Regions of vulnerability: Spatial modelling of different conceptual approaches

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1. Introduction

In the context of disaster risk reduction the concept of vulnerability has gained much importance in the last decade. However, the concepts and terminology has not been agreed yet and discussions are sometimes embedded within a strong theoretical scope. However, we believe that one of the essential objectives of a vulnerability assessment is risk reduction and the encouragement of a disaster resilience culture (Birkmann, 2006) expressed in the implementation of prevention, mitigation and preparedness measures. One approach is the identification of the spatial differentiation of the physical, social, economic, cultural, institutional and environmental vulnerabilities, allowing regular updates to support decision and policy makers within their disaster risk reduction measures and to identify trends and changes in hot spots of vulnerability. Even the spatial variables and indicators of vulnerability are rarely taken into account in assessments.

Different methodologies have been applied in the domain of GIScience to integrate different data and construct indices (see Nardo et al. 2005 or Fekete 2009). However, the applications usually are limited to administrative boundaries or represent a pixel-based approach, which is in our sense perceived as not the ultimate approach to present and model complex and integrated concepts, such as vulnerability.

2. Geon concept

Geons are constructed spatial objects, the word geon (from Greek *gé* = Earth and *on* = part, unit) is used as a generic term for conceptual *fiat* objects (Lang et al., in press). Geons are homogenous in terms of varying spatial phenomena *sensu* 'region', but with a strong link to policy intervention (Lang et al., 2008). The spatial construction of geons supports operational updates as a basic requirement for regular monitoring against a specific policy background. Geons are capable to reflect multidimensional problem spaces in real space representations, and by this, facilitate the modeling and mapping of systemic properties to policy-relevant, conditioned information (ibid.).

Biederman (1987) introduced the concept of *geon* in the field of cognitive psychology and formulate the hypothesis that "*cognitive objects can be decomposed into basic shapes or components*", such as basic volumetric bodies. Lang et al. (2008) have redefined the term for its application in the GIScience domain. The methodological key element behind the geon approach is a scale-specific spatial regionalisation of a complex, usually multidimensional spatial reality. Geons are scale-dependent, hierarchical 'earth-objects' with functional characteristics in both the self-integrative and self-assertive sense. When creating geons we act independently from administrative boundaries. Rather we transform continuous multidimensional spatial information into regions both in dimensional as in real space. In parallel to the original geon concept of Biederman one can highlight (1) the role of generalisation; (2) the

significance of the spatial organisation of the elements (3) the possibility of recovering objects in the cases of 'occlusions' (here: data errors, measure failures, lack of data, mismatch of data due to bad referencing).
Similar concepts have been implemented in the urban arena as spatial units which are different from administrative boundaries and rely more on the urban morphology or physical variables (e.g. Number of floors of the houses, year of construction, construction material, width of the roads, etc.) and boundaries defined by the community. Their objective is creating a "zoom" over some areas increasing the accuracy to analyse problems and develop more suitable policies for resources investment.

3. First results of vulnerability modelling

In the context of the EU funded research project BRAHMATWINN (http://www.brahmatwinn.uni-jena.de/) a method has been developed to spatially model the socio-economic vulnerability to floods (Kienberger et al. 2009). The approach has been implemented in the Salzach catchment in Austria. The area is generally prone to floods as the Salzach River is one of the most regulated rivers in the Europe.
In an initial step, vulnerability has been defined following the IPCC (2001) specifications as "*the degree to which a system is susceptible to, or unable to cope with the adverse effects of climate change*" (Kienberger et al. 2009), but has been adopted to meet requirements to allow a practical implementation. Therefore vulnerability is defined as a function of sensitivity and adaptive capacity, whereas adaptive capacity constitutes elements of social capacity and resilience. Currently the integration of exposure as an inherent characteristic of vulnerability is not clearly defined and differs in current academic discussions. We see vulnerability as a 'continuous' spatial characteristic, whereas exposure can be derived as an intersection with hazard zones (such as HQ100) and the different vulnerabilities in the affected area. Therefore vulnerability is a general characteristic of an area and is defined by different domains (e.g. social, economic, environmental, physical etc.) and has to be assessed for specific scales. In this context we applied a basin scale approach.
The major aim has been the development of spatial vulnerability units (VulnUs), which represent a spatial homogenous region of vulnerability and follow the geon approach outlined above. Specific and suitable indicators have been identified together with local experts and stakeholders to describe the different elements of the vulnerability function. Data sources emerge from governmental spatial data infrastructures and the grid-based results of the Austrian census, which allow the spatial disaggregated integration of population data.

The method developed (Kienberger et al., 2009), allows the spatial and disaggregated representation of vulnerability independent from administrative units. The methodology intends to build on an established vulnerability concepts and applies and expert based approach, for instance through Delphi exercises, to weight and identify different indicators and domains. For a first aggregation, Multi-Criteria Evaluation methods are applied which are then integrated through a weighted regionalisation approach (Baatz & Schäpe, 2000) to derive the homogenous vulnerability units. Next to that, different domains and indicators can be decomposed such as the sub-domains of adaptive capacity and sensitivity. One critical point remaining is the validation of complex approaches such as socio-economic vulnerability. However, the approach developed is felt to be one step ahead to allow the monitoring of vulnerability over time in space and within domains, and to provide decision makers with policy-relevant information.

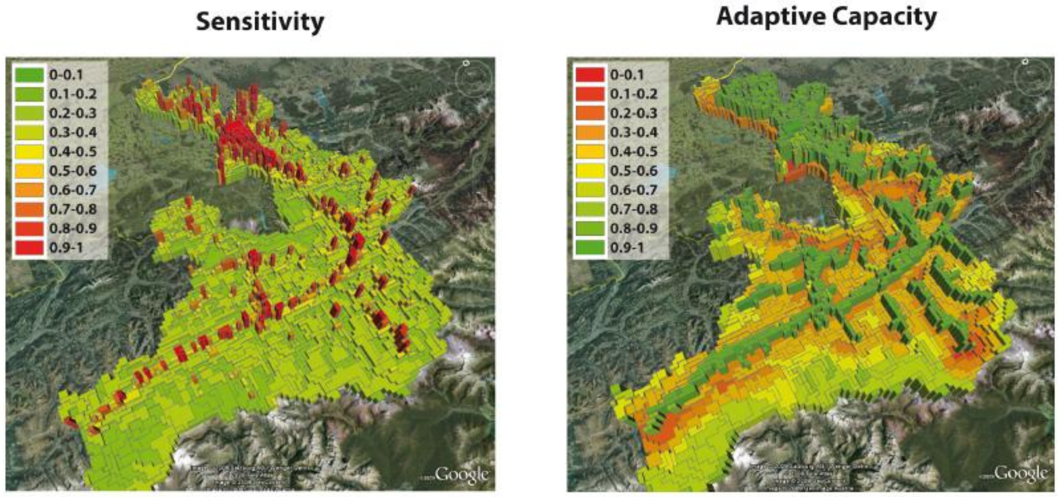

Figure 1. Showing the sensitivity and adaptive capacity domain of vulnerability (decomposability of the geon approach) (Kienberger et al., 2009)

4. Adaptation to different vulnerability concepts – Towards validation of concepts?

As mentioned above, commonly agreed concepts of vulnerability are still under way and could therefore not finally be validated. Having the results available from the first vulnerability modelling approach following an adapted IPCC version, currently new VulnUs are modelled applying a concept which has been developed in the EU FP7 research project MOVE (Methods for the Improvement of Vulnerability Assessment in Europe). To be able to carry out a possible calibration and validation process, the same methodology will be applied as it has been developed for the IPCC related approach. Also the possibility to undertake sensitivity analysis to identify how such changes in the parameters or structure of the conceptual model affect changes of the spatial distribution of vulnerability is now open. Following this notion we will discuss differences which are related to changes in concept and how they may be applied to validate them and their impacts on the model results.

A second issue being highlighted is the choice of the appropriate scaling factor and therefore ‘generalisation’ from smaller unit levels towards vulnerability regions. Scale factor is an integral part of the relationship between pattern and process (Wu et al. 2006) to be monitored and it should be a fundamental parameter to be included in the geon concept to guide the delineation of vulnerability units. The importance of the scale in vulnerability assessments relates to the fact that every natural phenomena have their own inherent scale and the results in the research studies will change if the scale also change (Wu et al., 2006)

As this methodology is developed to support policy decisions, we will highlight and discuss the issue of the ‘right’ scale factor whereas scale is defined “as a continuum through which entities, patterns and processes can be observed and linked” (Marceau, 1999). The observational scale should be set out according to the scale in which the process are going on, or intrinsic scales (Wu, et al., 2006) because only when scales of observation and analysis are right, the characteristics of the vulnerability assessment are detected correctly. Furthermore, other authors have suggested that it is necessary a multi-scale approach to understand the relationships between social variables and biophysical processes (Evans et al., 2002). However, one of the most difficult tasks in integrated assessment modelling is to determine the level of complexity required in a model and which components of the model require more or less complexity (Evans, et al., 2002) and how to aggregate or disaggregate the data to avoid problems as ecological fallacy or modifiable areal unit problem (MAUP).

5. Conclusions

As demonstrated in the already implemented modelling of VulnUs the geon approach seems to be suitable to model complex phenomena. However, validation of concepts and identified parameters is still an unresolved issue. Through the comparison of the two different concepts modelled under the same methodological framework possibilities for their validation is explored. The indicators obtained through the validation process will be retaken to monitor and asses process and results from the observance of the policies.

Scale factor should be a fundamental parameter to be included in the geon concept to guide the delineation of vulnerability units and should be suitable to fit the requirements of policy makers. To base decisions on the spatial distribution of vulnerability units may require the transformation of such concept-related *fiat* objects into *bona fide* objects reflecting more genuine discontinuities in space (Lang et al., in press). This, however, would require a very rigorous and unified concept of how to model and map (and measure?) vulnerability in a strong interdisciplinary context.

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