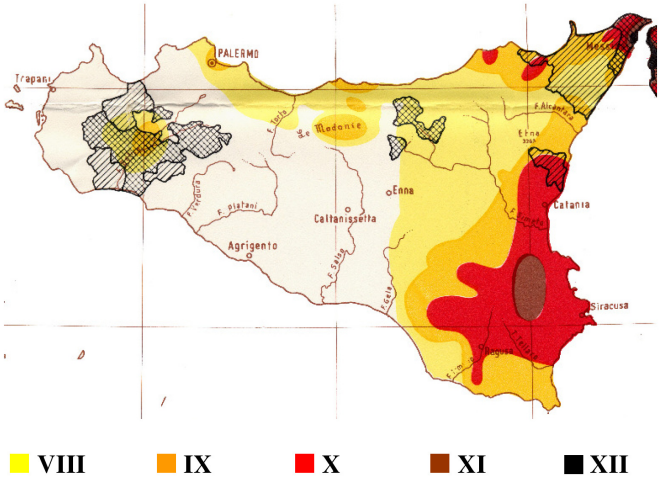


Figure 5 Historical seismicity of Sicily

3. RISK PERCEPTION AND ACTIVE PARTICIPATION IN MONITORING AND PREVENTING OF NATURAL HAZARDS

The main aim of the study is to develop socio-cognitive models and support tools to these models on theme of safety of territory. Models and simulations of trust schemes characteristic of risk prevention and emergency alert have been developed. The trust attitudes are essential to ensure efficacy and efficiency of prevention, alert, and intervention in the face of catastrophes.
The aim is to individuate what factors are favorable and unfavorable for the prevention both at the individual-cognitive level and in terms of social and collective dynamics.
Trust models concerning alert and intervention have to take into account many risk factors, with different activation thresholds, and various typologies of reaction for all the stakeholders. This requires not only the trust of citizens towards institutions (that is, their trust in the structure of prevention) but also the trust of institutions in citizens (as sources of information and as responsible agents in preventing and reacting to catastrophes).
Then study has been focused on how people perceive disasters and risks using tools, specifically built and pre-tested, or taken from the literature, to measure self efficacy, control and trust.
The information collected are put in relation with psychosocial characteristics of the population: this allows to identify socio-demographic profiles of people who perceive and represent disasters -and related risk- in different ways. From the results of the study, will be defined the specifications of the instruments to support interventions such as: promotion of bi-directional communication among decision-makers, technicians, volunteers and population to improve mutual trust; involving of the citizens in training on prevention, environment monitoring and intervention.
Over the last two decades, the most significant contributions to trust models for socio-technical systems have come from logical and formal approaches (Demolombe, 2001; Jones and Firozabadi, 2001; Josang, 2002; Liau, 2003), computational approaches (Zacharia and Maes, 2000; Yu and Singh, 2003; Huynh et al., 2006), and socio-cognitive approaches (Falcone et. al, 2003).
These three lines of research often overlap, but differ sharply for their aims. Logical approaches use mathematical logic to describe, analyze and implement trust relationships. Computational approaches use a trust model in an automatic system, independently for the representative structure.
Finally, socio-cognitive approaches consider trust as a mental attitude, strongly dependent on the social context.
In the research project formal and computational models of the individual and collective behavioral dynamics of stakeholders exposed to hydro-geological and seismic risk have been developed.
An effective management of trust attitudes in the context of natural catastrophes is complicated by a variety of factors: the number, diversity and complexity of relevant actors (individual and collective, public and private, natural and artificial), the actions and interactions that each of them is able to implement, often without any coordination. A comprehensive analysis of all these factors, as well as their interactions, allows to define and elaborate prevention rules with a high level of effectiveness and their adoption, tailoring them to various contexts and risk typologies.
For prevention, a central role is played both by the context in which the alert is produced that by the know-how previously accumulated through assimilation of the relevant prevention rules and their perceived trustworthiness.
In the intervention phase, there is need for an active participation of multiple subjects to a concerted effort, under high levels of stress: thus it is essential to model trust factors focused on interaction and cooperation between subjects. For all these reasons, success of intervention strategies during a natural catastrophe relies heavily on distributed delegation actions towards actors capable of guaranteeing full trustworthiness, based on their well-tested and widely acknowledged expertise. This is a trust capital that needs to be created before an intervention, but that demonstrates its value during such a crisis, in which the perceived competence of the relevant actors can of course further increase, in case of success.
The emergency management presents many criticalities due to various factors, like the human factor (reaction of panic, high number of victims, possible obstacles to the rescues), the environmental characteristics (presence of escape ways, extreme weather conditions, easy way or not to reach the interested area) and the coordination of the intervention itself (different agencies may use different procedures or may even evaluate the same situation in different ways, thus disagreeing on the kind of intervention).
Moreover, the way in which the emergence is managed can bring further difficulties: usually the interventions are coordinated at the top level, are based on strict procedures and not always consistent with one another, especially if the actors in the field are heterogeneous.

The research aims to create a simulation model of the critical situation, in which the actors involved are represented (citizens, rescuers, institutional subjects), giving attention to cognitive aspects, that is to the way actors make decisions, find out criticalities, communicate and coordinate with other relevant actors and with the environment.
Such model has been then implemented in a software tool, that is a simulation platform, through which it is possible to understand the dynamics of the interaction among the environment and the involved actors, comparing different strategies of emergency management and performing analyses aiming at finding out strong points and criticalities in the management, starting from the reference context. The results will be then used to give indications to the intervention agencies, but also to contribute to the creation of informative material for the population to be used in case of emergency.

4. OPEN SOURCE CLOUD COMPUTING SYSTEMS FOR ASSISTING LOCAL AUTHORITIES IN DEFENSE OF TERRITORY, ALERT AND EMERGENCY MANAGEMENT

Among the objectives of the study are those related to the development of early warning systems able to enable civil protection actions (evacuations, road closures, etc.), to be taken in critical situations, and to develop prevention and control systems that allow to provide indications of areas susceptible to landslide risk.
To achieve these goals has been realized an information system based on an *Open Source Cloud Computing* platform following a *PaaS* (Platform as a Service) and *SaaS* (Software as a Service) approaches.
The *SaaS* services are devoted to the evaluation of landslide risk and to the active participation in monitoring and preventing hydro-geological risk, by the modeling and simulation of social dynamics in the prevention and management of emergencies.
In particular, to assessment the landslide risk it is necessary to verify the evolution of a landslide, to identify potential correlation between piezometric levels, to monitor rainfall and landslide displacements levels, to check landslide displacements levels after an intense or prolonged rainfall, to provide indications of potential landslide risk areas.
This requires knowledge of landslides classification, evaluation of landslides intensity and return period, prediction of time-evolving phenomena, evaluation of landslides hazard and vulnerability level in urban areas.
The *Paas* Service consists in implementing a GIS platform which allows the adoption of analysis techniques that could not be otherwise introduced, thanks to the ability to perform calculations on a large number of parameters and to the possibility of overlapping and cross-referencing spatial data. This task aims to expand the potential of traditional GIS, creating an horizontal platform that allows the simultaneous management of both data from consolidated databases, and data from the monitoring network. The information stored in the GIS will be exposed through open services.
The simulation models for the study of scenarios of interactions, both during risk prevention and management of emergencies, are translated into complex software components, due to factors inherent in the complexity of the models and the dynamics of interaction among various parameters involved.
In particular, the study is devoted to:

- analysis of predictive models of natural hazards, process characterization and identification of the entities;
- involved analysis of risk scenarios;
- for each risk scenario identification of patterns, elements that characterize it;
- design and implementation of a test-bed based on the model simulation.

5. DEVELOPMENT OF SMART APPLICATIONS FOR RISK GOVERNANCE SOCIAL MODELS

Systems integration, connectivity and interoperability among data sources play a key role during the early stage of disaster recognition and response.
The main objective of this part of the study is to investigate the individual and collective cognition during emergency and disaster management, with the aim to handle rescue operations, related with urban critical infrastructure, in order to characterize the dynamic and the interaction of all subjects involved in the emergency.
A desktop application for Local Authorities has been implemented, through which the institutional operators will be able to:

- manage the classification, evaluation, prediction, hazard and vulnerability estimation, risk assessment processes;
- manage the tools for modeling, simulation and participation of the Smart Community;
- access to monitoring and forecast information, access to GIS maps, simulate natural and social scenarios;
- access to specific decision support functionalities, which will allow for effective and efficient management of communications during the alert and emergency phases.

Informative applications based on real time risk maps, which will form a set of advanced systems to support citizens and technicians in alert and emergency scenarios, for risk prevention and emergencies management have been developed. The application consists of an advanced system which combines weather forecasts with the probable impacts on the territory, providing a forecast of the risk of occurrence of phenomena (landslide, flooding, etc..) and providing warnings and advices on roads practicability and on staying in specific areas.
Participative applications which allow the citizen to interact with the community, promoting bidirectional communication between technicians, decision makers, volunteers and the people, through social network have been implemented.
A model of main urban interconnected infrastructures (water, wastewater and gas networks), making more reliable the integration, connectivity and interoperability of data sources, from which information about such infrastructures are gathered has been designed.
The surveying and mapping of technological networks (telecommunications, transportation, energy, and water supply, networked systems) is a complex process that involves several expertise and technologies in order to develop, and effectively utilize and maintain database.
Different domain experts work in order to build a realistic representation of territory and in this process the quality of data plays a key role in order to ensure the expected results. Surveying and mapping task is carried on firstly by collecting information about technological networked systems. This task is mainly provided by field crews finding subsurface networks, figuring out the main characteristics of these networks, then hand-filling some datasheets.
The second main step is made up by the geo-referencing task. During this phase each node of the networked system is geo-referenced by using GPS or ground base instrumentations.
The final step is made up by the development of the Geographical Information System (GIS), representing the company's assets, in which all the relevant information are linked together in a location based platform.

5.1. Participative Applications for People - Institutions Interaction

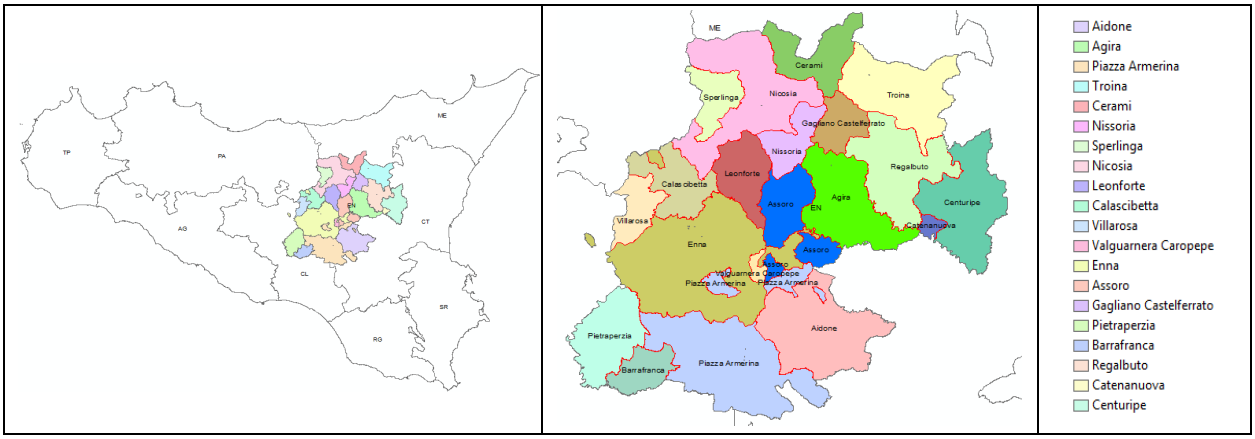
Many of deaths and injuries associated with debris flows are related to transportation infrastructures. Roads are the basic part of the urban texture supporting social and economic activities and represent the most critical infrastructures for disaster management. In addition the transportation system is strongly linked with other kind of technological networks as for examples: water supply, urban drainage, gas supply, telecommunication infrastructure, and electrical power system.
The complexity of this system is that different subjects often manage each of these infrastructures, even if they serve the same urban area and each of these infrastructures has its own measures to react to disasters.
Moreover, each organization has its own way to organize information, leveraging on geographical information system, supervisory control and acquisition system, simulation models and decision support system.
It is necessary to access directly to all the information stored and elaborated by such systems by using wireless connected devices. But if the recipient does not belong to the organization that own the data (the potentially threatened people) a serious problem of interoperability occurs.
In order to reduce the impact of natural hazards on urbanized areas, resident people need to identify, assess and control various factors that contribute to harm the affected area. As it has been described above these factors depend on a large set of heterogeneous information, which is often owned by different bodies, and which ranges from sensor data, demographic data, land use data, available transportation etc..
All this information needs to be integrated to allow seamless use and then they need to be processed and reliably and quickly communicated.
The main goal of the integration process is to develop a conceptual model that supports an interdisciplinary approach for the disaster management. First responders, experts from different disciplines, and people involved in the disaster require access to the same data, but for different purposes.

An innovative component for the processing of data acquired by multi-sensor platform, already available on different vulnerable regions and useful for the characterization of the areas interested by hydro-geological instability, for the optimization of the processing and the restitution times of final products will be integrated. The objective to pursue is as support to the prevention, monitoring and emergencies management activities.
The analysis of the data acquired by the multi-sensor platform allows to realize detailed studies and to extract detailed soil information, useful for the implementation of numerical simulation models regarding disastrous events.
The final purpose is to make available to the Entities, such as the Civil Protection, data describing in detail the land characteristics, to be usable and of support:

- in the prevision and prevention phases, so as to guarantee a proper land planning;
- in the emergency management phase, during and post event, in order to ensure a prompt reply of the institutions.

6. LIVING LABS TO TEST RESULTS IN THE PUBLIC ADMINISTRATION

The experimentation of the activities developed within the project will be carried out in the municipality of Ferrara, Matera and in the Province of Enna (Figure 6). In these areas there are historic centers with inestimable value, with a huge cultural tradition and great touristic importance.
These areas are located in geographical, geological and geomorphological environment that make them particularly vulnerable to natural hazards (earthquakes, landslides, floods) and that require a greater and more accurate knowledge of the issues related to these types of instability.
The main objective of the study is to promote sensibilization actions in the Public Administrations (PA) on the hydrogeological risk conditions as well as on mitigation measures and to contribute to the hazard analysis in the urban areas and to transfer to the Public Administrations the "*best practices*" for risk assessment, to contribute to the planning activities, prevention and mitigation of the effects related to natural disasters.
This last goal, in particular, want to contribute to the achievement of specific tools for sustainable urban planning policies in relation to landslide events.
The realization of a laboratory to accommodate a physical model of the evolution of landslides is also provided. Given the complexity of these events, this laboratory is believed to be of great interest to Public Administrations, for the purpose of the definition in the laboratory of the characteristics that networks sensors and simulation models must possess in order to effectively monitor the evolution of the phenomena studied.
Landslides are phenomena that often develop and evolve over ten years in which rapid movements are interspersed with long periods of latency.
This makes very difficult to collect a sufficient number of measurements for the design of an effective monitoring network and for the calibration of the models. A physical model of the landslide will solve this limit, allowing the production of sufficient number of significant measures.



(a) (b) (c)

Figure 6 Map of Sicily (a); the Province of Enna (b); Municipalities of the Province of Enna (c)

6.1. Test Site: Municipality of Enna

In recent years, most disasters occurred highlighted the ineffectiveness and weakness of prevention policies, leading to the need for new approaches to the problem. Approaches that must be able to deal in an integrated manner all aspects related to the topic and that call directly into question the "governance" of the territory.
City planning instruments have often proved ineffective to ensure environmental security in urban and territorial scale. The overlap of existing planning and environmental instruments often not ensured the security in terms of prevention and mitigation or monitoring with risk prediction logic.
The control and monitoring instruments are not suitable to interact in "real time" with people, operators and local authorities. It is evident the need for a coordination between competent technical authorities to the government of the territory, and specifically the Regional and Municipal Authorities and Basin Authorities, that supervise the planning acts within the guidelines of the various national and regional laws.
The main objective of the project is to acquire a greater knowledge on the instability issues affecting towns, by developing smart technology allowing the management and sharing of complex information, such as data bases relating to the existence and consistency in levels of natural phenomena hazard and vulnerability of resources exposed in urban areas.
The testing activities will take place in Sicily, with particular reference to the municipality of Enna (Figura 7), in collaboration with the Regional Department of Civil Protection and the Regional Province of Enna.
Due to its nature, and the complex morphological, geological and tectonic conditions as well as the particularly dishomogeneous and complicated hydro-geological aspects, the Sicily region is characterized by different types of instabilities such as landslides, floods, earthquakes, coastal instability and soil erosion.
Because of the shape of the area, the progressive abandonment of mountainous areas, the lack maintenance of the slopes and hydraulic structures, the presence of settlements in areas pertaining to rivers or in instability condition, the frequent inadequacy of infrastructure projects, events related to the hydro-geological risk together earthquakes are the ones that cause most damage.
Monitoring is an indispensable step for the understanding of the phenomenon and the evaluation on the slope safety conditions and the measurement of the factors affecting stability is a necessary support to technical decisions. An efficient monitoring system must allow to define the volumes involved, the soil movements and their spacial and time evolution, the dependence of these movements by the weather and hydraulic conditions and, finally, the influence of external factors not directly correlated to the landslide, such as earthquakes.
To develop predictive models for decision support it is possible to use laboratory experiments using small/medium/large scale physical modeling. The analysis of the experimental results can provide useful information on the mechanisms that must be considered in the implementation of the theoretical and numerical models able to reproduce the propagation of the phenomenon.
Therefore physical models allow to optimize the construction of the monitoring system, the choice of properties to be monitored in relation to the stratigraphic, geomorphological (Figure 8a) and hydro-geological conditions (Figure 8b), the number and location of tools to install, check of alarm systems based on the acquisition and interpretation of the physical properties predicting failure phenomenon.

Figure 7 Municipality of Enna (South Italy)

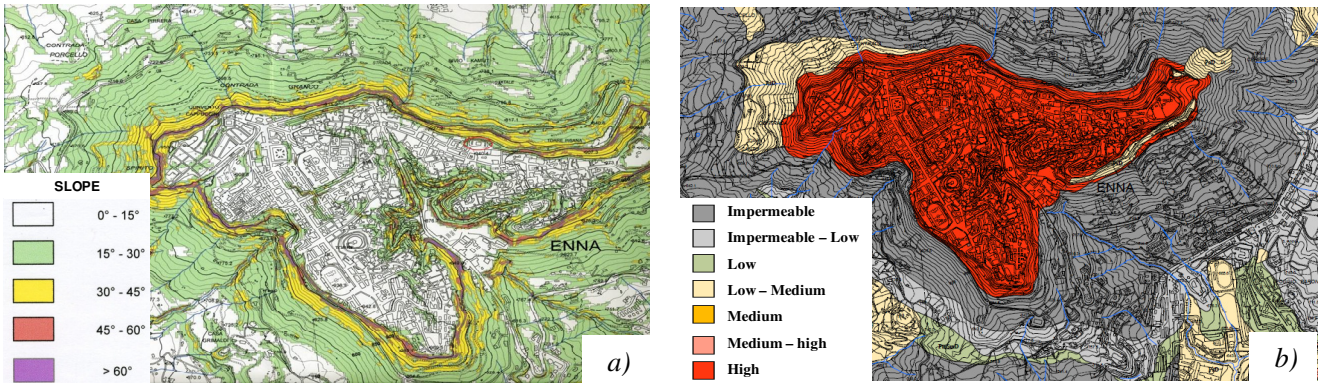


Figure 8 Slope a) and hydro-geological map b) of the Enna Municipality (South Italy)

7. CONCLUDING REMARKS

In the paper an approach to early warning system implementation is described. This description is tried to be proven by an implementation of a modeling and monitoring system on a real case. The case study is the Enna area in the south of Italy. The paper focuses on issues related to geotechnical aspects of disasters caused by landslides. The study is a part of a larger context that is the Project CLARA - *CLoud plAtform and smart underground imaging for natural Risk Assessment*, which aims to design and to develop an innovative procedure, based on the implementation of smart systems on cloud platforms, for monitoring sensitive elements of the territory.

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