Ecological impact of mining brownfields in Bucovina (Romania)

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ABSTRACT: The decline of mining activities in Romania has led to the appearance of large areas of mining waste, buildings and decommissioned equipment. Known by the name of mining wastelands, they challenge both the environment as well as the communities in which they are located. The problems created by the mining wastelands generate shock waves in the development of the rural territories hosting them and block their sustainable development. This paper highlights the stages of the evolution of different types of mining wastelands in Bukovina, with an emphasis on the environmental component, as well as on their possible integration using various forms of valorization. The data was gathered in 2017 as part of a research called "La dynamique des paysages culturels intégrant des aires avec des friches minières. Rétrospectives et perspectives géographique en Bucovine (Roumanie) et en Wallonie (Belgique)", funded by "L`Agence Universitaire de la Francophonie". We used the Rapid Impact Assessment Matrix (RIAM) methodology to assess the environmental impact of mining wastelands, which included 5 evaluation criteria and 15 components investigated (6 physical-geographical and ecological components, plus 9 socio-economic and cultural ones). The findings indicate that the ecological impact of abandoned mining areas is directly related to the area they occupy as well as the morphoclimatic system in which they are located. The socioeconomic component analysis highlighted the role of mine closure in increasing unemployment and lowering living standards, as well as a community takeover of some infrastructure elements through direct involvement of local government.

KEY WORDS: mining brownfields, rural territories, rural landscape, development.

1. Introduction

Romania is a country with a wide variety of mineral resources and a long history of environmental exploitation. Activities of exploitation and valorization of ore deposits and non-metallic substances cover an area of more than 8200 ha. Part of this area (approximately 46%) was assigned for production activities and the rest is covered by tailings sites, namely waste dumps and tailings ponds (Fodor and Baican, 2001), (Fodor, 2015). The mining companies dealing with the extraction of these types of useful minerals managed 577 waste dumps with a volume of stored rocks of about 200 million m^3, on a total area of 813 ha. Sixty-five tailing ponds resulted after the

processing of the extracted minerals, which cover an area of approximately 1350 ha and store over 360 million m^3 of waste rock.

As for Bukovina, the entire region has been strongly anchored in mining activities as far back as 1854, when the Austrian administration assigned by law free mining perimeters to those who discovered them, thus facilitating the penetration of foreign capital into the economy of the province. During1950-1990, mining brought prosperity and development to Bukovina, in addition to livestock farming, wood processing and tourism, and its mountain area managed to avoid the forced collectivization regime that covered the whole extra-Carpathian rural area.

After 1990, however, the socio-economic effects of economic conversion processes proved to be extremely serious, with mining areas rapidly becoming unemployment centers, aggravated by the lack of economic activities alternatives, capital and information. Alongside the economic problems, the rural area in the mining areas has been aggressively unbalanced, in terms of both the environment and the landscape. The 71 mining perimeters that ceased operations in Bukovina have generated a large number of wastelands that have shaped the landscape and transformed yesterday's choices into constraints for today and near future activities.

There are mining wastes deposited in 224 tailings dumps resulted from the exploration and exploitation of useful mineral substances, on an area of 280 ha, of more than 45.52 million cubic meters. In addition, there are wastes related to the nine tailings ponds (another 95 ha), with 14.63 million cubic meters of tailings resulting from the activity of preparation of useful mineral substances (Ionce, 2009). Among them, the Tărnicioara tailings pond in Ostra village, the second largest in Romania and the third in Europe, is located in the studied area.

All these mining wastelands are therefore both a communist heritage and a shift to another level of industrial activity, where the efficiency and globalization of markets bring new unknown facts into the mineral resource equation.

Whether it is dump grounds, abandoned constructions or mining equipments, their destiny is the result of economic, political, environmental, cultural and heritage decisions. The parties involved in the recovery of these territories (owners, government, inhabitants) have different management and reinsertion strategies of the mining wastelands into the economic circuit.

The paper pursued recovery dynamics of the area affected by the mining activities. The restructuring problems of industrial regions are widely addressed both in world literature and in the Romanian one. Even though the phenomenon of mining decline accompanied by deindustrialization is not new (Blackaby, 1979), communities dependent on mineral resources are a category that calls for special policies from governments and mining companies (Barnes and Hayter, 1994). Thus, Koutský et al. (2011) and Ianoș (1999) provide examples of the transformations of regional economies in the process of globalization. The adaptation of Central European industrial regions to the new international economic conditions is presented by Hospers (2005) but also by Hassink and Shin (2005), who issued a deindustrialization comparison between Europe and Asia.

Two topics are frequently addressed in connection with mine closure: environmental and socio-economic issues generated in the mining communities. First, the studies have focused on the impact on the communities, which is most often severe. Closure of a mine may lead to a sharp decline in the standard of living not only for former miners, but also for their families and the rest of the community, slowing the pace of economic and social life with profound effects on quality of life, quantified by Singh and Chand (2000), Pillalamarry and Pathak (2014). In the same category of the impact on communities there is also the sustainable use of infrastructure created by mining activities, as well as the long-term economic impact of mine closure (Hilson and Murck, 2000).

Cessation of mining activities all over the world is mainly related to the deterioration of the environment (Nimară and Tofan, 2015) and the rehabilitation of the areas affected by mining activities (Andrews-Speed et al., 2005; McGuire, 2003; Smith and Underwood, 2000). This is because the negative environmental effects such as water quality (Hosu, 2003), soil vulnerability (Darmer and Dietrich, 2001) and environmental safety affect communities long after the closure of the mine (Ilies, 2008; Hamann, 2004).

A very important plan related to the mining areas is also the one that follows the degree of social and economic resilience of communities directly affected by the cease of mining activities (Matei, 2017).

2. Study area

The study was carried out following the opportunities created by a project funded by the Francophone University Agency (AUF), Central and Eastern Europe Bureau between 2016-2017 in the Bukovina mountain area, in 3 communities that have mining wastelands on their territory: Fundu Moldovei, Şaru Dornei and Ostra (Chiriţă and Smitz, 2017). Their distribution in the territory is shown in Fig. 1.

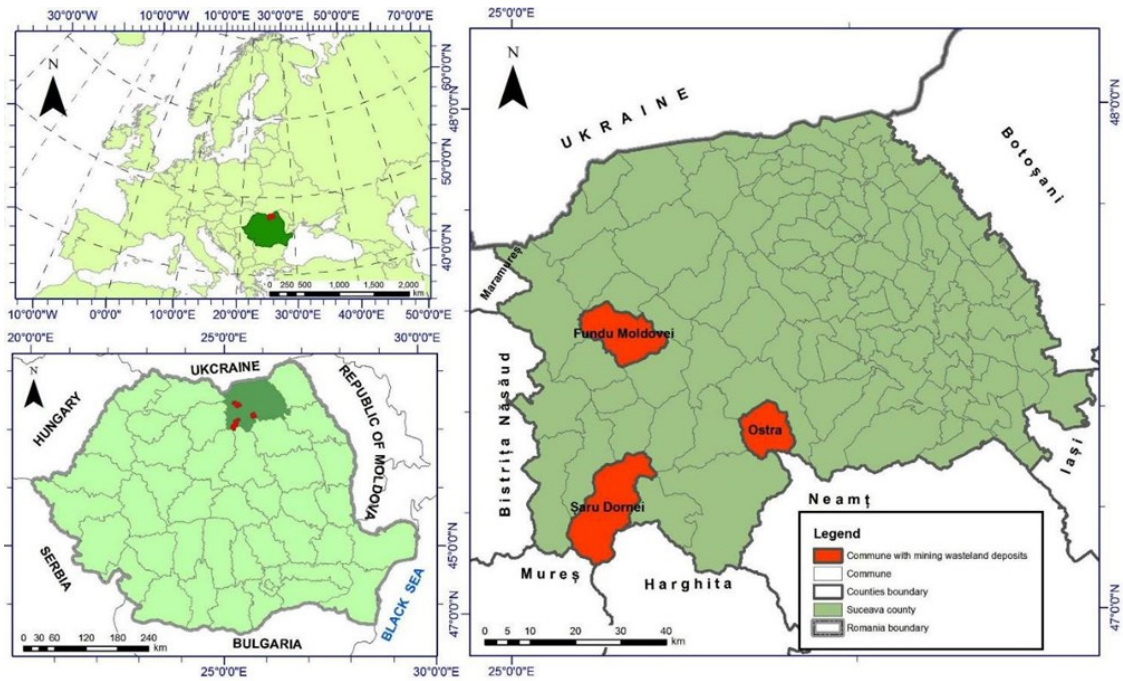

Figure 1 Location of the analyzed area.

Among the identified mining wastelands, the following four were chosen:

1. Copper ore-processing plant (flotation) and tailings deposit resulted from the complex ore processing at Fundu Moldovei (on the territory of the Fundu Moldovei village);
2. Complex ore exploitation at Ostra (on the territory of the Ostra village);
3. Manganese quarry at Dealu Rusului (on the territory of Şaru Dornei village);
4. Sulphur quarry at Negoiu Românesc - Pietricelu in the Călimani Mountains, inside Călimani National Park (on the territory of Şaru Dornei village).

3. Methods

The large number of environment variables affected by ore exploitation required a matrix analysis to synthetically quantify local and regional impacts. That is why we proceeded with an assessment of the impact of mining wastelands on the environment by means of an assessment matrix (Rapid Impact Assessment Matrix (RIAM), considered in terms of mining wastelands reintegration into the natural and economic landscape of the region, according to statistics from companies and labor force.

The matrix confronts the assessed mining activity and the potentially affected environmental factors. The intensity and importance of impact are quantified at the intersection of activities with the environmental factors. The description of anthropogenic impact categories follows the methodological principles used by Pastakia and Jensen (1998), but further modifications of Muntean (2005), Kuitunen and Hirvonen (2008) and Ijäs et al (2010) were taken into account.

The 15 environmental components we assessed were initially selected from the Leopold et al. (1971) matrix and adapted to the analyzed mining wastelands' assessment methodology, then divided into two categories: physical-geographic components and socio-economic and cultural components. Each component received an evaluation mark (score), according to the impact intensity (Table 1) outlined by 5 evaluation criteria (adaptation after Pastakia and Jensen (1998) and Irimia et al. (2011)). The established evaluation criteria were split, according to the methodology, into two major types:

A - criteria that can individually change the environmental score obtained;

B - criteria that cannot individually change the environmental score.

Table 1 Environmental Impact Assessment Criteria and Assessment Scores.

Assessment Criteria	Scale	Description
Importance of the environmental factor (A1)	4	Important for national interests
	3	Important for regional interests
	2	Important only for the locality
	1	Important only for the locating of the mining wasteland
	0	Without importance
Magnitude of environmental effect (A2)	+3	Major benefit
	+2	Significant improvement of the status quo
	+1	Improvement of the status quo
	0	No change / status quo
	-1	Negative change to status quo
	-2	Disadvantages or significant negative changes
	-3	Disadvantages or major negative changes
Permanence (B1)	1	No changes
	2	Temporary
	3	Permanent
Reversibility (B2)	1	No changes
	2	Reversible
	3	Irreversible
Cumulative (B3)	1	No changes
	2	Non-cumulative (unique)
	3	Cumulative (synergistic)

To attain the environmental impact assessment matrix the following calculations were devised:

$$A_1 \times A_2 = A_t$$

$$B_1 + B_2 + B_3 = B_t$$

$$A_t \times B_t = ES,$$

where:
A_1, A_2, B_1, B_2, B_3 are assessment criteria established through the RIAM method;
A_t, B_t are the marks obtained by multiplying, respectively adding the values assigned to the evaluation criteria;
ES is the environmental score for the analyzed factor (calculated in detail in Annex), which determines the category of impact of the analyzed mining wasteland (according to Table 2).

Table 2 Classification and description of anthropogenic impact categories based on environmental scores.

Environmental score	Impact category
Over +101	Change / major positive impact
+76 to +100	Change / significant positive impact
+51 to +75	Change / moderate positive impact
+26 to +50	Change /positive impact
+1 to +25	Change /Slight positive impact
0	No change of status quo
-1 to -25	Change / Slight negative impact
-26 to -50	Change /negative impact
-51 to -75	Change / moderate negative impact
-76 to -100	Change / Significant negative impact
Under -101	Change / Major negative impact

A particular emphasis was put on the analysis of the impact generated by the socio-economic and cultural components, given the premise from which the authors started, that is to test the re-integration capacity of the mining wastelands into the economic life of the communities they belong.

4. Results and discussion

The mining and storage of the resulting tailings affected all environmental components of the mining wastelands analyzed in Bukovina. Mention should be made, from the outset that the assessment was carried out in 2017, at a variable period from the mine closure. Thus, the activity at Ostra ceased in 2006, at Fundu Moldovei it ceased in 2002, the mining operation in Negoiu Românesc – Pietricelu from the Călimani Massif ceased in 1998 and in 1997 at Dealu Rusului. It is therefore a time when each mining wasteland had a different path in relation to the environment, depending on the type of ore deposits, frequency of stabilization and renaturation works, but mainly on the distance from people communities.

The 15 environmental components analyzed include 6 physical-geographical and ecological components and 9 socio-economic and cultural components. The physical-geographical and ecological components combine geomorphological, biological, pedological, climatic and

hydrological assessments. To provide fluency of the analysis, we detailed the environmental impact assessment criteria for the four mining wastelands in Annex.

We noted for all four locations:
1. The very important role of the wasteland areal surface;
2. The role played by the position of the mining wasteland in relation to the morphoclimatic system in which it appeared;
3. The role of overall landscape dynamics, especially through the Water Management Program and renaturalisation.

Hence, in significantly affected areas most indicators reach maximum negative levels. At the Călimani mining exploitation, the effect was critical because the affected area is very large (420 ha), compared to Ostra (63.5 ha), where the lower relief intensity and the smaller areas of the old mines generated moderate impact values on the physical-chemical and ecological components. In the case of Colacu (Fundu Moldovei), substantial increases in the values associated with the B1-B3 criteria should be associated to the existing risks but also to the force of these impact elements on the community, which is located near the exploitations (100 m from the first house). In comparison, the technological risks at Dealul Rusului are smaller for the same reasons, as the location is further away from people communities (1.58 km).

When reporting the position of the mining wasteland, a very important factor is the morphoclimatic system. The existence of current risks associated with mining wastelands increases greatly with altitude. The meteorological and hydrological phenomena in the high mountain areas of Călimani can trigger technological hazards with mass movements of some parts of the waste dumps as well as other types of current geomorphological processes. Under similar altitude conditions, the most vulnerable to risks are recent mining wastelands and, in particular, those where non-ferrous ores were exploited. This explains the lower impact values of the partly renatured wasteland from Dealu Rusului in the Bistrita Mountains.

From the point of view of the overall landscape dynamics, the factors that contributed to the high score of the environmental impact are, primarily, the local relief intensity (in the case of the Călimani mine exploitation) and the proximity of the wastelands to an active hydrographic network or to nearby people communities (Fundu Moldovei). The lowest values of the four wastelands are recorded at Dealu Rusului (in Bistrita Mountains) where, despite the high relief intensity, *the impact is slight negative* because much of the quarry and tailings dumps have been ecologically restored. At Fundu Moldovei renaturation took place on old tailings dumps (Praşca I and II) and only partially at Colacu through pioneer vegetation of birch and alder. At Ostra, renaturation is present due to the stability of the slopes and the role of the mining wastelands as enclaves in the forest area. To partially conclude, we noted that most of the situations with a *significant negative impact* and *major negative impact* are located in the mining exploitation of Călimani, followed by Ostra and Fundu Moldovei, through the affected areas and the quality of the water draining the wastelands.

From the microclimatic point of view and the existing vegetation, the wastelands at Fundu Moldovei, Ostra and Dealu Rusului have a *slight negative* or *negative impact.*

Synthesizing the RIAM for the *socio-economic and cultural components*, detailed in Annex, the analysis records the following:

a) The important role that mining has had on the territorial imbalances of the environment regarded as support (land use, open and wild spaces, forested areas);

b) The indirect role mining has had on the overall socio-economic aspects of the analyzed rural communities (human interest and lifestyle, aesthetics and landscape quality, unemployment rate, recreation and leisure, anthropogenic structures and access routes).

a). As a result of the analysis, the highest impact values in the categories: *land use, open and wild spaces, forested areas*, were registered at Fundu Moldovei and Ostra, where the mining exploitations generated rural features like "village of miners" or dormitory localities, with direct social impact fora long period of time. The explanation is given by the territorial proximity of the mining exploitations to communities. Given the fact that usable agricultural land area is small in the mountainous Bukovina, confinement to mining operations for a part of them has created a *significant negative impact* in the host communities.

There is a *significant negative* environmental *impact* for the aforementioned components at the Călimani mining exploitation, because it is located within the Călimani National Park, near the full protection area.

If at Fundu Moldovei and Călimani there is a *major negative impact* on the forested areas, in the case of Ostra and especially Dealu Rusului, the effect on the forest area is diminished due to the insularity of the actual exploitation, the position in the forestry domain or as a result of the renaturation of these areas with pioneering species. We noted, in the case of Ostra community, the existence of some tailing ponds developed on large areas (Tărnicioara and Valea Străjii), which represent about half of the mining wastelands. They themselves have a significant / major negative impact and represent significant risks for the Ostra community, the hydrographic network and the downstream localities. For the same reason, our analysis recorded very high values at Fundu Moldovei and Ostra on B1 (permanence) and B3 (cumulative) criteria on land use, forest areas and landscape quality.

Taking into account the ecological reconstruction and slopes stabilization activities of the last four years at the Tărnicioara pond, it is expected that the values given to this component will evolve, so that, subsequent to the RIAM matrix application, the impact on the environment will diminish considerably.

b). as for the role that the mining exploitations have had on the socio-economic aspects of the analyzed rural communities, the changes in lifestyle were the most visible. We found the most significant negative impact in Fundu Moldovei and Saru Dornei, directly related to the attitude of the community after the mine closure, of nostalgia and regret. Although it would have been natural for this indicator to have high values at Ostra as well, the difference is given by the post-mining resilience of each of the three villages. Thus, Ostra, having the largest number of miners in all the three communities, also had the largest number of retired personnel at the closure of the large mines in the region. As miners' pensions were higher than the national average, this minimized the negative social effect the population has felt. Another type of resilience in Ostra was the shift towards working abroad, which also diminished the social impact through cumulated allowances. In addition, Ostra and Fundu Moldova still have a number of people currently working in functional mines.

In terms of reversibility and cumulation of socio-economic and cultural indicators, the values are high in Ostra and moderate at Şaru Dornei and Fundu Moldovei.

A very important element we analyzed in the three communities was the unemployment rate. According to the National Statistics Institute (2017), the highest values of the unemployment rate are recorded in Ostra (5%), compared to 2.1% in Fundu Moldovei and 1.5% in Şaru Dornei, the latter two in a decreasing trend: Fundu Moldovei, from 5.9% in 2010 to 2.1% in 2018, Saru Dornei from 4.3% in 2010 to 1.5% in 2018.

The local administration got involved in the post-mining matters either by taking over housing units (Ostra, Neagra Şarului) or by taking over infrastructure elements, water supply, energy or other facilities, which constituted the starting point for projects with European funding to support communities. This explains why the only *slight positive* or *slight moderate negative impact* element in the RIAM matrix appears at the level of access paths.

The effect of mine closure on anthropogenic structures and recreational and leisure ones was significantly negative at the mining operation Calimani, which is the most severe impact as it is an area located in a protected region but also because this area is located in a high mountain range with distinct effect on the downstream communities.

Finally, the study notes the major negative impact that mining wastelands have on the aesthetics and landscape quality. The very high degree of visibility from the main access routes to the mining wastelands appears in Ostra and Fundu of Moldavia and it is lower at Dealu Rusului and Călimani.

However, the quality of the affected landscape in Călimani, Fundu Moldovei and Ostra has a *significant negative level*. This is due to the fact that the wasteland areas are very large, the landscape is irreparably disturbed, there is a radical change of the environmental components and nature restoration is difficult. Ecological reconstruction actions in these waste areas are expensive and can only solve some of the local drainage problems, directing the meteoric waters or stabilizing the ridge slopes. The high negative impact of the waste landscape is even greater as it is near compact forest areas (Ostra), of whole protection areas (Călimani) or within the built-up areas of localities (Fundu Moldovei).

5. Conclusion

Rural areas with mineral resources and ceased mining activities are currently under intense economic and environmental pressure, mobilizing all their internal resources and forcing them to redefine themselves. Mining wastelands are a reality of Bukovina's economic landscape and play an important role in structuring the communities that host them. Although they were created in the context of environment-society relationship, which worked during the centralized economy, the responsibility for their integration into a new economic functional stage rests mostly with the communities.

The survey conducted in these three communities showed that mining wastelands are not perceived as components of the current rural landscape, but only as a former source of jobs that has ceased to be useful. From this point of view, we conclude that a first step in their future valorization would be to accept them as elements of cultural heritage landscape.

The main steps of this approach will be to:

• Establish the legal status of the mining wastelands, in relation to the possible actions of the local and regional/ county administration and those of their owner, the Ministry of Economy;

• Evaluate development directions through local public-private partnerships;

• Elaborate territorial planning policies anchored to the needs and potential of the wastelands, supported by centrally funded regional policies or European projects.

Public associations, environmental NGOs and local entrepreneurs will have to confirm their role in the full development of the complex cultural and touristic potential and be able to advance projects to local administrations in order to reconsider wastelands as cultural heritage areas of Bukovina, future areas of tourist attractiveness and uniqueness of the Romanian Carpathians.

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Supplementary Material (Annex) - Assessment of environmental impact of wastelands criteria breakdown

Table A1 Wasteland Fundu Moldovei: Flotation plant for copper ore and tailings deposit from complex ore mining; Area: 6.53 ha; Altitude: 753-790.

Environmental Component	Assessment criterion						
	A1	A2	B1	B2	B3	SE	CI
Physical-geographic and ecological components							
Affected soil area	3	-3	3	3	3	-81	Significant negative impact
Land morphology	3	-3	3	3	3	-81	Significant negative impact
Water quality	4	-2	3	3	3	-72	Moderate negative impact
Microclimates and topoclimates	2	-2	3	2	3	-32	Negative impact
Stability of land. Current geomorphological processes	2	-2	3	3	3	-36	Negative impact
Arborescent vegetation	2	-2	2	3	3	-32	Negative impact
Socio-economic and cultural components							
Land use	2	-2	3	3	3	-36	Negative impact
Open and wild spaces	2	-2	3	3	3	-36	Negative impact
Forested areas	1	-2	3	3	3	-18	Slight negative impact
Human interests and lifestyle	4	-3	3	3	2	-96	Significant negative impact
Aesthetics and landscape quality	2	-3	3	3	3	-54	Moderate negative impact
Unemployment rate	3	-3	1	2	2	-36	Negative impact
Recreation and leisure	2	-3	2	2	3	-72	Moderate negative impact
Anthropogenic structures	1	-3	3	3	2	-24	Slight negative impact
Access routes	1	-3	3	3	2	-24	Slight negative impact

Table A2 Wasteland OSTRA: Complex ore quarry; Area: 63.5 ha; Altitude: 893-1115 m.

Environmental Component	Assessment criterion						
	A1	A2	B1	B2	B3	SE	CI
Physical-geographic and ecological components							
Affected soil area	3	-3	3	3	3	-81	Significant negative impact
Land morphology	2	-3	3	3	3	-54	Moderate negative impact
Water quality	3	-3	2	3	3	-72	Moderate negative impact
Microclimates and topoclimates	2	-1	2	3	2	-14	Slight negative impact
Stability of land. Current geomorphological processes	2	-2	2	2	3	-28	Negative impact
Arborescent vegetation	2	-2	2	3	3	-32	Negative impact
Socio-economic and cultural components							
Land use	2	-1	3	3	2	-16	Slight negative impact
Open and wild spaces	3	-1	2	3	2	-21	Slight negative impact
Forested areas	1	-1	3	3	3	-9	Slight negative impact
Human interests and lifestyle	2	-3	3	2	2	-42	Negative impact
Aesthetics and landscape quality	2	-2	3	3	3	-36	Negative impact
Unemployment rate	3	-3	2	2	3	-63	Moderate negative impact
Recreation and leisure	2	-2	3	3	3	-36	Negative impact
Anthropogenic structures	2	-2	3	2	2	-28	Negative impact
Access routes	3	0	2	3	2	+21	Slight positive impact

Table A3 Wasteland Dealu Rusului, Șaru Dornei village (limit with Panaci), manganese quarry; Area: 53.6 ha; Altitude: 1549 m.

Environmental Component	Assessment criterion						
	A1	A2	B1	B2	B3	SE	CI
Physical-geographic and ecological components							
Affected soil area	3	-1	2	2	3	-21	Slight negative impact
Land morphology	3	-2	3	3	2	-48	Negative impact
Water quality	3	-1	2	2	2	-18	Slight negative impact
Microclimates and topoclimates	2	0	1	2	2	8	Slight positive impact
Stability of land. Current geomorphological processes	1	-1	2	3	3	-8	Slight negative impact
Arborescent vegetation	2	-1	2	2	3	-14	Slight negative impact
Socio-economic and cultural components							
Land use	2	-1	2	2	2	-12	Slight negative impact
Open and wild spaces	2	-2	2	2	3	-28	Negative impact
Forested areas	2	-2	2	2	2	-24	Slight negative impact
Human interests and lifestyle	2	-2	2	2	2	-24	Slight negative impact
Aesthetics and landscape quality	2	-2	3	2	2	-28	Negative impact
Unemployment rate	2	-2	3	2	3	-32	Negative impact
Recreation and leisure	2	-1	2	2	1	-10	Slight negative impact
Anthropogenic structures	2	0	2	2	1	10	Slight positive impact
Access routes	2	0	2	2	2	12	Slight positive impact

Table A4 Wasteland Călimani National Park, Negoiu Românesc-Pietricelu, sulphur exploitation in Călimani Massif, on the territory of Șaru Dornei village, Suceava county; Area: 420 ha; Altitude: 1570 – 1700 m.

Environmental Component	Assessment criterion						
	A1	A2	B1	B2	B3	SE	CI
Physical-geographic and ecological components							
Affected soil area	4	-3	3	3	3	-108	Major negative impact
Land morphology	4	-3	3	3	3	-108	Major negative impact
Water quality	4	-3	2	2	2	-72	Moderate negative impact
Microclimates and topoclimates	3	-2	2	2	2	-36	Negative impact
Stability of land. Current geomorphological processes	3	-3	3	3	3	-81	Significant negative impact
Arborescent vegetation	3	-3	3	3		-81	Significant negative impact
Socio-economic and cultural components							
Land use	3	-3	3	3	3	-81	Significant negative impact
Open and wild spaces	4	-3	3	2	3	-96	Significant negative impact
Forested areas	4	-3	3	2	3	-96	Significant negative impact
Human interests and lifestyle	4	-3	3	2	2	-84	Significant negative impact
Aesthetics and landscape quality	4	-3	3	3	3	-108	Major negative impact
Unemployment rate	2	-2	2	2	2	-24	Slight negative impact
Recreation and leisure	4	-3	2	3	2	-84	Significant negative impact
Anthropogenic structures	4	-3	2	3	3	-96	Significant negative impact
Access routes	3	-3	2	2	2	-54	Moderate negative impact