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The Risk Data Hub loss datasets

The Risk Data Hub Historical Event Catalogue

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Abstract

In recent decades, the systematic collection of disaster related data has rapidly become a crucial concern; there is a growing recognition of the importance of post-disaster loss data, which are an essential mean to inform policy decisions oriented to reduce disaster risk as they are strictly linked to a variety of aspects: from the understanding of the impacts of occurred events to the calibration and validation of forecasting models till the evaluation of progresses in reducing disaster risk. Post-event damage and loss data have an intrinsic key role in all the phases of the DRM.

Records of damage and losses occurred due to past disastrous events are not always available. Rarely countries have procedures and databases to collect and store post-event damage data; in many countries there are no organizations in charge of collecting data and open global datasets often have different quality of data (Petrucci at al., 2018). At European level loss and damage data are available through global multi-hazards databases (Wirtz, K., et al., 2014), but there is no authoritative loss database that can provide a trend at European level (De Groeve, 2015).

The Disaster Risk Management Knowledge Centre (DRMKC) is currently developing a web-based geographical information system platform, the DRMKC Risk Data Hub (RDH), which aims at improving the access and share of curated EU-wide disaster risk information in order to support the implementation of international actions for DRM. Currently, Risk Data Hub structures the information into three modules that covers the Exposure Analysis, Historic Events – as an EU-wide loss and damage database and Risk Analysis module.

The aim of this document is to report the methodology used to create the Historic Events module and the use that can be done of damage and loss data.

The RDH Historical Event Catalogue consists in a collection of past events data occurred in EU created from a wide array of data published in several sources and datasets. This collection makes use of inventoried data; precisely different open access datasets have been interrogated collecting European-related records on past disastrous events. Both hazard and loss data have been systematically collected from various sources, checked, linked and homogenized to be provided in tabular and geospatial format in order to create the RDH Historical Event Catalogue.

The work carried out consists in an effort done to improve the existing lack of homogeneous and comparable data on past events occurred across European Countries. This work represents an assemblage of sources that become complementary. Considering that each source focuses on different aspects of the impact events, the objective of the collection is to describe the phenomenon, gather data on loss and damage records and present the spatial extent of the damages. Finally, analyses intended to illustrate ways of examining global loss data and identifying possible trends in terms of peril or geographical prone areas within the European Countries are performed on the collected damage and loss data.

1 Introduction

In recent decades - and especially in the context of the adoption of the Sendai Framework for Action on Disaster Risk Reduction 2015-2030, the predecessor Hyogo Framework for Action 2005-2015, and the Paris Agreement - the systematic collection of disaster related data has rapidly become a crucial concern; loss data accounting is now in demand at all levels from national, to European and international. There is a growing recognition of the importance of post-disaster loss data, which are essential not only for understanding the impacts of occurred events but they are fundamental also to support a variety of actions aimed at reducing disaster risk. They are fundamental component in the construction of trends, observation of vulnerability and resilience fluctuation, calibration and validation of forecasting models and in the preparation of evidence-based National Risk Assessments (NRA) - Decision No.1313/2013/EU of the European Parliament and of the Council on a Union Civil Protection Mechanism (UCPM)- which requires a sound collection of disasters damage and loss data for a wide range of events of different nature (Poljanšek et al., 2018). Post-event damage and loss data have an intrinsic key role in all the phases of the DRM.

Records of damage and losses occurred due to past disastrous events are not always available. Rarely countries have procedures and databases to collect and store post-event damage data; in many countries there are no organizations in charge of collecting data and open global datasets often have different quality of data (Petrucci at al., 2018).

Global datasets provide low resolution data as they contain aggregations of information; therefore many assumptions are performed on the data in order to have homogeneous information that can cover large areas. The lack of consistency of data collection, which is the result of different methodologies used during the collection, the different scope and the different spatial scale considered lead to data which have a questionable accuracy and that can be hardly comparable (UNISDR, 2015). Disaster loss datasets are based on different methodologies, such as the definition or threshold for what qualifies a disaster, as well as in the procedures used to collect the data. Disaster loss and damage datasets do not provide a complete picture of the events and often they do not include records for "smaller" but often recurrent events.

At European level the loss and damage data are available through global multi-hazards databases (Wirtz, K., et al., 2014), but there is no authoritative loss database that can provide a trend at European level (De Groeve, 2015).

In such a context, different open access datasets have been interrogated collecting European-related records on past disastrous events. Both hazard and loss data have been systematically collected from various sources, checked, linked and homogenized to be provided in tabular and geospatial format in order to create the RDH Historical Event Catalogue.

The RDH Historical Event Catalogue is an integrating part of the RDH web-platform development. The Risk Data Hub proposes to become the reference point for data collection, developing a centralised pan European platform for collection of loss and damages data.

The RDH Historical Event Catalogue consists in a collection of past events occurred in EU created from a wide array of data published in several sources and databases. The work carried out consists in an effort done to improve the existing lack of homogeneous and comparable data on past events occurred across European Countries. This work represents an assemblage of sources that become complementary. Considering that each source focuses on different aspects of the impact events, the aim of this work is to define the event, gather data on loss and damage records and present the spatial extent of the damages.

Most of the sources considered, are internal JRC databases: European Forest Fire Information System (EFFIS), EFAS (European Flood Awareness System), Emergency Management Service Rapid Mapping (EMS Copernicus), European Drought Observatory (EDO) etc. Moreover, having a European-wide coverage and with a reduced access to national records, the identified sources for information are various: online media (e.g. Europe Media Monitor), online encyclopaedia (Wikipedia), existing multi-hazards databases (e.g. Munich Re, Swiss Re, EM-DAT, GLC), EU services (e.g. EMS Copernicus, ERCC), EU financed projects (e.g. Share) or academic research.

Finally, the RDH Historical Events Catalogue offers an overview of currently available collection of past events and related losses and damages. This collection makes use of inventoried data which eventually is spatially represented as maps of impacted areas or further structured into different types of analysis (e.g. Sendai targets or EU Solidarity Funds).

This document presents firstly a damage and losses datasets review, then the description of the RDH Historical Event Catalogue construction divided in different phases such as: the data collection methodology; the procedure to construct a complete and efficient set of damage and losses data; and, finally an analysis of the records which leads to a better understanding of the quality/amount of collected data of past events and the possible information that can be retrieved from them with an effort to evaluate the level of compliance with some selected existing forecasting models.

2 Discussion on post-disaster loss data and current datasets

Due to the growing recognition of the importance of post-disaster loss data many agencies and organizations started working on disaster data collection establishing priorities on its methodologies and quality of the results. At the European level, many initiative and activities have been and are still carried out in the Directorate General Joint Research Centre (JRC) and in the Academia. In 2014 an EU expert working group on disaster damage and loss data has been established (De Groeve et al., 2014) to identify the gaps and challenges for recording loss data in Europe with participants from Member States, United Nations Office for DRR (UNISDR) and academic and scientific institutions. The EU working group main aim was to establish a common framework for recording disaster damage and loss data in the European Union, but the situation is still characterized by gaps and high level of fragmentation that needs to be improved in order to have a more integrated interpretation of events' impacts with a view to support a variety of actions. Available post event damage data still present many weaknesses since they do not allow to perform robust statistics and analyses due to the lack of standardization in the collection methodologies and the inconsistent adopted taxonomy; and, their reliance is questionable since they are not based on evidence-based assessments: they can be either affected due to the lack of integration between different phases of the damage data collection (collection – storage -management) and the original information is usually transferred from one source to another through traditional flat files, or retrieved from unverified organizations and media reports which provide only preliminary estimates and thus enter the international loss databases. In regards, since as underlined by a 2013 report (De Groeve et al., 2013) much information and useful knowledge can be drawn from damage and loss data, detailed studies have been conducted in EU founded projects such as IDEA (see http://www.ideaproject.polimi.it), Educen (see www.educenhandbook.eu section 6) and LODE (see https://www.lodeproject.polimi.it).

Damage and loss data could support a variety of actions:

- Policy monitoring (construction of trends, observation of vulnerability and resilience fluctuation, forensic analysis)
- Policy actions (compensation, legislation, investments, cost benefit analysis)
- Prevention and preparedness (Early Warning Systems, response actions, reconstruction process with a view to build back better, response)
- Disasters' impact evaluation (loss accounting, systemic and cascading effects)
- Risk modelling (deterministic and probabilistic)

Therefore, the granularity of the data becomes fundamental. High level of detail would allow the aggregation of information according to geographical scale needed. Data should be collected at the asset level, for different societal sectors which consider both physical as well as functional and systemic damage, and the their temporal evolution. All the above features are key for their intrinsic multi-usability. Sharing a common goal with LODE project (https://www.lodeproject.polimi.it/) financed by DG ECHO, the RDH will take advantage of the technological development for the L&D data-recording interface. The outcome of this collaboration is foreseen to bring technological development for RDH in agreement to local needs.

However as mentioned, available data derive from unverified organizations and media reports which enter international loss databases frequently interrogated for numerous researches and analyses. In the following chapters, a review of available datasets - global, regional, national and local - is presented.

2.1 Global datasets

In the following sections different datasets are analysed and compared, defining the main peculiarities, strengths and weakness when possible.

The three global multi-peril loss databases, EM-DAT, NatCat and Sigma, which provide a global coverage for a large time span, are firstly discussed. The data of these datasets are entered in the system according to different criteria and definitions, below the description. However it is worth to mention that definitions are delineated and adopted according to the aim for which every database has been created (Menoni and Margottini, 2011).

The Centre for Research on the Epidemiology of Disasters (CRED) at Louvain University in Belgium manages the Emergency Events Database (**EM-DAT**) which started operating in 1988 with the initial support of the World Health Organization (WHO) and the Belgian Government is one of the most known global datasets, which focuses mainly on health aspects with information that dates back to 1900. The database encompasses humanitarian data such as fatalities, injured and evacuated. Moreover, economic loss data based on information provided by UN organizations and other institutions (Lloyds) and press agencies are present. Criteria for inclusion in the database are as follows: ≥ 10 people killed, and/or ≥ 100 people reported affected, and/or a declaration of a state of emergency, and/or a call for international assistance. The global database is publicly accessible previous registration, therefore is one of the most cited in literature. However, amongst disaster databases, EM-DAT provides one of the most comprehensive and transparent explanations of the methodology employed (Tschoegl et al., 2006; Wirtz et al., 2014). EMDAT defines a disaster as “a situation or event, which overwhelms local capacity, necessitating a request to national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction and human suffering” (CRED, 2006).

On the other hand, the database managed by SWISS RE of man-made and natural catastrophe losses (**SIGMA EXPLORER**) stores records which go back to 1970. The reinsurance company has been publishing annually statistical analyses since that time. Information regarding the hazard such as the date and location of the event are included, complemented by the value of the losses, victims, injured and homeless. The sources of the database are mainly insurance and reinsurance periodicals, internal reports, Lloyd's list, online database and news. Raw data are not openly available, only statistical analyses are publically accessible.

Finally, **NATCATSERVICE** from MUNICH RE was established in 1974, it contains only natural hazards related data. World-wide data suitable for analytical evaluation are available starting from 1980. In addition to metadata, information about insured and economic losses is present. Records are completed from information gathered through internal reports primarily and through external organizations. The database has closed accessibility. Reviews with essential information are published yearly.

Considering that, both Sigma and NatCat have been designed to meet insurance companies' needs, definitions and thresholds, therefore the meaning of the data, are far different from datasets created with other scopes. According to Sigma, "a natural catastrophe is a harmful event determined by natural forces. Such an event generally results in a large number of individual losses involving many insurance policies" (Swiss Re, 2018); while NatCat classifies disasters in four classes according to the economic losses caused (marginal, small, medium, large, and catastrophic). According to Munich Re Glossary (2018) a natural catastrophe is an "extreme natural forces causing human and/or economic loss of considerable scale and disruptions of societies. It can be of local, regional or global scale". In quantitative terms a catastrophic event is a "natural loss event with fatalities ≥ 1000 or normalised overall loss ≥ US$ 100m, 300m, 1bn, or 3bn depending on the assigned Worldbank income group of the affected country".

EM-DAT and NatCat contain individual entries for each country affected, while Sigma records the same event as the basis for each entry even if it affects multiple nations. Moreover, the dates of the events do not always coincide: the same event can be reported at different dates, EM-DAT which has humanitarian scope records the date in which it was declared the humanitarian emergency, while in the reinsurance datasets the date is related to the event occurrence itself (GFDRR, 2002).

However, global databases include mostly catastrophic events. Marginal loss events are ignored in statistical analyses. Applying minimum thresholds limits the understanding of the occurrence of smaller events.

Table 1. Global datasets and characteristics

	EM-DAT	**NatCat**	**Sigma**
Access	Public	Partially public*	Partially public*
Period covered	1900-present	1979-present	1970-present
Disasters Considered	Natural (considering epidemics), technological, conflicts	Natural	Natural, man-made
Main Sources	Un agencies, Lloyds, press agencies	Lloyds, internal reports, reinsurance periodicals	Lloyds, internal reports, reinsurance periodicals

*raw data are not accessible, only statistical analyses are published

At the global level, but hazard-based there are noteworthy initiatives:

- The Significant Earthquake Database of the National Geophysical Data Center (**NOAA**) which contains information on destructive earthquakes around the globe. Information concerning past events and their impact were collected in order to populate the RDH Historical Event Catalogue;
- The Global Landslide Catalog (**GLC**) accessible from the NASA's open data portal which stores information on mass movements triggered by rainfall around the world. Number of injured and fatalities and qualitative description of the event are the details collected from the open dataset.
- The "Global Active Archive of Large Flood Events" managed by the Dartmouth Flood Observatory (**DFO**), which documents flood events from 1985 to the present. The database provides tabular and georeferenced data of all flood events and includes information on location, rivers involved, beginning and end date where possible and duration, number of people killed/displaced, the cost and cause of damages, and information about the area affected, which is unfortunately roughly estimated, and qualitative magnitude of the flood. Government, academic institutions, news media provide information, along with satellite-based sources.

2.2 Regional and National Dataset

Countries do not always have procedures and databases to collect and store post-event damage data; in many countries there are no organizations in charge of collecting data and in the few countries where databases exist non-governmental institutions operate for the collection and management of the data (Wirtz et al., 2014).

The Network for Social Studies on Disaster Prevention in Latin America (LA Red) began developing the **DesInventar** methodology in 1994. Currently, the United Nations Office for Disaster Risk Reduction (UNISDR) is promoting a global initiative to create national disaster databases with a clear defined methodology, using for this purpose the DesInventar methodology and software. DesInventar maintains approximately 16 national level natural and technological disaster databases in Latin America. The databases represent over 44,000 disaster event entries. DesInventar collects variables such as number killed, injured, and estimated economic losses, but also attempts to collect damage variables related to infrastructure in order to track social effects of disasters. As the databases created with the Desinventar methodology contain data collected at the national level, more comprehensive information are being stored such as small and medium scale disasters that are often not represented in larger scale databases (Tschoegl et al., 2006). DesInventar utilizes government agencies, NGOs, and research institutes for source data; however it relies on news media as a priority source.

A well-organized country-level hazard database is **SHELDUS** for United States. It covers the period from 1960 to 2016 for several perils such as floods, wildfires, hurricanes, tornados etc. The database contains information on the date of an event, affected location (county and state) and the direct losses caused by the event and insured crop losses. Correspondingly, in Canada there is an ongoing effort to manage and record data in the Canadian Disaster Database (CDD). Data regarding natural, technological and conflict-related disasters and their impacts are collected. Government is one of the sources of information along with emergency management and insurance organizations (Tschoegl et al., 2006).

Whereas, considering European Countries and regions several are the different are the datasets or the initiative launched to collect damage and losses data. However, they generally focus on small areas or on few hazards if not even only one.

Examples are the **Swiss Flood and Landslide Damage Database** managed by the Swiss Federal Research Institute WSL which has been systematically collecting information on flood and mass movement damage in a database since 1972, being Switzerland recurrently affected by hydrogeological events (Hilker et al., 2009); and, the DISASTER database for Portugal (Zezere et al., 2014). The **DISASTER** database contains georeferenced information about floods and landslides and their impacts in Portugal in the period 1865-2010.

Another regional case is the database of Mediterranean Flood Fatalities (**MEFF**). MEFF is the result of a study about flood mortality in the Mediterranean area covering a period from 1980 to 2015. Information on fatal accidents was disaggregated; the database is characterized by fields describing victim's profile and the circumstances of the accidents for five specific areas (Catalonia and Spanish Balearic Islands, South France, Greece, Calabria). It is interesting to mention that, in literature, often the number of fatalities caused by natural hazards as floods, storms, and landslides are aggregated, making it impossible to analyse them separately. While the research in consideration focuses on flood fatalities only with a special regard to the understanding of the features leading to fatal accidents in a specific geographical framework. The construction methodology of this database represents a good step towards the challenge posed from the Sendai Framework guidelines to collect damage and loss data to construct the population's indicators.

A significant collection of damage and loss data is the 'Historical Analysis of Natural Hazards in Europe' database (**HANZE**) of the Delft University of Technology which provides a compilation of past damaging floods for 37 European countries. Comprehensive and accurate information on date, location, extent and economic losses of past damaging floods from 1870 to 2016 is provided. Considering that *histo*ric data on floods losses and casualties are neither comprehensive nor standardised for European Countries (Mitchell 2003), the study represents a significant effort done to alleviate the situation. Records of past events were obtained from a large variety of sources (more than 300), including international and national databases, scientific publications, and news reports. However, as events which affected only a small part of one region, with no fatalities and less than 200 persons affected, were not included, the database excludes event which can be significant for specific geographic and social context of Europe.

However, in addition to all the previously analysed datasets, other initiatives worth of attention are described below. Several are the local and single-hazard datasets that generally focus on small areas, so that the data have a high resolution and contain information which can be used to answer to the Sendai Framework for Disaster Risk Reduction 2015–2030 (UNSIDR, 2015) call, such as the identification of possible vulnerable groups in terms of gender and age, and the recognition of the circumstance in which people lost their lives in order to reduce losses in terms of lives and affected people and to increase community resilience to geo-hydrological hazards. These initiatives are: studies regarding the impact of catastrophic events for 141 countries over the period 1981-2002 and its interaction with the genders (Neumayer and Plumper, 2007), the study of Salvati et al., 2018 which specifically considers the gender and the age of fatalities occurred due to flood events; and other works such as LAND-deFeND (Napolitano et al., 2018), DamaGIS flood geodatabase for France (San-Martin et al., 2018), Inungama, a flood geodatabase for Catalonia (Barnolas et al., 2007); Global Volcanism Program (GVP) of Washington D.C. which documents current and past activity for all volcanoes on the planet active during the last 10,000 years (GVP, 2013); related to floods at national level existing databases are: HOWAS21 database (Kreibich et al., 2017) in Germany, Swiss Flood and Landslide Damage Database (Kron et al., 2012) in Switzerland; FloodCat database (Molinari et al., 2013) in Italy; AZORIS, GIS database for Azores which contains data for different hazards (Gaspar et al., 2004); the National Landslide Databases of Great Britain and Slovenia (Foster et al., 2012; Komac et al., 2015). Moreover, specific technological disaster datasets that should be mentioned are MARS (Major Accident Reporting system) managed by the JRC of the European Commission which records industrial accidents that have occurred since 1980, with information on the date of incident, type of industry, accident type, substance type, immediate effects such as fatalities, injured, material loss, emergency measures taken and lesson learned; and MHIDAS (Major Hazard Incident Data Service) maintained by AEA Technology on behalf of the UK Health and Safety Executive which records disaster involving hazardous materials with a worldwide coverage, but focusing mainly on events occurred in the UK and the US (Menoni and Margottini, 2011).

3 The RDH Historical event collection methodology

Considering the circumstances related to the weaknesses and gaps of the methodologies for the collection of damage and loss data and therefore their resulting quality and resolution, an effort has been done to improve the fragmented situation of European-wide damage and loss available data through the creation and compilation of the RDH Historical Event Catalogue.

The methodological approach used for the construction of the first RDH Historical Event Catalogue model is based on the systematic collection of damage and loss data, preliminary from various publicly accessible sources to start shaping the RDH archive. A large number of sources have been consulted encountering many challenges and restrictions.

Despite the uncertainty that can affect historical data, the collected available data represent the only tool for the construction of databases of hazardous events and their impacts over a large area as the one used for the RDH Historical Event Catalogue.

Different open access datasets have been interrogated collecting European-related records on past disastrous events. Both hazard and loss data have been systematically collected from various sources, crosschecked, linked and homogenized to be provided in tabular and geospatial format. Every available record has been crosschecked with the previous data, and the catalogue has been updated, or modified accordingly. As a result, the original information contained in the different sources consulted has been improved by compiling and linking it with information from other sources to construct the Catalogue.

This collection, obtained from available existing historical data, presents incompleteness due to the aforementioned gaps of the current situation. As consolidated in the literature, it is impossible to validate most of the data coming from open dataset, because independent additional information is not available (Petrucci et al., 2018). Actually the common situation is that available information is barely sufficient to compile comprehensive and complete catalogues and datasets. The level of reliability of the collected disaster damage and loss data cannot be really delineated. According to the study conducted in De Groeve et al. (2014) the level of reliability, which is generally associated to quality, depends on the type of procedure used for the quantification of a given loss component and the availability of adequate and sufficient data to perform such quantification. But available data is frequently insufficient, such as in the current case, consequently it is not possible to perform adequate statistical analysis to define the quality level. The Pedigree method (De Groeve et al., 2014) could be an appropriate mean to analyze the overall quality of the process that lead to the data under analysis, but it requires information regarding both collection and processing of the data, which are currently unavailable for the sources and datasets interrogated for the present work. For instance, the Pedigree method requires information regarding accuracy during the collection phase – method, human error analysis – comparison with independent measurements, reliability of the source – data based on measurements or assumptions, completeness etc. Given the available data, it is not even possible to express a level of agreement or disagreement between different sources since rarely the same record has been found more than once. Therefore, defining qualitative expressions of uncertainty is the only option.

Moreover, the collected data are partially compliant with the Sendai Framework Indicators. Information about mortality can be retrieved (Target B), but reliable information about affected people (Target A) becomes already an issue since datasets have different or not clear definitions of "affected people". No evidence is present regarding critical infrastructures and basic services; available data consist in the total "Economic Loss" and no indication is available regarding the impact on different societal sectors (Target D) neither regarding the estimation method.

However, the work carried out is not focused on testing the quality of existing records, but rather on collecting, crosschecking and linking information deriving from heterogeneous sources to provide a comprehensive set of damage and loss data occurred in European Countries due to hazardous events according to the available data.

The present work, which originally aims at making the best use of available data to start shaping the RDH Historical Catalogue, on the one hand represents the first step towards the objective of improving the fragmented situation where most of the studies carried out and the information remain spread without having the possibility to be exploited according to their potential. On the other hand, highlights the scarcity of quality damage and loss data which are essential for different purposes in all the phases of the DRM cycle creating further awareness regarding gaps in the current situation which should be filled with better developments, improvements and researches.

4 The RDH Historical Event Catalogue Characteristics

4.1 Hazard consideration

Four modules compose the RDH Historical Event Catalogue. Each module corresponds to the hazards considered for the collection of damage and loss data and differs in terms of temporal coverage and variables considered. Specifically, the hazards considered in the present work are:

- FLOOD precisely:
    - RIVER FLOOD
    - FLASH FLOOD
    - COASTAL FLOOD
- EARTHQUAKE
- FOREST FIRE
- LANDSLIDE

4.2 Spatial coverage

The RDH Historical Event Catalogue covers almost all the European area. The records collected refer to all 28 European Union member states, all European Free Trade Agreement members, the four microstates located in Western Europe (Andorra, Monaco, San Marino and the Vatican) and one Crown Dependency of the United Kingdom (Isle of Man).

4.3 Temporal coverage

The RDH Historical Event Catalogue is characterized by an assorted temporal coverage for each hazard considered. As data have been retrieved from different sources, the catalogue has been shaped in accordance with the available information. The time coverage details are listed in Table 2 according to each module of the catalogue.

Table 2. RDH Historical Event Catalogue's time coverage by hazard considered

HAZARD		**Time Coverage**
FLOODS	RIVER FLOODS	1871-2018
	FLASH FLOODS	
	COASTAL FLOODS	
EARTHQUAKES		1992-2018
WILDFIRES		2000-2018
LANDSLIDES		1993-2018

4.4 Source of information

The sources of information consulted during the research to collect information in order to define occurred events, and their impact are listed below:

- Historical Analysis of Natural Hazards in Europe' database of the Delft University of Technology (HANZE) which provides a compilation of past damaging floods from 1870 to 2016 for 37 European countries.
- The Dartmouth Flood Observatory (DFO) at the University of Dartmouth in USA which is a global data depository for spatially referenced floods, which covers the period from 1985 to the present.
- The SHARE European Earthquake Catalogue (SHEEC): a set of seismic events occurred in Europe, with the exception of Greece and surrounding areas, from 1900 to 2006. Mainly the information contained in the catalogue regards: date, time, magnitude, latitude and longitude.

- The Greek seismological catalogue of the University of Athens containing hazard related information.
- The Significant Earthquake Database of the National Geophysical Data Center (NOAA).
- Information concerning the date, location and geographical extent of forest fires was provided by the European Forest Fire Information System (EFFIS). The time coverage of the forest fires ranges from 2000-onwards. Moreover, information on fatalities and injured was retrieved from annual reports of EFFIS, though the information is given for fire-season and not per event.
- The Global Landslide Catalog (GLC) accessible from the NASA's open data portal contains information on mass movements triggered by rainfall around the world and their impact. Number of injured and fatalities and qualitative description of the event are the details collected from the open dataset.
- The Emergency Events Database (EM-DAT) of the Centre of Research on Epidemiology of Disasters in Brussels and United States Office for Foreign Disaster Assistance.
- Copernicus Emergency Management Service (Copernicus EMS) provides information for emergency response in relation to different types of disasters. Satellite imagery is the main data source; the produced maps from the list of activations of rapid mapping were connected to the RDH Historical Event records.
- The free online encyclopaedia Wikipedia was also used as a source of information to delineate the impact of past events especially quantitative information such as fatalities, injured and economic losses was collected.
- The Emergency Response Coordination Centre (ERCC) Daily Maps service of the European Commission has been consulted. The ERCC publishes maps, available to the public, regarding the most important events which contain concise information regarding the impact and the extension of events.
- FloodList, founded by Copernicus, which brings news and information on floods, occurred worldwide, is another source consulted.
- Europe Media Monitor (EMM) natural hazards dataset is a source of information considered for RDH Historical Event Catalogue. Data from this source are not yet implemented; however in the near-future EMM data will be included in the catalogue.

However, sources serve for different purpose: some identify the event; others offer records about the event's losses and damages while others provide the location and the extension of the disastrous event. This work provides a methodological example in bringing together all these information.

HAZARD CATALOGUES

Mainly information such as date of occurrence, geographical extent, location and intensity of the events has been collected from Hazard Catalogues and where necessary this information has been georeferenced through GIS software.

The different sources analysed are reported below for each hazard:

- FLOODS : Hanze, DFO
- EARTUQUAKES: SHEEC, University of Athens Catalogue, NOAA
- FOREST FIRES: EFFIS
- LANDLIDES: GLC

DAMAGE AND LOSS SOURCES OF INFORMATION

In order to have a complete catalogue, additional source of information have been analysed to gather historical impacts of disastrous events.

The different sources analysed are reported below for each hazard:

- FLOODS : Hanze, DFO, EM-DAT, COPERNICUS, WIKIPEDIA
- EARTUQUAKES: NOAA, EM-DAT, WIKIPEDIA
- FOREST FIRES: EFFIS, WIKIPEDIA
- LANDLIDES: GLC

4.5 Criteria of selection for inclusion in the database

Within RDH Historical Event Catalogue an historical event is defined by a temporal and spatial extension, magnitude of impact, hazard type, cause, damage type and reference of the event (source or original ID).

Criteria of selection for inclusion in the catalogue were not specifically severe. Since the present work consist in an effort done to bridge the gaps between the information generated from different sources, the primary and most essential inclusion criteria is: at least one of the record's attributes related to the impact (see Annexes 1, 2, 3 and 4) had to be available for an event. It is important to be noticed that, since the catalogue is a collection of damage and loss data, the records are entered by impact accompanied by adequate information to identify the event or the phenomena (see first technical report JRC114712 on DRMKC RDH). However, it is common (and depending on the source and of the hazard) that the location of the impact is referred to the spatial occurrence of the hazard (i.e. EM-DAT for an earthquake the location consist in the epicentre and not in the place of occurrence of the damage). The Landslide Module represents another example, where data retrieved (in this case from the GLC Catalogue) covers incomplete impact record types (and this is the case of all the datasets used in the RDH). The impacts recorded refers to injured people and fatalities but not to other impacts (e.g. affected people or economic losses). Therefore, for the some impact types, the event is reported in the catalogue even if no impact was reported.

Hazard event identification provides data to characterize the event both in terms of spatial and temporal scale, however datasets do not provide detailed information. According to De Groeve et al (2013) the loss database should contain enough data on the hazard to uniquely identify it and to provide useful search and filtering functions for studies and analyses.

4.6 Challenges

As different sources were analysed, data collected with different approaches and for different scopes were stored, therefore many difficulties, in terms of creating a catalogue with homogeneous data, were encountered. Main challenges in creating a coherent catalogue were due to:

- Differences in the time of occurrence
- Differences in the definitions of the attributes
- Differences in classifying the type of disaster
- Differences due to more than one entry of a single event
- Differences in classifying the spatial extent and the exact location of an event
- Differences in the definitions of the indicators
- Differences in currencies and prices of economic losses

Differences in the time of occurrence

An event could be reported at different dates, especially disasters like floods which end also after couple of months. In this case, the events had to be verified and crosschecked with the location primary and other attributes to know whether or not it was the same event coming from other sources. In addition, according to the literature EM-DAT records the day it was declared as humanitarian emergency (GFDRR, 2002), while other sources usually record a period for the disaster itself (start/end) and not always the criterion by which the end date is set by some datasets is known.

Differences in classifying the type of disaster

Disasters are not always classified in the same way by different databases. This becomes an obstacle especially in the case of associated disasters or secondary disasters, for example a flood which caused landslide or an earthquake which triggered an avalanche, may be recorded as one or the other (i.e. the event occurred in South Italy, specifically in Abruzzo region on 18th January 2017, where an avalanche has been triggered by different shakes causing 29 fatalities). Verification that two different disaster types occurring in the same country on the same day should be done. This is not always possible especially if location is not properly assigned in the different databases.

Differences due to multiple entry of a single disaster event

A disaster could be registered as multiple events, if they occurred in different regions of a country in consecutive time and the same event could be recorded in another data set as a specific single event with the total dead and affected for all the affected areas. This situation came across the linking phase between different sources such as COPERNICUS rapid activation mapping for flooding events and HANZE dataset or Daily Maps from DG ECHO for forest fires and EFFIS burned area polygons. A clear example could be the heavy rainfall events happened in United Kingdom during the winter of late 2015 and beginning of 2016 which led to flooding in a vast area. HANZE database reports a single event with start date on 05/12/2015 and end date on 26/01/2016 with flood source the Ouse River (England) while COPERNICUS makes available two activation maps with two specific unique identifier codes one with activation on 05/12/2015 for Cumbria region and one on 27/12/2015 for England. Moreover, this specific case remains not easy to handle as in the same period a flood occurred also in Northern Ireland, so Wikipedia consider all the events under the name "2015-16 Great Britain and Ireland floods" and COPERNICUS makes available another map produced on 11/01/2016 for Northern Ireland. Therefore, it becomes complicated to link the events under a clear and specific record.

Differences in classifying the spatial extent and the exact location of an event

A disaster could be reported two times in the same database, under two different ID or the same according to the entry criteria. This case was encountered specifically in the cases of cross-border events which are generally doubled and not always information about the proportion of the impact on each country/region involved is available.

Differences in the definitions of the indicators

Generally definitions are given for each dataset; however, there is an ambiguity of terminology that makes difficult to delineate what some indicators precisely represent (i.e. affected, displaced and/or evacuated people). This limits comparisons between data retrieved from different sources. A concrete example is the definitions given by DFO e HANZE database:

— AFFECTED PEOPLE (HANZE): "Number of people whose houses were flooded. The reported numbers often only show the number of evacuees or homeless persons. If only the number of houses flooded was reported, the number persons affected was estimated by multiplying the number of houses by 4".

— DISPLACED PEOPLE (DFO): "This number is sometimes the total number of people left homeless after the incident, and sometimes it is the number evacuated during the flood. News reports will often mention a number of people that are 'affected', but we do not use this. If the only information is the number of houses destroyed or damaged, then DFO assumes that 4 people live in each house. If the news report only mentions that "thousands were evacuated", the number is estimated at 3000. If the news reports mention that "more than 10,000" were displaced then the DFO number is 11,000 (number plus 10%). If the only information is the number of families left homeless, then DFO assumes that there are 4 people in each family".

Accordingly, it is noticeable that definitions are not clear, moreover during the work it has been noticed that for some events the two values were exactly the same and for others they showed complete different order of magnitude. This led to confusion making the linkage process fairly complicated. In order not to miss the information from DFO a different class of attributes has been created to store the "Number of displaced" so that the user can evaluate which specific value is preferable for his case according to the definitions.

Differences in currencies and prices of economic losses

The different sources of information analysed during the study, reported different currencies of the economic losses. For instance, EM-DAT reports economic losses in American dollars, while HANZE reports economic losses in the currency used at the time of the event and then the same amount converted in euro in 2011 prices. Therefore in order to make a homogeneous and standardized collection the economic losses needed to be converted.

4.7 Conversion of economic damage values

Economic losses collected during the study needed to be adjusted in order to have comparable values. Principally economic losses occurred due to floods and earthquakes were collected. The main sources of information were: HANZE, EM-DAT, and Wikipedia.

HANZE database contains economic losses both in the original currency of the time of the event (nominal values) and in Euro deflated to 2011 prices. Though, in EM-DAT, the value of estimated damage in monetary terms is given in Dollars (US $). For each disaster the amount of damage corresponds to the damage value at the time of the event. Finally Wikipedia either reports the damage in dollars or in Euro.

Therefore in order to make a homogeneous and standardized collection the damage data in monetary terms needed to be converted. The conversion has been conducted following the same approach of HANZE database. Sendai Loss Data guidance invites States to express losses into USD, to enable global summation and recommends to use official exchange rate, in the RDH catalogue losses are adjusted but converted in Euro since comparison is done between European countries. However nominal loss and GDP deflator are at the base of the computation, the reference year is selected to homogenize all the values and from the reported adjusted losses using the correct methodology it is possible to further convert in USD deflated to the preferred year of reference.

HANZE database consists in a comprehensive set of data and information, it provides a set of currency information, GDP data and deflator indexes for the area and time coverage considered in the study establishing the 2011 as the reference year. Thereafter, in order to make all the records homogeneous and comparable, HANZE methodology has been adopted for economic losses deriving from other sources. However, as aforementioned in EM-DAT and Wikipedia the estimated damage in monetary terms is given in dollars (US $) but HANZE does not provide a methodology for the exchange rates. Conversions have been carried out through a methodology accessible from the Portal for Historical Statistics of Stockholm University (Historical currency converter edited by Rodney Edvinsson).

The economic losses measured in dollars at the time of the event have been converted in the currency of the country at the time of the event (nominal values). After that, the currencies have been converted and normalized in Euro- 2011 prices- using the conversions factors between new and old currencies and the GDP deflator indexes of HANZE database.

An example of conversion and normalization to 2011 prices is shown below.

The sample of the explanation regards the earthquake of magnitude 7.3 happened in Romania in 10/11/1940. According to the RDH Historical Event catalogue the occurrence of this event caused a total of 1000 fatalities and 4000 injured. Recorded economic losses are equal to 10 million dollars (US$) at the time of the event.

Following the aforementioned procedure the conversion has been carried out as follow:

Through the Historical Converter the equivalent of 10 million Dollars (US$) in year 1940 has been transformed in ROS in 1940 prices equal to 1986 million Romanian Silver Leu:

10 mln US$ (1940) = 1986 mln ROS (1940)

Once the nominal value has been obtained, it has been converted to Romanian Socialist Leu, Old Leu and finally to the current Leu:

1986 mln ROS /20000/20/10000= 0.4965 RON

The obtained value of current Leu has been divided by 4.2391 to obtain the value in Euro and finally adjusted with the Deflator index (2011 prices):

10 mln US$ (1940) = 39902 mln EUR (2011)

5 The RDH Historical Event Catalogue

The RDH Historical Event Catalogue is a collection of past events occurred in EU created from a wide array of data published in several sources and databases. It offers an overview of currently available collection of extreme events and related losses and damages. Therefore the data collected is not an aggregation of official national datasets, but rather a collection of sources that become complementary in a collection of existing practises, which use methodologies and practices widely used and recognized at scientific and policy level.

5.1 Content overview

As a result of the research, a catalogue composed from four modules, corresponding to the hazards considered has been created. The RDH Historical Event Catalogue presents a ***total of 18960 records***, both in tabular and geospatial format.

Each event-module differs in terms of temporal coverage and variables considered.

The module containing the Flood's records covers a period from 1870 to 2018. It is composed from three subclasses with data regarding:

— River floods: 827 events

— Flash Floods: 879 events

— Coastal floods: 56 events

In the **Flood's module** fatalities, affected, flooded area and economic losses (mln euro in 2011 prices) are reported.

The **Earthquake's** module contains a total of 211 events occurred in in the period from 1901 onwards; each event is characterized by the magnitude and the exact time of occurrence. Moreover, information regarding fatalities, injured, affected and economic losses (mln euro in 2011 prices) is presented.

The **Landslide's** module covers a period from 1993 to 2018 comprising a total of 580 events across Europe. Each event is qualitatively described in terms of spatial extent and information about injured and fatalities is reported.

Finally the **Wildfire's module** is characterized from a relatively minor temporal coverage in comparison with the aforementioned modules, though it embraces a comparatively big amount of hazard-related records. The wildfire's records have not been classified as events; the catalogue includes a total of 16407 burned areas across European countries called "Phenomena" according to the architecture of the RDH (see Antofie, T. et al., 2019). As these records are most of the time seasonal or linked with climatology (heat waves, drought) the inventory of burned areas is aggregated according to the season or time period the records refers to. Therefore, finally the module contains numbers of fatalities and injured per fire-seasons and total area burned as well. Tables 3 and 4 present detailed information regarding the collected records.

Table 3. Total sum of fatalities, injured and affected people per hazard

HAZARD		**Time Coverage**	**#EVENTS**	**#FATALITIES**	**#INJURED**	**#AFFECTED**
FLOODS	RIVER FLOODS	1870-2018	827	5769	-	6037963
	FLASH FLOODS		879	10510	-	1118692
	COASTAL FLOODS		56	2225	-	352471
EARTHQUAKES		1992-2018	211	125399	54428	2526894
WILDFIRES		2000-2018	-	662	3359	-
LANDSLIDES		1993-2018	580	231	103	-

Table 4. Total sum of economic losses and affected area per hazard

HAZARD		Time Coverage	#EVENTS	ECONOMIC LOSSES (Mln EUR 2011)	AFFECTED AREA (km^2)
FLOODS	RIVER FLOODS	1870-2018	827	144953	116513
	FLASH FLOODS		879	69371	2904
	COASTAL FLOODS		56	13483	3791
EARTHQUAKES		1992-2018	211	170915	-
WILDFIRES		2000-2018	-	-	66256
LANDSLIDES		1993-2018	580	-	-

*Wildfires are not grouped in events because of coherency with definitions; however the collection presents a total of 16407 burned area polygons

5.2 Comprehensiveness, completeness and origin of the data

Given the differences between the origins of the data, some data processing has been performed.

Not every record entered in the RDH Historical Events Catalogue presents complete set of values for the damage and losses attributes (see Annexes 1, 2 3 and 4); but, more significantly, it is important to highlight that often, if not even always, it is not specified if the value of some attributes was not recorded or it was null. A detail of great importance, which would have been beneficial to know for indicators such as fatalities, injured and affected. Not having available and clear indicators makes comparisons less reliable and statistics inconsistent and highlights the need for a more systematic and comprehensive damage and loss data collection. A comparison of the events and records is presented in Table 5.

Table 5. Comparison between events and total records present in the catalogue

HAZARD		Time Coverage	#EVENTS	FATALITIES	INJURED	AFFECTED	ECONOMIC LOSSES (Mln EUR 2011)	AFFECTED AREA (km^2)
FLOODS	RIVER FLOODS	1870-2018	827	505	-	358	38	122
	FLASH FLOODS		879	720	-	306	236	23
	COASTAL FLOODS		56	34	-	21	10	14
EARTHQUAKES		1992-2018	211	153	106	82	57	-
WILDFIRES		2000-2018	-	-	-	-	-	ALL
LANDSLIDES		1993-2018	580	55	30	-	-	-

Additionally, a quantitative analysis of the origin of the data, by hazard type, has been carried out.

For the Flood's module most of the data were implemented from HANZE database. Nevertheless many of the events reported in HANZE have been found in the DFO database and connected. Some Copernicus activations have been correspondingly linked. For the river flood a total number of 827 records is present, of this amount a total of 629 has been directly implemented from the HANZE-Event database. However, 119 events have been found in DFO, therefore the ID code used in the database has been inserted in the "Source" category of attributes. Finally, to 11 of those an ID code of the Copernicus rapid map activation has been linked. Though, the remaining 198 records have been implemented directly from the DFO database, from those events 13 have been linked to the ID code of the Copernicus rapid map activation.

While for the flash floods over a total of 879 records coming from HANZE database a link has been done with DFO for 77 events and 8 with Copernicus.

Regarding Coastal floods only 2 events have been found in the DFO.

Concerning Earthquakes, SCHEEC and Athens's University Seismological Catalogue were the main fonts for the hazard-related information (latitude, longitude, time of occurrence, magnitude). While for damage and loss data most of the information was retrieved from EM-DAT, NOAA and Wikipedia. A number of 61 events has been collected from SHEEC and 29 from Athens's University Seismological Catalogue. While over the total number of collected events, 96 has been found in EM-DAT, 90 in NOAA and 118 in Wikipedia.

Although, temporarily for the Landslides module no double-check and linkage with different sources has been carried out since no open-source dataset or available information have been collected yet.

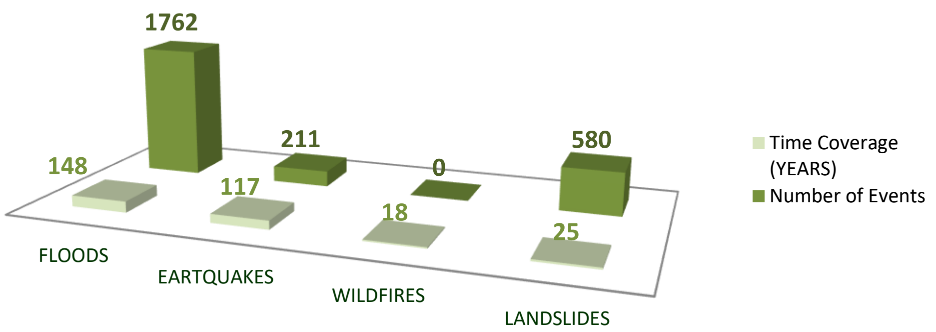
Concerning the Wildfire module, no number of events is present, however the RDH Historical Event Catalogue stores a total of 16407 records of burned areas across European countries reporting georeferenced location, date and hectares impacted. Yearly number of fatalities and injuries has been collected for the period 2000-2018 for the most affected European countries.

6 Analysis of the collected data

The following section offers an overview of the collected data through analyses and comparisons in order to have a more quantitative understanding of the damage and losses caused by natural hazards across Europe.

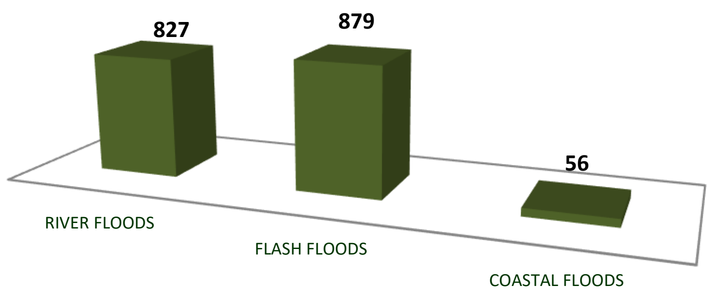
A general overview is presented in order to understand the amount of data collected and their respective values. However, an indicative exploration of the records is firstly performed considering that the different modules present very heterogeneous time coverage; therefore, comparisons need to be performed carefully. It is worth to specify that the wildfire's number of events has been reported intentionally equal to zero since this study doesn't focus on the definition of "Events" and for this hazard a total amount of 16407 burned areas across European countries is collected and these records are generally referred to seasons or linked to climatology (heat waves, drought), hence the inventory of burned areas is aggregated according to the season or time period the records refers to (Fig. 1).

Figure 1. Number of events in relation with the time coverage of the module



As illustrated in Figure 1 the RDH Historical Event Catalogue presents higher number of records for floods. This for two reasons: (1) most of the data have been retrieved from a solid and robust dataset which focuses only on flood events (HANZE Dataset); (2) the records go back to 1870; therefore, events occurred in 148 years are collected. Those past events have been classified in river, flash and coastal floods (*Fig. 2*).

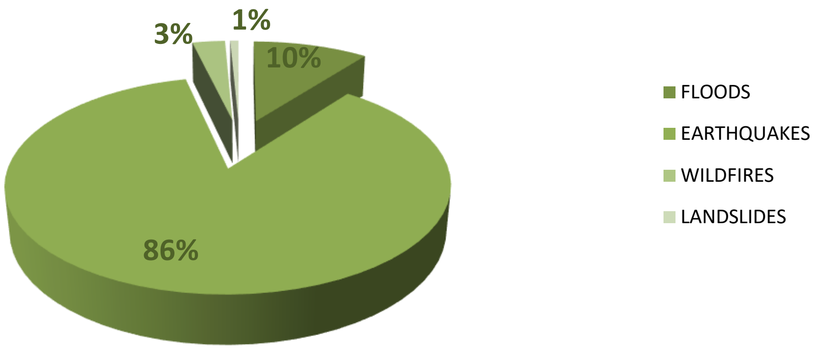
Figure 2. Number of Floods by type



Complementary to this, the RDH Historical Event Catalogue contains earthquake's records happened in the last 117 years across Europe, wildfire's records for a time span of 18 years; finally, landslide's records for a period of 25 years.

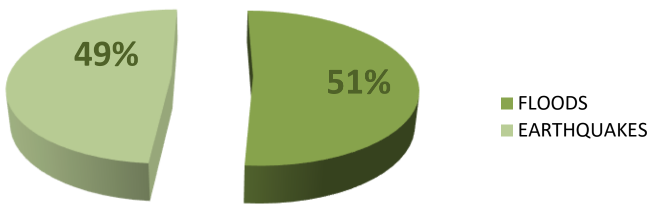
Considering the differences of the temporal coverage for the hazards considered in the RDH Event Catalogue, Figure 3 illustrates the average of causalities by year displaying a greater percentage (86%) for earthquakes fatalities which reach a total of 125399 fatalities during 117-years, followed by floods fatalities (10%) equal to 19107 occurred during the last 148-years. Minor percentages refer to wildfires (3%) and landslides (1%) fatalities; 662 fatalities occurred in the last 18-years due to wildfires and 231 fatalities occurred due to landslides in the last 25-years are recorded in the RDH Catalogue.

Figure 3. Share of average number of fatalities by year



The RDH Historical Event Catalogue contains damages in monetary terms for floods and earthquakes. Specifically, within the 148 years considered, floods caused a total of 230 billion Euros worth of damage. On the other hand, over a 117-year period considered, earthquake caused 170 billion Euros of damage. The proportion of the economic losses is shown in Figure 4.

Figure 4. Share of average economic losses by year



6.1 Most destructive events

From the analysis of the collected data, a list of the deadliest and costliest events can be defined. Examining the data, regardless the temporal coverage of each module, the values listed in Table 6 have been retrieved.

Table 6. Deadliest and costliest events

		THE DEADLIEST			**THE COSTLIEST**		
		COUNTRY	YEAR	FATALITIES	COUNTRY	YEAR	mln € (2011)
FLOODS	RIVER FLOODS	France	1875	500	Italy	1966	11863
	FLASH FLOODS	Spain	1962	805	Spain	1983	11521
	COASTAL FLOODS	Netherlands	1953	1835	Germany	1962	4932
EARTHQUAKES		Italy	1908	75000	Italy	1980	44000
WILDFIRES		Greece	2018	100	-	-	-
LANDSLIDES		Portugal	2010	42	-	-	-

The deadliest flood, between the different types, was the North Sea flood occurred in 1953. The flood caused by a heavy storm struck in the Netherlands, Belgium and United Kingdom killed more than 2000 people (Gerritsen, 2005). The highest number of deaths, equal to 1835, was reported in Netherlands. On the other hand, the costliest one was a river flood occurred in Italy in 1966 causing about 12 billion Euros worth of damage. However, according to the data collected the deadliest river flood occurred in France in 1875 causing 500 deaths, while both the deadliest and costliest flash floods occurred in Spain. Finally, the costliest coastal flood occurred in Germany in 1962 causing about 5 billion Euros worth of damage.

No economic losses data are available for wildfires and landslides, however the deadliest landslide (42 deaths) refers to the event occurred on 20th of February 2010 in Madeira Island, Portugal. It is worth to notice that this record is a clear example of the challenges encountered during the research; since the landslide event under consideration was the result of an extreme weather event which caused an extensive flood and considering that the number of fatalities caused by natural hazards such as floods which triggered landslides is often an aggregated value (Petrucci et al., 2018), it becomes impossible to retrieve separately the exact number of deaths caused by the flood and/or the mudslide.

Through the last eighteen years, the deadliest wildfire season began in Greece in the Attica area in July 2018 during the 2018 European heat wave. A series of wildfires struck in the region causing 100 fatalities and 172 injuries. This incident is classified as the second-deadliest wildfire event in the 21st century, after the Black Saturday bushfires occurred in 2009 in Australia that caused 180 deaths (Wikipedia, 2018).

In conclusion, it arises that earthquakes are the most catastrophic natural hazard, in terms of both fatalities and overall economic losses caused per event. The most catastrophic earthquake between 1901 and 2018 in terms of fatalities was the Messina Earthquake occurred on 28th of December 1908 between Sicily and Calabria in southern Italy with a magnitude of 7.1 which caused 75000 deaths. On the other hand, the costliest event, between the most catastrophic events recorded in the catalogue, was the Irpinia Earthquake occurred in southern Italy on November 1980 with a magnitude of 7.2 which caused a total of 44 billion Euros of damages. However, as stated by Wirtz et al. (2014) the highest losses in economic terms are often caused by earthquakes.

6.2 Most affected countries

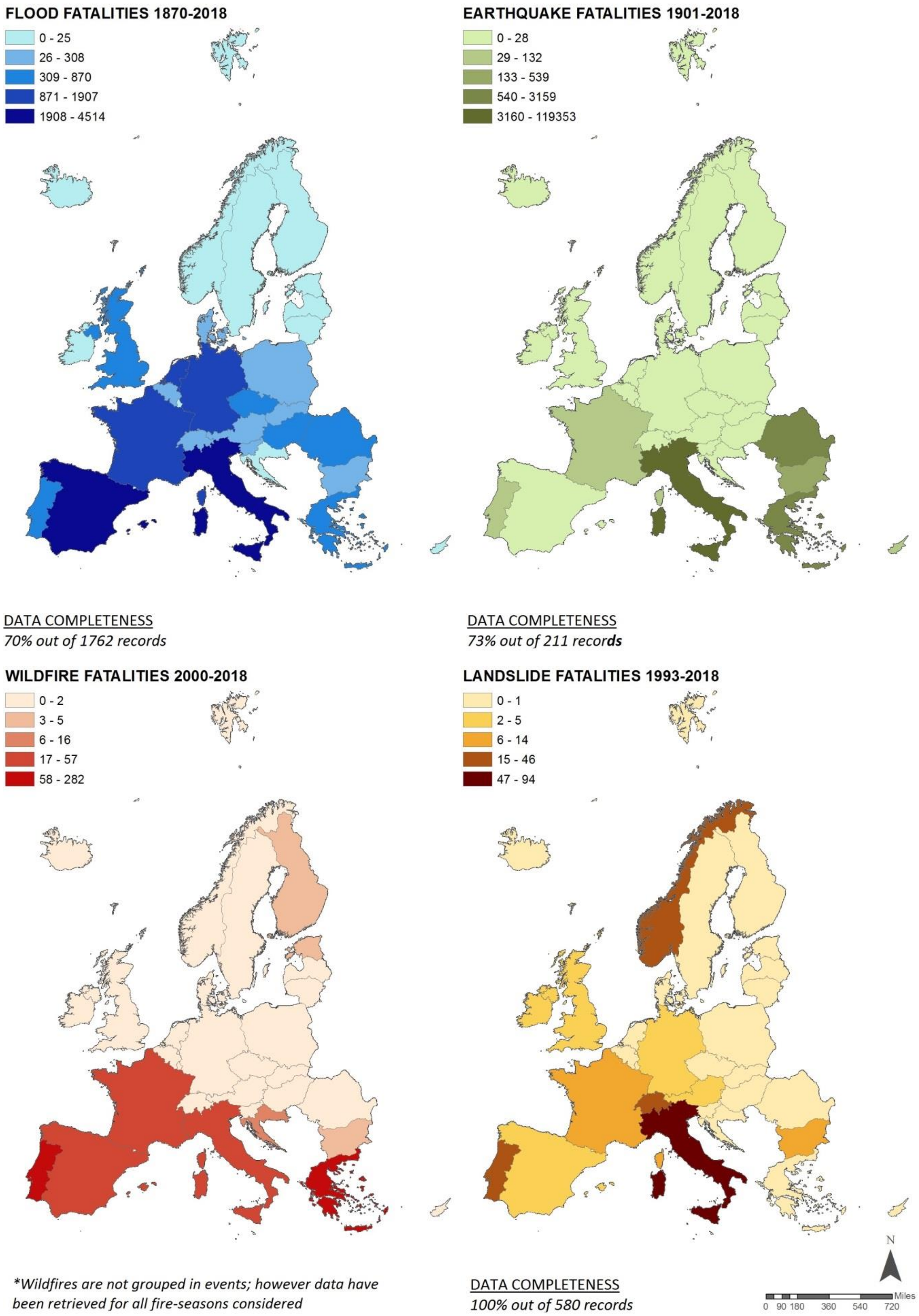
Data collected during the research can be analysed by country. Regardless the time coverage of each module, a ranking of the most affected counties can be performed.

Damage and loss data collected and stored in the RDH Historical Events Catalogue can be used to perform general analysis for European countries. According to the analysed values, the most affected countries in terms of fatalities are illustrated in Figure 5 for each time coverage and hazard considered. Spain and Italy are the most affected countries in terms of flood fatalities for the past 148-years followed by Netherlands. Italy stands between the most affected countries also for fatalities occurred due to earthquakes and landslides; while, for fatalities occurred due to wildfires, Greece is the most affected country, followed by Portugal. Detailed values are listed in Table 7.

Table 7. Top three most affected countries – FATALITIES AGGREGATED VALUE

	Time Coverage	**MOST AFFECTED COUNTRIES**	**FATALITIES**
FLOODS	1870-2018	Spain	4514
		Italy	4491
		Netherlands	1907
EARTHQUAKES	1901-2018	Italy	119353
		Romania	3159
		Greece	2056
WILDFIRES	2000-2018	Greece	282
		Portugal	201
		Italy	57
LANDSLIDES	1993-2018	Italy	94
		Portugal	46
		Switzerland	27

Figure 5. Fatalities Maps by hazard for specific time coverage

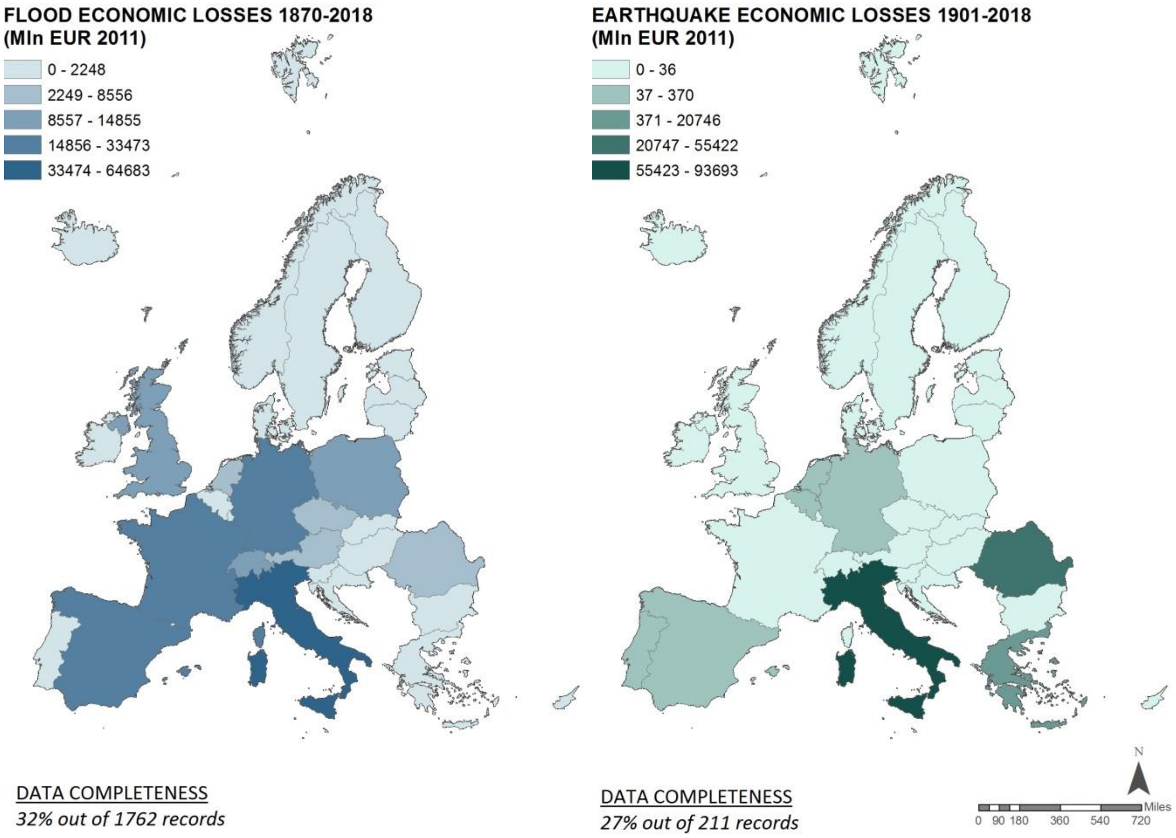


Losses in terms of economic impact are reported only for floods and earthquakes. Italy is the most affected country for both hazards (Fig. 6). Following, Germany and Spain are the second and third most affected countries concerning flood impacts; while concerning earthquakes' economic impact Romania and Greece are listed between the top three affected countries.

Table 8. Top three most affected countries – ECONOMIC LOSSES AGGREGATED VALUE

	Time Coverage	MOST AFFECTED COUNTRIES	ECONOMIC LOSSES (mln EUR 2011)
FLOODS	1870-2018	Italy	64683
		Germany	33473
		Spain	28144
EARTHQUAKES	1901-2018	Italy	93693
		Romania	55422
		Greece	20746

Figure 6. Flood and Earthquake Economic Losses for specific time coverage

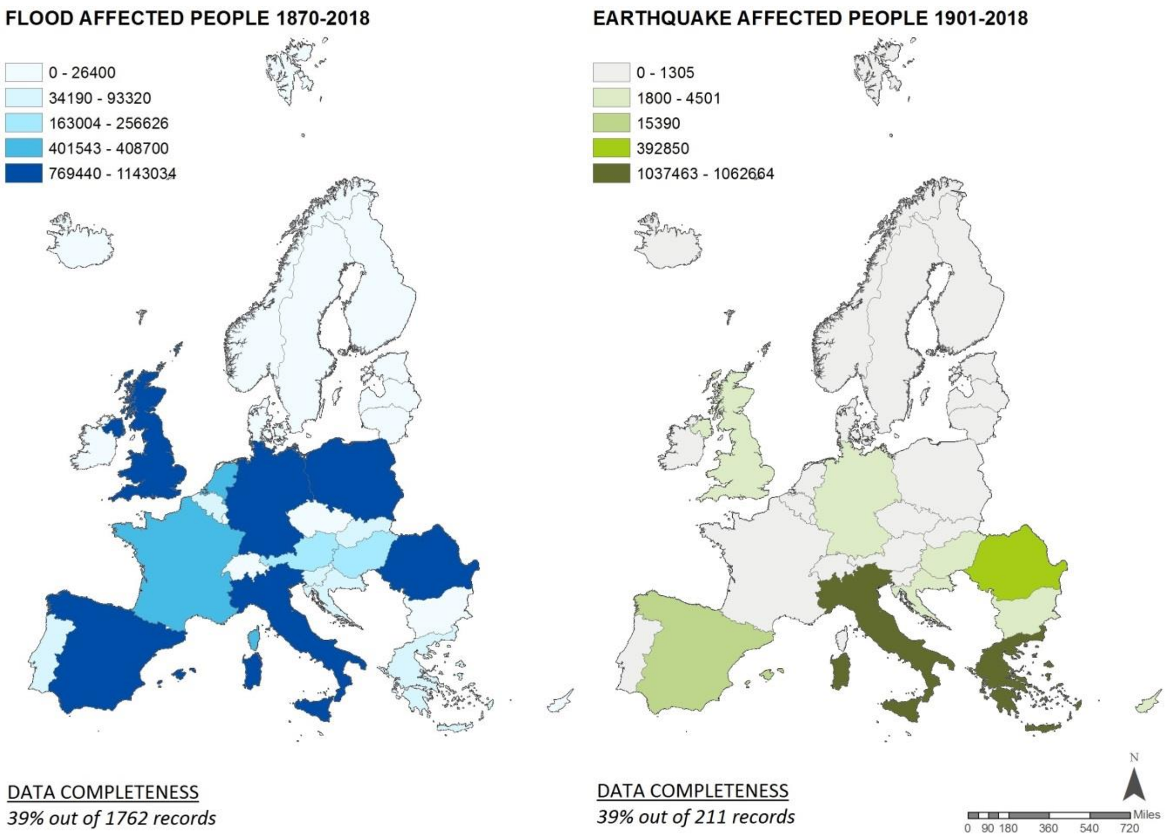


Moreover, an aggregated sum of affected people for the same two hazards has been performed (Fig. 7). Detailed values for the top three affected countries in terms of affected people are listed in Table 9.

Table 9. Top three most affected countries – AFFECTED PEOPLE AGGREGATED VALUE

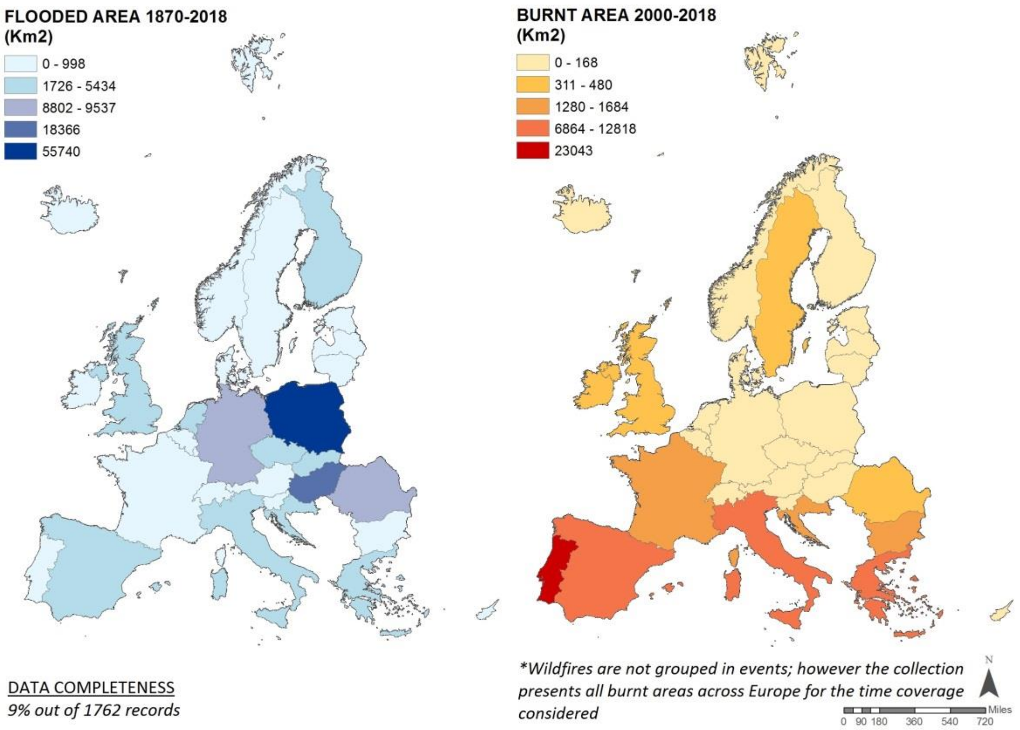
	Time Coverage	MOST AFFECTED COUNTRIES	AFFECTED PEOPLE
FLOODS	1870-2018	Poland	1143034
		Germany	922050
		United Kingdom	920235
EARTHQUAKES	1901-2018	Italy	1062664
		Greece	1037463
		Romania	392850

Figure 7. Flood and Earthquake Affected people for specific time coverage



According to the collected data, a comparison between the most affected countries in terms of flooded and burnt area can be performed (Fig. 8). The most affected countries in terms of flooded area, for the past 148-years, are: Poland (55740 km^2 of total flooded area, where the worse episodes have been in 1980 due to river flood - San, Wisłok, Odra, Wisła, Noteć, Wieprz, Bóbr - affecting a total of 17450 km^2 and in 1970 with an area flooded of 10000 km^2), Hungary (18366 km^2 of flooded area) and Romania (4783 km^2 of flooded area). While, concerning burnt areas, the most affected countries, for the past 18-years, are: Portugal (2304275 km^2 of burnt area), Spain (1281828 km^2 of burnt area) and Italy (754666 km^2 of burnt area).

Figure 8. Flooded and Burnt area for specific time coverage

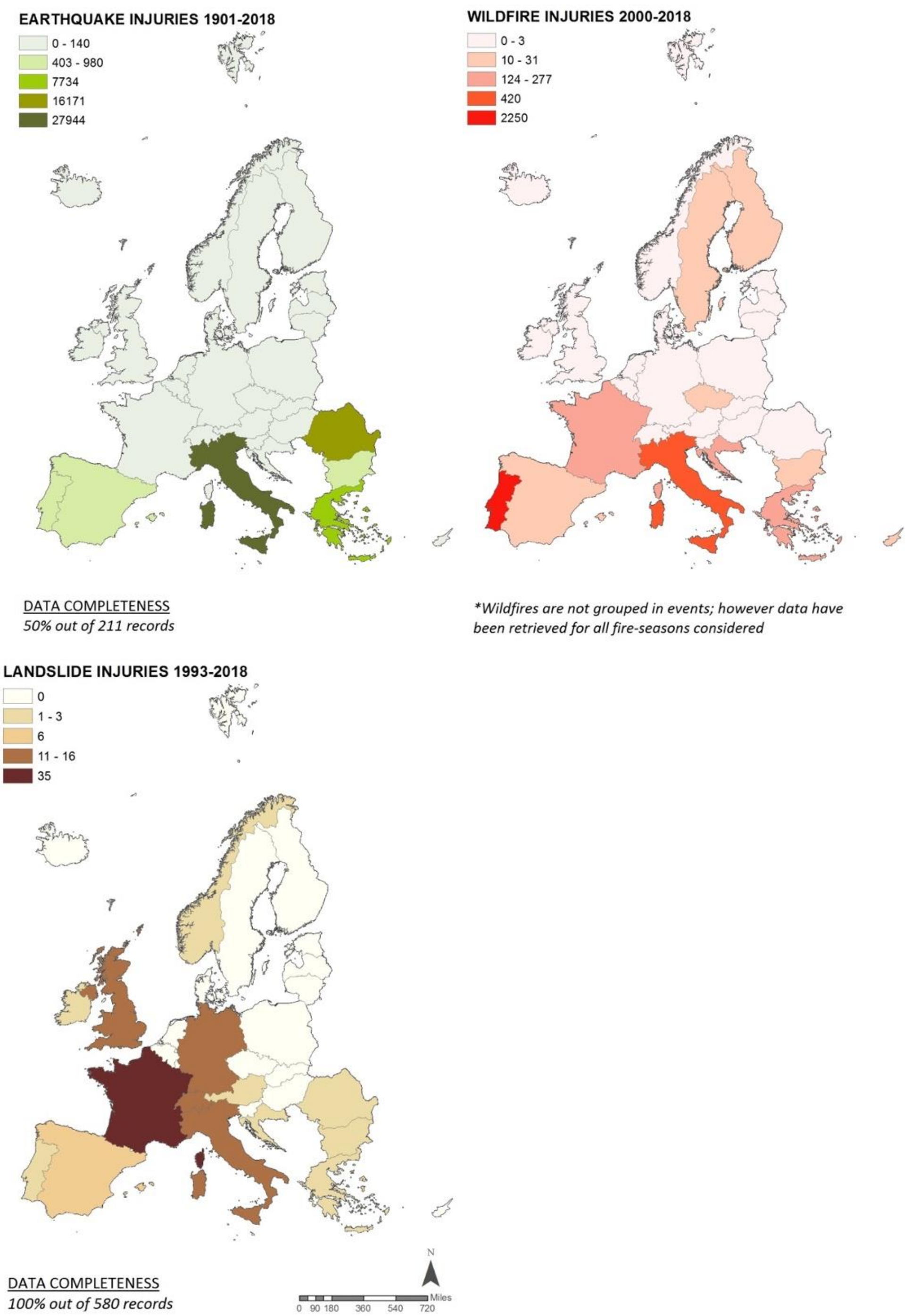


The stored data show Italy at the top for number of injured due to earthquake followed by Romania and Greece. On the other hand, Portugal counts the highest number of injuries for wildfires, followed by Italy and Greece. Finally, France, Switzerland and Italy are the most affected counties in terms of injuries occurred due to landslides.

Table 10. Top three most affected countries – AFFECTED PEOPLE AGGREGATED VALUE

	Time Coverage	**COUNTRIES**	**INJURED**
EARTHQUAKES	1901-2018	Italy	27944
		Romania	16171
		Greece	7734
WILDFIRES	2000-2018	Portugal	2250
		Italy	420
		Greece	277
LANDSLIDES	1993-2018	France	35
		Switzerland	16
		United Kingdom	12

Figure 9. People Injured Maps by hazard for specific time coverage



6.2.1 Completeness and its influence on the analysis

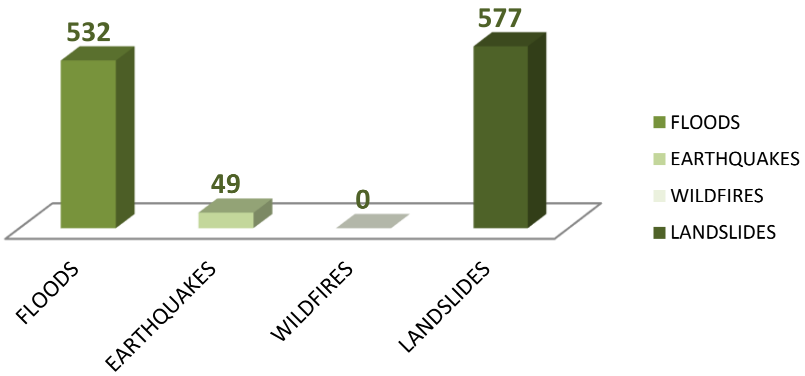
Comprehensiveness and completeness of the data has been already discussed in Chapter 5.3 and quantitative information is reported in Table 5 which clearly shows the scarce amount of damage and losses attributes. Some of the performed analysis demonstrate the excessive insufficiency of data to make reliable comparisons and consistent statistics, thus emphasises the deficiency and fragmentation of the current damage and loss data availability and drives attention towards the need for a more systematic and comprehensive damage and loss data collection for more reliable information.

6.3 Impact data processing for the past 18-years

6.3.1 Fatalities and economic losses

In order to have a better perspective of the risks that European Countries face, some analyses have been carried out on selected records covering the same temporal range which goes from 2000 to 2018. Figure 10 shows the number of events by occurred in the past 18-years. Wildfires are not grouped in events because of coherency with definitions; the collection presents a total of 16407 burned area polygons for the period 2000-2018 called "Phenomena" according to the architecture of the RDH (see Antofie, T. et al., 2019), hence the inventory of burned areas is aggregated according to the fire-season.

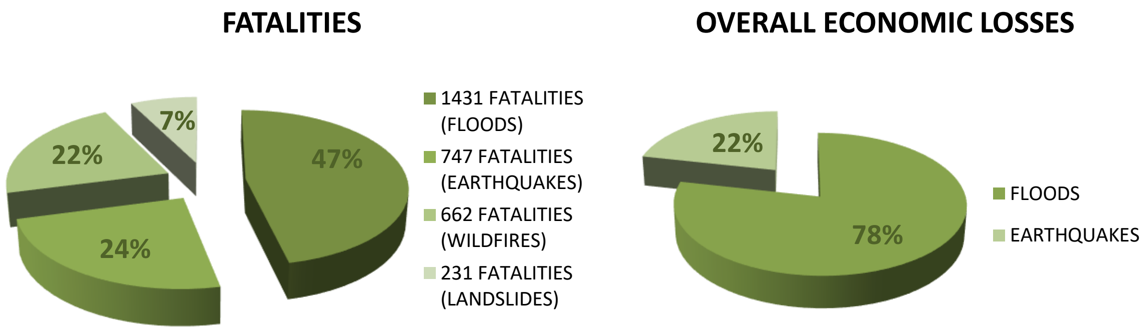
Figure 10. Number of events by Hazard (2000-2018)



The discrepancy between the values obtained from the two different analyses is remarkable. The difference of the results is not only due to the homogenization of the time considered but is also due to the characteristics of the records itself. The Landslide's catalogue covers a period from 1993 onwards, but as matter of facts between a total of 580 events only 3 are prior the year 2000. While floods from a total of 1753 events along the whole time coverage get reduced to 532 events for the last eighteen years.

However, according to the temporal coverage normalization, floods caused both the highest number of fatalities and amount of economic losses during the past eighteen years as shown in Figure 11.

Figure 11. Fatalities and economic losses for common time coverage (2000-2018)



Both charts show a net difference between the previous Figures 3 and 4, where losses and fatalities are taken into account as average by year and a greater percentage for earthquakes fatalities and losses is shown.

This result appears to be in contrast if compared with other studies such as Corbane et al. (2017) which states that earthquakes are the second deadliest natural events in Europe after extreme temperatures for the period 1980-2014 according to EM-DAT records. Even though the total time span considered is different a certain correspondence could be expected; the meaning of such difference lies in the fact that in 1980 Italy experienced one of the deadliest earthquake in Irpinia (4689 deaths – EM-DAT) which is not considered in figure 11 give the time frame, and explanations could be found in the fact that in recent decades there has been an increased sprawl in areas prone to floods which created an increased exposure of human lives (Jongman et al., 2012; Brown et al., 2014). Moreover the data collected in the RDH Catalogue represent a step forward since damage and loss data retrieved from several complementary sources.

6.3.2 Affected and injured people

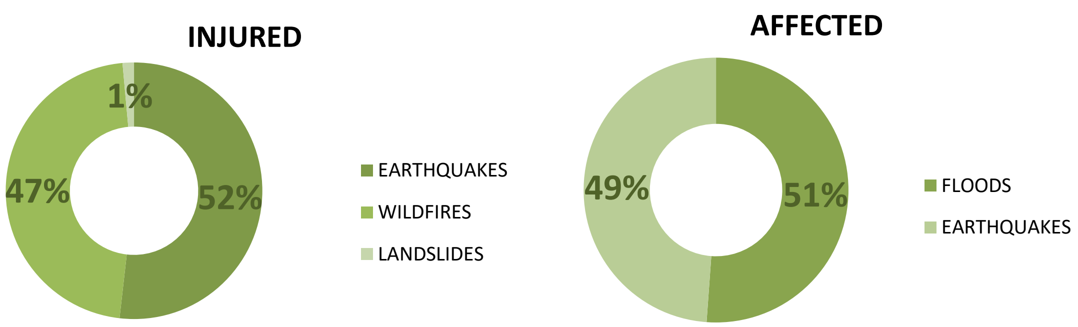
The RDH Historical Event Catalogue contains other specific people-related attributes, such as number of affected people for floods and earthquakes and number of injured for earthquakes, wildfires and landslides. Table 11 lists a sum of the collected values for both injured and affected people for the different hazards considered.

Table 11. Affected and injured people, totals per hazard

HAZARD		Time Coverage	#EVENTS	#INJURED	#AFFECTED
FLOODS	RIVER FLOODS	2000-2018	332	-	12890
	FLASH FLOODS		189	-	199232
	COASTAL FLOODS		11	-	24950
EARTHQUAKES		2000-2018	49	3721	226489
WILDFIRES		2000-2018	-	3359	-
LANDSLIDES		2000-2018	577	103	-

*Wildfires are not grouped in events because of coherency with definitions; however the collection presents a total of 16407 burned area polygons

Figure 12. Percentage of affected and injured perople from all-hazard totals



6.3.3 Affected area

The occurrence of disasters leaves vast areas under the effect of their impacts; in the RDH Historical Event Catalogue hectares of burned areas and square kilometres of flooded areas are collected. Their values are summed and listed by hazard in Table 12.

Table 12. Total affected area per hazard

HAZARD		Time Coverage		#EVENTS	AFFECTED AREA (km^2)
	RIVER FLOODS		2000-2018	332	116513

FLOODS	FLASH FLOODS			189	2904
	COASTAL FLOODS			11	3791
WILDFIRES		2000-2018		-	66257

*Wildfires are not grouped in events because of coherency with definitions; however the collection presents a total of 16407 burned area polygons

6.3.4 Limitations of the approach

The decision of analysing data concerning events occurred in the period 2000-2018 has been determined by the need to have homogenous time coverage for all hazards. In such a perspective, the impact of wildfires is clearer. The RDH Event Catalogue records a total of 662 deaths, 3359 injuries and 66257 square kilometres of burned areas.

Forest fires are complex phenomena caused by a combination of different factors such as land management, human activities, and especially climate and weather conditions. Climate change affects the occurrence of forest fires due to both weather conditions and effects on vegetation. Hazardous conditions are expected to evolve increasing the fire danger due to climate change in Europe and especially around the Mediterranean (Jesús San-Miguel-Ayanz et al., 2018; Ciscar et al., 2018).

In conclusion, it is fundamental to highlight that these statistic are performed on existing data which have been merged together from various sources which from the origin lack in terms of consistency and resolution.

However, the analyses of damage and loss data shown are intended to illustrate ways of examining global loss data and identifying possible trends in terms of peril or geographical prone areas within the European Countries.

6.4 Discussion of trends

The data stored in the RDH Event Catalogue show several peculiarities in terms of temporal coverage and hazard-related characteristics; however considering that flood and earthquake records cover the longest time span a trend analysis has been performed for the past 50 years. Results are shown in the Figures 13 and 14.

Figure 13. Logarithmic trend of average fatalities from earthquake per event in the last 50 years

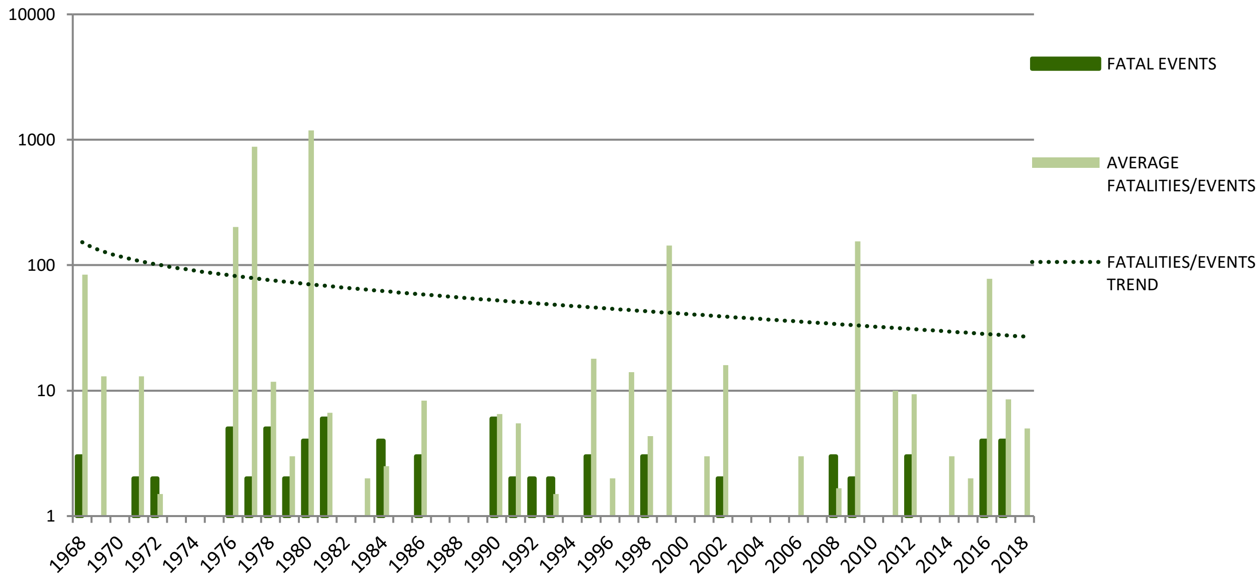
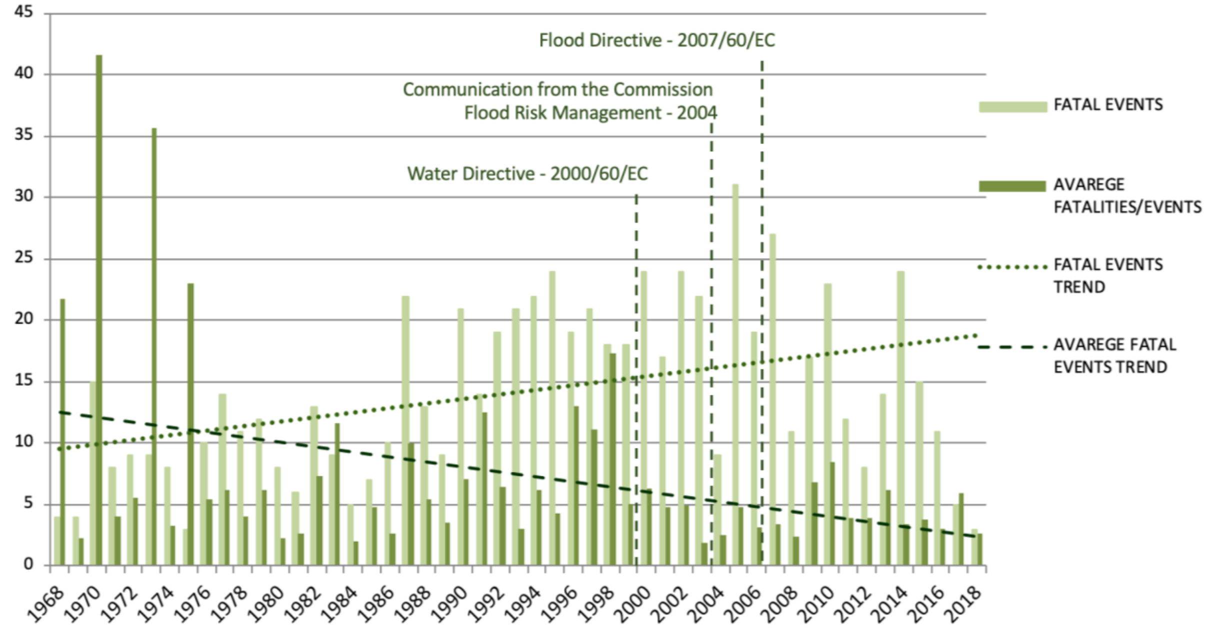


Figure 14. Linear trend of average flood fatal events in the last 50 years



Both charts show interesting and peculiar results. The number of earthquake fatalities across Europe show oscillations over the last 50 years but no clear increasing trend has been recorded throughout the study period.

For the same study period, the number of fatalities per flood event show a decline despite the noteworthy increase of fatal flood events with fewer deaths per event in the same period.

7 Discussion of results

EARTHQUAKES

Over the last 50 years, earthquakes in Europe have resulted in thousands of victims; nonetheless trends show a general decrease over time in the number of victims due to earthquakes. The observed decrease can be explained by a general increase and improvement of knowledge and earthquake coping- and adapting-capacities, a tangible example could be represented by the actions undertaken at national level in a seismic country such as Italy (Dolce, 2012). This remarkable result could be an evidence of the improved collective actions performed. However, it is known that the consequences of earthquakes differ in function of the region in which they strike according to its socio-economic development (The Guha-Sapir, 2011). Specifically, the impact of earthquakes is directly related to the degree of disaster mitigation and preparedness measures taken in the prone areas (Noji, 1997). Compliance to building codes, zoning ordinances, strategic urbanization development and, retrofitting of structures can significantly reduce the devastation of major earthquakes saving many lives and prevent buildings collapse (Anbarci et al., 2005; Spence et al., 2004); however structural measures to reduce buildings' physical vulnerability have been strongly promoted for seismic risk (Menoni and Margottini, 2011). Moreover, the influence of the adoption of Eurocodes and parallel national standards and improvements in civil protection's capability to manage emergencies and post-event actions should be better analyzed.

FLOODS

According to the results of this study, the number of fatalities per flood event show a decline despite the noteworthy increase of fatal flood events with fewer deaths per event in the same period. Floods are still a significant threat to people and to societal sectors, causing loss of human life and extended economic damages, however trends indicate that flood disasters have been progressively less lethal over time. Already Diakakis in a work carried out in 2016 has highlighted how, despite the increase in recorded flood events in Greece in the last decades, related mortality does not show a corresponding rise. Also in Portugal, according to Pereira et al. (2016) analysis indicate a significant decrease of the annual flood mortality in the period from 1970–2010, this result is explained by the adoption of structural and non-structural mitigation measures, i.e. hydropower dams used to regulate peak flows of the main rivers and improved early warning system for floods and the evacuation of people living in floodplain areas. If few studies have been carried out to examine qualitative aspects of mortality(Diakakis, 2016), the increased value observed in the recurrence of fatal events could be explained by: (i) the increased reporting of small impact events in later years due to improved telecommunication (Kundzewicz et al., 2013); (ii) the projected increase of flood risk not only due to socio-economic developments but also due to climate change factors (Alfieri et al., 2018; Alfieri et al., 2015; Forzieri et al., 2016; Kreibich et al. 2014;).

7.1 Floods cause most fatalities

Despite the decreasing trends in flood mortality, they are still responsible for most human loss and economic damages to societal sectors. Figure 11 shows that for the period 2000-2018 floods cause most fatalities.

Many initiatives such as the Global Human Settlement Layer (see https://ghsl.jrc.ec.europa.eu), the Atlas of Urban Expansion (see http://www.atlasofurbanexpansion.org) provide clear dimensions of the massive urbanization occurred in the last century with a rapid expansion and sprawling growth of cities and metropolitan regions. It has been repeatedly claimed with respect to flood hazards in Europe that the main driver of increases in observed losses over the past decades is increased physical and economic exposure (Bouwer, 2013; Hallegatte et al., 2013; Jongman et al., 2014, Barthel et al., 2012; Forzieri et al., 2017; UNISDR, 2015).

Those hazard prone areas (coastlines, flood plains etc.) attracted non only economic and urban development, offering significant economic benefits (Jongman et al., 2012; Brown et al., 2014); but also coastal and mountain tourism activities (Kellens et al., 2012; Ruin et al., 2008).

As more people and assets are exposed, risk in these areas becomes more intense. Moreover, urban development affects the occurrence of floods increasing runoff due to reduced vegetation and draining soil surface. This leads to an increase of volumes and frequencies of floods, therefore this conveys to a greater exposure of communities to increasing flood hazards (Konrad, 2003; Wamsler, 2013; Hallegatte et al., 2013).

7.2 Signs of increased resilience and lower vulnerability

Are those trends the reflection of increased resilience and lower vulnerability?

There is a very limited discussion and examination of qualitative aspects of mortality (Diakakis, 2016) and on possible improvements and advances of civil protection's capability to manage emergencies, and no information on the improvements of policies and on their implementation in the context of prevention and adaptation (Menoni and Faiella, 2019).

FLOODS

Do the Flood Directive (2007/60/EC) which addresses flood risk mitigation through structural measures and vulnerability reduction, preceded by the Water Directive (2000/60/EC), influence the seen change in mortality trends?

To answer this question, detailed studies should be conducted, but in recent years EU has taken an active role towards disaster prevention and mitigation; initiatives such as European Flood Alert System (EFAS) which from 2003 provides probabilistic flood forecasting to local authorities (Thielen et al., 2009) and Meteoalarm, developed by the European Meteorological Services Network, which provides warnings for extreme weather events across European countries (Alfieri et al., 2012); investments in technology and green infrastructures (European Court of Auditors, 2018), the promotion of sustainable land use practices, improvement of water retention and the controlled flood, represent a concrete shift towards a general improvement of the existing conditions. Awareness campaign conducted among citizens to raise flood awareness, such as in Italy the "Io non rischio" campaign conducted by the Civil Protection, show a renewed and intensified attention towards prevention, protection and preparedness aspects.

The implementation of the Floods Directive with its requirements (Preliminary flood risk assessments – 2011, Flood hazard and risk maps, - 2013, Flood risk management plans – 2015) increased Member States awareness about the risk they face shifting attention from protection against floods to management of flooding risks, this leads to increased resilience and lower vulnerability.

8 Conclusions and recommendations

This chapter is intended to summarize the main findings and recommendations resulting from the work carried out for the construction of the Risk Data Hub Historical Events Catalogue. It may be appropriate to re-call the main concepts related to the work:

- Collection of existing damage and loss data from different sources;
- Harmonization of the collected data;
- Analysis of the records to provide an overview of the potential of damage and loss data;
- Creation of an open-access dataset.

Damage data collection is the result of a systematic process to collect human, physical and economic losses as well social and environmental impacts caused by a hazardous event. Knowledge of damage and losses and their patterns, extent and root-causes is the key factor to improve both coping- and adaptive-capacities in order to avoid or reduce potential future damage and losses not only where the impact occurred, but also in areas similar to the ones that have been affected (Menoni et al., 2016; De Groeve at al., 2015).

In a context where reliability of past damage and loss data remains an open question (Zêzere et al., 2014), weakness and gaps in the current state of the art have been concretely identified and observed, with the aim to handle them in order to produce a solid ground for a comprehensive damage and loss catalogue for European Countries. This is an open-ended work which represents a basis for future improvement in terms of:

- Improvement of past-event damage assessment

The work clearly highlighted all the gaps in the present damage and losses collection methodology through all the challenges encountered when existing data need to be analysed and/or compared (see Paragraph 4.6)

- Integration of additional source of information

The catalogue makes use of inventoried data, collecting, crosschecking and linking information deriving from heterogeneous sources; nonetheless, considering that a vast number of initiatives which report damage and loss data for specific areas or hazards has been found, additional source of information should be integrated to provide a more comprehensive set of damage and loss data, not only trying to populate the existing modules, but also considering other types of hazards such as droughts and man –made accidents.

In conclusion, considering that the work carried out is not focused on testing the quality of existing records, but rather on collecting, crosschecking and linking information deriving from heterogeneous sources to provide a comprehensive set of damage and loss data occurred in European Countries due to hazardous events; it can be stated that RDH Historical Event Catalogue represents a substantial contribution to the fragmented situation where most of the studies carried out and the information remain spread without having the possibility to be exploited according to their potential and a significant incentive to improve the damage and losses data collection process through the identification of clear and practical existing weakness.

Finally, considering that the Disaster Risk Management is complex field in continuous development, as an outcome of the work some recommendations can be mentioned:

- A natural disaster can impact different sectors; damage and loss data should be collected for each sector so that the overall damage that a community as suffered can be correctly estimated and correct information can be retrieved.
- Damage and loss data are generally collected for compensation purpose; therefore, their quality reflects their scope. Specific conditions and directions shared across all European Countries should be delineated in order to analyse the damage drivers and causes.
- Terminology and taxonomy should be clearer and mutual between all the stakeholders involved if the real impact of the events has to be understood and compared with other occurrences or between different geographical areas.

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List of abbreviations and definitions

DRM	Disaster Risk Management
DRMKC	Disaster Risk Management Knowledge Centre
EDO	European Drought Observatory
EFAS	European Flood Awareness System
EFFIS	European Forest Fire Information System
EMM	European Media Monitor
EU	European Union
GFDRR	Global Facility for Disaster Risk Reduction
GHSL	Global Human Settlement Layer
RDH	Risk Data Hub

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Annexes

In order to have a better understanding of the RDH Historical Event Catalogue contents, the following tables delineate loss and damage datasets characteristics structured by the type of event.

Annex 1. Recorded information contained in the Historical Event Catalogue – Flood module

FLOODS	
ATTRIBUTE	DESCRIPTION
ID Code	Unique identifier code automatically generated by the system
Hazard type code	Descriptive code for each type of hazard (FL - river flood; FLSH - flash flood; CF - coastal flood)
Country code	Iso2 country code
Region code	Affected regions listed through the Nuts3 code
Year	Year of the event
Country name	Country in which the event occurred
Start date	Date on which the event started (or ended if further information are not given)
End date	Date on which the event ended
Type	Type of flood event, which can be River, Coastal or Flash. The events were implemented according to the HANZE database delineations.
Flood source	Name of the river, lake or sea from which the flood originated (qualitative and non-complete list of attributes)
Area flooded	Inundated area in km^2
Fatalities	Number of deaths due to the flood, including missing persons
Person affected	Number of people whose houses were flooded. However, according to HANZE database the reported numbers of persons affected often only show the number of evacuees or persons rendered homeless by the event. If no other number was available, those ones were used. If only the number of houses flooded was reported, the number persons affected was estimated considering 4 people in each house.
Losses (nominal value)	Economic damage in the currency and price of the time of the event
Losses (mln EUR, 2011)	Economic damage in euro adjusted by inflation indexes

Cause	Descriptive attribute containing the meteorological causes of the event
Notes	Descriptive attribute containing relevant information concerning the event (i.e. triggering factors etc.)
Sources	List of datasets, publication and other forms of sources from which the information was retrieved

Annex 2. Recorded information contained in the Historical Event Catalogue - Earthquake module

EARTHQUAKES	
ATTRIBUTE	DESCRIPTION
ID Code	Unique identifier code automatically generated by the system
Hazard type code	Descriptive code of the hazard (EQ - earthquake)
Country code	Iso2 country code
Region code	Affected regions listed through the Nuts3 code
Year	Year of the event
Country name	Country in which the event occurred
Start date	Date on which the event started (or ended if further information are not given)
End date	Date on which the event ended
Epicentre	Latitude and longitude
Magnitude	Measure of the seismic energy
Time of occurrence	Exact time of the occurrence of the event
Fatalities	Number of the deaths
Injured	Number of injured people
Person affected	Number of affected people (umber of evacuees or persons rendered homeless by the event)
Losses (nominal value)	Economic damage in the currency and price of the time of the event
Losses (mln EUR, 2011)	Economic damage in euro adjusted by inflation indexes
Notes	Descriptive attribute containing relevant information concerning the event (i.e. inconsistency between sources)

Sources	List of datasets, publication and other forms of sources from which the information was retrieved

Annex 3. Recorded information contained in the Historical Event Catalogue – Forest Fire module

FOREST FIRE	
ATTRIBUTE	DESCRIPTION
ID Code	Unique identifier code automatically generated by the system
Hazard type code	Descriptive code of the hazard (FF - forest fire)
Country code	Iso2 country code
Region code	Affected regions listed through the Nuts3 code
Year	Year of the event
Country name	Country in which the event occurred
Start date	Date on which the event started (or ended if further information are not given)
End date	Date on which the event ended
Area burned	Area burned by the fire given in hectares
Fatalities	Number of fatalities per fire-season
Injured	Number of injured per fire-season
Notes	Descriptive attribute containing relevant information concerning the event
Sources	List of datasets, publication and other forms of sources from which the information was retrieved

Annex 4. Recorded information contained in the Historical Event Catalogue - Landslides module

LANDSLIDES	
ATTRIBUTE	DESCRIPTION
ID Code	Unique identifier code automatically generated by the system
Hazard type code	Descriptive code for each type of hazard (FL - river flood; FLSH - flash flood; CF - coastal flood)
Country code	Iso2 country code

Region code	Affected regions listed through the Nuts3 code
Year	Year of the event
Country name	Country in which the event occurred
Start date	Date on which the event started (or ended if further information are not given)
End date	Date on which the event ended
Fatalities	Number of fatalities
Injured	Number of injured
Cause	Descriptive attribute, cause of the event (i.e. rain, earthquake etc.)
Notes	Descriptive attribute containing relevant information concerning the event (i.e. qualitative description of the extension of the phenomenon)
Sources	List of datasets, publication and other forms of sources from which the information was retrieved

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