DATA SURVEY AND MANAGEMENT TECHNIQUES IN CIVIL PROTECTION EMERGENCIES

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ABSTRACT:

Calamitous events cause modifications in soil morphology and damages in infrastructures. The knowledge of these modifications can be very useful for the Civil Protection operations. However, survey operations, even if they are supported by the most modern geomatic technologies, are still very difficult, if they are not impossible, because of the adverse operative conditions, like for examples: difficulties for moving in zones subjected to thunderstorms, or short sight conditions determined by volcanic eruptions. Not all of the usual surveying techniques, in these conditions, can be successfully applied. Therefore it is important to arrange instruments and methodologies for surveys, studied and tested for different scenarios, to front timely and effectually the need of the case. Among the most technologically advanced approaches, it is very important to quote *laser scanning*, very effective and quick to evaluate the damages suffered from operas and infrastructures (buildings, bridges, road embankments, ..), and *multispectral images' analysis*, useful for the research of dispersed polluting substances owing to the spill of transported hazmat or for the environmental analysis related to the occur of fires or volcanic eruptions. The contribution of the techniques of aerial and terrestrial *photogrammetry*, for the definition of the new morphology caused by remarkable hydro-geological damages, is always valid. Besides, it is important to avoid neglecting the new potentialities of the modern robotic topographical instruments, very useful for the traditional approaches for the soils and buildings, and of *satellite positioning*, that, especially in RTK modality, can find an application for the positioning of helps and even to individuate a perimeter for the interested areas (for example, landslides and flooded surfaces). In this paper it is proposed a wide overview of scenarios and thr consequently necessity of surveying that can be determined after calamitous events, with a particular attention to the effects induced by seismic events and hydro-geological damages, forest fires and volcanic eruptions; case by case, it is suggested, on the basis of precedent experiences achieved in this field, the most suitable techniques of surveying and of data management.

1. RISK EVALUATION METHODOLOGY

In the operations of civil protection, in particular for the preventive evaluations of potential damage scenarios, it is usual procedure referring not only to deterministic approaches, because of the ineluctable uncertainty of inquired phenomenon and of the produced effects.

The risk evaluation is carried out using an international standard methodology, based on different unrelated steps, finalised to put in evidence various territorial aspects and human activities that could be involved in the determination of risk conditions. Using this methodology (which is briefly reported below), a lot of experiences on territorial planning for risk reduction have been realized in Italy and abroad.

The first step consists in the **hazard evaluation**, or rather in the "prevision" of localisation, magnitude and consequential natural effects of the calamitous event.

The further step, or rather the **exposure analysis** (applied to territorial context characterized by a verified hazard) consists in the individuation of the most susceptible areas to damage by calamitous events, based on the presence and distribution of anthropic elements (population, buildings, infrastructural systems, etc.). In general, the elements exposed to risk are usually classified in four categories: population, buildings, infrastructures, goods.

The total exposition of a territorial system could be expressed not only by the quantity of the damageable elements, but also considering the functions of the subsystems that the calamitous event could make ineffective because of direct or indirect damage to people or buildings. The total level of exposure tends to increase not only in function of the number of the risky elements but even by the complexity and hierarchical importance of the functions which a particular system acts in the territory.

Another important step, for the risk analysis, is the **vulnerability evaluation** that consists in the estimation of the propensity of people, goods or activities to be damaged or modified by calamitous events. In other words, vulnerability is an indicator that measures, on the one hand, the loss of efficiency of the territorial system and, on the other hand, the residual ability to act the typical functions of the system.

The conclusive phase of the process, that could take place by different aggregation and/or confrontation techniques, leads to the evaluation of the total risk, meant as a loose of functional capability of a system (or part of a system) caused by suffered damages.

2. GEOGRAPHICAL INFORMATION SYSTEM AS A SUPPORT FOR CIVIL PROTECTION INTERVENTIONS

Geographical Information System (GIS) represents an optimal complement for all the activities and the surveying techniques related to emergencies (natural and not natural) managed by Civil Protection. So, it looks useful to describe firstly a quick examination about potentiality that today are available by

modern GIS and, in a second step, a more detailed investigation about different type of risk.
During the elaboration of prediction and prevention studies finalized to Civil Protection, in fact, it is preliminarily necessary to evaluate the strategic function and the vulnerability of the territorial infrastructures system (road network, health centre, barracks, etc…) useful to support Civil Protection activities.
In particular, it is possible to develop the study concerning then next themes:

1. the infrastructural system analysis, with a specific reference to its functionality in emergency condition (helps coordination and management, injured people assistance, escape path);
2. the individuation and characterisation of the "essential" infrastructure in relation to hypothesized risk scenarios (prefecture and coordination helps centres, hospitals, lifelines, etc.);
3. the census and survey of structures and civil construction that if damaged could compromise the functionality of Civil Protection support apparatus;
4. the individuation and localisation of the critical elements of infrastructural patrimony and the elaboration of intervention proposals for the mitigation of expected damage caused by the loss of system efficiency (structural retrofitting interventions on bridges, viaduct, etc., and emergency mobility plans, etc.).

The wideness of the studied area and the involvement of numerous territorial problems determine the necessity of using GIS (Geographical Information System) not only for the great amount of data storage and management but above all as a useful instrument for studied phenomenon analysis.
Having a complete and exhaustive geographic data-bank finalised to Civil Protection interventions is very important to predispose every activities of planning and surveying.
Indeed, the knowledge of natural resources available in emergency condition (related to the localisation, the typology and the importance of the calamitous events) consents to individuate, thanks to decisional support algorithm, not only the best helps supply centres, but even the most opportune methodologies for damages surveying. In this sense, another strategic advantage is the possibility to supervise the emergency teams in a coordinated and integrated way since the preliminary alert step to the operative phase of damage surveying and management step. The modern techniques of Real Time GIS represent a great potentiality for the optimised management both for surveying and first aid operation.
In the last years, the European Community has manifested great attention to the problems of Civil Protection, pointing out that National Organizations, that have to improve their efficiency, have not been fully benefiting by the opportunities of new technologies since these last were offered. For these reasons, some trans-national project (such as FORMIDABLE and EGERIS) have been financed. Both the experiences, already concluded, have created more efficient organizational structures and have found the instruments necessary for the intervention teams and for the implementation of the methods for territorial data acquisition.
In particular the relations and communication modalities among central coordination of activities and local and mobile operative units have been improved.
Moreover, a specific hardware architecture, composed by a hand-held PC with a GPS receiver and GPRS terminal has been selected.

Considering the high variety of risk typologies and the great differences about the information to manage and to elaborate, every GIS application have to be considered as a "specialized" independent work environment related to a particular scenario. Because of the difference of data and models required to analyse and to manage every risk type, it is necessary to predispose many **specialized GIS application**, based on high informative detail and accuracy and great cartographic scale. Everyone of these specialized GIS have to be co-ordinate with the Central Civil Protection GIS, characterized by a common geographic databank based on less greater cartographic scale and containing general information useful during emergencies, such as territorial resources location, population spatial distribution, etc. Both central and specialized GIS have to be intended as two different co-ordinated components aimed to evaluate and, eventually, to manage territorial risks. So, the entire system have to be planned using advanced one-to-many relationship on different geographic databank and cartography.
GIS has to be intended not only as a *decision support system*, but they reach the best expression if interpreted as a dynamic working environment where it is possible to elaborate, also in *real time*, new information from available data and to simulate complicated phenomenon using mathematical models, using vector or GRID basis.

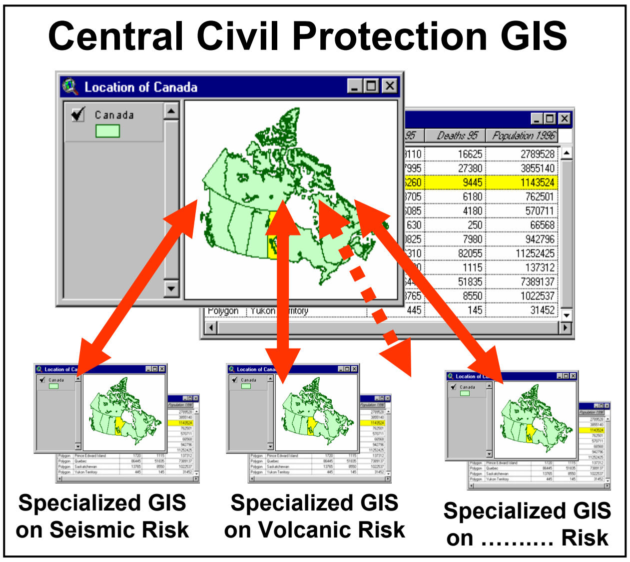

Figure 1. Specialized GIS on different risk type related to Central Civil Protection GIS

3. HAZARD SCENARIOS AND GEOMATIC ROLE AS A SUPPORT IN CIVIL PROTECTION INTERVENTIONS

Further on, there is a synthetic description of the most important aspects related to different hazard scenarios and of the geomatic contribution for the knowledge and the management of these.

3.1 Seismic risk

Seismic risk evaluation is generally articulated in three steps:

1. Seismic hazard study finalised to the definition of scenario and to the adoption of the most probable attenuation model related to the historic seismology and the geologic and tectonic features of the territory;
2. Analysis of the indirect exposure related to the distribution of population and of territorial

infrastructures that have to be granted as accessible after an earthquake.

3. Structural vulnerability of human infrastructure evaluation correlated to the features (physical, mechanical, technologic aspects, etc.) of the different components.

Usually, the most part of the attention has been addressed to buildings because of the population inside. In the last twenty years it has been turned to the importance of the role of the lifelines (D'Andrea et alii, 1999; Cafiso et alii, 2001, 2003) in particular of road infrastructures for the limitation of damages following seismic catastrophic events.

Indeed, destruction or serious damages of highway or road network portions can cause the inaccessibility to some, even wide, urban areas, interruption or use-overload of road network or other means of transport, delay in helps from the outside, difficulties in access to Civil Protection services, to sanitary structures, to train stations, to airports, to power stations and electric lines and to all the other strategic elements of the network systems. Finally, in the case of a system functionality loss, there could be serious effects as, for example, the immediate one on population, the one consequent to the delay of rescues, and in the long term on the productive system and on the market for the unavailability of goods.

In this scenario, survey techniques, both in preventive phase and in emergency management, have an essential role to define the sensitivity and vulnerability of the territory (essentially related to the geo-morphological) and of infrastructures (buildings, road, piping, etc.).

In this sense, disposing of opportune supports dedicated to the knowledge of the territory (as a constantly updated numerical and digital cartography that is completed by a digital soil model) is very important. These supports have to be consultable within a suitable territorial informative system in order to carry out all the elaborations that the various expected scenarios should require. This approach allows, in case of a catastrophic event, to collect, to elaborate and to supply all the output necessary to the coordination of the intervention teams. In the simulation of a seismic event on the Italian territory (in EGERIS European project), the teams assigned to the macro-seismic survey and to the functionality of road networks survey have been activated in the short term while, in the long term, the ones for the census of the infrastructural damages started. All the operators on the field were equipped with hand-held computers (PDA) with cartographic software, GPS, and GPRS connections. Once received preliminary data, the teams have surveyed the geo-referenced territorial data of the site and transmitted them to the operating stations. These, after the GIS update, proceeded to compute both for the state of the isosist lines and for the viability conditions; this last is an indispensable element in order to coordinate in the best way the researchers and the rescue teams.

An aerial survey, realised with *photogrammetric digital cameras* and laser scanners, can offer a very important contribute. This technology, integrated with a GPS and an INS, consents to perform the surveys and to obtain the external orientation parameters without the need of teams on site; thanks to that is possible, in very short times, to produce a cartographic base of the event and a DTM, a very effective instrument to carry out all the necessary measurements in order to represent the modification of the territory.

Moreover, the survey with laser systems on urban areas, allows to produce particularly effective supports for a first evaluation of the damages received by infrastructures, especially if there is the possibility to carry out a comparison with a laser survey performed before the catastrophic event.

Moreover, also satellite remote sensing could be useful to quickly obtain from acquired images the distribution map of damages about buildings and infrastructure system (both in urban and rural environment). Using advanced software tools for the image analysis and classification and exploring invisible bands of the spectrum such as the thermic infrared, it is possible to individuate escapes of gas and point of fires that could cause, especially in urban context, great induct damages. For example, in the case of Kobe (1995), the damage from fires indirectly caused by the quake was evaluated as comparable to that caused directly by the quake, in as much as the interruption of the access ways prevented to the emergency services to reach the devastated areas for many hours.

For the management of the post-calamitous events it is important to dispose of information about road network condition. Research units of University of Catania and Palermo are still working on the classification of road network damages due to calamitous events by high resolution images.

The use of this kind of technologies allows the preparation of the supports necessary to the decision-maker, in a time faster than the traditional surveying methodologies; the quikness in consequent interventions, indeed, is very important to limit the human being loss.

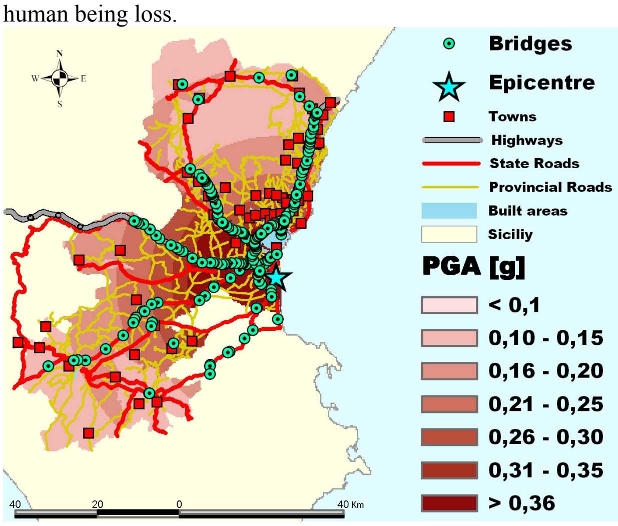

Figure 2. Specialized GIS on seismic risk. The calculated GRID PGA (Peak Ground Acceleration) layer is overlaid by road network and bridges vector layers

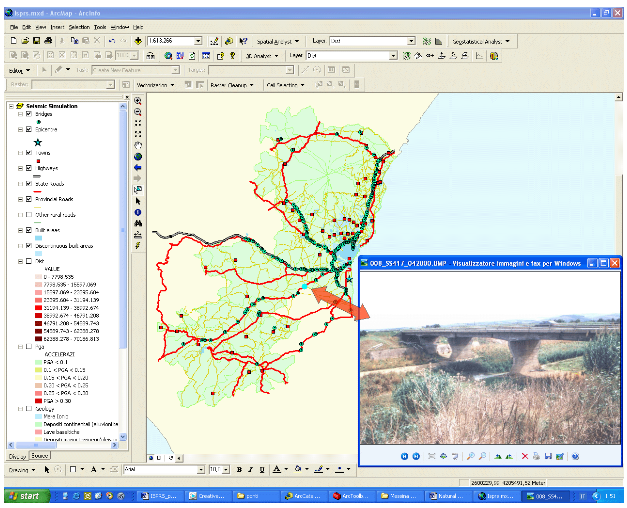

Figure 3. Specialized GIS on seismic risk. The hyper-linked photographic documentation to bridges' layer

In figure 2 it is presented a screenshot of a GIS application on Catania Province territory (Italy) about seismic risk. In particular, it is applied an attenuation law (Sabetta, 1987) for the PGA (Peak Ground Acceleration) estimation, using GRID layers regarding: geology, distance from the supposed epicentre, seismic wave transmission model of different types of soil, etc. Once obtained a PGA spatial distribution by the GRID map calculation function, vector layers about built areas, road network and structural and functional point of interest (such as bridges and viaducts, airport, barracks, etc..) have been overlaid. In particular, bridges theme has been realized by quick-static GPS survey on site. The bridges theme's database, moreover, contains several useful data for structural vulnerability evaluation (such as geometric dimensions, building materials, design criteria, state of conservation, etc.) and hyper-linked photographic documentation.

3.2 Hydro-geologic risk

Hydro-geologic studies generally foresee three scenarios:

1. **Hydro-geologic meltdown**: The analysis is based on specific local features (lithology, cultivation, etc.) and on propensity to landslide of the soils of the studied areas;
2. **Flood**: this hazard scenario gives downflow condition in the section of major interest in relation to the potential risk condition due to specific features of sites and to volume of water predictable for different period of return;
3. **Overflow**: this scenario gives the perimeter of the areas potentially interested by exceptional wave, due to the breakdown or collapse of an embankments, or exceptional flood.

Besides, the areas with an high hazard can be individuated even thanks to thermic and pluviometric data and to the census of crumbling movements.

The application of techniques of satellite remote sensing or direct aerial *photogrammetry* and of *laser-scanner surveys*, in case of event, allows the survey of the accident without any teams on the site for surveying the support points. Thanks to that it is possible to supply the emergency teams, in very short time, all the geographic, territorial and environmental information that are fundamental for the coordination of research and rescue teams to help the involved population and put the territory into safety conditions.

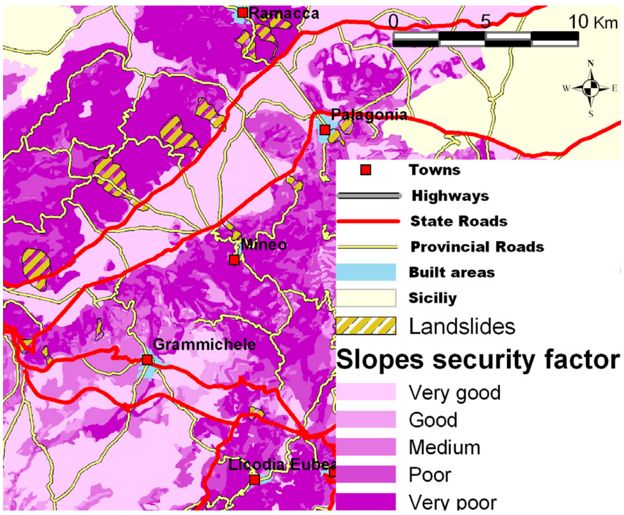

Figure 4. Particular of specialized GIS on hydro-geologic risk.

GPS technology is useful also for soil movements *monitoring*, indeed, it has been successfully applied on a landslide (in Regalbuto town, in Catania Province) where 2-3 cm displacements have been weekly recorded. GPS accuracy is comparable to traditional approach, but many advantages have been noticed: shorter surveying time and the immediate disposal of terns of coordinates. By these it is possible to evaluate roto-translation movements of the studied structure (in the case, a retaining wall) using plane equations passing through three not aligned point pertaining to the structure.

GIS application could be useful also for prevention planning about hydro-geologic risk. Starting from geologic and lithologic cartography it is possible to estimate the most important mechanical parameter for soils, such as internal friction angle. Applying GRID function to DTM it is easy to derive a slope map and, then, to apply a model to evaluate the slopes' static security factor. By the application of specific geotechnic models (Ambraseys, 1988; Newmark, 1965) on these data and on a PGA distribution map (such as the one in fig.2) it is possible to evaluate the slopes' seismic security factor and, eventually, to calculate the displacements.

Another useful prevention activity is the census and the geometric survey of existing landslides in order to realize a GIS vector theme for useful overlaying with road network or built areas.

3.3 Volcanic risk

Concerning the volcanic risk, scenarios, elaborated by experts, give the perimeters of the areas characterized by different hazard level due to lavic intrusion. The most interesting national cases are the territory of Etna, the area of Vesuvio and the Eolian archipelago.

Recent Etna activities (2002-03) have put in evidence another, not considered yet, hazard factor, in addition to the lavic one: gas and ashes emission that, if protracted for a long time, may causes heavy condition for human health and for road system functionality (with serious consequences for trading and production activities).

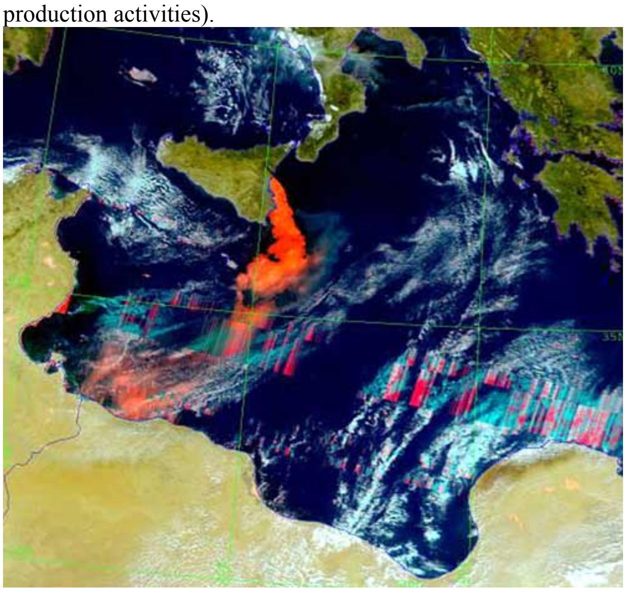

Figure 5. Satellite image on central Mediterranean area (July 2002). Etna's gas and ashes emission is evidenced in red false colour because of an higher temperature

The survey technique, in this sense, offers a valid support is the aerial survey with multispectrum images camera. The potentiality of infra-red camera allows the direct acquisition of

many information otherwise hard or impossible to be found. The monitoring of the movements of the volcanic front and disposing of detailed thermal data is very important as the possibility to transfer these data to the control stations in real time. These georeferenced data are used to update the GIS of the event (cartography, altimetric land model and aerial satellite images). With the elaboration of the parameters of the eruptions, it will be possible to preview the directions and to dispose the evacuation of civil population, the protection of infrastructures, road networks and productive activities.
The management of an eventual emergency can require, especially in the case of wide areas (such as the area around Etna and Vesuvio), the evacuation of the towns.
In opposition to the other risk typologies that have been examined, in which the evaluation tends to the creation of scenarios (useful both for the prevention and for the management of emergencies) for volcanic risk the elaboration of a hazard scenario has a meaning only for the second aspect. This difference is due to various causes:

- Volcanic eruptions impact, both effusive and explosive, is so great that whatever countermeasure could be inefficient.
- Etna volcanic activities, generally, carry out very slowly so that it is possible to alert population, with a notice ahead in time, and eventually to evacuate the areas at risk.

For these reasons, the methodology used for the volcanic risk evaluation of road network has a theoretical basis and a specific aim that distinguish it from the other methodologies. Indeed, for obvious reasons, road network can't grant any kind of resistance to eruptive and/or explosive events and therefore, the concept of a real "intrinsic vulnerability" of the infrastructure doesn't make any sense. Despite this, even in this case, road network assume an extremely important role in the management of volcanic emergency. It has, indeed, to support all the action for an eventual evacuation of all the towns that are at risk, allowing at the same time, if necessary, the access to the areas hit by the event to all the means of help (fireman vehicles, excavator, etc.).
Having an efficient road network system that gives the possibility to execute easily the above-mentioned actions is a determining factor for a optimised management of volcanic emergency.
To this aim preventive surveying activities have to be addressed to the evaluation of the functionality of road network system, in order to determine geometric and structural features.

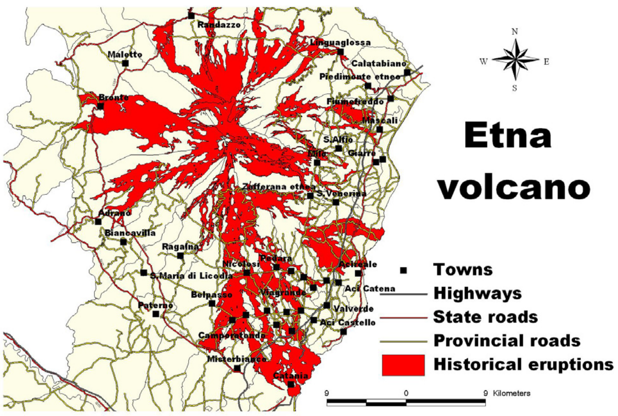

Figure 6. Specialized GIS on volcanic risk: historic eruption is overlaid by road network and town centre localization

For this reason, real time GIS offers a very important contribute. These informative territorial systems are based on sensors GPS that, using phase and code differential corrections, consent in real time the positioning of objects on the map.
Currently, there are different types of integrate GPS-GIS systems, that on the basis of their potentialities and functionality, are qualified for the update of geographic database to the different scales.
Depending on the necessary precision, the system is formed or by a GPS of a geodetic class, with sub-centimetric precision, or by a hand – held GPS, with metric precision.
In the first case, the client – rover, is integrated or connected to a notebook, enabled to receive and apply differential corrections through protocols GSM, GPRS or UMST. In the second case, it is possible to use a hand–held GPS/PDA (with operating system and a program of cartographic visualization), enabled to receive and apply differential corrections through protocols GSM, GPRS or UMTS; the cartography have to be transformed in WGS84 datum by a unique parameters set that is valid for all the area of study.
In this way, the operators can update the cartography simply moving into the site, on foot or by car; the survey data can be transmitted, according to the type of connection, to the control centre for the updating of the GIS.

3.4 Forest fire risk

Hazard scenario is given by the tendency to fire of wooden areas, based on vegetation characteristics (Mussumeci et alii, 1999), on meteorological and climatic condition, on the morphology of the land, etc. Management problems regard both air and land operations; in particular, land operations are always indispensable to face the front of the fire from the bottom and even to make a reconnaissance aimed to the extinction of residual flames not blown out by airplane.
Referring to the elaborated scenarios about wooden areas fire tendency, GIS environment functionalities allow (Mussumeci, Condorelli, 2001) the application of methodologies to simulate and manage the emergency, useful for the optimisation of road network exploitation based on territorial resources location (fireman barracks, watering sources, etc.).

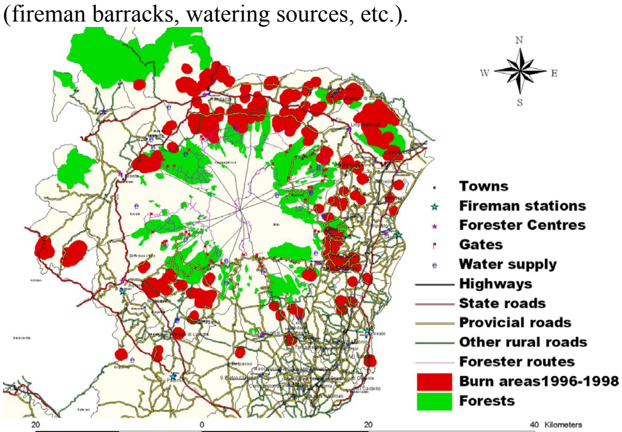

Figure 7. Specialized GIS on forest fire risk: wooden areas overlaid by burn areas (1996-98). Fireman and forester station, possible water supply point have been positioned.

In particular, it is possible to start with a preliminary "a priori" network analysis step, elaborated in GIS environment by specific models, in order to individuate fireman centres to alarm and best road routes to achieve the fire. There is a successive step of Real Time check, along road network, for vehicles' movements, opportune provided with GPS, and eventually a redefinition of initially foreseen routes if road action conditions (traffic, etc...) can't allow the reaching of destinations in predicted time. The redefinition of optimal routes approaching and, eventually, of the starting stations, can depends on phenomenon evolution that can be observed and controlled in Real Time by surveyors' teams GPS equipped, or predicted in GIS (Mussumeci, Condorelli, 2001) using opportune propagation models (Rothermel, 1972).

For this scenario, it is really important to have carried out aerial infrared surveys in order to update the maps of risk. These surveys must be accomplished during the seasons that are mainly interested by fires, to implement provisional models based on real data and not on presumed parameters.

The procedure is based on three main levels:

1° level: Prevention.

It is based on two step: one on site and one in flight.

In flight: mapping and monitoring dry area leaf and hot spots.

On site: using multipurpose sensors for the estimatimation of environmental parameters (ground temperature, air temperature, air humidity). The data are integrated into a real time GIS, by radio, GSM, GPRS, UMTS or by microwaves or in post-processing. The system will be equipped of specific provisional models to forecast the calamitous event and/or the fire risk and alert the operators when the critical parameters have been overcome.

2° level: Emergency Management

the informative system and the airplanes, will consent to the operators to have a real time vision of the calamitous event, based to the monitoring of the parameters and the speed and extension of the flame front.

This will permit to:

1. suggest to the staff of the civil protection, a secure way for the evacuation of the population and the movement of the emergencies teams;
2. suggest the best approach for the extinction operations, minimizing the risks for the teams and preserving the civil and industrial buildings.

3° level: After–event Management.

Airplanes will consent the monitoring and the mapping of the burnt areas, and the updating of GIS. It gives the possibility to quantify the damages that cultivations suffered, the green areas and the percentage of ground interested by the event and of the environmental patrimony.

3.5 Risk in transport of hazmat (hazard materials)

Hazard aspects (accidents probability with a release of hazmat) and vulnerability (with a reference to the possible consequences on human health or on environment caused by an eventual accident) of road infrastructure have to be considered. Risk analysis on road stretches that connect starting point to destination point of hazmat has to be finalised to the localisation of the most critical stretches and consequently to the individuation of the minus dangerous road routes in order to minimise the exposition of population and to plan eventual mitigation interventions.

The use of airplane, equipped with infra–red camera, permit the survey and the mapping of chemical and bacteriological polluting agents, on water and soil, of industrial discarded materials, of hazmat pouring and of hydrocarbon presence.

Moreover is possible to survey the gradient of temperature caused from the industrial waters, the quantification of the agents that pollute the water surface (interested from vessel in motion, in damage, from submarines wrecks), the survey and quantification of substances that pollute water in front of industrial buildings on the coast.

4. CONCLUSIONS

In this work the contribute of geomatic techniques for surveying and managing spatial data for Civil Protection emergency has been explored. Different risk types have been searched out such as seismic, hydro-geologic, volcanic, forest fire and hazmat transportation. Many of the traditional or modern geomatic techniques are useful, maybe essential, both for prevention planning and optimal emergency management. In particular, GIS, GPS, remote sensing satellite images, direct photogrammetry and 3D laserscanning applied to different emergency type allow high productivity and accuracy. Regarding GIS a multilevel data-structure has been proposed, based on a Central Civil Protection GIS and on many linked specialized GIS about each risk type.

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