Vulnarability in Relation to Risk Management

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OUTLINE

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Basic Definitions

Risk = Hazard x Elements at risk x Vulnerability

Vulnerability: The degree of loss to a given element or set of elements within the area affected by a hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss).

Elements at risk: Population, buildings and engineering works, infrastructure, environmental features and economic activities in the area affected by a hazard.

Hazard: Probability that a particular danger (threat) occurs within a given period of time.

Vulnerability in Risk Assessment

- What are the probable dangers/problems? [Danger Identification]
- What would be the magnitude of dangers/problems? [Hazard Assessment]
- What are the possible consequences and/or elements at risk? [Consequence/Elements at Risk Identification]
- **What might be the degree of damage in elements at risk? [Vulnerability Assessment]**
- What is the probability of damage? [Risk Quantification/Estimation]
- What is the significance of estimated risk? [Risk Evaluation]
- What should be done? [Risk Management]

Vulnerability as a 2-D Concept

Perspective I (Pyhsical vulnerability): This investigates human system's sensitivity to the impacts of the hazard(s). **i.e. the hazard event is the active agent while the human system is the passive agent**

Perspective II (Social vulnerability): This puts the human system on the central stage. It arises from studies of underlying structural factors that make human societies susceptible to external hazards.

Vulnerability as a 2-D Concept

Main Difference in Perspectives I and II

1. Social vulnerability concentrates on determining the coping capacity of the society, which is determined by some indicators such as poverty, health, access to insurance, housing quality, social status, etc. However, physical vulnerability is a function of the type and intensity of natural hazard and characteristics of the elements at risk.
2. Although the concept of vulnerability has some negative connotations, the definition of social vulnerability is relatively more positive as it concentrates on the coping capacity of the society (resilience). This is in contrast to physical vulnerability, in which the main focus is on degree of loss.
3. Physical vulnerability changes depending on the type and intensity of the natural hazard, whereas the assessment of social vulnerability does not consider these factors. In other words social vulnerability basically is not hazard-specific.
4. Social vulnerability is dependent on the phases of the disaster, which is called short/long-term vulnerability. Short-term vulnerability refers to the period immediately after the disaster, while long-term vulnerability is mostly related to the post disaster-recovery period.

Vulnerability Assessment

Generalized quantitative models for vulnerability assessment are essential:

- For effective use of QRA in landslides
- Risk assessment for multi-hazard situations

Problems of Landslide Vulnerability

The nature of landslides makes the development of quantitative models difficult. Because;

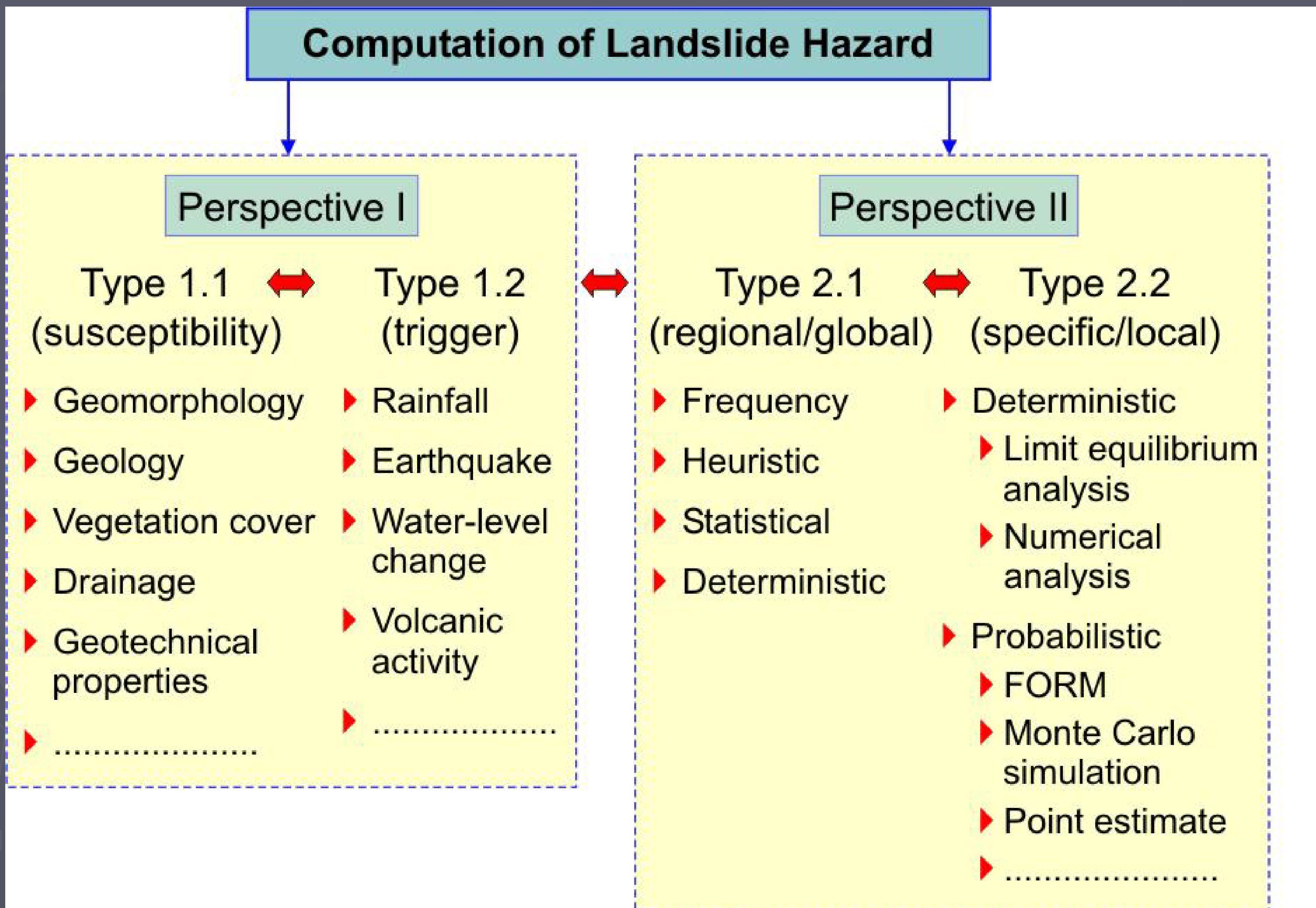
1. There is no unique way of computing landslide hazard (Difference in hazard computation).

2. Landslides are spatially discrete phenomena unlike earthquakes, floods and hurricanes, which have spatially continuous loss measurement parameters such as ground motion, rainfall and wind speed (Difference in Phenomena) .

3. The notion of risk in landslides varies according to focus of interest (Notion of risk).

Problems of Landslide Vulnerability

Difference in hazard computation



Problems of Landslide Vulnerability

Difference in Phenomena

Landslides are spatially discrete phenomena, whereas earthquake, flood, and wind are spatially continuous phenomena, which use continuous loss measurement parameters, such as:

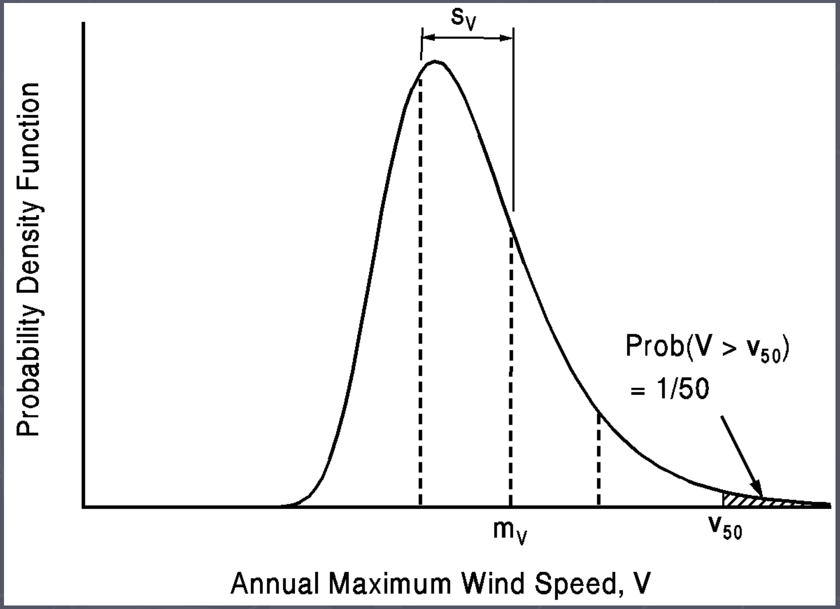
1. Ground Motion in earthquakes
2. Rainfall in floods
3. Wind speed in storms

There is no such a measure in landslides since it is discrete in space.

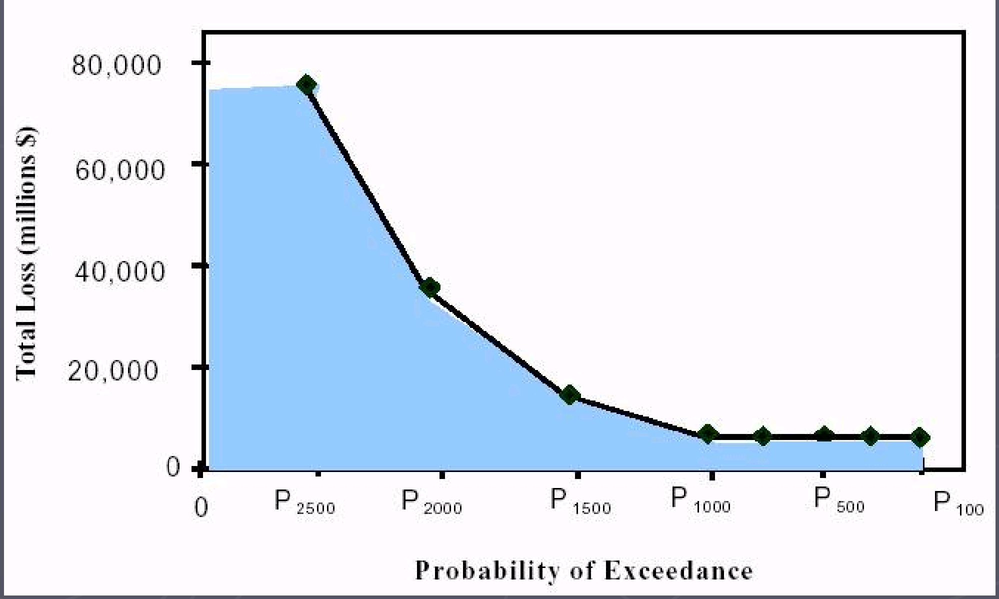
Problems of Landslide Vulnerability

Difference in Phenomena

Continuous loss measures



Definition of 50-year return period wind speed based on 1/50 exceedance probability (Phoon et al. 1995)



Probabilistic loss curve (HAZUS 2001)

Problems of Landslide Vulnerability

Notion of Risk

Type of Risk	Definition
Acceptable	Society desires to achieve
Tolerable	Society wants to live with so as to secure certain net benefits
Individual	Imposed on a particular individual due to landslide hazard
Societal	Imposed to society as a whole
Voluntary	Voluntarily faced to gain benefits
Involuntary	Imposed by a controlling body, not the free choice of people
Specific	Evaluated for a specific element at risk
Total	Sum of specific risks

Problems of Landslide Vulnerability

Notion of Risk

Level of generalization

Risk formulation	Source
Risk = Hazard x Consequences	Einstein (1988)
$Rs = H \times V$	Varnes (1984)
$Rt = Rs \times E = (H \times V) \times E$	Varnes (1984)
$Rt = \Sigma(Rs \times E) = \Sigma(H \times V \times E)$	Fell (1994)
$Rs = P(Hi) \times \Sigma(E \times V \times Ex)$ $Rt = \Sigma$ Rs(Landslide events 1,…, n)	Lee & Jones (2004)
$R(DI) =$ $P(H) \times P(S \backslash H) \times P(T \backslash S) \times P(L \backslash T)$	Morgan et al. (1992)
$R(PD) = P(H) \times P(S \backslash H) \times V(P \backslash S) \times E$	Dai et al. (2002)

Current Status of Landslide Vulnerability Assessment

- The attempts up to now, focus on quantification of vulnerability to be used for specific risk, which is also empirical in the sense that they are usually the resultant from expert opinions.

- There is no systematic method to evaluate total risk, which involves evaluation of vulnerability based on different attributes of element at risk.

Current Status of Landslide Vulnerability Assessment

Example for landslide vulnerability (Glade 2003 – modified from Heinimann 1999)

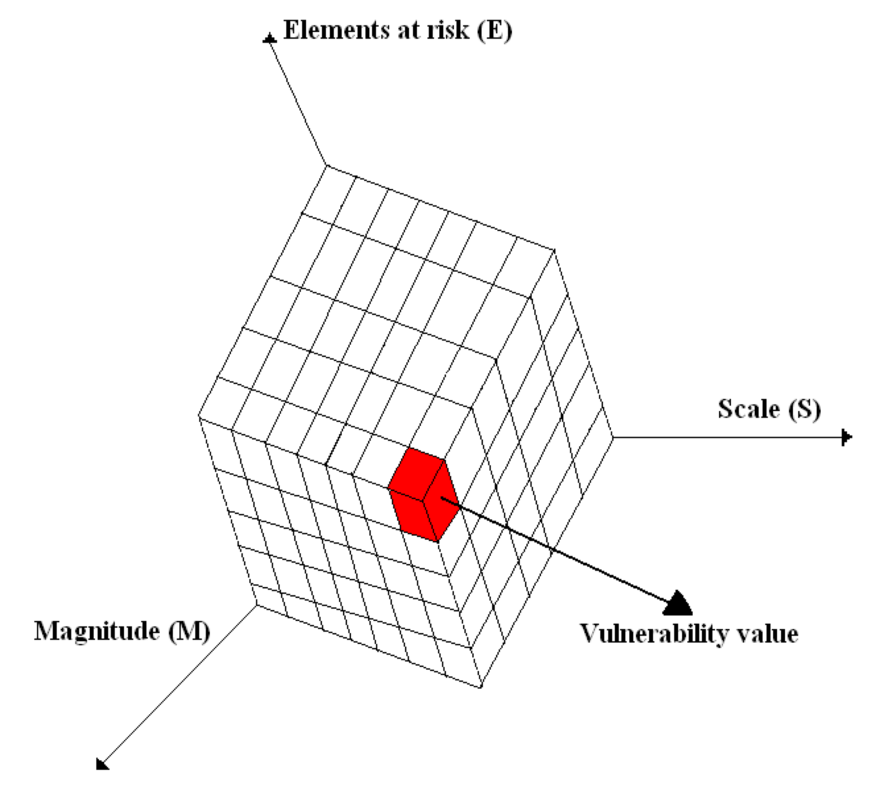
Building type	Debris flow magnitude			Rock fall magnitude		
	Low	Medium	High	Low	Medium	High
Settlement area	0.001	0.01	0.1	0.0001	0.01	0.1
Centre of settlement	0.001	0.01	0.1	0.0001	0.01	0.1
One/two family house	0.001	0.01	0.1	0.0001	0.01	0.1
Apartment building	0.001	0.01	0.1	0.0001	0.01	0.1
Commercial building	0.001	0.01	0.1	0.001	0.01	0.1
Industrial building	0.001	0.01	0.1	0.001	0.01	0.1
Barn	0.001	0.01	0.1	0.001	0.01	0.1

A Conceptual Framework for Vulnerability Assessment

A 3-D conceptual framework for the assessment of vulnerability is proposed:

- **magnitude (M)**
- **scale (S)**
- **elements at risk (E)**

are the three dimensions



A Conceptual Framework for Vulnerability Assessment

Vulnerability needs to be modelled in a 3-D array based on the following dimensions:

1. **Magnitude ($M(\underset{\sim}{x})$)**

$\underset{\sim}{x}$ is the vector of parameters for defining the magnitude of the landslide such as:

- volume (x_1)
- velocity (x_2)
- depth (x_3)
- run out (x_4)
- areal extent (x_5)

A Conceptual Framework for Vulnerability Assessment

2. Elements at risk ($E(\underset{\sim}{x})$)

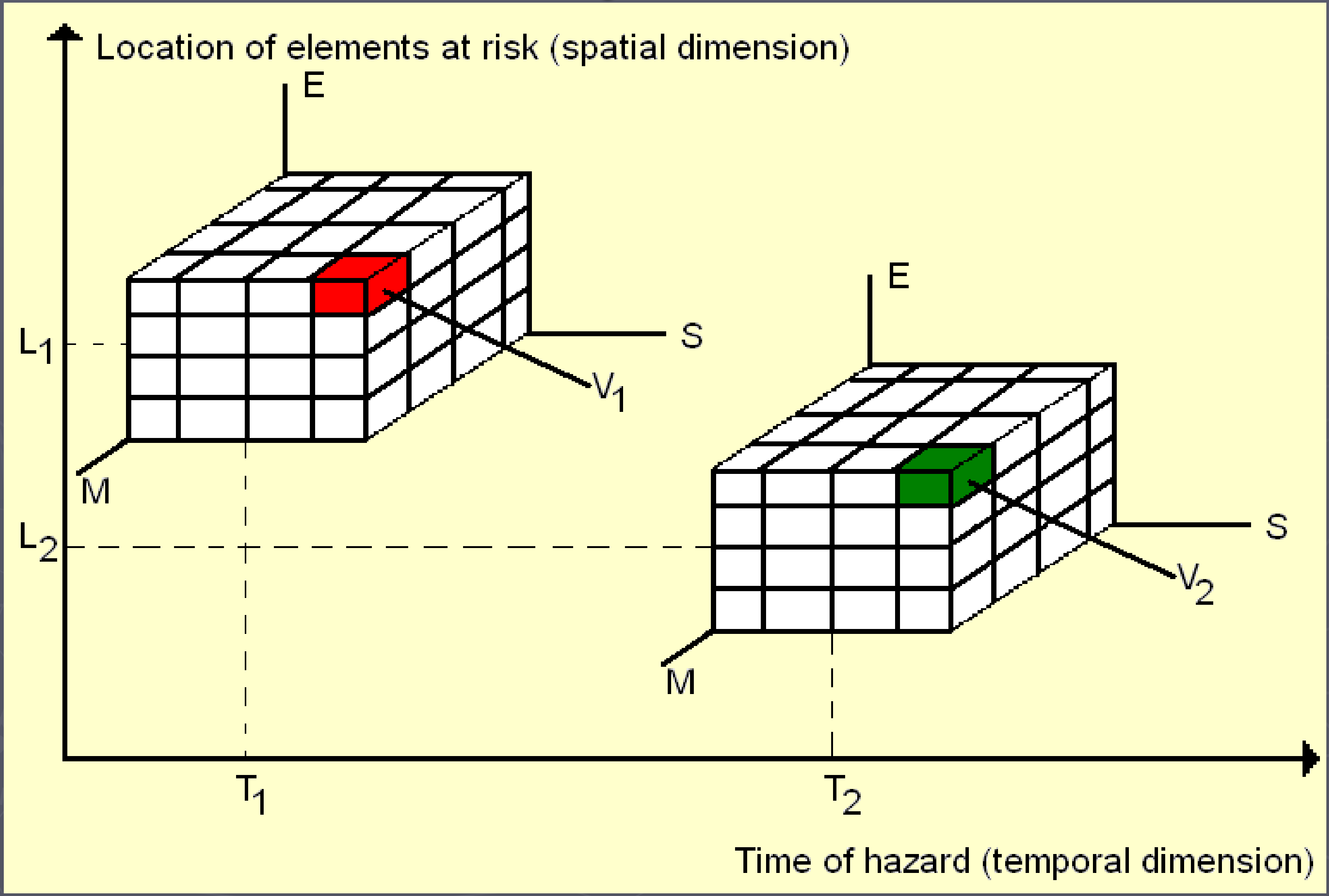
$\underset{\sim}{x}$ is the vector of elements at risk such as:

- Physical (building, road, lifelines, etc.)
- Societal (lives lost, injuries, etc.)
- Economical (Monetary)
- Environmental

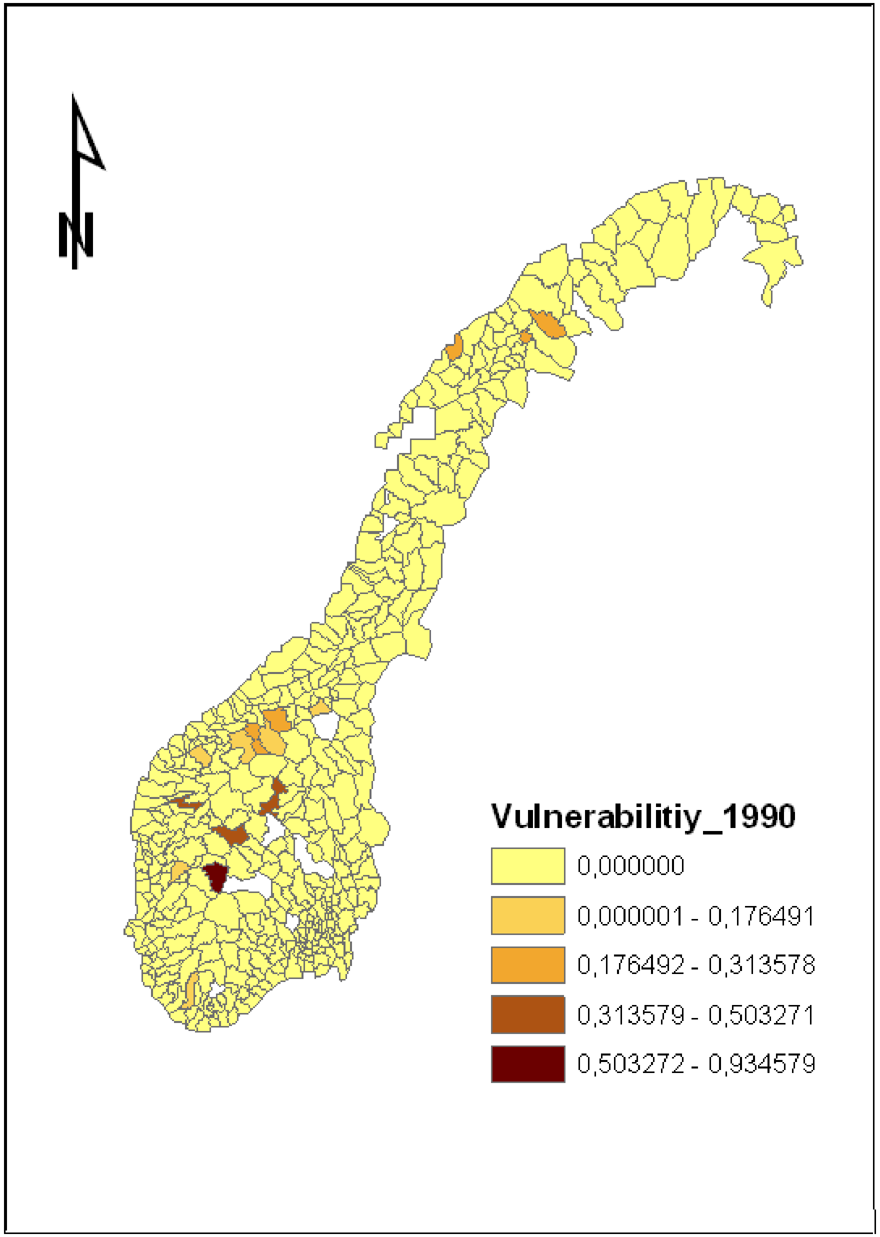
3. Scale (S)

(Specific/local vs. Global/regional)

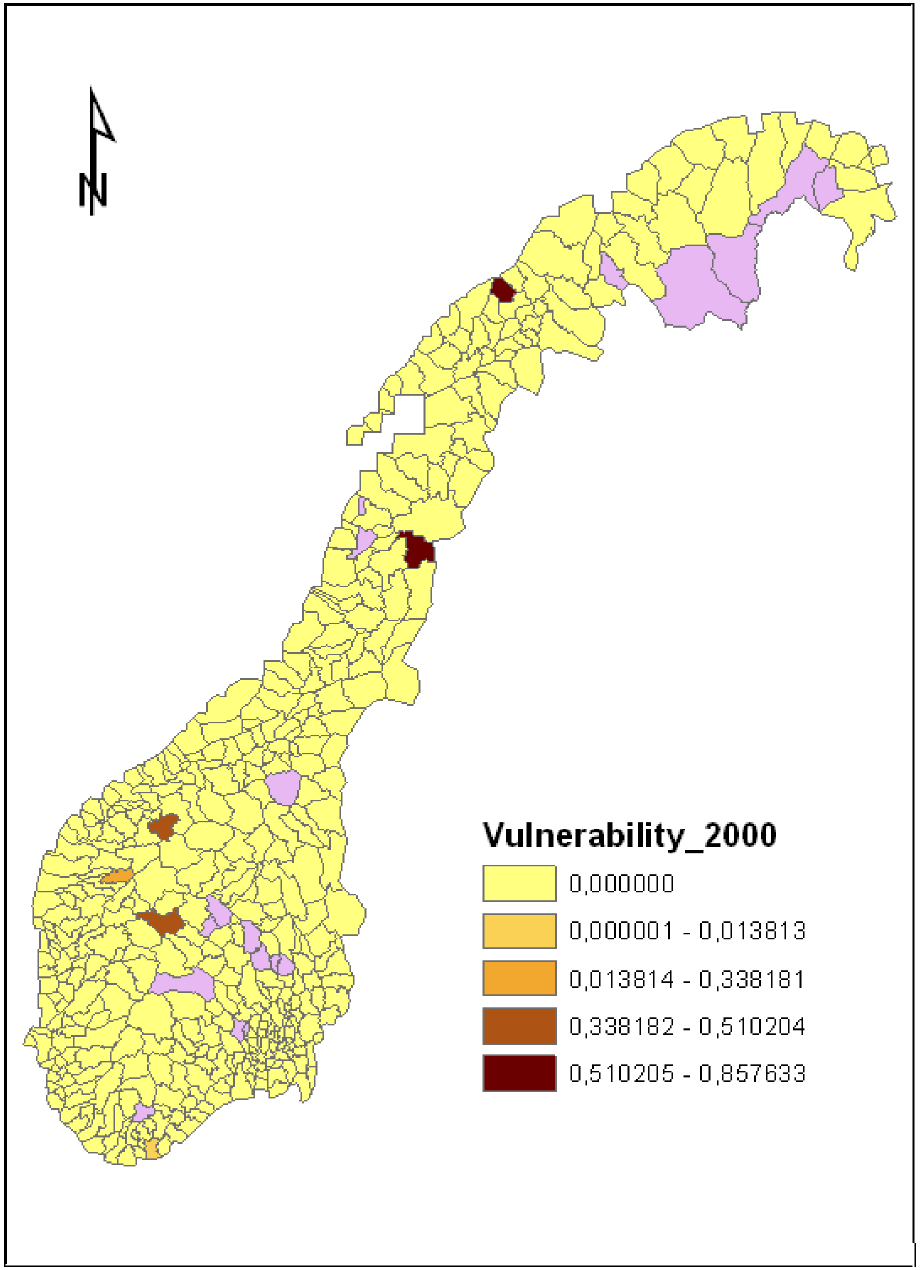
A Conceptual Framework for Vulnerability Assessment



Popolation Vulnerability for 1980 - 1990



PopulationVulnerability for 1990 - 2000



Conclusions

1. The vulnerability assessment for landslides requires systemmatic approaches.
2. The existing loss estimation methods for other natural hazards can be adapted for landslides.
3. It is essantial to establish relation between the magnitude of hazard and its consequences.
4. The existing databases for landslides are not adequate for determining relations between magnitude and consequences.
5. Future data collection efforts should focus on reporting the landslide magnitude indicators and damages.

THANKS

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