SOCIO-ECONOMIC VULNERABILITY TO FLOODS AND FLASH-FLOODS IN THE BEND SUBCARPATHIANS, ROMANIA

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ABSTRACT

The current study aims to assess the level of socio-economic vulnerability to floods and flash-floods (FF) in the context of environmental change, as well as in relation to the mitigation measures undertaken by local authorities to cope with these phenomena.

The study area is located in the Bend Subcarpathians (Romania), a region recognized for its high tectonic mobility and dynamics of hydro-geomorphic processes (e.g. floods and flash floods, landslides). The case study area was significantly affected by FF events (e.g. 1975, 2005, 2010), with a high impact on rural settlements in terms of significant losses to their assets. A system of socio-economic vulnerability indicators, developed within the VULMIN project, have been used to assess the socio-economic vulnerability to floods and FF impact at the level of rural settlements (LAU2 level), including social indicators (e.g. human capital, accessibility, livelihood conditions), as well as economic indicators (e.g. economic well-being).

Keywords: Bend Subcarpathians, index of socio-economic vulnerability, response and adaptation to floods

INTRODUCTION

The extreme hydro-meteorological events (e.g. heavy rainfalls and the resulted floods and flash-floods), are of major concern for local communities worldwide due to their high return period (1-5 years) with significant impact on society and environment. Their increased occurrence and magnitude influences population response, which becomes limited to individual measures (e.g. buildings consolidations and household relocations), especially in the rural communities with a low adaptive capacity. It is also the case of the human settlements located in the study area, the Bend Subcarpathians (Romania), a region recognized for its high tectonic mobility and dynamics of hydro-geomorphic processes. During the last years, several FF events occurred in the region (e.g. 2005, 2010), with a high impact on local communities in terms of significant losses to their assets. Therefore, the present analysis, conducted within the framework of VULMIN project (*Flood vulnerability of settlements and environment in Romania*

within the context of global environmental change, http://www.igar-vulmin.ro), focuses on the assessment of the socio-economic vulnerability to floods and FF for the settlements of two counties located the Bend Subcarpathians, Prahova and Buzău (Fig. 1), where natural hazards, including floods and flash-floods represent a high environmental threat for local communities and which require adequate measures for mitigation and adaptation. The reasons for which this approach was undertaken and the two Subcarpathian counties selected are based on the following arguments: a) the area is highly prone to slow-onset floods, specific for many of the medium- and large-size Subcarpathian river basins, but also to flash floods, the most common hydro-meteorological hazard in the area meeting favorable triggering conditions (e.g. small catchments, steep slopes, high relief fragmentation, low duration heavy rainfalls, etc.), and b) it conveys a representation of socio-economic vulnerability at the further scale of a 'household' analysis conducted in the area [1], by providing a composite vulnerability index at commune level and, thus, serving decision-making process, particularly in terms of funds allocation and mitigation measures.

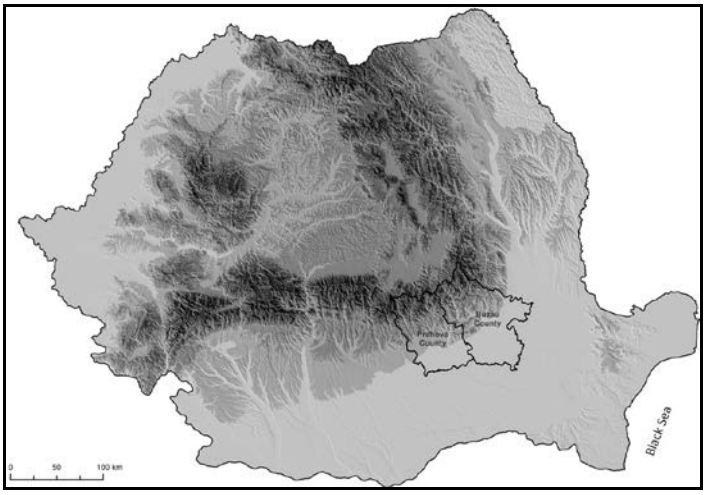

Fig. 1. Study area position in Romania

CONCEPTUAL FRAMEWORK

The VULMIN conceptual framework is consistent with the current international approaches of vulnerability [2] and defines the human settlements vulnerability to floods not only by their potential exposure to such extreme events, but also by their socio-economic and cultural characteristics, which are influencing the level of potential impact (sensitivity) and their ability to cope with consequences of the floods (adaptative capacity) [3]. The assessment of vulnerability to natural hazards is still a challenge to the scientific community and various qualitative and quantitative approaches have been proposed so far. The present tendency is to include multiple dimensions of vulnerability (social, economical, physical and cultural dimensions) in holistic approaches, such as the MOVE Framework - *The Methods for the Improvement of Vulnerability Assessment in Europe* [4] and KULTURisk Framework (SERRA – *Socio-economic regional risk assessment*) [5]. Preparedness, response and adaptation are integrated in vulnerability assessment, the need to understand the context in which extreme events are causing

extreme impacts being stated by international bodies and organizations such as IPCC [6] and UN (*Sendai Framework for Disaster Risk Reduction 2015-2030*).

Assessment of vulnerability raises the question whether measuring vulnerability is a feasible approach, given that vulnerability is not a directly observable phenomenon, but a theoretical concept [7]. In this context, operationalising the concept of vulnerability (i.e. translating the concept in terms of observable phenomena) is considered an appropriate approach, rather than the actual measurement of vulnerability.

The use of indicators is one way to operationalize the concept of vulnerability. Recently developed indexes of vulnerability to floods [8], [9] integrate a variable number of indicators, targeting both those characteristics of the systems which are increasing sensitivity and thus accentuate the impact of floods, as well as features that improve response and adaptive capacity, reducing vulnerability to floods.

METHODOLOGICAL APPROACH

In the present research, the index of socio-economic vulnerability to flood and flash-floods ($I_{SEV\text{-}FF}$) was developed over several phases:

1. Selecting the set of VULMIN indicators. The main challenges in establishing the selection criteria for vulnerability indicators are determined by the multiple dimensions of vulnerability to natural hazards that need to be considered, related both to the local context of the analyzed systems and to external factors that could influence vulnerability (e.g.: institutional factors; political, socio-economic or environmental changes at national or regional scale). On the other hand, selecting indicators should take into account uncertainties: the set of indicators is developed given the likelihood of extreme events, the potential impacts and the potential response of the affected systems. In other words, based on the current state of the system, the set of indicators provide information about its future state [10]. The VULMIN vulnerability indicators were also selected in order to ensure comparability of the results, either at temporal scale (how the vulnerability of a system evolves over time) or at spatial scales. Another criterion was to choose indicators appropriate to the users' profile (decision makers and local communities), thus indicators that can translate a complex context in simple terms.

Table 1 depicts the selected indicators used in the assessment of socio-economic vulnerability (SEV) to floods and FF, their unit of measurement and their assumed influence upon the constructed index. Two major categories were considered as basic criteria for the selection of the indicators, namely, the *social dimension* (i.e. it includes indicators reflecting the population structure, living conditions and education), the *economic dimension* (i.e. it is linked to the population well-being and economic development context).

They express the endogenous characteristics of a region or area and determine its regional adaptation potentials. Generally, it is considered that different development-levels of regions (characterized both by diverse physical infrastructure, as well as socio-demographic and economic characteristics) correspond to different levels of response and adaptation potentials of the region [11].

Table 1

VULMIN indicators of socio-economic vulnerability to floods and flash-floods

Dimensions of vulnerability to floods	Evaluation criteria	Subcriteria	Indicators	Influence on socio-economic vulnerability
Social	Human capital	Health	I1. Number of doctors per 1000 inhabitants	↓
		Education	I2. Gymnasium graduates (% in total number of children aged 11-14)	↓
		Age	I3. Children (under 10 years of age, % in the total number of inhabitants)	↑
			I4. Elderly (over 75 years of age, % in the total number of inhabitants)	↑
		Ethnicity	I5. Roma (% in the total number of inhabitants)	↑
	Accessibility	Transportation network	I6. Road density (km/km^2)	↓
		Clean water supply	I7. The amount of drinking water supplied to consumers (thousand m^3 per capita)	↓
Economic	Economic well-being and economic development	Income level	I8. Herfindahl-Hirschman Index (HHI)	↑
			I9. Unemployed people (% in the active population)	↑
		Dependence on agriculture	I10. Agricultural employees (% in the total working population)	↑

Note: ↓- high values of indicators correlate with low levels of SEV; ↑ - high values of indicators correlate with high levels of SEV

High values of some of the indicators are related to a high potential impact of floods and, consequently, high levels of socio-economic vulnerability. The socio-demographic vulnerable groups generally have a limited response capacity to floods, raising issues of evacuation difficulties (children, elderly), little or no access to insurance systems, difficult relationship with the authorities and low income level (Roma ethnics). On the other hand, high values of variables reflecting access to health services, education and and adequate physical infrastructure of the areas (accessibility and the existence of the water supply facilities, critical in terms of evacuation and preventing post-floods epidemics) are usually related to high levels of response and adaptive capacity, thus to low levels of socio-economic vulnerability.

The economic structure of an area has an important influence in the socio-economic vulnerability analyses of regions as it is a strong determinant of the potential response and adaptation to the impact of an extreme event. In this respect, it is considered that a diverse economy with low levels of unemployment is associated to increased levels of productivity which in turn leads to increased competitiveness, the tertiary sector being usually the driver of growth. In such cases, the regions are better prepared to respond to the consequences of extreme events and show higher potentials of adaptation than specialized regions whose economic mechanisms of growth are limited by such factors as lack of entrepreneurs to ensure further investments and growth [11].

To express the economic status of the analyzed region in terms of its relevance to socio-economic vulnerability evaluation, the Hirschman-Herfindahl Index (HHI index) was used. This index aggregates the regional (LAU level) employment shares, showing the sectoral concentration of the economic activities. However, in terms of the economic condition of the households in the rural areas, their economic profile is still largely dependent to a high extent on agricultural incomes and show increased vulnerabilities to effects of natural hazards.

The final step in selecting vulnerability indicators was the evaluation of the multicollinearity among the indicators in order to avoid the overestimation of the index. In the present study, the multicollinearity was checked by Pearson correlation coefficients and subsequently were selected those indicators that are less correlated among each other. Population over 75 years of age and the share of agricultural employees out of the total working population were initially considered as indicators but were dropped from the analysis due to their strong correlation with population under 10 years of age, and with HHI respectively. In this case, the indicator of population under 10 years of age can be used as a general determinant for vulnerable persons, while HHI can be considered as an overall expression of the economic status with relevance to the present assessment of the socio-economic vulnerability at the commune level (LAU2).

2. Building a database. To assess the socio-economic vulnerability of the rural settlements in the Bend Subcarpathians into a broader administrative context, data (based on the 2011 Census results) were collected for the counties of Prahova and Buzău entirely (LAU2 level, 188 settlements). In this way, it will be possible to highlight areas homogeneous in terms of SEV that might extend beyond the limits of the Bend Subcarpathians.

3. Data normalization. Before being integrated into an index, data on selected indicators were scaled to fit in the range [0.0, 1.0] using the min-max normalization technique. Two normalization formulas have been used, depending on the indicators' influence on SEV level:

$$Value_n = \frac{(Value_r - Value_{\min})}{(Value_{\max} - Value_{\min})} \quad (1) \quad \text{and} \quad Value_n = \frac{(Value_{\max} - Value_r)}{(Value_{\max} - Value_{\min})} \quad (2)$$

Indicators for which a higher value implies an increase of SEV (I3, I5, I8, I9) were normalized according to the formula (1)[1], and the rest of them, in whose case a higher value implies a decrease of SEV, were normalized using formula (2).

4. Integrating indicators in a single index. In order to calculate the index of socio-economic vulnerability to flood and flash-floods ($I_{SEV\text{-}FF}$), the normalized values of selected indicators were aggregated by addition.

RESULTS AND CONCLUSION

The results represent the construction of a synthesised vulnerability index by combining demographic, social and economic aspects of the localities of two counties situated in a specific environment in the Bend Subcarpathian areas, Romania.

The spatial distribution of the socio-economic vulnerability index highlights on the one hand the regional disparities in the analysed area and, on the other, different degrees of adaptation potentials (Fig.2). The lowest values of the vulnerability index (< 3) are associated with the most affluent area in the region, specifically the well-known tourist zone "Valea Prahovei" (i.e. western part of the study area, passing the high piedmont plain of Ploieşti, the Subcarpathian structures up to the Bucegi Mts. in the north, and following the way from Bucharest to Braşov, one of the most travelled route). It includes the county town of Prahova (Ploieşti) as well as Câmpina town both benefitting from a rather diverse economy, low levels of unemployment and good infrastructure facilities, and Sinaia, Azuga and Buşteni mountain resorts whose tourism activities contribute a growing economy. Likewise, the connecting localities along this route also display low values of the vulnerability index, suggesting, at the same time, the polarizing character of the mentioned towns. On the contrary, in the eastern neighbouring county (i.e. Buzău County) only the county town, Buzău (which is located in a piedmont plain area), shows low levels of vulnerability being a consequence of its status, as it concentrates services, administrative, financial and education activities. The adaptation potential in these areas is considered high and most of the local communities resilient to extreme events.

The eastern part of the Prahova County, including the mountain localities of the Ciucaş and Tătarului Mts. (in the eastern part of the South Romanian Carpathians) as well as the localities in the Subcarpathian area in both analysed counties display medium-high values of the vulnerability index (3.75 – 4. 00). Many of the localities situated in the Subcarpathian area of the Buzău County as well as the communes surrounding the Buzău town and those located in the northern part of the Bărăgan Plain (south Romania) fall in the same category. These rural areas show a high degree of concentration of the agriculture activities and an ageing population facing a low economic power.

Higher values of the vulnerability index (4.00 – 5.00) are met in the areas at the contact at the two counties, in the Subcarpatians and piedmont plain, as well as in the Câmpia

[1] $Value_n$ = normalized value, $Value_r$= indicator's value to be normalized (real value), $Value_{min}$= minimum value of series, $Value_{max}$= maximum value of series

Gherghiţei (south of the Prahova County) and in the Bărăgan Plain (south of the Buzău County). Likewise, several communes in the eastern part of the Buzău County show high values of socio-economic vulnerability.

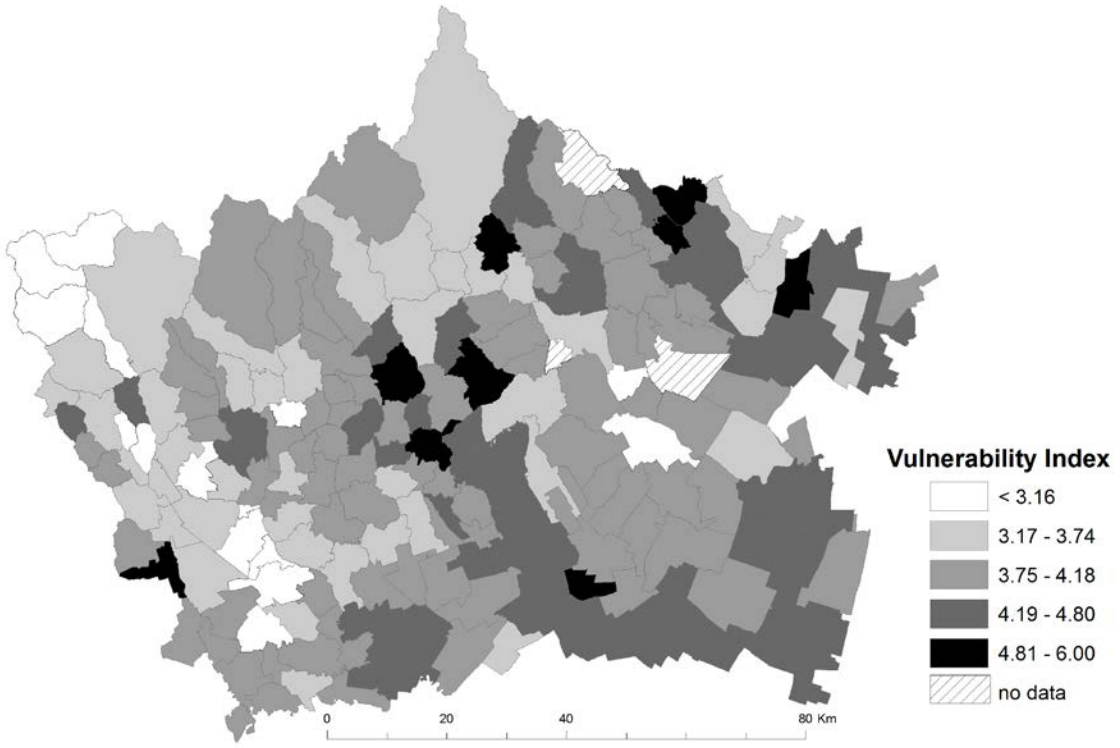

Fig. 2. Map of the socio-economic vulnerability index to floods and flash-floods in the Bend Subcarpathians, covering Prahova and Buzău counties, Romania

These settlements are small-sized rural localities, affected by depopulation and ageing processes, isolated from urban areas. Worth mentioning that the rest of the towns in the Buzău County, e.g. Nehoiu, Râmnicu Sărat, do not display high potentials of adaptation due to their declining economic capacity, while the mountain localities of the Buzău Mts. (north of the Buzău County) show a relatively low values of the index as a consequence of the good connectivity towards the neighbouring counties in the north (Covasna and further on Braşov) as well as of the tourism increasing sectoral profile. Highest values of the vulnerability index are sparsely met in several isolated rural communes of the Buzău Subcarpathisns.

The regional disparity shown above through the socio-economic vulnerability index in the analysed counties comply to a large extent with other case-studies on natural hazards and social evaluations undertaken in this Subcarpathian area [12], [13].

The present assessment provides a better understanding of the socio-economic factors related to critical adaptive capacity levels to floods and FF, and also ensures a theoretical basis in identifying priority areas in terms of intervention. The management aspects related to natural hazards governance require consideration on the potential consequences of climate change, focusing on increased awareness and preparedness of local people in front of extreme events, such as flash-floods, as well as on a stronger cooperation among the public institutions involved in the management of natural hazards events.

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