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TIME AND SPACE IN DISASTER

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Disasters in time and space

Early attempts to define disasters were based on the exceedence of certain loss thresholds. For instance, Sheehan and Hewitt (1996) classified as disasters all those events that killed or injured at least 100 people or caused at least US $1 million damage. This definition was further developed in more qualitative terms, e.g., by UNDRO (1984) "... an event, concentrated in time and space, in which a community undergoes severe danger and incurs such losses to its members and physical appurtenances that the social structure is disrupted and the fulfillment of all or some of the essential functions of the society is prevented." Other definitions reduce the term disaster to those events where ".. large numbers of people exposed to hazard are killed, injured or damaged in some way ..." (Smith, 2004, p. 5). In this context, Smith also states, that "there is no universally agreed definition of the scale on which loss has to occur in order to qualify as a disaster." Further, Smith (2004, p. 22) writes that "... a disaster generally results from the interaction, in time and space, between the physical exposure to a hazardous process and a vulnerable human population." For statistical purposes some authorities require the impact of a natural event to exceed certain thresholds of areal extent, as well as lives lost, or economic costs before they are classified as disasters. In this contribution, disasters are defined as those damaging events that exceed the coping capacity of affected individuals, groups, or institutions and, in some cases, even nations. This definition avoids the use of absolute quantitative measures, which can vary dramatically between different countries, or in more general terms, between different social groups.

Thus, irrespective of the magnitude of the natural event, disasters are defined in terms of human impact and related consequences. In the contextual framework of natural hazards, disasters can be localized. They occur at a specific location or in a region as a sudden onset or as slow creeping, often unstoppable processes. Sources and affected areas can be very distinct with easy to delineate boundaries (e.g., a debris flow with source area, travel path, and deposition) or difficult to assess (e.g., pollution of ground water). Whereas the boundaries of source and impact areas may be identifiable after an event, it is not always possible to predict where a disaster may occur. Some hazards that give rise to disasters tend to recur in the same locality; these are described as *location-specific*, e.g., lahars, debris flows, snow avalanches, and in some cases earthquakes and volcanic eruptions. *Non–location-specific* hazards which are more or less random in terms of place of occurrence include events such as drought, epidemic, and many weather related phenomena. However, because vulnerability and resilience of human communities have a large influence on the magnitude of consequences resulting from a hazard event, most disasters occur in the poorer less-developed countries of the world (Table 1). Nevertheless industrialized regions can also suffer from major disasters, for example, when design thresholds of mitigation structures are exceeded (refer to Hurricane Katrina in USA). Although economic losses can be large in industrialized regions, in contrast, in the transient states, loss of life and other direct effects on the population are generally much higher (Table 1). These differences do not simply represent a decadal trend, but can be observed over much longer periods (e.g., OFDA/CRED International Disaster Database).

Because of the human element implicit in the notion of disasters an understanding of their causes and behavior requires information not only on the properties and patterns of the natural event, but also on the socioeconomic conditions of the affected area. In numerous regions of the world, people are unable to divert resources toward counter measures against natural hazards. They have to face much more dramatic problems such as unemployment, famine, crime, and so on. These problems become much more severe with constantly growing cities and urban agglomerations and thus, these social groups become increasingly vulnerable toward natural events. Some socioeconomic factors that turn an event into a disaster relate to:

- Demographic characteristics
- GDP
- Urbanization
- Emergency preparedness
- Insurance coverage
- Community perception and awareness

These factors alone are all subject to constant, often rapid change, producing dramatic transformations of the human condition within time and space. Consequently, risk is changing as well – and as a result the magnitude and areal extent of disasters have tended to increase with time. Thus, not only do the characteristics of the physical process change (e.g., more intense rainstorms, stronger winds, higher waves), but also the elements at risk undergo a continuous change (Hufschmidt et al., 2005; Keiler, 2004).

Another important issue is the time lag between the triggering input, the occurrence of the process and the resulting disaster. In the case of a debris flow, it is straightforward. Heavy rain accumulates in the flow lines and starts to move erodible material until there is sufficient sediment that the debris flow is formed, travels down a channel and affects the downstream people or infrastructure. Other processes such as soil erosion caused by human activity are much more difficult to assess. The time lag between deforestation, start of soil erosion and erosion cycles that are based on the timing of the precipitation event and the agricultural usage is often very large. Also, the onset of the associated disaster is gradual rather than sudden. In such cases agricultural productivity slowly decreases and although the affected social groups might be able to cope with these changes in the beginning, the continuous increase of pressure and then the sudden drop of productivity can lead also to a disaster. Therefore, it is important to consider the chain of cause – consequence for disasters (Figure 1).

As indicated earlier, both slow and fast-onset natural hazards can cause disasters. The consequences of the fast-onset processes are mostly clearly visible and these disasters are often quantifiable in terms of their impact. In contrast, slow onset disasters continue over long periods. Besides desertification and soil erosion, other examples include water pollution or subsidence through extensive ground water removal. These "creeping" or gradual processes still cause disasters in the above defined sense – at some stage, there may be no soil left for agricultural use and the farmers have to move, or the ground water has been extensively extracted to an extent, where there is no readily available water. The now nearly dry Aral lake (Waltham and Sholji, 2001) is a dramatic example of excessive water usage in the upper catchment for irrigation purposes to the extent, that in certain years virtually no water reaches the lake (Cai et al., 2003). The lake now has more or less disappeared causing a dramatic disaster for the affected population – not only in terms of water shortage and depressed economy, but also in terms of an increase in the impact of pesticide polluted dust storms (O'Hara et al., 2000). Therefore, the time lag between input and consequences can be several years, and in some cases, even decades.

Another issue in this context is difference between the source area and the potential effects. Although snow avalanches, rock falls, and hurricanes have distinct and localized occurrences and consequential damage potential, a debris flow or a flash flood might be initiated high up in the catchment area but will cause destructive damages far away from the source. Similarly tsunami with travel distances of thousands of kilometers or ash clouds from volcanic eruptions with consequent and long-lasting flight interruptions are other examples (e.g., eruption of Icelandic volcano Eyjafjallajokull in March and April 2010).

Different perspectives

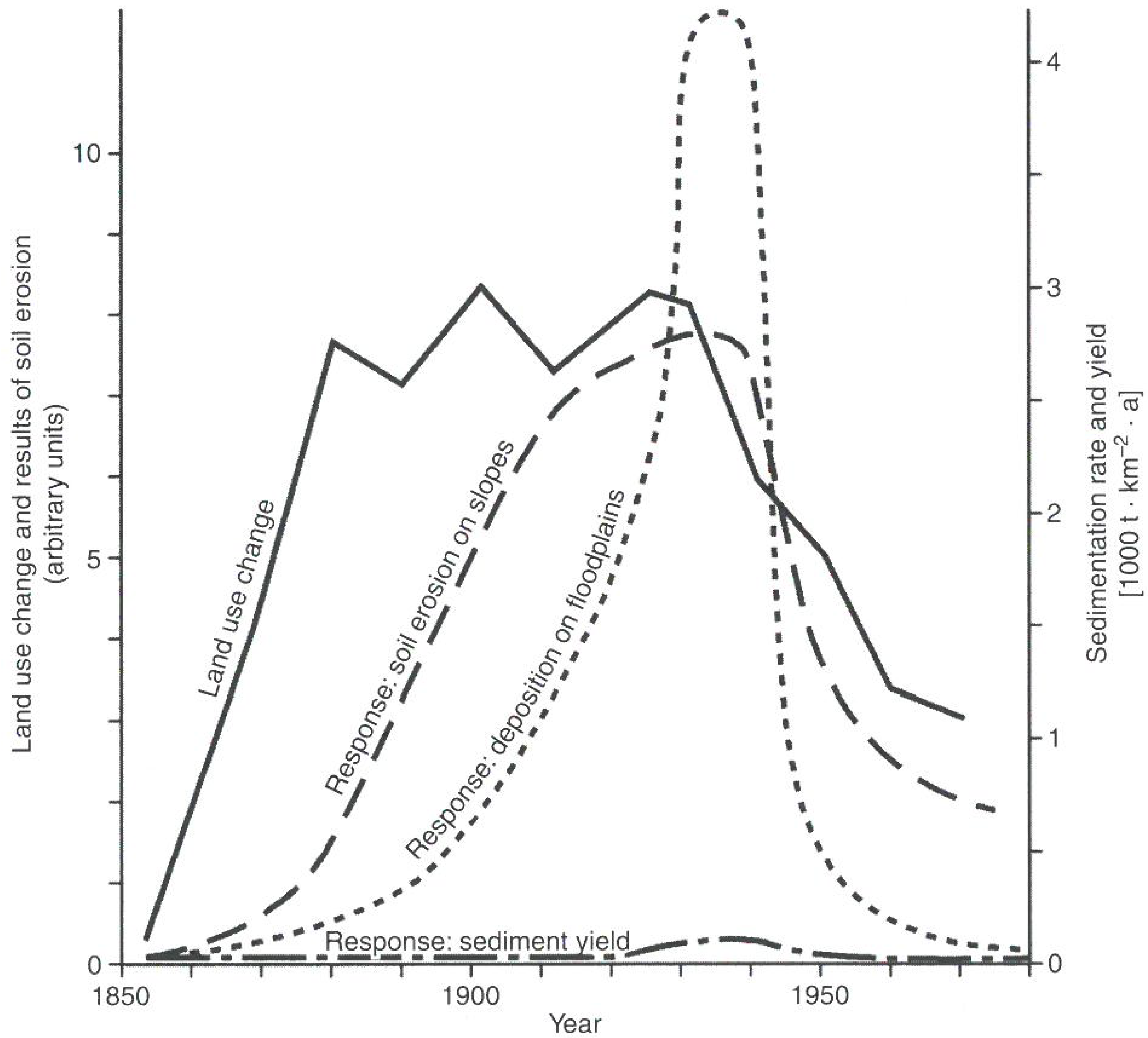
Assessing the temporal and spatial distribution of disasters is often very difficult particularly for events that have taken place in the past when instrumental and other records are limited. The human memory and associated observations can be useful sources of information. However, the larger the time lags between event occurrence and the recording of the event, the vaguer the information. In addition, smaller events are more often forgotten in

Time and Space in Disaster, Table 1 Selected entries of natural disasters for the period 1999–2009, ordered by largest numbers of (A) fatalities, (B) injuries, and (C) economic damages. (Note: *Gray shaded boxes* are not relevant for the respective entry. Data extracted from the EM-DAT: The OFDA/CRED International Disaster Database – www.emdat.be, maintained by CRED (Centre for Research on the Epidemiology of Disasters), Université Catholique de Louvain, Brussels (Belgium), and accessed 05.05.2010)

Date		Location		Type of event			Consequences		
Start	End	Country	Region	Main	Subtype	Name	Killed	Totally affected ($\times 10^6$)	Est. damage (Mio US$)
(A) Disasters with largest fatalities									
26.12.2004	26.12.2004	Indonesia	Aceh province (Sumatra)	Earthquake (seismic activity)	Tsunami		165,708		
02.05.2008	03.05.2008	Myanmar	Ngapadudaw, Labutta	Storm	Tropical cyclone	Cyclone Nargis	138,366		
12.05.2008	12.05.2008	China P Rep	Wenchuan country	Earthquake (seismic activity)	Earthquake (ground shaking)		87,476		
08.10.2005	08.10.2005	Pakistan	Bagh, Muzzafarabad	Earthquake (seismic activity)	Earthquake (ground shaking)		73,338		
26.12.2004	26.12.2004	Sri Lanka		Earthquake (seismic activity)	Tsunami		35,399		
26.12.2003	26.12.2003	Iran Islam Rep	Bam (Kerran province)	Earthquake (seismic activity)	Earthquake (ground shaking)		26,796		
16.07.2003	15.08.2003	Italy	Milan, Turin (Piemont)	Extreme temperature	Heat wave		20,089		
26.01.2001	26.01.2001	India	Kachch-Bhuj, Ahmedabad	Earthquake (seismic activity)	Earthquake (ground shaking)		20,005		
01.08.2003	20.08.2003	France	Paris region – all countries	Extreme temperature	Heat wave		19,490		
26.12.2004	26.12.2004	India	Tamil Nadu state, Andaman	Earthquake (seismic activity)	Tsunami		16,389		
(B) Disasters with most affected people									
00.07.2009	00.08.2009	India	Bongaigaon, Cachar	Drought	Drought			300	
23.06.2003	28.07.2003	China P Rep	Zhejiang, Jiangsu	Flood	General flood			150	
15.06.2007	00.07.2007	China P Rep	Sichuan, Anhui, Hubei	Flood	General flood			105	
14.03.2002	31.03.2002	China P Rep	North	Storm	Local storm			100	
08.06.2002	18.06.2002	China P Rep	Shanxi, Sichuan, Hubei	Flood	Flash flood			80	
10.01.2008	05.02.2008	China P Rep	Zhejiang, Sichuan	Extreme temperature	Extreme winter conditions			77	
00.04.2002	00.00.2002	China P Rep	Guangdong, Fujian	Drought	Drought			60	
00.10.2009	00.03.2010	China P Rep	Yunnan, Guizhou, Sichuan	Drought	Drought			51	
00.04.2000	00.00.2001	India	Gujarat, Rajasthan	Drought	Drought			50	
00.01.2003	00.01.2003	China P Rep	Inner Mongolia Autonomous	Drought	Drought			48	

Time and Space in Disaster, Table 1 (Continued)

Date		Location		Type of event			Consequences		
Start	End	Country	Region	Main	Subtype	Name	Killed	Totally affected ($\times 10^6$)	Est. damage (Mio US$)
(C) Disasters with largest economic damage									
29.08.2005	19.09.2005	United States	Mobile, Bayou La Batre	Storm	Tropical cyclone				125,000
12.05.2008	12.05.2008	China P Rep	Wenchuan country, Wencgua	Earthquake (seismic activity)	Earthquake (ground shaking)				85,000
12.09.2008	16.09.2008	United States	Galvestin, Brazoria	Storm	Tropical cyclone				30,000
23.10.2004	25.10.2004	Japan	Niigata	Earthquake (seismic activity)	Earthquake (ground shaking)				28,000
10.01.2008	05.02.2008	China P Rep	Zhejiang, Sichuan	Extreme temperature	Heat wave				21,100
15.09.2004	16.09.2004	United States	Alabama, Louisiana	Storm	Tropical cyclone	Ivan			18,000
23.09.2005	01.10.2005	United States	Louisiana, Texas	Storm	Tropical cyclone	Rita			16,000
13.08.2004	13.08.2004	United States	Florida	Storm	Tropical cyclone	Charley			16,000
24.10.2005	24.10.2005	United States	Florida Keys, Naples	Storm	Tropical cyclone	Hurricane "Wilmna"			14,300
16.07.2007	16.07.2007	Japan	Niiagata prefecture	Earthquake (seismic activity)	Earthquake (ground shaking)				12,500



Time and Space in Disaster, Figure 1 Potential time lag between cause and different responses (Dearing et al., 2006), for the example, of soil erosion. Please note that such time lags operate as well in the social system.

time. Within historical research on former disastrous events, this is often a major problem (refer to entry "*Disaster Research and Policy, History*"). Therefore, graphs showing the development of disasters over time have to be treated with care (e.g., Figure 2). Such trends might reflect a number of factors unrelated to actual occurrence, such as increased awareness and thus enhanced reporting, better data availability, higher exposure of elements at risk, and so on. It is therefore important to carefully analyze temporal records to ensure any apparent trends are indeed real.

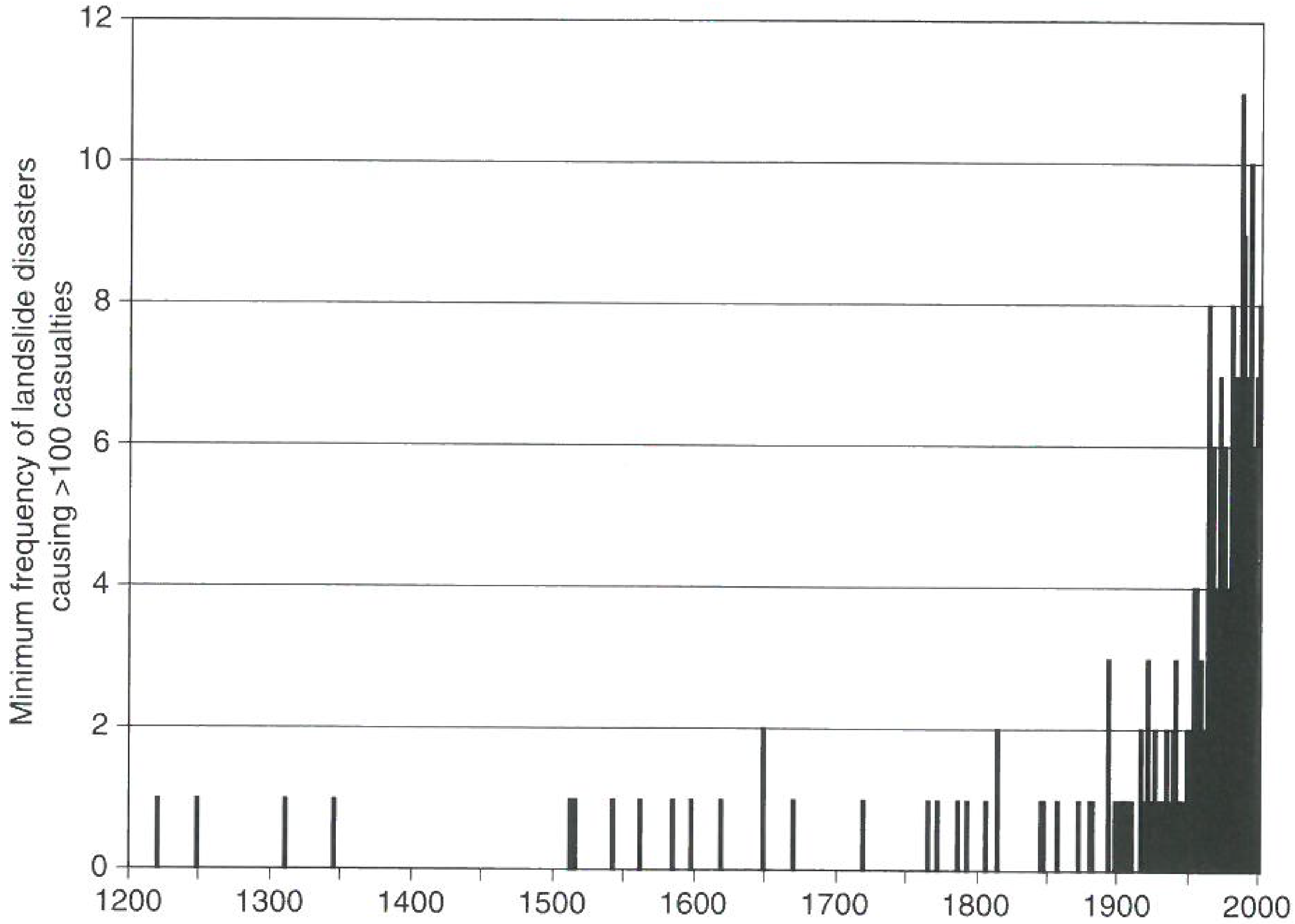
In recent years, media coverage has changed the public perception of disasters. For example, in some parts of the world, very small and localized events receive prominent media attention and provide a false impression of the magnitude of the event (e.g., snow avalanches in Galtür, Austria on the 22.02.1999). On the other hand, significant disasters such as desertification in certain regions often do not receive equivalent reporting representation and are thus not perceived by the public as large disasters.

Media, of course, play an important role in emergency management and disaster communication as well as being an important educational source about the causes and consequences of disasters. For instance, in Germany two large floods occurred in the Rhine valley within the 2 years (1995 and 1996). The result of comprehensive media coverage on the first flood meant that the public were well informed and were better prepared for the second flood and as a result the damages of the second flood were much lower (Engel, 1997). This again demonstrates the need to examine media reports carefully before using these in any form of magnitude frequency record, particularly noting the effect of reporting on events closely associated in time.

Future trends

There is a need for a better understanding of the causative factors of disasters, not only in terms of increased knowledge within natural sciences issues, but also within the social sciences. In this respect, of critical importance is the need to investigate the relationships between these two systems, the interconnections, the dependencies, the different reaction and response times, and the spatial implications associated with each system.

Therefore, studies of disasters should not confine themselves solely to post-event analysis and single-case studies. In order to understand better the root-cause-consequence principle in all its dimensions long-term investigations are necessary. Monitoring is a crucial part



Time and Space in Disaster, Figure 2 Historical data of landslide disasters causing >100 causalities (Glade and Dikau, 2001). Note: This graph does not necessarily express a real increase of landslide disasters, but is purely reflecting the available reports and the better reporting within the last decades.

of this process, in particular, monitoring the natural system, the social system and – most importantly – the linkages between these elements. The resultant understanding of the basic underlying causes, the factors enforcing or reducing adverse affects, and – in principle – how disasters happen can support decision and policy makers in evaluating potential developments and promoting sustainable development for potentially disaster prone regions.

Summary

It has been stressed, that for a detailed and useful understanding of time and space in disasters, all factors have to be taken into consideration, the natural science, the social science, and the inherent interrelationships. It is evident, that disasters do not stop at any pre-subscribed boundaries, whether ethical, governmental, or topographic. Physical hazards can change their behavior, onset time, processes, and intensity in time and space. The human condition and state of development is also changing with implications for vulnerability and resilience. Associated risks and disaster occurrence can consequently change dramatically in time and space. The changing dynamic of disaster occurrence represents one of the most important and concerning elements of global change facing mankind.

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