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# A GIS tool for historical instability processes data entry: An approach to hazard management in two Italian Alpine river basins

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ABSTRACT

Analysis of instability processes requires historical data over a range of temporal and spatial scales. While historical data offer a wealth of information about when, where and how a flood or a landslide happened or may recur, managing the data remains problematic. Before the data can be entered into historical and geographical databases, they need to be extracted from a vast variety of paper documents and transformed into a standard format. To do this, we developed a Geographical Information System (GIS)-based tool that permits easy data entry for comparing information on different temporal and spatial scales. The GIS tool was combined with a methodology for spatial data analysis to identify main hazardous areas. The historical and geographical databases were then queried with this tool to obtain the frequency of catastrophic events and their spatial recurrence. The GIS tool allowed accurate and rapid data management for establishing a connection between textual and spatial information for new data generation.

This paper illustrates a methodology that utilizes the GIS tool for analyzing instability processes in two Italian river basins in the Western Alps.



## 1. Introduction

According to a report by Munich Re (2002), floods throughout Europe in August 2002 caused damage of over 15 billion euros. Since 1990, over 30 floods have cost billions of US dollars and claimed numerous human lives (Kundzewicz et al., 2005) in Southeast Asia, Europe and North America (Munich Re, 2005 and 2006). Catastrophic floods have also struck the northwest Mediterranean basin (Spain and France in Dolz, 1993 and Llasat et al., 2005) and northern and central Europe (Germany, Poland, Hungary and Romania) (Benito et al., 2004; Dubicki et al., 2005; Kundzewicz et al., 2005; Masaryk Institute, 2004; Varga, 2000[1]). In recent years, instability processes in Italy have caused calamities and considerable damage to property and infrastructures. In the last 80 years alone 11,000 landslides and 5400 floods have occurred (Luino, 2005). Since 1980, the Italian State has spent 42.4 billion euros or about 5.7 million euros per day (Luino, 2005) in compensation and remedial works for natural disasters.

These studies underscore a decline in the number of disaster victims in Western countries and a significant increase in material damage with mounting costs to national governments. The rise in instability processes and related costs is beyond the scope of this paper. Nonetheless, a knowledge of historical events and their causes is useful for studying them on a long-term scale to understand where instability processes may happen and what preventive measures should be undertaken to counteract them.

Floods and landslides are complex phenomena with different hazard levels. Meteorology and hydrology play an influential role in triggering them: heavy rains, long rainy periods and snowmelt are major factors but are insufficient alone to explain why calamitous phenomena occur. Other conditions such as previous precipitation, terrain and surface run-off need to be taken into account (Llasat et al., 2005). In addition, these natural phenomena interact with human activities. Land use and its evolution, as well as civil and hydraulic infrastructures, can influence the natural response of floods and landslides (Arnaud-Fassetta et al., 2005). In brief, each event is the result of a complex interaction between meteorological, environmental and human factors.

In-depth historical research has established that nearly all areas currently affected by instability processes were so in the past; understanding this continuity may aid in hazard investigation and zonation (Benito et al., 2004; Tropeano and Turconi, 2004). Furthermore, historical research can play an integral part in reconstructing instability processes, describing different triggering factors particular to a type of phenomenon, and constructing local and regional scenarios. Flood frequency estimates derived from historical data are based on hydrological measurements such as peak water levels recorded by gauges and marks on buildings (Bardsley, 1989; Bayliss and Reed, 2001; Cheng-Zheng, 1987;

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[1] Varga M. (2000). An Extraordinary Challenge for the Hungarian Basin Organizations: The Historic Flood in the Tisza River Basin. http://www.riob.org/ag2000/varga_english.htm.

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Condie and Lee, 1982; Helms et al., 2002; Sutcliffe, 1987). Full-scale studies exploiting historical documents as a support to estimating natural hazard in Europe (Marchi and Tecca, 2006; Meunier, 1988; Naef and Bezzola, 1990; Rickenmann and Zimmermann, 1993; Tropeano, 1989) and elsewhere around the world (Gori and Burton, 1996; Reid et al., 1991; Zeng and Zaho, 1992) relate to both floods (Luino and Turitto, 1996; Tropeano and Turconi, 2004) and landslides (Chau et al., 2004; Ibsen and Brunsden, 1996) and give qualitative but not quantitative information. Numerous published studies have used historical data, but few have examined historical data as an information source for classifying phenomena typology and damage.

Historical material and data about local events and instability processes can be obtained from a wide variety of sources: town libraries, municipal and governmental archives, parish and newspaper archives. Abundant as this information is, accessing, extracting and organizing data from archival sources is problematic because they are not collated for scientific use (Ibsen and Brunsden, 1996). The same caveat holds true for searching and retrieving data from the Internet (online databases and news and governance web sites), which has become a new source of material in recent years.

In response to the need for systematic data collection and management, the Research Institute for Geo-Hydrological Protection (hereinafter IRPI) of the Italian National Research Council in Torino, since its foundation 38 years ago, searches and collects information about past natural phenomena, their description, as well as the damage they cause in the Po river basin and the Italian Alps (Tropeano and Turconi, 2004). The bulk of the historical documents consists of archival data (some 100,000 original papers), a library (about 15,000 published documents such as articles, reports, books and conference proceedings) and selected newspaper collections dating back to the early 1800s. Most date from the beginning of the 19th century, some from the 17th and 18th and centuries, and others as far back as the 14th century. These unedited manuscripts, maps and photographs of events have been integrated with records, measurements, notebooks, photographs and interviews made by the IRPI staff (Govi and Turitto, 1997; Tropeano and Turconi, 2004).

But before data can be coherently reconstructed, various types of archives need to be found and explored from which documents can be selected and collected for analysis (Govi et al., 1990). During this process, particular attention is given to technical projects, reports, warnings, notes and manuscripts. These data are usually integrated with drawings, maps and photographs (Ibsen and Brunsden, 1996; Tropeano and Turconi, 2004).

However, the use of historical data for analyzing geomorphological processes is problematic (Ibsen and Brunsden, 1996):

- a document may not report relevant evidence (date, magnitude and duration of an event) or may emphasize the effects without describing phenomenon typology and characteristics;
- each archive has a specific temporal and spatial span;
- observer perception, competence and attitudes; different reporting styles and presentation can introduce unknown error;
- historical accounts are usually reliable but may not be a first-hand source, because many are written or rewritten some years after the original record;
- the same event can be reported in several archives.

In addition, records reflect changes in reporting fashion; for example, newspaper and journal accounts of natural events during wartime may have been influenced by the reporter's other priorities. Over time, the number of records has gradually increased, becoming less descriptive and more summary but with better scientific descriptions. Although this has made records more suitable for modern data analysis with instruments like GIS, historical data still require in-depth interpretative analysis, nonetheless.

In brief, one of the main problems with transforming data into suitable information is the diversity of archive materials, recent and past, that describe events and their recurrence in many different ways. One solution to the problem is a logical process and a methodology for studying instability processes based on a tool specifically created for rapid and systematic data entry of historical information from published and unpublished documents in a Geographical Information System (GIS). The GIS tool enhances access to historical data, allows a better visualization of the GIS database, with easier data handling and greater uniformity of historical information. In particular, the archived data permit preliminary subdivisions of an area according to different hazard levels. The GIS tool offers an effective support for solving problems related to geomorphological process analysis based on historical data. The problem of the specific temporal and spatial span of each historical archive is obviated, since the GIS tool can collect information from several sources and assemble it. At the same time, the missing of some important details (i.e. date or magnitude of the event) and differences in reporting style and presentation can be solved with the use of predefined definition (i.e. landslides classification of Cruden and Varnes, 1996) to obtain a standard description. Furthermore, the use of a GIS database overcomes the problem of identifying the same instability process reported in different archives and the risk of data duplication.

This paper illustrates how the GIS tool and our methodology were applied to two river basins in the Italian Western Alps.

## 2. GIS and historical data

Many countries in Europe (especially, France, Germany, Italy, Spain and the United Kingdom) and around the world have extensive but uncompiled, uncatalogued and unanalyzed historical archives from which useful data for studying instability processes can be derived (Ibsen and Brunsden, 1996). Currently, GIS is widely used for historical data management because it allows the storage of geographical as well as textual information. However, GIS potential is not always exploited as an instrument for storing and analyzing data: many databases are created with other software (i.e. Ms Access, Oracle, FileMaker, etc.) so that GIS merely displays geographical information (i.e. Iffi Project[2]; Avi project[3]; SPHERE Project[4]) as some papers have emphasized (Carrara et al., 1999; Casas et al., 2002; Davoine et al., 2004).

Historical data concerning natural phenomena derive from maps, aerial photographs and documents (newspapers, journals, technical reports, etc.). Maps and aerial photographs are analyzed and sometimes georeferenced in a GIS, and channel adjustments, flood involved areas or past landslide inventories are created (Chau et al., 2004; Winterbottom, 2000). Historical data from published and unpublished documents are seldom managed with a GIS database (Copien et al., 2008).

In instability processes analysis, historical data form the base of hazard investigation. But all sorts of details need to be

[2] Iffi Project:Inventory of Italian landslides. http://www.mais.sinanet.apat.it/cartanetiffi/.

[3] Avi Project: Inventory of areas affected by landslides and floods in Italy. http://avi.gndci.cnr.it/welcome_en.htm

[4] SPHERE Project: Systematic, Palaeoflood and Historical data for the improvEment of flood Risk Estimation: http://www.ccma.csic.es/dpts/suelos/hidro/sphere/enter.html