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Vulnerability assessment methodology: A tool for policy makers in drafting a sustainable development strategy of rural mining settlements in the Apuseni Mountains, Romania

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ABSTRACT

Mining settlements are hierarchically integrated in a system of localities at local, county, micro-regional, regional, national, European and even global level. Therefore, this study has a holistic approach to understanding and analyzing the territorial, social, economic or environmental regeneration and development processes as well as the vulnerability degree of selected mining settlements of the Apuseni Mountains located in the north-western part of Romania. The paper has a twofold purpose. First, it aims to contribute to the ongoing process of geographical and environmental research conducted in Romania by proposing new methodologies developed based on available data and an in-depth analysis of the local issues by linking regional, national, and international models. Second, it aims to facilitate the decision-making process by developing a tool useful in the planning and sustainable development of the Apuseni Mountains at multiple scales (local, county and regional). In order to address current challenges faced by the selected area, the authors propose a novel calculation methodology for the vulnerability of the mining settlements and use GIS technology to elaborate a geospatial database and vulnerability map of the mining villages. Correlated data provided a vulnerability assessment method for rural settlements that might help facilitate the identification of feasible sustainable development solutions and serve as a tool for policy makers in drafting an integrated sustainable development strategy. The results reveal the importance of an integrated approach of the vulnerabilities occurring in rural settlements, especially the mining ones.

1. Introduction

The Apuseni Mountains area has gained attention and world media coverage over the past few years due to the Rosia Montana Project. Discussions have been carried out regarding possible environmental, economic, demographic, or patrimony changes that might occur as a consequence of the modern mining project. Many questions have been answered (satisfactorily or not) by the Rosia Montana Gold Corporation

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and are available on their website, especially those addressing increasing concerns about the vulnerability of the area to possible environmental hazards. Even though this present study includes the Rosia Montana area of the Apuseni Mountains, the authors chose to address the vulnerability of all the rural settlements formerly reliant on mining activities and located in the Apuseni Mountains area because of the complexity of the economic and social changes that took place here over the past 25 years. Starting from the premise that ''vulnerability is registered not by exposure to hazards (perturbations and stresses) alone'' – in our case the effect of the mining activities on the natural environment and the local population-, but also ''resides in the sensitivity and resilience of the system experiencing such hazards'' (Turner et al., 2003), namely the coping strategies of the local population and the national and local governance during the periods of reconversion, this paper calculates and analyzes the vulnerability degree of the rural settlements located in Alba County based on the conditions and processes resulting from ten carefully selected factors or aspects.

The current literature includes over 25 different definitions, concepts and methods of vulnerability analysis (Birkmann, 2007). Vulnerability is defined by ISDR (2004) as a set of ''conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards.'' The physical factors (spatial distribution and quality of the built-in environment) may be represented by factors such as: population density, distance to/from a settlement, quality of construction materials and of the techniques used to build the infrastructure.

In addition, vulnerability represents one of the components of *risk*, along with *hazard* and *exposure*, each of these being in turn closely connected to the three large elements of the geographical space: *nature*, *society*, and *territory*. Based on the elements that define rural settlements (built-in area, population and land), the typology of rural settlements in the selected area was established according to three predetermined criteria, namely: socio-economic characteristics of the area within the village limits (especially the built-in area of the village), population size, and functions of the land located outside the village limits.

The vulnerability of human settlements has been extensively studied nationally and internationally (Sorocovschi, 2010; Surd et al., 2007; Birkmann, 2007; Adger et al., 2004; Alasia et al., 2008; Cannon, 1994; Dwyer et al., 2004; Anderson, 2000; Ozunu and Botezan, 2012). Research regarding various methodologies of assessing vulnerability (be it social, economic, ecological) were conducted in the last decades by various authors (Knox, 1980; Luers, 2005, Luers et al., 2003; Fedeski and Gwilliam, 2007; Wilhelmi and Morss, 2013; Zabeo et al., 2011; Das et al., 2012; Plummer et al., 2013). A thorough review on vulnerability assessment methods is given by De Lange et al. (2010). Based on Turner et al. (2003) framework for vulnerability analysis in sustainability science, the concept of *resilience*, defined as the ability and capacity of a system to ''bounce back'' and ''maintain certain structures and functions'' despite ''disturbances'' has been also considered in this study as a critical component of analysis.

The focus of this study is to gain an in-depth understanding of the way(s) rural mining settlements located in the Apuseni Mountains cope and respond (resilience), and adjust and adapt to exposure beyond the political, institutional, and socio-economic restructuring, all within a larger European context.

In presenting this vulnerability framework for a mining area of major national and international importance, the authors suggested a simplified assessment of the critical components that may increase the area's vulnerability to hazards if appropriate institutional structures and certain stakeholders are not actively involved.

2. Materials and methods

The complexity of economic and social processes occurring in Romania during the last decades has determined changes and disturbances of the urban and rural environment. The rural settlements in the mining area of the Apuseni Mountains are no exception, especially after the restructuring of the Romanian mining sector following the 1989 social unrest. As a matter of fact, the entire Romanian industrial system underwent a rapid restructuring process in the first 3–4 years after 1989 by the closure of a large number of inefficient plants and industrial units (Marinescu et al., 2013).

Usually, the evolution and characteristics of human settlements are closely related to the predominant economic sectors. In particular, mining activities imprint the villages a special physiognomy, usually negative. In this paper the researchers started from the assumption that in order to develop a vulnerability framework for the Apuseni Mountains one should consider vulnerability as the dominant feature of a mining area, both during mine operation, and after mine closure. Consequently, the implementation of adequate sustainable development actions to mitigate the negative effects of mining activities by the decision makers is unlikely without a correct assessment of the vulnerability degree of settlements based on a complex approach of the determinant factors. Therefore, quantifying the vulnerability degree of a mining area (and implicitly of the component settlements) based on the indicators included in the mining settlements vulnerability assessment scoring grid represents the first step in the planning process when trying to identify adequate solutions for sustainable development. This way, the priority domains (that may differ based on the type of settlements and their dominant features) in need of major interventions may be identified, thus facilitating the decision making process for the achievement of the short-, medium-, and long-term objectives.

2.1. *Data collection*

The sampling frame for this research includes the mining areas in the Apuseni Mountains (NW of Romania) selected based on pre-determined criteria. The administrative criterion was of primary importance, but other basic criteria such as metallogenetic features and the past or present existence of mining activities of extracting the ferrous and non-ferrous metalliferous minerals were considered as well. The delineation of the mining areas in the Apuseni Mountains was based on the detailed analysis of settlements, considering parameters such as metallogenesis (districts, metallogenic fields or knots), site accessibility, type of mining activities (mining perimeter and exploitation, types of mined ores), as well as other geographic particularities. Based on these characteristics, the administrative–territorial units containing mining settlements were identified and grouped in 11 mining areas. These areas were also classified according to the dominant type of the mined ore. Of these, seven areas host gold-silver and polymetallic ores and are located in the Gold Quadrilateral (Alba and Hunedoara counties), two sites involve iron ores mining (Cluj county), one mining area hosts uranium (Alba and Bihor counties) and one site is for bauxite mining (Bihor county) (Fig. 1).

The restructuring of the mining sector in Romania has caused mass layoffs, implicitly followed by decreased purchasing power. The issue of localities seriously affected by mine closure has represented a priority of the Romanian Government, resulting in several disadvantaged areas being declared at national level. The regime of *disadvantaged areas*, as regulated by Romanian legislation (Romanian Government, 1998; Romanian Parliament, 1999), defines them as those geographical areas included in one or several administrative–territorial units (ATUs) and meeting at least one of the following requirements:

- ATUs with productive mono-industrial structures, mobilizing more than 50% of the employed population;
- ATUs which are mining areas where the personnel was made redundant and reduced to more than 25%;
- ATUs where collective redundancies were conducted after the liquidation, restructuring or privatization of some economic operators affecting more than 25% of the employees residing in the respective area;
- ATUs where unemployment rate exceeds the average national value by 30%;
- ATUs located in remote areas, without means of communication and with a very poor infrastructure.

Many of the mining areas included in the current research overlap some disadvantaged areas. The following areas in the Apuseni Mountains have been declared disadvantaged by the Romanian Government: Brad mining area (15 rural settlements), Apuseni mining area (12 rural settlements), Stei–Nucet mining area (three rural settlements), Borod – Şuncuiuş – Dobreşti – Vadu Crişului mining area (four rural settlements) and Popeşti – Derna–Aleşd mining area (only the town of Aleşd is located in the Apuseni Mountains).

More recent regulations (Romanian Government, 2001) have replaced the "disadvantaged areas" notion with that of "industrial restructuring areas". In addition, the conditions necessary for the declaration of a disadvantaged area were drafted and regulated (Romanian Parliament, 2004), some of which are mentioned below:

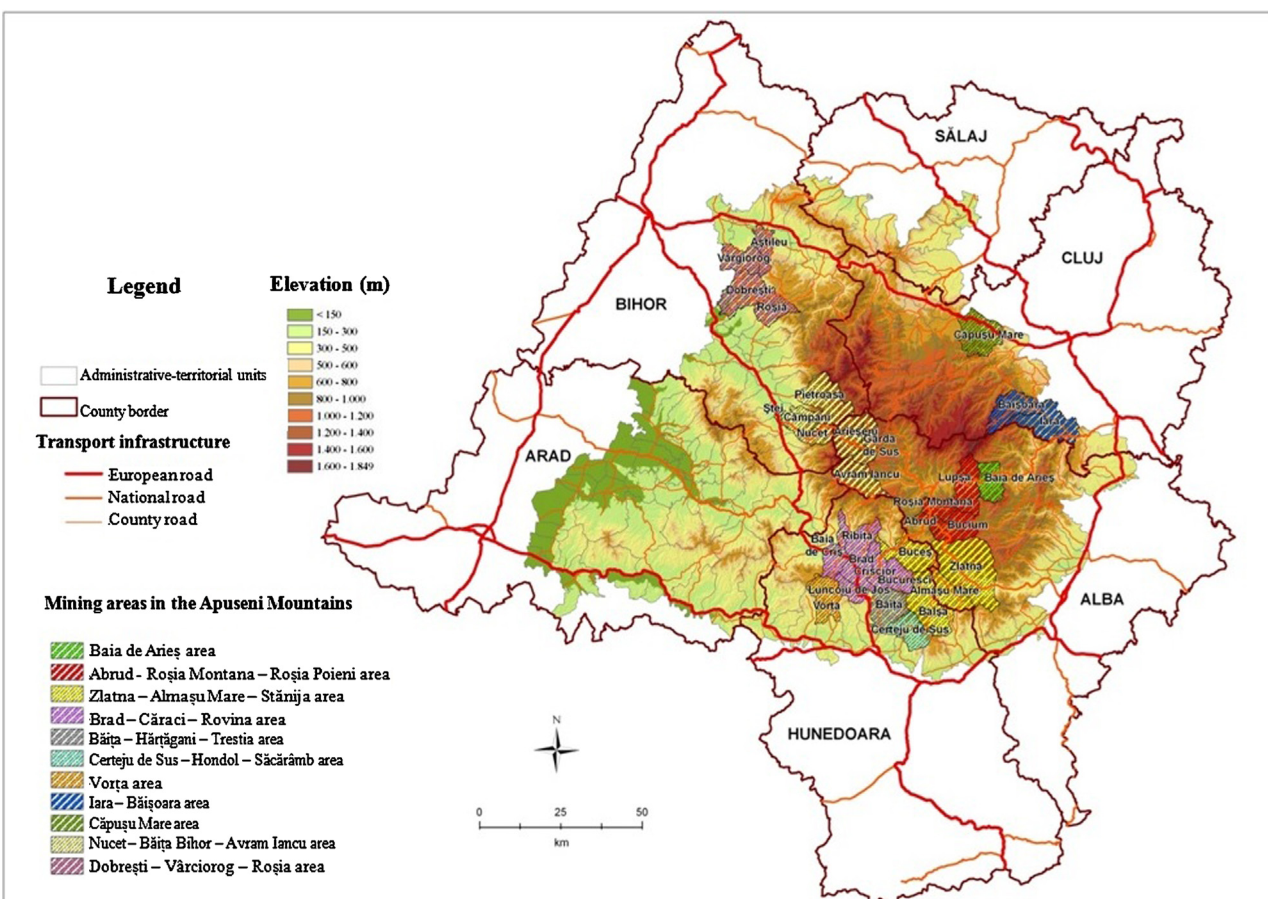

Fig. 1 – Location of the settlements in the Apuseni Mountains mining areas.

- the percentage of the unemployed in the total number of labor resources is 3 times higher than that of the unemployed, during the last 3 months preceding the month when the disadvantaged area documentation was drafted;
- these are remote areas without means of communication and with a very poor infrastructure.

The Central and Southern part of the Apuseni Mountains in Alba county: Zlatna–Ponor area was identified as ‘‘severely disadvantaged’’. Geographically speaking, this severely disadvantaged area partially overlaps the 3 mining areas subjected to this study: Baia de Arieş mining area, Abrud – Roşia Montana – Roşia Poieni mining area, and the Zlatna – Almaşu Mare–Stănija mining area.

Starting from the premise that the physiognomy and specificity of the mining rural settlements are dictated by the exploitation activities of the mineral resources and that this induces a series of risks upon the components of a mining settlement, a classification of risks was attempted according to 3 essential periods in the life of a mine:

- the period of mining activities (regardless of the intensity of mining activities, economic profitability, mining technologies used etc.);
- the period of restructuring and closure of mines and related activities;
- the post-mining period, immediately following the cessation of the mining activities.

Depending on the three above-mentioned periods, the dominant risk was identified, which by its nature may generate a series of risks, vulnerabilities, and hazards, as illustrated in Fig. 2.

Without intending to make an exhaustive approach of risks induced to mining settlements, this classification has the purpose of identifying and reviewing those risks that might occur and have negative short-, medium- and long-term effects. The above-mentioned criteria may directly influence the basic stages in the evolution and development of a settlement. However, this inventory of risks only includes the aspects determined or influenced by the mining activities,

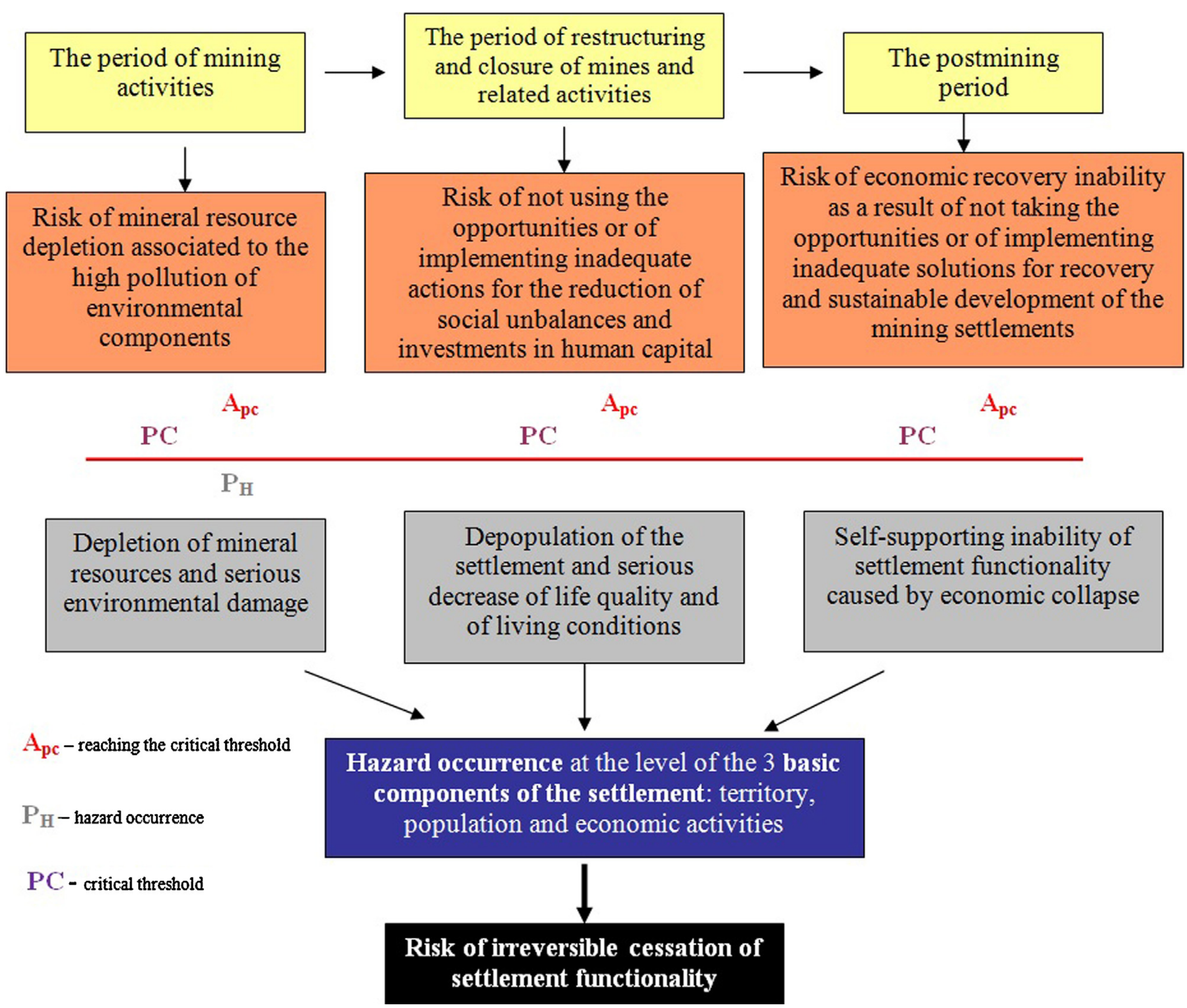

Fig. 2 – Dominant risk depending on the 3 important stages in the evolution of a mining settlement and the consequences of a hazard occurrence.

while a complex analysis of the risks induced to mining settlements should also consider the typology of additional risks. Despite the existence of several other papers where social, economic, and environmental risks as pertaining to the mining areas of the Apuseni Mountains have been previously studied (Surd et al., 2007; Muntean and Constantin, 2009; Ştefănescu et al., 2011, 2013; Levei et al., 2011, 2013; Moldovan et al., 2013; Ozunu et al., 2009; Forray, 2002; Forray and Hallbauer, 2000; Florea et al., 2005; Bird et al., 2005; Costan et al., 2010), this paper is unique in its approach to addressing such limitation. Thus, the study pursues to achieve a complex image of vulnerability of mining settlements taking into account their dynamics and evolution. Therefore, the three major stages of a mining settlement correspond to different vulnerability typologies.

2.2. *The vulnerability assessment methodology of mining settlements*

The mining settlement vulnerability calculation methodology was based on:

- the analysis and prioritization of aspects influencing directly or indirectly the balance, evolution, and sustainable development of settlements;
- the identification of sets of relevant statistical indicators depending on the above-mentioned aspects and the relations between these indicators;
- the establishment and rationale of the value classes which set the basis for the quantification of the mining settlements vulnerability degree;
- the validation of the assessment method, based on the mathematical formula of the vulnerability degree of the rural settlements from the Apuseni Mountains in the Alba county.

When proposing a vulnerability assessment method for the settlements, we started from the mathematic formula for risk calculation, as proposed by Crichton (1999):

$$R = H * E * V \quad (1)$$

where R is risk, H is hazard, E are the exposed elements, and V is vulnerability. This equation shows that vulnerability is the ratio between risk and the product between hazard and the exposed elements.

Considering the major differences between the urban and rural settlements, this paper proposes a vulnerability calculation methodology for rural settlements. Future research is intended to approach vulnerability in urban areas. The choice of rural settlements was motivated by the specificity of the Apuseni Mountains from the perspective of economic activities, of the predominantly rural space, and of the predominant type of population (the high percentage of residents located in the rural areas).

The first step was setting up the context and framework for the identification of relevant indicators for the proposed calculation method. Therefore, a set of four relevant and pragmatic questions was used to develop the formula needed to assess the vulnerability of mining settlements in order to facilitate the identification of sustainable development solutions. These questions and their answers are:

- Question 1: What is the main purpose of applying the mathematic formula for the vulnerability assessment of the rural settlements (particularly of the mining settlements)?

  Answer: To assess the vulnerability of a number of rural settlements in order to identify future trends related to sustainable development based on development policies at the national and European level.

- Question 2: What are the basic elements analyzed in terms of vulnerability?

  Answer: Vulnerability will be assessed for all basic components of a rural settlement: territory, population, economic activities, and environment.

- Question 3: What is the main objective of applying the mathematic vulnerability assessment formula for a rural settlement?

  Answer: To facilitate the decision making process within the local public administration by prioritizing the actions and allocation of financial resources. Depending on the vulnerability degree (very low, low, medium, high or major) in terms of the four components mentioned above, integrated projects can be developed and implemented for vulnerability mitigation and sustainable development.

- Question 4: What is the basic principle in developing the calculation methodology for the vulnerability assessment of rural settlements?

  Answer: To provide an overview of the vulnerability degree of a rural settlement through an integrated approach of its components and to define the relations between these indicators based on the cause–effect principle.

Consequently, a summarization of the main associated elements was conducted while taking into account the 3 basic elements in the analysis of vulnerability (risks, hazards and exposed elements). Therefore, risks may be: natural, technological, demographic, environmental, social, economic, administrative, associated to community behavior, or induced by the lack of accessibility. At the same time, hazards may be: natural, environmental, technological or economic. The exposed elements are: the territory, the population, the economic activities and the environment.

Due to the complexity and dynamics of the rural settlements, vulnerability was determined based on the conditions and processes resulting from 10 factors or aspects, among which the most important are:

- Geographical factors
- Aspects related to public infrastructure
- Aspects related to accessibility
- Demographic factors
- Social factors
- Decision-making and administrative factors
- Psychological and motivational factors
- Economic factors
- Environmental factors

- Restrictive aspects in the sustainable development process.

The starting point for the formula is the following

$$\frac{\sum_{i=1}^{n} F_i}{n} \quad (2)$$

where, n = the number of indicators specific to each factor (e.g. for F1, $n = 5$; for F2, $n = 4$; for F3, $n = 10$, etc.); F = the determinant factor for vulnerability; i – the indicators specific to each factor.

In this context, n is a fix variable, i.e. for factor F1 there are five indicators, for factor F2 there are four indicators, for factor F3 there are 10 indicators and so on (see Table 1).

$$V\_rur\_settlem = \frac{\sum_{i=1}^{5} F1_i/5 + \sum_{i=1}^{4} F2_i/4 + \sum_{i=1}^{10} F3_i/10 + \sum_{i=1}^{4} F4_i/4 + \sum_{i=1}^{3} F5_i/3 + \sum_{i=1}^{5} F6_i/5 + \sum_{i=1}^{7} F7_i/7 + \sum_{i=1}^{3} F8_i/3 + \sum_{i=1}^{5} F9_i/5 + \sum_{i=1}^{9} F10_i/9}{10} \quad (3)$$

where, F1, F2, . . ., F10 – the determinant factors of vulnerability (10 types of important factors have been identified); i – the indicators specific to each factor.

The proposed mathematical formula is an arithmetic mean where the numerator represents the sum of the arithmetic means of the 10 factors (each with its indicators), and the denominator is 10 (the number of factors). This is worth mentioning because it provides the opportunity to compare the results achieved for each particular factor in an objective manner.

A number of 55 indicators were used within the formula, each of these indicators being assigned some value ranges (Table 1). When choosing the 55 indicators, the authors considered the context and framework set up by the four research questions and answers which provided them with an overview of the most important aspects, starting from the purpose, role and expected outcomes of this vulnerability assessment methodology. The proposed indicators provide information both on the three major components of the settlement (territory, population, economy), and on the dynamics of the analyzed settlement evolution generated by social, psychological, political, administrative, and environmental phenomena. Depending on the measured indicators, the following weight is granted:

- If five value ranges are assigned to an indicator, then a weight from 1 to 5 is assigned, depending on the extent of vulnerability in each rural settlement: a.5p. (major), b.4p. (high), c.3p. (medium), d.2p. (low), e.1p. (very low);
- Value 4 is chosen if there is one negative aspect and value 1.5 is chosen if there is one positive aspect (these values were calculated as follows: for the negative aspect, the arithmetic mean of the values was calculated for ‘‘major’’, ‘‘high’’ and ‘‘medium’’, and for the positive aspect, the arithmetic mean was calculated for the values ‘‘low’’ and ‘‘very low’’).

Quantitative research design was used. The quantitative indicators chosen for the formula were obtained by applying mathematical methods (map analyses), closed-ended questions questionnaires (e.g. indicators for the psychological and motivational factors) or acquisition of quantifiable data from the decision-making factors at commune level. The statistical indicators were based on centralized data at ATU level in Romania.

The psychological and motivational factors were graded by questionnaires applied to the population in the study area (a sample of 20 persons/UAT). The attitude of the population regarding the community’s sustainable development process and the level of proactive community engagement was also obtained through a primary, cross-sectional survey. The questionnaire was drafted based on attributes such as attitudes, solidarity, cooperation, change, public engagement, opportunities, education and training, etc. Lastly, the Boolean data type was used for data interpretation with two possible values, true and false (in this case, affirmative and negative).

After applying the calculation formula presented above, the results obtained for each administrative–territorial unit in the rural area were processed using Table 2 below.

These results were also cartographically illustrated by means of the Geographic Information Systems technology in the commune vulnerability map (Fig. 3).

3. Results and discussion

As mentioned before, the Apuseni Mountains area, more particularly the rural settlements of Alba County, was selected for this study due to the presence of mining activities which lead to the hypothesis that this area might have a higher vulnerability degree.

Table 3 below presents the numeric values for a set of indicators used in the calculation formula of the rural settlements from the Apuseni Mountains in Alba county.

The values obtained for the administrative–territorial units in the case study area after the application of the vulnerability degree calculation formula based on the 55 indicators mentioned in Table 1, are presented in Table 4. The values of vulnerability degree obtained after the application of the formula ranged between 2.4 (Albac, Arieşeni, Gârda de Sus) and 4.8 (Ciuruleasa).

Results show that the highest degree of vulnerability is presented by the communes: Ciuruleasa, Avram Iancu, Roşia Montana and Lupşa. Intense mining activities have been developed in the communes Roşia Montana, Lupşa and Avram Iancu, and the regeneration of the mining sector has drawn serious social imbalances very difficult to overcome so far. A high degree of vulnerability was recorded by the commune Almaşu Mare, where mining exploitations were also identified, in addition to a series of communes that provided labor to mining settlements in the Apuseni

Table 1 – The indicators used for the analysis of the determinant factors in the vulnerability assessment of a rural settlement (complete data are given in Supplementary Material 1).

Factors	Indicators	Measuring unit	Sources and means for the measuring and validation of indicators	Value range for rating
1. Geographical factors	Type of relief specific to the settlement	Elevation (m)	Analysis of relief based on the elevation map	a. Flood plains (0–20 m) and high mountain areas (over 1200 m), b. remote mountain areas (800–1200 m), c. low mountain areas, plateaus or high hills (600–800 m), d. intramountainous depressions, low hills and plateaus areas, e. plains and depression areas
	The soil and climate potential analyzed based on the predominance of the soil types or classes depending on their fertility	%	Analysis of maps of the soil areas depending on the type or class	a. Predominance of soils from the protisoils, pelisoils, hidrisoils or umbrisols, b. predominance of soils from spodisols class, c. predominance of soils from the cambisols class, d. predominance of soils from luvisols class, e. predominance of soils from the molisols class (the most fertile soils, i.e. chernozem, leached chernozem, grey soils)
	The hydrographic network depending on the order with the smallest number (a small number, for example 1.2 indicates a superior hydrographic order)	Order	Analysis based on the map of the hydrographic network	a. Order 6 and higher b. Order 5, c. Order 4 d. Order 3, e. Order 1 or 2
	Distance between the commune center and the most distant locality	km	Analysis of the commune administrative–territorial map	a. >20 km, b. 15–20 km, c. 10–15 km, d. 5–10 km, e. <5 km
	Inexistence during the last 3 years of some natural phenomena with a negative impact on the settlement (drought, floods, landslides etc.)	Yes/no	Data provided by the commune local authority	x. no, y. yes
2. Aspects related to public infrastructure (derived from the equipment level)	Number of non-electrified dwellings	No.	Data from the Statistics Department of the Alba County	a. >50, b. 20–50, c. 10–20-, d., 5–10, e. <5
	Number of non-electrified houses	No.	Data from the Statistics Department of the Alba County	a. >50, b. 20–50, c. 10–20-, d., 5–10, e. <5
	Percentage of localities connected to the sewage system	%	Data from the Statistics Department of the Alba County	a. <50%, b. 50–75%, c. 75–90%, d. 90–95%, e. >95%
	Percentage of localities connected to the drinking water network	%	Data from the Statistics Department of the Alba County	a. <50%, b. 50–75%, c. 75–90%, d. 90–95%, e. >95%
	Percentage of localities connected to the electricity network	%	Data from the Statistics Department of the Alba County	a. <50%, b. 50–75%, c. 75–90%, d. 90–95%, e. >95%
3. Aspects related to accessibility (transport, information, education and health) ...				
4. Demographic factors ...				
5. Social factors ...				
6. Decision-making and administrative factors ...				
7. Psychological and motivational factors ...				
8. Economic factors ...				
9. Environmental factors ...				
10. Restrictive aspects in the sustainable development process ...				

Table 2 – Quantification of the vulnerability degree at commune level based on the result obtained after applying the calculation formula.

Value range	Type of vulnerability
<2.5	Low vulnerability
2.5–3.5	Medium vulnerability
3.5–4.5	High vulnerability
4.5–5	Major vulnerability

Mountains: Mogoş, Ocoliş, Horea, Sălciua, Bistra, Scărişoara, Întregalde and Poşaga.

By contrast, a low degree of vulnerability was found in the communes Albac, Arieşeni, Gârda de Sus and Meteş. Low vulnerability of the above mentioned communes is due especially to their potential and opportunities. Except for Meteş, all other three communes have both a natural and anthropic touristic potential and have attracted growing interest and tourist flow. Winter sports and ecotourism are the types of tourism that attract the largest number of tourists in the area. Meteş, the other commune with a low vulnerability degree, recorded during the past years significant development due to the very short distance to the Alba Iulia municipality (21 km) and Zlatna town (16 km), which led to its visible economic and touristic development.

Beside the overall value of vulnerability degree for each ATU, the specific values of each factor can be analyzed, due to the modular approach used in designing the mathematical formula. The arithmetic means of the indicators were suggested for each of the 10 factors, thus providing the opportunity to process the results as unbiasedly as possible. If, for example, high values of factors 2 and 3 are noticed (aspects related to infrastructure and accessibility), the decision-makers are compelled to draft policies and implement projects to improve mobility of local residents and accessibility of non-residents (tourists, investors, employees, etc.) by investing in infrastructure, thus leading to an increased quality of life and to the economic development of the locality.

The detailed analysis also revealed that all the components of a rural settlement are vulnerable, not only the population and the environment, but also the economic activities. Furthermore, the obtained results clearly demonstrate the importance of approaching the complexity of the rural mining areas vulnerabilities in an integrated manner. Regardless of the type of vulnerability, all components of a settlement may be affected both directly and indirectly. The more indicators are included in the analysis and the better the relations between them are analyzed, the better the vulnerability degree reflects more accurately the reality.

Dealing with indicators expressing dynamic social, economic and environmental phenomena, one should also consider the multitude and complexity of indicator cross-over effects. For example, a social problem that was identified pertaining to the lack of social capital was found to significantly contribute to an economic problem (more specifically to the increase of transaction costs). Social indicators with high rates such as the unemployment, illiteracy and poverty seem to correlate with low levels of public engagement in the decision-making

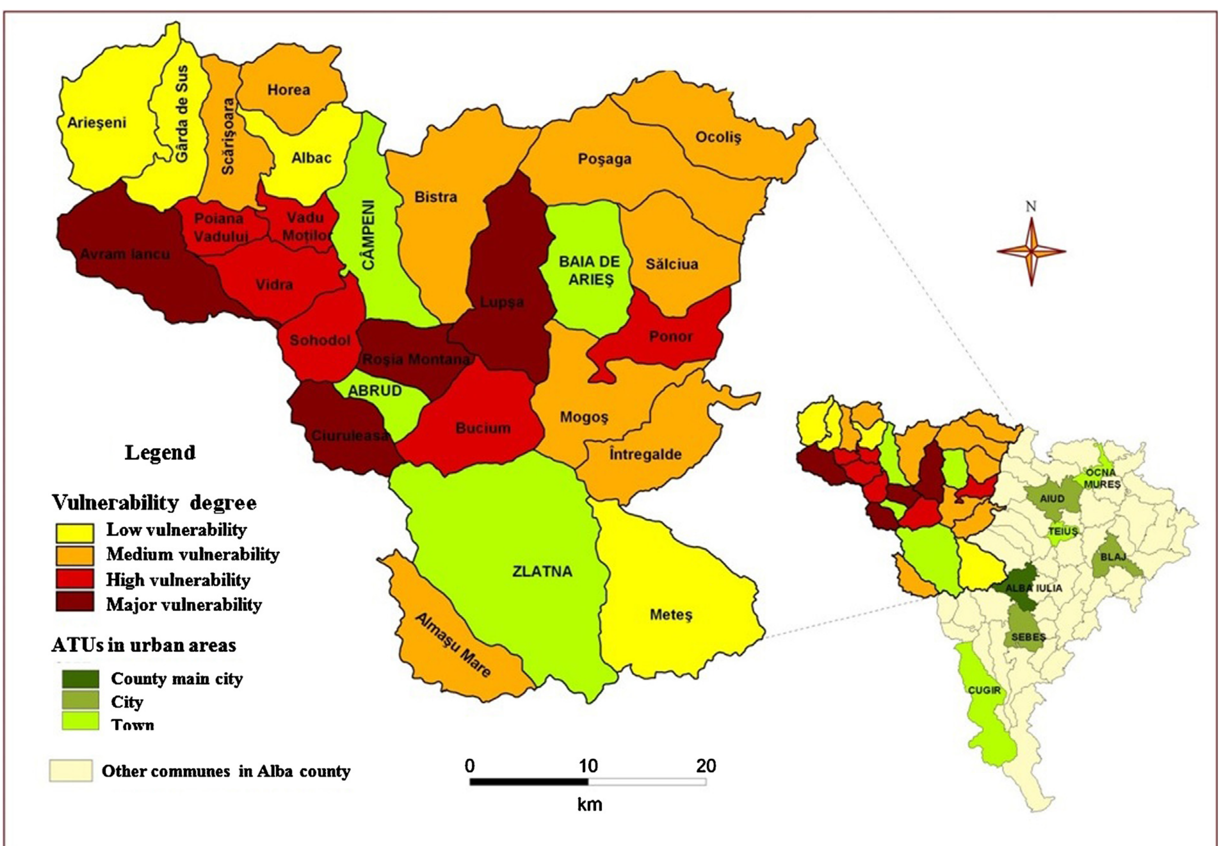

Fig. 3 – Vulnerability degree of communes in the Apuseni Mountains in Alba county.

Table 3 – Indicators used for vulnerability assessment of rural settlements (the equipment level and accessibility).

ATU	NOHou	TNL	DCount	NVWE	NHNE	PHNE	PHWS
Albac	772	16	90	0	0	0.00	31.25
Almaşu Mare	734	7	40	0	0	0.00	57.14
Arieşeni	736	18	110	1	17	2.31	0.00
Avram Iancu	905	33	100	1	16	1.77	0.00
Bistra	1600	35	82	0	0	0.00	0.00
Bucium	935	30	65	0	0	0.00	0.00
Ciuruleasa	496	9	70	0	0	0.00	0.00
Gârda de Sus	666	17	105	1	8	1.20	0.00
Horea	827	15	98	0	0	0.00	0.00
Lupşa	1324	23	82	1	1	0.08	0.00
Meteş	1090	12	15	1	6	0.55	0.00
Mogoş	546	21	85	0	0	0.00	0.00
Ocoliş	510	4	100	0	0	0.00	0.00
Poiana Vadului	415	11	107	0	0	0.00	0.00
Ponor	379	6	105	0	0	0.00	0.00
Poşaga	686	7	115	2	16	2.33	0.00
Roşia Montana	1518	16	80	0	0	0.00	0.00
Sa˘lciua	714	6	130	0	0	0.00	0.00
Sca˘rişoara	700	14	115	0	0	0.00	0.00
Sohodol	796	31	85	1	12	1.51	0.00
Vadu Moţilor	553	12	92	0	0	0.00	0.00
Vidra	797	39	90	4	15	1.88	0.00

Notes: ATU – Name_ATU_rural, NOHou – Total no. of houses, TNL – total no. of localities, DCount – distance to the county capital (km), NVWE – no. of villages without electricity, NHNE – no. of houses non-electrified, **PHNE** – percentage of houses non-electrified, PHWS – percentage of houses with water supply.

Table 4 – Numeric values of rural settlements vulnerability degree obtained after the application of the formula.

Rural ATU	Value obtained after the application of the formula	Vulnerability degree
Albac	2.4	Low vulnerability
Arieşeni	2.4	
Gârda de Sus	2.4	
Meteş	2.5	
Mogoş	2.9	Medium vulnerability
Almaşu Mare	3	
Ocoliş	3	
Horea	3.2	
Sa˘lciua	3.2	
Bistra	3.3	
Sca˘rişoara	3.3	
Întregalde	3.4	
Poşaga	3.4	
Bucium	3.6	High vulnerability
Vadu Moţilor	3.7	
Poiana Vadului	3.8	
Vidra	3.8	
Sohodol	3.9	
Ponor	4	
Lupşa	4.6	Major vulnerability
Roşia Montana	4.6	
Avram Iancu	4.7	
Ciuruleasa	4.8	

process, resulting in public decisions made by a minority of stakeholders whose actions are driven by personal interests. As stated by Kua (2007), failure to involve a wide range of stakeholders in the policy collaboration process leads to nonfulfillment of integrated sustainable development.

Local and regional governance issues may lead to social and environmental problems. For example, a greater negotiation power in terms of decision-making of some stakeholders (political stakeholders, mining companies) compared to others (local community, NGOs) may lead to decisions made to the detriment of the latter.

Considering the multiple dimensions of the vulnerability concept, the identification of the type of vulnerability is essential, in concordance with the clear objective of identifying the solution for the mitigation of its impact under the conditions of a certain risk, exposure or hazard etc.

4. Conclusions

In view of integrated development of the rural settlements, the current paper is applicative, providing an answer to an essential question in the planning process: to what extent are the rural settlements relying on mining activities vulnerable? Even a partial answer to this question would represent a step forward in the local and regional planning process and a significant source in identifying strategic sustainable solutions by the local authorities and other stakeholders.

Considering the multidimensional nature of the vulnerability concept and the challenges faced by Romania in collecting and monitoring a series of statistical indicators relevant for localities, the development of a mathematical formula to enable the quantification of the vulnerability degree of the rural settlements was a difficult, complex and carefully substantiated process. Therefore, in the end, a set of 55 relevant indicators was chosen to enable an integrated analysis of the rural settlements and their vulnerability. Moreover, the modular approach of the proposed formula for vulnerability calculation provides the opportunity to conduct a more in-depth analysis of each factor and its indicators and to identify the indicator cross-over effects.

Depending on the vulnerability degree of a rural settlement (low, medium, high or major), integrated projects for the vulnerability mitigation may be developed and implemented, providing the necessary strategic development framework for their sustainable development.

The theoretical and applied research, but also the field work conducted led to the conclusion that the vulnerability of rural settlements in the Apuseni Mountains (particularly those located in the Alba county) is determined especially by the intensification of the depopulation and demographic ageing phenomenon. Several other causes contribute to the vulnerability increase, such as the low degree of capitalization or limited access to information regarding the development opportunities. Another element would be the shallowness or negligence of the decision-making in relation to the rapid environmental degradation of the mining areas due to the existence of abandoned mining sites in an advanced state of decay or presenting numerous risks both for the environment and for the exposed population. The Roşia Montană case is distinct and noteworthy, as it involves a high degree of subjectivity, strongly influenced by the recent international media coverage.

The lack of sustainable development strategies in the study area is partially due to the failure to observe the "think global, act local" principle by the local authorities, who should adopt local policies and sustainability programmes in line with the global sustainability goals (such as improving health and education, poverty reduction, protection of the environment, etc.).

The combination of top-down policy guidance with a bottom-up stakeholder participation model is necessary in the Apuseni Mountains area to prevent unwanted prevalence of particular stakeholder groups (whether they have economic, social or environmental interests) and to avoid problem-shifting. In order to formulate viable sustainability strategies/policies at local level, all stakeholders should be correctly identified and the relations between them should be highlighted (mutual benefits/interests).

Although the region does not lack resources (natural potential, touristic potential, ethnographic heritage, crafts and traditional activities, etc.), these are very poorly used for the sustainable development of the area. Last but not least, a major cause of the high vulnerability is the mentality of the local population and authorities who need to learn a different way of thinking about the environment and of embracing ecological mentality through sustained effort and individual and collective responsibility.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.envsci.2015.05.010.

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