Journal of Hydrology 541 (2016) 510–522

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Analysis of damaging hydrogeological events in a Mediterranean region (Calabria)

Luigi Aceto[a], Tommaso Caloiero[b,*], A.A. Pasqua[a], Olga Petrucci[a]

[a] National Research Council of Italy, Research Institute for Geo-hydrological Protection (CNR-IRPI), Rende (CS), Italy

[b] National Research Council of Italy, Institute for Agriculture and Forest Systems in the Mediterranean (CNR-ISAFOM), Rende (CS), Italy

ARTICLE INFO

Article history:
Available online 24 December 2015

Keywords:
Landslides
Floods
Damaging Hydrogeological Events

SUMMARY

Damaging Hydrogeological Events (DHEs) are periods of severe weather conditions affecting wide areas for several days, and causing mainly damaging landslides and floods. In order to characterise the DHEs, we analysed the historical series of the events that affected a Mediterranean region (Calabria, southern Italy) throughout 92 years of observation. Depending on their magnitude, we classified the events as: major catastrophic, catastrophic, extraordinary and ordinary. In winter events, damaged areas and damage were greater than those resulting from the other seasons. Nevertheless, the majority of the events took place in autumn, when, in addition to landslides, a relevant percentage of flash floods and floods also occurred. Results also show that the frequency of major catastrophic and catastrophic events has decreased since 1971, and that, in recent decades, Calabria has suffered from damaging effects even though rain did not reached extreme characteristics. In fact, the duration of triggering rain, the maximum daily rain of the events and the out coming frequency of the high return period of rain show a decreasing pattern throughout the study period. As to what concerns the damaging phenomena, landslides were identified as the most frequent in every season and in every type of events, the eastern side of the region was the most frequently and heavily damaged. According to literature, the trend of number of victims per event is also decreasing.

The proposed analysis can be applied to different study areas in order to assess the relative magnitude of DHEs and their evolution throughout the years. The classification criterion can be useful to compare different events for either scientific or insurance purposes, and to identify the typical rainfall-damage scenario of a study area.

1. Introduction

Hydro-meteorological events represent the vast majority of global disasters (UNISDR, 2007). Within this purview, we define *Damaging Hydrogeological Events* (DHEs) as episodes of severe weather conditions which produce damaging phenomena such as landslides and floods, causing economic damage and affecting the population (Petrucci et al., 2009a).

The characteristics of the DHEs strictly depend on the climatic, geomorphological and anthropogenic characteristics of the affected area. In fact, the effects of a rainfall event can be extremely different from place to place, according to the local susceptibility to landsliding or flooding and the presence/absence of assets and people. Moreover, several events which affect a region can have different effects, due to the random pattern of rain and the discontinuous distribution of damageable elements.

According to the United Nations Development Project (UNDP), vulnerability is the condition "determined by physical, social, economic, and environmental factors or processes, which increase susceptibility to the impact of hazards" (UNDP, 2004). In recent years, there have been increased efforts to map vulnerability to disasters for policy, relief, and decision-making purposes (Maynard-Ford et al., 2008). A vulnerability map gives the precise location of sites where people, the natural environment or property are at risk due to a potentially catastrophic event that could result in death, injury, pollution or other destruction (Edwards et al., 2007). Several methodological approaches to assess damage have been published in different areas of the world, such as Scotland (Winter et al., 2013; Winter, 2014), Switzerland (Papathoma-Köhle et al., 2012) and Italy (Petrucci et al., 2010; Petrucci, 2013; Ciampalini

* Corresponding author at: Via Cavour 4/6, 87036 Rende (CS), Italy. Tel.: +39 0984 841464.

E-mail address: tommaso.caloiero@isafom.cnr.it (T. Caloiero).

http://dx.doi.org/10.1016/j.jhydrol.2015.12.041
0022-1694/

et al., 2015). Unfortunately, currently, neither a criterion to assess the "magnitude" of a DHE, in terms of rain and damage, nor a methodology to compare the damage caused by different events affecting a study area exist. To identify the most appropriate definition and methods for qualifying and quantifying damage, public administrations often request the support of scientific experts, to obtain a picture of the events that may occur (*ex ante*), or have just occurred (*ex post*), and to properly direct funds for damage mitigation and compensation (Molinari et al., 2014).

Several authors have looked at the series of past events in order to establish a correlation between their trend with changes in climatic features (Brázdil et al., 2011; Bullón, 2011) or in increasing urbanisation (Baioni, 2011). The knowledge of the scenarios of historical DHEs provides an overview of the most frequently damaged anthropogenic elements which, in the absence of structural measures, can act as points of possible crisis during future events. This information can be useful in decision support, emergency management planning and implementation of prevention and response measures. Moreover, it can play an important theoretical guiding role in meteorological disaster prediction, and future disaster prevention and reduction (Guan et al., 2015). Additionally, the historical series of DHEs which affected a region may offer didactic information to share with the population in order to improve the consciousness of risks affecting the areas in which they live, or can be used to calibrate loss estimation models (Papathoma-Köhle et al., 2015). The knowledge of losses caused by past DHEs can make local communities aware of the costs of damage to public and private property, thus allowing them to match those costs with the ones required for DHEs countermeasures, such as insurance or risk reduction programs. Indeed, participatory responses to natural disasters can be considered as the primary tool for disaster risk reduction, as highlighted in post-communist Central European countries by Raška and Brázdil (2015). Moreover, an insight into past disasters allows to assess the performances of multiple mitigation strategies (Day and Fearnley, 2015) and, consequently, to help in the management of future events in which the simultaneous occurrence of landslides and floods must be taken into account. In fact, landslides and floods are categorically different and the scientific community usually approaches them separately, although they happen simultaneously and must be faced at the same time, in terms of emergency management, damage assessment, physical vulnerability assessment (Papathoma-Köhle et al., 2011) and societal risk assessment (Salvati et al., 2010). However, the problem of the absence of measurement procedures and continuous series of data must also be considered. In effect, though continuous series of rain measurements at different temporal scales are available in several countries since the past century, no measurements of damage exists. Moreover, all the elements concurring to defining damage have a subjective value, and damage appraisal can vary depending on the aim of the assessment, the subject performing it, the amount/quality of data available (Petrucci and Gullà, 2009, 2010), and the scale at which the disaster is analysed, due to the relative size of the disaster itself (Voss and Wagner, 2010).

For the Calabria region (southern Italy) a methodology to summarise the relative magnitude of DHEs has been proposed and gradually improved, based on the exceptionality of both damage and rain (Petrucci et al., 2009b; Gullà et al., 2012; Petrucci, 2013; Aceto and Petrucci, 2014; Caloiero et al., 2014; Gariano et al., 2015).

In this paper, we investigated the DHEs occurred in Calabria over a period of 92 years, and the variations in both rain and damage component, based on a series of 21 events registered between 1921 and 2013.

2. Background

Landslides and floods are radically different but, during severe weather periods, they can simultaneously cause damage to assets and/or people. In fact, either landslides or floods can threat population, albeit with different mechanisms (Jonkman, 2014), or they can destroy roads, causing economic damage (Barredo, 2009) and affecting the efficiency of strategic emergency response structures in urban areas (Albano et al., 2014). In this paper we focus on both landslides and floods triggered by rain which occur in a selected time and space.

To investigate the relationships between triggering rain and its resulting effects, catalogues of past phenomena are crucial. These data storage have been realised either for mass movements (e.g., Kirschbaum, 2014; Taylor et al., 2015), or floods (e.g., Barnolas and Llasat, 2007; Llasat et al., 2013), using standard information sources such as newspapers (e.g., Devoli et al., 2007) or, more recently, social media (e.g., Pennington et al., 2015).

Historical data cannot be replaced because they are the only way to obtain information on past damaging event. Nevertheless, several limitations widely studied in literature must be taken into account (Petrucci and Pasqua, 2008; Petrucci and Gullà, 2009; Gullà et al., 2012):

- Both data availability throughout the years and the contents of the different types of information sources can change widely from a country to another.
- Historical research can never be considered complete because of various causes such as document losses (i.e., fires) or unavailability of information sources (i.e. if documents are located in private and/or inaccessible archives).
- Temporal and/or spatial descriptions of phenomena, as well as imprecise terminology can characterise non-scientific data sources. Data must be carefully analysed and interpreted, better if by persons deeply knowing the local idioms, frequently used to describe meteorological events and their consequences.
- The details of the information strictly depends on the scale at which it is collected. National newspapers usually supply less details than local ones.
- The irregularity of data availability in some sources such as newspapers can depend on both external factors (i.e. wars) or internal ones (gaps in the publication).
- Information concerning older events is generally less detailed than that pertaining to recent phenomena, due to a greater data source availability in recent years (i.e., the strong information diffusion offered by the internet makes greater amount of data about current events available).
- Data concerning less populated areas are very rare. The damaging phenomena able to "leave a trace", in terms of historical documents, must have damaged something. Except for scientific articles, numerous sources focus more on the effects (damage) than to the phenomenon itself.

Several authors gathered data on entire phenomena which caused damage during extreme weather periods. Papagiannaki et al. (2013) prepared a database of high-impact weather events that has affected Greece since 2001 with floods, flash floods, hail, snow/frost, tornados, windstorms, and lightning. Similarly, for Northern Portugal, Zêzere et al. (2014) and Santos et al. (2014) collected the occurrences of floods and landslides between 1865 and 2010 into the DISASTER database. Garcia-Urquia and Axelsson (2014) presented the development of a database for rainfall induced landslides, in Tegucigalpa (Honduras) for the period 1980–2005, including also data about tropical storms, hurricanes,