Doctoral School on Engineering Sciences
Università Politecnica delle Marche

Extended summary

Implementation and testing of a database in a GIS environment for analysis of the hydrogeological risk

Curriculum: Engineering of materials, waters and soils

Author

Clemente Folchi Vici d'Arcevia

Tutor

Prof. Torquato Nanni

Date: 31-1-2012

Abstract. A database has been implemented, developed and tested in a GIS environment designed for control, management and planning of the hydrogeological risk analysis. In italy there is a dramatic situation, in which phenomena such as landslides, floods and pollution populate daily press and media, calling attention to the absolute necessity for a proper planning and land use. It has bee shown that the need to manage a considerable amount of multidisciplinary information and integrate and compare them within each other for more information requires the development of an appropriate control systems using the typical functionalities of Geographic Information Systems. First of all, noted the extreme heterogeneity in the geological risk, both from a disciplinary point of view and for the data organization within a Geographic Information System, with serious consequences on the actual interchangeability of the data, it was necessary to analyze the terminology used in international context. For a real control of the main hazards of a basin it was also emphasized that, rather than hydrogeological risk studies, it is more correct to use the terms of natural and anthropic risk. On this basis, a conceptual model of database has been developed highlighting the relationships between the different disciplines. Later, an alphanumeric relational database in GIS environment was designed and implemented to integrate the various aspects of land issues related to geological, geomorphological, hydrogeological, hydrological, and anthropical fields. This structure was tested on a sample drainage basin, entering first the available historical data and integrating them with other data from the monitoring stations of the area for which special forms have been developed to import data. Then a series of analytical examples

was developed showing the interrelationship between the geological, hydrogeological, geomorphological, hydrological and anthropical components of the basin in the establishment of hydrogeological risk situations. The above mentioned system is innovative in an attempt to overcome the considerable fragmentation and specificity existing in the field of natural and anthropic risk and GIS databases.

Keywords. Natural risk, anthropic risk, natural hazard, anthropic hazard, GIS

1 Problem statement and objectives

a) b)

Figure 1) Maierato's landslide (2010, a) and Genova's flood (2011, b)

Over the last decades in Italy and around the world there has been a progressive deterioration of public safety and property resulting from the "hydro-geological risk."
Phenomena as landslides, flooding, floods are part of the natural evolution of the Earth's surface, but surely human activities have intensified such catastrophic phenomena particularly in recent decades.
The situation on the national and global hazards due to landslides, flooding and pollution has provided the inspiration for the definition of this PhD research project
The control and prevention of known hydrogeological risks (landslides and floods in primis) and the pollution require a deep knowledge of many components, arising from a variety of scientific fields that deal with the natural and the anthropogenic system, which interact in complex ways. In this context, we need both to manage a considerable amount of multidisciplinary information, both to integrate and compare them within each other in various ways in order to obtain more information.
The design of a database in a GIS environment is a very complex work.
We have to take into right consideration the context in which it operates, with the necessary flexibility to adapt to a regulatory, technological and methodological framework, which evolves very quickly. In this context one of the most important is that, in order to provide useful access to the information contained in it, and the constant comparison with other existing databases in the field of national and international context, it is necessary that structure, terminology, methodology and meta-information of the data are adequately standardized.
In recent years there has been some progress in this direction, thanks to the European Directive INSPIRE (Infrastructure for Spatial Information in Europe) and the standardization work of international and national bodies with the publication of its Intesa GIS specification, as well as the Digital Administration Code and the National Spatial Data Directory (RNDT) CNIPA.

Nevertheless, the situation is today still largely heterogeneous, both from a disciplinary point of view both regarding the organization of data within a Geographic Information system. The various sector are still operating with different methods and terminology, thus limiting a lot, in fact, the real possibility of access to data and mutual exchange of information between the various research groups or Entities that hold them, with serious consequences for the ability to analyze and prevent the natural and anthropogenic hazards and risk.
The PhD research project has therefore the goal to implement, develop and test a database in a GIS environment, which was a means for the correct analysis of the most common problems of what is commonly referred to geological risk, albeit extended to pollution, identifying the river basin as a unit of study areal base, in order to provide a useful tool for a correct environmental planning (figure 2, conceptual model of GIS database).
The choice of limiting the types of natural hazard to potential landslides and floods and anthropogenic pollution has been functional to ensure the most important quantitative risk analysis in the catchment areas.

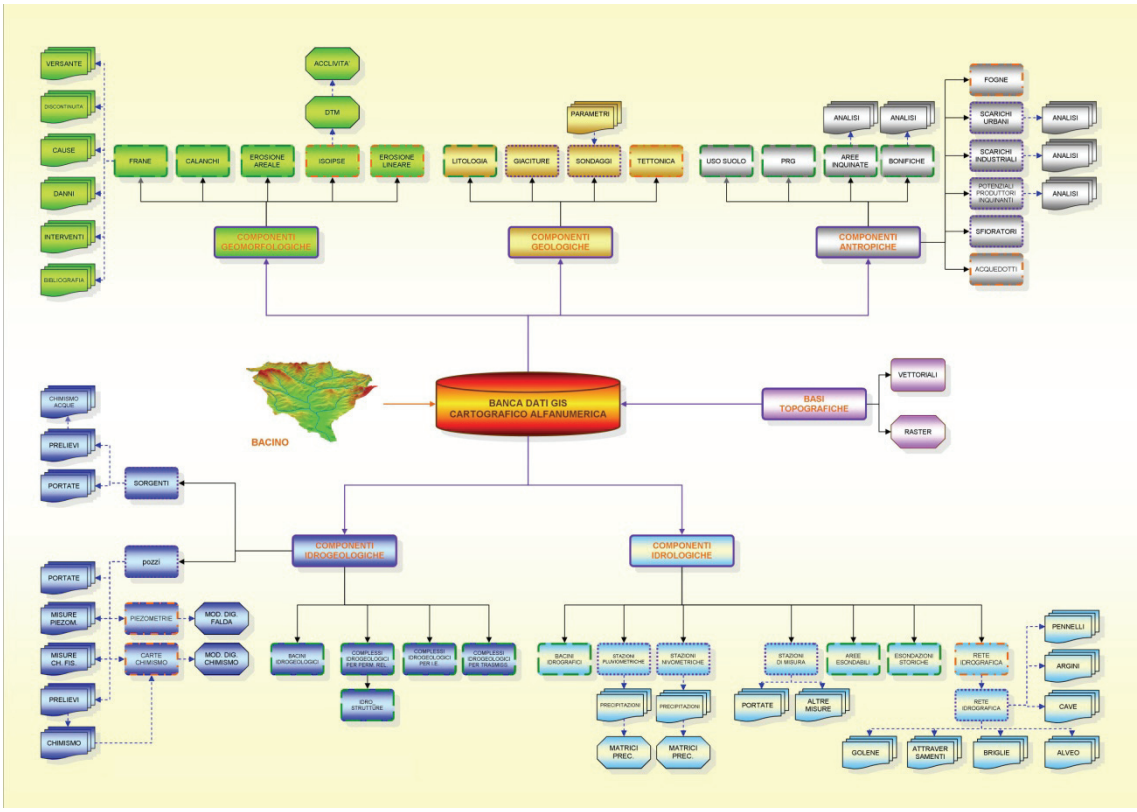

Figure 2: GIS database conceptual model

2 Research planning and activities

The research planning had these following points

– to analyze the terminology commonly used in international field to strictly define those to be used as a basis for the database structure. This was necessary to provide accepta-

bility and shareability structure guarantees, founded on the adoption of scientific community common definitions.
- To analyze the national and international situation in the field of natural/anthropic risk and hazard database
- To implement, develop and test a natural/anthropic risk database in a GIS environment;
- To test the structure on a sample drainage basin, entering first the available historical data and integrating them with other data from the monitoring stations of the area
- To developed a series of analytical examples was showing the interrelationship between the geological, hydrogeological, geomorphological, hydrological and anthropical components of the basin in the establishment of hydrogeological risk situations.
- To editing some planning sample hydrogeological maps.

3 Analysis and discussion of main results

The developed GIS database represents an innovative multi-disciplinary approach to the studied problem, constituting an attempt to overcome the extreme fragmentation and specificity exists in the field of natural/anthropic risk GIS databases. It functionality provided qualitative and quantitative analysis of the main natural and anthropogenic risks at the basin scale causes.

4 Conclusions

The proposed structure is currently used by the multidisciplinary research group in other study cases, regarding the analysis of water resources, prevention of natural and anthropic risks (landslides, floods and water pollution), and planning and management.
We are using it both in Italy and other countries. For example, in June 2011, I completed a period of research at Hue University (Vietnam), beginning a collaboration on these issues for the problems of the Song Hong river flood and the potential contamination of alluvional aquifers.
The current architecture of the database operates on a local station. For the future evolution (figure 3) there is a proposed LIFE project with the patnership of Environmental Ministry (MATTMA), ISPRA and Marche Region.
The goals of the project are:
- to carry out a joint research in the field of risk analysis;
- to create a remote control systems to monitoring the drainage basin natural/anthropic risks and hazards, using sensors specifically designed for and implemented by our research group;
- to complete the GIS database with other functions;
- to transfer the projected database in WEBGIS environment.
- To connect the remote system and WEBGIS

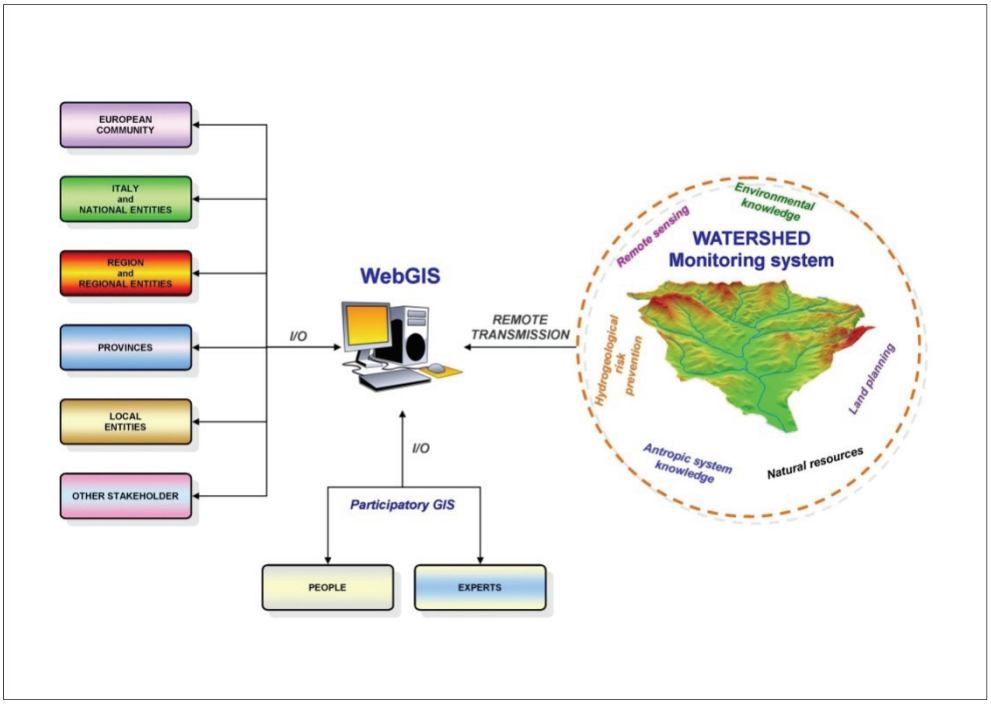

Figure 3: the future of the project

References

[1] Bates, R. L., & Jackson, J. A. (1987). Glossary of Geology (3rd. Edition ed.). Alexandria, USA: American Geological Institute.

[2] Beven, K. J., & Kirkby, M. J. (1979). A physically based, variable contributing area model of basin hydrology. Hydrol. Sc. Bull. , 24 (1), 43-69.

[3] Canuti, P., & Esu, F. (1995). Glossario internazionale per le frane. Rivista Italiana di Geotecnica , 29 (2), 143-150.

[4] Cardinali, M., Reichenbach, P., Guzzetti, F., Antonini, G., Cacciano, M., Castellani, M., et al. (2002). A geomorphological approach to the estimation of landslide hazards and risks in Umbria, Central Italy. Natural Hazards and Earth System Sciences , 57-72.

[5] Carrara, A., D'Elia, B., & Semenza, E. (1987). Classificazione e nomenclatura dei fenomeni franosi. Geol. Appl. e Idrogeol. , 20 (2), 223-243.

[6] Cruden, D. M. (1991). A simple definition of a landslide. IAEG Bull , 43, 27-29.

[7] Cruden, D. M., & Varnes, D. J. (1996). Landslides Types and Processes. Washington: National Academy Press.

[8] DRM. (1985). Catalogue de mesures de prévention , Mouvements de Terrains. Plan d'Exposition aux risques. Rapport Administratif et technique provisoire, Premier Ministre. (443) .

[9] DRM. (1988). Evaluacion de la vulnérabilité. Plan de exposition aux risques. La Documentation Française, 112. , 112. Ministère de l'Environnement, Direction de l'Eau et de la Prévention des Pollutions et des Risques.

[10] DRM. (1990). Les études préliminaires à la cartographie réglementaire des risques naturels majeurs. Secrétariat d'État auprès du Premier ministre chargé de l'Environment et de la Prévention des Risques technologiques et nature.

[11] Einstein. (1988). Special lecture: Landslide risk assessment procedure. In C. Bonnard (A cura di), Proc. 5th Int. Symp. on Landslides, 2, p. 1075-1090. Lausanne.

[12] Fell, R. (1994). Landslide risk assessment and acceptable risk. Canadian Geotechnical Journal ,

31 (2), 261-272.
[13] Giacomelli, P., Sterlacchini, S., & De Amicis, M. (2003). La valutazione del rischio di frana. Aestimum , 42, p. 31-52.
[14] Humbert, M. (1977). La Cartographie ZERMOS. Modalités d'établissement des carte des zones exposées à des risques liés aux mouvements du sol et du sous-sol. Cartographie ZERMOS (1/2) , Série II, Sect. III, 5-8. BRGM Bull.
[15] Humbert, M. (1976). Le cartographie en France des Zones Exposées à des Risques liés aux Mouvements du Sol. Cartes ZERMOS , 16 , 80-82. IAEG Bull.
[16] INSPIRE. (2010). D2.8.I.8 INSPIRE Data Specification on Hydrography –.
[17] INSPIRE. (2011). D2.8.II.4 Data Specification on Geology – Draft Guidelines.
[18] INSPIRE. (2010). D2.8.III.12 Data Specification on Natural Risk Zones – Draft Guidelines. CE.
[19] ISPRA, APAT, & SGN. (1989, 2006). IFFI (Inventario Fenomeni Franosi in Italia).
[20] Nanni, T. (1992). Il bacino del fiume Musone: geologia, geomorfologia ed idrogeologia. Firenze: S.E.L.C.A.
[21] Nanni, T. (1980). Note sulla geologia dell'anconetano (Vol. 50). Ancona: Istituto di geologia applicata, Università di Ancona.
[22] Nanni, T., Coltorti, M., & Garzonio, C. A. (1992). Bacino idrografico del bacino del Fiume Musone. Geologia - Geomorfologia - Idrogeologia. In T. Nanni (A cura di), Il bacino del fiume Musone: geologia, geomorfologia ed idrogeologia. Firenze: S.E.L.C.A.
[23] Panizza, M. (2001). Problemi attuali di rischio e impatto ambientali in alta montagna. Mem. Soc. Geogr. Ital. , 66, 53-68.
[24] Perrot, A. (1988). Cartographie des risques de glissements en Lorraine. In C. Bonnard (A cura di), Proc. 5th Int. Symp. on Landslides, 2, p. 1217-1222. Lausanne.
[25] Sharp, J. M. (2007). A glossary of hydrogeological terms. Tratto il giorno 2010 da http://www.geo.utexas.edu/faculty/jmsharp/sharp-glossary.pdf
[26] UNISDR. (2009). Terminology on DRR. Tratto il giorno 2010 da Sito UNISDR: http://www.unisdr.org/we/inform/terminology
[27] Varnes, D. J. (1958). Landslide types and processes. Landslides and engineering practice, National Research Council Highway Research Board Spec. Rept. , 29 , 20-47. Washington D.C.: Eckel E.B.