

ROLE OF DIGITAL ORTHOPHOTOS IN ENVIRONMENTAL DISASTER MANAGEMENT

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ABSTRACT

Recurrent disasters that affect densely populated areas subject to high geologic risks are primarily conditioned by the frequency of occurrence of natural events and by the morphology and structure of the landscape but a prominent cause of the resulting damages is the dishomogeneous and ill structured geographic information available which influences also the mechanism of reaction to the event. An effective defense against natural or man-made disasters always includes a phase of acquisition and updating of environmental information. The knowledge acquired must be reliable, homogeneous and up to date. But in addition to addressing the natural phenomena that may bring on the disasters, the information should be capable of addressing also the available resources to plan effectively protective measures and to make rapid decisions in emergency conditions.

The color digital orthophoto, now routinely operational, constitutes today the most effective and economical instrument for studying risks before the occurrence of the disasters: as a georeferenced tool and as a connective link for emergency planning.

The paper describes a general model of environmental information by semicontinuous monitoring of large areas at risk using the 1998 Sarno landslide events of southern Italy as an example. The model proposes to standardize, within a quality control system, the management process relative to the situation prior to the event, the phases immediately after the occurrence of the disaster and the planning of post-disaster operations including the estimate of damages up to the normalization phase.

INTRODUCTION

The recurring hydrogeologic hazards that plague Italy are brought about by the geologic fragility of the landscape and induced by natural events such as intensive rains and earthquakes. But among the background causative factors of the costs associated with the hazards is the non homogeneous and ill organized land use and resource information available as well as the cause and effect mechanisms related to the human pressure on the environment. Among the human causes one must list urban spread over geologically weak areas, encroachment on flood plains and the covering up of stream channels and soil with concrete not to mention the general flight of agriculture from hillsides and the accelerated deforestation. The actions have come about not only out of environmental ignorance but also out of speculative and even illegal planning.

An effective defense against natural or man induced environmental disasters, always implies, prior to making decisions about protection measures, a phase of acquisition and updating of geographic information. The information we have and that which is acquired in time needs to be organized in appropriate data banks, efficiently built and maintained and programmed to be easily accessible and properly centered in their most significant aspects to meet the needs that present themselves from time to time. In this phase of acquisition and archiving of the environmental information, the role of cartography is preeminent in a general way as the basic platform for georeferencing events. Just as important is the function of cartography to assist in the evaluation of preventive measures. These measures are normally classified as "structural" and "non structural" where the first are those that control the risk factors by modifications of the landscape to diminish the risk or to protect against it. Because it is not possible to protect everything against any type and level of risk it is important that the structural measures be planned adequately within the available resources.

The economics aspect of the environmental risk problem make worthwhile an increase in the non structural interventions on the landscape. It may be developed along these lines:

Stress land use planning accompanied by appropriate legislation directed to and to be strictly enforced by the Public and Private Administration particularly as it concerns the control of new constructions.

Draft emergency plans that cover the landscape at risk

Increase the information, training and education in land use at all community levels as the events of November 1994 and of May 1998 have indicated that both basic and technical environmental risk knowledge is low or non existent

Non structural interventions on the landscape do not entail modifications of the terrain. They do not aim to decrease the probability of occurrence of a hazard and the ensuing damages but rather aim at increasing knowledge about the potential disasters, developing reliable forecasting models and improving relationships with local residents. These activities rely greatly on the availability of appropriate cartography starting with the delimitation of the risk areas (zoning) which is fundamental for the planning of terrain modifications brought about by large scale industrial and residential developments.

In general we can say that cartography helps in two ways, in the prevention and in the post event assistance (including in this the most immediate steps after the event and those related to reconstruction and restoration)

In Italy, the Compagnia Generale Riprese aeree (CGR) in its activity of documenting by aerial photography and photogrammetry the catastrophic events of the last decades has identified a possible model of organizing the cognitive, photogrammetric, topographic and cartographic activities relative to national environmental disasters. It does this by means of digital color orthophotos and satellite positioning systems to locate and circumscribe real and potential disaster areas thus aiding the development of forecasting models, a correct estimate of damages and a rational planning of post event operations. The digital orthophoto as a metrical information tool for the preparation of risk maps is an extremely versatile and concrete means for geographic monitoring and for coordinating disaster activities with a dynamic component making it capable of being adjusted to all technological evolutions and land use variations.

THE DIGITAL COLOR ORTHOPHOTO

The orthophoto may be defined as cartography with a photographic base that maintains the planimetric tolerances of the traditional maps at the same scale to which is or may be associated and an elevation content of equivalent precision. The orthophoto is less costly and more rapidly available than the equivalent traditional map while it integrates the principal characteristics of aerial photography (informational content) and of traditional maps (metric content). The primary users are first of all those concerned with civil defense, environmental protection, land use planning, public works, agriculture, cadaster, soil studies, geologic mapping, hydrology, archeology, etc..

For Italy the CGR is producing a color digital orthophoto coverage of the entire country at the nominal scale of 1:10 000 and ground resolution of 1m. It is the result of the differential rectification of aerial photography taken during may-september 1998 with 150mm cameras at the relative altitude of 6000m. The images are digitized and georeferenced in the National geodetic-cartographic system (Roma40- Gauss Boaga) with geometrical adjustments made on the basis of a digital terrain model specifically made for the purpose.

The minimal module is made up of a section of the regional technical map at the scale of 1:10 000 and it is fitted within the 1: 50 000 National cartography of the Istituto Geografico Militare (IGM), the official national cartographic agency of the country, as a submultiple called a *sezione*, in analogy with the definitions of the Italian Geodetic Commission

LAND INFORMATION FOR THE PREVENTION OF DISASTERS

From a practical point of view it is necessary to define the quantity and quality of the information instruments needed for drafting hazards' operational plans; in brief the landscape information needed by the civil defense organizations. If we consider the needs of prevention, three different levels of land use information become apparent:

A first level cartographic system or a **location** level

A second level cartographic system or a **working** level

A third level cartographic system or a **detail** level

Although the documentation for the first two levels must be prepared for all areas defined as vulnerable, that for the third level needs to be developed only where the morphologic characteristics of the terrain or the risk type demand it. The first level of **location** requires tools to determine the general boundaries of the event and the detection of the risk areas. It should also be possible to assess generally the structures and the infrastructures involved (roads,

industrial parks, residential areas, principal electric, telephone gas, etc. lines). The topographic map that best fits these requirements would be the 1:50 000 scale because of the area it covers (600 sq.km) and its informational content. Unfortunately the existing cartography is not homogeneously updated and, more than that, is not available for the entire country.

The tools for the second level cartography or the **working** level should permit the delimitation of the areas at risk and their subdivision in classes of risks. It should be possible to place in evidence terrain morphologies subject to hazards such as river banks in the case of flooding. The vertical resolution of this instrument should be less than 2m and it should be spatially homogeneous and updated.

Where the terrain morphology or the type of risk require a high planimetric or altimetric precision level for a correct interpretation of a problem, if one were to prepare a flood inundation map of an area for example, it would be necessary to prepare an instrument ad hoc. This would constitute the third level or that of **detail**. It would include those circumstances where small differences make large area impacts or where points on the ground need to be determined and portrayed with great precision (geologic faults).

Often it is very useful, at times it is compelling, to have a historical documentation of an area subject to hazards. In these circumstances the availability of an aerophotogrammetric archive becomes particularly significant.

LAND INFORMATION FOR AID AND RECONSTRUCTION

The analysis of damages induced by a landslide represents a vivid and easily understood example of the superiority of the digital orthophoto with respect to the classic cartographic map or the simple aerial photography. Here the updating of the terrain informational content and the quick production time of the orthophoto are considered essential to assess with certainty:

- the type of damages following the occurrence of a specific disastrous event

- the accurate quantification of the geographic dimensions of each area with a given class level of damage

- a reliable estimate of damages

- the scientific planning of the use of the human, financial, and material resources needed for emergency assistance and reconstruction

A conjunctive quantitative and qualitative analysis would not be possible with only the aerial photos because of the terrain relief that introduces in the photo a continuous variation of the image scale not to mention the distortion brought about by the aircraft movements. Use of the existing cartography would be useless because, obviously, it does not portray the damages. The use of both the aerial photography and the cartography would, at best, only permit a qualitative analysis of the hazard

With the digital orthophoto the user can perform additional tasks to those listed above, specifically

- Enlarge the image to examine qualitatively specific areas of interest beyond the metric capability of the orthophoto to evaluate aspects only available from the information content of the aerial photo

- Overlay the orthophoto image with vectorial data originating from other sources (thematic maps)

- Associate objects on the orthophoto with alphanumeric information arising from different databases

AFTER THE EVENT LAND INFORMATION

The emergency following immediately after the occurrence of an environmental disaster requires the availability of information on the landscape for an optimal use of the resources at hand. Time enters here into the picture and a large part of the data and the parameters that describe the landscape, whether they are geometric, geologic, biologic or human, become modified with time. Mostly it means slow variations that bring about an outdated of the information and the related documents so that a constant job of updating is to be expected. But in addition to these slow and progressive variations in time, environmental disasters introduce immediate variations on the landscape. In these cases the whole matter of spatial information becomes atypical and must be dealt with very realistically. It may be divided under 4 fundamental needs along equivalent chronological moments:

- Knowledge of the most recent preexisting conditions of the area

Knowledge, in real time, of the environmental situation immediately after the disaster to plan disaster aid and emergencies

Knowledge of the environment in quasi real time to plan the first reconstruction activities or the eventual provisional relocation of damaged installations

Knowledge of the environment in due course for the definitive planning of the reconstruction or of the post event normalization and, after, for a documentation of what was done

AN EXAMPLE: THE SARNO RIVER EVENT OF 1998

On 5-6 May 1998, following intense rains in the region of Campania a series of landslides developed on the carbonate slopes of the upper basin of the Sarno River involving the communities of 4 municipalities. The landslides occurred in the form of quick mudflows following the existing drainage channels. Starting at the drainage divides the mudflows reached very high velocities as they progressed downstream eventually arriving at the plains where they spread as fans and struck directly various urban centers and industrial areas with disastrous effects. More than 160 people died. The first slides started in the late afternoon of 5 May, continuing all night. About 100 slides were recorded; some of the flows spanned 3km in length. More than 200 000cubic meters of mud flowed over a relief of 800m.

The Compagnia Generale Ripresearee, alerted to the existing conditions as reported by the media on the evening of 5 May, had a photogrammetric plane ready on the morning of 6 May and a photogrammetric survey was conducted as soon as light conditions permitted it. The flight was carried out under rain flying below the cloud cover. The first photographic material was in the hands of the Protezione Civile, the civil defense agency of Italy, the same afternoon.

The before-the-event geographical information on an area brings on the ever present problem of map updating. It is a general cartographic problem which becomes particularly significant in hazards prone areas for which the availability of up to date information on roads and infrastructures in general is fundamental both during the prevention phase and for post event planning as in the development of a general evacuation plan. Under these circumstances a product based on little cost and quick production is much to be preferred to an optimal but dated conventional cartography be that numerical or analogic. For the Sarno River event the most up to date product comprised the b/w aerophotogrammetric coverage of Italy flown in 1994 by the CGR. An orthophoto of part of the area struck by the slide is shown in figure 1. Though taken at 11 000m above the ground the quality of the photography of the survey is such that products at the scale of 1: 10 000 can be derived without any problem. Conditions portrayed on this image can be considered to be those existing just before the disaster save for the construction of a few houses and perhaps one or two small industrial plants.

Knowledge on real time of the situation immediately after the event requires a high degree of efficiency, competence, and quickness of response on the part of those organizations charged with defending against the disaster. Technically the only valid response to the need of information is the photogrammetric product, whether the classic aerial nadiral photo or, for a better grasp of the details of the structures involved, with panoramic low level photographic coverages from airplanes or helicopters. A possible alternative is represented by high resolution satellite images which however fail if clouds are present and are anyhow available only if the satellite happens to be passing over the area at the right moment. For the Sarno area the data available for civil defense consisted of the ad hoc material collected as the main event had just taken place.

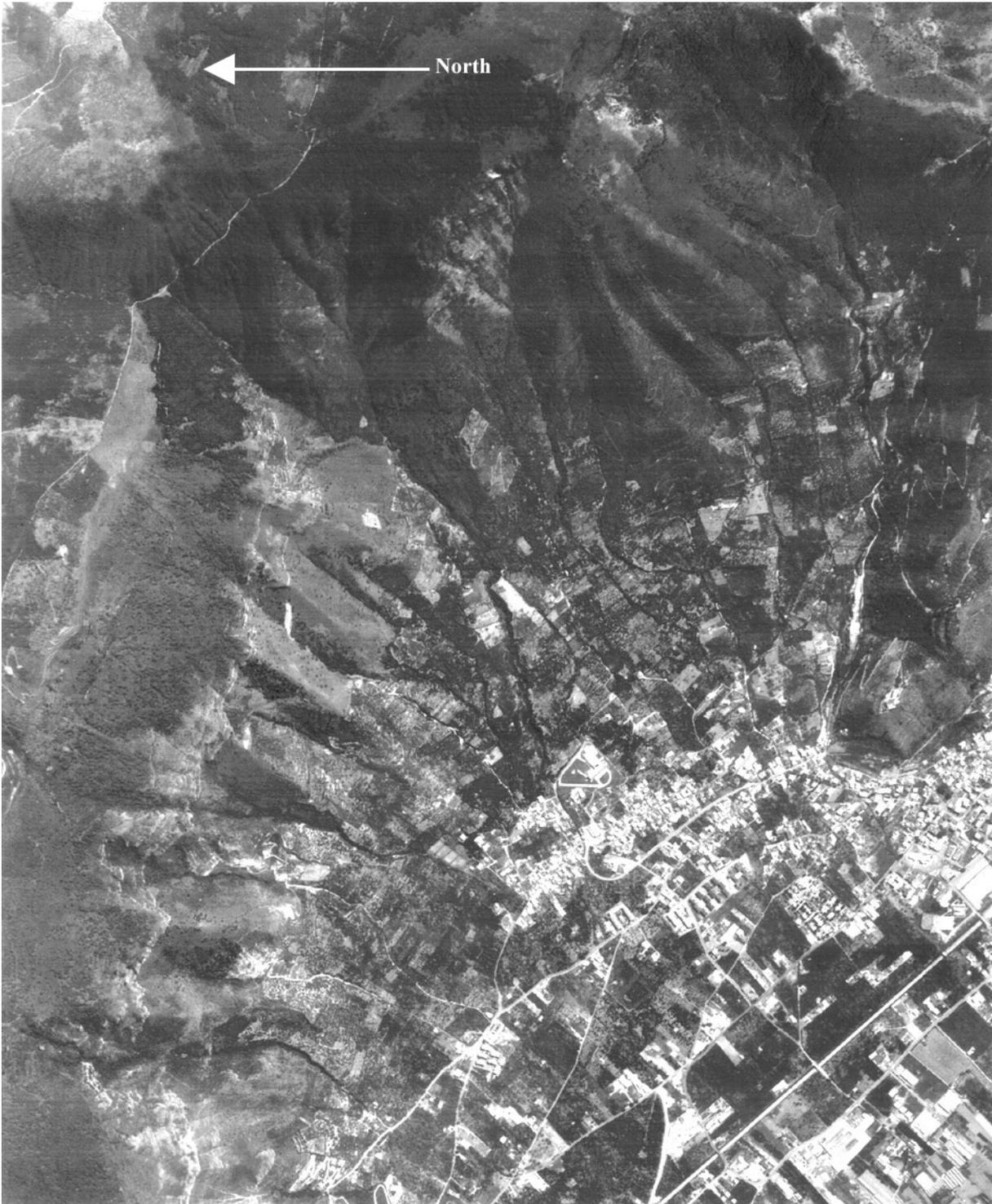


Figure 1 Example of the 1:10 000 scale digital orthophoto of the Sarno area developed from the 11 000m b/w aerial photographic coverage of Italy of 1994. This image constitutes the best documentation of the area before the disastrous slide event of May 1998

The documentation for the first post event activities represents the crucial product for disaster recovery. The most urgent interventions require that the area involved in the disaster be covered photogrammetrically in the shortest possible time. In emergencies the standard operating procedures of photogrammetric surveys regarding the choice of season and atmospheric conditions that best fit light's angle and vegetational cover may not be met. At the same time the direct use of the aerial photos is hampered by the lack of metric constancy and the difficulty of photointerpretation by those not professionally equipped to do it. The color orthophoto overcomes these difficulties and presents itself as

the product with no competitors or alternatives. For the Sarno area the orthophoto of figure 2 was prepared immediately from the aerial photography taken as soon as weather conditions permitted, i.e. a few days after the event.



Figure 2 Example of the 1:10 000 scale digital orthophoto of the Sarno area developed from the 6 000m color aerial photographic coverage of Italy of 1998. This image constitutes the best documentation of the area just after the disastrous slide event of May 1998

The normalization phase represents the last chapter of the disaster story. Traditionally the cartographic product related to this phase has been the large scale, rigorously standardized product. But the production of this extremely important product, the basic tool to guide all reconstruction and restoration of the environment and all the more needed if the pre disaster cartography was poor, takes months to complete. And for the people affected by the disaster recovery times are always late. Again the orthophoto of the disaster area at the proper scale presents itself as the optimal tool to satisfy these needs. For the Sarno basin, color orthophotos for all the disaster area, beyond those prepared for the immediate needs in near real time, became available before the end of May as an accelerated effort and part of the ongoing but nearly finished coverage of all of Italy with color digital orthophotos at the scale of 1:10 000 by the CGR.

CONCLUSION

Availability of up to date maps by civil defense organizations is essential to guide field operations and recovery planning following environmental disasters. Color aerial photography immediately after the event followed by the production of digital orthophotos from this or other taken soon thereafter, is today the best visual and metric areal documentation that can be summoned to help improve the consequences of the disaster. The existence of a well maintained archive of photogrammetric data is of much help to document preexisting conditions and to map them.

Where appropriate, civil defense organizations should be made aware of the existence of the color digital orthophoto and a working linkage should be instituted by photogrammetric companies with them in order to share in the documentation and recovery efforts.