Natural Hazards (2005) **34:** 151–175

Global Perspectives on Loss of Human Life Caused by Floods

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(Received: 26 September2003; accepted 15 April 2004)

Abstract. Every year floods cause enormous damage all over the world. This study investigates loss of human life statistics for different types of floods and different regions on a global scale. The OFDA/CRED Database contains data on international disasters and is maintained by the Centre for Research on the Epidemiology of Disasters in Brussels (CRED) in cooperation with United States Office for Foreign Disaster Assistance (OFDA). Information from this source on a large number of flood events, which occurred between January 1975 and June 2002, is evaluated with respect to flood location and flood type. Due to the limited availability of information on coastal flood events, the scope of this study is limited to three types of freshwater flooding: river floods, flash floods and drainage problems. First, the development of loss of life statistics over time is discussed. Second, the dataset is analysed by region, by flood type and by the combination of type and region. The study shows that flash floods result in the highest average mortality per event (the number of fatalities divided by the number of affected persons). A cross analysis by flood type and location shows that average mortality is relatively constant for the different types over various continents, while the magnitude of the impacts (numbers of killed) and affected for a certain type varies between the different continents. On a worldwide scale Asian river floods are most significant in terms of number of persons killed and affected. Finally, a comparison with figures for other types of natural disasters shows that floods are the most significant disaster type in terms of the number of persons affected.

Key words: flood mortality, loss of life, floods, flood damage, natural disasters

1. Introduction

Every year floods cause enormous damage all over the world. In the last decade of the 20th century floods killed about 100,000 persons and affected over 1.4 billion people. These figures are derived from the OFDA/CRED International Disaster Database, maintained by the Centre for Research on the Epidemiology of Disasters in Brussels (CRED) in cooperation with United States Office for Foreign Disaster Assistance (OFDA). The statistics show that floods have a large impact on human well-being on a global scale. As a direct consequence floods may lead to economic damage and damages to eco-systems and historical and cultural values. Furthermore floods can lead to the loss of human life and other (non-lethal) human health effects, (Ohl and Tapsell, 2000; WHO, 2002; Hajat *et al.*, 2003). Indirectly floods can cause the loss of economic and agricultural production and a decrease of socio-economic welfare (Appleton, 2002). Future developments may lead to a growth of the worldwide risks of flooding. The effects associated with global warming, such as sea level rise, more intensive precipitation levels and higher river discharges, may increase the frequency and the extent of flooding on a worldwide scale. Global population growth, more intensive urbanization in flood prone areas and the limited development of sustainable flood-control strategies, will increase the (potential) impacts of floods.

This study considers the most serious and irreversible type of consequences of flooding, namely loss of human life. Previous studies have focused on the analysis of flood fatalities for a specific country, for example for Australia (Coates, 1999) or flash flood fatalities in the United States (French *et al.*, 1983, Mooney, 1983). Another study by Berz *et al.* (2001) has documented general statistics of various natural disasters on a worldwide scale. However, a study that analyses global statistics on loss of human life caused by floods is not yet found in the literature. Although every flood can be considered as a unique event with unique characteristics, patterns may be observed when a large number of floods is studied. This study investigates loss of life statistics for different types of floods and different regions with information from the OFDA/CRED International Disaster Database concerning a large number of flood events worldwide. It provides insight in the magnitude of loss of life in floods on a global scale. Furthermore, this investigation will relate the severity of the different flood events to their characteristics and their location of occurrence.

This paper is structured as follows: Section 2 gives a description of the available information and the methodology for classification of data. Section 3 presents the results of the evaluation of loss of life statistics for floods. These statistics are compared with figures for other natural disasters in Section 4. Section 5 presents the conclusions of this study.

2. Analysis of Flood Data from the OFDA/CRED International Disaster Database

2.1. THE OFDA/CRED INTERNATIONAL DISASTER DATABASE

The OFDA/CRED International Disaster Database (EM-DAT) contains essential core data on the occurrence and effects of over 12,800 mass disasters in the world from 1900 to the present. The database is compiled from various sources, including UN agencies, non-governmental organisations, insurance companies, research institutes and press agencies. EM-DAT is publicly accessible at http://www.em-dat.net/. The main objective of the database, as given on the CRED website, is to serve the purposes of humanitarian action at national and international levels. It is an initiative aimed to rationalize decision-making for disaster preparedness, as well as providing an objective base for vulnerability assessment and priority setting. A disaster is included in the database when at least one of the following four criteria is fulfilled: 10 or more persons are killed, 100 or more persons are affected, there is a declaration of a state of emergency, or there is a call for international assistance. Each disaster is recorded by type, date, country and numbers of people killed, injured and affected. The definition given on http://www.em-dat.net/for persons affected is: People requiring immediate assistance during a period of emergency, i.e. requiring basic survival needs such as food, water, shelter, sanitation and immediate medical assistance. In addition also people that have been injured and left homeless after a disaster are included in the total number of affected.

The quality of the data incorporated in the database strongly relies on the quality and the reliability of underlying sources. Especially the estimates of numbers of people of killed and affected may include substantial uncertainty and the figures should be regarded as indicative. Structural regional differences in the numbers reported may emerge due to differences in development of the structures for reporting disaster damage, the availability and accuracy of demographic data, and misreporting of events for political reasons. Furthermore smaller disasters in developing countries may be under-reported and not reflected in global data. Given the broad definitions adopted, additional difficulties may exist in estimating the number of affected for a disaster. An accurate estimation of the number of affected may especially be difficult in complex combined emergencies in developing countries including large numbers of displaced persons.

Specific issues with respect to classification of events in EM-DAT can be recognised. The first type concerns spatial aggregation issues. In some cases multiple separate events are aggregated to one record in EM-DAT. For example, separate floods, which struck different parts of China throughout August 1998, are combined in one record (Disaster number: 19980165). Classification problems may occur in assigning a disaster type since the distinction between different types may not always be clear. Famine can be caused by drought, a tsunami may result in flooding, and landslides might be triggered by floods. Specific classification problems arise in the categorisation of floods associated with windstorms such as cyclones and hurricanes, as is more extensively discussed in Section 2.2. EM-DAT is a very valuable compilation of data from other sources, but the issues discussed above might be crucial in the interpretation of the data.

A further assessment of the quality and accuracy of the available data on natural disasters is given by Guha-Sapir and Below (2002). That study compares publicly accessible EM-DAT with two private disaster databases: NatCat, maintained by Munich Reinsurance, and Sigma maintained by Swiss

Reinsurance. All three databases include natural and man-made disasters. A further comparison shows that differences exist between databases with respect to number of events included and completeness of records. However, due to the increasing commonality of data sources these differences reduced significantly with time, i.e. records that date from the 1980's had greater discrepancies than those from the 1990's.

2.2. METHODOLOGY OF CLASSIFICATION OF FLOOD EVENTS

The impacts of a flood will be strongly influenced by the characteristics of the flood itself and the characteristics of the flooded area. For example, rapidly rising flash floods can cause more devastation than small-scale inundations due to drainage problems, and developing countries might have fewer capital resources to spend on flood protection than industrialised regions. In this study each flood event is categorised according to area characteristics and flood characteristics with available information from EM-DAT and its underlying sources.

2.2.1. *Area Characteristics*

Area characteristics such as population density and magnitude, land-use, warning- and emergency-systems differ on a regional scale and will have influence on the loss of life caused by a flood. Also the level of flood protection and the organisation of flood defence and disaster management are important factors. Communities in developing countries might be more resilient to floods than industrialized countries due to experience with past floods and a strong social, structural and environmental coping capacity. However, they will have fewer capital resources to spend on sustainable protection strategies. Complex developed communities might be more vulnerable to disasters, but they have the ability to obtain better protection systems. The factors discussed above mainly concern socio-economic factors. Also geophysical and climatic factors play an important role in the regional characteristics of floods. Many aspects are relevant in assessing the relation between flood vulnerability and location. No general expectancy with respect to the influence of area characteristics can thus be formulated.

2.2.2. *Flood Characteristics*

To a large degree the devastation caused by a flood will be influenced by its physical characteristics and its impacts on human attributes such as assets, lives, etc. These include the hydraulic characteristics of the flood, such as water depth, flow velocities and rate of rising of the waters. Also the predictability of the flood, determining the possibilities for evacuation, is a key factor in the final loss of life. The type of flood largely determines these factors. Due to the complex inter-related processes that can cause flooding, it is not a simple task to classify them. In Berz *et al.* (2001) and French and Holt (1989) three types are distinguished: coastal, river and flash floods. In the classification proposed in this study a fourth type, drainage problems, is added to account for the less catastrophic events associated with heavy rainfall. Also tsunamis and tidal waves will lead to (coastal) flooding and are added. Since this article focuses on natural disasters, dam breaks are excluded, as they are generally considered as human-induced (or manmade) disasters. Six types of floods are distinguished, which are further listed and described in Box A: coastal floods, flash floods, river floods, drainage problems, tsunamis and tidal waves. These types of floods show significant differences in predictability and impact profile. It is expected that loss of life statistics will differ between them.

Box A: Types of floods distinguished in this study

- *Coastal floods* (or storm surges): These occur along the coasts of seas and big lakes. Wind storms (for example hurricane or cyclone) and low atmospheric pressure cause set-up of water levels on the coast. When this situation coincides with astronomical high tide at the coast, this can lead to (extreme) high water levels and flooding of the coastal area.
- *Flash floods:* These occur after local rainfall with a high intensity, which leads to a quick raise of water levels causing a threat to lives of the inhabitants. The time available to predict flash floods in advance is limited. Severe rainfall on the flood location may be used as indicator for this type of flood. Generally occurs in mountainous areas.
- *River floods:* Caused by flooding of the river outside its regular boundaries. Can be accompanied by a breach of dikes or dams next to the river. The flood can be caused by various sources: high precipitation levels, not necessarily in the flooded area, or other causes (melting snow, blockage of the flow). In general, extreme river discharges can be predicted in some period in advance.
- *Drainage problems:* caused by high precipitation levels that cannot be handled by regular drainage systems. This type of flood poses a limited threat to life due to limited water levels and causes mainly economic damage.
- *Tsunamis (or seismic sea waves):* Series of large waves generated by sudden displacement of seawater (caused by earthquake, volcanic eruption or submarine landslide); capable of propagation over large distances and causing a destructive surge on reaching land.
- *Tidal wave/bore:* Abrupt rise of tidal water caused by atmospheric activities moving rapidly inland from the mouth of an estuary or from the coast.

In the analyses in this study some of the types of floods are excluded for several reasons. Although tsunamis and tidal waves may result in flooding of coastal areas, they are generally categorized as a separate hazards and they are excluded from this study.

Specific classification problems appear in the classification of windstorm events, such as cyclones and hurricanes, which result in flooding and flood-related fatalities. These types of events are generally categorised in EM-DAT as windstorm events and not as floods. As an illustration of this issue two examples are outlined below. Two events categorized in EM-DAT as windstorm events were the Hurricane Floyd in the United States in 1999 (EM-DAT disaster number 19990327), resulting in 77 fatalities in the United States, and the tropical cyclone 2B in Bangladesh in 1991(EM-DAT disaster number 19910120), resulting in an estimated 138,866 fatalities. Event descriptions and data on the mortality are presented in NOAA (2001) and MMWR (2000) for Hurricane Floyd and in Chowdhury *et al.* (1993) for cyclone 2B. From these sources it can be concluded that in both cases the majority of fatalities was flood-related. Nevertheless, these events are categorized as windstorms in EM-DAT. It is believed that many wind-induced floods in coastal areas are wrongly classified as windstorms in EM-DAT. Due to this limitation no representative selection of coastal floods could be achieved. For this reason it was decided to limit the scope of this study to freshwater flooding: only river floods, flash floods and drainage problems events are considered.

2.3. ANALYSED FLOOD DATA

At the time of the investigation (summer 2002) EM-DAT contained data on 1891 flood disasters, which occurred between January 1975 and June 2002. Since limited information was available on flood events before 1975, these events have not been included in the analysis. In the investigation of underlying sources 11 flood events were added to the dataset, which were originally not included in EM-DAT, see appendix A for an overview of these events. The total dataset consisted of 1902 flood events. The following types of information available in the database were used: location (country, continent, region), date of the disaster and information considering the number of killed and total number of affected people. However, not all of the 1902 flood records have complete information, for example numbers of killed or affected people are missing.

2.3.1. *Classification of Flood Data*

First, all records have been categorised by location, based on the information on location (country, region and continent) available in EM-DAT. No information concerning the flood type distinguished in section 2.2 is given in

EM-DAT. Therefore it has been attempted to classify the events in the dataset by flood type with the event descriptions given in the underlying sources of the database. The most important source was the periodical Lloyds Casualty Week. Also other sources, such as UN and Red Cross reports were used. Since the underlying sources were not available for all 27 considered years, mainly events that occurred in the 1990's were classified. Classification of event type was in many cases complicated since the description of the event did not contain relevant information on flood type or characteristics. In other cases the flood event had characteristics of two types and could be considered as a combined event, for example when heavy rainfall causes flash floods in the mountains and river floods in the flood plain. In these situations, the flood type, which is thought to have dominated loss of life, has been chosen as the primary flood type. Based on the underlying sources and the event description in the comments section of EM-DAT, 19 events within the floods category were categorised as coastal floods. These were removed from the dataset, since the scope of this study is limited to freshwater floods. The fact that coastal floods form a limited part of the total flood dataset (1.05%), supports the point made in Section 2.2, i.e. that a substantial number of flood events in coastal areas might have been categorised as windstorms in EM-DAT. An overview of the analysed data, and the number of available records for different selection criteria is given in Table I.

Since information on the location is known for all records, in total 632 have complete information on location, type of flood, and the number of killed and total affected persons. In the analysis of the statistics different subsets of the total dataset are selected to allow maximal use of the available

Table I. Overview of available number of records for different variables

Subset of total dataset	Number of records
All flood events in EM-DAT 1975–June 2002	1891
Flood events added to dataset (Appendix A)	11
Coastal flood events removed from dataset	−19
Total dataset of freshwater floods	1883
Categorised by location	1883
Deaths reported	1761
Total affected reported	1505
Both deaths and total affected reported	1505
Categorised by type	719
Deaths reported	696
Total affected reported	632
Both deaths and total affected reported	632

data. With respect to the completeness of the dataset, it has to be stated that the dataset will not cover all flood events that occurred throughout the world. However, considering the large number of analysed events, it is believed that the considered dataset forms a representative sample of worldwide freshwater flood events.

3. Analysis of Human Loss of Life Caused by Floods Worldwide

3.1. INTRODUCTION AND GENERAL OVERVIEW

This study evaluates global flood statistics for different types of floods in different regions with respect to the numbers of killed and total affected, and the mortality. As a first parameter of the magnitude of flood effects the numbers of killed are analysed. Many adverse, but non-lethal effects, such as the loss of home and property, may occur amongst those that are affected by a flood. Together with the number of killed, the total number of affected can also be considered as an indicator of the extent of the impacts of a flood event. The relative severity of an event can be expressed in a mortality number. Mortality is defined in this study as the fraction of total number of affected persons that lose their life in a flood event.

$$\text{Mortality} = \text{number of fatalities}/\text{total number of affected}$$

Note that in other contexts mortality is defined alternatively, for example as the number of killed per capita per year. However, the measure of mortality used here gives a better insight in the magnitude of human loss of life as it includes an estimate of the actually affected population by an event.

Over the considered period, January 1975–June 2002, 1883 freshwater flood events in the database are reported to have killed 176,864 people and affected 2.27 billion. The five floods with most persons killed are shown in Table II.

The event with most fatalities occurred in 1999 in Venezuela: about 30,000 people died during flash floods and extensive land and mudslides. Table II illustrates that the numbers of affected reported in the dataset differs strongly between events. While tens or hundreds millions have been affected in large-scale floods in India and China, the number of total affected persons is limited for other events.

The remainder of Section 3 will contain the analysis of chronological developments in the statistics (Section 3.2), the evaluations by region (Section 3.3), flood type (Section 3.4) and the combination of region and flood type (Section 3.5), and a discussion of determinants of loss of life in floods (Section 3.6).

Table II. Overview of the ten freshwater flood events with most people killed

Country	Year	Month	Day	Killed	Total affected	Description
Venezuela	1999	12	19	30,000	483,635	flash and river floods and landslides around Caracas and other areas
Afghanistan	1988	6		6345	166,831	floods in Badakhshan, Baghlan, Heart, Kabul, Jouzjan,Samangan, Takhar provinces
China, P. Rep.	1980	6		6200	67,000	floods in Sichuan, Anhui, Hubei
India	1978	7		3800	32,000,000	floods in north and northeast India
China, P. Rep.	1998	8	6	3656	238,973,000	river floods combined with storms and landslides in Hubei, Hunan, Sichuan, Jiangxi, Fujian, Guanxi Prov.

3.2. CHRONOLOGICAL DEVELOPMENT

In this section chronological trends in the dataset statistics are investigated. The number of floods included in the dataset per year is shown in Figure 1. This analysis is limited to the period 1975–2001, since no complete information is available for the year 2002.

The figure shows, especially in the late 1990's, a significant increase in the number of flood events included in the dataset per year. Whether this growth is due to an increase in the number of occurring flood events, or due to a more accurate and extensive data collection cannot be directly derived from the data. However, the improvement in data collection is believed to play an important role in this increase, since WHO (2002) states with respect to EM-DAT: "Since 1975 there was a substantial improvement in reporting and data collection, and since the 1990's more than 90% coverage was achieved." Furthermore the data on other natural disasters in EM-DAT shows similar growing trends in the number of reported disasters per year. A structured and standardized data collection over time will enable researchers to recognize unbiased time patterns in the occurrence of natural disasters.

Figure 2 shows the total numbers of killed and affected per year, together with the average number of people killed and affected per event. For all four series trend lines are included.

The trend analysis shows a slightly growing trend in the numbers of people killed and affected per event. Since also the number of flood events per year

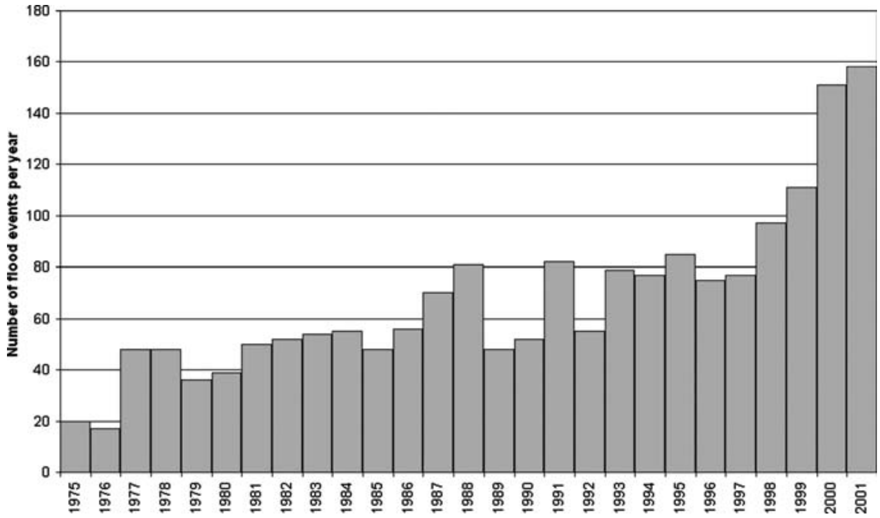

Figure 1. Number of flood events per year included in the dataset for the period 1975–2001.

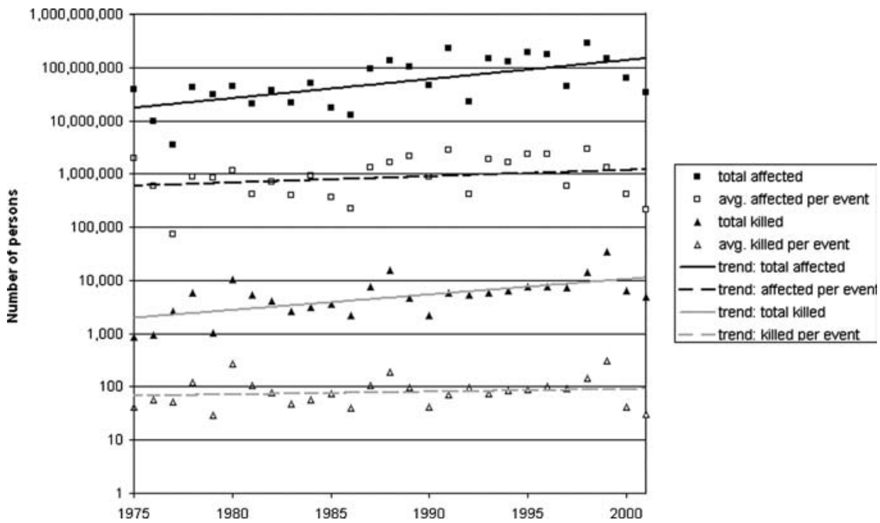

Figure 2. Chronological development of global flood statistics: Numbers of killed and affected per year, average number of people killed and affected per event, and trend lines, for the period 1975–2001.

increases (see Figure 1) a stronger growing trend in the total numbers of killed and affected can be observed. As such these results do not follow the general trends in impacts of natural disasters of the past 30 years, which show a decrease in the numbers of killed and an increase in the number affected (IFRCRCS, 2003). As noted by Pielke (1999) specific care should be taken with the interpretation of such data on flood fatalities. Several issues may influence temporal trends, such as the occurrence of extreme events and the completeness and accuracy of the considered data. Furthermore developments in socio-economic determinants play an important role, such as developments in population numbers, urbanization, infrastructure and disaster management systems.

3.3. ANALYSIS BY REGION

The relation between flood location and impact statistics has been investigated on two levels: by continent and by region. Table III shows the statistics by continent for the number of people killed, affected, and the average mortality per flood event. The presented numbers show large standard deviations due to the fact that these presented figures are all averaged over significantly varying events.

The mortality averaged over all global flood events amounts 1.14%. If Oceania is excluded, no significant differences in mortality between the continents is found. However, some major differences between continents appear when numbers of killed and total affected are considered. While mortality for European floods is highest of all continents, the impacts in terms of persons killed and affected for the floods in Europe are relatively limited when compared with other continents. Asian floods result in an average 1.12% mortality, but affect and kill more people than floods in other continents as they affect substantially larger areas with large populations.

The statistics have also been analysed by the 17 regions defined in EM-DAT. The analysis shows that considerable variations in flood mortality between different regions exist within one continent. For example, highest mortality is found for the Southern Africa region (5.7%) and lowest for Western Africa region (0.08%). The high average of South Africa can be explained by the small number of events included (26) and the dominance of one high mortality event, a flash flood in Laingsburg (South Africa) in 1981 with a 56% mortality. The West African dataset does not include any high mortality event and therefore has a substantial lower average mortality. Similarly the dataset for European floods has a high average mortality (2%), due to the inclusion of some high mortality flash flood events. As the occurrence of certain types of (high mortality) floods is believed to be a major reason for regional differences, the systematic regional biases in reporting and data collection mentioned in Section 2, are expected to have less influence on the outcomes. The aggregated statistics by region also do not indicate a relation between flood mortality and its determinants, such as socio-economic development of region. This issue is further discussed in Section 3.6.

Table III. Number of killed and total affected per event by continent. Table indicates the number of analysed records, and average and standard deviation values

Continent	Number of records	Killed per flood		Total affected per flood		Event mortality	
		Average	Standard deviation	Average	Standard deviation	Average %	Standard deviation %
Africa	303	42	165	99,958	258,951	1.29	8.13
Americas	453	100	1410	109,221	460,434	1.07	5.53
Asia	728	160	483	3,604,429	18,236,759	1.13	5.11
Europe	220	12	23	45,975	170,358	1.41	6.38
Oceania	57	4	8	10,178	33,377	0.09	0.36

Table IV. Number of killed and total affected per event by flood type. Table indicates the number of analysed records, and average and standard deviation values

Flood type	Number of records	Killed per flood		Total affected per flood	
		Average	Standard deviation	Average	Standard deviation
Drainage problems	70	12	36	156,873	770,639
Flash	234	181	1958	55,152	241,708
River	392	118	355	3,373,617	18,913,961

3.4. ANALYSIS BY FLOOD TYPE

In this section the flood events have been categorised by one of the three defined flood types (flash flood, river flood and drainage problems). Table IV shows the statistics by flood type on the average numbers of killed and total affected per flood event. Figure 3 indicates the magnitude of the floods, for the events with one or more fatalities. The total number of affected people is shown on the x-axis and the number of killed on the y-axis. The average and standard deviation of event mortality by flood type are shown in Figure 4. Table IV indicates that on average flash floods kill most persons per event, while river floods affect most persons. Figure 3 shows that floods with high numbers affected are river floods. Most of these events occurred in Asia: the first 45 floods with the highest number of people affected all occurred in China, India, Bangladesh and Pakistan. Flash floods form a majority of the floods with lower numbers of affected persons. Event mortality is in the order of magnitude of 10^{-3}–10^{-4} for events with 100,000 persons affected, while mortality is in the order of magnitude of 10^{-5} for events with 100 million affected. As the affected population increases, generally the affected area will increase. This will therefore include areas where the flood effects will be less lethal (Graham, 1999). Secondly, more time for warning and evacuation will be available when a large area is affected, since the flood will need considerable time to progress through the area. Figure 4 shows that average mortality is highest for flash floods, as these are rapidly developing events, which severely affect smaller areas. River floods affect larger areas and more persons, but result in relatively low values for numbers of fatalities and mortality per event. Loss of life and mortality are low for drainage problems. A large part (50%) of the drainage problem events in the dataset cause one or zero fatalities.

An analysis of variation coefficients shows that the relative variation of the mortality for the analysis by flood type is smaller than for the analysis by continent. The variation coefficient is a measure for the variation in the results and can be obtained by dividing the standard deviation and average

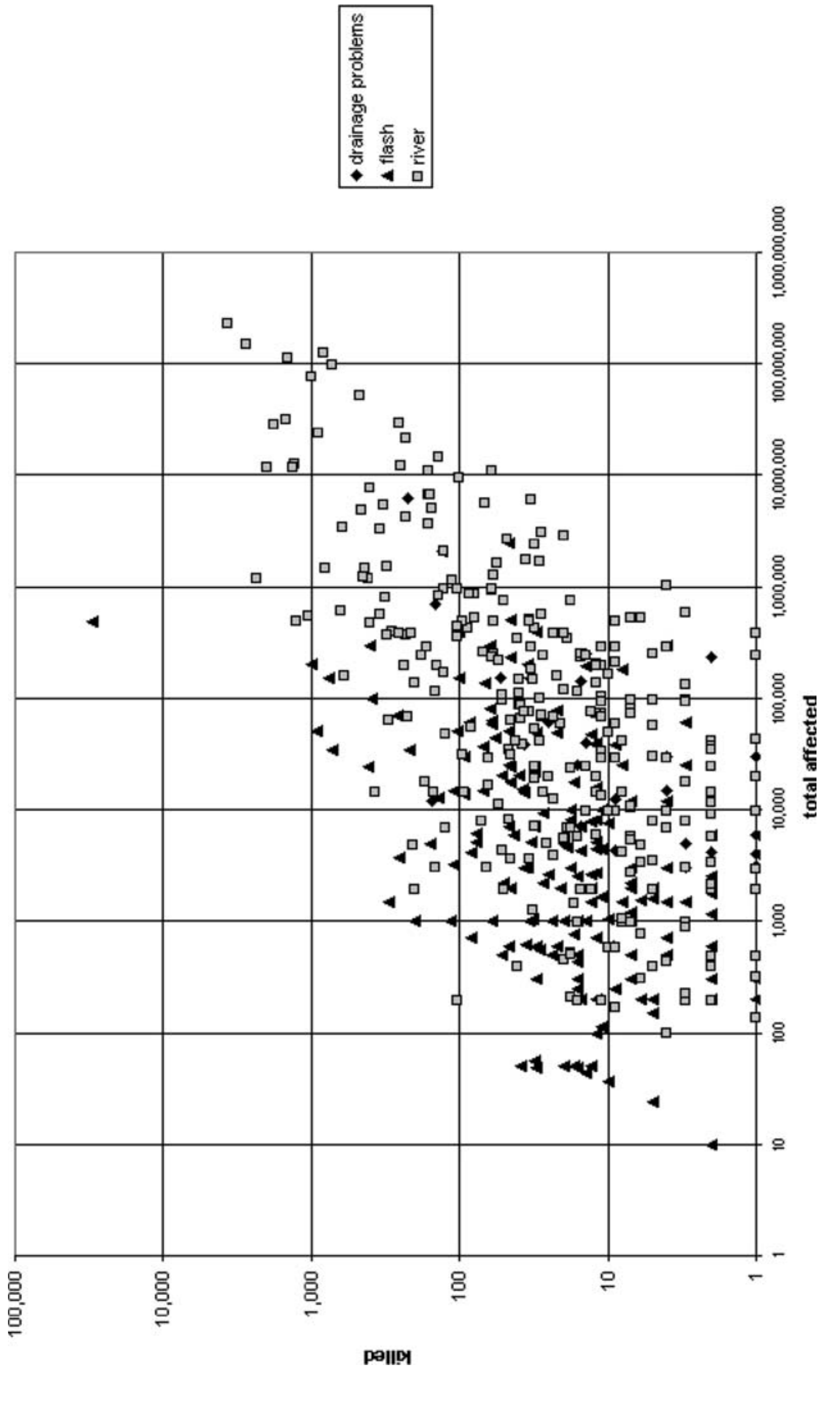

Figure 3. Number of fatalities and people affected for floods with fatalities by flood type.

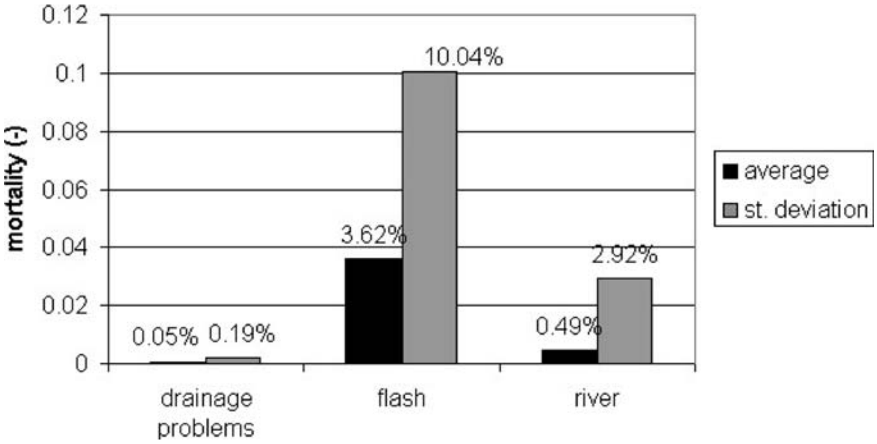

Figure 4. Average and standard deviation of mortality per flood event for different types of floods.

values. While variation coefficients for the analysis by continent range from 4.5 to 6.3 (derived from Table III), variation coefficients for the different flood types are lower: drainage problems: 3.5; flash floods: 2.8. Only river floods statistics show a somewhat higher variation coefficient of 6.0. However, in general this indicates that the flood type is a better variable in interpreting flood mortality than flood location.

3.5. CROSS ANALYSIS BY CONTINENT AND FLOOD TYPE

In this section the combined relevance of flood location and type is considered. In total 719 flood events are categorised by both flood type and continent (also see Section 2.3), which killed over 88,000 persons and affected 1.36 billion. First, the contribution to the total reported of number of killed for the combination of continent and flood type is shown in Figure 5.

Figure 5 shows that especially river floods in Asia and flash floods in Americas contribute much to the total number killed. In the case of the Asian river floods multiple separate events, each causing hundreds to thousands of victims, contribute to the cumulative number killed. The high contribution of flash floods in Americas is almost totally determined by the disastrous flash flood event in 1999 in Venezuela which killed about 30,000 persons. Apart from the contributions of Asian flash floods and American and African river floods, other individual continent-flood type combinations do not contribute significantly to the total numbers killed.

A similar analysis for the contribution of continent-type combinations can be carried out for the number of total affected. In the dataset, numbers of

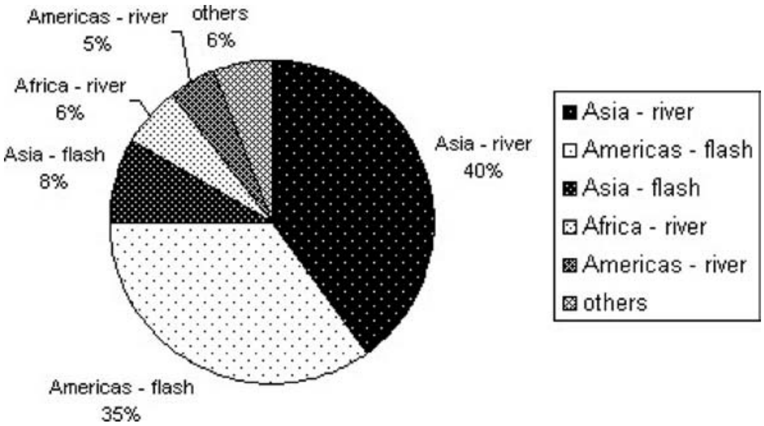

Figure 5. Contribution to total number of killed for the combinations of continent and flood.

total affected are reported for 632 flood events, which affected over 1.36 billion persons. It appears that Asian river floods account for more than 96% of the total affected persons. This is due to the large-scale river floods in the Asian region and the large populations living in the affected regions. Examples are the 1996 and 1998 floods in China, which affected 154 and 238 million persons respectively. While the Asian river floods almost totally determine the cumulative number of affected, their contribution to the total number of killed is smaller (see Figure 5). Other flood continent-type combinations each account for less than 1% of the total number of affected. The average mortality per flood event for the combination of continent and flood type is shown in Figure 6.

Figure 6 indicates that in general mortalities are quite constant by flood type considered over the different continents. For example, flash floods result in the following average mortalities for the different regions Africa (4.2%), Americas (2.7%), Asia (3.2%) and Europe (5.6%). Similar consistency is shown for river floods in the different continents (Americas: 0.33%, Asia: 0.30%, Europe: 0.47%), with an outlying average mortality of 1.46% for African river floods. For Oceania not enough records are available to be able to draw any reasonable conclusions. Table V shows more specific data for the American, Asian and European river floods.

It shows that the average mortalities per event are of the same order of magnitude. However, the average impact of the events (i.e., the average numbers of killed and affected) differs strongly between the continents, as is also shown in Figure 5. Especially Asian river floods are more significant in terms of persons killed and affected, both when the averages per event and the contribution to the total numbers for floods are considered. A further

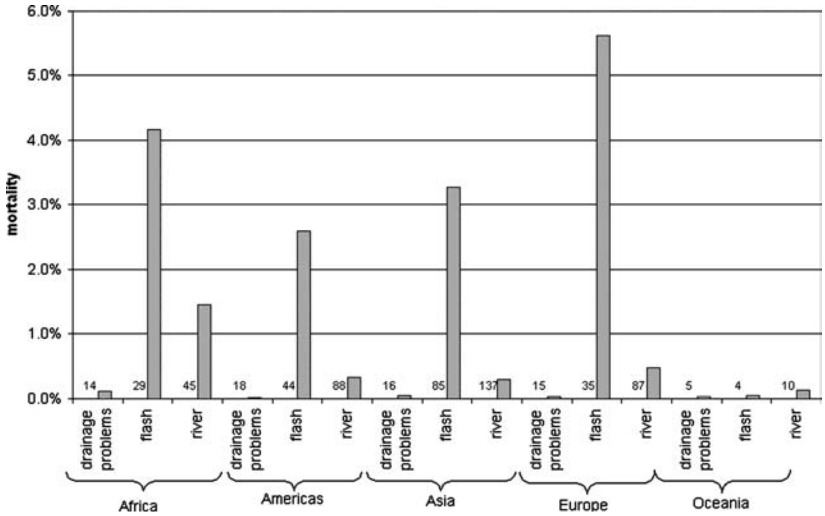

Figure 6. Average mortality per event by continent and flood type. Figures at the bottom indicate the number of analysed records.

Table V. Comparison of data on river flood statistics for Americas, Asia and Europe. Table shows averages per flood event and contribution to total number of persons killed and affected in floods

Flood continent and type	Number of records	Average per flood event			Contribution to total number of	
		Mortality (%)	Killed	Affected	Killed (%)	Affected (%)
Americas - river floods	93	0.33	46	76,744	4.67	0.52
Asian - river floods	148	0.30	241	8,873,735	40.03	96.42
European - river floods	103	0.47	10	52,918	1.15	0.40

analysis of the flood type and continent combinations in the dataset will show a similar pattern: while average mortality seems to be quite constant among the different types of floods, average flood magnitude (numbers of killed and affected) differs between the continents.

Figure 6 only shows average mortality. An analysis of variation coefficients for the combination of continent and type shows that values range between 1 and 5.2, with an average of 2.8. The variation coefficients for the combinations of continent and flood type are smaller than the variations obtained for flood type only, which has resulted in an average variation coefficient of 4.

3.6. DISCUSSION OF DETERMINANTS OF LOSS OF LIFE IN FLOODS

The results in the previous paragraphs highlighted the importance of flood hazard characteristics, as average flood mortality significantly differs between the flood types. However, the losses caused by a disaster will just as much be a function of the human (vulnerability) context. The results of the regional analysis in Section 3.3, did not reflect the influence of socio-economic conditions, as in these results the hazard characteristics were dominant. The considered dataset in this study does not include information on socio-economic factors, which can be used for further interpretation. Past work may well provide insight in the interaction between socio-economic factors and disaster losses. A study by Haque (2003) considered the relations between natural disaster losses and their determinants in South and South-East Asia. In analysing predictors for natural disaster death statistics significant correlations were found for demographic variables (population density, labour force and urban population). Moreover, the study revealed shifts in the influence of variables over the considered period denoting the importance of socio-economic developments in the chronological trends. On the one hand, development may reduce disaster vulnerability due to better emergency preparedness, coping ability and response (Haque, 2003). On the other hand, the development of protection systems and capacities may not keep up with the development of the values to be protected, and thus lead to an increase of vulnerability. Overall, the available evidence proves that disaster losses cannot be only be related to hazard characteristics and that they cannot be separated from societal and developmental factors.

4. Comparison of Flood Statistics With Other Natural Disasters

In this section the impacts of flood events worldwide are compared with the consequences of other natural disasters. This section is not intended as a full analysis of all different kinds of natural disasters, it merely attempts to relate the impacts of floods to other types of natural disasters. EM-DAT includes information on several types of other natural disasters: drought, earthquake, epidemic, extreme temperature, famine, insect infestation, slide, volcano, wave/surge, wild fire and windstorm. The issues in categorising and reporting events (discussed in Section 2.1) might bias the distribution of events and statistics over the different disaster categories. However, despite these limitations a comparison between data for different types of disaster can provide insight into the impacts of the various natural disaster types.

Table VI. EM-DAT data on natural disasters for the period 1975–2001. Table shows number of events and total number of killed and affected persons, and their contribution to the total numbers. Last column shows the average mortality per event

Disaster type	Number of events		Total killed		Total affected		Average mortality per event (%)
	Number	Percentage	Number	Percentage	Number	Percentage	
Drought	495	(8)	560,381	(28)	1,381,353,218	(33)	0.1
Earthquake	548	(9)	483,552	(24)	79,316,329	(2)	3.1
Epidemic	656	(10)	143,276	(7)	17,712,233	(0)	10.1
Famine	62	(1)	282,299	(14)	62,913,301	(2)	0.2
Freshwater floods	1816	(29)	175,056	(9)	2,198,579,362	(52)	1.2
Wind storm	1741	(28)	279,894	(14)	462,772,019	(11)	2.6
Others	969	(15)	65,892	(3)	19,484,370	(1)	
TOTAL	6287		1,990,350		4,222,130,832		

Numbers in paretheses denote percentage.

The analysed data covers the period 1975–2001. In total 1.99 million persons were killed and over 4 billion persons affected in the 6287 reported disasters in this period. In Section 3.1 a growing trend in the number of flood events per year was observed for the late 1990's. Similar growing trends with respect to number of reported events and number of affected are observed for the other types of disasters in other sources, for example MünichRe (2003) and IFRCRCS (2002). Table VI presents the EM-DAT data on the main types of natural disasters with respect to the number of events, number of persons killed and affected, and average mortality per event. Disaster types that contribute less than 5% to the total in the "total killed" and "affected" categories are aggregated in the "others" category (i.e. extreme temperature, insect infestation, slide, volcano, wave/surge, wild fire). It is worth noting that this comparison only considers the statistics on loss of human life. In a more comprehensive comparison of natural disasters their different natures and damage "footprints", resulting in different extents and compositions of direct and indirect consequences, should be taken into account.

Of all recorded natural disasters for the considered period, floods were the most frequently occurring, followed by windstorms. Droughts and earthquakes killed most persons. While other disasters are more significant with respect to numbers of killed, floods by far affect the most persons, in total almost 2.2 billion. These results with respect to the distribution of numbers of events and persons killed over the different disaster categories agree with the results obtained by Shah (1983) for the period 1947–1980. It has to be noted that droughts were not included in that study. Of the 30 natural disasters, which affected most persons in the period 1975–2001, 21 were floods. The large contribution of floods to the cumulated number of affected persons in natural disasters is determined by Asian river floods, as is also discussed in Section 3.5. Table VI shows that especially epidemics and to a lesser extent earthquakes and windstorms are generally high mortality events. Average flood mortality is relatively low, but it is shown that this will strongly depend on the flood type. Average flash flood mortality (3.6%) is in the same order of magnitude as average earthquake (3.1%) and windstorm mortality (2.6%). The relatively high average event mortalities for these events with little or no warning possibilities indicate the importance of warning and evacuation before and during disasters in the reduction of loss of life.

The figures in Table VI do not indicate how often an event with a certain magnitude occurs. The frequency of occurrence in a certain period can be plotted against the consequences of an event in a so-called FN curve. This type of curve is used in several countries for the risk assessment of various hazardous activities (chemical sites, airports, transport of dangerous goods), see for example Jonkman *et al.* (2003) for an overview of applications. In these applications the FN curve is used to show the expected frequency of occurrence of a certain event in the future. In this paper the FN curve is used to assess the frequency of occurrence of natural disasters with certain consequences in the past. A similar use of FN curves for the analysis of occurrence of historical landslides is given by Guzzetti (2000). Figure 7 shows, for

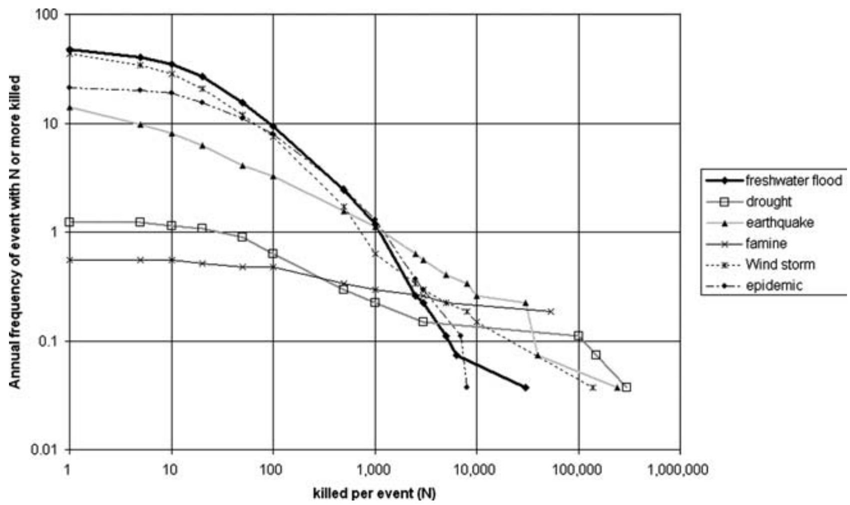

Figure 7. FN curves for various types of natural disasters for the period 1975–2001. It shows the frequency of occurrence of a disaster with N or more fatalities in the considered period on a double logarithmic scal.

the period 1975–2001, the worldwide annual frequency of occurrence of an event with N or more persons killed on a double logarithmic scale. The types of disasters which contribute most to the total number of killed in Table VI (flood, drought, earthquake, famine, wind storm, epidemic) are depicted. This analysis does not take into account growing trends in the number of disasters per year, the frequencies shown in the graph are averaged over a period of 27 years.

Figure 7 shows that floods and windstorms were for the considered period the most frequently occurring natural disasters in the category of disasters that caused between 1 and 1000 fatalities per event. In the higher ranges of numbers of fatalities per event, earthquakes, famines and droughts occurred most frequently. The flood with most fatalities took place in 1999 in Venezuela, killing approximately 30,000 persons. The figure shows that multiple earthquakes, famines and droughts with even more fatalities, sometimes over 100,000, occurred.

A similar analysis can be carried out for the frequency of occurrence of disasters with a certain number of affected people (graph not shown). This analysis indicates that floods are the most frequently occurring disaster in all ranges of numbers of affected persons. For disasters over one million affected, droughts are also important. The event in the period 1975–2001 which affected most people of all natural disasters was not a flood, but a drought in 1987 in India which directly and indirectly affected about 300 million persons.

5. Conclusions

In the period 1975–2001 a total of 1816 worldwide freshwater flood events killed over 175,000 persons and affected more than 2.2 billion persons. These figures indicate the enormous impacts of flood disasters on a worldwide scale. In this study loss of life statistics for different types of floods and different regions have been investigated. Available information from the OFDA/CRED International Disaster Database (EM-DAT) has been analysed for a large number of global flood events which occurred between January 1975 and June 2002. The study is limited to freshwater flood types (drainage problems, flash and river flood) since the data on the occurrence of coastal flood events is included in different disaster categories in EM-DAT. The following can be concluded:

- When considered on a worldwide scale, Asian river floods are most devastating in terms of number of persons killed and affected. In the considered dataset these floods accounted for 40% of the total number of flood fatalities and for 96% of the total persons affected. These figures outline the importance of preventive and mitigating measures specifically aiming at the Asian region.

- No significant differences in average mortality per flood event (= number of killed/number of affected) could be observed between different continents. Larger differences are obtained when the average flood mortality per event is assessed for the 17 world-regions defined in EM-DAT. The differences are mainly caused by the dominance of some high mortality events in the regional datasets. These results do not indicate a relation between mortality and the underlying determinants, such as socio-economic development of the region.
- Significant differences in average mortality per event are observed when the different types of floods are distinguished. A low average mortality is obtained for drainage problems. Average mortality for river flood events is 0.49%, but it has to be noted that these events are very significant in terms of numbers of persons killed and affected. Highest average mortality per event, 3.6%, is obtained for flash floods. Although flash floods generally affect a limited number of persons when compared with other types of floods, they can be considered as the most deadly type of flood. The high mortality for unexpected flash floods illustrates the importance of the development of good warning and prediction systems.
- A comparison with statistics for other natural disasters which occurred in the period 1975–2001 shows that freshwater floods are most significant in terms of numbers of affected persons, affecting over 50% of all reported natural disaster victims in the considered period. A combined analysis of the frequency of disasters with certain impacts shows that floods the most frequently occurring events in the category of natural disasters which caused between 1 and 1000 fatalities per event.

This study constitutes a comprehensive analysis based on publicly available data. However, several issues which are crucial in further interpretation can be identified. First of all, the obtained mortalities per flood events show considerable variations, which are expressed in high standard deviation values. Given these large variations and the uncertainties in the estimation of numbers of people killed and affected, the presented results should not be used as predictors for the loss of life to be expected in specific flood events. However, these global statistics do provide insight in typical patterns in the consequences of different types of floods.

Secondly, there are issues associated with accuracy of the reported numbers, the spatial and temporal aggregation of events, and the disaster type categorization in EM-DAT. Specific difficulties have been indicated with respect to the categorisation of (coastal) flood events associated with the occurrence of windstorms such as hurricanes and cyclones. Therefore this analysis was limited to freshwater floods. Extremely high death tolls have been reported for coastal flood events in the past. Chowdhury *et al*., (1993) report 139,000 fatalities for the floods in Bangladesh following the 1991 cyclone 2B and 220,000 fatalities after the 1970 cyclone. This emphasizes the importance of the inclusion of these events in future analyses of global statistics on floods and fatalities. It is recommended to develop a consistent categorisation methodology for all flood events, to be able include coastal flood events in further studies on loss of life in worldwide floods.

Furthermore, the insight into the causes and factors associated with flood mortality is limited. This outlines the need for more and better quantitative data on health impacts associated with all categories of flooding, including centralized and systematic national reporting of deaths and injuries from floods using a standardized methodology (WHO, 2002).

Further flood specific research should provide insights in the relations between flood losses and hazard characteristics and vulnerability factors, including societal, organizational and developmental characteristics. More insight in such relations will provide a basis for formulation and (cost) effective prioritization of mitigation strategies and policies. Haque (2003) suggests that interventions into population growth and distribution can be used as instruments for disaster damage mitigation. Furthermore improved land use planning, the development of early warning systems and the use of financial economic tools can lead to mitigation of the damages. Other policy developments might concern the strengthening of international emergency preparedness and response. More evidence is needed to prove and compare the effectiveness of such policies. The development of risk indicators, for example for (potential) loss of human life, is important in the development of risk reduction strategies and risk management practices. The results of this study show that the global statistics on loss of human life provide the possibility to (partly) evaluate the influence of hazard and vulnerability aspects and trends in disaster impacts. Finally, the results of this study show that too many people die in and are affected by floods. Further preventive and mitigating policy actions are necessary.

Acknowledgements

The author wishes to thank Matthijs Kok (HKV Consultants) and Paul Verwijmeren (ING), and Debby Guha-Sapir and Regina Below of CRED for their help in the analysis of the data. Ilan Kelman (Cambridge University, CURBE) and Herman van der Most (WL|Delft Hydraulics) are gratefully acknowledged for their comments on draft versions of this paper.

Appendix A

Flood events added to original dataset (source: Lloyds Casualty Week)

Country	Year	Month	Day	Killed	Total affected	Type
Venezuela	1996	12	5	0	10,000	River
Peru	1997	2	16–19	300	1500	Flash
Indonesia	2001	2	10	94	15,000	River
Philippines	2001	2	19	16	Unknown	Flash
China, P. Rep.	1998	5	25	128	174,000	River
Paraguay	1998	5	7	0	75,000	Drainage problems
Uzbekistan	1998	7	8	93	14,000	Flash
Spain	1996	8	8	83	700	Flash
Ethiopia	1996	8	26	1	20,000	River
Japan	1998	8	4	1	30,000	Drainage problems
United States	1998	10		18	7000	River

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