2 Theoretical Background

The United Nations have declared the last decade of the 20th century the 'International Decade of Natural Disaster Reduction (IDNDR)'. Amongst others this has promoted research regarding the conceptual approaches to disaster management, which has led to common acceptance of socio-economic parameters strongly influencing the extent of natural disasters. However, there is still very limited agreement on the exact terminology related to the issue. Definitions of the most common terms within disaster studies, such as 'hazard', 'vulnerability', 'resilience' and 'coping capacity' continue to be debated. Proposed definitions vary significantly according to the thematic context for which they are created, such as health, food and conflicts, or according to the element that is of central interest, for example population or economic assets. Additionally, there is no consistent definition of any of these terms even when they are used within the same context. 'Vulnerability' In particular is not precisely defined and often overlaps with the definition of 'risk'. Many authors interchange vulnerability with exposure (see also: ALEXANDER 2000) which, as will be described later (see chapter 2.1.4), are two complementary components of risk.

2.1 Terminology

In the following chapters the existing terminology within the world of disaster, risk and vulnerability will be discussed. Those definitions most appropriate for the scope of this study are framed and placed in front of each subchapter. It is stated whether these definitions are literally sited, a modified version of an already existing definition or a creation by the author.

2.1.1 Disaster

Disaster:
A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources.

(Source: UNISDR 2004).

Disaster synonyms used by practitioners and experts have included calamity and catastrophe. Similar words are emergency and crisis. According to ALEXANDER (2000) disasters are abrupt shocks to the socio-economic and environmental system, involving loss of life and property. In the past a disaster was seen as an event that occurs when hazards are 'realised' (RAHN 1986; SMITH 1996; WHITTOW 1979). However, SMITH's (1996, p 22) definition includes the human aspect by claiming "a disaster generally results from the interaction, in time and space, between the physical exposure to a hazardous process and a vulnerable human population". Nowadays, it is widely accepted that a disaster is multifaceted and open to a range of different interpretations.

There is no threshold to the extent of events that would count them in or out as ‘disasters’ (FOSTER 1976). Often the poor, disadvantaged and less developed populations or groups within a society suffer most from disasters. Though this may seem a trivial statement, the influence of people’s condition on the extent of a disaster’s impact has only been recognised in literature since the 1980s (e.g. WIJKMAN 1984). And it was only in the 1990s that more importance was given to the socio-economic situation of disaster-stricken populations (e.g. BLAIKIE et al. 1994: QUARANTELLI 1995). It is now widely accepted that disasters may be triggered by natural events, but are at least partially exacerbated by social or socio-economic factors leading to incapacity to cope with the hazardous impact (BURTON et al. 1993; SMITH 2000; ALEXANDER 2003).

Looking at disasters as the interaction between vulnerable populations and extreme events stresses the negative effect on communities and provides motivation to initiate mitigation and preventative measures (COBURN 1994a; LINDSAY 2003). Disaster definitions that include people’s condition are valid for all ‘types’ of disaster if grouped according to triggering hazards, such as accidents, conflicts or geo-physical events. The definition that is provided by the UNISDR (see above) has been chosen as the most appropriate definition for this work.

2.1.2 Risk

Risk: The probability of harmful consequences or expected losses resulting from a given hazard to a given element at danger or peril, over a specified time period.

(Source: author).

In dictionaries ‘risk’ is often described as ‘hazard’, ‘danger’ or ‘exposure to mischance or peril’ (JONES et al. 2001). Not surprisingly in everyday speech the terms ‘risk’ and ‘hazard’ are often used interchangeably. Additionally, linguistic problems may amplify confusion since there is no direct translation from the English word ‘hazard’ into for example French, German, Dutch or Italian, where the idea of hazard has to be circumscribed with expressions such as ‘*risque*’, ‘*péril*’, ‘*Risiko*’, ‘*Gefahr*’, ‘*risico*’ or ‘*pericolo*’. In technical definitions the terms ‘risk’ and ‘hazard’ are linked to each other but should be clearly distinguished. For economists and engineers risk mainly signifies a probability of the occurrence of (negative) impacts and their generated losses (MECHLER 2003). In management terms ‘risk’ is also seen as a measure of uncertainty about the achievements of set objectives (MCNAMEE 1999). OKRENT (1980, p 372) clarifies the difference between risk and hazard in the context of natural disasters within the following analogy: “two people crossing an ocean, one in a liner and the other in a rowing boat. The main hazard (deep water and large waves) is the same in both cases but the risk (probability of drowning) is very much greater for the person in the rowing boat”. Though the difference is here unambiguous, there are still numerous attempts to formulate it in a variety of definitions. Some examples of risk definition in the hazard and disaster management literature are:

- “Risk can be considered as the possibility of suffering harm from a hazard” (EASTMAN et al. 1997).
- “The concept of risk implies the possibility of suffering a loss” (BURBY 1991).

- "The potential for accidental incapacitation or casualty, the chance of dying immediately or in the future as a result of exposure to any one of the listed activities or substances" (LAFOND & GOSSELIN 1994).
- "Risk is a function of the probability of the specified natural hazard event and vulnerability of cultural entities" (CHAPMAN 1994).
- "The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human induced hazards and vulnerable conditions" (UNISDR 2004).
- "The term risk refers to the expected losses from a given hazard to a given element at risk, over a specified future time period" (COBURN 1994b).

Most of the proposed definitions emphasise the *likelihood of occurrence* as one of the main determinants of risk (THYWISSEN 2006). The attempt to mathematically determine risk stems from the economic and engineering perspective and will be part of a later discussion in chapter 2.2 where it is attempted to formalise an equation for risk estimation. In the here proposed definition of risk parts of the UNISDR (2004) definition have been combined with that of COBURN (1994b), which can be found in the Disaster Management Training Program of the UNDRO. In this joint definition the term 'probability' as well as the reference to a specific hazard, the element at danger and the time dimension are included. The potential elements at danger or risk can be lives (lost), persons (injured), property (damaged), and / or economy (disrupted). The focus of this study is on the risk of loss of life.

It is broadly accepted in the scientific community that risk cannot only be determined as a function of hazard, describing the possibility of physical harm, but must also include the vulnerability of the element at risk (see for example CANNON 1993; GARATWA & BOLLIN 2001). The term vulnerability as discussed in chapter 2.1.4 is by and large based on the socio-economic context of the people affected. As CHAPMAN (1994) already embraces in his definition, vulnerability is also dependent on the cultural context. In different cultures the individual's or group of individuals' perception of hazards (or risk and underlying causes of disasters) varies. As a result these adjustments to a hazardous event differ due to varying interactions between cultural and natural systems (WHITE 1974).

2.1.3 Hazard

Hazard:
A potentially damaging physical event, phenomenon and/or human activity, which may cause loss of life or injury, property damage, social and economic disruption or environmental degradation. Hazards can be single, sequential or combined in their origin and effects.

(Source: after UNISDR 2004).

Disasters are triggered by *hazards*, a term that needs to be differentiated from the expressions 'event' and 'risk'. In the food security-related literature the authors tend to use the term risk in order to describe external events or hazards (CHAMBERS 1989; DILLEY & BOUDREAU 2001). In the disaster-related literature some authors limit hazards to naturally induced events whilst others include those events triggered by human activities. GARATWA &

BOLLIN (2001) distinguish between truly natural hazards (such as earthquakes) and socio-natural hazards (forest fires, floods, landslides etc.), which are triggered or aggravated by a combination of extreme natural events and human intervention in nature. However, most authors agree that hazards, unlike events, always have the potential to cause harm to people, property or the environment:

- "A condition or situation which has the potential to create harm to people, property, or the environment" (IPENZ 1983).
- "A potential loss that can cause human, social, environmental or economic harm" (GARDENIER 1992).
- "A potential threat to humans and there welfare" (SMITH 1992).
- "A geologic hazard is a phenomenon associated with geologic processes that can produce a disaster when a critical threshold is exceeded and can result in significant loss in life or property" (COATES 1981).

Having included the human aspect in the above proposed definition it is still necessary to draw a distinction between the terms 'risk' and 'disaster': 'Risk' as defined above is (at least theoretically) a computable probability of *loss of a certain element,* a 'hazard' only has the *potential* to cause negative consequences (if and to what extent these consequences will become reality is dependent on the 'vulnerability' of the element at risk, which will be explained later). In contrast a 'disaster' signifies that the potentially negative consequences have become reality due to the occurrence of a hazard. In order to properly grasp this meaning of hazard the rather long but all-embracing definition of the UNISDR has been chosen, as framed and cited above.

Magnitude	Only those occurrences that exceed some common level of magnitude are extreme
Duration	The length of time over which a hazardous event persists
Areal Extent	The space covered by the hazardous event
Speed of Onset	The length of time between the first appearance of an event and its peak
Spatial Dispersion	The pattern of distribution over the space in which its impacts can occur
Temporal Spacing	The sequencing of events, ranging along a continuum from random to periodic

Table 1: Description of hazards' characteristics (source: after GRAVLEY 2001).

When using the description of hazard in order to explain a certain risk it is important to know the basic characteristics of hazardous events such as location, time, intensity and frequency as shown in Table 1.

Hazard group	*Hazard type*	*Examples*
Purely geogenic	Geological	Earthquake, volcanic eruption, tsunami, *landslides, subsidence*
Geo / Anthropogenic	*Meteorological*	*Cyclones, lightning & fires, drought, avalanche, hail storm, cold spell*
	Oceanographic	*Sea storm, storm surge*
	Hydrological	*Flood, flash flood*
	Biological	*Epidemics, crop blight, insect infestation*
Purely anthropogenic (technological)	Explosion	
	Release of toxic materials	
	Severe contamination	
	Structural collapse	
	Transportation, construction or manufacturing accident	
Purely anthropogenic (conflict)	Crowd-related	Riot, crowd crush
	Terrorist activity	Bombing, shooting, hijacking
	Political conflict	International and civil war, revolution and 'coup d'état'

Table 2: Groups and types of hazards (source: author).

With respect to their causes, hazards may be allocated to various classes according to their level of geogenic (or 'natural') and anthropogenic (or 'man-made') origin (see Table 2). As mentioned above and pointed out in its definition, hazards often have interrelated causes. For example, a landslide might be triggered by heavy rainfall but determined in its severity by deforestation. Often one hazard is triggered by another one. For example, volcanoes may cause landslides, which in turn cause tsunamis. Or an earthquake may provoke the destruction of buildings and infrastructures such as dams, which will result in other hazards such as floods. Geogenic hazards triggering technological disasters, in particular due to the release of toxic chemical material, are called 'Natechs' (CRUZ et al. 2006). Additionally, it is most likely that in the near future the number of anthropogenic hazards triggered by disputes about access to limited natural resources such as water will increase significantly.

Increasingly frequently the expression 'environmental hazard' is used for events that are caused by a mix of geogenic and anthropogenic incidents and circumstances. In particular this is the case for hazards associated with global climate change. According to GARATWA & BOLLIN (2001) these should be defined as 'socio-natural' events. Those hazards that are potentially triggered or in their extent modified by an environmental change have been listed in Table 2 in italics.

SMITH (2000, p 16) developed a "spectrum of […] hazards from geophysical events to human activities. Hazards that are increasingly man-made tend to be more voluntary in terms of their acceptance". According to SMITH's spectrum (Figure 1) the hazards are placed in the upper left corner if purely natural and involuntarily (for example earthquake) and in the lower right corner if purely manmade and voluntary (for example mountaineering). Most of the hazards listed are located in the area in between these two extreme cases. A range of possible manmade influence indicated by a horizontal arrow was added to those hazards that might be purely natural but might also have some anthropogenic triggering component.

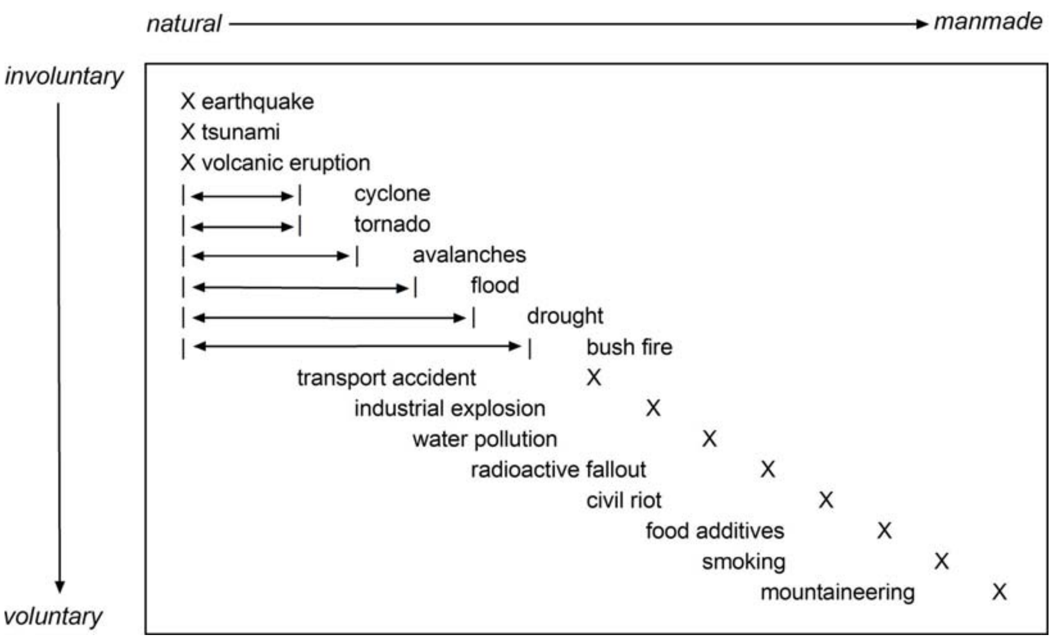


Figure 1: Spectrum of hazards (source: after SMITH 2000).

In this work all those hazards will be excluded, which are clearly based on technological accidents or conflicts. All events are included which exhibit some natural (largely triggering) component.

2.1.4 Vulnerability

> Vulnerability:
> The characteristics of a person or a group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural or man-made disaster - noting that vulnerability is made up of many political-institutional, economic and socio-cultural factors.

(Sources: IFRC 1999; GARATWA & BOLLIN 2001).

The terms 'vulnerable' and 'vulnerability' are debated in papers related to a wide range of topics, from development and humanitarian aid to risk and disaster management. This section reviews some existing definitions, with a focus on vulnerability within the context of disasters caused by natural and / or 'socio-natural' hazards. Later on vulnerability will be elaborated as a concept within the remit of wider disaster research.

The term 'vulnerability' was introduced as a response to the hazard-centric perception of disasters in the 1970's (for example WHITE 1974). With its growing recognition at the beginning of the 1980's, 'vulnerability' was used to express the understanding that the extent to which people suffer from calamities depends on (a) "the likelihood of being exposed to hazards" and (b) "their capacity to withstand them, which relates to their socio-economic circumstances" (DILLEY & BOUDREAU 2001, p 231).

WISNER (2001) points out that the term 'vulnerability' is used in the hazard and disaster literature in a number of ways and identifies the following groups:

- structural, engineering vulnerability,
- lifeline infrastructural vulnerability,
- communications system vulnerability,
- macro economic vulnerability,
- regional economic vulnerability,
- commercial vulnerability (including insurance exposure),
- social vulnerability.

According to WISNER (2001, p 1) "a comprehensive approach conducted at municipal, county/ parish, state/ provincial, nation, or regional level must include such a wide range of vulnerabilities". In the following a focus is put on those aspects of vulnerability which are directly linked to the people and the risk to harm or lose their lives.

Vulnerability definitions often overlap with definitions of 'risk'. For example:

- "[…] the degree of loss to a given element at risk or set of such elements resulting from the occurrence of a phenomenon of a given magnitude and expressed on a scale of 0 (no damage) to 1 (total loss)" (BUCKLE et al. 2001).
- "Vulnerability: Degree of loss (from 0% to 100%) resulting from a potentially damaging phenomenon" (UNISDR 2004).

- “Vulnerability is defined as the degree of loss to a given element at risk (or set of elements) resulting from a given hazard at a given severity level” (COBURN et al. 1994b).

The last definition has been published in a Training Manual of the UNDP Disaster Management Training Programme. It has often been cited and has been used widely e.g. by the GRAVITY group of UNDP / UNEP. Having in mind the lack of clarification between ‘risk’ and ‘vulnerability’ definitions COBURN et al. (1994b, p 41) claim “that the distinction between this definition and that of risk is important to note. Risk combines the expected losses from all levels of hazard severity, taking account also of their occurrence probability”. ALEXANDER (2000) even considers using another expression such as ‘innate risk’ instead of vulnerability for risk analysis in order to avoid confusion.

Another group of definitions emphasises rather the *potential* of loss due to an adverse response to events. For example:

- “Vulnerability can be defined as the potential for attributes of any system, human or natural, to respond adversely to the occurrence of hazardous events” (KALY & PRATT 2004).
- “Vulnerability is the potential to suffer harm or loss in terms of sensitivity, reliance and reliability” (BENSON & CLAY 2003).

SUSMAN et al. (1983) introduce the topic of a population’s capacity to ‘absorb’ and ‘recover’ as a measure of their vulnerability:

- “The degree to which different classes in society are differentially at risk, both in terms of the probability of occurrence of an extreme physical event and the degree to which the community absorbs the effects of extreme physical events and helps different classes to recover”.

This definition emphasises the temporal dimension of hazardous impacts. However, for the author’s understanding, the ‘exposure’ part of this definition, that is the ‘probability of occurrence of an extreme physical event’ should be separated from the pure vulnerability part, which emphasises the characteristics of the people at risk. According to CHAMBERS (1989) and BOHLE (2001) the *internal* dimension of vulnerability refers to defencelessness and insecurity, the capacity to anticipate, cope with, resist, and recover from the impacts of a hazard. The *external* dimension involves exposure to risks and shocks. Since the latter is mainly depending on the geo-location of the population it is here recommended to keep it separate from the vulnerability component for any risk model developments (see also Equation 1 below).

For the purpose of this work, the most appropriate vulnerability definitions are those targeting a population’s characteristics and including the temporal dimension by considering the mechanism of response. The most suitable definition is therefore that provided by the IFRC (1999), which is basically the ‘working definition’ that was given by BLAIKIE et al. (1994), complemented by the last sentence of the definition proposed by GARATWA & BOLLIN (2001).

For clarification it is helpful to add the following lines of a vulnerability definition by MANI (2002, p 1):

“A vulnerable human being is:

1. capable of being physically (emotionally or spiritually) wounded;
2. open to attack or damage (physical, emotional, or spiritual); and
3. lacking in defence or support mechanisms (at the levels of state/government; community; household; and individual)".

Within the context of food insecurity, SEN (1981) initiated a reconsideration of classic drought and flood-driven famines by claiming that starvation is based on a lack of access to food rather than food availability. In addition, limited food access is caused by social, political and economic rather than natural circumstances. However, although practitioners, experts and researchers agreed on the need to further emphasise the socio-economic situation, their view on the concept of vulnerability and the underlying definitions diverged strongly depending on the approach adopted. ALWANG et al. (2001) attempted to address this by comparing different scientific disciplines and their understanding of 'vulnerability'. They first point out the differences in vulnerability definitions within the literature of poverty dynamics, food security, disaster management, sociology, anthropology, ecology-based environment etc. They then list common themes of which the following two are of particular interest for this work:

- The poor are more vulnerable.
- Households are vulnerable to a variety of negative outcomes that can be measured in different ways. Additionally, vulnerability is caused by multiple sources of risk.

In fact 'vulnerable' and 'vulnerability' are often seen as substitutes for 'poor' and 'poverty'. CHAMBERS (1989, p 1) points out the danger of confusing both terms and states that "vulnerability though is not the same as poverty. It means not lack or want, but defencelessness, insecurity, and exposure to risk, shocks, and stress. […] Poverty, in the sense of low income, can be reduced by borrowing and investing; but such debt makes households more vulnerable". In general, poor people have fewer assets and opportunities to withstand and respond to harmful impacts. By considering four main natural hazards, the UNDP calculates that those countries classified under 'high human development' represent 15 % of the population exposed, but only 1.8 % of deaths (UNDP 2004b). In addition, the statistics of the IFRC (2001) for the years 1990-2001 reveal that the average number of people killed per natural disaster was 353 for 'medium and low' developed countries and 22 for 'highly' developed countries (see also GARATWA & BOLLIN, 2001). This suggests that poverty and underdevelopment play an important role for vulnerability assessment, but other factors should also be taken into account.

The variety of negative outcomes and sources of risk raises the question of the necessity to specify causes for and effects of disasters in order to describe vulnerability. The WORLD FOOD PROGRAMME (WFP 2004, p 2) states that in order "to be useful, vulnerability has to be defined in terms of what it is that a population is considered to be vulnerable to and its definition therefore requires specificity". In the context of disaster management this means specifying exogenous events and shocks (Table 2). In the context of food security however, research tends to focus on the consequences rather than the causes of a disaster (in this case: famines). This outcome-oriented approach was initiated by CHAMBERS (1989) and was further developed by DOWNING (1991, p 5), who states, that "vulnerability refers to a consequence rather than a cause. Using vulnerability in reference to a cause insinuates a negative consequence without completing the reference". This approach is now broadly accepted in the food security literature (BLAIKIE et al. 1994; DILLEY & BOUDREAU 2001). According to DILLEY & BOUDREAU (2001) it represents a fundamental divergence of vulnerability concepts between the disaster management context and food security research.

The outcome-related approach, though reasonable in the context of famine and hunger is not helpful in clarifying concepts (e.g. for vulnerability measurements) and the ongoing discussion is widening rather than narrowing the gap between theory and practice (DILLEY & BOUDREAU 2001). This work follows the disaster management approach and focuses on vulnerability determination by looking at specific exogenous impacts.

2.2 Risk Equation

One important outcome of the research carried out within the scope of the IDNDR was the emphasis on the dependency of risk (R) on the three components of hazard (H), exposure (E) and vulnerability (V) as visualised by CRICHTON (1999) in the 'risk triangle' (Figure 2).

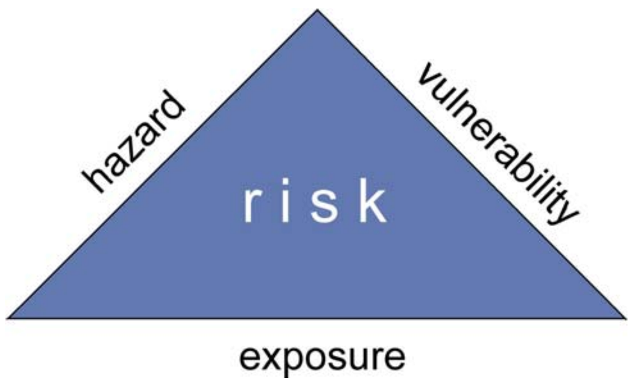


Figure 2*:* The "risk triangle" (source: after CRICHTON 1999).

This concept in its original version or slightly modified has been widely accepted and applied for research on natural disasters (for example PEDUZZI et al. 2002; GRANGER 2003; DILLEY et al. 2005). It can be expressed as:

$$\mathbf{R_{ah} = H_{ah} \times E_{a} \times V_{ah}} \qquad \textbf{(Equation 1)}$$

[a – area affexcted; h – type of hazard]

Subscript 'h' relates to the type of hazard (determined in its severity and its temporal extent) and subscript 'a' is the geographical region affected by hazard 'h'. Exposure is the number of people located in area 'a'. The resulting risk refers to the potential lives lost regarding hazard 'h' in area 'a'. Vulnerability is people's ability to cope with hazard 'h' in area 'a'. Since the degree of vulnerability of the people living in the affected area may vary, the vulnerability in Equation 1 has to represent the average vulnerability of a single individual within area 'a'.

The risk equals 0 if one of the three components of hazard, exposure or vulnerability is 0. In the case of earthquakes there is no risk if (1) there is no likelihood of an earthquake occurring and / or (2) the region affected is not populated and / or (3) the population is not vulnerable (all houses are built to a high level of earthquake security).

It should be noted that:

a) Vulnerability changes with the severity and type of hazard (the houses might be built earthquake safe but only up to a certain standard, or they might be earthquake resistant but vulnerable to floods).
b) For this work, people is the only *element at risk* considered. Other possible elements could be physical assets such as built-up areas, transport lines or similar types of infrastructure.
c) Risk determination requires knowledge of the spatial distribution of hazardous events and the elements at risk.

'Hazard' and 'exposure' can be determined by using, respectively, physical parameters and demographic datasets. The concept of vulnerability is more complex and more difficult to describe. It is necessary to rely on approximating methods such as proxy indicators when attempting to quantitatively estimate a population's vulnerability.

2.3 The concept of vulnerability

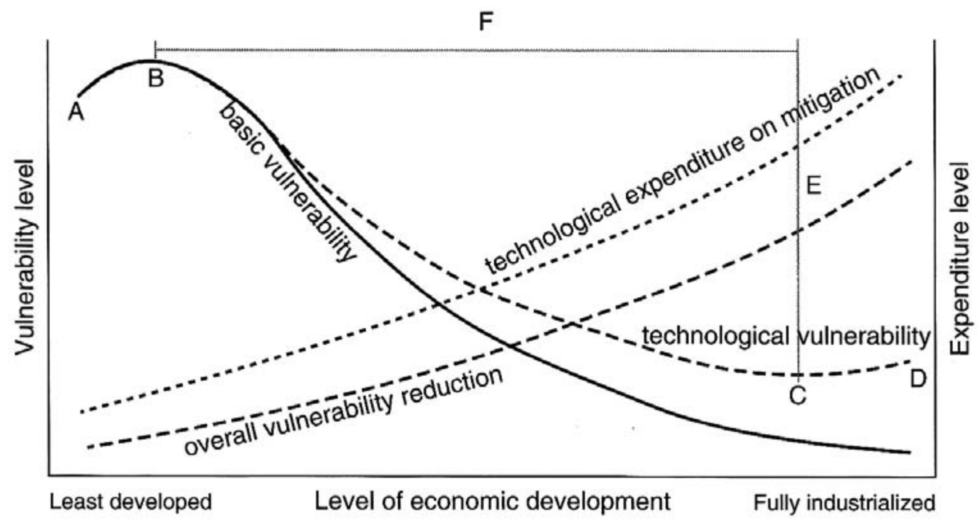
Vulnerability is related to poverty. The poorest societies have the fewest resources and opportunities to noticeably reduce vulnerability. However, while poverty is generally linked to income or availability of goods and degree of well-being based on wealth, the concept of vulnerability has a broader remit that also embraces cultural and social components (CHAMBERS 1989). Not being poor does not necessarily mean not being vulnerable and vice versa. For example a household may have a relatively high income but due to the low development status of the community it belongs to, may be more vulnerable than households with less income in a more developed community[2]. The disastrous impact of floods after the hurricane Katrina in New Orleans / USA in summer 2005 on very specific groups of the population showed that parts of a rich society can be highly vulnerable to hazardous events due to low social status and poverty.

In fact, the state of development is often used as an indicator to determine vulnerability. ALEXANDER (2000) places the level of vulnerability in relation to the 'economic development' of a country (Figure 3). 'A' represents the poorest societies with few resources and few opportunities whilst 'B' represents countries with a slightly increased economic development where assets at risk grow faster than attempts at risk mitigation. 'C' represents an industrialised society with high economic development at a minimum point of vulnerability and 'D' a very high developed society where economic growth places assets in danger before risk can be reduced.

ALEXANDER (2000) also points out that there is a specific reduction of vulnerability that can be achieved with existing technology if development takes place (represented by line E).

[2] It should be mentioned that wealthy households disregard their level of vulnerability usually have the possibility to increase their coping capacity by means of preparedness such as insurance polices.

He calls the difference between high level vulnerability in less developed countries and low level vulnerability in high developed countries the ‘mitigation gap’ (represented by line F).



A – Poorest societies
B – Countries with slightly increased economies
C – Industrialised society with high economic development
D – Very high developed society
E – Reduction of vulnerability achieved with technology
F – ‘Mitigation gap’

Figure 3: Vulnerability in relation to the level of economic development and mitigation gap (source: ALEXANDER 2000).

It should be noted that the development process of a society might exclude certain social or cultural groups. This is particularly the case where rapid national economic development, measured by indicators such as the Gross National Product (GNP), can hide the fact that part of a population may remain disadvantaged, with a low-development status. These groups are also most likely to be found in high risk areas. Affiliation with a specific social or cultural group might therefore have certain implications for an individual’s vulnerability. Composite indicators created particularly for measuring development such as the widely used Human Development Index (HDI) and Human Poverty Index (HPI) are available globally but only rarely at sub-national scale, and hence not adequate for vulnerability assessments at a finer resolution.

2.3.1 The temporal component of vulnerability

Vulnerability is dynamic and its characteristics change over time. It may change slowly as a result of the development process (Figure 3) but it may also change very quickly due to a sudden hazard or disaster. When people are made homeless or become refugees as a result of a sudden hazardous event such as an earthquake or conflict, their vulnerability increases abruptly and they are more susceptible to future disastrous events. Schematically, the effect of extreme disastrous events on the vulnerability of a society can be introduced. In Figure 4 the blue dashed line represents the ideal change of a society's vulnerability from high to low values due to an increasing level of development represented by the red dashed line. Unfortunately societies often suffer from a sequence of disasters that offsets their achievements within the development process and maintains their high vulnerability level (solid blue line). Each significant disastrous event increases the overall vulnerability of the society abruptly and interrupts its steady developmental improvements.

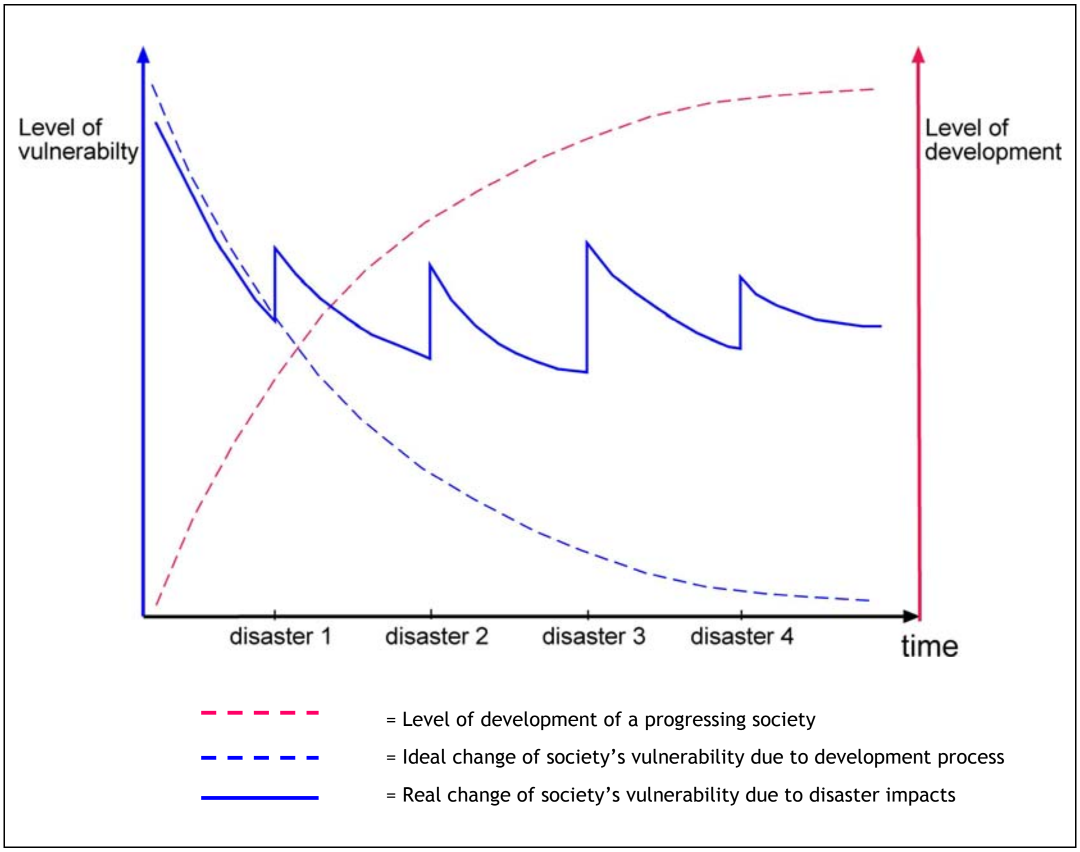


Figure 4: The effect of disastrous events on a society during the development process (source: author).

The temporal aspect of vulnerability is best discussed within the context of the disaster management cycle (Figure 5). The idea of dividing disasters into different phases was first developed by disaster researchers in the late 1970s. Since then four main phases have been defined: Mitigation, preparedness, response and recovery. Later the longer-term concepts of 'development' and 'prevention' (VOGEL 2001) were introduced. According to the UNISDR (2004) these terms are defined as follows (excluding the very complex term 'development'):

Prevention: Activities that provide outright avoidance of the adverse impact of hazards and the means to minimise related environmental, technological and biological disasters.

Mitigation:	Structural and non-structural measures undertaken to limit the adverse impact of natural hazards, environmental degradation and technological hazards.
Preparedness:	Activities and measures taken in advance to ensure effective response to the impact of hazards, including the issuance of timely and effective early warnings and the temporary evacuation of people and property from threatened locations.
Response:	The provision of assistance or intervention during or immediately after a disaster to meet the life preservation and basic subsistence needs of those people affected. It can be of an immediate, short-term, or protracted duration.
Recovery:	Decisions and actions taken following a disaster with a view to restoring or improving the pre-disaster living conditions of the stricken community, while encouraging and facilitating necessary adjustments to reduce future disaster risk.

Figure 5 shows the disaster management cycle by dividing it into a pre-disaster preparation and a post-disaster response phase and by identifying the main stages in temporal relation to the main impact. Thus, this illustration covers both the activities usually associated with (short-term) disaster preparedness and emergency actions as well as the long-term processes of recovery, development and mitigation of future risk.

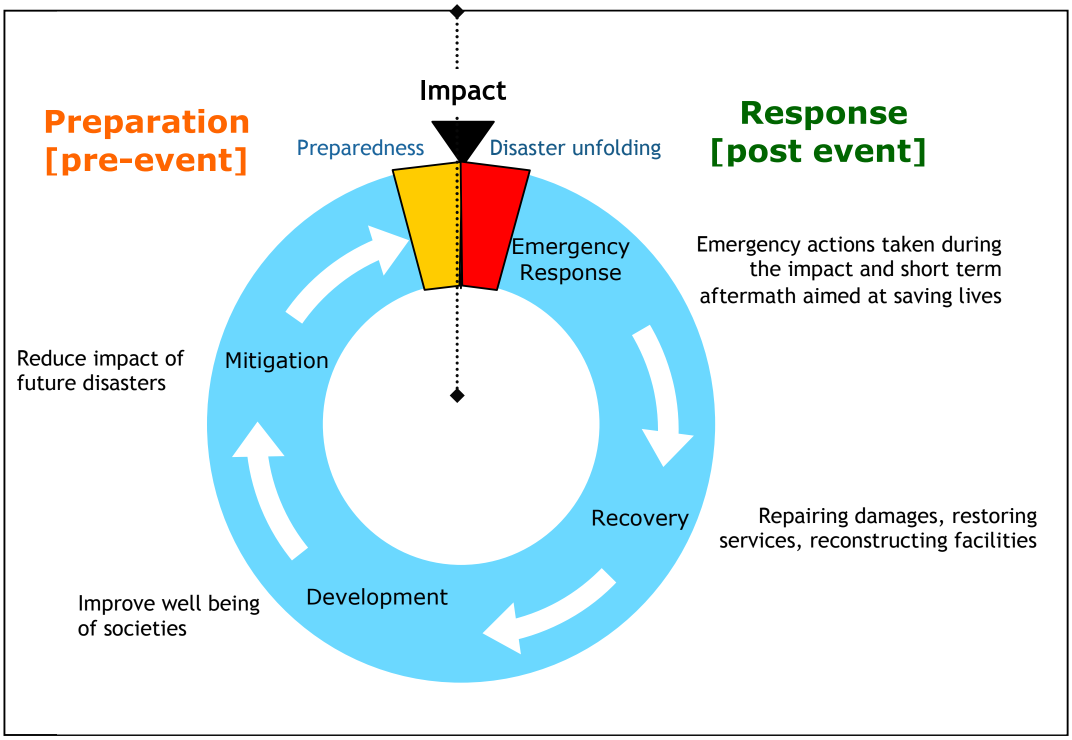


Figure 5: Disaster management cycle (source: after ADPC 2003).

Vulnerability is a dynamic characteristic of a population that changes continuously and possibly significantly when this population is exposed to hazardous events. A pre-event and post-event vulnerability can be identified. Vulnerability in the pre-event phase tends to be determined by physical assets and is based on financial resources available before the disaster. Socio-cultural aspects such as the level of fatalism amongst the population may also play an important role, for example in implementing mitigation measures. Vulnerability in the post-event phase is mostly determined by the institutional setting, organisational infrastructure and strength of social networks. Equally important are the quality of health services or, as mentioned earlier, access to financial resources when a disaster occurs.

Other authors have split the concept of vulnerability in a similar way though not related to temporal change. UNISDR (2003) and JIGYASU (2002) distinguish between the subordinate components of a physical (or primary) vulnerability and a 'socio-economic' (or secondary) vulnerability.

A number of authors (e.g. ALWANG et al. 2001; WISNER et al. 2004, PLATE 2006) point to the dynamic and temporal aspects of vulnerability. However, most authors focus on the post-event phase and designate 'coping capacity', 'resilience' and 'ability to recover' as the important characteristics of vulnerability. There is no clear terminological distinction made between these expressions and no unambiguous temporal allocation given. As a description of pre-event vulnerability, the term 'susceptibility' is often used. However, it is predominantly explained as 'exposure' to hazards (WHO 1999).

Here it is proposed to use the terms 'susceptibility' for vulnerability in the pre-event phase and 'resilience' for vulnerability in the post-event phase. Resilience can then be further subdivided into an immediate aftermath 'coping capacity' and a longer term post-event 'recovery' (Figure 6). Susceptibility would be predominantly determined by physical features, while resilience by socio-economic characteristics.

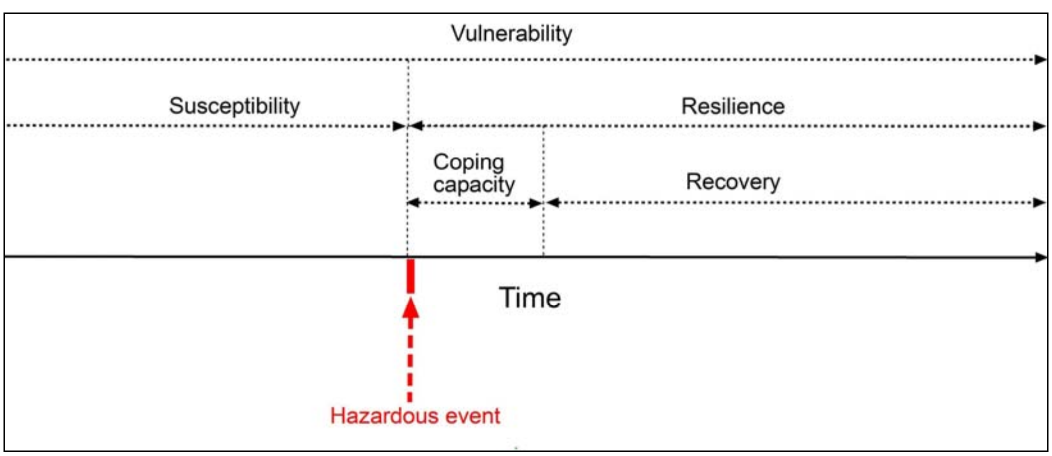


Figure 6: Terms in relation to a sudden hazard impact (source: author).

The population's susceptibility to an earthquake event, for example, would be mainly determined by whether a building is 'earthquake safe' (attaining defined earthquake safety standards). The measurement of the degree of coping capacity would be mainly based on the existence of emergency plans and the speed of initiating rescue actions. The ability to regain pre-event status in the recovery phase would be facilitated by sufficient insurance and / or the support of society, family and friends.

In slow onset disasters with hazardous events extending over time, susceptibility, copying capacity and recovery overlap (Figure 7). For a certain time period a certain part of the affected population is still in a pre-disaster 'susceptibility' phase, whilst an increasing proportion of the population has already entered the post-disaster resilience state.

Estimation of loss of life is relatively easy for sudden hazards. The affected area's extent is usually well defined and the time period may last days or weeks. Within this period the people have either been rescued / helped, or their lives lost. By and large the victims can clearly be allocated to the hazardous event. The number of casualties resulting from a slow onset disaster is much more difficult to assess. Such events may have a permanently damaging effect on the population or part of the population (e.g. children) even before being recognised as disasters. The temporal and spatial limits of slow onset disasters are vaguer and more difficult to define. A clear allocation of victims is often impossible.

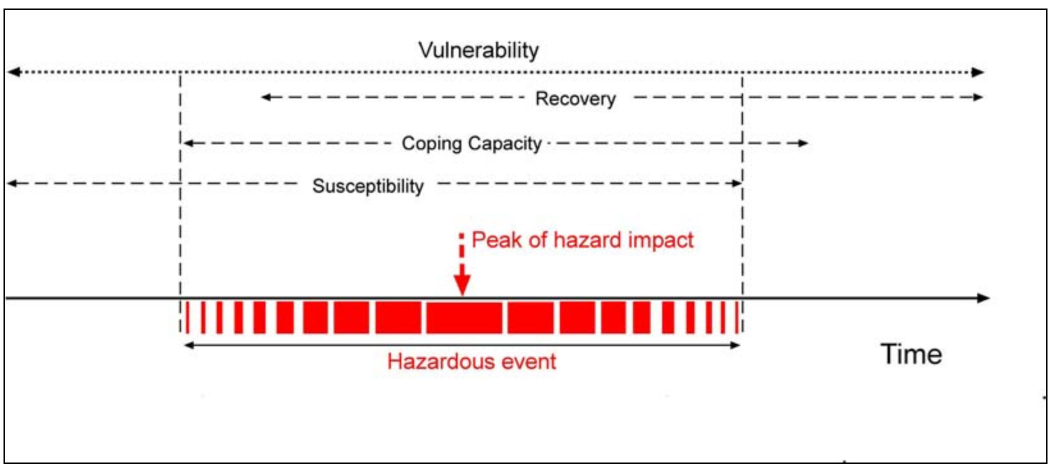


Figure 7: Terms in relation to a slow onset hazard (source: author).

Figure 8 schematically compares the number of casualties for the two typical groups of hazards, those of sudden and slow onset. The unit of the y-axis is kept to 'deaths / day' though it might be more relevant to monitor longer time periods (weeks or months) when considering slow onset disasters.

The green line shows graphically the impact of sudden hazards such as earthquakes, volcanic eruptions, flash floods and cyclones. The blue line represents the schematic development of slow onset disasters caused, for example, by epidemics or droughts.

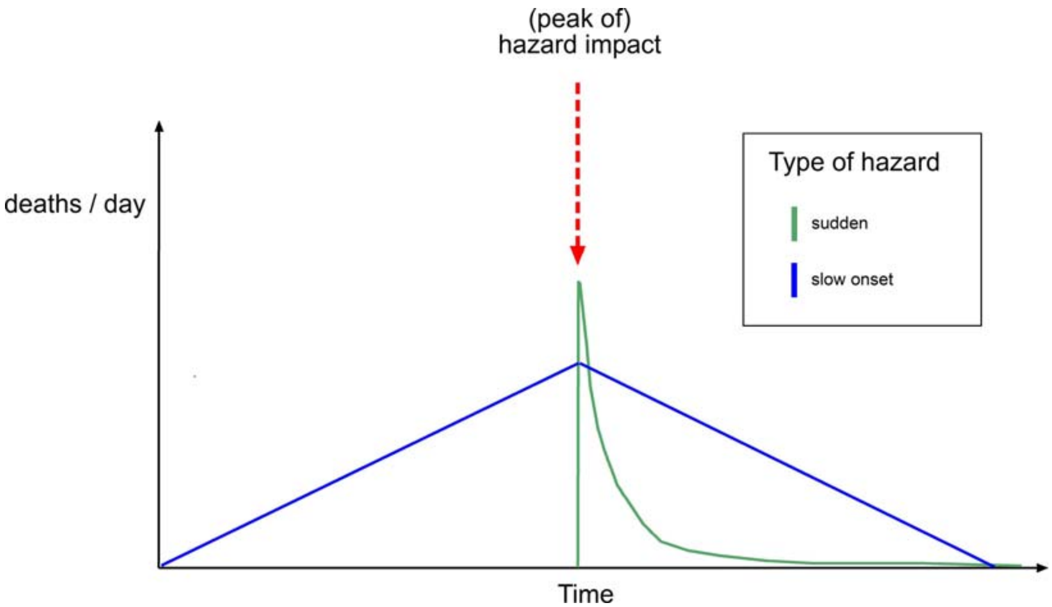


Figure 8: Scheme of the development of deaths / day for sudden and slow onset hazards (source: author).

The problems arising from these temporal aspects of disasters have to be considered when assessing the quality of existing databases on disaster casualties. It also requires changes in the risk equation, in particular for slow onset (and longer enduring) disasters since vulnerability changes over time. Additionally, the 'exposure' part of the equation, in this case the number of people affected by the hazard, may change significantly, for example in the case of droughts when people may out-migrate in order to avoid famine.

In order to include the temporal aspect in Equation 1 the risk component can be specified:

$$R_{ahd} = H_{ahd} \times E_{ad} \times V_{ahd} \qquad \textbf{(Equation 2)}$$

[a – area affexcted; h – type of hazard; d – a specific day of the disaster]

where 'd' is a certain day within the time period over which the disaster takes place. The overall risk of loss is then expressed as a function of the risk of the single days of the disaster:

$$R_{ah} = f\,(r_{ahd\,1}\,,\, r_{ahd\,2}\,,\, r_{ahd\,3}\,,\, \ldots\,,\, r_{ahd\,n}) \qquad \textbf{(Equation 3)}$$

[a – area affexcted; h – type of hazard; d – a specific day of the disaster; n – number of days the disaster lasts]

where $r_{ahd\ 1}$ is the risk due to hazard 'h' within the area 'a' on the day 'd 1' and 'n' is the number of days over which the disaster lasts.

Figure 9 and Figure 10 show the number of absolute accumulated fatalities due to a sudden hazard and slow onset hazard respectively, relating to its temporal development. The y-axis on the left hand side represents percentages of people living in the area affected by the hazard. The black dashed lines parallel to the x-axis indicate from top to bottom schematically: the overall population of the affected area, the percentage of these people who are vulnerable to the hazardous event, and the fraction of these vulnerable people who lost their lives due to the hazard. The x-axis represents the progress in time. The vertical dashed red lines show the hazard impact of a sudden hazard and the peak of hazard impact of slow onset disasters respectively. The shaded areas indicate the accumulated percentage of fatalities of the overall exposed population. The course of the black line bordering this area represents the temporal development of a disaster with respect to the lives loss, its maximum extent corresponds with the lowest dashed black line indicating the overall percentage of fatalities.

On top of the figures Figure 9 and Figure 10 the main lines of Figure 8 are superimposed in green colour representing the absolute number of deaths / day for sudden and slow onset hazards respectively.

Figure 10 illustrates the more complex picture of slow onset hazards compared to sudden events (as visualised in Figure 9) regarding the temporal evolution of number of fatalities caused by the disaster. Both figures are very abstract representations of what could be described as an 'average' sudden or slow onset hazardous event and they are limited in their scope. For example, they do not show the differences in the level of vulnerability within the affected population, neither at a specific time such as the hazard impact, nor in respect to a temporal development. Hence the figures do not reflect the increase of vulnerability of a population surviving a single hazardous event and being more prone to lose their lives if there was an ensuing disaster.

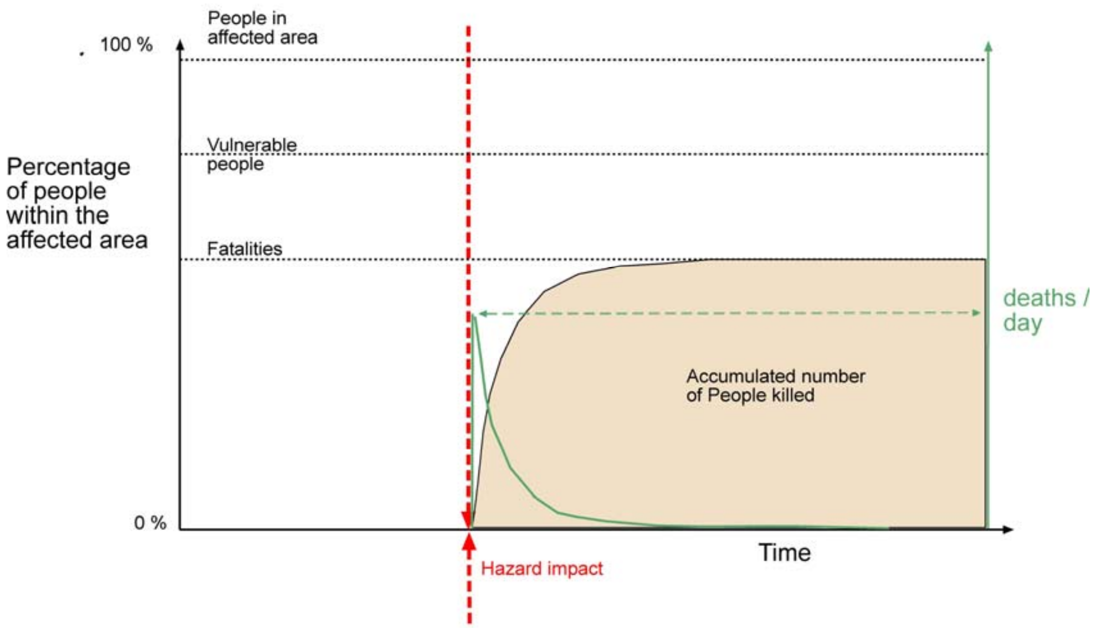


Figure 9: The absolute number of people killed and the deaths / day in relation to the temporal development of a sudden disaster (source: author).

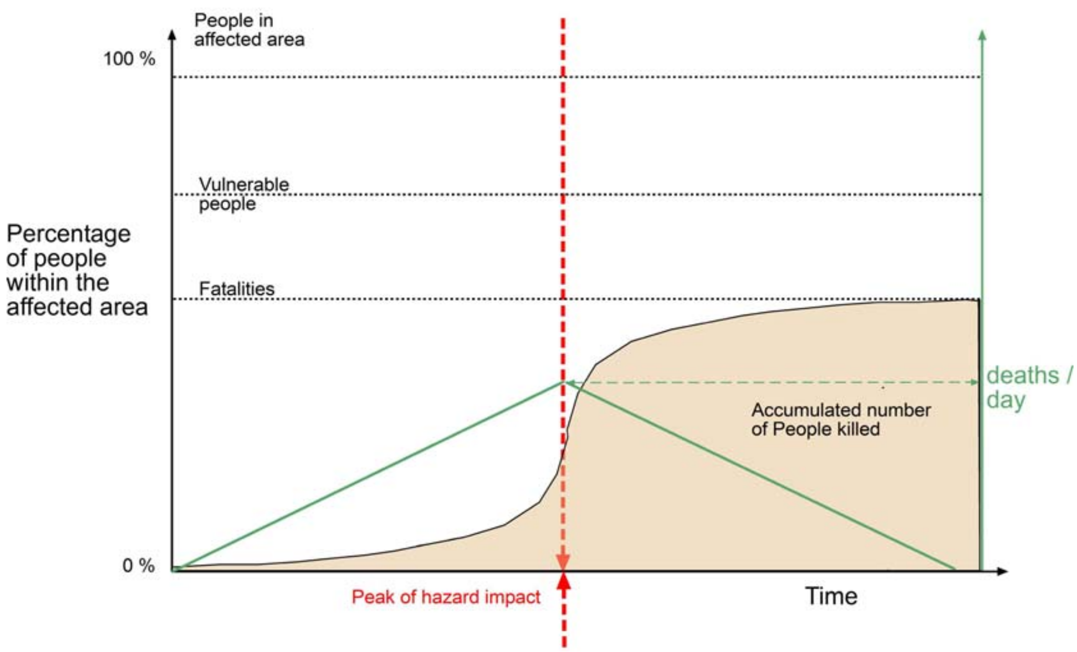


Figure 10: The absolute number of people killed and the deaths / day in relation to the temporal development of a slow onset disaster (source: author).

2.3.2 The social levels of vulnerability

Individuals were specified as the element at risk and the number of casualties as the focus of the risk assessments. However, in order to determine the vulnerability of each person within a population at risk the inspection cannot be restricted to the individual level. This is because the vulnerability of individuals is based on a composition of parameters linked to different 'social levels' that each individual belongs to. These social levels are of administrative, social and cultural / ethnic nature, each of them holding various characteristics which may contribute positively or negatively to the overall vulnerability of an individual person (Figure 11). The social levels identified for vulnerability estimations are:

- the individual;
- the household;
- the administrative community;
- the cultural community;
- the national and regional.

The individual, household, administrative community and national levels usually follow a hierarchical spatial order and the administrative partition of a country. The regional and cultural community level may intersect the other social levels confined by administrative limits. Figure 11 sketches this spatial hierarchy by clearly allocating individuals to a specific household, households to a specific sub-national administrative community, and administrative communities to one country. The social affiliation of an individual with a cultural or regional community may intersect with parts of this spatial hierarchy though this is not compulsory. The Kurdish people are a typical example of an ethnic group whose traditional living space intersects with the administrative borders of several nations and whose vulnerability level may differ from members of other ethnic groups living in the same country.

The total vulnerability $V_{ahd\ tot}$ of an individual to a hazard 'h' within an area 'a' and for a day 'd' can be computed by compounding vulnerability as a function of the vulnerabilities at the six defined social levels:

$$V_{ahd\ tot} = f\,(V_{ahd\ in}, V_{ahd\ hs}, V_{ahd\ ca}, V_{ahd\ cc}, V_{ahd\ cn}, V_{ahd\ rg}) \qquad \textbf{(Equation 4)}$$

[a – area affexcted; h – type of hazard; d – a specific day of the disaster
tot – overall vulnerability

Social levels:
in – individual, hs – household, ca – administrative community,
cc – cultural community, cn – country rg – region]

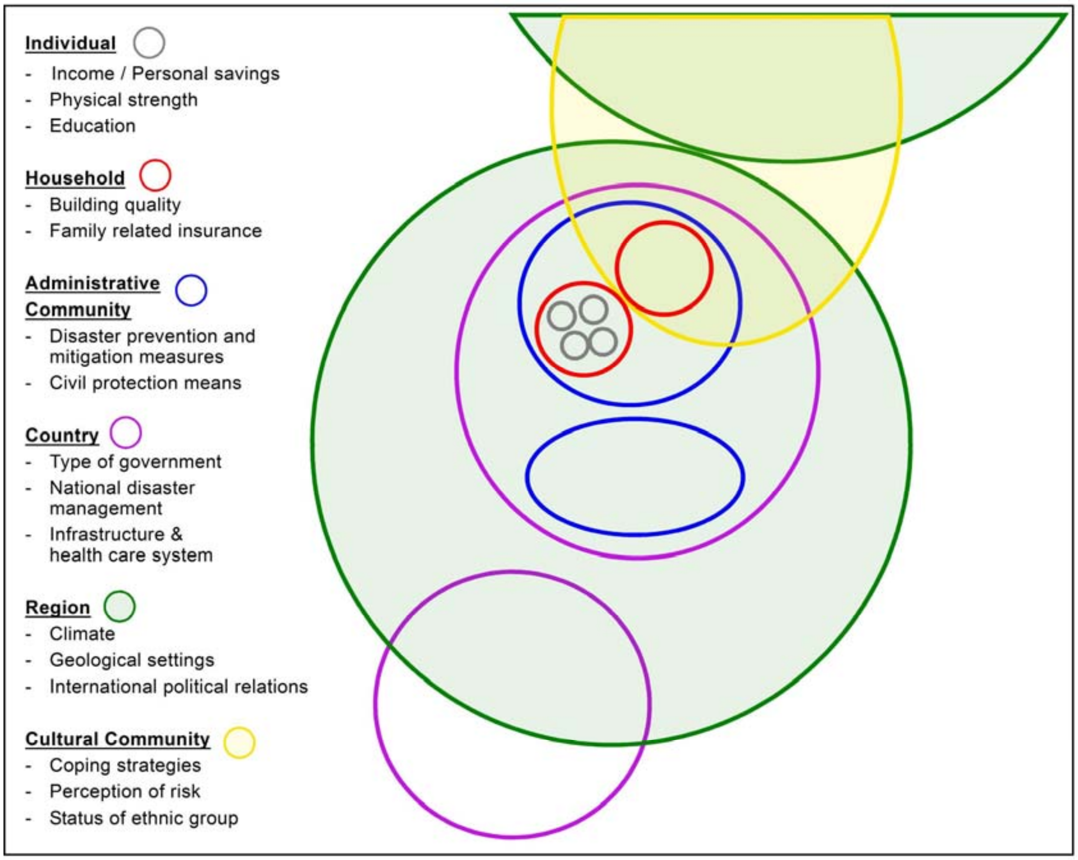


Figure 11: Conceptual diagram of social levels and examples of relevant characteristics identified for the assessment of vulnerability. Each level contributes to an explanation of the overall vulnerability of people (source: after SCHNEIDERBAUER & EHRLICH 2006).

2.3.3 Hazard dependent and hazard independent vulnerability

The vulnerability of an individual or a group of individuals belonging to a certain social level can be more accurately quantified if a distinction is made between hazard independent and hazard dependent parameters. Hazard independent parameters describe the strength or weakness of an individual or people to withstand stresses derived from their exposure to any natural or man-made hazard. Typically, hazard independent parameters describe general aspects of development including income, health and education but also the access to information or the existence of national disaster plans. Hazard dependent parameters describe people's vulnerability to the impact of a given hazard. They are largely of physical nature, such as the quality of building or the construction of dams, but also include social and cultural aspects, such as the percentage of the population vaccinated or drought preparedness.

Vulnerability can thus be broken up into (1) a general vulnerability and (2) a hazard specific vulnerability.

$V_{adh\ tot} = f(V_{ad\ gen}, V_{adh\ sp})$ **(Equation 5)**

[a – area affexcted; h – type of hazard; d – a specific day of the disaster
tot – overall vulnerability
gen – hazard independent part of vulnerability sp – hazard specific part of vulnerability]

With $V_{ad\ gen}$ describing the hazard independent part of vulnerability and $V_{adh\ sp}$ determining the vulnerability to a specific hazard 'h'. Both parts include the specifiaction of vulnerability at the different social levels as shown in Equation 6 and Equation 7, respectively.

(Equation 6)

$V_{ad\ gen} = f(V_{ad\ in\ gen}, V_{ad\ hs\ gen}, V_{ad\ ca\ gen}, V_{ad\ cc\ gen}, V_{ad\ cn\ gen}, V_{ad\ rg\ gen})$

[a – area affexcted; d – a specific day of the disaster;
gen – hazard independent part of vulerability

Social levels:
in – individual, hs – household, ca – administrative community,
cc – cultural community, cn – country rg – region]

(Equation 7)

$V_{adh\ sp} = f(V_{adh\ sp\ in}, V_{adh\ sp\ hs}, V_{adh\ sp\ ca}, V_{adh\ sp\ cc}, V_{adh\ sp\ cn}, V_{adh\ sp\ rg})$

[a – area affexcted; d - a specific day of the disaster h – type of hazard;
sp – hazard specific part of vulnerability;

Social levels:
in – individual, hs – household, ca – administrative community,
cc – cultural community, cn – country rg – region]

2.3.4 Vulnerability quantification

The numerous definitions of vulnerability correspond to numerous ways of conceptualising and quantifying it. Most measures of vulnerability are tailored to a small area or a specific region (e.g. COBURN et al. 1994b; IFRC 2002; CANNON et al. 2003). VOSS & HIDAJAT (2001) pose the question of whether it is possible to model vulnerability at all and if so at what scale. Recently global assessments of environmental vulnerability to climate change have been developed. Their methodological approaches include the creation of composite indices (e.g. SCHELLNHUBER 2001; SOPAC 2003). Methodologies to address the socio-economic characteristics of vulnerability worldwide are still at an early stage of development. Recently, global vulnerability assessments tackling various hazards have been attempted (UNDP 2004b; DILLEY et al. 2005).

A major difficulty in assessing vulnerability is the lack of an external reference, which eliminates the possibility of estimating the quality or accuracy of a model approach. For example, when a model is developed to estimate the population of a given area, one can assess this model's quality by comparing it with the real population number within sample sites. But for a model that attempts to assess vulnerability no tangible values for quality assessment exist. The lack of reference data may be substituted by damage records of past hazardous events (UNDP 2004b; DILLEY et al. 2005). However, this approach entails two major problems: (1) the varying quality of data relating to previous disasters and (2) the difficulty of normalising past events according to their strength in order to allow comparison of damage impact. As a result of these limitations, a global vulnerability assessment is at best only possible through the use of general proxies and will always result in relative rather than absolute estimations (DILLEY et al. 2005).

Vulnerability would ideally be derived as defined in Equation 6 and Equation 7. This follows previous research, for example CARDONA et al (2003), who also stress that at each social level (as identified in chapter 2.3.2), at least one characteristic and a corresponding measurable indicator covering the physical, economic, social, educational, political, institutional, cultural, environmental and ideological dimension should be defined. In practice it is difficult to clearly allocate a characteristic to a specific level. For this reason it is here attempted to identify the most significant characteristics and parameters for each social level for both, the hazard dependent and hazard independent fraction of vulnerability. Following, a selection of potentially available and measurable indicators is associated with these parameters. When establishing this list of indicators a focus was set to the application of remote sensing techniques. Earth observation data based on remote sensing recording methods has a great potential to support frequently updated vulnerability estimations in particular for those regions and areas where field work is difficult or impossible to carry out.

The author is aware of the complexity of this methodology, the lack of accuracy estimations and the impossibility of including all aspects of vulnerability. However, the results of the implementation of the concept described above should outweigh these constraints.

2.4 Vulnerability parameters and indicators

Based on the theoretical background developed in the previous chapters it is possible to specify those aspects of vulnerability, which may be monitored and/or measured for vulnerability estimations in practice. Therefore, hazard dependent and hazard independent parameters and potential indicators are listed in Table 3 and Table 4, respectively. The parameters were selected with the aim of including a representative number of dimensions at the different 'socio-administrative levels'. The choice of the corresponding indicators was based on three criteria: (1) availability and coverage, that is the number of countries / areas covered (2) measurability and accuracy and (3) frequency of up-date. The following compilation of parameters and indicators does not pretend to be complete. It intends to summarise important aspect of vulnerability determination. Due to the complexity of the concept of vulnerability many more aspects of vulnerability could be added.

The parameter and indicator selection was made with a focus on developing countries. A number of indicators are only relevant to the specific economic, institutional and environmental situation in those countries (e.g. access to drinking water or children's malnutrition). In order to maintain the general applicability of the methodology, aspects that are specific to a certain region or to a particular group of people are not considered. For practical and computational reasons from now the individual and the household level are considered to be one entity.

2.4.1 Hazard independent parameters and indicators

Hazard independent parameters are relevant for vulnerability to any type of natural hazard. Table 3 lists these parameters and corresponding indicators emphasising the level of development, the efficiency of administrative and disaster management and the involvement in armed conflicts.

Individual / Household

At the individual / household level the hazard-independent parameters cover demographic, social and economic topics. 'Age', 'income', 'health / disability' and 'education' are basic features describing the physical and economic strength of an individual and his / her dependents. People's health and education contributes to an explanation of their general capacity to cope and deal with external impacts. It can be expressed through 'classic' indicators for development measurement such as life expectancy, malnutrition and illiteracy.

Of specific importance is the HIV infection rate as AIDS victims are likely to be unable to continue as bread-winners. In addition, they place a burden on the household budget with medication, medical attendance and funeral costs.

All hazards considered may have a very strong direct or indirect impact on natural resources within the affected area. Hence, dependency on a subsistence economy in the primary sector (i.e. agriculture, pastoralism and fishing) is likely to be highly relevant to levels of resilience. The ability to recover can be determined by household savings, and individual and family related insurance, as well as the existence of social or neighbourhood networks. For these parameters no indicators that are currently available and that cover developing countries could be identified.

Access to information is decreasing vulnerability. The population's access to information is important for knowledge relating to early warning or post-disaster emergency and relief actions. An appropriate indicator is the average number of communication devices per capita (e.g. TV's, radios).

For most developing countries data at individual level are not available. Any measure has to be derived from the average values at country level.

Social levels	**Parameters**	*Indicators*
Individual and Household	-Age -Income -Health / disability -Education -Subsistence economy in primary sector -Savings -Individual and family related insurance -Neighbourhood network -Access to information	*-Average age* *-GDP per capita* *-Malnutrition of children < 5* *-Life expectancy* *-HIV / AIDS infection rate* *-Illiteracy rate* *-Productivity per capita (primary sector)* *-Number of mobile phones, TVs, radios /p.capita*
Administrative Community	-Infrastructure / Accessibility -Presence and quality of civil protection, incl. early warning / emergency plans / disaster management capacities -Disaster preparedness -Degree of autonomy / participation in decision making procedures and access to resources	*- Traffic infrastructure / Road network* *- Density of rural population* *- Level of urbanisation* *- Level of Corruption*
Country	-Regulatory Environment -Armed conflicts with involvement of national government -Population structure -Economic system -Economic dependency -Infrastructure / services -National Disaster Planning -Forecast and Early warning system -Emergency management system and capacities -Insurance services	*-Type of government* *-Number of signed international agreements* *-Number and intensity of conflicts* *-Number of IDPs (internally displaced people) and refugees* *-Fertility rate* *-Sex ratio* *-Age average* *-Trading activities - rate of GDP* *-External aid as ratio of GNI* *-Contribution of primary sector to GDP* *-Remittances from abroad* *- Urban population growth* *- Transportation and communication network* *- Number of missing values of important indicators*
Region	-Climate -Regional political stability	*-Climate records and their long-term changes* *-Number and intensity of international conflicts*
Cultural Community	-Status of community -Armed conflicts with involvement of the community -Gender inequality -Perception of risk and approach towards emergencies (cultural beliefs) -Coping strategies (incl. farming methods and land tenure systems)	*-Political Discrimination of ethnic groups* *-Economic Disadvantages of ethnic groups* *-Cultural restrictions of ethnic groups* *-Intra - and inter-communal conflicts and their intensity* *-GDI*

Table 3: Selected hazard independent parameters and potential indicators for vulnerability at different 'social levels' (source: after SCHNEIDERBAUER & EHRLICH).

Administrative community

Parameters of physical and institutional infrastructure are predominantly determined at the sub-national administrative community. The physical infrastructure is important for access to potentially hazard-struck areas or information, and can be measured by the network of roads or other traffic lines and mobile phone coverage or internet access, respectively. The institutional infrastructure provides the framework for disaster mitigation, preparedness and response activities, which are usually implemented and managed at this administrative level.

Efficiency or quality assessment of the institutional setting can only be approached with indirect indicators (such as the level of corruption). The suggested use of indicators relating to urban and rural populations is based on the assumption that the institutional setting for disaster management is of higher quality when the ratio of urbanisation is high and the rural population density is low.

The procedures of decision-making in disaster management and potential for the participation of the population in these procedures are crucial for pre- and post-disaster activities. These parameters are not quantifiable, although they may be explained and classified qualitatively. However, worldwide available indicators do not exist.

Country

National governments define policies that affect people countrywide and influence directly or indirectly their level of vulnerability. The lack of legal obligations to implement certain aspects of disaster management and civil protection as well as involvement in conflicts can weaken a nation regarding its preparedness and resilience to the impact of hazardous events. The regulatory environment and the number of conflicts the government is involved in (within the country or internationally) are therefore relevant parameters for an assessment of vulnerability at national scale. Targeted indicators could be the type of government (democratic, autocratic, military regime etc.), the number of signed international agreements, as well as the number of armed conflicts, accommodated refugees and IDPs.

The population structure of a society may serve as an indirect indicator for the country's development status. For example, high fertility rates and a disproportionally high fraction of young people are both indicators of low development status. Population structure such as a high dependency ratio, that is the proportion of the economically active population to the economically inactive population, may indicate societal vulnerability. War or out-migration may create an imbalance in sex ratio or age pattern and weaken a society.

Economic factors are also highly influential in relation to vulnerability at the national scale. Financial resources, a strong vital economy and participation in international trading activities all contribute to a reduction in vulnerability. Possessing these features usually results in the construction of high quality physical and medical infrastructure, the installation and maintenance of early warning systems and modern civil protection or the compensation of costs for reconstruction in disaster struck areas. Relevant indicators for the assessment of a country's economic system are numerous. It is here suggested using trading and primary sector activities as well as the fraction of external aid. Additionally, remittances from abroad, that is the money sent home from expatriates, assists in revealing economic weakness indicating a lower level of resilience.

As for the parameters discussed at the administrative community level, the existing infrastructure and capacity for disaster management and its underlying institutional setting at the national level have been looked at. Relevant direct indicators are those describing the national transport and communication network. Rapid urban population growth usually gives rise to a lack of infrastructure and therefore a lack of disaster management capacity. In addition, it is suggested to use the lack of existing values of important and widely-used indicators as measurement in itself of weak and unreliable public administration and institutions.

Region

Parameters acting at regional level that may be cross-national can be of physical or socio-economic nature. Extreme climate conditions of a region, such as droughts, intersect administrative borders and play an important role by weakening the resistance of its population to other types of hazard. Global data on various climate characteristics and their variations are now available as a result of the research conducted on global climate change.

The stability or instability of social systems within a region may be based on ethno-linguistic groupings of people that also intersect administrative borders. It is therefore suggested to monitor the number and intensity of international conflicts as one facet of vulnerability assessment.

Cultural community

A ‘cultural community’ may be defined by cultural, social and / or ethnic traits. The characteristics of external relations and the internal value system contribute to determining its level of vulnerability. For example, a functioning cultural community may provide strong social networks, which can be used to support disaster victims. On the other hand culturally influenced fatalism towards the occurrence of natural hazards may result in the lack of implementation of pre-event mitigation measures.

It is here proposed estimating external relations by looking at the status quo of the community and conflicts it is and has been involved in. Relevant indicators are the assessment of political discrimination, economic disadvantage, and any cultural restrictions inflicted on the community, as well as the number and intensity of armed conflicts caused by ethnic, religious or similar tensions.

The internal value system may be approached by looking at gender inequality levels and the perception of risk based on cultural beliefs, combined with developed coping strategies. Coping strategies may include adapted farming methods and land tenure systems. However, the only available indicator identified of relevance for an assessment of internal values is the GDI (Gender Development Index), which looks at differences in life expectancy, and levels of education and income amongst men and women.

2.4.2 Hazard dependent parameters and indicators

Hazard dependent parameters are relevant for one or more specific hazards studied and are largely of physical nature. Table 4 lists these parameters and corresponding indicators and

Social levels	**Parameters**	*Indicators*	*Ea*	*Vo*	*Cy*	*Fl*	*Dr*	*Ep*	*SD*	*RS*
Individual and Household	- Quality and age of building	- *Building construction date combined with law enforcement considering earthquake safety*								
		- *Main building material*							X	X
		- *Urban growth*							X	X
	- Size / Height of building	- *Number of floors*								X
		- *Number of families / residential building*								
	- Location of dwelling	- *Terrain information (for example slope gradient)*							X	X
		- *Altitude (relating to sea level or local watersheds)*							X	
	- Hygiene	- *Access to drinking water*								
		- *Quality of sewage system*								
Administrative Community	- Preparedness for floods	- *Dams*							X	X
		- *Legal regulations relating to floods*								
	- Preparedness for earthquakes	- *Percentage of earthquake resistant built houses*								
		- *Law considering earthquake resistant buildings*								
	- Local environmental degradation	- *Soil degradation / soil sealing*							X	X
		- *Erosion*								X
	- Constraints for agricultural use	- *Soil, terrain, climate conditions regarding agricultural activities*							X	X
Country	- Countrywide and regional environmental degradation	- *Deforestation Rate*							X	X
	- Vaccination	- *Number of people vaccinated,*								
		- *Legal regulations for vaccinations*								
Region	- Sufferance from climate change	- *Significant change of measurable climate characteristics*							X	
	- Land use	- *Land cover*							X	X
	- Relief	- *Slope / Elevation*							X	X
Cultural Community	- Preparedness for droughts	- *Adaptation of land use methods according to climate conditions (culture of certain crops, sustainable use of resources)*								
	- Customs of sexual behaviour	- *Prevalence of protected sexual intercourse practices*								
		- *Contraception methods*								

Ea = earthquakes, Vo = volcanoes, Cy = cyclones, Fl = floods, Dr = droughts, Ep = epidemics
SD = Spatial Data, RS = Remote Sensing Data

	No or very low importance		Low to medium importance		High importance	x	Data available

Table 4: Selected hazard dependent parameters and potential indicators for vulnerability at different 'social levels' (source: after SCHNEIDERBAUER & EHRLICH 2006).

includes information on the relative importance of each indicator for the different hazards. Table 4 also lists whether indicator data are available as 'spatial data' and which indicators may be acquired through remote sensing techniques. 'Spatial data' refers to geo-located information and can thus be represented on a map or analysed by using GIS techniques. Remote sensing data refers to satellite images but may also include aerial photographs.

Individual / Household

Hazard dependent parameters at household level are typically related to the dwellings and other infrastructure people use in their everyday life. For example the quality, age, size and height of buildings are important. The buildings' general stability varies with different building material. This is relevant for vulnerability to earthquakes, cyclones, floods and partly volcanoes. Due to the possible impact on the dweller's health, it also has some relevance for epidemics. Direct indicators for the buildings' size and height are the number of floors and inhabiting families (for residential houses). Indirectly, the overall quality of buildings may be assessed by the speed of physical urban growth, with high growth rates often resulting in low quality control. The construction of earthquake resistant housing may depend on the relevant legislation and its date of enforcement.

The location of dwellings also influences the susceptibility of their inhabitants to a number of hazards. Due to a disadvantaged position a building might be in danger of basaltic flows or landslides and mudflows triggered by earthquakes or exceptional rains. Buildings built at low altitude near the coast or in occasionally flooded areas might be vulnerable to floods and cyclones. Areas at risk due to elevation or terrain might be defined with the help of digital terrain models (DTMs).

The fact that poor people tend to live in locations of higher risk, such as polluted areas or regions with sever climate, is also relevant for vulnerability to epidemics. Levels of hygiene are relevant for all hazards but in particular for epidemics. In addition, access to potable water is of importance for vulnerability to droughts.

Administrative Community

Mitigation measures are typically implemented at administrative community level. Examples are the construction of dams or earthquake resistant housing. Such precautions usually require an appropriate legal framework, the presence of which indicates reduced vulnerability.

The level of environmental degradation is of particular relevance for vulnerability to floods, droughts and cyclones. The effects of environmental degradation might vary with climate conditions and affect areas of different dimensions. In the table environmental degradation is mentioned twice, linked to administrative community and country level respectively, taking into account the available indicators. This is despite the fact that in reality local, countrywide and regional environmental degradation cannot be separated from one another.

Soil degradation and sealing, deforestation and erosion have largely a negative impact on water balance and infiltration rates, which in turn leads to rapid runoff and water shortages. In the case of droughts, the degradation of the environment may aggravate an already existing natural constraint on agricultural use caused by, for example, low soil quality, steep terrain, and / or severe climate conditions. Soil degradation and erosion might be assessed by using geo-datasets of relatively fine resolution.

Country

Environmental degradation is restated at country level in order to emphasise the extent of areas that might be affected by a human impact on the environment and the negative influence this could have on vulnerability to floods and droughts. An available indicator at this level is the countrywide deforestation rate.

The number of people vaccinated in a country is of primary concern for vulnerability to epidemics and is largely dependent on relevant national legislation. Vaccination rates are also important when considering the aftermath of hazards. The ensuing disruption to health care and deteriorated sanitary conditions increase vulnerability, particularly in countries where vaccination levels are low.

Region

Human-induced environmental degradation discussed in the ‘administrative community’ section that includes soil degradation, deforestation and erosion may extend beyond the administrative community to affect entire regions. Also, changes in climate and in particular global warming may have an impact on the vulnerability of a whole region. The implication of global climate change is most likely to mean having to cope with a change in temperature and water supply, which is most relevant to vulnerability for slow onset hazards such as droughts and epidemics. It must be pointed out that there is a risk stepping into the exposure part of the risk function when looking at increased vulnerability due to a change in climate, since climate change as such may be seen as a hazard.

The type of land use, though finally depending on human activities, is in the first instance determined by regional physical features such as soil quality and climate. Similar to the level of environmental degradation, it characterises in particular vulnerability to floods, droughts and cyclones. Certain land use types may influence vulnerability to epidemics such as malaria in irrigated agricultural areas. The terrain, assessed by slope and elevation values, may have an effect on vulnerability to floods and cyclones. Again, there is the risk stepping into the exposure part of the risk function when considering these aspects.

Cultural community

Cultural values held by communities play an important role. Drought preparedness is largely influenced by the cultural setting and determined by the sustainable use of natural resources and an adaptation of land use methods to climate conditions. Cultural values also determine sexual customs and behaviour that are strongly dependent on affiliation to a social, and / or ethnic group, and crucial when looking at vulnerability to HIV infection. Due to its taboo status, it is difficult to find reasonable values for the proposed indicators relating to the prevalence of unprotected sex and / or methods of contraception.

2.4.3 Discussion

From an analysis of the data available for vulnerability assessments it can be noted that

1. There are a number of indicator sets linked to the economic, social and, educational dimension. There are a very limited number of available indicators for

determination of the political, physical and environmental dimension, whilst there are insufficient indicators describing the institutional, cultural and ideological setting.

2. Even though the number of indicators that can be used to quantify a dimension might be quite large, their accuracy and the frequency of their acquisition may prove to be inadequate.
3. Those countries that are assumed to be vulnerable have the most significant data gaps. In fact, the lack of indicator values may be used as an indicator in itself (see 'country level' in Table 3).
4. Though a number of indicators are supposed to describe individual characteristics (such as GDP per capita), they are often only available as countrywide average data.
5. Ideally, rapid changes in the vulnerability of a population relating to the time of day or the phenological season when a hazard occurs should also be taken into account. Likewise it would be useful to look at the time when an earthquake occurs or whether an agricultural area is flooded just before or after the harvest.

Table 4 shows that there are quite a number of indicators available as geo-datasets and / or possibly acquired through remote sensing techniques. In contrast to the structural indicators describing the socio-economic parameters, which are usually available at country level, these data cover the physical and / or environmental aspects of vulnerability. Being available as vector or raster datasets of relatively fine resolution they may support a vulnerability assessment at sub-national level.

Table 4 also indicates a slight correlation between the dimension of the area potentially affected by a specific hazard and the social level of the most relevant parameters and indicators: The smaller the affected area the more 'local' the social level. That is, the vulnerability to more local events such as earthquakes, volcanoes and local cyclones is predominantly determined by parameters of individual and household scale. Whereas in the case of hazards that have an impact on larger areas, such as floods, droughts and epidemics, the parameters at national and regional level are more important.

2.5 Conclusions

The concept of vulnerability is complex and a realistic determination of people's vulnerability in large areas or worldwide extremely difficult. In order to account for all important facets it is useful to allocate vulnerability parameters and corresponding indicators to 'social levels', as well as indicate whether they have a general importance or are hazard specific. The compilation of these parameters and indicators for a worldwide vulnerability assessment of populations exposes the need to tackle the following issues for future applications:

- Some indicators chosen for vulnerability determination show high correlation with one another. Given these correlations, those indicators that are not adding any significant value to vulnerability information should be excluded. Once the set of selected indicators is compiled for all relevant countries and years, and after their values have been normalised, the most valuable variables can be identified based on the calculation of correlation matrices and factor analyses (see chapter 3.4).

- In order to compose a useful composite indicator for vulnerability assessment it may be useful to define weighting factors for each indicator. For this procedure a variety of techniques have been developed (SAISANA & TARANTOLA 2002). However, in the case of vulnerability, except for expert knowledge there is no reference data with which the quality of the resulting composite indicator could be evaluated.
- Most of the indicators represent structural characteristics of the observed population, group or society and therefore change only slowly with time. However, people's vulnerability may change quickly (e.g. due to conflicts, as result of hazardous events etc.). Therefore, ideally, the developed composite indicator should be able to represent at least partly these possible rapid developments.
- A number of more qualitative parameters that are highly relevant for vulnerability assessments, such as disaster management capacities or risk perception, are difficult to describe and hardly any of the frequently globally surveyed indicators could support their determination. The relevant information can only be compiled with time-consuming local expert consultation.