What makes flood events significant for the European policies?
An analysis of threshold-based criteria

EEA – ETC/CCA Technical Paper

Version: 4.0
Date: 18/12/2013

EEA activity: 2.1.2

European Environment Agency

European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation

Cover photo: Shutterstock (www.shutterstock.com) imagine 141725623 , Hungarian Parliament with the flooding Danube. Black and white version.

Organisations: European Environment Agency (EEA) together with European Topic Centre on Climate Change impacts, vulnerability and Adaptation (ETC/CCA)

This working paper has been produced as a contribution to the Potential European Flood Impact Database (EEA et al., 2013)

Author
Jaroslav Mysiak (ETC/CCA -Euro-Mediterranean Centre on Climate Change CMCC),

Co-authors

Fabio Farinosi (ETC/CCA - Euro-Mediterranean Centre on Climate Change CMCC), Wouter Vanneuville (European Environment Agency EEA)

Reviewers

Mikko Huokuna (ETC/CCA - Finnish Environment Institute SYKE), Volker Meyer ETC/CCA - Helmholtz Centre for Environmental Research – UFZ)

EEA Project managers: Wouter Vanneuville & André Jol

The European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation (ETC CCA) is a consortium of European institutes under contract of the European Environment Agency:
CMCC Alterra AU-NERI CUNI FFCUL MetOffice SYKE THETIS UFZ UPM

Executive summary

Floods are among the costliest and the deadliest hazards in Europe (EEA, 2011). The estimated normalised direct losses over the recent decade (2000-2011) are very likely higher than 60 billion in 2011 Euro value (see also EEA et al., 2013).

Significant flood events are those events recognised as exceptional in terms of physical characteristics (usually intensity or return period but also in terms of scale and duration), inflicted impacts (i.e. damage/losses or people affected), and/or those that for other reasons compelled emergency declaration or policy change. The definition of what constitute '*significant*' depends on the purpose of the assessment and accordingly varies substantially. The Floods Directive (FD, 2007/60/EC) does not postulate any criterion of *significant flood* but uses the term in relation to events that '*had significant adverse impacts on human health, the environment, cultural heritage and economic activity*'. The EU Solidarity Fund (EUSF) specifies *major disasters* for which an aid from the Fund may be granted as those events which cause damage higher than 3 billion Euro in 2002 prices or more than 0.6 per cent of the affected country's *gross national income* (GNI). The EUSF can also be mobilised for *regional extraordinary* disasters not fulfilling this criterion in the case the disaster affects major part of the population, and pose '*serious and lasting repercussions on living conditions and the economic stability of the region*'. Recently, a more articulated definition of the extraordinary regional disasters has been proposed (damage that exceeds 1.5 per cent of gross domestic product at the NUTS 2 level). The existing global disaster databases apply other thresholds mainly based on population affected or the implied economic damage. Barredo (2007) and EEA (2011) specify the thresholds as a percentage of the combined GDP of all EU member states.

In the *Technical Paper on Flood Impact Database* (EEA et al., 2013) we have argued that there is a substantial scope for improving our knowledge about (and lessons learned from) the most important flood events in Europe. Despite numerous pledges, the understanding of full social value lost to floods, that is one that includes indirect (higher order) and intangible effects of floods, is less than satisfactory. As a consequence, the drivers of risk and vulnerability are inadequately contended. While making the case for an *European Flood Impact Database* we argue that the past significant flood events should be revisited and their economic damage re-assessed[1]. The proposal for disaster loss recording throughout Europe (De Groeve et al., 2013) goes further and proposes a way of harmonising the disaster impacts. In parallel, the European Environmental Agency has reviewed existing guidance documents for assessing the economic impacts of natural hazards (EEA et al., 2013).

In this paper we analyse the flood events in Europe (the 33 member countries and 6 cooperating countries of the European Environmental Agency) since 2000 and examine how many of them would satisfy the various threshold criteria applied or proposed by

[1] Independently, but consistent with this plea, the *Directorate General Climate Action* has launched a call for tenders (CLIMA.C.3/SER/2013/0019) for a pilot study analysing economic implications of past climate extremes (along floods also droughts, wind storms and extreme temperatures) in Europe

European policies and literature. We have approximated the economic losses in EM-DAT for which no original record is available. Furthermore, we have extended the EUSF criteria to the sample EM-DAT data set.

In order to identify the significant flood events (SFE) in the past records, we recommend the following rule: In cases in which the economic assessment is available, the population affected (>1,000) and damage (0.6 per cent of GNI) may be applied. Where such information is available, the 0.6 GNI criterion can be replaced by 1.5 per cent regional GDP or 500 evacuated persons. In cases for which no economic assessment of damage is available, the affected population threshold can be set to 5,000.

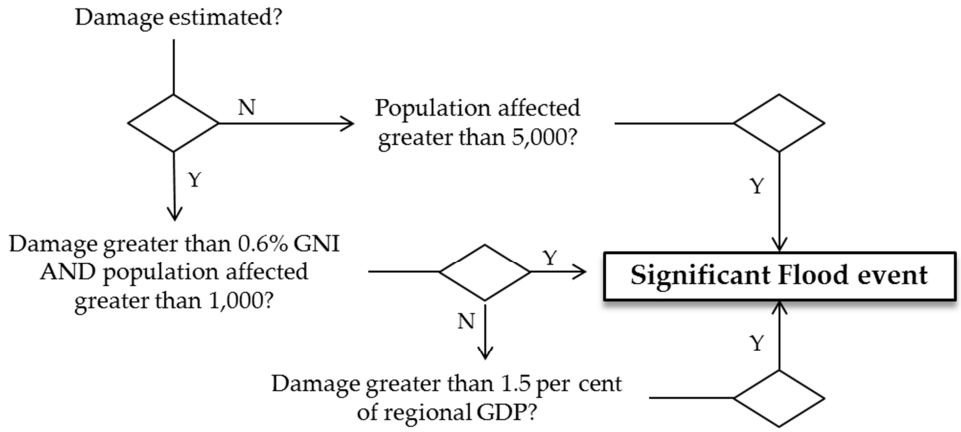


Figure 1: Proposed algorithm for selecting significant flood events in Europe

Since April 2012, the *Copernicus Emergency Management Service*[2] (CEMS) provides, upon request, geospatial information (delineation of flooded areas, impact assessment) from disaster stricken regions derived from satellite remote sensing and completed by available in situ or open data sources. Since then CEMS provided assistance to the emergency management in the cases of July 2012 flood in Sweden, November 2012 floods in Sweden and Wales, January 2013 flood in Zaragoza/Spain, March 2013 flood in Slovenia, April flood in Croatia and UK, June 2013 floods in Germany, Czech Republic, Hungary and France; and July and November 2013 floods in Italy. For a CEMS assisted flood events, the geographic extent of the impacted area and population affected (evacuated, brought to the shelters, and otherwise affected by substantial reduction of essential services) makes it possible to better approximate the flood damage.

ETC/ICM (2013) has analysed the data submitted by the Member States (MS) in the context of the reporting obligations under the FD (EC, 2007). The coverage of the estimated impacts of reviewed flood events is very heterogeneous across the MS and the economic and social impact estimates are available only for a relatively small fraction of all events. In the future research, the above rule for determination of the SFE will be applied to the reported events.

[2] emergency.copernicus.eu/mapping

1. Introduction

Floods are among the *deadliest* and *costliest* hazards in Europe. The EEA (2011) estimated that the cumulative direct economic losses inflicted by floods over the period 1998-2009 exceeded 60 billion Euro (in 2009 Euro values). This is a conservative estimate which undervalues the true social costs of floods because i) only direct costs are counted for, neglecting the indirect and intangible losses; and ii) the assessment considers only those events recorded in the EM-DAT Disaster Database for which economic costs are available (~40 per cent of all recorded events in the reference period). Even so, the available evidence underscores that floods poses significant threat to European communities and economies. Barredo (2009) estimated the normalised losses due to major flood events in Europe over a longer period (1970-2006) to 105 billion.

The human induced climate change is very likely to lead to sizable increases of economic losses due to floods, if no adequate adaptation measures are put in place. The existing studies project an increase of annual flood-related economic losses in Europe by the end of the century by 7.7-15 billion Euro (Ciscar et al., 2011; Feyen et al., 2012) for the IPCC-SRES scenarios A2 and B2, and by 50 billion for the scenario A1B[3] (Rojas et al., 2013).

***Significant* flood events are those recognised as exceptional in terms of physical characteristics** (usually intensity/return period but also scale and duration), **inflicted impacts** (i.e. damage and losses, people affected), and/or those that **compelled emergency declaration** or **policy change**. The definition of what constitute '*significant*' depends from the purpose and may vary significantly. The Floods Directive (EC, 2007) does not postulate any criterion of *significance flood* but uses the term in relation to flood events that '*had significant adverse impacts on human health, the environment, cultural heritage and economic activity*'. The EU Solidarity Fund (EUSF, European Council, 2002) specifies *major disasters* for which an aid from the Fund may be granted as those which cause damage higher than 3 billion Euro in 2002 prices or more than 0.6 per cent of the affected country's *gross*

[3] The A2 family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than in other scenarios. The B2 family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2 and intermediate levels of economic development. While these scenarios are also oriented towards environmental protection and social equity, they focus on local and regional levels (IPCC, 2000; Nakicenovic and Swart, 2000). The A1 scenario family describes a future world of very rapid economic growth, global population that peaks in the mid-century and declines thereafter, and a rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 family develops into three groups that describe alternative directions of technological change in the energy system, distinguished by their technological emphasis and where the A1B scenarios there is a balance of all sources (where balanced is defined as not relying too heavily on one particular source, on the assumption that similar improvement rates apply to all energy-supply and end-use technologies) (IPCC, 2000; Nakicenovic and Swart, 2000)

national income (GNI). Global disaster databases (like EM-DAT, NAT-CAT-SERVICE, SIGMA) apply additional thresholds criteria (population affected, number of fatalities), in addition to the implied economic damage. Barredo (2007) and EEA (2011) specify the thresholds as a percentage of the combined GDP of all EU member states.

Some flood events fulfil simultaneously all criteria. The August 2002 Central European flood reportedly caused direct economic damage of more than 14 billion Euro in Germany, Austria and Czech Republic alone (Dankers et al., 2007; de Kok and Grossmann, 2010; James et al., 2004). It led to the establishment of the EUSF. Similarly, the May/June 2013 floods in the same countries caused damage of more than 12 billion Euro[4,5] (MunichRe, 2013). The events triggered an aid from the EUSF (360 million Euro to Germany, 21.6 and 15.9 million respectively to Austria and Czech Republic under the *neighbourhood country* criterion). The Summer 2007 flood in the United Kingdom triggered a major policy review called for '*urgent and fundamental changes in the way the country is adapting to the likelihood of more frequent and intense periods of heavy rainfall*', among other '*a step change in the quality of flood warnings*', '*robust building and planning controls*', and a better '*protection for critical infrastructure*' (*The Pitt Review: Learning lessons from the 2007 flood*, 2008). The October 2000 Piedmont flood in Italy caused direct economic damage that exceeded 11 billion Euro. The subsequent legal review paved the way for an overhaul of the flood risk management in Italy, leaving the country better prepared for similar extreme events (Mysiak et al, 2013).

The scope of this paper is to analyse the available information about flood events in Europe (member and cooperating countries of EEA), and examine how many of them would satisfy the various threshold criteria. This paper ties in with the earlier report that explored the potential for an European Flood Impact Database, and parallel efforts to harmonise the flood impact estimation. The ultimate purpose of all these efforts is to specify methods and practices for populating the potential European Flood Impact Database.

2. Threshold criteria defining major/significant floods

The *intensity* of the precipitation, in case of flash floods, and the (peak) *river discharge*, in case of fluvial floods, are arguably impartial measures of the weather related extreme events.

- The Floods Directive (EC, 2007) refers to *significance flood* in relation to flood events that '*had significant adverse impacts on human health, the environment, cultural heritage and economic activity*' (article 4 paragraph 2c, article 5 paragraph 1). It postulates three categories of flood hazard but without assigning specific return period (RP)[6]

[4] According to the EC(2013b), the damage in Germany, Austria and Czech republic amounted to 9.6 billion Euro

[5] Arguably, the 2013 event in specific places led to higher river discharges but caused less damage (Neuhold, 2013)

[6] The return period is defined as 1/P with P the annual exceedance probability. E.g. an annual exceedance probability P of 0.1 (10%) implies a return period RP of ten years. Also the symbol T is frequently used for the return period.

to all of them: i) events with *low probability* or *extreme events*; ii) events with *medium probability* (RP ≥ 100 years), and flood *with high probability*.

- The US *National Oceanic and Atmospheric Administration* (NOAA) classifies flood events into *minor*, *moderate*, *major* and *record* flooding (see also Annex 1). *Minor* events (return period RP 5-10 years) cause minimal or no property damage, and marginal threat to public health. *Moderate* events (RP 15-40) lead to inundation of structures and roads near streams and may necessitate evacuations of people and/or transfer of property to higher elevations. *Major* events (RP 50-100) involves extensive inundation and evacuations, whereas record events are usually those that equals or exceeds the highest stage or discharge at a given site during the period of record keeping (NOAA, 2013a).
- *Dartmouth Flood Observatory* (2013) uses three flood severity classes based on re-occurrence period, impacts and extension of impacted area: i) large flood events: significant damage to structures or agriculture; fatalities; and/or 1-2 decades-long reported interval since the last similar event; ii) very large events: with a greater than 2 decades but less than 100 year estimated recurrence interval, and/or a local recurrence interval of at 1-2 decades and affecting a large geographic region (> 5000 sq. km); iii) extreme events: with an estimated recurrence interval greater than 100 years.

Declaration of natural-hazard-triggered *emergency* provides access to disaster assistance or funds. Although sometimes based on well specified criteria, they involve a large discretion of executive bodies. *Emergency* means any occasion or instance for which, in the determination of the executive bodies, assistance is needed to supplement regional and local efforts and capabilities to save lives and to protect property and public health and safety, or to lessen or avert the threat of a catastrophe. In Italy for example, the state of emergency can be declared in cases in which the extent or intensity of natural hazard events require deployment of "extraordinary means and power" (article 2 of the law 225/1992) (Mysiak et al., 2013)

In Europe, the EUSF may be considered as an 'emergency' declaration. The Fund is triggered by (*major*) events causing damage of more than 3 billion Euro in 2002 prices, or at more than 0.6 per cent of its gross national income (GNI). The 3 billion threshold criterion is arbitrary chosen and favour larger economies (Germany, France, United Kingdom, Italy and Spain) whose GNI is substantially larger than in the case of other EU Member States. Note that since 2002 the EUSF has been mobilised for these countries only twice in the case of 2002 flood in Germany and 2007 flood in UK. Hence without the 3 billion threshold criterion, the EU largest economies would be excluded from the aid provided by the EUSF under the category 'major event'.

In exceptional circumstances, the EUSF may be mobilised for disasters below the threshold if affecting disproportionally a region (*majority of its population, and having serious and lasting repercussions on living conditions and economic stability*). In this case the aid is limited to 75 million per annum (7.5 per cent of the annual budget). The proposed reform of the

EUSF (EC, 2013a) recommends a more articulated definition of the extraordinary regional disasters as those inflicting a damage that exceeds 1.5 per cent of gross domestic product (GDP) at the Eurostat statistical unit (NUTS2).

The global disaster databases (EEA et al., 2013) apply different thresholds for the recorded events (Table 1). The EM-DAT database applies a threshold combining number of casualty, economic damage and declaration of state of emergency. NAT-CAT-SERVICE does not specify exact thresholds which may also partly explain why the aggregate annual estimates of losses differ from those of EM-DAT. SIGMA database applies thresholds that are similar to those of EM-DAT but distinguishes between insured and uninsured losses.

Table 1: Comparison of threshold criteria across major sources

Source	Threshold	Notes
European solidarity fund (Council Regulation 2012/2002)	*Major events*: > 3 billion Euro in 2002 prices or alternatively > 0.6 per cent of its gross national income (GNI); *Neighbourhood criterion*: exceptionally, neighbouring EU member or candidate countries affected by the same disaster can also benefit from assistance; *regional events*: if majority of population affected or if event has serious and lasting repercussions on living conditions and economic stability;	In 2005 the European Commission proposed to extend the scope of the EUSF and revise the major disasters threshold > 1 billion in 2007 prices or in excess of 0,5 % of GNI (EC, 2005). In 2013 the EC proposed revision of the regional disaster threshold as >1.5 per cent of the region's GDP (measured at NUTS2 level) or weighted average of the affected regions (EC, 2013a).
EM-DAT The International disaster database	10 casualties and/or 100 affected and/or declaration of state of emergency/call for international assistance (Guha-Sapir and Below, 2002)	
NAT-CAT-SERVICE natural catastrophe loss database (MunichRe)	If any property damage, any person sincerely (sic) affected (injured, dead). Before 1980, only major events	
SIGMA database SwissRe	More than 20 casualties and/or 50 injured and/or 200 homeless and/or insured losses more than 35 million USD and/or total losses exceed 70 millions	
European Environmental Agency (2011) and Barredo (2007)	> 70 casualties and/or more than 0.005 per cent of EU GDP in damage	

Choryński et al., 2012; Kundzewicz et al., 2012; Pińskwar et al., 2012)	Flood severity (FS) based on mean return or recurrence period (RP) (1: $RP < 10 - 20\ years$, 1.5: $20 < RP < 100$, 2: $RP > 100$); Flood magnitude (FM) $FM = log_{10}(Duration \times Severity \times Affected\ area.$ Major floods $FS \geq 1.5\ AND\ FM \geq 5$	Based on Dartmouth Flood Observatory record 1985 - 2012

In Europe, *significant flood events* (SFE) have been defined by Barredo (2007) as those causing more than 70 casualties and/or more than 0.005 per cent of EU GDP in damage. Barredo (ibid) has identified 47 events over the period 1950-2005. The list of SFE has been successively extended by EEA (2011). The Barredo (2007) and EEA (2011) definitions of thresholds neglects the impacts of SFE on regional/national economies of small countries, a limitation that is resolved in the EUSF definition, albeit arbitrary. A better account of the impacts on regional economy could be introduced by specifying (additional) threshold criteria in terms of portion of regional (NUTS2 or NUTS3 level) GDP, in a similar way as this is done in the eligibility criteria for aid from the Cohesion Fund[7] under the convergence objective (< 75 per cent of EU average).

Neither Barredo/EEA nor the EUSF definitions, however, consider the cumulative effect of all flood events in a given year. This leads to a situation in which more aid is paid from EUSF to countries that experienced fewer flood events in a given year in the case of parity of total suffered losses.

3. Material and methods

The subsequent analysis has been conducted on a sample of EM-DAT 256 recorded flood[8] events in the 33 EEA Member Countries and 6 Cooperating countries over a period 2000-2011[9]. The economic damage estimate is available for 78 events (~30 per cent of the sample), whereas the estimates of population affected is included in 202 cases (~79 per cent). Some 142 events caused loss of life of 1 021 persons (Figure 1). On all accounts, 2002 was the most significant (costliest, deadliest and largest in term of affected population) year over the past decade. The year 2000 is the second costliest, whereas the years 2005 and 2010 were among the deadliest. The years 2004 and 2007 belong to the years with largest affected population. In each year, less than 40 per cent of recorded events are

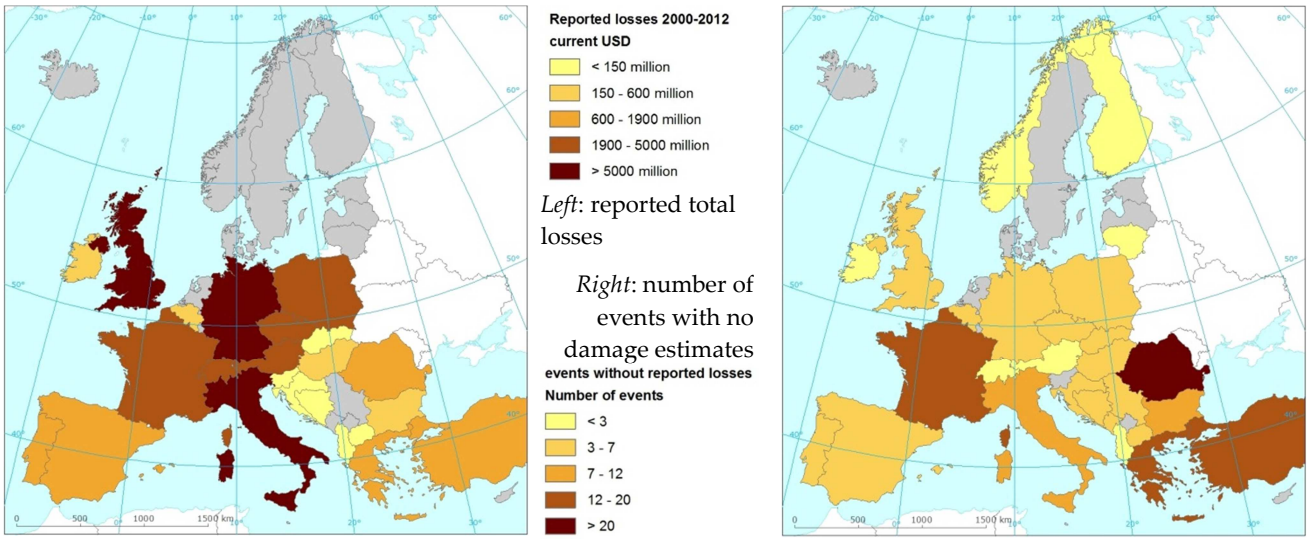
[7] Council Regulation (EC) No 1084/2006 of 11 July 2006 establishing a Cohesion Fund and repealing Regulation (EC) No 1164/94. The Cohesion Fund contributes to interventions in the field of the environment and trans-European transport networks. It applies to Member States with a Gross National Income (GNI) of less than 90% of the Community average (see for more detail http://ec.europa.eu/regional_policy/information/legislation/index_en.cfm#cohesionfund)

[8] Only events classified as flood (and not wet mass movement) have been considered

[9] The 33 member countries include the 28 European Union Member States together with Iceland, Liechtenstein, Norway, Switzerland and Turkey. The cooperating countries are six West Balkan countries Albania, Bosnia and Herzegovina, the former Yugoslav Republic of Macedonia, Montenegro, Serbia as well as Kosovo under the UN Security Council Resolution 1244/99. From among EU28 countries, there are no floods recorded in the EMDAT over the reference period 2000-2011 for Cyprus, Denmark, Estonia, Luxembourg, Latvia, Malta, Netherlands, and Sweden. The reference sample do not contain any events for the EFTA countries Liechtenstein and Iceland; and Kosovo under UNSC Resolution 1244/99 as EEA cooperating partner.

accompanied with the estimated economic losses. The EM-DAT recorded events without estimates of economic damage pose substantial limits to the exercise set to identify the SFE in Europe. However, EM-DAT is the only Pan European open access disaster database

Map 1 and Figure 2 shows that most flood-affected European countries over the reference period are Romania followed by France, Italy and Greece; whereas the largest losses were sustained in UK, Germany, Italy and France. The Map 1 also shows that the Romania, France, Greece and Italy are among the countries mostly affected by floods for which no information about economic damage is available.



Map 1: Total reported damage (2000-2012) and number of events for which information about losses is not available

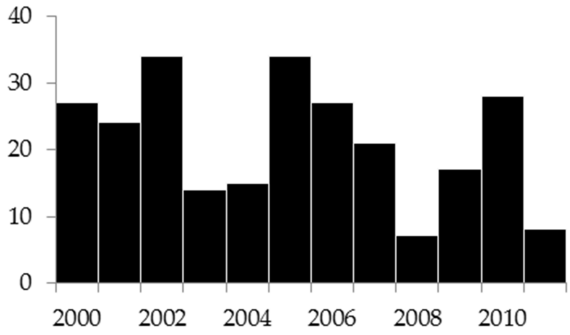
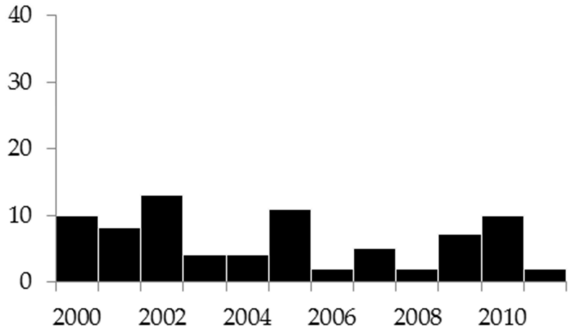
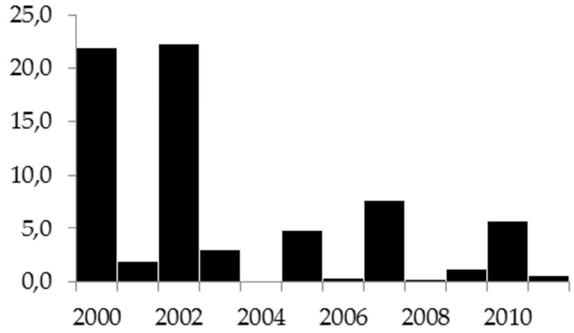


Figure 2: Number of flood events in EEA 39 member and cooperating countries over the period 2000-2011. *Source*: EM-DAT database of natural disasters, own elaboration.

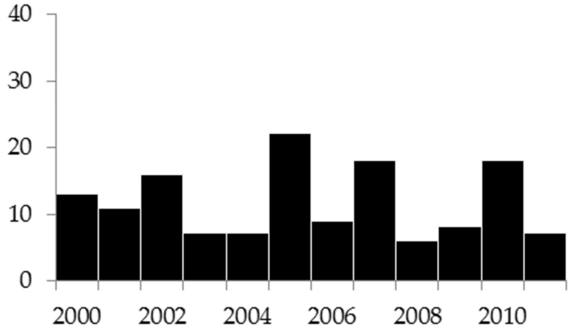
Below, the figures 1a-1c show the number of events with reported characteristics (losses, fatalities and affected population); figures 1d-1f show total losses, fatalities and affected population



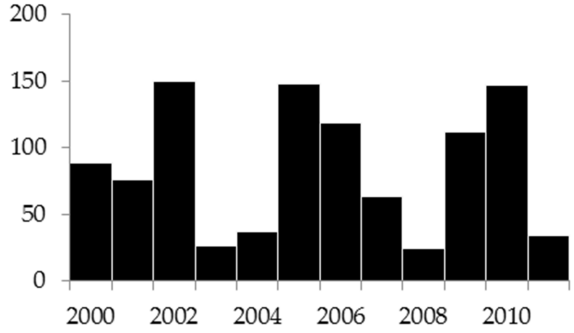
1a) Number of events with reported losses



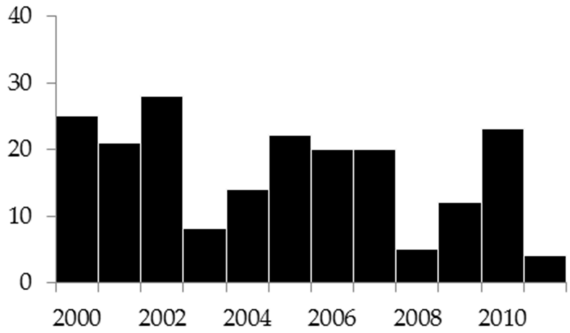
1d) Overall losses (in billion) in 2011 Euro value



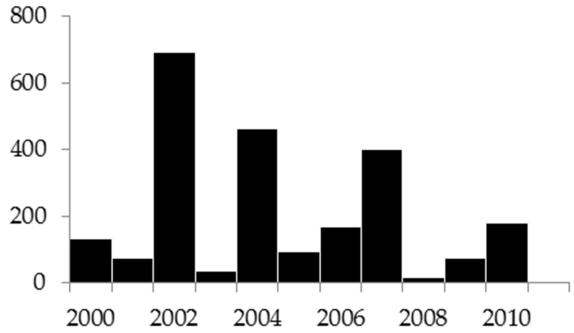
1b) Number of events with reported fatalities



1e) Annual fatalities



1c) Number of events with reported affected population



1f) Total number of affected peope (in tousands)

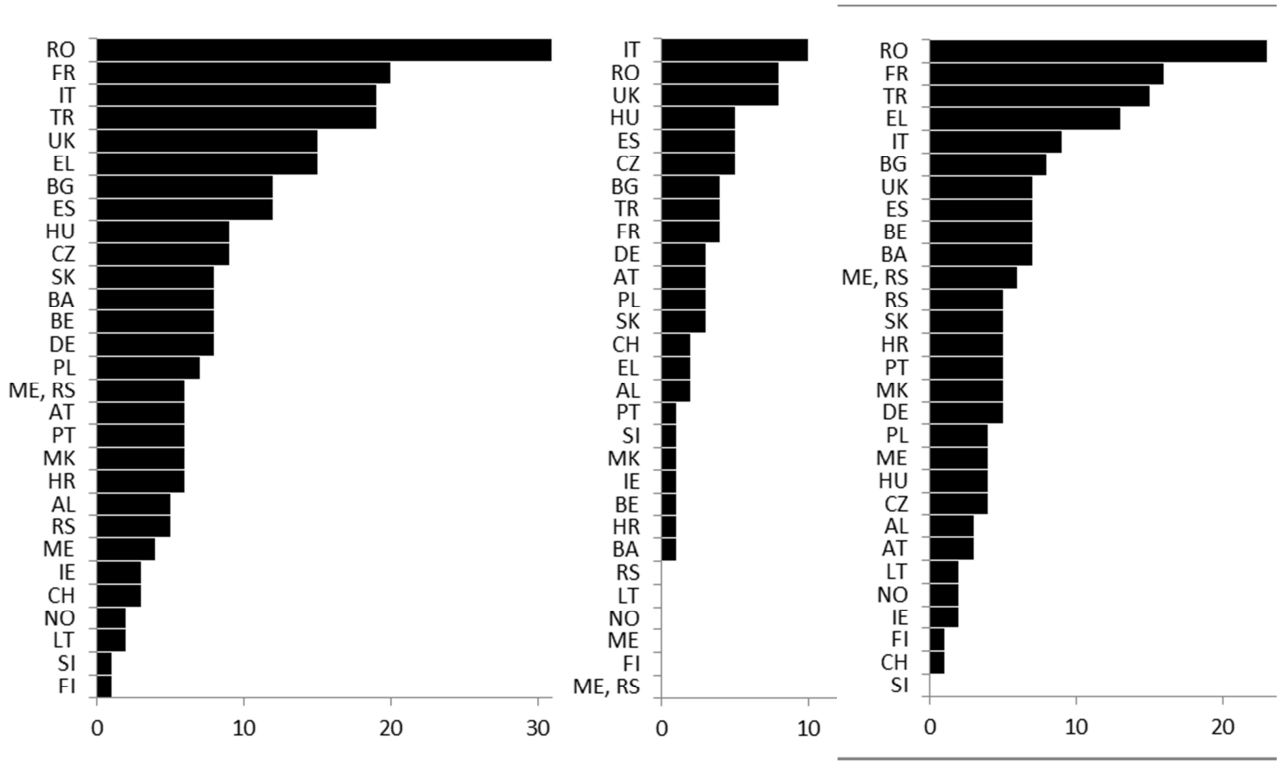


Figure 3: Number of EM-DAT recorded flood events (2000-2011) by country: total number (left); events with recorded economic losses (*middle*), number of events for which no record of economic impacts is available (*right*)[10].

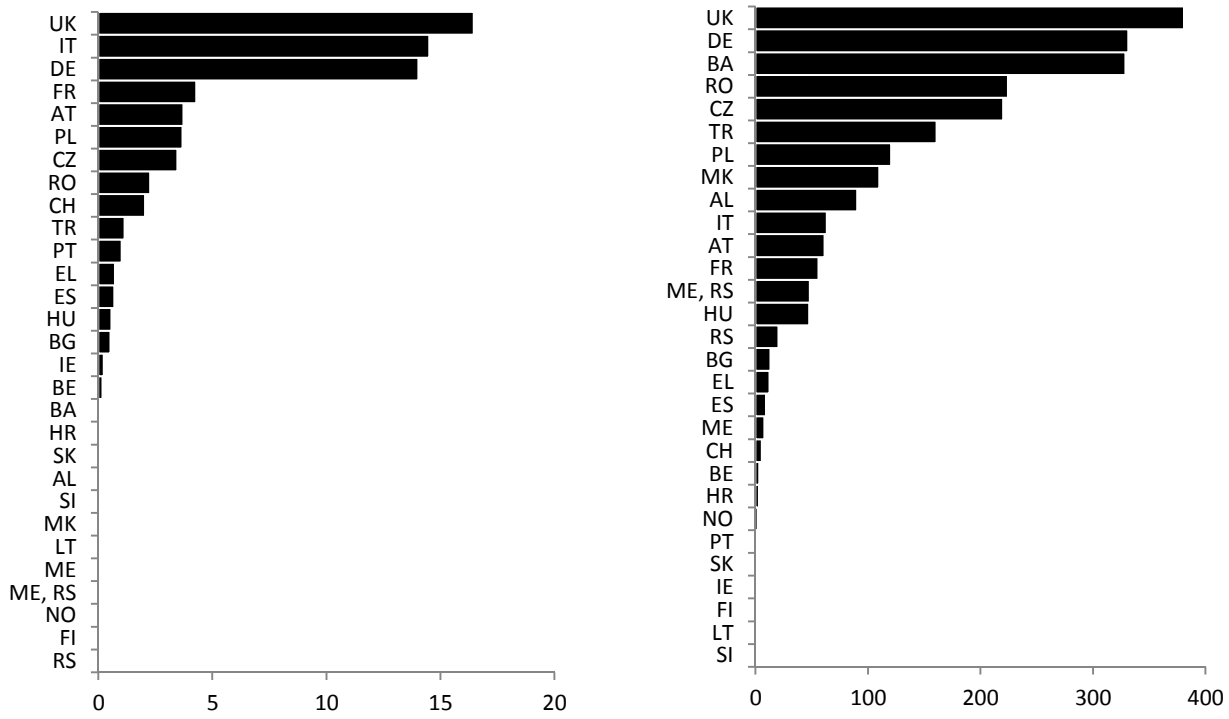
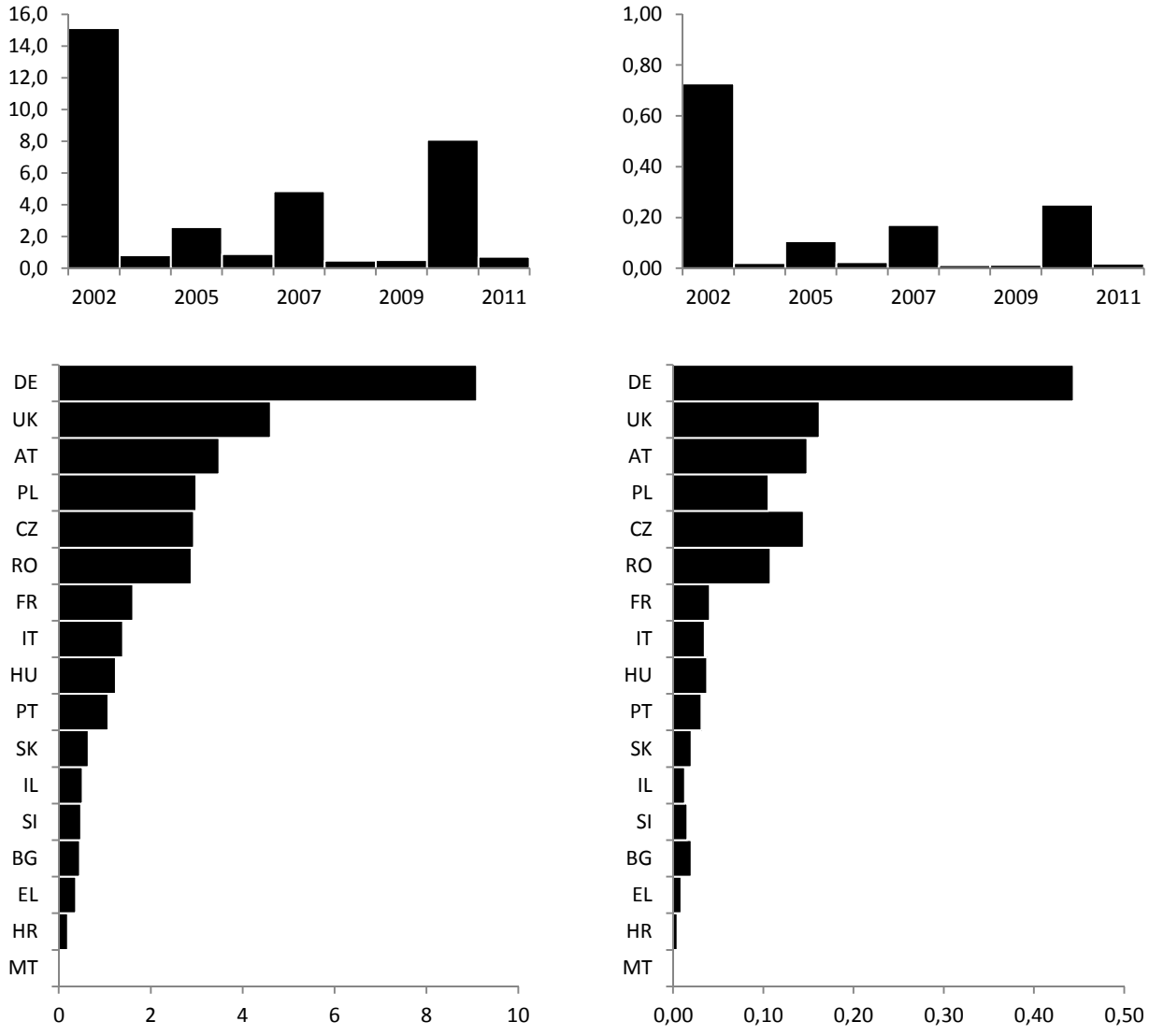


Figure 4: Cumulative **country-wise** impacts of the EM-DAT recorded flood events (2000-2011) in EEA member and cooperating countries; (left) total economic damage in billions of 2011 Euro value; (right) number of affected persons in thousands[4].

[10] Serbia and Montenegro (ME, RS), or the Federal Republic of Yugoslavia, ceased to exist in 2006. From then on, The Republic of Serbia (RS) and Montenegro (ME) are listed separately.

Furthermore, the sample includes all events for which the EUSF has been mobilised. Until September 2012[11], the EUSF has approved over 3 billion Euro of aid to the disaster stricken, flood being the most common cause (1.34 billion or 42 per cent of the approved aid). The 29 events for which the aid from the Fund was mobilised, include 17 *major* events in 12 MS, 9 *regional* events in 7 MS, and 3 *neighbouring country* events in 2 MS.



A) Number of fatalities

B) Number of affected persons (in thousands)

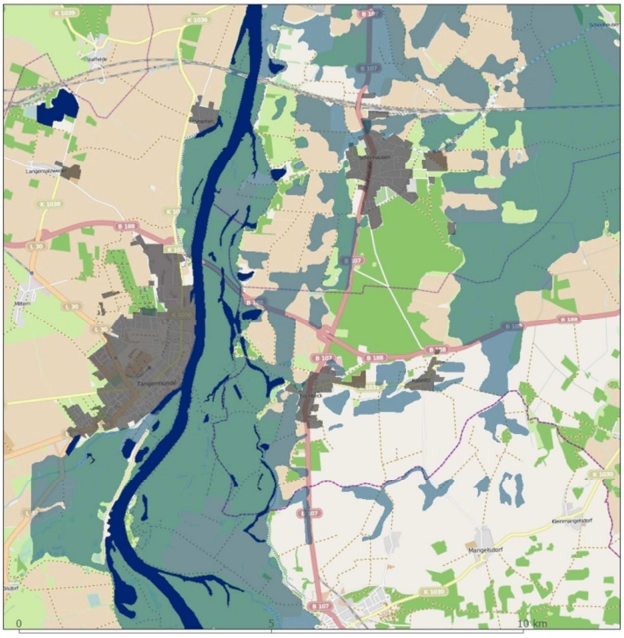
Figure 5: Cumulative **country-wise** impacts of the events for which EUSF aid had been mobilised (2002-2011) in EU Member States; (left) total economic damage in billions of 2011 Euro value; (right) number of affected persons in thousands.

It is worth to mention that since April 2012, the Copernicus Emergency Management Service[12] (CEMS) provides, upon request, geospatial information (delineation of flooded areas, impact assessment) from disaster stricken regions derived from satellite remote

[11] After September 2012 and until most recent data (October 2013) there are 5 additional flood events for which EUSF has been mobilised: the October 2013 floods in Croatia and Slovenia; November 2012 flood in Austria, and the earlier mentioned Summer flood in Central Europe (Germany, Austria and Czech Republic) (EC, 2013b)

[12] emergency.copernicus.eu/mapping

sensing and completed by available in situ or open data sources (Map 2). The provided information enables more detailed analysis not pursued here because the service has been launched only recently and does not cover the floods during the period analysed in this paper.



Map 2: Flood delineation produced by the Copernicus Emergency Service for the 2013 Summer Flood: Saxony Anhalt, Germany. Data published[13] on 2013-06-21, own elaboration.

5. Application of different threshold criteria

In this section we explore different threshold criteria applied to the sample EM-DAT data set (section 3), taking into account the events recognised as significant by EEA (2011) and those for which the EUSF was mobilised. Out of the 29 EUSF events, 22 have been identified in EM-DAT database. From among these 22 events, 4 do not include any estimate of economic damage. For the remaining 18 events, the estimates of losses made for the scope of EUSF and reported in EM-DAT are closely correlated ($r = 0.97$) but considerably different: in all but 4 cases the EUSF estimated damage is higher by average by 11 per cent (with substantial variation). In contrary, the EM-DAT recorded losses highlight some cases that would have qualified for aid from the EUSF.

For the subsequent analysis we have approximated the economic losses in EM-DAT for which no original record is available (see also Annex 2). Making use of a close correlation between the population affected and reported economic losses ($r = 0.70$), we have *approximated* the losses for the 141 events in EM-DAT (over the period 2000-2011) for which no economic damage information is available but for which the population affected is reported (see Annex 1 for detail). The simple linear regression model show statistically significant ($p = 0.5$) influence of losses over population affected, but the simple model is (expectedly) able to explain only a half of the observed variability ($R^2 = 0.503$). The confidence interval for the predicted values is large even at the lower significance level (90

[13] http://emergency.copernicus.eu/mapping/ems-product-component/EMSR047_01FISCHBECK_DELINEATION_OVERVIEW/2

per cent). For this reason we have used the upper confidence bound along with the predicted value.

Furthermore, we have extended the EUSF criteria to the sample EM-DAT data set. The EURSTAT does not provide information about GNI[14] for some of the countries covered in our analysis[15]. These countries have been provisionally excluded from the analysis but will be included if the respective macroeconomic measure is obtained from other sources. Because the EUSF threshold (0.6 per cent of GNI) is calculated based on the data from previous years (e.g. 2005 threshold is based on GNI in 2003), and the GNI for the period before 2000 is indicated in ECU instead of EUR, we have excluded the records from 2000 and 2001. The reduced EM-DAT data set now contains 174 (instead of 256) records. The Barredo/EEA threshold (5 per thousand of a per cent point of EU GDP) has been calculated using the EUROSTAT data and ranges between 460 million Euro in 2000 and 632 million in 2011.

In the reduced data set, for some 22 events the EUSF had been mobilised. (Note that not all EUSF events are included in EM-DAT). Out of them 14 are classified as major by EEA (2011). Most of the other occurred in 2010-2011 that is beyond the period of reference considered in EEA (2011), with exception of Ireland November 2009 flood. Eight EUSF events do not satisfy Barredo/EEA damage condition. If instead of EUSF damage estimates the EM-DAT recorded damage is considered, the number of events not satisfying Barredo threshold increases to 14. None of the 22 events satisfies the Barredo/EEA mortality criterion.

The number of EEA (2011) major events in the reduced dataset (consisting of 174 records) amounts to 41, including 13 EUSF events. In this subset, based on EUSF damage estimate, 5 out of 13 EUSF events do not satisfy Barredo/EEA damage threshold and none the mortality threshold. Based on the EM-DAT damage estimate, 21 events failed to satisfy the Barredo/EEA damage criterion and once again, none satisfy the mortality threshold.

Fifty-eight events satisfy the proxy criterion of at least 1.000 person affected (that represent the upper bound of damage regression model in annex 1). Twelve satisfy the Barredo/EEA damage criterion but 117 does not have any indication of the economic losses.

The review criteria are ubiquitous and not mutually exclusive. The EUSF relax the overall economic damage constrain but in arbitrary way. The Barredo/EEA list of SFE employ NAT-CAT-SERVICE data in addition to the EM-DAT data, because the NAT-CAT-SERVICE database is not publicly accessible, we could not replicate their assessment. The European events may also be expressed by number of EU MS affected by the same event. The EM-DAT database incorporated a unique identification number for events that led to damage and losses in different countries and hence are composed by more than one

[14] Income, saving and net lending/ borrowing - Current prices (nama_inc_c, code B5GM), accessed in February 2013

[15] Specifically, the former Yugoslav Republic of Macedonia, Albania, Montenegro, Serbia (only from 2002 onwards), and Bosnia-Hercegovenia

record. There are 19 events that affected more than one EEA member or cooperating country and 10 that affected simultaneously more than 2 countries.

In order to identify the significant events in the past records, we recommend the following algorithm: In cases in which the economic assessment is available, the population affected (>1.000) and damage (0.6 per cent of GNI) may be applied. Where such information is available, the 0.6 GNI criterion can be replaced by 1.5 per cent regional GDP or 500 evacuated persons. In cases for which no economic assessment of damage is available, the affected population can be set to 5,000.

Applying these criteria to the EM-DAT sample set yields 30 events, sixteen of which are also classified as major by EUSF nineteen by Barredo/EEA. From among the data for which no economic assessment in EM-DAT is available, only 5 EEA records and none of the EUSF is left out.

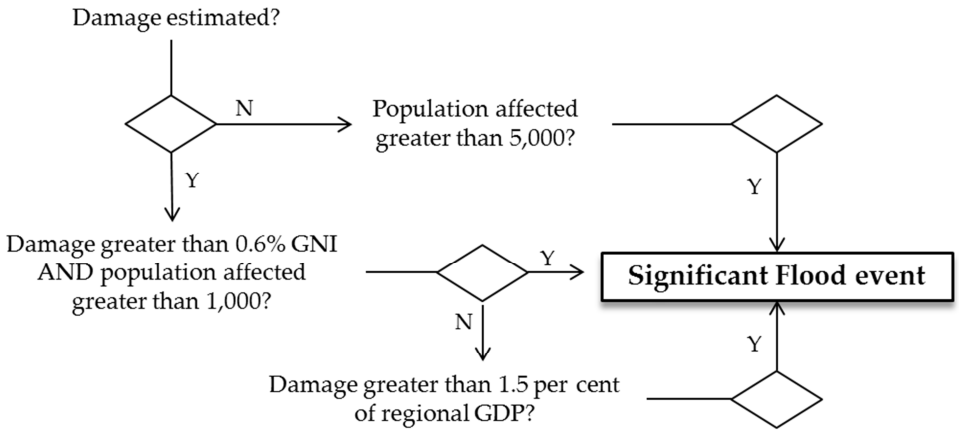


Figure 6: Proposed algorithm for selecting significant flood events in Europe

For a new data, better information should be collected with respect to the geographic extent of the impacted area, population affected (evacuated, brought to the shelters, otherwise affected – by substantial reduction of essential services). The recorded damage should be summarised at the scale of river basin districts RBDs (or management units) and brought into relation with the regional GDP (NUTS2 or NUTS3). The *Copernicus Emergency Management Service*[16] (CEMS) provides, upon request, geospatial information (delineation of flooded areas, impact assessment) from disaster stricken regions derived from satellite remote sensing and completed by available in situ or open data sources.

ETC/ICM (2013) has analysed the data submitted by the Member States (MS) in the context of the reporting obligations under the FD (EC, 2007). The coverage of the estimated impacts of reviewed flood events is very heterogeneous across the MS and the economic and social impact estimates are available only for a relatively small fraction of all events.

[16] emergency.copernicus.eu/mapping

In the future research, the rule for identification of the SFE will be applied to the reported events.

References

Barredo, J I, 2009. Normalised flood losses in Europe: 1970-2006. Natural Hazards And Earth System Sciences 9, 97–104.

Barredo, J. I., 2007. Major flood disasters in Europe: 1950–2005. Natural Hazards 42, 125–148.

Choryński, A., Pińskwar, I., Kron, W., Brakenridge, R., Kundzewicz, Z.W., 2012. Catalogue of large floods in Europe in the 20th century, in: Kundzewicz, Z.W. (Ed.), Changes in Flood Risk in Europe. IAHS Press and CRC Press/Balkema (Taylor & Francis Group), IAHS Special Publ. 10, Wallingford, pp. 27–54.

Ciscar, J.-C., Iglesias, A., Feyen, Luc, Szabo, L., Van Regemorter, D., Amelung, B., Nicholls, R., Watkiss, P., Christensen, Ole B, Dankers, R., Garrote, L., Goodess, C.M., Hunt, A., Moreno, A., Richards, J., Soria, A., 2011. Physical and economic consequences of climate change in Europe. Proceedings Of The National Academy Of Sciences Of The United States Of America 108, 2678–2683.

Dankers, R., Christensen, Ole Bossing, Feyen, Luc, Kalas, M., De Roo, A., 2007. Evaluation of very high-resolution climate model data for simulating flood hazards in the Upper Danube Basin. Journal of Hydrology 347, 319–331.

Dartmouth Flood Observatory, 2013. No Title.

De Groeve, T., Poljansek, K., Ehrlich, D., 2013. Recording Disaster Losses Recommendations for a European approach.

De Kok, J.-L., Grossmann, M., 2010. Large-scale assessment of flood risk and the effects of mitigation measures along the Elbe River. Natural Hazards 52, 143–166.

EC, 2005. REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the European Union Solidarity Fund. COM(2005) 108 final.

EC, 2007. Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks. OJ L288, 6.11.2007.

EC, 2013a. Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Council Regulation (EC) No 2012/2002 establishing the European Union Solidarity Fund.

EC, 2013b. EU Solidarity Fund Interventions since 2002 (NOVEMBER 2002 – OCTOBER 2013).

EEA, 2011. Mapping the impacts of natural hazards and technological accidents in Europe - An overview of the last decade. EEA Technical Report No 13/2010, http://www.eea.europa.eu/publications/mapping-the-impacts-of-natural.

EEA, JRC, ETC/CCA, 2013. Towards a potential European flood impact database. EEA - JRC – ETC/CCA Joint Technical Paper, European Envirnmental Agency, http://cca.eionet.europa.eu/reports/EEA_JRC_ETC-CCA%20JTP.

ETC/ICM, 2013. Historic flood events in Europe: European case studies based on the reporting under the Floods directive. ETC/ICM Working Paper 2013.

Feyen, Luc, Dankers, R., Bodis, K., Salamon, P., Barredo, Jose I, 2012. Fluvial flood risk in Europe in present and future climates. Climatic Change 112, 47–62.

Guha-Sapir, D., Below, R., 2002. THE QUALITY AND ACCURACY OF DISASTER DATA A COMPARATIVE ANALYSES OF THREE GLOBAL DATA SETS.

IPCC, 2000. IPCC special report emission scenarios: Summary for Policymakers.

James, P., Stohl, A., Spichtinger, N., Eckhardt, S., Forster, C., 2004. Climatological aspects of the extreme European rainfall of August 2002 and a trajectory method for estimating the associated evaporative source regions. Natural Hazards and Earth System Science 4, 733–746.

Kreibich, H., Thieken, A.H., Petrow, T., Muller, M., Merz, B., 2005. Flood loss reduction of private households due to building precautionary measures - lessons learned from the Elbe flood in August 2002. Natural Hazards and Earth System Sciences 5, 117–126.

Kundzewicz, Z., Pinskar, I., Brakenridge, R., 2013. Large floods in Europe, 1985-2009 (vol 58, pg 1, 2013). Hydrological Sciences Journal-Journal Des Sciences Hydrologiques 58, 736.

Kundzewicz, Z.W., Pińskwar, I., Brakenridge, G.R., 2012. Large floods in Europe, 1985–2009. Hydrological Sciences Journal.

Marchi, L., Borga, M., Preciso, E., Gaume, E., 2010. Characterisation of selected extreme flash floods in Europe and implications for flood risk management. Journal of Hydrology 394, 118–133.

Meyer, V., Priest, S., Kuhlicke, C., 2012. Economic evaluation of structural and non-structural flood risk management measures: examples from the Mulde River. Natural Hazards 62, 301–324.

Mueller, M., Kaspar, M., Matschullat, J., 2009. Heavy rains and extreme rainfall-runoff events in Central Europe from 1951 to 2002. Natural Hazards and Earth System Science 441–450.

MunichRe, 2013. Natural catastrophes in the first half year of 2013. Geo Risks Research, NatCatSERVICE.

Mysiak, J., Testella, F., Bonaiuto, M., Carrus, G., De Dominicis, S., Cancellieri, U.G., Firus, K., Grifoni, P., 2013. Flood risk management in Italy: challenges and opportunities for th eimplementation of the EU Floods Directive (2007/60/EC). Natural Hazards and Earth System Science 13, 1–13.

Nakicenovic, N., Swart, R. (Eds.), 2000. Special Report on Emissions Scenarios. Cambridge University Pres, Cambridge, United Kingdom.

Neuhold, C., 2013. Flood 2013 in Austria. Contribution during the workshop "Land Unter in Europa", September 2013. Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management.

NOAA, 2013a. National Weather Service.

NOAA, 2013b. High Water Level Terminology.

Pińskwar, I., Kundzewicz, Z.W., Peduzzi, P., Brakenridge, G.R., Stahl, K., Hannaford, J., 2012. Changing floods in Europe, in: Kundzewicz, Z.W. (Ed.), Changes in Flood Risk in Europe. IAHS Press and CRC Press/Balkema (Taylor&Francis Group), IAHS Special Pub. 10, Wallingford, pp. 83–96.

Rojas, R., Feyen, L., P., W., 2013. Climate Change and River Floods in the European Union: Environmental, Socio-Economic Consequences and the Costs and Benefits of Adaptation. Global Change (in review).

Socher, M., Boehme-Korn, G., 2008. Central European floods 2002: lessons learned in Saxony. Journal of Flood Risk Management 1, 123–129.

The Pitt Review: Learning lessons from the 2007 flood, 2008.

Uhlemann, S., Bertelmann, R., Merz, B., 2013. Data expansion: the potential of grey literature for understanding floods. Hydrology and Earth System Sciences 17, 895–911.

Ulbrich, U., Bruecher, T., Fink, A.H., Leckebusch, G.C., Krueger, A., Pinto, J.G., 2003. The central European floods of August 2002 : Part 1 – Rainfall periods and flood development. Weather 58, 371–378.

Annex 1 Impacts experienced by flood events of different intensity (NOAA, 2013b)

Minor flood events	Moderate flood events	Major flood events
- water over banks and in yards; - no building flooded, but some water may be under buildings built on stilts (elevated) - personal property in low lying areas needs to be moved or it will get wet - water overtopping roads, but not very deep or fast flowing - water in campgrounds or on bike paths - inconvenience or nuisance flooding - small part of the airstrip flooded, and aircraft can still land - one or two homes in the lowest parts of town may be cut off or get a little water in the crawl spaces or homes themselves if they are not elevated	- several buildings flooded with minor or moderate damage - various types of infrastructure rendered temporarily useless (i.e. fuel tanks cannot be reached due to high water, roads flooded that have no alternates, generator station flooded) - elders and those living in the lowest parts of the village are evacuated to higher ground - access to the airstrip is cut off or requires a boat - water over the road is deep enough to make driving unsafe - gravel roads likely eroded due to current moving over them - widespread flooding, but not deep enough to float ice chunks through town - water deep enough to make life difficult, normal life is disrupted and some hardship is endured - airstrip closed - travel is most likely restricted to boats	- many buildings flooded, some with substantial damage or destruction - infrastructure destroyed or rendered useless for an extended period of time - multiple homes are flooded or moved off foundations everyone in threatened area is asked to evacuate - National Guard units assist in evacuation efforts erosion problems are extreme - the airstrip, fuel tanks, and the generator station are likely flooded - loss of transportation access, communication, power and/or fuel spills are likely - fuel tanks may float and spill and possibly float downstream ice chunks floating through town that could cause structural damage high damage estimates and high degree of danger to residents

Annex 2 Regression model

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,709(a)	,503	,493	1516,03600

a Predictors: (Constant), Population
b Dependent Variable: Loss current

ANOVA(b)

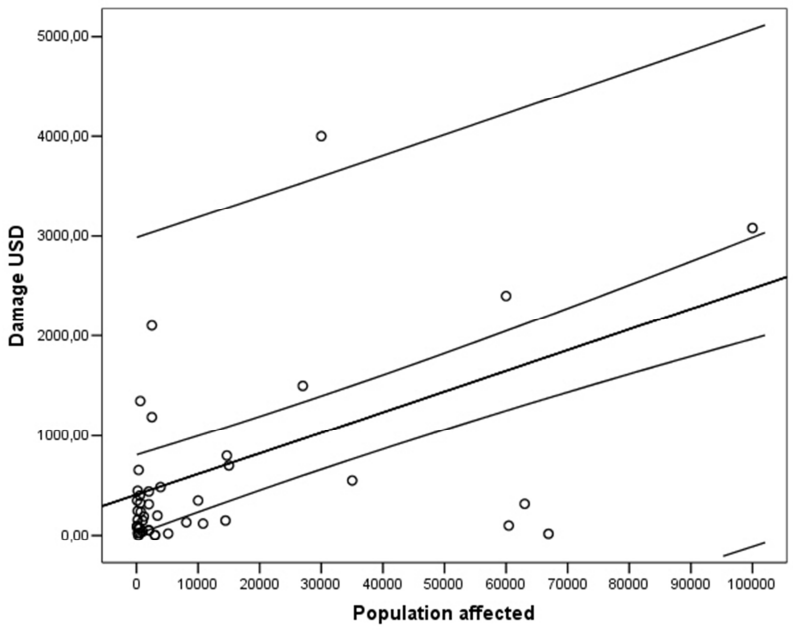
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	107157739,077	1	107157739,077	46,623	,000(a)
	Residual	105724796,800	46	2298365,148		
	Total	212882535,877	47			

a Predictors: (Constant), Population
b Dependent Variable: Loss current

Coefficients(a)

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	409,896	237,602		1,725	,091	-68,373	888,165
Population	,021	,003	,709	6,828	,000	,015	,027

a Dependent Variable: Loss current



Annex 3: List of 174 events (see section 5) and the criteria leading to the selection of the significant flood events (SFE). Note: *ID* refers to the EM-DAT unique identifier, *Year* of occurrence of the event, *Country* where the event occurred. *Significant* by list the events previously recognised as significant by EEA (2011), Barredo (2007) and through the European Solidarity Fund (EUSF). *Impacts* are expressed in terms of people affected, damage in EUR (2011 value); and *loss* specified for events for which EUSF has been mobilised. *Threshold* specific information includes additional information (EUSF applied criterion of 0.6 per cent of *gross national income* GNI or 3,000 million Euro in 2002 values; and Barredo, 2007/EEA, 2011 criterion of 0.005 per cent of the EU-27 GDP). The column SFE denotes the significant flood events identified through the application of the proposed methodology, also highlighted in green. The subsequent columns show the results of individually applied threshold criteria.

ID	Year	Country	Significant by		Impacts			Threshold		Significant events according this work			
			EUSF	*EEA 2011*	*People*	*Loss EUR*	*Loss EUSF*	*EUSF*	*GDP*	***SFE***	*0.6%GNI*	*5,000 People*	*0.005% EU GDP*
2002-0467	2002	DE	1	1	330108	11864	9100	3000	497	**1**	1	1	1
2002-0463	2002	UK			200			3000	497				
2002-0488	2002	UK			250			3000	497				
2002-0774	2002	UK			300			3000	497				
2002-0012	2002	FR			180			3000	497				
2002-0553	2002	FR			800			3000	497				
2002-0574	2002	FR	1	1	2500	1213	835	3000	497				1
2002-0343	2002	IT						3000	497				
2002-0472	2002	IT			20	33		3000	497				
2002-0740	2002	IT		1	10000	350		3000	497	**1**		1	
2002-0171	2002	ES			430	91		3000	497				
2002-0879	2002	ES			50	99		3000	497				
2002-0050	2002	BE			600			1550	497				
2002-0101	2002	BE			1200			1550	497				
2002-0550	2002	BE			600			1550	497				
2002-0813	2002	BE						1550	497				
2002-0450	2002	TR			3000			1311	497				

2002-0489	2002	AT	1	1	60000	2455	2900	1230	497	**1**	1	1	1
2002-0694	2002	EL			210			830	497				
2002-0764	2002	EL						830	497				
2002-0777	2002	EL			180			830	497				
2002-0806	2002	EL						830	497				
2002-0814	2002	PT			60			748	497				
2002-0773	2002	IE			300			548	497				
2002-0479	2002	CZ	1	1	200000	2455	2300	376	497	**1**	1	1	1
2002-0506	2002	HU			1430	4		287	497				
2002-0447	2002	RO			4500			242	497				
2002-0466	2002	RO			3900			242	497				
2002-0471	2002	RO			301	0		242	497				
2002-0513	2002	SK				4		132	497				
2002-0552	2002	BG				1		82	497				
2003-0001	2003	FR						3054	505				
2003-0586	2003	FR	1	1	27000	123	785	3054	505	**1**		1	1
2003-0043	2003	IT		1	1000	141		3054	505				
2003-0433	2003	IT		1	350	588		3054	505				1
2003-0001	2003	BE						1584	505				
2003-0627	2003	TR						977	505				
2003-0044	2003	EL			450			884	505				
2003-0097	2003	EL		1		557		884	505				1
2003-0117	2003	EL						884	505				
2003-0001	2003	PT			36			786	505				
2003-0001	2003	RO						270	505				
2003-0048	2003	RO			600			270	505				
2004-0423	2004	UK		1	1008	79		3066	530				
2004-0568	2004	IT			200			3066	530				

2004-0145	2004	ES			600	12		3066	530				
2004-0369	2004	PL			600			1253	530				
2004-0102	2004	TR			50000			1146	530	**1**		1	
2004-0209	2004	TR						1146	530				
2004-0424	2004	TR			100			1146	530				
2004-0369	2004	HU			393			401	530				
2004-0365	2004	RO			14128			289	530	**1**		1	
2004-0444	2004	RO			14000			289	530	**1**		1	
2004-0369	2004	SK			230			155	530				
2005-0364	2005	DE			450			3118	554				
2005-0451	2005	DE		1		179		3118	554				
2005-0516	2005	FR			3000			3118	554				
2005-0647	2005	FR			1000			3118	554				
2005-0451	2005	CH		1	2500	178		1906	554				
2005-0512	2005	BE			210			1682	554				
2005-0364	2005	AT			900			1337	554				
2005-0451	2005	AT	1	1		569	592	1337	554				1
2005-0340	2005	TR			3000			1263	554				
2005-0415	2005	TR						1263	554				
2005-0131	2005	PL			3600			1139	554				
2005-0313	2005	FI			400			867	554				
2005-0131	2005	CZ						489	554				
2005-0131	2005	HU						423	554				
2005-0473	2005	HU				39		423	554				
2005-0131	2005	RO			600			308	554				
2005-0214	2005	RO	1	1	3400	155	489	308	554	**1**	1		
2005-0337	2005	RO		1	5102			308	554	**1**		1	
2005-0365	2005	RO	1	1	14669	665	1050	308	554	**1**	1	1	1

2005-0473	2005	RO			2000	255		308	554				
2005-0545	2005	RO			30800			308	554	**1**		1	
2005-0747	2005	HR			250			176	554				
2005-0131	2005	SK						168	554				
2005-0473	2005	SI				5		154	554				
2005-0265	2005	BG	1	1		8	222	112	554	**1**	1		
2005-0338	2005	BG		1	200	25		112	554				
2005-0727	2005	BG			12000			112	554	**1**		1	
2005-0473	2005	BG	1	1		163	237	112	554	**1**	1		
2005-0545	2005	BG						112	554				
2005-0429	2005	LT						97	554				
2006-0156	2006	DE		1	1000			3203	585				
2006-0617	2006	ES						3203	585				
2006-0419	2006	CH			3000			1933	585				
2006-0334	2006	TR						1448	585				
2006-0619	2006	TR		1	63015	251		1448	585	**1**		1	
2006-0156	2006	AT		1	516			1398	585				
2006-0302	2006	PL			500			1191	585				
2006-0541	2006	EL			3000	4		1104	585				
2006-0568	2006	EL			90			1104	585				
2006-0617	2006	PT			240			886	585				
2006-0349	2006	CZ			115			525	585				
2006-0156	2006	CZ		1	4200			525	585				
2006-0156	2006	HU	1	1	32000		519	467	585	**1**	1	1	
2006-0209	2006	RO						351	585				
2006-0320	2006	RO		1	600			351	585				
2006-0312	2006	RO		1	5712			351	585	**1**		1	
2006-0335	2006	RO		1	600			351	585				

2006-0127	2006	RO			600			351	585				
2006-0156	2006	RO			17071			351	585	**1**		1	
2006-0302	2006	SK			100			196	585				
2006-0156	2006	SK		1				196	585				
2006-0156	2006	HR		1				195	585				
2006-0209	2006	BG						124	585				
2006-0156	2006	BG						124	585				
2007-0349	2007	DE						3267	620				
2007-0201	2007	UK		1	200	334		3267	620				
2007-0247	2007	UK	1	1	30000	299	4612	3267	620	**1**	1	1	1
2007-0278	2007	UK		1	340000	2916		3267	620	**1**		1	1
2007-0132	2007	ES			280			3267	620				
2007-0174	2007	ES		1	550	296		3267	620				
2007-0551	2007	ES			3600			3267	620				
2007-0349	2007	CH		1	101	257		2028	620				
2007-0168	2007	TR			750			1740	620				
2007-0330	2007	TR			186			1740	620				
2007-0554	2007	TR			2250			1740	620				
2007-0554	2007	EL			600			1141	620				
2007-0068	2007	RO			500			465	620				
2007-0340	2007	RO			960			465	620				
2007-0393	2007	RO			1400			465	620				
2007-0421	2007	RO			1400			465	620				
2007-0171	2007	BG			1000			139	620				
2007-0322	2007	BG			10			139	620				
2007-0554	2007	BG			60			139	620				
2008-0055	2008	UK			300			3267	624				
2008-0381	2008	UK			3000	3		3267	624				
2008-0216	2008	IT						3267	624				

2008-0420	2008	IT			300			3267	624				
2008-0579	2008	IT		1		27		3267	624				
2008-0074	2008	PT			110			936	624				
2008-0306	2008	RO	1	1	11000		471	567	624	1		1	
2009-0228	2009	DE				14		3399	588				
2009-0497	2009	UK		1	3900	325		3399	588				
2009-0428	2009	IT		1	5140	13		3399	588	1		1	
2009-0262	2009	TR			111			2125	588				
2009-0355	2009	TR		1	35020	378		2125	588	1		1	
2009-0228	2009	PL		1	150	71		1799	588				
2009-0228	2009	AT				143		1624	588				
2009-0279	2009	AT						1624	588				
2009-0497	2009	IE	1				521	981	588				
2009-0228	2009	CZ		1	14450	17		735	588	1		1	
2009-0015	2009	RO						722	588				
2009-0228	2009	RO			4			722	588				
2010-0380	2010	DE						3467	614				
2010-0233	2010	FR				1229		3467	614				1
2010-0582	2010	IT			300			3467	614				
2010-0647	2010	ES			30			3467	614				
2010-0193	2010	PL	1		100000	2451	2994	2135	614	1	1	1	1
2010-0380	2010	PL			700			2135	614				
2010-0601	2010	BE			690	174		2108	614				
2010-0619	2010	EL			150			1353	614				
2010-0068	2010	PT	1		618	986	1080	995	614	1	1		1
2010-0193	2010	CZ	1		1200	151	205	882	614				
2010-0217	2010	CZ						882	614				
2010-0380	2010	CZ	1		200	122	437	882	614				
2010-0251	2010	RO	1		12237		876	814	614	1	1	1	1

2010-0193	2010	HU	1		2000	35	719	593	614	**1**	1		1
2010-0193	2010	SK	1		200	20	650	378	614	**1**	1		1
2010-0217	2010	SK			650			378	614				
2010-0193	2010	HR			300	66		277	614				
2010-0619	2010	HR			810			277	614				
2010-0619	2010	BG			90			203	614				
2010-0380	2010	LT						188	614				
2011-0012	2011	DE						3536	632				
2011-0439	2011	FR			2300			3536	632				
2011-0416	2011	IT	1			398	722,5	3536	632				1
2011-0436	2011	IT						3536	632				
2011-0475	2011	ES			2400			3536	632				
2011-0012	2011	BE						2032	632				
2011-0377	2011	TR			3			1978	632				
2011-0453	2011	IE			600	237		806	632				
Total			***22***	***41***	***1531064***					***30***	***14***	***24***	***18***