Resilience of Mining Communities to Long-Term Environmental Stress in the Apuseni Mountains Area (NW of Romania)

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Abstract
The vulnerability of mining communities is one of great interest to governments, mining companies, non-governmental organizations and other stakeholders, becoming an acute issue of current sustainable development strategies. The question how to address the vulnerability of these particular settlements and communities impelled us to analyze the concept of resilience in the sustainable development context. Resilience is to communities all over the world a dominant concept which plays an essential role in guiding their sustainable development policies and strategies. The purpose of this chapter is to identify the specific aspects of the "resilience" term applied to the context of vulnerable mining communities. The research includes the theoretical background of the resilience of mining communities and identifies the most relevant resilience building factors. The present study is particularly important since the recently adopted 2030 United Nations Agenda for Sustainable Development focuses on enhancing community resilience. The findings may set the basis for more in-depth analysis and field research to identify and address the factors that affect the mining communities' abilities to be resilient.

Keywords: resilience, vulnerability, mining communities, environmental impact, sustainable development.

1. Introduction

The "resilience" concept has multidimensional aspects, being used in various scientific disciplines, such as physics, risk management, and social sciences. Generally, resilience is defined as "the capacity of a system to absorb shocks and disturbances, while still maintaining the same functions, structure and feedbacks" (Walker & Pearson, 2007). The term was introduced in ecological systems by Holling in 1973, who defined resilience as "a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables" (Holling, 1973). Over the last decades, the concept was frequently used in disaster risk management, due to its meaning of returning to an original state and Coles & Buckle (2004) defined it as "community's capacities, skills, and knowledge that allow it to participate fully in recovery from disasters".

Starting from the resilience concept, the purpose of this chapter was set to identify the specific aspects of the term applied to the context of vulnerable mining communities. The research includes the theoretical background of the resilience of mining communities and identifies some of the most relevant resilience building factors.

To achieve this purpose, the authors find Ganor & Ben-Lavy's (2003) definition most appropriate to the specific research context: "the ability of individuals and communities to deal with a state of continuous, long-term stress; the ability to find unknown inner strengths and resources in order to cope effectively; the measure of adaptation and flexibility". Taking this definition as a reference point and considering the large differences between the urban and rural setting of a mining area, the best conceptual clarifications of resilience were searched for in the specific context of the mining settlements in the Apuseni Mountains, NW of Romania.

Analyzing the literature addressing the concept of urban resilience, the most relevant definition considered by the authors was that referring "to the ability of an urban system –- and of its constituent socio-ecological and socio-technical networks across temporal and spatial scales – to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity" (Meerow et al., 2016). In the disaster risk reduction framework, urban resilience is seen as "a sustainable network of physical systems and human communities, capable of managing extreme events; during disaster, both must be able to survive and function under extreme stress" (Godschalk, 2003).

In terms of rural settings, resilience is "the capacity […] to adapt to changing external circumstances in such a way that a satisfactory standard of living is maintained. This also includes the capacity to recover from management or government mistakes" (Heijman et al., 2007). By analogy to urban resilience (Colding, 2007; CSIRO, 2007) the rural resilience concept "determines the degree to which a specific rural area is able to tolerate alteration before reorganizing around a new set of structures and processes" (Heijman et al., 2007).

The 2030 Agenda for Sustainable Development which was recently adopted by the United Nations highlights the importance of enhancing community resilience, aiming at "making cities and human settlements inclusive, safe, resilient, and sustainable" (UNSDG, 2015).

2. Measuring and assessing urban and rural resilience

Any territorial, social or economic system defining an urban or rural settlement has certain levels of vulnerability, risk, adaptive capacities, flexibility and resilience, which define that particular system, making it unique. Given the dynamics, the complexity, and the evolution of the settlements, these have shown an increasing trend towards development and resilience building.

The main factors shared both by urban and rural resilience refer to climate changes, natural and technological risks (including Natech – natural hazards triggering technological accidents), technological progress, people mentality, economic dynamics and evolution, and internal and external socio-political phenomena. There are many researches approaching the urban resilience assessment by use of mathematical formulas and resilience indexes in a more complex, holistic, pragmatic, and empirical manner (ARUP, 2016; ARUP, 2014; Attoh-Okine et al., 2009; Barbat et al., 2015; Cole, 2014; Flax et al., 2016; Pisano, 2012). We only mention here the City Resilience Framework and the City Resilience Index developed by Arup, which address urban resilience in terms of "four key dimensions" (Arup, 2016; Arup, 2014):

1. People: health and well-being;
2. Organization: in terms of economy and society, including all the social and financial systems which ensure the operation of urban systems;
3. Place: infrastructure and environment; and
4. Knowledge: good governance based on informed, inclusive, integrated, and iterative decision-making.

These four critical dimensions of urban resilience are based on 12 goals. These are minimal human vulnerability, diverse livelihood and employment, effective safeguards to human health and life, collective identity and community support, comprehensive security and rule of law, sustainable economy, reduced exposure and fragility, effective provision of critical services, reliable mobility and communications, effective leadership and management, empowered stakeholders, and integrated development planning. The City Resilience Index comprises 52 resilience indicators which are assessed based on both qualitative and quantitative data. Until now, the Index has been tested in five cities: Shimla (India), Concepcion (Chile), Arusha (Tanzania), Hong Kong (China), and Liverpool (United Kingdom) (Arup, 2015).

Although, from the quantitative point of view, there are more theoretical and empirical research outcomes on the identification of methods and mathematical formulas to calculate or measure urban resilience, the rural resilience also receives a relatively high attention, as there are some analysis and assessment methods available (Quaranta & Salvia, 2014; Schouten et al., 2009). The scientific literature includes some rural resilience assessment methods depending on various aspects or components, such as communities, households, agriculture, food safety, health, education, transport, climate changes, natural hazards, ecology, land use, energetic efficiency, natural resources, and economy. Unlike the urban environment, a Rural Resilience Index complex enough to approach in an integrated manner a sufficient number of indicators to cover all fields specific to rural areas has not been yet identified.

3. Environmental stresses in the Apuseni mining area

The mining communities under study are located in the NW part of Romania, in the Apuseni Mountains, which represent the most complex mountainous sector in the Western Carpathian Mountains (Figure 1). The landforms include relatively small mountains (less than 1850 m) and intramountainous depressions, resulting from several tectonic cycles, the last one being the Alpine cycle. The geological context was favorable to the formation of large mineral ores, such as gold, silver, iron, copper, zinc, and lead (Popescu et al., 1995), which have been mined since Roman times.

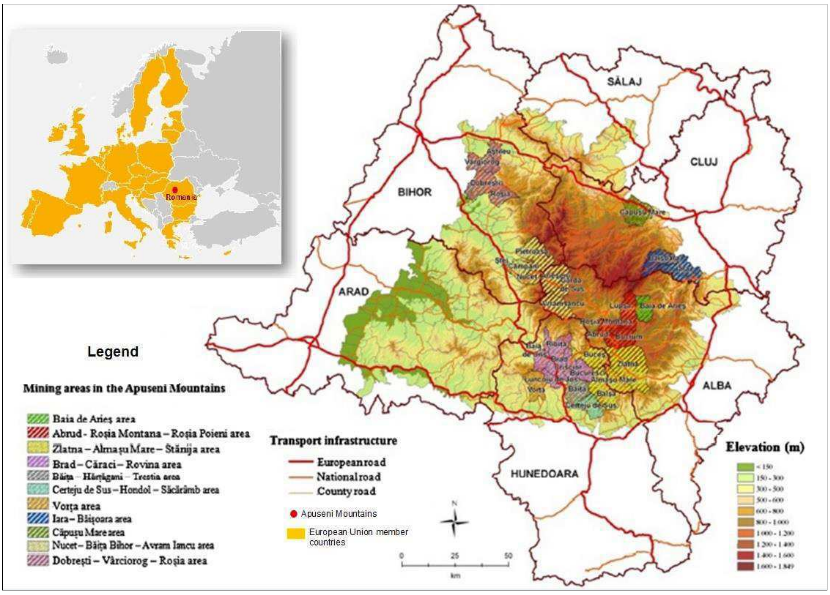

Figure 1. Location of the mining areas in the Apuseni Mountains
Source: Adapted from Constantin et al., 2015

Eleven mining areas were identified in the study perimeter, where mining of metalliferous ores (ferrous and non-ferrous) was conducted, with major environmental impact and development of a specific anthropogenic landscape. These mining areas can also be grouped by the type of the main ore mined (Table 1): 7 gold-silver and polymetallic ores mining exploitations in the Golden Quadrilateral (Alba and Hunedoara counties), 2 iron mining exploitations (Cluj county), 1 uranium exploitation (Alba and Bihor counties), and 1 bauxite exploitation (Bihor county) (Constantin, 2011). Among the metalliferous (ferrous and non-ferrous) exploitations in the Apuseni Mountains, the most scientifically attractive are those located in the Golden Quadrilateral, which includes the Northern part of the Hunedoara county and the Western and North-Western parts of the Alba county, hosting the largest gold deposits in Europe (Vlad, 2005).

Table 1. Mining areas in the Apuseni Mountains based on administrative-territorial criterion

No	Mining area	Mining exploitation	Main ores mined
1	Baia de Arieş	Baia de Arieş	gold, lead, zinc
2	Abrud - Roşia Montana - Roşia Poieni	Roşia Montana	gold
		Roşia Poieni	copper
3	Zlatna - Almaşu Mare - Stănija	Zlatna	gold, lead, zinc
4	Brad - Căraci - Rovina	Brad	gold, copper
5	Certeju de Sus – Hondol – Săcărâmb	Certeju	gold
6	Băiţa – Hărţăgani – Trestia	Băiţa	gold, lead, zinc
7	Vorţa	Vorţa	gold
8	Iara - Băişoara	Iara Băişoara	iron, lead, zinc, gold
9	Căpuşu Mare	Căpuşu Mare	iron
10	Nucet - Băiţa Bihor - Avram Iancu	Băiţa Bihor	uranium
11	Dobreşti - Vârciorog - Roşia	Dobreşti	bauxite

Source: Constantin, 2011

The past and present metalliferous mining exploitations activities have determined the physiognomy of the region. The anthropogenic landforms resulting from mining are defined especially by blowholes, waste heaps, and tailing dams.

The area includes few active mines, while most of them are closed and/or abandoned. The pollution problems did not disappear once the mining activity ceased. The abandoned mining sites include large amounts of wastes with a high content of mobile metals and particulate matters, which, through their drainage by the rivers or rainfall waters, are carried away and introduced into the aquatic circuit. That is the reason the abandoned mining sites represent large scale environmental pollution sources, especially of the hydrographical networks. The scientific literature mentions the acid mining drainage as the main source of pollution in the hydrographical basin of the Arieş River, as well as in the sub-basins of its tributaries (Forray, 2002).

The natural potential to generate acid drainage adds to these anthropogenic sources. The rocks with the highest potential to generate acid waters in the area are the volcanic breccia. The pH values decrease below 2, thus driving a massive mobility of heavy metals in the rock (Baciu, 2007).

By the lixiviation of the rainfall waters through the tailing dams, the latter charge with pollutants, especially heavy metals. High levels of some metals (Pb, Cu, Cd, Zn) concentrations in Arieş water and its tributaries and the low pH values due to the significant metallic sulphur content of tailings and sediments suggest that, even when closed, the mines and tailings dams from the area represent continuous pollution sources of natural waters, even after the mining activities have ceased (Ozunu et al., 2009).

Taking into consideration the long history of mining in the area, one can speak of historical soil pollution. This phenomenon has been greatly amplified during the last 4-5 decades due to the low technological level and to the inadequate exploitation/processing methods, as well as to the intense pace of exploitation. The pollution was considerably enhanced by the storage of tailings on unprotected terrains, under the circumstances of high levels of heavy metals and toxic substances used in the processing of metals. The affected areas have extended along the time by their subjection to the natural processes (precipitations, frost/defrost, wind, and water seepage). The close connection between the environmental media water and soil has led to the situation that the water pollution sources mentioned above constitute also soil pollution sources.

The presence in the study area of 20 tailing dams storing some of the 36 million tonnes of mine tailings in Romania (Modoi et al., 2009) containing toxic heavy metals, combined with the soil erosion issues (Ştefănescu et al., 2011) increase the landslide and Natech risk in the area. The highest risk induced by tailing dams is represented by the unexpected collapse/breach. Past events such as Baia Mare mining disaster in January 2000 or Borşa incident in the same year, as well as the 1971 failure of the tailings dam just upstream of Certeju de Sus are regrettable examples (Bird et al., 2008; Modoi et al., 2009; Zobrist et al., 2009). These are typical examples of Natech incidents, when natural phenomena (heavy rainfall and sudden snow melting) caused dam failures.

4. The resilience building factors in the studied mining areas

Considering the above-mentioned aspects, the region's evolution and socio-economic development was determined by the mining activities developed here since ancient times. The dominant feature of these mining areas is the environmental, social, and economic vulnerability of the mining settlements and communities. Stress resistance or resilience is the antonym of "vulnerability", which generates persistent dysfunction, an alternative outcome to renewed and adapted functioning (Norris et al., 2008). The persistent dysfunction of a certain region or community can be caused by natural resource degradation, loss of agricultural production, urbanization, demographic changes, climate change, political instability, and economic decline.

Previous studies (Alexandrescu, 2011; Botezan et al., 2015, Constantin et al., 2015; Surd et al., 2007; Sorocovschi, 2010) in the rural parts of the study area have shown a rather high vulnerability degree determined mainly by the intensification of the depopulation and demographic aging phenomena, low degree of resource capitalization or limited access to information regarding the development opportunities. To these, one may add the poor governance translated into the shallowness or negligence of the decision-makers regarding the rapid environmental degradation of the mining areas; this is caused by the presence of abandoned mining sites which continue to pose threats to the environmental factors and exposed communities (Constantin et al., 2015).

In order to identify the resilience building factors, community resilience can be addressed as a set of networked adaptive capacities identified by Norris et al. (2008) and tailored to the specific mining context. These adaptive capacities are: social capital, economic development, community competence, and information and communication.

Considering the complexity of the defining aspects of the mining settlements, some specific socio-economic features of the mining areas in the Apuseni Mountains are mentioned below. In terms of **social capital,** the mining settlements, especially the rural ones, present a series of negative demographical phenomena as a result of mine closure. The most serious of these are: enhanced depopulation and demographic aging phenomena, increased unemployment rate among the young population, low natality, low percentage of active population, etc. Another restrictive aspect in the socio-economic regeneration of the settlements after the closure of mining activities is represented by the mentality of the population characterized by reluctance, rigidity, and resistance to changes and opportunities which can determine economic development and society progress. This was the fate of the former mono-industrial towns, particularly the mining ones, which are faced with a high poverty rate. The same situation can be seen in the small, agricultural, or newly founded towns.

Economic development of mining areas is translated into resource management, infrastructure, resource equity and social vulnerability, investment opportunities, and economy diversity. The configuration of the mining settlements is the result of both spontaneous development closely connected to the mining exploitation (most of the rural mining settlements) and of the development based on urban planning documentation and land use planning (e.g., the small towns of Ștei and Nucet in Bihor county were built especially for the mining activities and have a relatively new history).

Given the geologic and metallogenetic features, the metalliferous resources (ferrous and non-ferrous) are located in the mountainous area; hence, low accessibility is one of the biggest problems of the mining areas in the Apuseni Mountains. Therefore, many rural mining settlements are remote, with poor road infrastructure. The mining towns in the Apuseni Mountains are small and have medium accessibility. The settlements, especially the rural ones, are also characterized by a poor, little functional insufficient or, in some areas, even inexistent public infrastructure. This makes the settlements unattractive both for residents, and for possible investors. Moreover, these are also poorly equipped in terms of social services (education, health, culture, recreational activities, etc.). From the land use planning point of view, there are many fragmented properties, while the mentality of the residents is one of reluctance regarding possible economically beneficial enterprises.

Last, but not least, as previously mentioned, one of the most important actions following mine closure should have been the resolution of the environmental problems, ecological rehabilitation of the affected areas, and post-mining works in compliance with the related regulations. Unfortunately, although funds have been assigned for rehabilitation, there actually has been, with few exceptions, a high degree of ignorance on behalf of the decision-makers in addressing the environmental issues responsibly. In addition, there are still many areas where the pollution rates are high due to both the lack of impact mitigation, assessment and monitoring system, and the shallowness of rehabilitation activities. Analyzing the last decade, we can say that decision-makers in the Apuseni Mountains and, in general, in Romania, have proven a low capacity of managing the accession of new funds and resources and of efficiently using the existent ones. Moreover, the funds from the programs dedicated to the training and active re-integration of unemployed miners were also inefficiently managed.

Before the mine closure, most of the mining areas in the Apuseni Mountains were acting as demographic convergence areas. The policies and projects meant for the development of the settlements in the Apuseni Mountains after mine closure till now clearly indicate the fact that there is no strategic vision for the integrated sustainable development and no culture regarding partnerships in developing and implementing viable projects. Furthermore, the "spatial conflict between the uses of the environment has negative economic implications" (Alexandrescu, 2011). These implications are highly visible in Roşia Montană, where several economic sectors such as mining, agriculture, and forestry have long provided good income to the local community, while the development of the new mining project would make the local economy dependent on a sole income source: mining (Alexandrescu, 2011). However, there are many development opportunities of the mining settlements in the Apuseni Mountains translated into resilience building factors, such as investments and encouraging entrepreneurship to be reflected in the development of the local economy.

Such opportunities can be pursued in the following fields of activity: (i) tourism and especially agritourism (the Apuseni Mountains have a rich natural heritage – caves, gorges, natural reservations, natural monuments, etc., as well as anthropic heritage, which is favorable to promotion of local values; (ii) capitalization and promotion of crafts and traditional occupations; (iii) exploitation of construction rocks (the Apuseni Mountains are highlighted as a "petrographic mosaic"); (iv) organic agriculture (especially the development and expansion of the zootechnical sector, cultivation of local fodder crops, etc.); (v) wood processing (which is a tradition for the residents; however, the raw material is not used in an efficient manner and many of the small companies limit their activity to primary processing of the wood, without producing end products); (vi) capitalization of industrial sites; (vii) development of light industries, especially the manufacturing of clothes, shoes, and leather goods (considering the high unemployment rates among the female population, but also the presence of workforce which can be easily re-trained and actively re-integrated).

Community competence includes collective action and decision-making, capacities that arise from collective engagement and consultation. Collective action is complex and challenging in the face of environmental threats (Norris et al., 2008) and it is proven in our study area by the powerful conflict generated by the Roșia Montană mining project. This conflict led to massive street protests known as the 2013 "Romanian autumn" movement (Goțiu, 2013). Among the community skills that can build resilience one could mention engaging constructively in group process, resolving conflicts, collecting and analyzing data, and resisting undesirable influences (Goodman et al., 1998). Environmental threats also activate and enhance collective action, when local groups formed mainly by directly affected residents oppose bad political decisions. Starting from local NGOs opposing a dangerous and disadvantageous mining project in Roșia Montană, there was a growing power of international NGOs which militated against corporate misconduct and spoke against the exploitation of the lands and of powerless communities (Alexandrescu, 2011). This is another community competence resilience building factor, which deals with the capacity to recover from management or government mistakes (Heijman et al., 2007).

Information and communication of the communities conducted in a fair and correct manner is another resilience building factor which contributes to collective efficacy and empowerment. A powerful and engaged community is an informed one. Proper risk communication is essential for community resilience (Ganor & Ben-Lavy, 2003) and it should be based on solid scientific knowledge on local environmental risks and on the needs of the communities.

5. Conclusions

The studied region lacks neither resources (natural potential, touristic potential, ethnographic heritage, crafts and traditional activities, etc.), nor the adaptive capacities to enhance resilience, as they were highlighted in this research.

With a more efficient management of existing resources and better decision-making in terms of funds accession and project implementation, the resilience of the studied mining area would significantly improve. Moreover, this would be enhanced by the proper re-training and active re-integration of unemployed people who lost their jobs following the mine closure. Despite the high vulnerability degree determined mainly by the intensification of the depopulation and demographic aging phenomena, low degree of resource capitalization or limited access to information regarding the development opportunities, the region is clearly one of great development potential, due to its valuable natural and anthropic heritage.

The long-term environmental stress induced by the mining activities has not only affected the quality of life and landscape, but it has also increased the overall vulnerability of the region. The improperly closed or abandoned mines are still a threat to the environment and health of population and require immediate rehabilitation measures.

In economic terms, despite the long-established mining profile of the region, the problem of high poverty rate can only be addressed by economic diversity. Agriculture, tourism, agritourism, light industry, and wood processing activities are good income sources to the local community, while the economic dependency on mining, however profitable it may seem, would only lead to increased social and economic vulnerability in the long run.

Conclusively, the main factors that make the region resilient are the rich resource legacy, skilled and entrepreneurial workforce, diversified economy, better access infrastructure, development of supportive financial system to provide funds, competitiveness, and better governance supported by science, and last but not least, enhanced collective responsibility.

Conflict of interest

The authors declare they have no conflict of interest in relation to this paper.

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