

RETHINKING SUSTAINABLE DEVELOPMENT OF RURAL SPACE THROUGH THE IMPACTS OF INDUSTRIAL ACTIVITY: A CASE STUDY OF PETROȘANI MINING BASIN (HUNEDOARA COUNTY, ROMANIA)

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Abstract: The Petroșani coal-mining basin is one of the oldest in Romania. Over time, mining activity has damaged the natural environment in rural areas. Also, the mining industry has led to increased urbanization. The environmental problems in the Petroșani basin should be strategically viewed as a challenge to implement the short term measures to reclaim the land impacted by mining so as to reintegrate them into economic circuits. The purpose of the study is to highlight the environmental issues related to extractive industry. The environmental problems in the Petroșani mining basin were investigated using several indicators (the environment transformation index, the naturality index). The authors also propose several land reclamation measures in order to support the sustainable development of rural space in the Petroșani mining basin.

Keywords: Underground mining, coal quarry, mine drainage, environment, rehabilitation

1. INTRODUCTION

At the international level, the interest shown in the sustainable development of rural space, particularly in remote rural areas, has increased in the past few years, leading to the emergence of specific policies. Thus, various strategies have been adopted aiming at improving the quality of life (Winterton & Warburton, 2012; Burja & Burja, 2014) through a multifunctional approach that would originate in an analysis of all available resources and opportunities, and putting opportunities to best use.

Rural economies have been the subject of numerous studies, focusing on an analysis of the impacts of industry development (damage to the native environment, conflicts with other economic activities, growing pressures to expand extractive industries, increased demands for access to indigenous lands, social conflicts between local populations and the immigrants) (Cheshire, 2010; O'Faircheallaigh, 2013; Cheshire et al., 2014). Concerns have also been raised about the decline of farming (Øian, 2013) and identifying opportunities

for boosting the economic development of the rural space (Briedenhann & Wichens, 2004; Iorio & Corsale, 2010; Øian, 2013).

Coal-mining affects the environment both by exploitation operations (open-pit and underground) and production operations linked to obtaining the final product, coal. Coal is used for generating thermal energy, and the combustion process generates air pollution (Traistă et al., 2003).

The mining industry is a significant cause of environmental degradation by its waste dumps, flotation ponds, discharge of mine waters or breaching of tailing dams (Altun et al., 2010; Brașovan et al., 2011; Stumbea, 2013; Ciszewski et al. 2014; Marschalko et al. 2014). There are also concerns about emissions and associated environmental impacts (Horaicu et al., 2010; Brașovan et al., 2011; Traistă et al., 2003), mine drainage (Braghină et al., 2010; Nagy-Korodi et al., 2012; Nadaroğlu et al., 2014; Heviánková et al., 2014), soil erosion (Braghină et al., 2010; Ștefănescu et al., 2011), soil contamination (Damian et al., 2008; Horaicu et al., 2010; Karbassi, 2014),

and subsidence (Costache, 2010; Marschalko et al., 2014). Mining areas, even if drained by small streams, may also affect large river systems and impair aquatic habitat over hundreds of kilometers (Byrne et al., 2010). The mining and post-mining activities, as well as the ore processing industry, cause health problems to human communities (Traistă et al., 2003; Braghină et al., 2010; Merciu & Stoica, 2010; Gurzău et al., 2012).

Dump heaps are a typical example of human impact on mining deposit regions (Onciu et al., 2007). Dump-fields are associated with the releasing of toxic metal elements into the environment including water sources within mine catchments. Many of the dump heaps are situated directly on the ground and without any suitable safeguards these waste deposits are subject to weathering by natural environmental factors (wind, storm flows) which enlarges affected areas (Nagyová et al., 2013). The presence of dump heaps decreases species richness and simplifies the ecosystem structure (Onciu et al., 2007). Species, that are characteristic for polluted zones, dominate in plant communities and many animal populations become locally extinct. The diminution of environmental impacts due to mining activities and reinsuring the ecological balance in the mining sites is managed by rehabilitation or reclamation practices (Kun et al., 2012; Marian et al., 2012; Măciacășan et al., 2013).

The Petroșani mining basin is one of the oldest coal-exploitation regions on Romanian territory. The first coal mines were established in the latter half of the 19th century (Baron, 1998), and over time the basin has grown into the main source of black coal in Romania, a process helped along by coal becoming the primary source of energy during the communist period. The earliest forms of coal resource exploitation were rudimentary, explained by the presence of coal close to the surface (digging shallow pits to reach outcrops, in several places in the Petroșani, Petrila and Vulcan areas) and it came as the result of private initiatives. Shortly afterwards, the economic value of the coal reserves captured the interest of the Austrian-Hungarian Empire, which took steps to take over the process of mining. From then on, coal mining in the Petroșani basin became large-scale industrial exploitation. The extended lifespan of the coal mines, backed by the increase in the amounts of coal mined and the inauguration of new coal fields in the communist period, led in time to increased pollution.

2. METHODOLOGY

Currently, there are numerous tools and methods to determine the environmental impacts of

mining activity.

The environmental problems caused by the extractive industry in the Petroșani mining basin were investigated using several indicators (the environment transformation index, and the naturality index). In order to identify the effects of mining-industry operations, several research trips were undertaken during 2010-2014 to make the inventory of several case studies that had been severely impacted by the extractive industry (e. g. mining activities that are performed in open pit: Campu lui Neag, or in underground exploitation: Jiet, Lonea). Also, the field research was made to complete a database containing information related to areas affected by mining (concerning the identification and location of the sites, forms of pollution).

ArcGIS was used for the geospatial database and for the modelling of relevant maps (mapping of the impact of the mining activity).

In addition, aerial photographs were used, too, for the vectorization of dump heaps, tailings dams, open pits, underground mining works, processing plant, land use categories and other relevant variables in the investigated area.

The authors consulted different studies to identify actual methods used in mining-waste management in order to propose several remediation measures of the post mining sites.

3. RESULTS AND DISCUSSION

Systematic coal mining in the Petroșani basin started in 1840 and brought about a genuine economic and demographic boom. The rise to power of the communist regime in Romania in 1960 meant a more active involvement in planning of the territory and economic capitalization of the coal resources. At the same time, the expansion of urban space generated severe pressure on rural space. Subsequently, rural settlements were included under the administrative authority of cities. Forced-expropriation and demolition decisions (where necessary) were made in certain rural regions where new mining perimeters were opened (e.g. Campu lui Neag Village, located in the eastern part of the basin). Several villages located on the border between hill and mountain areas have been less exposed to territorial planning initiated in the communist period; their remoteness favored the preservation of rural types of settlements.

The oldest coal mines in the rural area of Petroșani basin go back to 1865 when the Romanian state got actively involved in the local economy by conducting several mineral-survey studies which led to the opening of coal mines in Lonea, Jieț, Sălătruc

and Răscoala – with mining at the Sălătruc and Răscoala mines only lasting for a few years because of the low coal reserves there; the Cîmpa mine opened in 1885, and the Dâlja mine opened in 1890.

During the Communist era, mining activity expanded to the following coal fields: Câmpu lui Neag and Valea de Brazi (both inaugurated in 1986 and closed down in 1998), the Lonea-Pilier mine (opened in 1986 and placed in conservation in 1997), and the Isroni and Livezeni mines (both opened in 1987 and then closed down in 1990 and 1997, respectively). The sole mine in a rural area that is still in service nowadays is the Lonea mine, located on the premises of the town of Petrila.

Petroșani mining basin is an example of an area affected by air pollution due to the thermoelectric power plants' works, as well emissions from the coal fields (Traistă et al., 2003).

The biggest area of degraded land in the analyzed rural area was affected by dumps, abandoned quarries, induced subsidence, settling ponds and pollution of the soil, the surface water and the groundwater (Fig. 1).

Sterile dumps in rural areas cover farmland and forested land, resulting in contamination of the fertile topsoil. They also trigger a reconfiguration of the morphology of the land (Onciu et al., 2007), meaning spectacular landform reversals, with typical

depression morphology replaced by man-made hills of varying size (Titu & Surdeanu, 2007). In addition, both sterile dumps and mine quarries trigger an “anthropic parasitism” of the initial morphology of the terrain (Titu & Surdeanu, 2007).

Most slag heaps are located close to rural settlements or in village estates where, in close proximity, there are developed livestock activities (Fig. 2).

Natural forestation of the land with *Hippöphae rhamnoides* (sea buckthorn) occurred in certain areas as a result of the mineral composition of the slag heaps (Fig. 3).



Figure 2. Sterile dump at Lonea mining exploitation

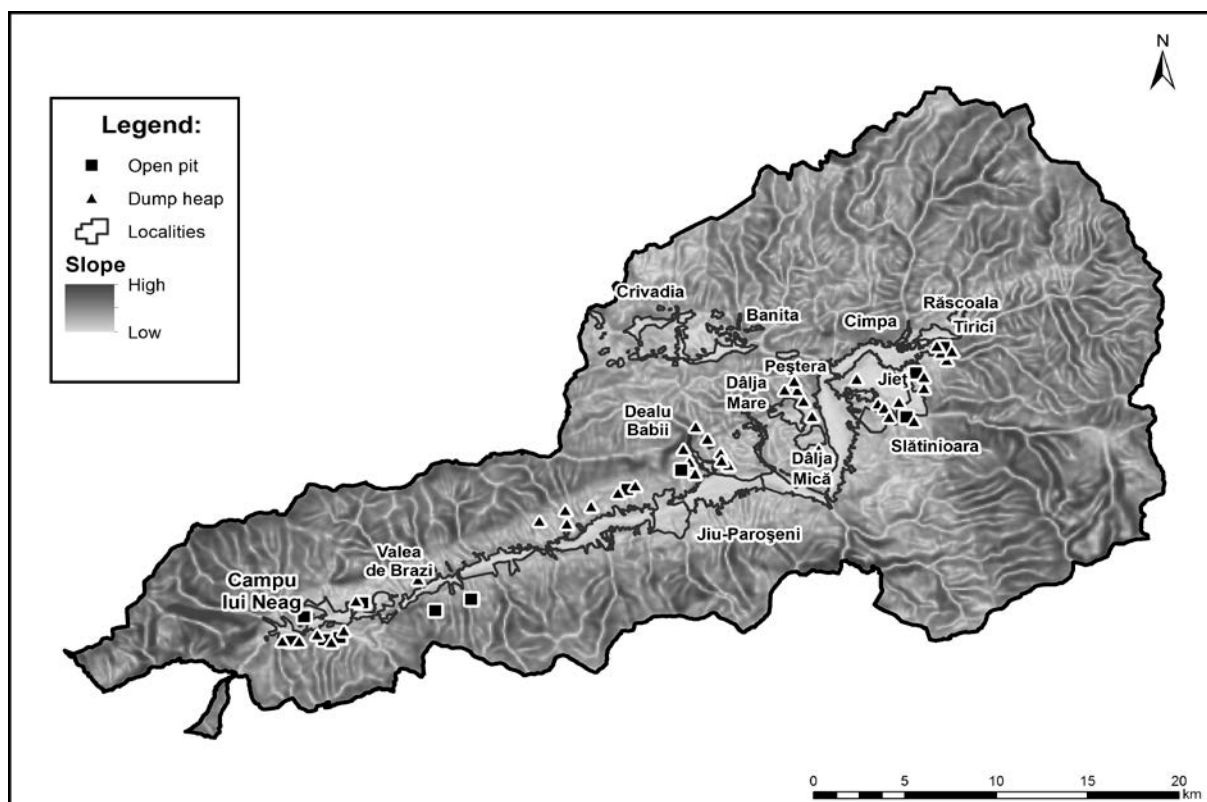


Figure 1. Declivity map showing the position of quarries and dumps in the rural areas inside the Petroșani mining basin



Figure 3. Dump heap at Campu lui Neag open pit

Sea buckthorn is observed in the higher content of Ca and lower content of Mg in fruits compared with the average standard value, confirming that dump soil is richer in calcium than in magnesium (Braşovan et al., 2011).

Other areas, free of dump soils, are devoid of small trees (Braşovan et al., 2011). Sometimes slag heaps form dam walls on dry-washes thereby creating lakes (Fig. 4).



Figure 4. Dump heap partially covered by small trees, and forming a dam fall to create a lake

Because many sterile dumps lack any sort of rehabilitation and control, their structure may undergo transformation, under the impact of slumps, landslides (Fig. 5) and mudslides.



Figure 5. Landslide in a former mining perimeter (Jieţ village)

Some sterile dumps are impacted by various forms of erosion (flows, ravines) (Fig. 6).



Figure 6. Sterile dump impacted by forms of erosion (Jieţ village)

The largest surface area of land impacted by sterile dumps is located in the area of the Lonea coal field (42.44 ha) (Costache, 2010).

Open pit mining was the dominant type of coal mining in the rural study area. These mines were flooded with water after mining activity ceased (Fig. 7).



Figure 7. Water flooded open-pit (Campu lui Neag village)

The environmental transformation index was calculated to provide an assessment of the impact of mining on the rural environment in the Petroșani mining basin. The index calculates the ratio between the natural surface (covered by forest and grazing-land) and the built-up surface inside a particular area (Ioja et. al., 2006; Zarea & Ionuș, 2012). The data indicate that the highest index figures are found in the central part of the Petroșani basin, the region where human activities exerted the most pressure and the region where several mining ventures are still in operation today (Fig. 8).

The data indicate that in the eastern part of the basin, where mining enterprises have been closed for a longer period, the environment's regeneration capacity is apparent and the index values are lower.

The naturality index was calculated as well so as to assess the impact of mining on the environment; the naturality index calculates the ratio between forest land surface and overall surface (Pătroescu, 1988; Zarea & Ionuș, 2012). The lowest values occur in the central part of the mining basin, where settlements and mines are concentrated (Fig. 9) and where there was massive deforestation (with the timber used in mining as well, to build support arches in the underground galleries). The highest naturality index values are typically found in the mountain areas, where human activities have a lower impact.

Another indicator used was physiological density, which calculates the ratio between the overall number of people and the arable land area (Avram, 2011). This indicator highlights the impact of industrial activity on the amount of farmland in the rural area under discussion. Numerous mining sites were developed in the central part of the Petroșani basin, which happened to be the most fertile tracts of land. During the period when most mining sites were still in service, sterile dumps led to a lower surface area of arable land. The data reveal that the highest indicator values are found on the eastern edge of the mining basin (Fig. 10), where the mining sites were typically small-sized, and all the mines have been decommissioned, and where the rural population is employed in agriculture.

The second area with high physiological density values is concentrated in the rural area close to the town of Vulcan, where the mines have also been closed. Subsistence agriculture is the dominant activity practiced in the rural areas in the Petroșani Basin, following layoffs in the mining sector.

In the villages located inside the mining basin, the original village centres lack clear demarcations from the overall village estate, so that farmed land extends as far as the village estate borders, frequently climbing to the foot of the mountain slopes on the borders of the basin.

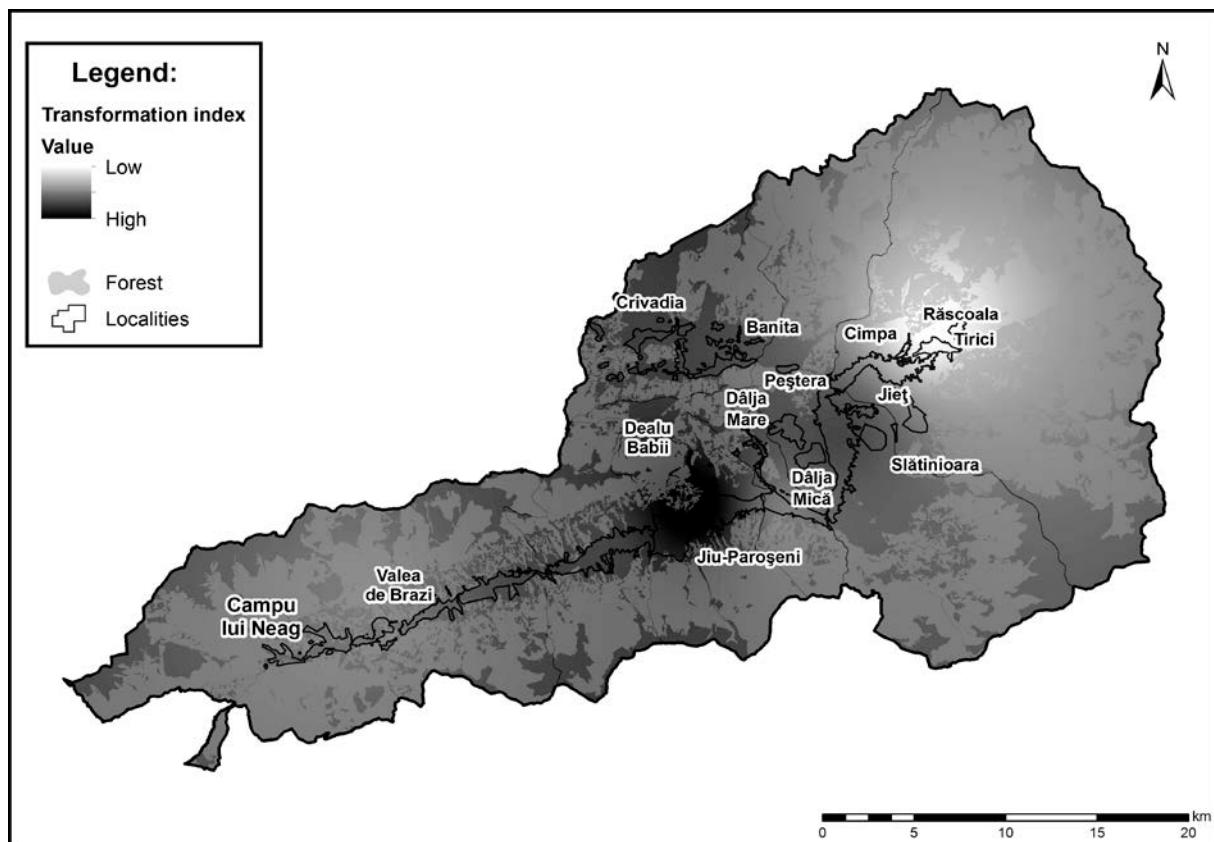


Figure 8. Spatial distribution of the values of environmental transformation index in the Petroșani mining basin

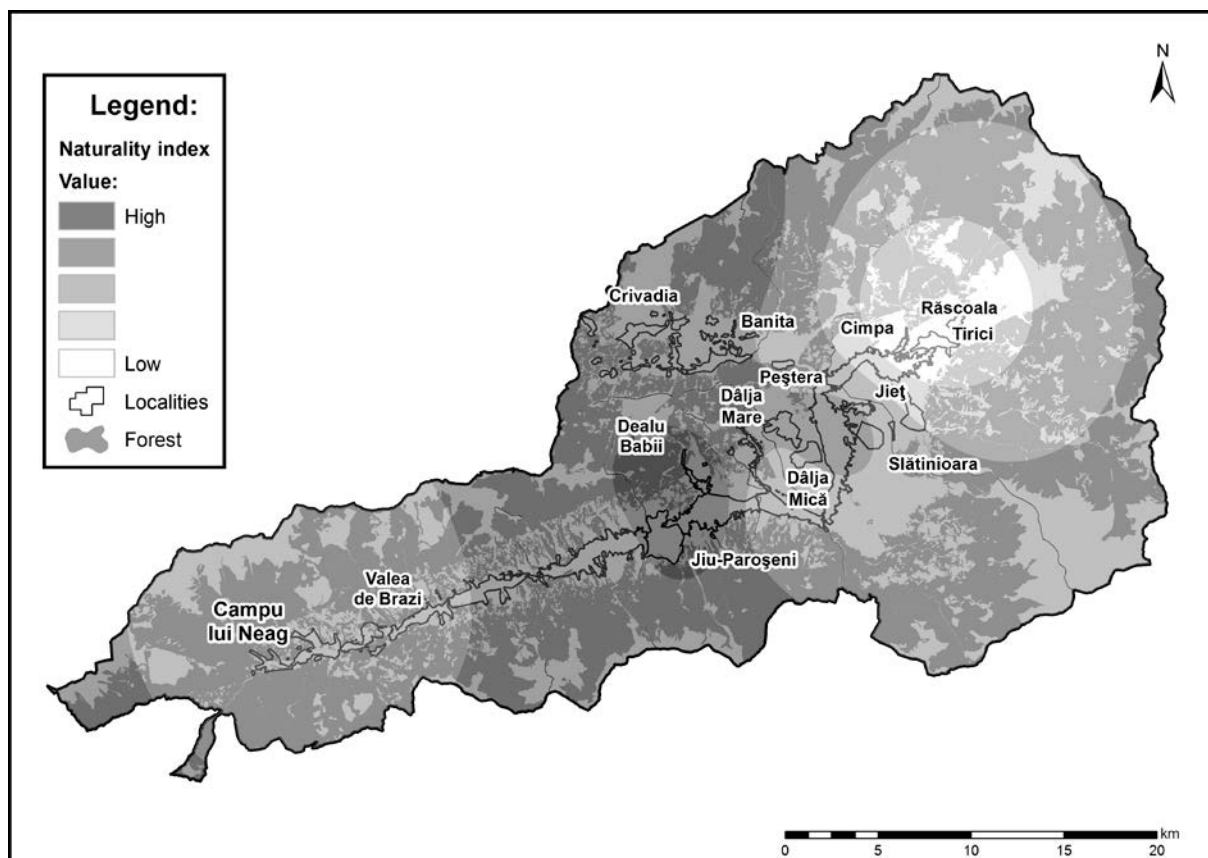


Figure 9. Spatial dynamics for the values of naturality index in the Petroșani mining basin

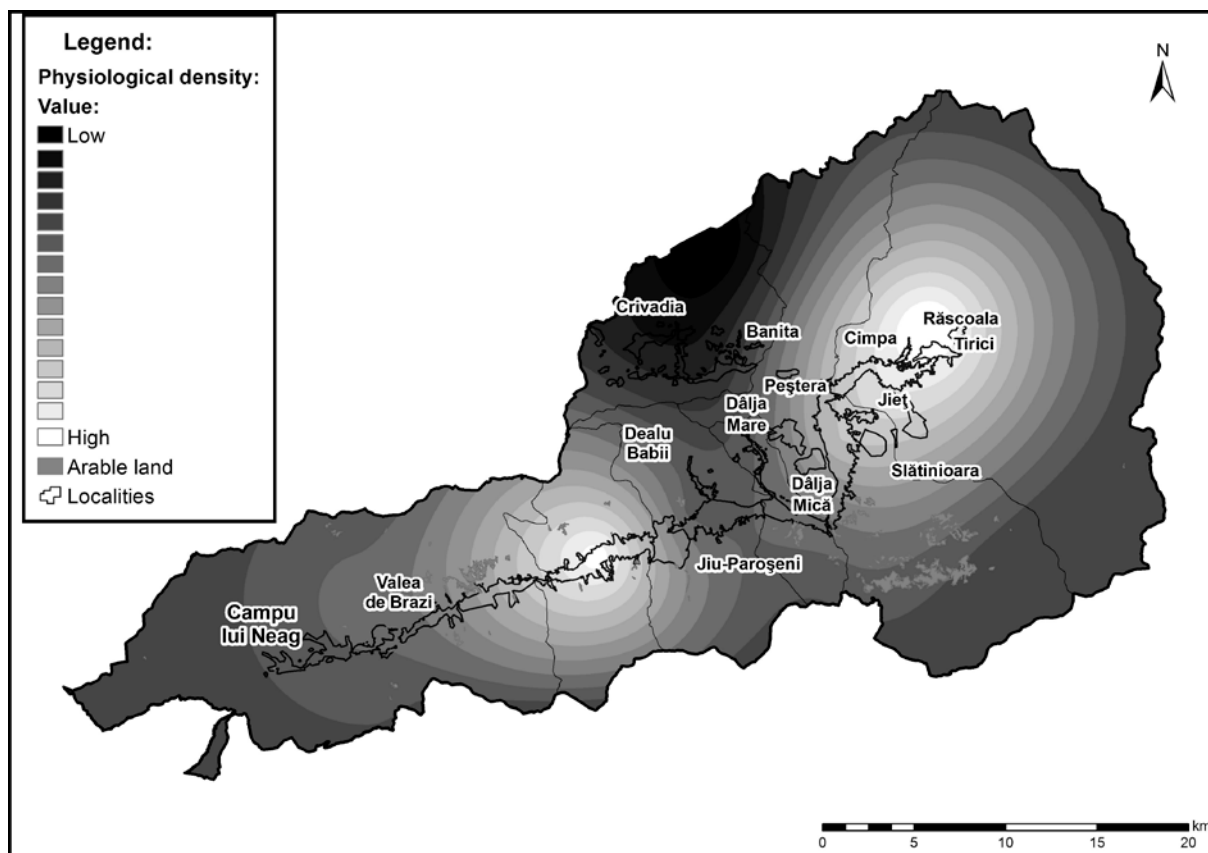


Figure 10. Spatial dynamics for the values of physiological density index values in the Petroșani mining basin

The presence of land cultivated at medium altitude is also due to the presence of quite fertile soil (such as rendzinas soils typical of karst areas rich in humus).

Given the current socio-economic context characterized by a significant reduction of mining, rehabilitation of coal fields is necessary. One of the steps towards rehabilitation is the administration of the dump heaps, an action that is also linked to the reincorporation of the land covered by dump heaps into economic circuits. This measure complies with the guidelines of sustainable development and with global trends, particularly the increasing care and attention given to protection and rehabilitation of the environment. The first phase in the functional reintegration of dump heaps consists in engineer work (technical rehabilitation), being a critical phase as it is the foundation for the next phases.

The technical rehabilitation phase involves morphological and morphometric adjustment and stabilization of the slag heap structures. The second phase consists in ecological (biological) rehabilitation which involves the reconstruction of the usable (productive) capability of the anthropic soils by means of a complex program involving draining, refertilization, harvesting, seed selection and competent administration of meadows and grazing land so as to prevent soil degradation by livestock (Titu & Surdeanu, 2007). After rehabilitation, the dump heaps may be reincorporated into the forestry and agricultural circuit, which is the functional reintegration phase (Titu & Surdeanu, 2007).

Rehabilitation of land affected by extractive operations may take the form of bioremediation, which covers various layers of multiscale complexity involved in polluted land cover with a green coated and/or the disposal of toxic waste from the contaminated sites (Lorenzo, 2008): ex. phytoremediation (plant selection and plantation geometry depending on the geological structure, climate and local flora and fauna) (Pulford & Watson, 2003; Kun, 2012).

Rehabilitation of mining sites has effects of an environmental and aesthetic nature (Kun, 2012).

Measures to rehabilitate mining sites are a priority in the steps to rethink development of the rural space within the borders of the Petroșani basin. This action is justified by the current economic situation, impacted by industrial reorganization, which has led to the closure of several mining sites and the lay-off of a sizeable proportion of the workforce (e.g. 16 000 miners were dismissed in 1997). Even nowadays there is a dependence of the labour force on the mining industry.

The Romanian Agency for Sustainable Development of Industrial Areas (ARDDZI) was created with the purpose of facilitating the redevelopment of mining areas by means of designing and implementing development projects; it is a public institution with a juridical function, replacing the former National Agency for Development of Mining Areas (Emergency Decree no 14/2009). The Agency's main purpose is to promote sustainable development of economically depressed areas which experienced industrial reorganization; they initiate new projects aimed at making best use of the resources and the socio-economic potential of the respective regions.

Also, in the context in which universities are considered as being „enablers” or „animateurs” of regional development (Uyarra, 2010), which may contribute to social, cultural and environmental development (Boucher et al., 2003), the University of Petroșani is another stakeholder who has the ability to contribute to the rehabilitation of mining sites. In the two strategic documents of the higher education institution – „Strategic Plan 2013-2016” and „Operational Plan 2014”, this University aims to become an opinion leader of the civil society (Strategic Plan 2013-2016) that contributes to the reconstruction and recovery of the mining areas and to the reconstruction of the degraded lands (Operational Plan 2014). Given the study programmes of the undergraduate level and the masters of “Environmental Engineering” specialization at the Faculty of Mining, University of Petroșani has contributed to create specialists in „Engineering and Environmental Protection in Industry”, „Waste Management Engineer”, as well as in „Environmental Impact Assessment and Ecological Restoration”. Also, by developing partnerships with other institutional actors from the area, this higher education institution has the potential to become the main stakeholder that contributes directly or indirectly to solve the environmental problems generated by the former mining sites.

The economy of Petroșani Depression is undergoing a difficult transition, which led to it being declared an underprivileged area, due to the severe current negative effects of the Communist regime's irrational economic policies of coal exploitation. The rural area in the Petroșani basin has tourist potential, which might be properly used to reduce the dependence on traditional economic activities in the area that fail to make the best use of resources.

Tourism is accorded a central role in rural development policy in areas facing economic

restructuring processes and in the regeneration of depressed rural areas (Briedenhann & Wichens, 2004).

The situation of the rural area under study is the result of the influence of several historical, social, cultural and economic factors that left a specific cultural imprint. In the future, tourism can become a basic activity for the local economy. The preconditions for the development of rural tourism consist of good access (road and rail), and in recently-built tourist infrastructure.

The development of rural tourism must be grounded in a well-structured plan, which should allow for efficient use of tourism resources, without endangering them, so as to prevent tourist activities from detracting from the quality of the rural environment. The challenge for rural tourism is to develop it sustainably to create a profitable and environmentally sustainable industry (Ferrari et al., 2010).

4. CONCLUSION

The Petroșani mining basin is a complex area from the point of view of geology, economy and the system of human settlements. Such complexities require a thorough analysis of the interactions between the natural environment and the man-made environment. These interactions revealed negative consequences on both the natural landscape (the presence of several types of pollution both on the surface and underground), and on the system of settlements (the development of urban settlements) to the detriment of the rural area. Mining was the main economic activity until 1989 which led to the decline of agriculture. Later, industrial reorganization led to a rebound of agriculture in the rural regions.

The study identified steps towards the rehabilitation of mining areas, with the purpose of limiting the effects of mining pollution. These measures will serve as foundation for the optimization of land usage and functional reintegration of the post-mining areas.

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