Economics of Disasters and Climate Change
https://doi.org/10.1007/s41885-018-0037-2

ORIGINAL PAPER

Examining the Natural Environmental Hazards Over the Last Century

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Received: 14 July 2018 / Accepted: 5 October 2018/Published online: 25 October 2018

Abstract

The purpose of the paper is to present an extended literature review with statistical results on natural environmental hazards relying on data from the last 117 years (1900–2016). More specifically, inspired by a statement in Smith's (1996) book "the rich lose their money but the poor lose their lives" in this study we detect the high-risk areas and correlate them with economic characteristics in an attempt to accept or reject the above statement. Particularly, we hypothesize that the most developed countries have high economic losses and that the least developed countries have great fatalities. In this way we examine if fatalities are proved to be significant in the least developed countries and the total economic damages are proved to be significant in the most developed countries. A number of graphical presentations come to strengthen the statistical results by using map visualization techniques.

Keywords Environmental hazards risk · Disaster · Economic impact · Damage · Fatalities

JEL Classification D62 · H12 · I31:Q50

Introduction

Knowing the vulnerability that characterizes the environment and taking into account the human activities that come to strain the current situation, we can think of the less prosperous future we will bequeath to the next generations. Even if we overlook human activities or suppose they do not exist, the nature by itself is not characterized by a static condition, meaning that it changes in a daily base. If we search the word "nature" in any dictionary we

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will find a great variety of different definitions given by human beings, however, regarding the environmental definition, nature is described as the collection of any existence in the universe we live and is not man-made. Tectonic plate movement is a typical example of those changes. We cannot blame human activities for those movements and at the same time we cannot do anything in order to avoid them. Apart from the tectonic plate movements, there is a great list of natural processes or phenomena that may occur leading to uncountable losses such as life losses, property damage, economic losses and environmental damage. The international literature recognizes those processes with the term “natural environmental hazards”.

“Hazard is a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage” (UNISDR 2009). Based on the definition of hazard, the occurrence of one hazardous event may cause chain effects to society, economy, health, and the environment. All those categories are topics of high interest nowadays due to the fact that all of them are facing difficult time for different reasons the last decades. The economic crisis, political changes, pollution and its impact on health and climate change are the main factors that influence the categories mentioned above. Environmental hazards come to add more influence to the existing problems. Similar to the definition of hazard is the one that is given for the term disaster. “Disaster is a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resourse” (UNISDR 2009).

Many people confuse the meaning of “hazard” with the meaning of “risk”. Risk is a term that exists in everyone’s life not only when an unexpected event occurs but in any decision someone has to make. As Smith mentions in his book (Smith 1996 p.54) the Chinese word *“wei-ji”,* which is the word that is used to describe risk, is formed by the words opportunity and danger and it includes the two main aspects of the word risk. Compared to hazard, risk is the probability of occurrence of the under examination event and all the possible drawbacks that this event may have (UNISDR 2009). Okrent (1980) illustrates the term hazard (or cause) as the possible threat of people and their property while risk (or consequence) as the probability of this specific hazard to occur (Islam et al. 2013). We can have an environmental hazard such as an earthquake which may not lead to environmental risk if the area of the event is not inhabited (Okrent 1980). In Smith’s book (Smith 1996) when a hazard results to a large number of fatalities such as killed, injured or homeless people as well as huge economic damage then we tend to call it “environmental disaster”, however, he mentioned that there is no globally accepted definition. The International Disaster Database[1] gives a definition to disaster as the “situation or event, which overwhelms local capacity, necessitating a request to national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction and human suffering. Though often caused by nature, disasters can have human origins” (EM-DAT 2017).

Our effort is the first trying to present with details all those environmental hazards that are attached in the main group of natural environmental hazards as well as to examine the occurrence of different natural environmental events which are recognized as hazards and make an effort to present possible direct and indirect losses as well as whether they are space and time concentrated or not.

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The structure of the paper is the following: section 2 reviews the existing relevant terminology helping in the understanding of this complicated field of research, while in section 3 an extended literature review is provided. In section 4, methodology and data are presented, while in section 5 the results of the analysis are presented followed by the discussion. Finally the paper concludes in section 6 providing important statements and fundamentals for further research.

Terminology Review

The environmental hazard is a complicated field of research which contains a great variety of terms and definitions. Hazard can be divided into natural and man-made (also known as anthropogenic or technological), however, there is a difficulty to categorize an event to one of the two categories. Sometimes, the root of the event is difficult to be determined so the humans are not able to decide with certainty whether it is a natural or a man-made hazard (Smith 1996). Another distinction of hazard is between hazard to people, goods, and environment. That distinction is easier to be defined. *Hazard to people* is anything that can cause death, injury, disease, and stress. The *hazard to goods* is anything that can lead to property damage and economic loss. Finally, a *hazard to the environment* is anything that can cause loss of flora and fauna, pollution and loss of amenity (Smith 1996). One more distinction is made between *hazard intensity* and *hazard duration*, giving as hazard intensity the peak deviation beyond the threshold while hazard duration describes the length of time that the threshold is exceeded (Smith 1996).

Using a big dataset which includes all the different events as one category is an inappropriate method to investigate the different aspects both of influences and impacts. For that reason, the EM-DAT has divided all the environmental hazards into 3 main groups, the natural, the technological and the complex, which those three groups are formed by ten subgroups. More specifically, the natural hazards are formed by the biological, the climatological, the geophysical, the hydrological and the meteorological hazards and the extra-terrestrial, the technological hazards, are formed by the industrial, the miscellaneous and the transport hazards, while the complex hazards are a group that is formed by a specific situation called famine. The advantage of separating all different cases into groups, subgroups, types and subtypes is to approach each case from a unique point of view and estimate those factors that can lead to the occurrence or the disaster that this may cause, while at the same time to observe the factors that are influenced as an aftermath. All the different types will be analyzed into sub-sections by providing all the relevant terminology. The same flow will be used in the presentation and discussion of the results.

Biological Hazards

The term of *biological hazard* is described as “the process or phenomenon of organic origin or conveyed by biological vectors, including exposure to pathogenic micro-organisms, toxins, and bioactive substances that may cause loss of life, injury, illness or other health impacts, property damage, loss of livelihood and services, social and economic disruption, or environmental hazards” (UNISDR 2009). The database of CRED divides the biological subgroup into three types of hazard animal accidents, epidemic and insect infestation. The EM-DAT glossary (EM-DAT 2017) provides the definition of *animal accident* as “Human encounters with dangerous or exotic animals in both urban and rural developments”). What is interesting and has to be mentioned in that since 1900 there is only one significant animal accident event which occurred in 2014 in Niger and caused 12 deaths while at the same time affected 5 more people.

As mentioned in Smith (1996 p. 242–244), the World Health Organization defines the *epidemic disease* as "the occurrence of a number of cases of a disease, known or suspected to be of infectious or parasitic origin, that is unusually large or unexpected for the given place and time". The epidemic diseases are divided into bacterial, parasitic and viral diseases. The *bacterial disease* is the "unusual increase in the number of incidents caused by the exposure to bacteria either through skin contact, ingestion or inhalation (EM-DAT 2017). Some of the most well-known bacterial disease are cholera, tuberculosis, measles, whooping cough, tetanus and diphtheria (Smith 1996, p. 245). The *parasitic disease* is the "exposure to a parasite - an organism living on or in a host – causes an unusual increase in the number of incidents" (EM-DAT 2017). Some of the most known parasitic diseases are malaria, chagas disease, giardiasis and trichinellosis and may occur due to the consumption of contaminated water or food, or the contact with insects, animals (zoonotic) and pets (EM-DAT 2017).

The third type of biological hazards is the insect infestation, which based on the CRED database is divided into grasshopper events and locust events. According to EM-DAT glossary (EM-DAT 2017), *insect infestation* is the "pervasive influx and development of insects or parasites affecting humans, animals, crops and materials". Seaman et al. (1984) suggest that insect infestation tend to appear after the occurrence of another natural hazard. For that reason, they outline six main factors which may lead to such disease to outbreak. These six factors that can lead to a disaster-related disease can be a) the existence of the disease in the population even before the natural event, b) the ecological change that is caused from a disaster, c) the migration (movement) of the population, d) the damage (demolition) of the public utilities, e) the disruption of disease control programs and f) altered individual resistance to disease. What is also mentioned is the more than one factors may occur at the same time.

Large-scale disasters can be caused by biological hazards especially in the LDCs due to the lack of program controls. The immune system condition can be worsening due to malnutrition, lack of hygiene, restricted access to health care facilities and low-construction level of housing. Especially for the epidemics, the population subgroups which are more vulnerable are the very young ones, the elder and the disadvantaged whose immune system is eager compared to the other subgroups of the population (Smith 1996 p.244). Due to the significant drawbacks of the epidemics, in 1993 the World Health Organization (WHO) reorganized and renamed the Division of Emergency Relief Operations (ERO) into Division of Emergency Humanitarian Action (EHA) in an attempt to strengthen the sharp response to emergencies (Smith 1996 p. 245).

Climatological Hazards

The term *climatological hazard* is described as "a hazard caused by long-lived, meso-to-macro-scale atmospheric processes ranging from intra-seasonal to multi-decadal climate variability" (EM-DAT 2017). The database of CRED divides the climatological subgroup into two types of hazard: drought and wildfire. The complication of the environmental hazards appears once more even in the categorization of the hazard subtypes. Based on Smith (1996), the drought is part of the hydrological hazards,[2] while wildfire is part of the biophysical hazards.[3]

The EM-DAT glossary (EM-DAT 2017) provides the definition of *drought* as "an extended period of unusually low precipitation that produces a shortage of water for people, animals and plants". Because of the slow development that may last sometimes over years, droughts appear to be

[2] Will be analyzed in a following sub-section.

[3] Based on Smith (1996), biophysical hazards include extreme temperatures, epidemics and wildfires.

so different from other environmental hazards (EM-DAT 2017; Smith 1996 p.286). Moreover, drought is not a place concentrated hazards such as tectonic geophysical hazards which are tectonically or topographically concentrated. Drought can take place in any region of the globe (Smith 1996 p. 286). Moreover, drought can lead to different impacts depending on the region of occurrence. Although in the MDCs, there is no deaths connected to drought occurrence, in the case of the LDCs a drought event can lead to lack of water and food supplies which creates a strong bondage to drought and famine. Based on Wilhite and Glantz (1985), it is not appropriate to establish a global definition of drought events but each definition should be regionally concentrated.

The definition of EM-DAT glossary (EM-DAT 2017) concerning the *wildfires* introducing it as “any uncontrolled and non-prescribed combustion or burning of plants in a natural setting such as a forest, grassland, brush land or tundra, which consumes the natural fuels and spreads based on environmental conditions”. As described by Smith (1996), the most dangerous scenery (condition) for a wildfire to established is an area which after a period of active vegetation, has faced a long period of drought and recorded high temperatures, commonly during the same annum. These sceneries are common in Mediterranean areas where during summer, and after a productive winter-spring period, drought is a common condition and the existing climate condition allows high temperatures to be recorded. Due to the fact that wildfires tend to occur to rural areas, it has been observed that there is always ecosystem damage attached to those events (Smith 1996). Knowing that, fuel and weather are the two main elements which can light up a fire, and having already described the weather conditions above, it is important to mention that the type and the quantity of fuel can affect both the intensity and the spread rate of the fire (Smith 1996). The most dangerous period of a wildfire with the most fatalities and losses, both life loss and economic loss, is encountered during the first few hour of the fire (Cheney 1979).

Geophysical Hazards

The term *geophysical hazard* is described as “a hazard originating from solid earth.” (EM-DAT 2017). As it is mentioned in the EM-DAT glossary (EM-DAT 2017), the term geophysical hazard is sometimes substituted by the term geological hazard. This has been proven by the UNISDR (2009) which mentions that the geological hazard is a “geological process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage”. What is also commented by the UNISDR (2009) is that under the term of geological hazard we can include *earthquakes, volcanic activities* and *mass movements*. The database of CRED divides the geophysical subgroup into three types of hazard: earthquake, mass movement and volcanic activity.

According to the EM-DAT glossary (EM-DAT 2017) earthquake is a “sudden movement of a block of the Earth’s crust along a geological fault and associated ground shaking”. As *ground shaking* is recognized any “surface displacement of earthen materials due to ground shaking triggered by earthquakes or volcanic eruptions” (EM-DAT 2017). Although the natural environmental hazards tend to be recognized as random events may occur, the literature provides evidence for the non-randomness of these tectonic events. More specifically, Bolt (1988) mentioned that as far as randomness of earthquakes is concerned, there is a regional distribution due to the fact that more that 65% of all large earthquakes have been observed in an area around the Pacific Ocean which is recognized as the “*Ring of Fire*”. The fact that more that fifteen lithospheric plates exist which constantly move across the globe, increase the earthquake, as well as volcanic activity, occurrence across the tectonic margins (Smith 1996).

Regarding the losses counted due to earthquakes, it is important to mention that different factors, such as topography, frequency of occurrence, high population density, construction techniques and lifestyle, can influence the level of losses (Smith 1996). Another factor that may have a significant impact on the causalities is the time of the occurrence. The time of the event cannot influence the structural damage that may be caused, however, it can significantly influence fatalities, mentioning that during night hours fatalities are higher due to the fact that "victims" tend to sleep at those times.

When examining an earthquake, the main two measures that scientist take into consideration are *earthquake's magnitude* and *intensity*. Earthquake magnitude is described as the energy produced by the seismic waves and it is measured by a well-known scale, the Richter Scale, while earthquake intensity is the ground-shaking measure that is connected to the hazard impact and it uses the Modified Mercalli Scale for measurement purposes (Smith 1996). What is also important to have in mind is that the magnitude is not the only cause of fatalities due to the fact that there are other conditions which may influence the number of fatalities such as the *hypocentre*, which is the point of rupture, and the *epicenter*, which is the source point of the earthquake, additional to the factors that have already been mentioned (Smith 1996).

The CRED database divides the earthquakes into the following two subtypes, ground movements and tsunamis. On the other hand, Smith (1996), presented the subtype of tsunami as a secondary earthquake hazard. In other words, he assumed that a tsunami event is actually an earthquake-related hazard, and it is not recognized as a hazard by itself. In an attempt to describe the meaning of the word tsunami, we should once again refer to the Asian vocabulary and more specifically to the Japanese language which is the "mother" of the word tsunami. Therefore, the word tsunami derives from the words "tsu" which in Japanese meaning "port or harbour" and "nami" meaning "wave or sea". The EM-DAT glossary (EM-DAT 2017) comes to agree on the definition calling tsunamis "waves in the port" and describing them as "a series of waves (with long wavelengths when traveling across the deep ocean) that are generated by a displacement of massive amounts of water through underwater earthquakes, volcanic eruptions or landslides. Tsunami waves travel at very high speed across the ocean but as they begin to reach shallow water they slow down and the wave grows steeper". The reason why Smith (1996) recognizes tsunamis as an earthquake-related event, and it is similar to the EM-DAT term, is the fact that the main root of a tsunami is a tectonic movement of the seabed, also known as submarine earthquake, which is similar to a ground movement resulting to a wave, a disastrous wave when the discussion comes to tsunamis, breaking into the port and causing uncountable fatalities and damages.

Another type of geophysical hazard is the volcanic activity and for some scientists is a derivative of earthquakes. Based on the terminology given by the EM-DAT glossary (EM-DAT 2017), the volcanic activity is "a type of volcanic event near an opening/vent in the Earth's surface including volcanic eruptions of lava, ash, hot vapour, gas, and pyroclastic material". The common element between earthquakes and volcanoes is the fact that both of them appear to be distributed on the top of the tectonic plates (Smith 1996). In other words, the volcanic activities are highly correlated to the tectonic plate movements as in the case of the earthquakes. As Smith (1996) mentions, there are almost five hundred active volcanoes around the globe from which about the 80% are under the category of the subduction volcanoes. Volcanoes are categorized in three different types. The first and most dangerous category is the *subduction volcano* which took its name from the subduction zone where one tectonic plate is moving beneath another. That fact creates the most explosive volcano which historically has led to the most significant explosions. Known volcanoes of that category are the Fujiyama in

Japan, the Mt. Vesuvius in Italy, the Mt. Hood in Oregon and the Mayon in Philippines (Smith 1996). The second category is the *rift volcano* and compared to the first category is the case in which the two tectonic plates tend to diverge. The volcanoes that belong to this category tend to be less explosive compared to the other two categories. The last category is the *hot spot* which are located to the middle of a tectonic plate where the crust of the surface presents a weakness that allows molten material emerge from the earth's interior. The most known case of hot spots is the Hawaiian Islands complex that has been created due to such volcanic eruptions (Smith 1996). The type of volcanic activity hazard can be divided into two main subtypes: the ash fall and the lava flow. Based on EM-DAT glossary (EM-DAT 2017), the *ash fall* is a "fine (less than 4mm in diameter) unconsolidated volcanic debris blown into the atmosphere during an eruption; can remain airbone for long periods of time and travel considerable distance from the source", while on the other hand the *lava flow* is "the ejected magma that moves as a liquid mass downslope from a volcano during an eruption".

The last type of geophysical hazards is the *mass movement*. The short definition provided by the EM-DAT glossary (EM-DAT 2017) describes the mass movement as "any type of downslope movement of earth materials". Smith (1996) adds more description to that definition by mentioning that the downslope movement contains large volumes of materials which may be hazardous when the terrain of occurrence is mountainous. The CRED database divides the mass movement type of hazards into four subtypes: the avalanche, the landslide, the rockfall and the subsidence. Based on the EM-DAT definitions (EM-DAT 2017) the word *avalanche* describes "a large mass of loosened earth material, snow or ice that slides, flows or falls rapidly down a mountainside under the force of gravity". There can be either snow avalanche or debris avalanche. The *snow avalanche* has an expected definition meaning that is a mass downslope of snow and ice. The not so common term that has been used is the debris avalanche which can be either *cold debris avalanche* or *hot debris avalanche* being an unstable slope suddenly collapsing and results from volcanic activity leading to instability and collapse respectively. Once again, the connection between two or more events can be clear emphasizing even more the complexity of the environmental hazards. The term *landslide* is defined as "any kind of moderate to rapid soil movement including lahar, mudslide, debris flow. A landslide is the movement of soil or rock controlled by gravity and the speed of the movement usually ranges between slow and rapid, but not very slow. It can be superficial or deep, but the materials have to make up a mass that is a portion of the slope or the slope itself. The movement has to be downward and outward with a free face" (EM-DAT 2017). Although the EM-DAT glossary does not provide an official term for *rockfall*, Smith in his book (1996) explains the rockfalls as "movements of debris (mainly rock) largely through the air" (Smith 1996 p. 186). That hazard subtype is the simplest and most common type of all movements that have already been described and it occurs on steep faces. The last but not least subtype of geophysical hazards is the subsidence. The existing definition for that hazard is that the "*subsidence* refers to the sinking of the ground due to groundwater removal, mining, dissolution of limestone, extraction of natural gas, and earthquakes" (EM-DAT 2017).

What is important to mention, once again, is that the environmental hazards cannot be easily classified, which is one of the reasons which makes this field of research a very difficult and demanding research area. More specifically, the type of mass movement that has been described with details on the geophysical hazards (with the four subtypes included) also appears on the hydrological hazards under the term of landslides (including once again the same four subtypes and with any other addition on them). The terminology used is exactly the same, and it classifies those four event categories (avalanche, landslide, rockfall, subsidence) also under the hydrological hazards. That allows the researchers to analyze the events from different point of view. This unclear classification is one more evidence of the complexity of nature. Because of not knowing, or to be more specific because of not being absolutely sure of, the origin and the main route of cause of an event, we cannot classify it under one absolute category, therefore, we give flexibility to the researcher or analyst to place an event to a specific category after examining all the aspects that caused each specific occurrence.

Hydrological Hazards

The term *hydrological hazard* is described as "a hazard caused by the occurrence, movement, and distribution of surface and subsurface freshwater and saltwater" (EM-DAT 2017). The CRED Database separates the term hydrological from the term meteorological, however, the UNISDR (2009) recognizes all those phenomena under the same classification which is called *hydrometeorological hazards* (which will be described later on). Being focused on the database of CRED, the hydrological hazards are divided into two types of hazards: floods and landslides. As it has already been mentioned in the previous subsection of geophysical hazards, the type of *landslide* is exactly the same type as mass movement and it includes the avalanche, the landslide, the rockfall and the subsidence, so the repetition will be avoided.

The EM-DAT glossary (EM-DAT 2017) provides the definition of *flood* as "a general term for the overflow of water from the stream channel onto normally dry land in the floodplain (riverine flooding), higher-than-normal levels along the coast and in lakes or reservoirs (coastal flooding) as well as ponding of water at or near the point where the rain fell (flash floods)". Smith (1996) mentioned that this specific environmental hazard is one of the most common, if not the most common, and at the same time can have both advantages as well as drawbacks. The database of CRED divides the floods into three subtypes: *coastal flood, flash flood and riverine flood*, whose definitions have already been mentioned in the definition of flood. Based on Smith (1996), the river floods can be caused by atmospheric hazards such as rainfalls, snowmelts and ice jams, by tectonic hazards such as landslides and by technological hazards such as dam failures, while the coastal floods can be caused by atmospheric hazards such as storm surges and tectonic hazards such as tsunamis.

Since we had already explained the landslides, we will move forward to the meteorological hazards. In the beginning of this subsection we mentioned that UNISDR (2009) recognizes the hydrological hazards and meteorological hazards as a common category called *hydrometeorological hazards* which as describes as "process or phenomenon of atmospheric, hydrological or oceanographic nature that may cause loss of life, injury, or other health impact, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage" (UNISDR 2009). However, due to the fact that we are using the datasets from the CRED database, we should follow their categorization and we will analyze the hydrological and meteorological hazards separately.

Meteorological Hazards

Moving forward, the term *meteorological hazard* is described as "events caused by short-lived/small to mesoscale atmospheric processes (in the spectrum from minutes to days)" (EM-DAT 2017). The CRED database divides the meteorological hazards into three subtypes: the extreme temperature, the fog and the storms. The complication of the environmental hazards appears once more even in the categorization of the hazard subtypes. Based on Smith (1996), the severe storms are part of the atmospheric hazards,[4] while extreme temperature is part of the biophysical hazards. What is more, the subtype of fog is not mentioned at all by Smith (1996).

Extreme temperature includes the cold wave, the heat wave and the extreme winter conditions. *Cold Wave* is "a period of abnormally cold weather. Typically, a cold wave lasts two or more days and may be aggravated by high winds. The exact temperature criteria for what constitutes a cold wave vary by location" (EM-DAT 2017). *Heat Wave* is "a period of abnormally hot and/or unusually humid weather. Typically, a heat wave last two or more days. The exact temperature criteria for what constitutes a heat wave vary by location" (EM-DAT 2017). *Extreme winter conditions* are defined as "damage caused by snow and ice. Winter damage refers to damage to building, infrastructure, traffic (esp. navigation) inflicted by snow and ice in form of snow pressure, freezing rain, frozen waterways etc." (EM-DAT 2017).

Fog is defined as "water droplets that are suspended in the air near the Earth's surface. Fog is simply a cloud that is in contact with the ground" (EM-DAT 2017). What is interesting and deserves to be mentioned in that since 1900 there is only one significant fog event which occurred in 1952 in United Kingdom and caused 4000 deaths.

Storm includes the convective storm, the extra-tropical storm and the tropical cyclone. *Convective storm* is "a type of meteorological hazard generated by the heating of air and the availability of moist and unstable air masses. Convective storms range from localized thunderstorms (with heavy rain and/or hail, lightning, high winds, tornadoes) to meso-scale, multi-days events" (EM-DAT 2017). *Extra-tropical storm* is "a type of low-pressure cyclonic system in the middle and high latitudes (also called mid-latitude cyclone) that primarily gets its energy from the horizontal temperature contrasts (fronts) in the atmosphere. When associated with cold fronts, extratropical cyclones may be particularly damaging (e.g. European winter/windstorm, Nor'easter)" (EM-DAT 2017). *Tropical Cyclones* are defined as "storms of marine origin and they create coastal hazards because most of the systems decay rapidly over land areas" (Smith 1996 p. 211).

Extra-Terrestrial Hazards

The last and not so common natural environmental hazard is the extra-terrestrial hazard. Based on EM-DAT glossary (EM-DAT 2017), the *extra-terrestrial hazard* is "a hazard caused by asteroids, meteoroids and comets as they pass near-earth, enter the Earth's atmosphere, and/or strike the Earths, and by changes in interplanetary conditions that effect the Earth's magnetosphere, ionosphere, and thermosphere". What is interesting and deserves to be mentioned in that since 1900 there is only one significant extra-terrestrial event which occurred in 2013 in Russian Federation from which 1491 people were injured; 300,000 people were affected and the total economic damage was 33,000,000 USD. This event was classified under the type of *impact*.

Literature Review

We tend to believe that natural environmental events are characterized by randomness. In other words, we assume that all these events are unexpected and may appear at any time and in any place, which actually means that they are not determined by any factor. However, previous research has shown that not only these events are non-random but also, they are significantly

[4] The term meteorological hazard does not exist in Smith's classification.

influenced by a range of different factors. Moreover, certain circumstances may lead from an unexpected event to an environmental hazard.

Regarding the occurrence of appearance, it is well known that not all the events are attached to all regions but it depends on the geographical position of each country. Countries that are “placed” exactly above the tectonic plate joints are more risk-related to the geophysical environmental events such as earthquakes. Countries that are bordered with oceans are more risk-related to tsunamis and finally, the countries that have volcanos, whether actively or not, know that there is always the case of the volcanic eruption.

It is an often phenomenon to name specific areas, not necessarily at the same continent, with titles that show the high possibility of the occurrence. To be more specific, Bolt (1988) mentions a well-known region in the Pacific Ocean, the “Ring of Fire”, by trying to illustrate that more than 65% of the significant earthquake events were observed in an area on the Pacific Ocean due to the existence of the tectonic plates. The countries that are part of the “Ring of Fire” are country members both from the Americas and Asia, which leads to the assumption that we cannot examine those events with a continent-based analysis but dividing them to high frequency and low frequency regions. Onuma et al. (2017) prove that households which have recently faced a great disaster are more prepared to a possible upcoming one compared to those who have not faced a similar disaster in the short-run. Based on Parwanto and Oyama (2014), Japan is one of the countries globally that has the best earthquake early warning systems.

One of the factors that makes an event to be a hazard or even worse a disaster is the significant impact that this may leave after its occurrence. In other words, the number of people influenced is a decisive factor to call that specific event a hazard. The same logic is followed when we want to announce that a hazard unfortunately became a disaster. Sheehan and Hewitt (1969) when tried to give a definition of disaster they presented some threshold in order to determine the lowest losses for a disaster. More specifically, a hazard can be treated as a disaster if there are at least 100 dead people, or 100 injured people, or $1 million damage. Those thresholds were re-estimated by the EM-DAT and the new criteria for a disaster assume that if there are at least 10 dead people, instead of 100, then it is called disaster. Moreover, if there is a declaration of state of emergency and/or a need for international assistance then it is not just a simple environmental event but a disaster. A difficulty that may appear when estimating the losses is that we cannot always estimate the exact number of people influenced by the event due to the fact that the results may appear in the short-run or the long-run. For instance, we can report the number of people died during the disaster but we cannot estimate those who died few days after the event or people who may suffer from inconsistent illnesses caused due to that event. If we assume that we can make an estimation for the total number of affected people then we should take into consideration factors such as the population density. If the area of disaster is highly populated then as a consequence the number of affected people will be higher compared to the less highly populated areas. Significant role to the number of fatalities can have the time of occurrence. If the event takes place during the night hours when most of people are at their houses and probably sleeping, then they will not be able to react.

As we mentioned above, the economic loss is one of the determinants that will help us recognize if there is a disaster or not. The economic loss can be influenced by a great range of factors. Apart from the most obvious geophysical factors which are the magnitude and the intensity of the event, there are some other mainly economic factors that will influence the volume of economic loss. First of all, as Smith (1996) described, the economic position of a country, or a specific region, can have a significant impact both to the economic losses and the number of fatalities.

According to Smith (1996) "…. - the poor lose their lives while the rich lose their money." (Smith 1996, p. 33). That leads us to the distinction between developed and developing countries hypothesizing that the developed, or based on Smith rich (MDCs), countries are going to have higher economic losses compared to the developing, and based to Smith poor, countries. Smith (1996), used a similar distinction for countries mentions the most developed countries (MDCs) as the rich countries and the least developed countries (LDCs) as the poor countries. He also mentioned the Third World countries in the explanation of the structural paradigm. He drew a connection line between underdevelopment and economic losses. The economic losses in that case derives from the fact that those countries do not have the appropriate economic ability to create emergency plans as well as constructions based on the building codes proposed by the MDCs, so even with a less significant environmental hazards, the impacts will be dramatic in those countries. Nowadays, the term "Third World" is not an appropriate categorization for countries so there is a dichotomous distinction between developed and developing countries.

The building codes that have already been mentioned is an institutional framework that provides construction guidelines (Yamin et al. 2014). These guidelines are often used when a government building is under construction. Smith (1996) mentioned that public buildings like schools, offices, factories do follow those building codes so that they will be able to provide support while the disaster is in progress. As it is obvious, those building codes and the construction procedure are accessible by the high-income societies while the low-income societies do not have the ability to make choice on whether to settle so the location is usually an unsafe place where their main goal is to survive till the next day (Smith 1996). From that phenomenon, a new term has arisen due to the fact that the damages caused to the poorly constructed buildings are greater compared to the high-income societies. That gave the researchers the ability to create a new unofficial type of disaster called "classquake" (Smith 1996).

If we try to express the economic damage or loss as a ratio to national wealth, then the damaged occurs by a disaster mainly affects the lower income societies due to the low-income levels (Smith 1996). Although the economic damage is easily calculated, the difficulty comes when the prospect of analysis is the valuation of life. Even nowadays, the scientists have not found an approach which could give an exact value of loss concerning the life loss and including all different aspects that this loss may influence. The health expenditures could be considered as a direct impact on human loss value. However, there are omitted variables that increase the value of loss which are not easily approached.

Another difference between countries and how they consider the disaster has its roots on the past and goes from generation to generation. Few researchers have worked on that topic known as "Locus of Control" or "Act of God Syndrome" (Smith 1996; Gaillard and Texier 2010). The theoretical review on that topic was initially mentioned by Dynes and Yutzy (1965). Since then, most of the researches have ignored religion and its impact on people's beliefs (White and Hass 1975; Hewitt 1983, 1997; Drabek 1986; Burton et al. 1993; Dynes 1994; Chester 1998; Lewis 1999; Oliver-Smith and Hoffman 1999; Wisner et al. 2004). There are specific religions which have the belief that disaster is the punishment of God for their acts. So, having that in mind, they do not try to protect themselves by creating emergency plans but they accept that "punishment" as a sign of God.

Another difference between countries is the distinction between resilience and reliability. Based on Smith (1996), the MDCs, due to the fact that they have the economic ability to financially support protective devices against hazard, use the approach of reliability when those protective devices fail. On the other hand, and due to the lack of financial support, the LDCs accept the disaster as a normal part of life and with the method of recovery after the disaster, they use a measure called resilience in order to estimate the rate of that recovery (Smith 1996). As we can see, different economic conditions lead to different disaster approaches, so there is no global estimation which will treat the world as a unit.

What is also widely known and mentioned by Smith (1996), poverty gap is increasing when a disastrous event occurs due to the lack of essentials such as food stocks. In that case the demand and supply theory come to increase the price of the limited stocks which will automatically give access only to few people, especially those who can financially afford it.

Till that part we have analyze the factor that can cause a natural environmental hazard, or make people unable or even unwilling, to avoid that hazard. What will be analyzed further is the cascade of hazard impacts (Smith 1996). As it is mentioned above, an environmental hazard can have both losses and gains, which can be either direct or indirect. The direct losses are obvious if we consider the fatalities as well as the economic damages. People may die or get injured or homeless in case of house demolitions. The production of the suffered region may be affected which will automatically affect the GDP, the GDP per capital as well as the economic growth. Moreover, as it has been mentioned that an environmental disaster can increase the poverty gap as well as the inequality in a society or across countries.

The population of the specific area will also be negatively affected due to life loss. However, having in mind that a new disaster may occur, those who will survive by that disaster will consider migration as a solution and way of protection. That has also been stated by Munro and Managi (2017) who mentioned that tsunami victims, who have survived, are not likely to return to their homes after such a hazard. However, if the survived victims appear to have household ownership and/or job opportunities may decide to return to the area of disaster as it is proved by Sanaei et al. (2016). If the disaster caused adverse impacts on the environment and probably a type of pollution such as air pollution or water pollution, those who will remain in the polluted areas will may be face different illness factors that will increase mortality and at the same time will decrease the life expectancy. High CO_2 emissions is one of the most often variables affected after an environmental disaster.

Knowing that the economy is a vicious circle and that the negative influence to an economic variable can negatively affect other economic variables leading to a continues death spiral. When the production is almost destroyed then the society cannot produce what it need; as a result, the levels of imports increase while the level of exports decrease. The economy appears to have deficit, which will lead to external debt. If the economy is “strong” enough it will be able to welcome foreign direct investments after the disaster, otherwise the economy will follow the direction of lending.

All those impacts refer to the short-run, exactly after each occurrence. However, the gains, which are usually indirect, appear after same years or even after many generations. As described in the introduction, a disaster may change the whole scenery by transforming it into a new tourist attraction. This may lead to a new economic generation of growth with increased tourism which will lead to increased incomes and as a consequence increased GDP and GDP per capita.

Methodology and Data

Many different approaches have been used when examining environmental hazards or even disasters. Considering disasters as extreme events, the most common analysis is the extreme event analysis which is a probabilistic approach (Smith 1996). However, this approach appears to have many weaknesses that make it less appropriate for advanced analysis. Other proposed methodologies are

Bounded Rationality Theory, Prison of Experience, Revealed Preferences, Expressed Preferences, Cost-Benefit Analysis as well as Risk-Benefit Analysis and Willingness to Pay (Smith 1996).

In this paper, we make an initial attempt to point out the high and low frequency areas based on statistical and graphical presentation techniques. For those purposes we will use that datasets that are available in EM-DAT database. This database provides a full dataset of all types of environmental hazard described above for a 117-year time span. More specifically, it provides information from 1900 till 2016.[5] Every type of hazard is listed per year for each country and is followed by information regarding the occurrence per year as well as the fatalities and the economic damages. Particularly, the number of deaths, injuries, affected, and homeless people are reported as well as the economic damage in thousands.[6]

Before we start the sub-sectional analysis, it is important to have a general picture of the data we used in our analysis. Therefore, we calculated the total values recorded for each group of natural environmental hazards, as it can be seen in Table 1, from which we can draw some conclusions. First of all, the most occurred hazards are those which come under the category of biological hazards reaching 6011 events over the last 117 years. At the same time, the majority of deaths are the result of biological hazards. Regarding injuries, the highest record is mentioned in the case of meteorological, the third most occurred natural environmental hazard over the last 117 years, with almost 3,3 million injured people, while at the same time causing the most aggregated economic damage almost reaching the level of 1137 billion USD. The hydrological hazards, on the other hand, are responsible for the most homeless and affected victims of natural environmental hazards over the last century with over 96 million and 3562 million victims respectively.

We hypothesize that the most developed countries will have high economic losses and that the least developed countries will have great fatalities. In this way we examine if fatalities are proved to be significant in the least developed countries and the total economic damage are proved to be significant most developed countries. This analysis will be the fundamental base which will afterwards be used by the authors to build an advanced econometric approach in future research.

Results and Discussion

Having all these said and done, we move forward to the statistical and graphical representations which will help us accept or reject the hypotheses that have been established as inspired by (1996).

> H_A: The natural environmental hazards are space concentrated.
> H_B: The most developed countries face greater economic losses; the least developed countries face greater fatalities.

For the examination of the first hypothesis we have created region environmental hazard tables per region as well as map visualizations,[7] while for the examination of the second hypothesis we have created high aggregated values tables. In an attempt to locate the high-risk areas for each natural environmental hazard, we created world heat maps, using map techniques, which

[5] http://www.emdat.be/database Accessed: 05 May 2017

[6] The currency used in all cases is the American Dollar. No local currency units are used so that the results of the analysis will be comparable.

[7] All maps presented in the paper have been created using the R Studio. The R packages and routines are available on request.

Table 1 Total values per environmental natural hazard

	Occurrence	Deaths	Injured	Affected
Biological	6011	11,040,941	1,313,247	553,680,241
Climatological	1122	10,535,271	7914	2,636,212,659
Extra-Terrestrial	1	0	1491	300,000
Geophysical	1612	2678,022	2925,533	172,798,483
Hydrological	5354	7015,542	1370,944	3562,133,398
Meteorological	4453	1577,903	3,344,440	1,058,160,932
	18,553	32,847,679	8,963,569	7,983,285,713

	Homeless	Total Affected	Economic Damage ('000$)
Biological	9371,132	564,364,620	32,187,389
Climatological	255,468	2,636,476,041	200,671,880
Extra-Terrestrial	0	301,491	33,000
Geophysical	23,184,433	198,908,449	781,558,525
Hydrological	96,414,272	3,659,918,614	741,027,652
Meteorological	53,295,852	1,114,801,224	1,136,734,132
	182,521,157	8,174,770,439	2,892,212,578

will let the reader understand the scheme of each classification by the glimpse of their eye. Color pallets make the results more obvious compared to tables which contain the same information, however, need more time to be read.

Biological Hazards

As it has already been mentioned we will follow the same flow with the terminology so the first group of hazards that will be analyzed is the biological hazard. Based on Table 2, it is clear enough that the region that has suffered more by the biological hazards if the African Continent. Having in mind all the described subtypes that are included in the biological hazards, we can understand the reason of such a result. Epidemics and insect infestation are more prone to occur in least developed areas where the access to sanitation and drinking water is not taken for granted. What is also expected is to have increased fatalities, considering the great difference on the number of occurrences. The African Continent is the most vulnerable on biological hazards and if we take a closer look to Table 2 we can understand that more than 90% of all biological hazards occurred in Africa. More specifically, 5416 events of the total 6011 events occurred in African giving us a ratio equal to 90.1%. Based on that score, we have significant evidence to support the acceptance of the hypothesis 1 and suggest that biological hazards are space concentrated events which is also presented in Fig. 1.

Moving forward, we are trying to either accept or reject the hypothesis concerning the division between least developed countries and most developed countries and the losses they face. However, taking into consideration the fact that more than 90% of the events occurred in Africa, we expect both fatalities and possible economic losses to be gathered on the same continent. As it can be seen in Table 7 (see Appendix I), the ten countries with the most recorded biological events are located in African Continent. Moreover, the same table presents the fatalities and economic losses per event[8] which let us draw more conclusions about the hazards and its effects. Regarding deaths, it is shown

[8] The rest columns have been calculated by dividing the aggregated value of each fatality or economic loss to the occurrence in an attempt to estimate the average level of deaths, injuries, affected people, homeless people and economic losses respectively, using as a weight the value of appearance.

Table 2 Biological hazards - regional results

Biological								
Continent	Region	Occurrence	Deaths (‘000)	Injured (‘000)	Affected (‘000)	Homeless (‘000)	Total Affected (‘000)	Economic Damage (‘000,000$)
Africa	Eastern Africa	1777	1078	168	323,000	3804	326,972	6491
Africa	Middle Africa	837	68	28	19,545	694	20,267	140
Africa	Northern Africa	793	238	92	39,801	2537	42,430	17,213
Africa	Southern Africa	396	10	10	31,619	109	31,738	6242
Africa	Western Africa	1613	533	144	108,000	2227	110,371	1875
Americas	Caribbean	29	7.5	278	466	0	744	0
Americas	Central America	50	1.5	15	315	0	330	7
Americas	South America	79	15	80	2750	0	2830	104
Americas	Northern America	12	51	0	2416	0	2416	0
Asia	Central Asia	13	0.3	0.141	26	0	26.1	0
Asia	Eastern Asia	28	1.56	0.185	2310	0	2310.1	0
Asia	Southern Asia	167	4957	0.211	4210	0	4210.2	0
Asia	South-Eastern Asia	112	9	124	1296	0	1420.1	1
Asia	Western Asia	33	1	2	221	0	223	0
Europe	Eastern Europe	22	2500	0	18,173	0	18,173	0
Europe	Northern Europe	9	0.073	0	2	0	2	0
Europe	Southern Europe	12	0.047	0	14	0	14	0
Europe	Western Europe	7	0.034	0	1	0	1	0
Oceania	Australia & New Zealand	5	7	0	0.007	0	0.007	120
Oceania	Melanesia	10	0.451	372	13	0	385	0
Oceania	Micronesia	3	0.042	0	4	0	4	0
Oceania	Polynesia	4	0.008	0	3	0	3	0
		6011	**9478.481**	**1268.537**	**554,185.007**	**9371**	**564,869.507**	**32,193**

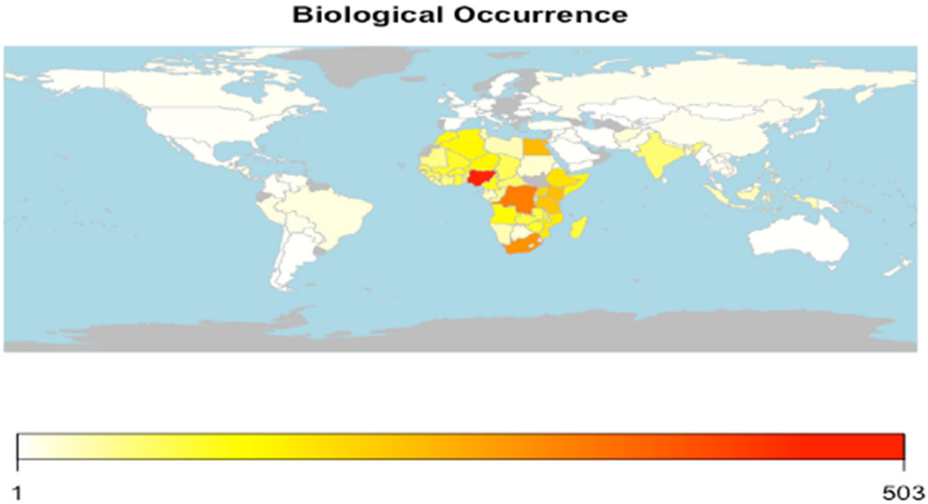

Fig. 1 Biological hazards – occurrence

that the four countries noting the most deaths are located in Eurasia, and not in Africa as it was expected, giving us the notion that although biological hazards are not that frequent on Eurasia, the times these occurred led to more deaths compared to the African fatalities (Halkos and Zisiadou 2018). Moving to the most Injured country of biological hazards we are surprised by the extremely high value recorder in Solomon Is[9] (Halkos and Zisiadou 2018). Once again, regarding injuries, it is shown that the four countries noting the most deaths are located in Oceania, America and Asia, and not in Africa as it was expected, giving us the notion that although biological hazards are not that frequent on those continents, the times these occurred led to more deaths compared to the African fatalities (Halkos and Zisiadou 2018). In contrast to deaths and injuries, the values of homelessness following a biological occurrence goes in line with the occurrence and the expectations these caused to us. In other words, all ten most suffered countries regarding the homelessness are located in African continent as it is presented by Halkos and Zisiadou (2018). The highest economic losses are also mainly located in African continent if we exclude Australia (place 2) and Colombia (place 6) of the most suffered areas (Halkos and Zisiadou 2018).

Based on all the evidence, we once again have the ability to mention that the biological events are mainly noticed in African continent however, regarding its effects, we cannot come to conclusion whether they affect significantly the least developed countries or most developed countries based on that statistically analysis and therefore, an advanced econometric analysis is proposed.

Climatological Hazards

Climatological Hazards is the next classification of the natural environmental hazards that we will analyze. Compared to the biological hazards, we can notice that the total amount of occurrence over the last 117 years is much lower. Based on Table 3, it is not clear enough which region has suffered more by the biological hazards due to the fact that all regions have

[9] The average injured people in Solomon Is due to biological hazards equals to 186,000 and to be precise, biological hazards (and more specifically viral disease) occurred once in 2013 and one in 2016 causing none injured and 372,000 injured respectively leading to (372,000/2 = 186,000) per event.

Table 3 Climatological hazards - regional results

Climatological								
Continent	Region	Occurrence	Deaths (‘000)	Injured (‘000)	Affected (‘000)	Homeless (‘000)	Total Affected (‘000)	Economic Damage (‘000,000$)
Africa	Eastern Africa	136	544	0.028	249,752	3	249,755	372
Africa	Middle Africa	31	3	0	13,837	4	13,841	85
Africa	Northern Africa	21	150	0	27,654	0.105	27,654.1	900
Africa	Southern Africa	45	0.630	0.530	27,763	6	27,769.5	3605
Africa	Western Africa	106	170	0.200	81,821	14	81,835.2	507
Americas	Caribbean	34	0	0	8332	0	8332	199
Americas	Central America	58	0.211	0	10,388	0	10,388	2485
Americas	South America	100	0.187	1	90,092	9	90,102	14,365
Americas	Northern America	135	1	0.912	1650	62	1713	76,217
Asia	Central Asia	5	0	0	6408	0	6408	107
Asia	Eastern Asia	95	3504	0.303	542,315	11	542,326.3	34,157
Asia	Southern Asia	54	6151	0	1,477,985	54	1,478,039	6177
Asia	South-Eastern Asia	68	10	0.478	66,009	23	66,032.5	12,778
Asia	Western Asia	26	0.120	0.154	5493	21	5514	802
Europe	Eastern Europe	48	0.220	2	5562	24	5588	2827
Europe	Northern Europe	3	0	0	0	0	0	1030
Europe	Southern Europe	71	0.280	0.460	10,446	5	10,451.5	27,327
Europe	Western Europe	18	112	0.161	6	0.006	6.1	1620
Oceania	Australia & New Zealand	51	1	1	7149	20	7170	14,990
Oceania	Melanesia	10	0.084	0	3430	0	3430	90
Oceania	Micronesia	3	0	0	119	0	119	0
Oceania	Polynesia	4	0	0	1	0	1	31
		1122	**10,647.732**	**4.226**	**2,636,212**	**256.111**	**2,636,475.2**	**200,671**

recorded almost some frequencies of climatological hazards. The region that faces the highest number of deaths, although the occurrence level is not that high, is the Southern Asia with 6150 thousand deaths in total over the last century, as well as the affected people, reaching almost the 1.5 billion people. Compared to the deaths, the injured people suffered from the climatological hazards appeared to be significantly lower, with a maximum value of 2 thousand people in Eastern Europe. Finally, the region with the highest economic damage is the Northern America reaching the 76,217 million USD. In total almost 2.7 billion people have been affected (injured, affected and homeless) over the last century due to climatological hazards, while 10,647.7 thousand people lost their lives globally. The total economic damage due to climatological hazards equals to 200,670 million USD.

The African Continent is once again the most vulnerable on biological hazards and if we take a closer look to Table 3 having 339 events in total which equals to almost 30% of all climatological hazards occurred globally. Table 3 also provides evidence that climatological hazards cause higher economic losses compared to the biological hazards. Based on Fig. 2, and analyzing the country level results, we can suggest that the most suffered country is USA which is also proven by Table 8 (see Appendix I) giving 107 events and the first place of Occurrence to USA. As we can see both in Fig. 2 and Table 8 (see Appendix I), the regions with the highest frequencies tend to be in America and Asia.

Moreover, the same table presents the fatalities and economic losses per event which allow us to draw more conclusions about the hazards and its effects. Regarding deaths, it is shown that Soviet Union recorded the most fatalities per event over the last century (Halkos and Zisiadou 2018). Moving to the most Injured country of biological hazards we are surprised by the extremely high value recorder in Russian Federation with almost 83 injured people per event (Halkos and Zisiadou 2018). In contrast to deaths and injuries, the higher values of homelessness following a climatological occurrence are located in African continent as it is presented by Halkos and Zisiadou (2018). The highest economic losses are also mainly located in Eurasia (Halkos and Zisiadou 2018).

What we should take into consideration is that climatological hazards refer to both droughts and wildfires as it has already been described on previous section. Each subtype has its own consequences leading to the fact that droughts appear to be almost twice more often than wildfires. Moreover, the fatalities and the affected people by wildfires are less compared to those from droughts. What is more, apart from the high levels of fatalities, and affected people, droughts appear to have 2.5 times higher economic losses than wildfires (Halkos and Zisiadou 2018). That statement underlines once again the

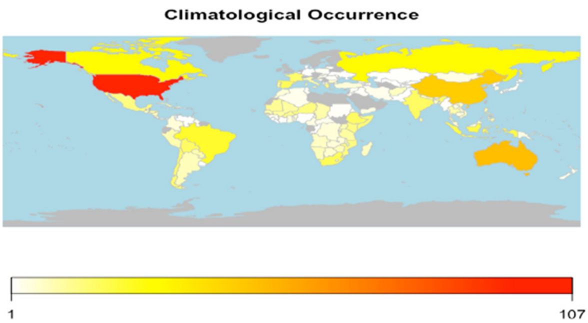

Fig. 2 Climatological hazards – occurrence

importance of a scientifically detailed dataset which takes into consideration all different subtypes of each possible natural environmental hazard.

As we can see, the greater number of fatalities per event is noticed in developing countries such as Bangladesh, India, China etc., while the great economic losses per event are noticed in developed countries such as Denmark, USA, Spain etc.

So, regarding the Climatological Hazards, and based on the database of CRED for the period 1900–2016, we do not have the ability to mention whether climatological hazards are space concentrated events but we can accept the hypothesis about the fact that the most developed countries face greater economic losses compared to the least developed countries which face greater fatalities is also accepted in this case, however the evidence is not highly significant based on that statistically analysis and therefore, an advanced econometric analysis is proposed.

Geophysical Hazards

Geophysical Hazards is the next classification of the natural environmental hazards that we will analyze. Compared to the climatological hazards, we can notice that the total amount of occurrence over the last 117 years is almost at the same level. In order to be more precise, the total amount of climatological hazards is 1122 events over the last 117 years while the geophysical events are just 1612 events (Table 4) over the last 117 years. Another similarity that we can spot is that the geophysical events are spread almost all over the globe with the most frequent region to be America once again, however, this time it is South America where there were 183 geophysical events in total. The region that faces the highest number of deaths is the Eastern Asia with 1089 thousand deaths in total over the last century, as well as the affected people, reaching the 72,102 thousand people. In total 198,907 thousand people have been affected (injured, affected and homeless) over the last century due to geophysical hazards, while 2678 thousand people lost their lives globally. The total economic damage due to geophysical hazards equals to 781,599.5 million USD.

Figure 3 provides information about the occurrence of geophysical hazards over the last century (1900–2016), suggesting that the Asian Continent appears to suffer more from those events. So, based on those evidence we can also confirm the statement of the Ring of Fire. The area that is described as Ring of Fire, focalizes the most often geophysical events during the last century. More specifically, Indonesia is the country with the most geophysical events over the last 117 years (Fig. 3, Table 9 (see Appendix I)) that equals to 169 events and China is the second country with 164 events for the same period of time. As we have mentioned, the Ring of Fire is not a region that is placed over one continent. Instead it is mentioned that it contains one part of the Asia and one part of the Americas. That has also been proven by the top 10 countries with the most geophysical occurrences (Table 9 (see Appendix I)) showing that apart from Iran and Turkey all the other countries are part of the well-known Ring of Fire. Table 9 (see Appendix I) also provides information about the fatalities per occurrence.[10] As we can see, the greater number of fatalities per event is noticed in developing countries such as Sri Lank and Haiti (Halkos and Zisiadou 2018), while the great economic losses per event are noticed in developed countries such as Japan or New Zealand (Halkos and Zisiadou 2018).

[10] Those amounts have been calculated by dividing the total amount of each fatality or loss of each country to the occurrence of each country. That gives us the average fatality or loss per occurrence.

Table 4 Geophysical hazards - regional results

Geophysical								
Continent	Region	Occurrence	Deaths ('000)	Injured ('000)	Affected ('000)	Homeless ('000)	Total Affected ('000)	Economic Damage ('000,000$)
Africa	Eastern Africa	47	0.681	3	535	81	619	795
Africa	Middle Africa	11	2	2	33	172	207	16
Africa	Northern Africa	35	21	57	612	839	1508	11,996
Africa	Southern Africa	9	0.071	0.165	3	0	3.1	20
Africa	Western Africa	5	0.338	1	24	5	30	0
Americas	Caribbean	21	256	300	3595	0.255	3895.2	8075
Americas	Central America	131	70	164	11,215	1952	13,331	12,263
Americas	South America	183	182	518	18,395	2435	21,348	43,168
Americas	Northern America	51	3	13	42	26	81	42,602
Asia	Central Asia	24	0.202	0.954	265	41	306.9	203.5
Asia	Eastern Asia	258	1089	841	72,102	4960	77,903	485,285
Asia	Southern Asia	228	436	667	37,756	8290	46,713	30,200
Asia	South-Eastern Asia	243	240	200	16,299	1676	18,175	15,114
Asia	Western Asia	97	92	101	6795	1254	8150	27,088
Europe	Eastern Europe	65	160	30	1779	971	2780	19,434
Europe	Northern Europe	10	0.001	0.008	10	0.069	10.08	125
Europe	Southern Europe	102	119	24	2412	416	2852	58,640
Europe	Western Europe	12	0.124	0.164	3	0.200	3.4	362
Oceania	Australia & New Zealand	15	0.621	2	643	0.720	645.7	25,797
Oceania	Melanesia	56	6	1	263	65	329	121
Oceania	Micronesia	2	0	0.071	0	0	0.071	120
Oceania	Polynesia	7	0.197	0.342	16	0.500	16.84	135
		1612	**2678.235**	**2925.704**	**172,797**	**23,184.744**	**198,907.291**	**781,599.5**

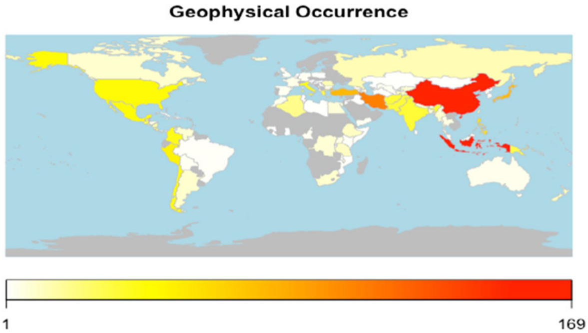

Fig. 3 Geophysical hazards – occurrence

What was interesting with geophysical hazards is the fact that with the term *earthquake* we could either describe the ground movement or the tsunami, and as it has been mentioned, that proves once again the complexity and the difficulty of the analysis. For that reason, we decided to present separately the ground movements (Halkos and Zisiadou 2018) and the tsunamis (Halkos and Zisiadou 2018). The results indicate that the most often phenomenon appear to be the ground movement (1251 events the last 117 years compared to just 64 tsunamis over the last century). Based on that statement, we assume to have greater economic losses on ground movements compared to tsunamis due to the great difference on occurrence. Surprisingly, although the ration tsunami to ground movement equals to almost 5% (eq.1) making the ground movement the most frequent geophysical phenomenon, the ratio of their economic losses equals to almost 49% (eq.2), making tsunamis the most disastrous phenomenon economically speaking.

$$\frac{Tsunami}{Ground\ Movement} = \frac{64}{1,251} = 0.051 \tag{1}$$

$$\frac{Economic\ Loss_{tsunami}}{Economic\ Loss_{ground\ movement}} = \frac{254,101,440}{523,315,137} = 0.485 \tag{2}$$

So, regarding the Geophysical Hazards, and based on the database of CRED for the period 1900–2016, we can accept the hypothesis of the space concentrated appearance of events, by proving the existence of the Ring of Fire. Moreover, the hypothesis about the fact that the most developed countries face greater economic losses compared to the least developed countries which face greater fatalities is also accepted in this case, by proving that the victim per events are higher in Haiti and Sri Lanka, while the economic losses are higher in Japan.

Hydrological Hazards

Hydrological Hazards is the next classification of the natural environmental hazards that we will analyze. Hydrological Hazard appeared to be a more often phenomenon compared to climatological and geophysical hazards. Actually, it is almost as often as the biological hazards. In order to be more precise, the total amount of biological hazards is 6011 events over the last 117 years while the hydrological events are just 5354 events (Table 5) over the last 117 years. A similarity that we can spot between climatological, geophysical and hydrological hazards is that all those

Table 5 Hydrological hazards - regional results

Hydrological								
Continent	Region	Occurrence	Deaths (‘000)	Injured (‘000)	Affected (‘000)	Homeless (‘000)	Total Affected (‘000)	Economic Damage (‘000,000$)
Africa	Eastern Africa	388	13	3	31,896	1750	33,649	2072.5
Africa	Middle Africa	126	2	2	3451	473	3926	36
Africa	Northern Africa	148	9	21	7562	1684	9267	3150
Africa	Southern Africa	64	2	0.377	2238	65	2303.4	1732
Africa	Western Africa	250	3	4.5	20,946	2142	23,092.5	1271
Americas	Caribbean	150	7	9	4237	194	4440	980
Americas	Central America	253	51.5	20	8852	338	9210	7370
Americas	South America	624	63	28	67,257	3400	70,685	36,456
Americas	Northern America	220	4	0.429	12,877	53	12,930.4	84,999
Asia	Central Asia	67	2	1	1029	103	1133	1303
Asia	Eastern Asia	532	6628	841	1,981,089	45,870	2,027,800	272,158
Asia	Southern Asia	857	170	147	1,241,864	35,247	1,277,258	102,918
Asia	South-Eastern Asia	695	29	263	157,767	2173	160,203	63,208
Asia	Western Asia	167	5	1	5146	865	6012	6857
Europe	Eastern Europe	238	16	10	8789	321	9120	29,100
Europe	Northern Europe	54	0.390	0.078	417	30	447	23,327
Europe	Southern Europe	212	6	18	4487	1580	6085	42,485
Europe	Western Europe	152	3	0.214	1052	0.260	1052.5	46,431
Oceania	Australia & New Zealand	101	0.378	0.088	337	7	344	14,828
Oceania	Melanesia	46	0.701	0.42	837	118	955.4	295
Oceania	Micronesia	5	0	0	1	0.085	1	0
Oceania	Polynesia	5	0.029	0.014	0.500	0	0.514	51.5
		5354	**7014.998**	**1370.12**	**3562,131.5**	**96,413.345**	**3,659,914.714**	**741,028**

hazards are spread almost all over the globe with the most frequent region to be Southern Asia once where there were 857 hydrological events in total. The region that faces the highest number of deaths is the Eastern Asia with 6628 thousand deaths in total over the last century, as well as the affected people, reaching the 1,981,089 thousand people. In total 3,659,914 thousand people have been affected (injured, affected and homeless) over the last century due to geophysical hazards, while almost 7015 thousand people lost their lives globally. The total economic damage due to geophysical hazards equals to 741,028 million USD.

Following the same procedure, Fig. 4 provides information about the occurrence of hydrological hazards over the last century (1900–2016), suggesting that the American and Asian Continents appear to suffer more from those events. Specifically, the highest frequency of hydrological hazard is spotted in Asia. In order to be more specific, three Asian countries China, India and Indonesia with 342, 324 and 233 total events respectively, showing that those countries are the most suffering from the hydrological hazards. However, although in the American Continent, the appearance is not that often, the hydrological hazards tend to be observed across the whole continent and not in specific areas (Fig. 4, Table 10 (see Appendix I)).

So, regarding the Hydrological Hazards, and based on the database of CRED for the period 1900–2016, we cannot significantly accept the hypothesis of the space concentrated appearance of events, based on Fig. 4. However, the hypothesis about the fact that the most developed countries face greater economic losses compared to the least developed countries which face greater fatalities is also accepted in this case, by proving that the victim per events are higher in China, while the economic losses are higher in Germany.

Meteorological Hazards

Meteorological Hazards is the last classification of the natural environmental hazards that we will analyze. Hydrological Hazard appeared to be a more often phenomenon compared to climatological and geophysical hazards but less often compared to biological and hydrological hazards. Actually, in order to be more precise, the total amount of meteorological hazards is 4453 events over the last 117 years (Table 6). A similarity that we can spot between climatological, geophysical, hydrological and meteorological hazards is that all those hazards are spread almost all over the globe with the most frequent region to be Eastern Asia once again where there were 699 meteorological events in total, as well as the affected people, reaching the 574,922 thousand people. In total 1,058,161 thousand people have been affected (injured,

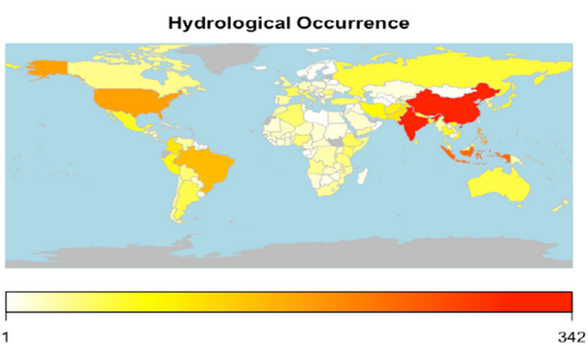

Figure 4 Hydrological hazards – occurrence

Table 6 Meteorological hazards - regional results

Meteorological								
Continent	Region	Occurrence	Deaths (‘000)	Injured (‘000)	Affected (‘000)	Homeless (‘000)	Total Affected (‘000)	Economic Damage (‘000,000$)
Africa	Eastern Africa	141	4.5	9	13,046	1796	14,851	3201
Africa	Middle Africa	20	0.095	3	101	38	142	0.282
Africa	Northern Africa	31	0.577	0.589	932	0	932.6	1203
Africa	Southern Africa	41	0.393	1	1273	20	1294	818
Africa	Western Africa	32	0.655	0.606	1120	41	1161.6	56
Americas	Caribbean	312	31	20	21,588	2083	23,691	33,867
Americas	Central America	220	42	24	15,219	792	16,035	43,545
Americas	South America	135	4	1829	5369	229	7427	2955
Americas	Northern America	688	37	15	13,693	441	14,149	639,681
Asia	Central Asia	13	0.147	0.062	2617	1.5	2618.5	843
Asia	Eastern Asia	699	245	328	574,922	15,869	591,119	199,756
Asia	Southern Asia	524	839	966	174,470	20,459	195,895	28,652
Asia	South-Eastern Asia	516	217	104.5	208,804	11,208	220,116.5	33,089
Asia	Western Asia	66	0.728	10	3442	11.5	3463.5	6544
Europe	Eastern Europe	182	64	24	3689	35	3748	3711
Europe	Northern Europe	114	6	0.163	1108	0	1108.2	23,350
Europe	Southern Europe	134	42	1	1022	15	1038	16,344
Europe	Western Europe	272	41	2	4346	0.800	4348.8	75,507
Oceania	Australia & New Zealand	123	0.805	4	8690	17	8711	19,893
Oceania	Melanesia	103	1	1.5	2090	134	2225.5	1658
Oceania	Micronesia	22	0.082	0.731	57	23	80.7	1019
Oceania	Polynesia	65	0.448	0.382	563	82	645.4	1044
		4453	**1577.43**	**3344.533**	**1,058,161**	**53,295.8**	**1,114,801.3**	**1,136,736.282**

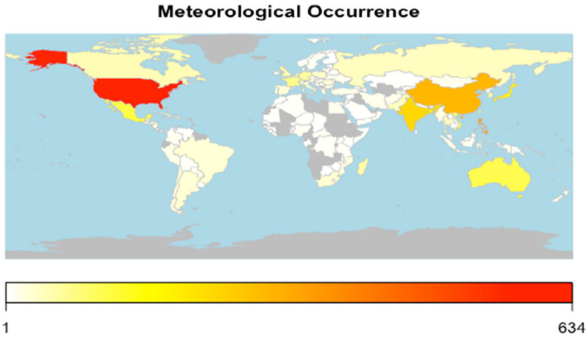

Fig. 5 Meteorological hazards – occurrence

affected and homeless) over the last century due to geophysical hazards, while 1577 thousand people lost their lives globally. The total economic damage due to geophysical hazards exceeds the 1,136,736 million USD.

Following the same procedure, Fig. 5 provides information about the occurrence of meteorological hazards over the last century (1900–2016), suggesting that the American and Asian Continents appear to suffer more from those events. Specifically, the highest frequency of hydrological hazard is spotted in America. In order to be more specific, United States of America records almost the double value of meteorological events (634 meteorological events) compared to the second of the classification which is Philippines (335 meteorological events) and the third one which is China (294 meteorological events) showing that those countries are the most suffering from the hydrological hazards. (Fig. 5, Table 11 (see Appendix I)).

So, regarding the Hydrological Hazards, and based on the database of CRED for the period 1900–2016, we cannot significantly accept the hypothesis of the space concentrated appearance of events, based on Fig. 4. However, the hypothesis about the fact that the most developed countries face greater economic losses compared to the least developed countries which face greater fatalities is also accepted in this case, by proving that the victim per events are higher in Myanmar, Peru, Lao and China, while the economic losses are higher in United States of America.

Conclusions

Nature is alive and it acts independently. This independence creates natural phenomena which under certain circumstances may have disastrous impacts either to human being or fauna. The purpose of this paper is to present with details all those environmental hazards that are attached in the main group of natural environmental hazards as well as to examine the occurrence of different natural environmental events which are recognized as hazards and make an effort to present possible direct and indirect losses as well as whether they are space and time concentrated or not.

When discussing the natural environmental hazards, what we should keep in mind is that all those events cannot be classified under one general term due to their diversification. As we have seen, different hazards occur to different regions, or in other words, in some cases there is an appearance of space concentration which needs to be examined using advanced techniques. Biological Hazards are the only natural environmental hazard that its occurrence and its drawbacks are highly correlated to the economic position of each country. As we described when discussing the results, the limited access to clear drinking water and sanitation may let epidemics and vireal diseases to thrive. At the same time, the drawbacks increase due to the lack of medicine which in any other case could be able to be minimized.

Due to the morphology of Earth and regarding the tectonic plates and their movements, we tend to observe specific hazard types in certain areas. Clear examples are the ground movements and the tsunamis. Apart from the obvious conditions that in order to have a ground movement or a tsunami we need to be above a joint of two tectonic plates, and regarding the case of tsunamis next to ocean as well, we have evidence of the existence of the known Ring of Fire. In other words, not all countries above the joint of tectonic place or next to ocean have the tendency to suffer from earthquakes due to the fact that the greatest percentage of occurrences appear to be to specific Asian and American countries.

Regarding the different negative effects that least developed countries and most developed countries face, there is evidence that the least developed countries tend to have more fatalities and affected people, while the most developed countries appear to have greater economic losses. However, this evidence is not significantly appeared and is not attached to all cases examined.

Future extentions will include more advanced econometric analysis with the consideration of more factors that may be affected such as macroeconomic, health and social factors as well as a dynamic and not static analysis where we may observe the possible effects, positive or negative, to forthcoming years. Moreover, the multiple disaster analysis as proposed by Managi and Guan (2017) is concidered to be fundamental due to the linkage between two or more events. Obviously, relying on frequencies and map visualization is a first approximation of the problem's dimensions and we believe that althought it is not scientifically acceptable to accept or reject with confidence the hypotheses established in this paper, these techniques gave us some evidence that should be examined in depth and with the proposed, by the literature, econometric methodology. The outcomes from such an analysis may be crucial to policy makers of governments by using them when creating systems of preparedness[11] for each country. If we are able to know and forecast the possibility of an event to occur based on our geographical position then we may be able to either avoid it, which may not be feasible when speaking about nature, or be more prepared in order to minimize the drawback.

Acknowledgements This work has been supported by the General Secretariat for Research and Technology and the Hellenic Foundation for Research and Innovation (HFRI). We would like to thank the Editor Professor Shunsuke Managi and the anonymous reviewers for helpful and constructive comments that improved the quality of the paper. Any remaining errors are solely the authors responsibility.

[11] Also examined by Goeschle and Managi (2018)

Appendix I

Table 7 Biological hazards - most suffered areas

	Country Name	Occurrence		Country Name	Total Deaths ('000)		Country Name	Injured ('000)		Country Name	Affected ('000)
1	Nigeria	503	1	Soviet Union	1250	1	Solomon Is	186	1	Soviet Union	9000
2	Congo	318	2	China	142	2	Haiti	40	2	Japan	667
3	South Africa	287	3	India	66	3	Philippines	6	3	Eritrea	510
4	Egypt	228	4	Bangladesh	13	4	Peru	6	4	Ethiopia	468
5	Kenya	223	5	Canada	7	5	Guatemala	2	5	Kenya	295
6	Sudan	220	6	Cabo Verde	3	6	Ghana	0.63	6	Malawi	290
7	Tanzania	212	7	New Zealand	3	7	Tanzania	0.56	7	Canada	287
8	Uganda	186	8	Ethiopia	2.5	8	Liberia	0.52	8	South Sudan	218
9	Ethiopia	171	9	Uganda	2	9	Sierra Leone	0.4	9	Mozambique	209
10	Mozambique	155	10	Niger	2	10	Iraq	0.3	10	Niger	201
	Country Name	Homeless ('000)		Country Name	Total Affected ('000)		Country Name	Total Damage ('000$)			
1	Madagascar	12	1	Soviet Union	9000	1	Algeria	92,079			
2	Algeria	7	2	Japan	667	2	Australia	40,000			
3	Sudan	7	3	Eritrea	511	3	Mauritius	30,822			
4	Benin	5	4	Ethiopia	469	4	Madagascar	24,488			
5	Mozambique	4	5	Kenya	295	5	South Africa	20,898			
6	Malawi	4	6	Malawi	294	6	Colombia	20,800			
7	Somalia	4	7	Canada	287	7	Reunion Is	15,875			
8	Ghana	2	8	South Sudan	218	8	Morocco	15,782			
9	Uganda	2	9	Mozambique	213	9	Tunisia	1,1020			
10	Togo	2	10	Niger	202	10	Mozambique	7322			

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Total Affected is that summation of Injured Affected and Homeless.

Table 8 Climatological hazards - most suffered areas

	Country Name	Occurrence		Country Name	Total Deaths ('000)		Country Name	Injured		Country Name	Affected ('000)
1	USA	107	1	Soviet Union	600	1	Russian Federation	83	1	India	81,873
2	Australia	48	2	Bangladesh	271	2	Chile	64.5	2	Iran	12,542
3	China	43	3	India	250	3	Benin	40	3	China	12,048
4	Hong Kong	40	4	China	81	4	South Africa	29.4	4	Korea	10,500
5	Canada	28	5	Ethiopia	24	5	Australia	25.8	5	Ethiopia	4538
6	Russian Federation	28	6	Sudan	15	6	Indonesia	23.9	6	Bangladesh	3572
7	Brazil	23	7	Cabo Verde	8.5	7	Israel	15.5	7	Kenya	3486
8	Indonesia	20	8	Mozambique	7	8	Portugal	15.5	8	Brazil	3428
9	South Africa	18	9	Niger	6	9	Mongolia	15.25	9	Ghana	3128
10	Spain	18	10	Somalia	2.6	10	Lebanon	15	10	Malawi	3047
	Country Name	Homeless		Country Name	Total Affected ('0000		Country Name	Total Damage ('000,000$)			
1	Myanmar	10,000	1	India	81,873	1	Ukraine	1690			
2	Nepal	6750	2	Iran	12,542	2	Iran	1100			
3	Yemen	5000	3	China	12,048	3	China	752			
4	Sierra Leone	2257	4	Korea	10,500	4	Denmark	752			
5	Benin	1151,8	5	Ethiopia	4538	5	Spain	745			
6	Canada	651.2	6	Bangladesh	3572	6	USA	607			
7	Congo	579	7	Kenya	3486	7	Indonesia	552			
8	Malaysia	500	8	Brazil	3428	8	Brazil	489			
9	Gambia	500	9	Ghana	3128	9	Mongolia	455			
10	Australia	424.5417	10	Malawi	3047	10	Portugal	410			

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Table 9 Geophysical hazards - most suffered areas

	Country Name	Occurrence		Country Name	Total Deaths ('000)		Country Name	Injured ('000)		Country Name	Affected ('000)
1	Indonesia	169	1	Haiti	111	1	Haiti	150	1	Haiti	1700
2	China	164	2	Sri Lanka	35	2	Sri Lanka	23	2	India	770
3	Iran	106	3	Martinique	15	3	Ecuador	7	3	Nepal	701
4	Turkey	78	4	China	5	4	India	6.5	4	Sri Lanka	516
5	Japan	77	5	Soviet Union	5	5	Morocco	6	5	China	432
6	Philippines	57	6	Pakistan	4	6	Pakistan	4.5	6	Chile	215
7	Peru	49	7	Morocco	3	7	China	4	7	El Salvador	190
8	Mexico	42	8	Italy	3	8	Argentina	34	8	Guatemala	168
9	USA	42	9	Japan	2.5	9	Peru	3	9	Azerbaijan	144
10	Chile	40	10	India	2	10	Nepal	3	10	Yemen	133
	Country Name	Homeless ('000)		Country Name	Total Affected ('000)		Country Name	Total Damage ('000,000$)			
1	Sri Lanka	480	1	Haiti	1850	1	Japan	4673			
2	Pakistan	157	2	Sri Lanka	1019	2	Haiti	4010			
3	India	63.5	3	India	840	3	New Zealand	2253			
4	Algeria	40	4	Nepal	708	4	Sri Lanka	1316.5			
5	Guatemala	38	5	China	464	5	Italy	1297			
6	Chile	33	6	Chile	250	6	Taiwan	1080.5			
7	China	28	7	Pakistan	220	7	USA	1014			
8	El Salvador	25	8	El Salvador	218	8	Chile	903			
9	Soviet Union	24	9	Guatemala	209	9	China	673			
10	Malawi	23.5	10	Yemen	147	10	Yemen	667			

(Islamic Republic of)

Table 10 Hydrological hazards - most suffered areas

	Country Name	Occurrence		Country Name	Total Deaths		Country Name	Injured		Country Name	Affected ('000)
1	China	342	1	China	19,316	1	Yugoslavia	2500	1	China	5727
2	India	324	2	Guatemala	1188	2	China	2423	2	Bangladesh	3402
3	Indonesia	233	3	Venezuela	899	3	Bangladesh	1315	3	India	2549
4	USA	181	4	Bangladesh	559	4	Indonesia	1098	4	Cambodia	719
5	Philippines	175	5	Soviet Union	540.4	5	El Salvador	1000	5	Thailand	692
6	Brazil	156	6	Netherlands	500.25	6	Taiwan	671.4	6	Pakistan	670.5
7	Colombia	113	7	India	229	7	Sudan	570	7	Korea	474
8	Pakistan	112	8	Japan	195	8	Czech Republic	185	8	Viet Nam	372
9	Afghanistan	101	9	Pakistan	159	9	Haiti	159	9	Myanmar	352
10	Bangladesh	94	10	Lebanon	147	10	Russian Federation	115	10	Mozambique	271,
	Country Name	Homeless		Country Name	Total Affected ('000)		Country Name	Total Damage ('000,000$)			
1	China	128,626	1	China	5858	1	Germany	1126			
2	India	69,190	2	Bangladesh	3449	2	Korea	702			
3	Sri Lanka	56,870	3	India	2618	3	China	692			
4	Bangladesh	45,270	4	Cambodia	738	4	UK	661			
5	Korea	44,003	5	Pakistan	708	5	Thailand	567			
6	Sudan	42,749	6	Thailand	695	6	Poland	567			
7	Pakistan	37,868	7	Korea	518	7	Italy	443			
8	French Guiana	35,000	8	Viet Nam	377	8	Czech Republic	442			
9	Italy	25,081	9	Myanmar	361	9	USA	422			
10	Benin	22,957	10	Mozambique	273	10	Spain	277			

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Table 11 Meteorological hazards - most suffered areas

	Country Name	Occurrence		Country Name	Total Deaths		Country Name	Injured		Country Name	Affected ('000)
1	USA	634	1	Myanmar	7615	1	Peru	114,062	1	China	1900
2	Philippines	335	2	Bangladesh	3251	2	Bangladesh	4800	2	Moldova	652
3	China	294	3	Russian Federation	1418	3	Costa Rica	1071	3	Philippines	465
4	India	234	4	Honduras	1119	4	Myanmar	1069	4	Viet Nam	440
5	Bangladesh	196	5	India	780	5	Ukraine	1027	5	India	418
6	Japan	181	6	Italy	705	6	Syrian Arab Republic	963	6	Tajikistan	401
7	Mexico	117	7	China	596	7	Japan	725	7	Bangladesh	364
8	Australia	110	8	Spain	544	8	Belarus	674	8	Mongolia	340
9	Viet Nam	99	9	Haiti	387	9	China	637	9	Israel	333
10	Taiwan	81	10	Hong Kong	377	10	Sri Lanka	560	10	Liberia	333
	Country Name	Homeless		Country Name	Total Affected ('000)		Country Name	Total Damage ('000$)			
1	Lao	200,000	1	China	1953	1	USA	995,998			
2	China	52,248	2	Moldova	658	2	Korea	678,946			
3	Bangladesh	51,161	3	Viet Nam	484	3	Oman	574,667			
4	Viet Nam	44,099	4	Philippines	481	4	Cayman Is.	499,511			
5	India	42,713	5	India	461	5	Germany	488,489			
6	Mozambique	26,889	6	Bangladesh	420	6	France	423,220			
7	Korea	24,739	7	Tajikistan	401	7	China	375,236			
8	Maldives	23,849	8	Peru	379	8	Sweden	371,250			
9	Haiti	23,784	9	Mongolia	340	9	Japan	350,717			
10	Madagascar	20,587	10	Liberia	335	10	Italy	311,431			

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