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VULNERABILITY CONCEPTS IN HAZARD AND RISK ASSESSMENT

by
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Vulnerability is an essential part of hazards and risk research and refers to the susceptibility of people, communities or regions to natural or technological hazards. The ESPON Hazards project defines vulnerability as combination of damage potential and coping capacity, but it also appreciates the versatile nature of vulnerability by acknowledging three vulnerability dimensions (economic, social and ecological). To measure vulnerability, indicators that cover both damage potential and coping capacity, as well as the range of all three vulnerability dimensions were used. Weighting and combining the feasible indicators created an integrated vulnerability index and an integrated vulnerability map to depict the vulnerability of all regions of the EU 27+2. The map was further combined with an aggregated hazards map to create the aggregated risk map of Europe.

Key words: natural hazards, risk assesment vulnerability, damage potential, coping capacity, Europe

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1 VULNERABILITY IN THE ESPON HAZARDS PROJECT

The ESPON Hazards project (2003:19) defines vulnerability as the degree of fragility of a person, a group, a community or an area towards defined hazards. Vulnerability is a set of conditions and processes resulting from physical, social, economic and environmental factors that increase the susceptibility of a community to the impact of hazards. Vulnerability also encompasses the idea of response and coping, since it is determined by the potential of a community to react and withstand a disaster.

One of the ESPON Hazards project's primary goals was to produce an aggregated risk map of the EU 27+2, which shows the degree of risk for each European NUTS3 region. The project defines risk as the combination of hazard potential and vulnerability:

Risk = Hazard potential x Vulnerability

The map is based on an aggregated hazard map and an integrated vulnerability map, and it enables us to see whether the level of risk is related to a region's hazard potential, its vulnerability or both.

To be able to portray the vulnerability of European NUTS3 -regions on a map, it has been important to consider regional vulnerability as extensively as possible. The Hazards project acknowledges damage potential and coping capacity as the two main components of vulnerability:

Damage potential + coping capacity =
regional vulnerability

At the same time, the project recognizes three dimensions of vulnerability: economic, social and ecological (ESPON Hazards project 2004 & Schmidt-Thomé 2005).

The economic dimension of vulnerability acknowledges economic damage potential, which can be understood as anything concrete that affects the economy of a region and can be damaged by a hazard. The economic dimension of vulnerability represents the risk to production, distribution and consumption.

Comfort et al. (1999) acknowledge the fact that advanced industrial societies, especially large urban centres, are especially vulnerable because the destruction of important and extensive systems of communications and infrastructure is costly and can have vast consequences on the economic stability, even on the global scale. The economic dimension offers an interesting approach to regional vulnerability, especially from the insurance company point-of-view of damage potential.

The social dimension of vulnerability acknowledges the vulnerability of people, and the emphasis is on coping capacity. Especially weak and poor population groups are considered vulnerable. Social vulnerability has to do with the different features of human beings.

Blaikie et al. (1994:9–10) argue that the most vulnerable groups are those who find it hardest to reconstruct their livelihood after a disaster. They find that, as a rule, the poor suffer more from hazards than the rich (see also Yohe & Tol 2001:8). The time dimension is relevant since reconstruction in poor areas can take a long time, which affects the economy and livelihood of the area drastically. Further, the poorer population groups do not always have a choice of where to locate, thus they might have to live in risky areas, for example on a muddy hillside or a flood plain (cf. environmental justice). Cross (2001) argues that people in small towns and rural communities are more vulnerable than people in large cities because of weaker preparedness.

Cannon et al. (2003) see social vulnerability as a complex set of characteristics that includes a person's initial wellbeing, livelihood and resilience, self-protection, social protection and social and political networks and institutions. Cutter et al. (2003) define social vulnerability as "a multidimensional concept that helps identify those characteristics and experiences of communities (and individuals) that enable them to respond and recover from natural hazards".

The ecological dimension of vulnerability acknowledges ecosystem or environmental vulnerability or fragility. In the case of ecological vulnerability, it is important to find out how different kinds of natural environments cope with and recover from different hazards.

According to Williams & Kaputska (2000), ecosystem vulnerability can be seen as "the inability of an ecosystem to tolerate stressors over time and space". Villa & McLeod (2002) state that environmental vulnerability can be either intrinsic or extrinsic. Intrinsic vulnerability is related to factors internal to the system (ecosystem health and resilience), whereas extrinsic vulnerability contains factors external to the system (present exposure and external hazard). Ecological vulnerability thus recognizes both ecological damage potential and coping capacity.

1.1 Other approaches to defining vulnerability

The field of vulnerability research embraces an array of different definitions for vulnerability. Blaikie et al. (1994:9) define vulnerability as "the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard".

According to the UNDP Bureau for Crisis Prevention and Recovery (UNDP 2004:11), human vulnerability is "a condition or process resulting from physical, social, economic and environmental factors, which determines the likelihood and scale of damage from the impact of a given hazard". This definition also encompasses response and coping, since vulnerability refers to the different variables that make people less able to absorb the impact and recover from a hazard event.

According to Cutter (1996), vulnerability is broadly defined as "potential for loss". However, vulnerability is understood in different ways and Cutter has found three distinct themes in vulnerability research (1996:530–533):

1. Vulnerability as hazard exposure: Research under this theme concentrates on the distribution of some hazardous condition, on human occupancy of such an area and on the degree of loss associated with a hazardous event. Vulnerability is a pre-existing condition.
2. Vulnerability as social response: Research under this theme concentrates on response and coping capacity, including societal resistance and resilience to hazards as well as recovery from a hazardous event. This approach highlights the social construction of vulnerability.
3. Vulnerability of places: Vulnerability of places is a combination of hazard exposure and social response within a specific geographic area.

The ESPON Hazards project can be viewed as a representative of the third, integrative approach. Vulnerability in the Hazards project is place-specific and it takes into account the damage potential (including human occupation, infrastructure and natural areas) and coping capacity of regions. The areal unit for the project is a so-called NUTS3 region, but the results are shown on maps of the EU 27+2.

Cutter (1996 , et al. 2003) has drawn together the different elements that contribute to the overall vulnerability of places in the hazards-of-place model of vulnerability (see Figure 1). Here, risk (likelihood of a hazard event) and mitigation (measures to reduce risk and/or its impacts) are combined to create hazard potential. The hazard potential is filtered through the geographic context (site and situation, proximity) and the social fabric of society (socioeconomic

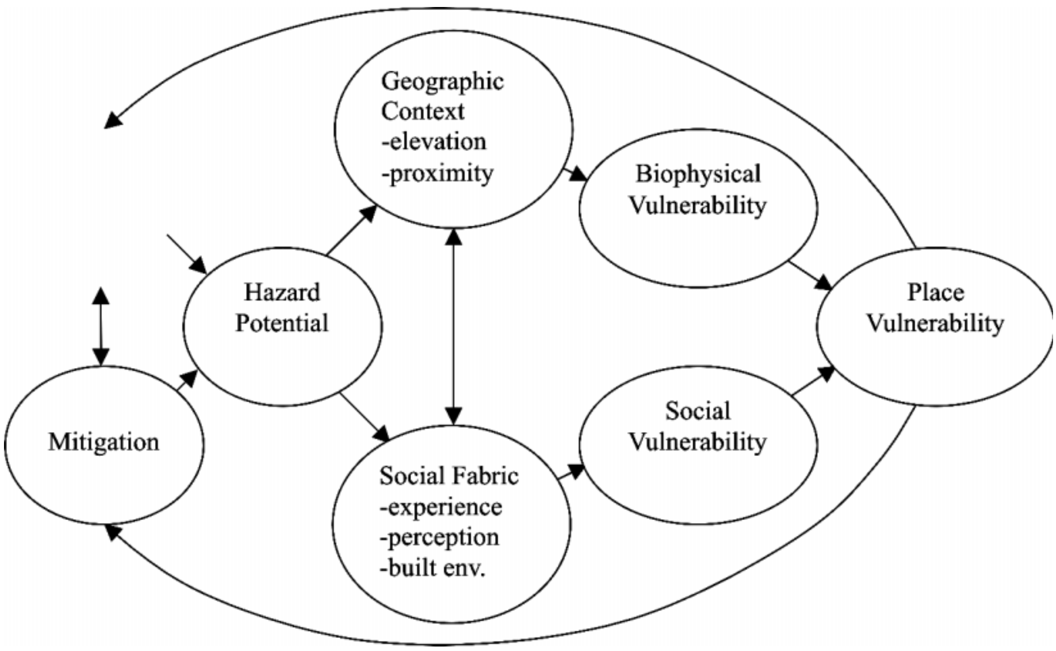


Fig. 1. The Hazards-of-Place model of vulnerability (Cutter et al. 2003).

indicators, risk perception, ability to respond) and either moderated or enhanced by them. Biophysical vulnerability and social vulnerability together form the overall place vulnerability.

The hazards-of-place model of vulnerability has an explicit focus on locality, since it depicts the overall situation and elements contributing to the vulnerability of a specific geographical area. The ESPON Hazard project's approach is similar, as it has combined hazards and the different elements of vulnerability to come up with a typology to depict regional risk. However, the definitions of risk and hazard potential differ in these two approaches. Cutter's risk, "the likelihood of occurrence (or probability) of the hazard" (1996:536), corresponds with the Hazard project's definition of hazard potential (magnitude and frequency). Cutter's hazard potential is a combination of risk and mitigation, where the Hazards project's risk is a combination of hazard potential and vulnerability.

1.2 Measuring vulnerability in the Hazards project

Vulnerability can be measured by a range of indicators. In the ESPON Hazards project, overall regional vulnerability is measured as a combination of damage potential and coping capacity. The basic criteria for choosing vulnerability indicators was that they should cover both damage potential and coping capacity, as well as the range of all three vulnerability dimensions.

Damage potential indicators measure anything concrete that can be damaged by a hazard and measure the scale of possible damage in a particular region. Coping capacity indicators measure the ability of a community or a region to prepare or respond to a hazard. They measure either human properties or the existence of infrastructure. At the same time, coping capacity indicators point out social and place inequalities. The indicators are introduced in Table 1.

The table shows for each indicator whether it represents damage potential or coping capacity. One indicator, tourism, can be considered both a damage potential indicator and a coping capacity indicator. Tourists affect the damage potential of a region since they are a population group in danger due to their lack of knowledge of local conditions and due to the fact that popular tourist sites are often in risky areas (see e.g. White and Hass 1975). During the Indian Ocean earthquake and tsunami of December 26th 2004, both the locals and the tourists had no previous experience with such a natural hazard. However, the damage potential of many regions was especially high because the tourist dwellings and attractions were located on the coast, where the tsunami hit.

Tourists affect the coping capacity of a region since they have, in most cases, no knowledge of how to cope in the event of a hazard, and they often don't know the region or the language and may not receive the necessary information to cope with the situation. Further, tourism is an important source of income for many regions, and a catastrophe can have severe and long-term effects for the regional economy and coping capacity in the long-term.

Table 1 further points out which of the three dimensions each indicator represents. In the case of damage potential indicators, it was pretty simple to point out the dimension for each indicator, although population density and tourism can be connected to either the economic or the social dimension. In the case of the six last coping capacity indicators of Table 1, it was not possible to pinpoint them to any of the three dimensions. All of these indicators measure mitigation and preparedness of the society, especially its infrastructure.

The vulnerability of natural areas is not easily measurable, especially since not all hazards pose a threat to the environment. ESPON project 1.3.2 (Territorial trends of the management of the natural heritage) states that "the only spatially-specific and methodologically consistent units available for environmental reporting are land areas that are distinguished either by their protection or designation status or by their land cover type." (ESPON Natural Heritage project 2004:102). The two indicators for the ecological dimension in Table 1, significant natural areas and fragmented natural areas, measure the vulnerability of the environment in two different ways, as referred to by the Natural Heritage project. Since there was no extensive and feasible data available on protected or otherwise significant natural areas, the Hazards project chose to use data on land cover type. The idea was that natural areas that are small and fragmented are vulnerable, since they are likely to be totally destroyed if a hazard strikes. However, some people argue that large, non-fragmented areas are more vulnerable than small frag-

Table 1. Possible indicators for measuring vulnerability in the ESPON Hazards project.

Indicator	**dp/ cc[1]**	**econ/soc/ ecol[2]**	**Description**	**Data avail- ability**
GDP/capita	dp	econ	High GDP/capita measures the value of endangered physical infrastructure and the extent of possible damage to the economy. Insurance company point of view.	+
population density	dp	econ/ soc	Measures the amount of people in danger.	+
tourism (e.g. number of tourists/number of hotel beds)	dp/ cc	econ/ soc	Tourists or people outside their familiar environment are especially vulnerable for two main reasons. First, they are generally unaware of the risks and don't necessarily understand the seriousness of hazardous situations. They don't necessarily know the local language and thus they are likely to miss important information. Secondly, tourist dwellings are often located in high-risk areas and might not meet the requirements of structural risk mitigation.	+/–
culturally significant sites	dp	econ	Such sites are unique and important for the cultural and historical identity of people, e.g. sites on the UNESCO world heritage list.	+/–
significant natural areas	dp	ecol	Areas with special natural values (e.g. national parks or other significant natural areas) can be considered vulnerable because they are unique and possibly home to rare species of flora of fauna.	+/–
fragmented natural areas	dp	ecol	Natural areas that are small and fragmented are vulnerable, since they are likely to be totally destroyed if a hazard strikes.	+
GDP/capita	cc	soc	Low GDP/capita measures the capacity of people or regions to cope with a catastrophe. In the Hazards project, the national GDP/capita was used because the presumption was that coping capacity is weak in poor countries and strong in rich countries. It was further presumed that there are no marked differences in coping capacity inside a country.	+
education rate	cc	soc	Measures people's ability to understand and gain information. The presumption is that people with a low educational level do not find, seek or understand information concerning risks as well as others, and are therefore vulnerable.	+/–
dependency ratio	cc	soc	Measures the proportion of strong and weak population groups. A region with a high dependency ratio is especially vulnerable for two reasons. First, elderly people and young children are physically frail and thus vulnerable to hazards. Secondly, elderly people and children may not be able to help themselves but need help in the face of a hazard. A region with a high dependency ratio is dependent on help from the outside.	+/–
risk perception	cc	soc	Indicates how people perceive a risk and what their efforts have been to mitigate the effects of a hazard.	–
institutional preparedness	cc		Indicates the level of mitigation of a region.	–
medical infrastructure	cc		Indicates how a region is able to respond to a hazard (e.g. number of hospital beds per 1000 inhabitants or number doctors per 1000 inhabitants).	+/–
technical infrastructure	cc		Indicates how a region is able to respond to a hazard (e.g. number of fire brigades, fire men, helicopters etc.).	+/–
alarm systems	cc		Indicates the level of mitigation of a region.	+/–
share of budget spent on civil defence	cc		Indicates the level of mitigation of a region	+/–
share of budget spent on research and development	cc		Indicates the level of mitigation of a region.	+/–

[1] dp = damage potential, cc= coping capacity
[2] econ = economic dimension, soc = social dimension, ecol = ecological dimension of vulnerability

mented areas due to their high importance to the whole ecosystem.

In an ideal situation, it would be possible to use all the indicators of Table 1 to measure vulnerability. The right-hand column in Table 1 shows the status of data available for each of the indicators within the ESPON Hazards project. Plus (+) stands for indicators where data was available and the indicator was used in the project. Minus (–) stands for indicators that could not be used due to a lack of data or difficulties in quantification (e.g. institutional preparedness and risk perception are in practice impossible to measure). Plus/minus (+/–) stands for indicators where data was available, but not feasible for the Hazards project. The most common problem was that the data was only available on a NUTS2, NUTS1 or NUTS0 level, but not on the NUTS3 level. Further, if there was NUTS3 data, it didn't necessarily cover the whole EU 27+2 area.

1.3 Other approaches to measuring vulnerability

There exists a range of different approaches to measure vulnerability. Two innovative approaches are introduced here.

Cutter et al. (2003) have concentrated on measuring social vulnerability, which is an integral part of the Hazards-of-place model. Here, social vulnerability includes both social inequalities (social factors that influence the susceptibility of population groups to harm and that affect their ability to respond) and place equalities (characteristics of communities and the built environment, such as level of urbanization and economic vitality). This definition includes both the social and economic vulnerability dimensions of the Hazard's project, although damage potential has a slightly smaller role in the model.

According to Cutter et al. (2003), vulnerability research has given much more attention to the study of biophysical vulnerability and the vulnerability of the built environment than to the study of social vulnerability. One obvious reason for this are the difficulties in quantifying and measuring social vulnerability. With the SoVI model, Cutter et al. have been able to compare the social vulnerability of all counties in the US using a statistical analysis of 42 independent variables. The strength of this approach lies in the multitude of variables and in the fact that the authors have been able to explain 76,4% of the variance among US counties with the help of 11 factors (e.g. personal wealth, age, density of the built environment, single-sector economic dependence). The SoVI index does not take hazard event frequency or magnitude into account, but Cutter at al. suggest expanding the model by adding both hazards as well as economic loss data to the model.

A second interesting model is UNDP's Disaster Risk Index (DRI), which measures and compares the physical exposure to hazards, vulnerability and risk between countries (UNDP 2004). Here, physical exposure refers to the number of people located in areas where hazardous events occur combined with the frequency of hazard events. In this model, population density is not seen as an indicator of vulnerability, but a condition for a disaster risk to exist. Vulnerability explains why, with a given level of exposure, people are more or less at risk. Vulnerability refers to the different variables that make people less able to absorb the impact and recover from a hazard event. These may be economic (lack of reserves), social (weak social organisation), technical (poorly constructed housing) or environmental (fragility of ecosystems).

The prime reason for developing the DRI was to improve the understanding of the relationship between development and disaster risk. With a separate analysis of four natural hazards, it became clear that disaster risk (risk of death in disaster) is considerably lower in high-income countries than in medium-or low-income countries. Further, it was found out that for example in the case of earthquakes, countries with high urban growth rates and high physical exposure can be associated with high levels of risk. The DRI is innovative for two reasons: it takes into account the development aspect and it uses a different set of vulnerability indicators for each hazard.

2 INTEGRATED VULNERABILITY INDEX AND MAP

The indicators in Table 1 marked with a plus (+) were used in the ESPON Hazards project to create an integrated vulnerability index and an integrated vulnerability map. To combine the four feasible indicators (marked with + in Table 1), the indicators needed to be weighted in a way that the overall regional vulnerability is 100%.

There are different methods for the weighting process. One possibility is not to assign different weights for the different indicators but to use an additive model, as Cutter et al. (2003) did in their SoVI index. In this case, all indicators received the same value. Another possible way to weigh the indicators is to use the Delphi method. This method was used in the Hazards project as a tool to weight hazards on regional and European levels, as well as to weight vulnerability components on the regional level. The decision not to use the Delphi method on the European level of vulnerability was mainly made on the basis of the case study results. Although the experts were able to assess the relevance of different hazards in their regions, they had difficulties deciding on the significance of different vulnerability components. It seems that not everybody was familiar with the concept of regional vulnerability, which made the task of weighting difficult. A European-level Delphi on vulnerability would most probably have proven too difficult for the experts, who would have had to consider the joint vulnerability of all NUTS3 regions in EU27+2.

In the ESPON Hazards project, the weighting was done by testing different weighting combinations for the four feasible indicators. The resulting sample maps allowed for the comparison of the different combinations and showed possible changes in the overall vulnerability of different regions. This "sensitivity test" was done with the following four combinations:

1. 30 + 30 + 10 + 30 (regional GDP, population density, fragmented natural areas, national GDP)
2. 25 + 25 + 25 + 25
3. 20 + 20 + 10 + 50
4. 20 + 50 + 10 + 20

Ideally, all four indicators would receive the same value of 25%, which altogether adds up to 100% regional vulnerability. However, due to the fact that the indicator fragmented natural areas only depicts one aspect of ecological vulnerability, the indicator was given the percentage value of 10. Each of the other three indicators was given the percentage value of 30. Figure 2 shows the integrated vulnerability index with the four feasible indicators.

The integrated vulnerability index was used to create the integrated vulnerability map for the EU 27+2. Map 1 depicts the vulnerability of all regions individually. The map was further combined with an aggregated hazards map to create the aggregated risk map for Europe.

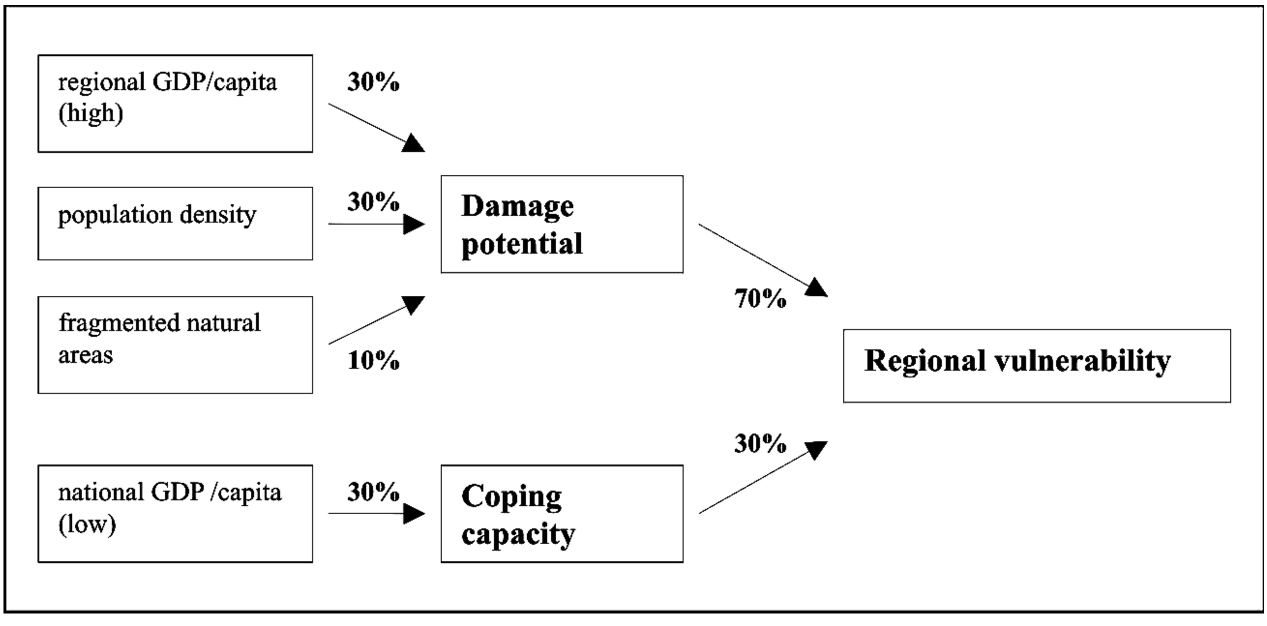
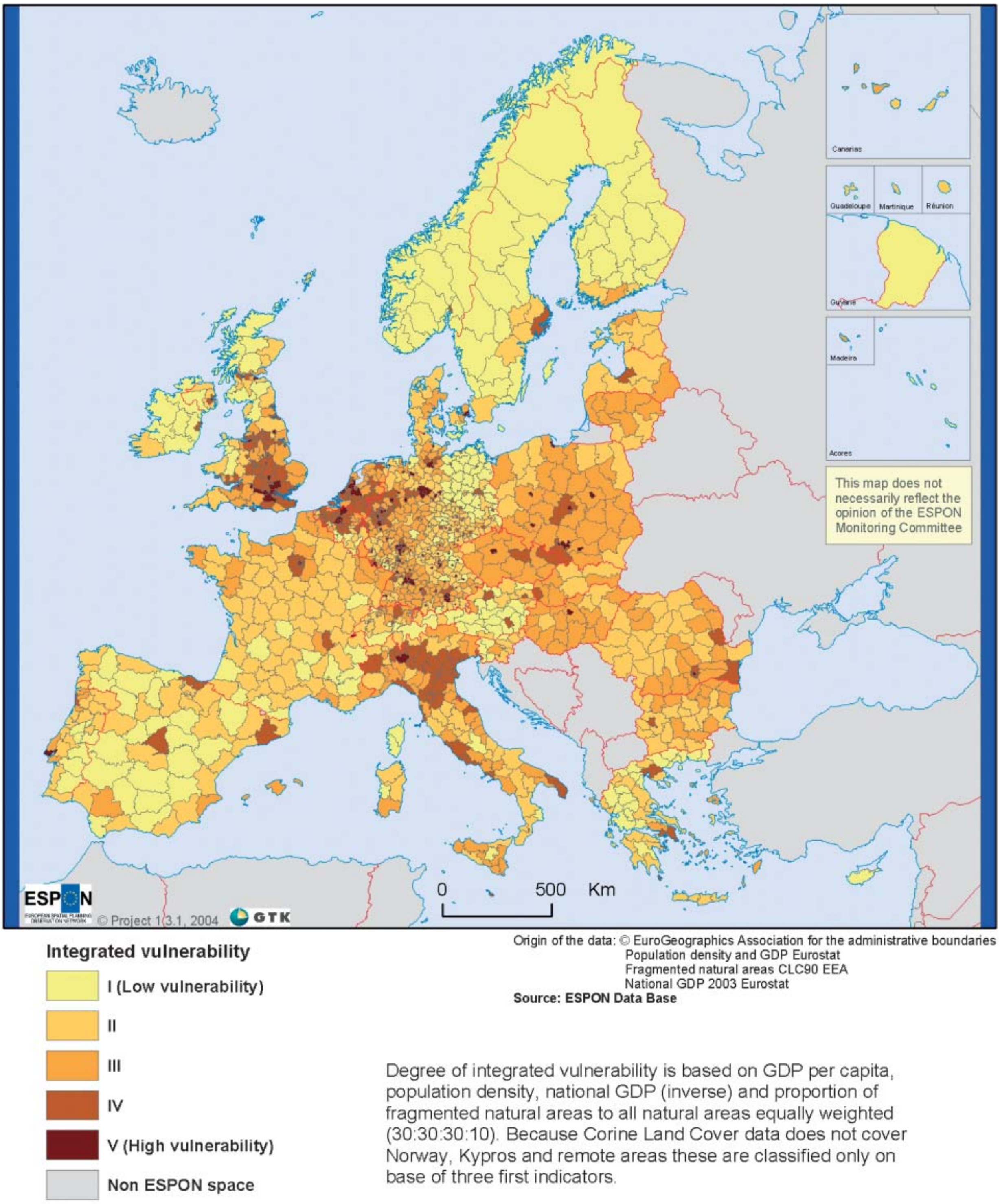


Figure 2. Integrated vulnerability index (~~ESPON Hazards project 2005~~Schmidt-Thomé 2005).



Map 1. Integrated vulnerability map (Schmidt-Thomé 2005). Map production Hilkka Kallio, GTK.

3 FUTURE RESEARCH NEEDS: HAZARD-SPECIFIC VULNERABILITY

In the future, it would be interesting to take a closer look at the hazard-specific nature of vulnerability. Although hazard-specific vulnerability is not a widely used concept in vulnerability research, it is possible to recognize at least two different approaches:

1. hazard centred: considering the relevant vulnerability indicators for a chosen hazard
2. region centred: first considering the hazards and then the hazard-specific vulnerability of a chosen region.

One example of the hazard-centred approach is the Disaster Risk Index of the UNDP (2004:32), which uses hazard-specific vulnerability indicators. The assumption is that factors that make people vulnerable to hazards are different for each hazard. The approach is hazard centred, since it considers three hazards (earthquakes, tropical cyclones and floods) and feasible vulnerability indicators for each of these hazards. The approach has also an areal connection, since in the DRI countries are indexed for each hazard type, for example, according to their relative vulnerability. Altogether 26 indicators were used for four hazards.

An example of the region-centred approach is Stock's (2003) analysis of the regional vulnerability in one German state (Nordrhein-Westfalen) with regard to climate change. The approach is region centred, since the starting point is the hazard potential and vulnerability of the municipalities in Nordrhein-Westfalen. This approach considers hazards related to weather and the idea is to determine the vulnerability of different sectors of the economy. According to Stock (2003:49), those parts of the natural environment and human existence that are sensible to weather determine the level of vulnerability of the region in question. One example of this approach is a map of the region that depicts those forested areas most vulnerable to storms.

The ESPON Hazards project has an a_real approach to vulnerability, to analyse the hazard potential, vulnerability and risk of all NUTS3 regions in the EU 27+2. However, the approach is not hazard-specific since the same vulnerability indicators are used in all regions and for all hazards. Using a hazard-specific approach would be especially useful when considering the vulnerability of a specific region (e.g. one NUTS3 region). In the Hazard project's case-study areas, the chosen methodology seemed somewhat general to bring out the essential results on the regional level. For example, a region in central Portugal plagued by forest fires needs to consider different vulnerability indicators than a region in southern Finland characterized by several technological hazards.

In addition to taking a closer look at the regional level, it is important to note that each hazard poses a different threat to different aspects of human life and the environment. For example, natural hazards are not necessarily a risk to natural areas, since forest fires, for example, are nature's way of clearing old forests and maintaining ecological diversity. However, some natural hazards can be enhanced by technology or intensified by a technological hazard, for example, a flood that reaches a chemical plant poses a severe threat to the environment. In the case of economic vulnerability, it would be interesting to consider damage potential of different sectors of economy. For example, oil spills are a threat especially to fishery and tourism, whereas agriculture can suffer severely and widely from floods and storms.

For a better knowledge of vulnerability in Europe, it would be interesting to take a look at the relevant hazards separately and consider the hazard-specific vulnerability for each of them. Further, hazards and vulnerability could be considered separately for specific regions, which would allow for the creation of regional risk profiles.

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