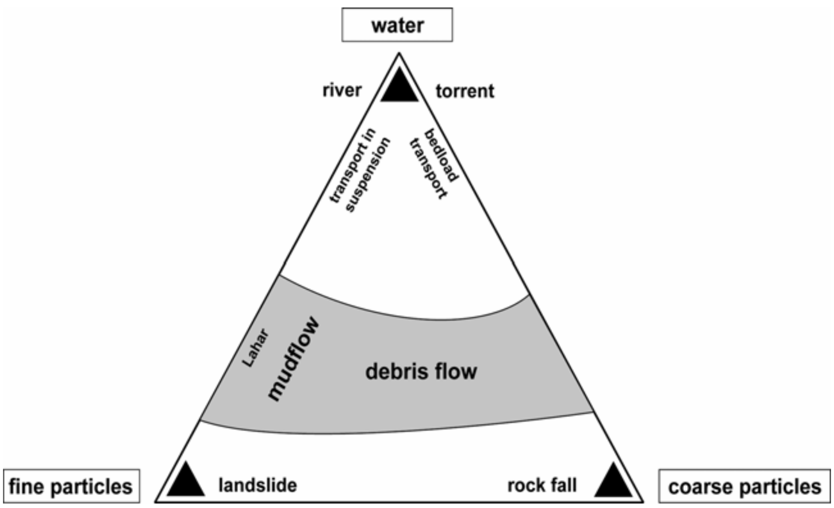
Vulnerability to torrent processes

Sven Fuchs

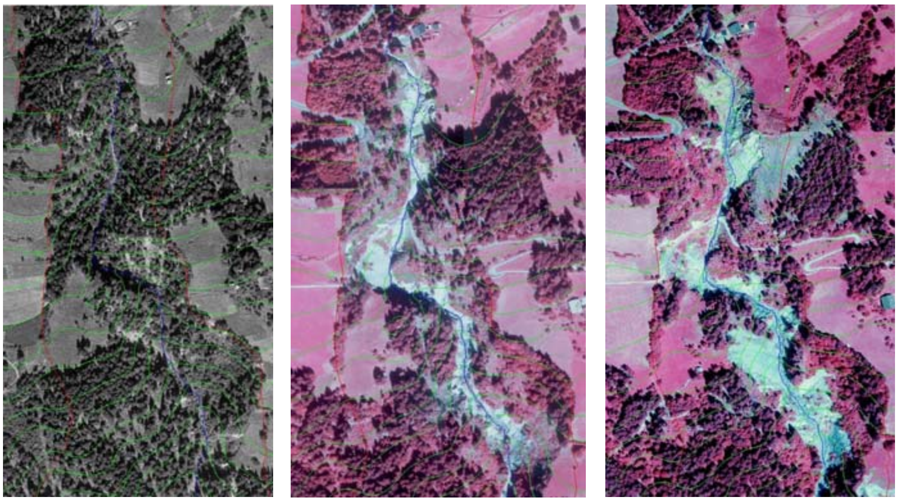
Torrent processes…



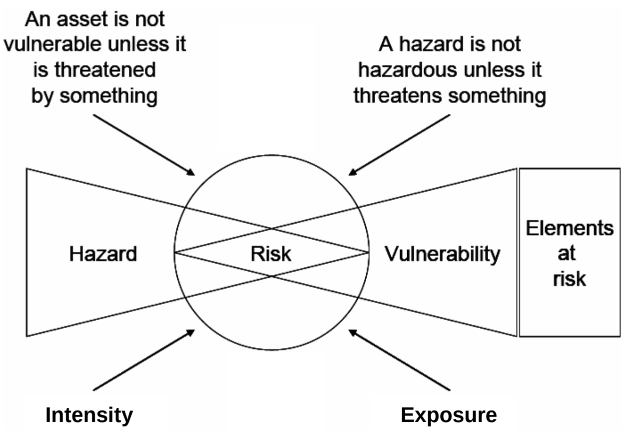
modified from Phillips & Davis 1991

Torrent processes…

Situation 1954 | Situation 1997 | Situation 2000



The concept of vulnerability



modified from Alexander 2005

Multidisciplinary approaches:

Introduction | Method | Results | Conclusion

Flooding Passau 13.08.2002

Po Shan Road Landslide, Hong Kong, 18.06.1972, www.hkss.cedd.gov.hk

Multidisciplinary approaches:

- (Natural) Scientist: v = 0,5 in both cases, but absolute values different.

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Flooding Passau 13.08.2002

Po Shan Road Landslide, Hong Kong, 18.06.1972, www.hkss.cedd.gov.hk

Multidisciplinary approaches:

- Social scientist: Vulnerability in Hong Kong considerably higher than in Germany…

Flooding Passau 13.08.2002

Po Shan Road Landslide, Hong Kong, 18.06.1972, www.hkss.cedd.gov.hk

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Quo vadis?

- Vulnerability as a **multi-dimensional** phenomenon, what might result in high vulnerability for social scientists might be negligible for engineers…(**Consensus**: Vulnerability has a spatial dimension)

Autoren	Definition
Gabor & Griffith (1980)	Vulnerability is the threat (to hazardous materials) to which people are exposed (including chemical agents and the ecological situation of the communities and their level of emergency preparedness). Vulnerability is the risk context.
Timmerman (1981)	Vulnerability is the degree to which a system acts adversely to the occurrence of a hazardous event. The degree and quality of the adverse reaction are conditioned by a system's resilience (a measure of the system's capacity to absorb and recover from the event).
UNDRO (1982)	Vulnerability is the degree of the loss to a given element or set of elements at risk resulting from the occurrence of a natural phenomenon of a given magnitude.
Petak & Atkisson (1982)	The vulnerability element of the risk analysis involved the development of a computer-based exposure model for each hazard and appropriate damage algorithms related to various types of buildings.
Susman et al. (1983)	Vulnerability is the degree to which different classes of society are differentially at risk.
Kates (1985)	Vulnerability is the 'capacity to suffer harm and react adversely'.
Pijawka & Radwan (1985)	Vulnerability is the threat or interaction between risk and preparedness. It is the degree to which hazardous materials threaten a particular population (risk) and the capacity of the community to reduce the risk or adverse consequences of hazardous materials releases.
Bogard (1989)	Vulnerability is operationally defined as the inability to take effective measures to insure against losses. When applied to individuals, vulnerability is a consequence of the impossibility or improbability of effective mitigation and is a function of our ability to detect hazards.
Mitchell (1989)	Vulnerability is the potential for loss.
Liverman (1990)	Distinguishes between vulnerability as a biophysical condition and vulnerability as defined by political, social and economic conditions of society. She argues for vulnerability in geographic space (where vulnerable people and places are located) and vulnerability in social space (who in that place is vulnerable).
Downing (1991)	Vulnerability has three connotations: it refers to a consequence (e.g., famine) rather than a cause (e.g., drought); it implies an adverse consequence (e.g., maize yields are sensitive to drought; households are vulnerable to hunger); and it is a relative term that differentiates among socioeconomic groups or regions, rather than an absolute measure or deprivation.
UNDRO (1991)	Vulnerability is the degree of the loss to a given element or set of elements at risk resulting from the occurrence of a natural phenomenon of a given magnitude and expressed on a scale from 0 (no damage) to 1 (total loss). In lay terms, it means the degree to which individual, family, community, class or region is at risk from suffering a sudden and serious misfortune following an extreme natural event.
Dow (1992)	Vulnerability is the differential capacity of groups and individuals to deal with hazards, based on their positions within physical and social worlds.

Smith (1992)	Human sensitivity to environmental hazards represents a combination of physical exposure and human vulnerability – the breadth of social and economic tolerance available at the same site.
Alexander (1993)	Human vulnerability is function of the costs and benefits of inhabiting areas at risk from natural disaster.
Cutter (1993)	Vulnerability is the likelihood that an individual or group will be exposed to and adversely affected by a hazard. It is the interaction of the hazard of place (risk and mitigation) with the social profile of communities.
Watts & Bohle (1993)	Vulnerability is defined in terms of exposure, capacity and potentiality. Accordingly, the prescriptive and normative response to vulnerability is to reduce exposure, enhance coping capacity, strengthen recovery potential and bolster damage control (i.e., minimize destructive consequences) via private and public means.
Blaikie et al. (1994)	By vulnerability we mean 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 hazard. It involves a combination of factors that determine the degree to which someone's life and livelihood are put at risk by a discrete and identifiable event in nature or in society.
Green et al. (1994)	Vulnerability to flood disruption is a product of dependence (the degree to which an activity requires a particular good as an input to function normally), transferability (the ability of an activity to respond to a disruptive threat by overcoming dependence either by deferring the activity in time, or by relocation, or by using substitutes), and susceptibility (the probability and extend to which the physical presence of flood water will affect inputs or outputs of an activity).
Bohle et al. (1994)	Vulnerability is best defined as an aggregate measure of human welfare that integrates environmental, social, economic and political exposure to a range of potential harmful perturbations. Vulnerability is a multilayered and multidimensional social space defined by the determinate, political, economic and institutional capabilities of people in specific places at specific times.
Dow & Downing (1995)	Vulnerability is the differential susceptibility of circumstances contributing to vulnerability. Biophysical, demographic, economic, social and technological factors such as population ages, economic dependency, racism and age of infrastructure are some factors which have been examined in association with natural hazard.
Gilard & Givone (1997)	Vulnerability represents the sensitivity of land use to the hazard phenomenon.
Amendola (1998)	Vulnerability (to dangerous substances) is linked to the human sensitivity, the number of people exposed and the duration of their exposure, the sensitivity of the environmental factors, and the effectiveness of the emergency response, including public awareness and preparedness.
Comfort et al. (1999)	Vulnerability are those circumstances that place people at risk while reducing their means of response or denying them available protection.
Weichselgartner & Bertens (2000)	By vulnerability we mean the condition of a given area with respect to hazard, exposure, preparedness, prevention, and response characteristics to cope with specific natural hazards. It is a measure of capability of this set of elements to withstand events of a certain physical character.

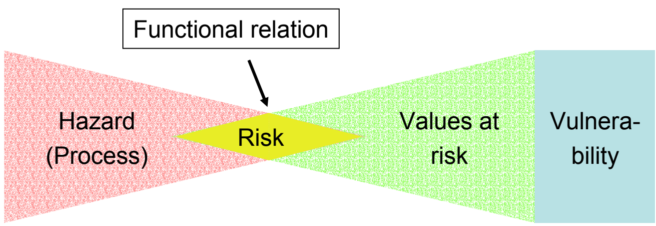
Alternative vulnerability indices?

- Physical vulnerability sub-index
  - construction materials of the buildings (masonry vs. reinforced concrete, ...)
    → building strength and resistance to processes
- Economic vulnerability sub-index
  - unemployment rate in flood prone areas
    → gives an idea of real life conditions and the economical recovery capacity after the hazard occurred
  - illiteracy rate of the population in flood prone areas
    → capacity to access information and to adopt civil protection preparedness measures (training and education)
- Demographic vulnerability sub-index
  - percentage of children and old people living in flood prone areas
    → translate the mobility capacity of most vulnerable people
  - number of social equipments and civil protection infrastructures localised in flood prone areas
    → identifies the contact points, also evaluating the reaction time of civil protection organisations
- …

Viseu, 2008, pers. comm. @ Risk Analysis 2008 (Greece)

Vulnerability and IRASMOS

- Using the natural scientists' approach



- …and neglecting any aspects of knowledge, decision problems,…

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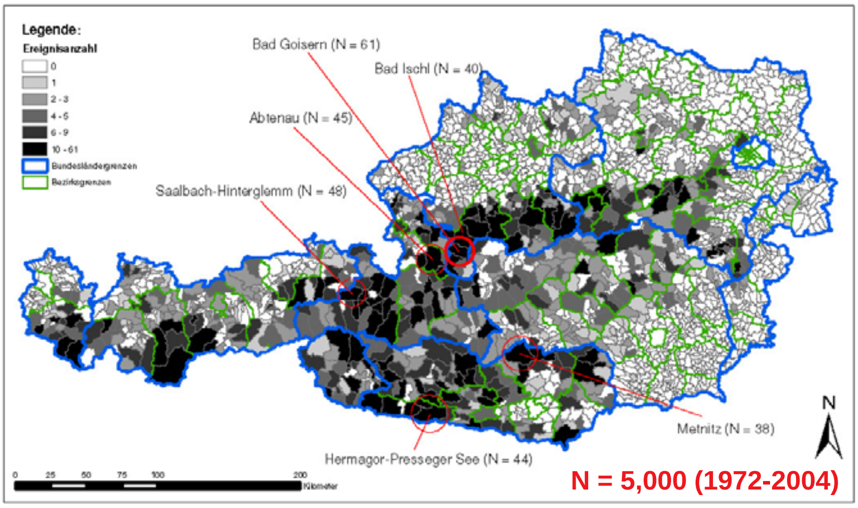
Torrent events matter…



N = 5,000 (1972-2004)

Oberndorfer et al. 2007

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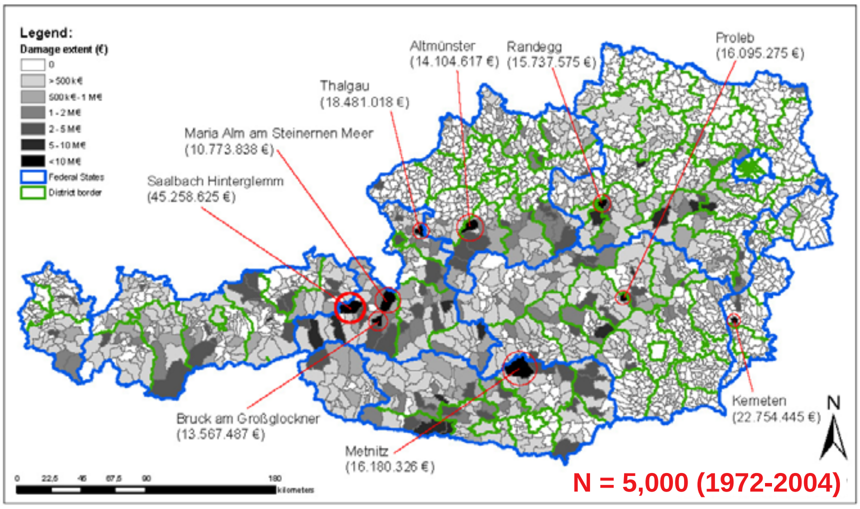

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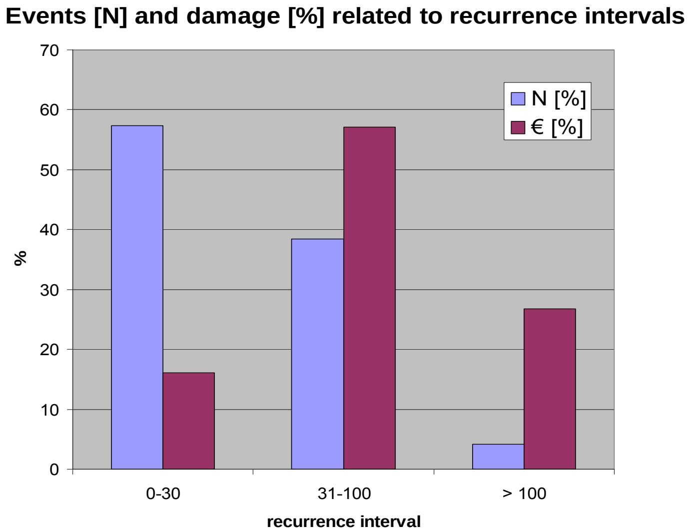

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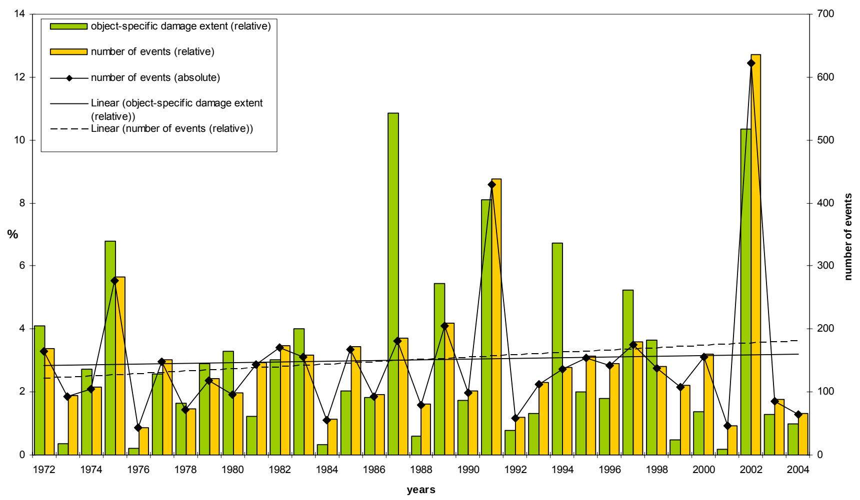

Oberndorfer et al. 2007

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Therefore: Risk analyses

- **Risk dependent on**
  - **the probability of occurrence** of a specific process and
  - the height of the **damage potential exposed**

$$R_{i,j} = f\,(p_{Si}, A_{Oj}, v_{Oj,\,Si})$$

$R_{i,\,j}$ = risk
p_{Si} = probability of scenario *i*
A_{Oj} = value at risk of object *j*
$v_{Oj,\,Si}$ = vulnerability of object *j*, dependent on scenario *i*

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$R_{i,\,j}$ = risk
p_{Si} = probability of scenario *i* ✓ *(magnitude/intensity)*
A_{Oj} = value at risk of object *j* ✓
$v_{Oj,\,Si}$ = vulnerability of object *j*, dependent on scenario *i* **?**

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Methods to determine vulnerability

- With respect to exposed buildings

Fuchs et al. 2007

Vulnerability			Intensity: qualitative				Intensity: (semi)quantitative			
			low	medium	high	very high	low	medium	high	very high
			not specified	not specified	not specified	not specified	not specified	h < 1 m or v < 1 m/s	h > 1 m and v > 1 m/s	not specified
Vulnerability	qualitative	(1) Leone et al. (1995/1996); Finlay (1996)	not linked to process intensity							
	qualitative	(2) Cardinali et al. (2002)	superficial	functional	structural	structural				
	quantitative	(3) Fell and Hartford (1997)	0.1	0.4	0.7	1.0				
	quantitative	(4) Michael-Leiba et al. (2003)	0.1 (distal)		1.0 (proximal)					
	quantitative	(5) Bell and Glade (2004)	0.1	0.2	0.5	not specified				
	quantitative	(6) Romang (2004)	not specified	0.1 - 0.2	0.5	not specified				
	quantitative	(7) Borter (1999) [for channel debris flows]					not specified	0.1	0.5	not specified

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Methods to determine vulnerability

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Fuchs et al. 2007

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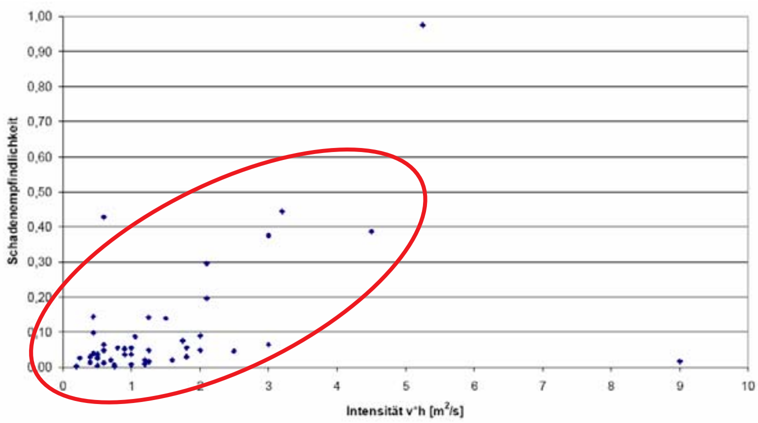
Methods to determine vulnerability

- With respect to exposed buildings



Kimmerle 2002

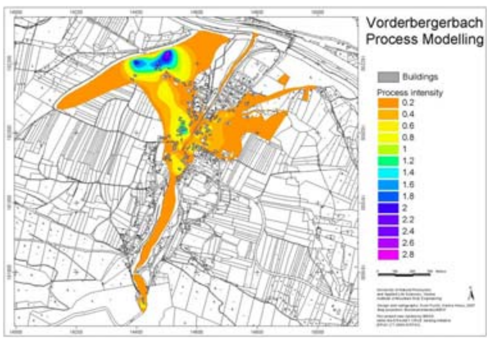
Methods to determine vulnerability

- Lack of data linking intensity to exposure

1. Vorderbergerbach (29 August 2003)
2. Wartschenbach (16 August 1997)

Method

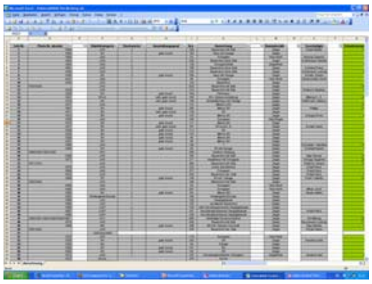
- **Analysis of the events**:
  - Event documentation (aerial photos, documents of Austrian Torrent and Avalanche Control Service)
  - Back-calculation using FLO-2D
  - Flow depths and accumulation heights **as a proxy for intensity***



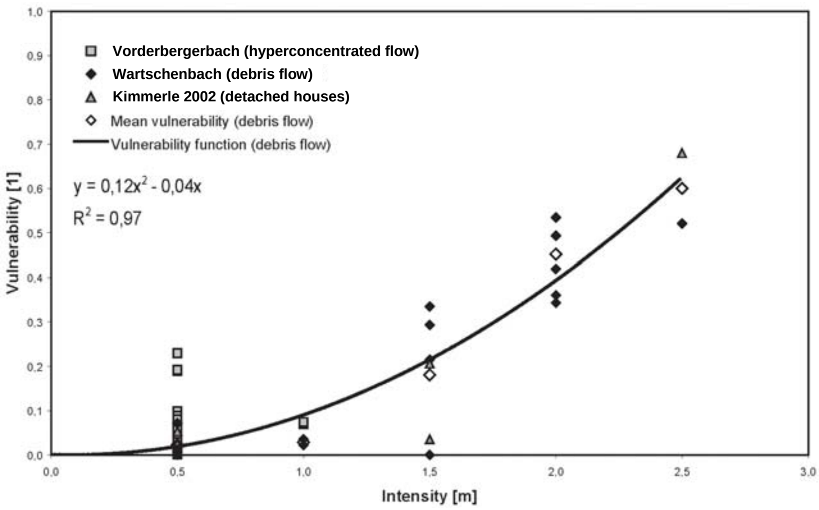
*Diversity in IRASMOS…

Method

- **Analysis of values at risk**:
  - Spatially explicit analysis of buildings
  - Assessment of values according to Keiler et al. (2006) (classification, floor space, height, reconstruction value, real estate appraisal)
- **Analysis of losses**
- $v = \dfrac{loss}{value}$



Results [detached houses]



Fuchs 2008

Results

- Appropriate solution for process intensities < 2.5 m
- Mathematically, valid between 0.33 m and 3.06 m

$$f_{(x)} = \begin{cases} 0 \;\; if \;\; x < 0.\overline{3} \\ 0.12x^2 - 0.04x \;\; if \;\; 0.\overline{3} \le x \le 3.06 \\ 1 \;\; if \;\; x > 3.06 \end{cases}$$

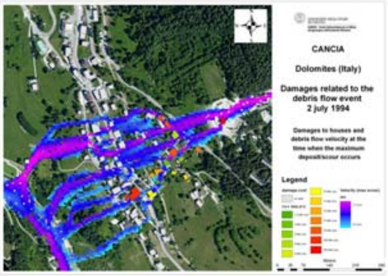
- Converges to the value of 1: $\lim_{x \to \infty} f_{(x)} = 1$

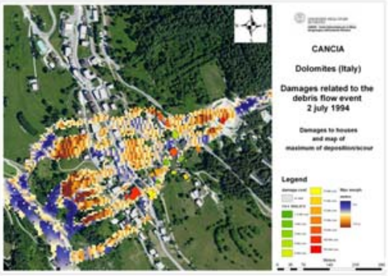
Conclusion

- Range is still considerable, in particular related to small process intensities → strong dependence on local structural protection
- **Vulnerability values below suggestions in literature**
- More data needed for a validation…

Conclusion

- E.g., validation by data from Italy (Univ. of Trento), see presentation of Matteo Dall'Amico





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