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RISK-BASED SELECTION OF REHABILITATION MEASURES FOR INACTIVE MINING DUMPS IN THE JIU VALLEY, ROMANIA

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Abstract: *Inactive mining dumps are persistent environmental liabilities in former mining regions, particularly where waste deposits are located near watercourses, settlements or areas with potential for ecological reuse. In the Jiu Valley, Romania, the long history of coal mining has generated numerous waste rock dumps with different degrees of contamination, morphological stability, vegetation development and receptor exposure. Although contamination indices are useful for identifying environmental pressure, rehabilitation planning requires the translation of risk information into site-specific action priorities. This paper proposes a risk-based decision-support framework for selecting rehabilitation measures for inactive mining dumps in the Jiu Valley. The approach integrates three categories of indicators: geochemical pressure, morphometric and stability pressure, and environmental vulnerability. These indicators were derived from existing inventory, morphometric, receptor-proximity and geochemical data obtained for fourteen inactive mining dumps. A Rehabilitation Action Priority score was calculated to assign each dump to one of four rehabilitation classes: urgent risk control and containment, active ecological stabilisation, monitored natural recovery with targeted intervention, and low-risk ecological reconversion. The results indicate that Balomir, Ramura 1 and 2 Lupeni, and Ramura 1, 2, 3 and 4 Petrila require the highest rehabilitation priority, while most other dumps require active ecological stabilisation rather than immediate containment. The proposed framework supports preliminary decision-making under limited resources and demonstrates that post-mining rehabilitation should move beyond simple contamination ranking towards action-oriented planning.*
Keywords: *inactive mining dumps; rehabilitation prioritisation; environmental risk; post-mining landscapes; ecological stabilisation; decision-support framework*

1. Introduction

Mining activities have contributed substantially to industrial development, but they have also generated long-term environmental pressures that may persist for decades after mine closure. Waste rock dumps and tailings-related deposits remain among the most visible post-mining landforms because they occupy large surfaces, modify local morphology and may act as sources of soil contamination, erosion, runoff, dust dispersion and landscape fragmentation [1, 2].

In former coal mining regions, the environmental condition of inactive dumps is highly heterogeneous. Some deposits are partially vegetated and show signs of natural stabilisation, whereas others remain exposed, eroded or hydrologically connected to streams, lakes or drainage pathways. The management problem is therefore not limited to determining whether a dump is contaminated, but also to deciding what type of intervention is technically appropriate and environmentally justified.

Traditional assessments of mining-affected soils frequently rely on metal concentrations, geoaccumulation indices, contamination factors or ecological risk indices [3, 4, 5]. These approaches are essential for identifying geochemical pressure, but they do not automatically indicate whether a site requires containment, erosion control, phytostabilisation, monitored natural recovery or ecological reconversion. A site with moderate contamination but high erosion and receptor proximity may require more urgent intervention than an isolated site with a similar geochemical profile.

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The Jiu Valley in Hunedoara County, Romania, represents a relevant case study for developing such a rehabilitation-oriented approach. Previous investigations identified numerous mining waste deposits in the region and documented contamination with heavy metals such as Cr, Cu, Ni, Zn, Co and Pb in soil samples collected from inactive dumps [6, 7, 8, 9]. The doctoral research on which this paper builds inventoried 49 mining dumps, of which 31% were inactive, and analysed soil samples from fourteen inactive dumps distributed from west to east across the basin [7].

The aim of this paper is to develop and apply a risk-based decision-support framework for selecting rehabilitation measures for inactive mining dumps in the Jiu Valley. The specific objectives are: (i) to organise available thesis-derived data into geochemical, morphometric and vulnerability indicators; (ii) to calculate a Rehabilitation Action Priority score; (iii) to classify dumps into rehabilitation action classes; and (iv) to associate each class with suitable technical, ecological and monitoring measures. The contribution of the paper lies in shifting the focus from contamination-centred assessment to action-oriented rehabilitation planning.

2. Study Area and Data Basis

The study area is the Jiu Valley coal basin, located in the south-western part of Romania, in Hunedoara County. The basin is bordered by the Retezat, Valcan and Parang Mountains and has a long history of underground coal mining and coal preparation. The regional landscape combines mountainous natural features with post-industrial landforms, including waste rock dumps, former mining platforms and associated infrastructure [6].

The analysis focused on fourteen inactive mining dumps belonging to the mining areas of Uricani, Lupeni, Vulcan, Livezeni and Petrila. These dumps are: Funicular Vechi and Balomir in Uricani; Bloc 0, Noua Victoria and Ramura 1 and 2 in Lupeni; Coroiești Ramura I, Tericon cota 630, Hypolit, Puț 7 Vest (tericoane) and Puț 7 Vest (halda veche) in Vulcan; Puț Auxiliar Est in Livezeni; and Ramura 1, 2, 3 and 4, Defor and Valea lui Ciort in Petrila.

The data used in this paper were extracted and reorganised from the doctoral thesis dataset. The source dataset includes inventory information on dump surface area and volume, receptor-proximity information regarding water bodies, settlements, wind exposure and agricultural activities, and geochemical data obtained from soil sampling performed in 2022 and 2023. The soil sampling campaign covered the fourteen inactive dumps and used two depth intervals, 0–20 cm and 20–40 cm. The investigated elements were Cr(total), Cu, Ni, Zn, Co and Pb [6].

For the present paper, the 2023 total contamination factor (FCT) was used as the main geochemical screening descriptor, while morphometric and receptor-proximity information was used to derive rehabilitation-oriented pressure scores. The purpose was not to repeat the thesis contamination assessment, but to convert existing data into a practical rehabilitation prioritisation model.

The fourteen inactive mining dumps analysed in this study are distributed along the main mining and settlement corridor of the Jiu Valley, from Uricani in the western sector to Petrila in the eastern sector. Their spatial distribution and rehabilitation-priority classes are shown in Figure 1. The map provides the geographical context of the investigated sites and highlights the relationship between dump location, nearby built-up areas and the hydrographic network.

As shown in Figure 1, the analysed dumps are not uniformly distributed across the basin, but are concentrated around the main former mining centres of Uricani, Lupeni, Vulcan, Livezeni and Petrila. The colour-coded classification indicates that Balomir, Ramura 1 and 2 Lupeni and Ramura 1, 2, 3 and 4 Petrila represent the highest-priority sites, whereas Funicular Vechi and Hypolit correspond to lower rehabilitation-priority classes. This spatial representation supports the interpretation that rehabilitation planning should consider not only contamination-related pressure, but also proximity to settlements, watercourses and former mining infrastructure.

The source indicators used for the rehabilitation-oriented screening are summarised in Table 1. These indicators were selected because they describe the main dimensions required for preliminary prioritisation: dump size, represented by surface area and volume; environmental and human exposure, represented by water and settlement receptors; and geochemical pressure, represented by the 2023 total contamination factor. Together, these parameters provide the basic dataset needed to convert inventory information into rehabilitation-relevant pressure scores.

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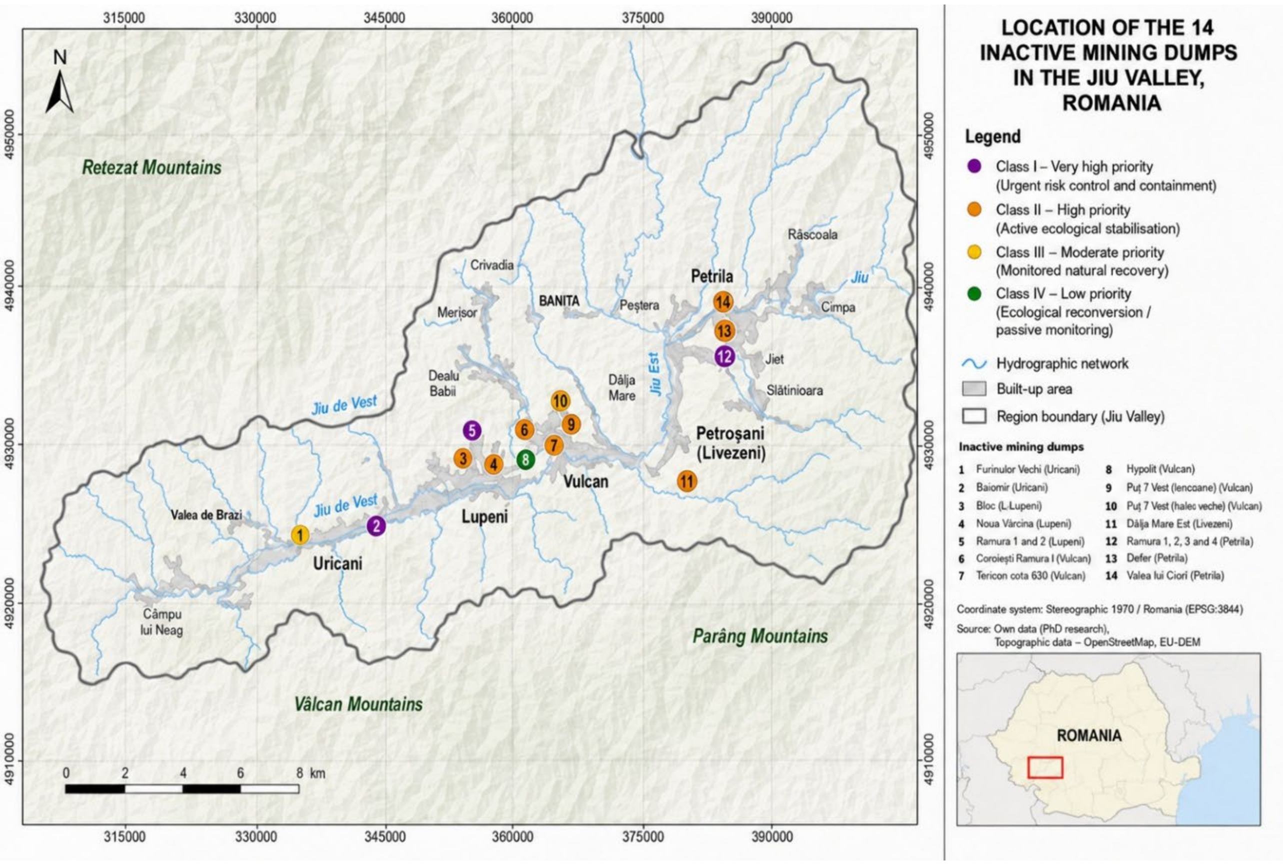

Fig.1. Spatial distribution and rehabilitation-priority classification of the fourteen inactive mining dumps analysed in the Jiu Valley, Romania

Table 1. Source indicators used for rehabilitation-oriented screening of inactive mining dumps in the Jiu Valley

No.	Mining area	Inactive dump	Area (m^2)	Volume (thousand m^3)	Water receptor	Settlement receptor	FCT 2023
1	Uricani	Funicular Vechi	51 700	31.169	-	-	2.82
2	Uricani	Balomir	130 000	39000	Pârâul Balomir, 100 m	100 persons, 100 m	2.76
3	Lupeni	Bloc 0	18 400	9.2	Pârâul Boncii, 30 m	-	2.79
4	Lupeni	Noua Victoria	31 800	2875	-	40 persons, 500 m	2.69
5	Lupeni	Ramura 1 and 2	11 420	7756.442	Lakes at dump base	-	2.76
6	Vulcan	Coroiești Ramura I	126 000	3.150	-	30 persons, 200 m	2.58
7	Vulcan	Tericon cota 630	13 700	220	-	25 persons, 200 m	2.65
8	Vulcan	Hypolit	2 500	5	-	-	2.57
9	Vulcan	Puț 7 Vest (tericoane)	100 000	1056.000	-	100 persons, 500 m	2.68
10	Vulcan	Puț 7 Vest (halda veche)	35 000	588.000	-	100 persons, 500 m	2.74
11	Livezeni	Puț Auxiliar Est	10 900	144	Torrents at dump base	100 persons, 300 m	2.03
12	Petrila	Ramura 1, 2, 3 and 4	800 430	5105.000	Lakes, 20 m	-	2.04
13	Petrila	Defor	127 500	2149.970	Cariera Defor lakes, 50-200 m	50 persons, 200 m	2.04
14	Petrila	Valea lui Ciort	7 190	21.570	Lake formed by torrents, 5 m	10 persons, 300 m	1.95

Note: Area values are expressed in square metres, while volume values are expressed as 10^3 m^3. The notation "-" indicates that no direct receptor was identified in the available dataset for the respective dump

Table 1 shows that the analysed inactive dumps differ substantially in terms of area, volume and receptor proximity. Some sites, such as Balomir, Ramura 1 and 2 Lupeni and Ramura 1, 2, 3 and 4 Petrila, combine relevant morphometric dimensions or direct proximity to water bodies with measurable geochemical pressure. Other dumps, such as Hypolit, have much smaller dimensions and no identified nearby water or settlement receptor, which suggests a lower rehabilitation urgency at the preliminary screening level. These contrasts justify the use of an integrated assessment approach, rather than a prioritisation based only on contamination values.

3. Materials and Methods

Conceptual approach

The proposed framework is based on the principle that rehabilitation priority should depend on three complementary dimensions: contamination-related pressure, physical/morphological pressure and receptor exposure. These dimensions are expressed through three ordinal scores: Geochemical Pressure (GP), Morphometric and Stability Pressure (MSP), and Environmental Vulnerability (EV). Each score ranges from 1 to 5, where 1 indicates very low pressure and 5 indicates very high pressure.

The scores were developed as a preliminary screening tool rather than as a final engineering design criterion. This distinction is important because rehabilitation design requires additional geotechnical, hydrological and ecological investigations. However, a screening model is useful for identifying sites where intervention planning should begin and for differentiating between urgent control, active stabilisation, monitored recovery and low-risk reuse.

Indicator scoring

GP was derived from the total contamination factor and from the distribution of the investigated heavy metals. Although the thesis classified all FCT values below 6 as indicating a low contamination degree, a relative geochemical scale was used in this paper to differentiate rehabilitation priorities within the group of inactive dumps [6]. This relative interpretation is justified because sites with similar legal classification may still differ in the number of metals detected, the relative intensity of enrichment and their spatial exposure.

MSP was derived from dump surface area, volume and qualitative stability-related information. Larger dumps, dumps with important volumes, exposed surfaces or higher erosion potential received higher scores. EV was derived from receptor-proximity data, including the presence and distance of water bodies, settlements, torrents, lakes, agricultural activities and wind exposure. Dumps directly connected to lakes, torrents or nearby settlements received higher EV scores.

The conversion of the source information into comparable ordinal scores is presented in Table 2. This scoring rationale was necessary because the input indicators are heterogeneous: geochemical contamination is expressed through FCT values, morphometric pressure is related to dump size and stability-relevant features, while environmental vulnerability depends on the proximity of water bodies, settlements or drainage pathways. By using a common 1–5 scale, the three pressure dimensions could be integrated within the same rehabilitation-prioritisation framework.

Table 2. Scoring rationale for rehabilitation-oriented pressure indicators.

Score	Geochemical pressure (GP)	Morphometric/stability pressure (MSP)	Environmental vulnerability (EV)
1	Very low relative contamination pressure	Stable, small or well-vegetated dump	Isolated site with no sensitive receptor nearby
2	Low relative contamination pressure	Low to moderate dimensions or limited exposure	Reduced receptor exposure
3	Moderate relative contamination pressure	Moderate dimensions, partial exposure or local stability concern	Moderate proximity to receptors or drainage pathways
4	High relative contamination pressure	Large dimensions, high volume or relevant physical exposure	Close proximity to water, settlements or agricultural receptors
5	Very high relative contamination pressure	Very large dump or strong stability/erosion concern	Direct or near-direct interaction with sensitive receptors

The scoring system presented in Table 2 allows each inactive dump to be assessed in a comparable manner, even when the original information differs in type and scale. Low scores indicate limited contamination pressure, reduced physical exposure or low receptor sensitivity, whereas high scores indicate stronger contamination relevance, larger or more exposed dump morphology and closer interaction with sensitive receptors. Therefore, the final prioritisation does not depend on a single indicator, but on the combined effect of geochemical pressure, morphometric/stability pressure and environmental vulnerability.

After assigning the three component scores, the integrated Rehabilitation Action Priority score was calculated using a weighted multi-criteria approach, as shown in Equation (1):

$$RAP = 0.40 \times GP + 0.30 \times MSP + 0.30 \times EV \quad (1)$$

where RAP is the Rehabilitation Action Priority score, GP is the Geochemical Pressure score, MSP is the Morphometric and Stability Pressure score, and EV is the Environmental Vulnerability score. The selected weights were assigned based on expert judgement and on the objective of giving slightly higher importance to geochemical pressure, while maintaining a balanced contribution of morphometric pressure and environmental vulnerability. Geochemical pressure was assigned a weight of 0.40 because contamination represents the primary environmental concern, whereas morphometric/stability pressure and environmental vulnerability were each assigned a weight of 0.30 because they control exposure, intervention urgency and the potential impact on surrounding receptors.

The resulting RAP values were then translated into four rehabilitation action classes, as presented in Table 3. These classes were defined in order to connect the numerical prioritisation score with practical rehabilitation directions, ranging from urgent risk control to passive monitoring or low-risk ecological reconversion.

Table 3. Rehabilitation action classes used in the proposed framework

RAP score	Class	Priority level	General management direction
≥ 4.00	Class I	Very high	Urgent risk control and containment
3.00–3.99	Class II	High	Active ecological stabilisation
2.00 –2.99	Class III	Moderate	Monitored natural recovery with targeted intervention
< 2.00	Class IV	Low	Low-risk ecological reconversion or passive monitoring

Table 3 provides the operational interpretation of the RAP score. Sites with RAP values equal to or higher than 4.00 are considered very high-priority sites and require urgent risk control and containment-oriented measures. Dumps with scores between 3.00 and 3.99 require active ecological stabilisation, while moderate-priority sites can be managed through monitored natural recovery combined with targeted interventions. Low-priority sites may be suitable for passive monitoring, ecological reconversion or controlled low-risk reuse, provided that future field validation confirms stable conditions.

The methodological sequence of the proposed decision-support framework is summarised in Figure 2. The figure illustrates how baseline site information is progressively transformed into integrated assessment criteria, multi-criteria scores, rehabilitation-priority classes and site-specific management directions. This stepwise structure was designed to support the selection of rehabilitation measures under conditions of limited data availability and variable site complexity.

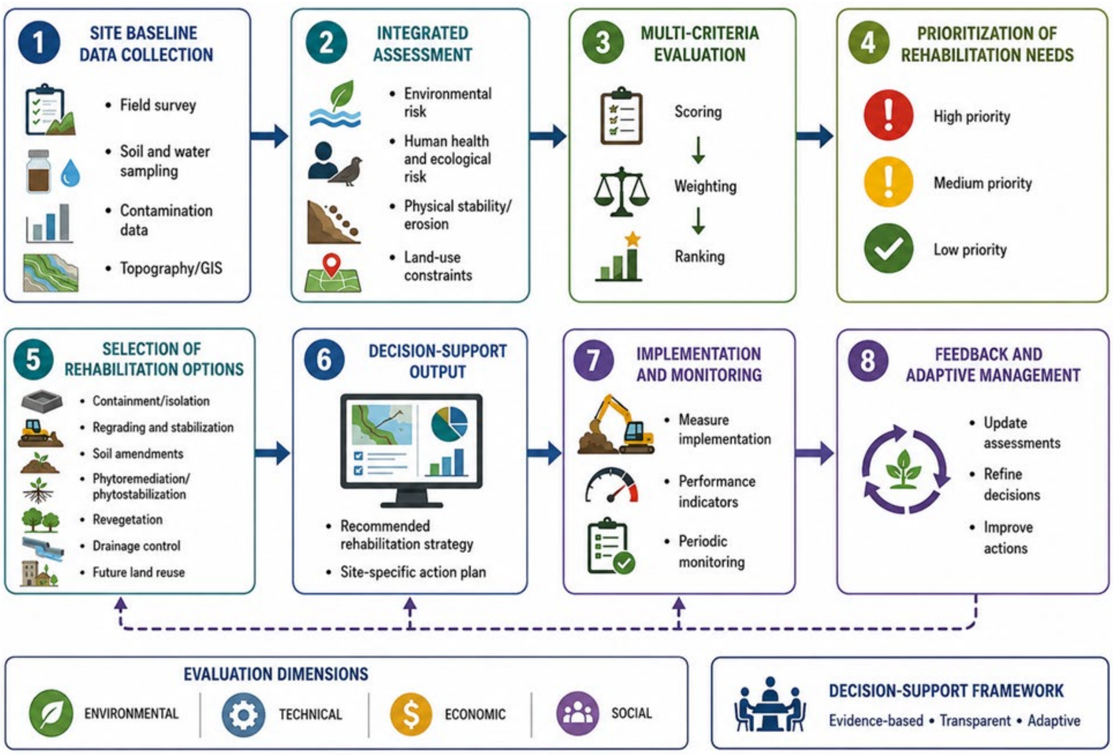

Fig. 2. Conceptual workflow of the proposed rehabilitation decision-support framework

Figure 2 shows that rehabilitation prioritisation should be interpreted as an iterative decision-support process rather than as a simple ranking exercise. By connecting baseline data, multi-criteria evaluation, rehabilitation options and monitoring feedback, the framework provides a practical structure for selecting and adapting rehabilitation measures for inactive mining dumps.

4. Results

Rehabilitation-oriented classification

The rehabilitation-oriented classification integrates the source indicators presented in Table 1 into the RAP model. The resulting scores are summarised in Table 4. This table represents the main operational output of the proposed framework, because it links each inactive dump to a specific combination of geochemical pressure, morphometric/stability pressure and environmental vulnerability. The classification should be interpreted as a preliminary decision-support result and not as a final technical rehabilitation design. Its purpose is to identify the appropriate direction of intervention for each inactive dump.

Table 4. Rehabilitation-oriented classification of inactive mining dumps in the Jiu Valley

No.	Mining area	Inactive dump	GP	MSP	EV	RAP	Class	Main recommended rehabilitation direction
1	Uricani	Funicular Vechi	4	2	1	2.50	Class III	Monitored natural recovery; periodic geochemical monitoring; vegetation maintenance
2	Uricani	Balomir	4	4	5	4.30	Class I	Priority risk control; runoff management; erosion control; phytostabilisation; periodic monitoring
3	Lupeni	Bloc 0	4	2	4	3.40	Class II	Active ecological stabilisation; monitoring of runoff pathways; local erosion control
4	Lupeni	Noua Victoria	3	3	3	3.00	Class II	Assisted revegetation; vegetation improvement; periodic field inspection
5	Lupeni	Ramura 1 and 2	4	4	5	4.30	Class I	Priority stabilisation; hydrological control near lakes; erosion control; phytostabilisation
6	Vulcan	Coroiești Ramura I	3	3	4	3.30	Class II	Active ecological stabilisation; vegetation maintenance; monitoring near human receptors
7	Vulcan	Tericon cota 630	3	2	4	3.00	Class II	Monitored stabilisation; vegetation maintenance; receptor-oriented monitoring
8	Vulcan	Hypolit	3	1	1	1.80	Class IV	Passive monitoring; ecological reconversion; maintenance of natural vegetation cover
9	Vulcan	Puț 7 Vest (tericoane)	3	3	3	3.00	Class II	Assisted natural recovery; local stabilisation; vegetation monitoring
10	Vulcan	Puț 7 Vest (halda veche)	4	2	3	3.10	Class II	Vegetation maintenance; geochemical monitoring; controlled ecological stabilisation
11	Livezeni	Puț Auxiliar Est	3	2	5	3.30	Class II	Active monitoring of torrents; vegetation maintenance; preventive runoff control
12	Petrila	Ramura 1, 2, 3 and 4	3	5	5	4.20	Class I	Priority intervention; hydrological monitoring; erosion control; vegetation maintenance; long-term surveillance
13	Petrila	Defor	3	3	5	3.60	Class II	Active ecological stabilisation; geochemical monitoring; control of water-related exposure pathways
14	Petrila	Valea lui Ciort	3	2	5	3.30	Class II	Monitoring of lake/torrent receptor; vegetation support; preventive stabilisation

GP = geochemical pressure; MSP = morphometric and stability pressure; EV = environmental vulnerability; RAP = Rehabilitation Action Priority. Scores were derived by reclassifying thesis-based geochemical, morphometric and receptor-proximity data into a relative 1–5 screening scale.

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The results presented in Table 4 indicate that Balomir, Ramura 1 and 2 Lupeni, and Ramura 1, 2, 3 and 4 Petrila fall into Class I, meaning that they should be prioritised for risk control and active rehabilitation planning. These sites combine relevant geochemical pressure with high environmental vulnerability or significant morphometric/stability pressure. Most of the remaining dumps fall into Class II, requiring active ecological stabilisation rather than immediate containment. Funicular Vechi is classified as Class III because its high geochemical pressure is not accompanied by high receptor exposure or major morphometric pressure, while Hypolit is classified as Class IV due to its very small size, low receptor exposure and favourable stabilisation potential.

To facilitate comparison among the analysed dumps, the RAP values were also represented graphically, as shown in Figure 3. This visual representation helps distinguish the sites requiring immediate intervention from those suitable for active stabilisation, monitored recovery or low-intensity management.

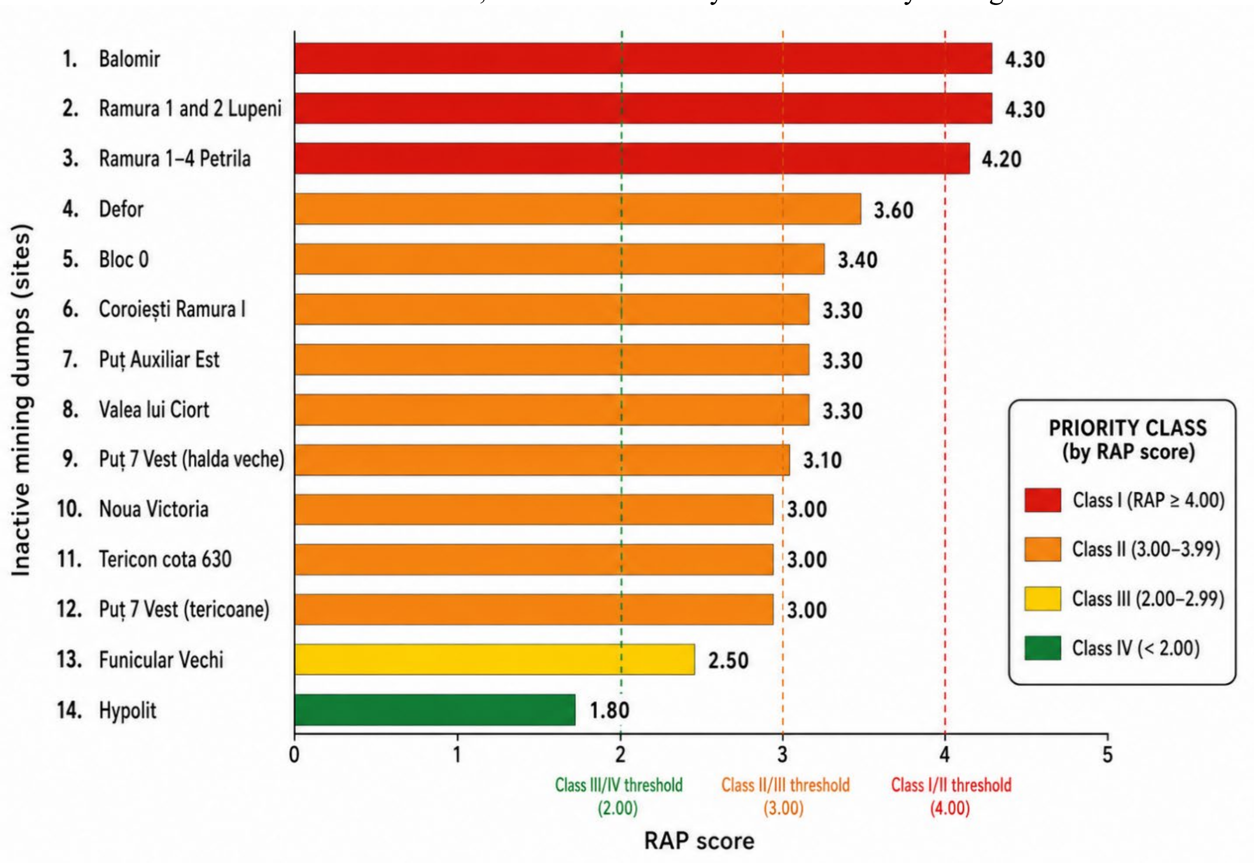

Fig. 3. Rehabilitation Action Priority scores for the analysed inactive mining dumps

Risk-to-action interpretation

The results show that a simple ranking based only on contamination would be insufficient for rehabilitation planning. For example, Funicular Vechi has one of the highest FCT values, but its low receptor exposure reduces the immediate rehabilitation urgency. In contrast, Ramura 1, 2, 3 and 4 Petrila has a lower FCT value, but its very high morphometric score and high environmental vulnerability place it among the priority sites. This confirms that rehabilitation decisions should integrate both source intensity and exposure pathways.

The rehabilitation classes obtained through the RAP model were therefore interpreted in relation to the expected intensity of management response. Class I dumps should be addressed through detailed field inspection, access management, hydrological control, erosion reduction, surface stabilisation and long-term monitoring. Class II dumps should be managed through active ecological stabilisation, vegetation maintenance and local erosion control. Class III dumps require periodic monitoring and targeted intervention where vegetation cover or stability declines, while Class IV dumps may be suitable for passive monitoring, ecological reconversion or controlled educational use.

This interpretation was synthesised into a risk-to-action matrix in order to translate the screening results into practical rehabilitation responses. The matrix presented in Figure 4 links the level of site risk and rehabilitation priority with the intensity of the management response, from passive management to intensive intervention.

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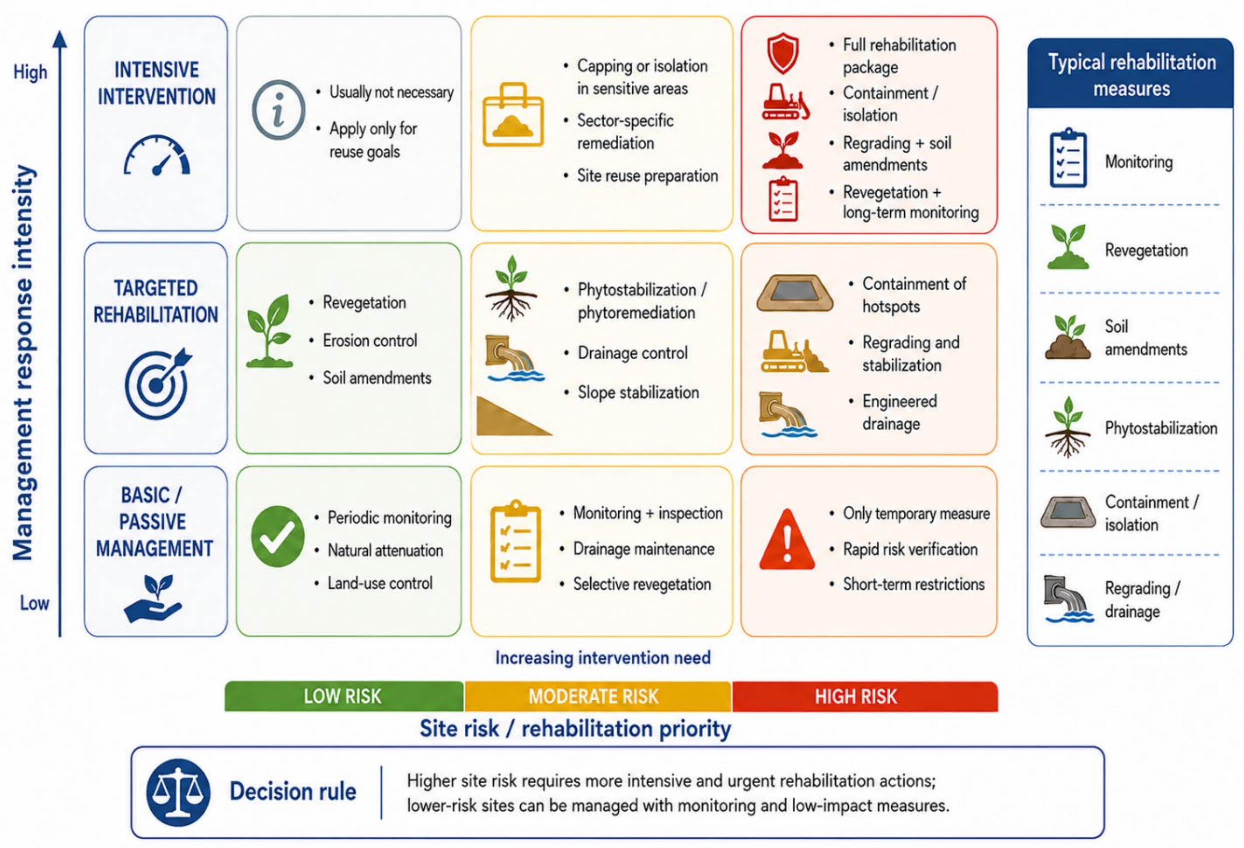

Fig. 4. Risk-to-action matrix for selecting rehabilitation measures

Figure 4 highlights that higher-risk sites require more intensive and urgent rehabilitation actions, whereas lower-risk sites can be managed through monitoring, natural attenuation or low-impact ecological measures. The matrix also shows that intervention intensity should increase when contamination pressure is associated with receptor exposure, erosion risk or hydrological connectivity.

Based on the same logic, Table 5 summarises the dominant site conditions, the main environmental concerns and the corresponding rehabilitation directions. This table provides a practical link between the RAP-based classification and the types of measures that may be considered during preliminary rehabilitation planning.

Table 5. Risk-to-action matrix for inactive mining dumps.

Dominant condition	Main environmental concern	Recommended direction	Examples of measures
High contamination + high vulnerability	Receptor exposure, runoff, leaching	Risk control and containment	Access restriction; drainage control; erosion control; monitoring
High contamination + moderate stability	Metal persistence and vegetation stress	Phytostabilisation	Tolerant vegetation; organic amendments; surface stabilisation
Moderate contamination + high erosion	Sediment transport and dust dispersion	Physical stabilisation	Slope reshaping; erosion mats; hydroseeding; runoff control
Moderate pressure + partial vegetation	Incomplete ecological recovery	Assisted natural recovery	Selective planting; gap filling; periodic inspection
Low pressure + stable morphology	Safe long-term reuse potential	Ecological reconversion	Biodiversity areas; educational trails; passive monitoring

Table 5 shows that the recommended rehabilitation direction depends on the dominant combination of contamination, stability and vulnerability conditions. Sites combining high contamination and high receptor vulnerability require risk control and containment-oriented measures, while sites with moderate pressure and partial vegetation cover may be managed through assisted natural recovery. This approach avoids over-engineering low-risk sites while ensuring that higher-risk dumps are not treated only through passive monitoring.

5. Discussion

The proposed framework demonstrates that rehabilitation planning for inactive mining dumps should not be based exclusively on contamination indices. Contamination is a fundamental component of risk, but post-mining rehabilitation also depends on dump morphology, physical exposure, vegetation development and the proximity of receptors. This is particularly relevant in the Jiu Valley, where inactive dumps are located in a complex landscape that includes watercourses, lakes, torrents, settlements, roads and former industrial platforms.

The classification obtained in this study is consistent with the idea that risk assessment should support management decisions. Class I sites require immediate attention because they combine multiple pressure dimensions. Balomir and Ramura 1 and 2 Lupeni are associated with water-related receptors, while Ramura 1, 2, 3 and 4 Petrila combines very high morphometric relevance with high environmental vulnerability. These characteristics justify priority intervention even where the geochemical classification alone may not indicate intervention-level contamination.

The framework also highlights the value of nature-based and low-cost rehabilitation options. For Class II and Class III sites, complete excavation or engineering encapsulation would often be unrealistic or unnecessary. Instead, ecological stabilisation, phytostabilisation, assisted revegetation and vegetation maintenance may reduce erosion, limit dust dispersion, improve landscape integration and contribute to long-term risk reduction [10], [11], [12], [13], [14], [15]. However, such measures must be accompanied by periodic monitoring, especially where water bodies or settlements are located nearby.

From a regional planning perspective, the model can support local authorities, mining stakeholders and environmental specialists in deciding where to allocate limited resources. It can also facilitate communication because a rehabilitation class is more directly actionable than a contamination index. While a numerical index indicates the existence of pressure, an action class indicates what type of management response is required.

The main limitation of the study is that the scores are screening-level values derived from existing thesis data. The model does not replace detailed geotechnical, hydrological or ecological investigations. Future applications should integrate high-resolution topographic data, updated vegetation mapping, seasonal runoff observations, geochemical speciation and stakeholder-based weighting. Nevertheless, the framework provides a transparent first-level decision-support tool for post-mining rehabilitation planning.

6. Conclusions

This paper proposed a risk-based decision-support framework for selecting rehabilitation measures for inactive mining dumps in the Jiu Valley, Romania. The framework integrates geochemical pressure, morphometric and stability pressure, and environmental vulnerability into a Rehabilitation Action Priority score.

The application of the framework to fourteen inactive dumps showed that Balomir, Ramura 1 and 2 Lupeni, and Ramura 1, 2, 3 and 4 Petrila should be treated as priority sites for risk control and rehabilitation planning. Most other dumps require active ecological stabilisation, while Funicular Vechi and Hypolit may be managed through lower-intensity monitoring and recovery pathways, depending on future field validation.

The results confirm that rehabilitation planning should move beyond contamination-centred assessment. A dump with high geochemical pressure but low exposure may require a different intervention than a dump with lower contamination but stronger hydrological or morphometric vulnerability. Therefore, the proposed risk-to-action approach provides a practical bridge between environmental assessment and post-mining management.

The framework is suitable for preliminary regional screening and can support the prioritisation of rehabilitation actions under limited technical and financial resources. In the Jiu Valley, such an approach can contribute to transforming mining legacies into safer, more stable and more sustainable post-mining landscapes.

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References

[1] **European Parliament and Council of the European Union,** 2006
Directive 2006/21/EC of the European Parliament and of the Council of 15 March 2006 on the Management of Waste from Extractive Industries and Amending Directive 2004/35/EC, Official Journal of the European Union, vol. L 102, pp. 15–34.

[2] **Garbarino E., Orveillon G., Saveyn H.G.M., Barthe P., Eder P.,** 2018
Best Available Techniques (BAT) Reference Document for the Management of Waste from Extractive Industries in Accordance with Directive 2006/21/EC, Joint Research Centre, European Commission, Luxembourg, BAT Reference Document EUR 28963 EN, DOI: 10.2760/35297.

[3] **Mhlongo S.E., Amponsah-Dacosta F., Kadyamatimba A.,** 2019
Development and Application of a Methodological Tool for Prioritization of Rehabilitation of Abandoned Tailings Dumps in the Giyani and Musina Areas of South Africa, Cogent Engineering, vol. 6, no. 1, article 1619894, DOI: 10.1080/23311916.2019.1619894.

[4] **Mitchell I., Hryczyszyn K., Read T.,** 2019
A Framework to Prioritise High-Risk Abandoned Mine Features for Rehabilitation in Western Australia, Proceedings of the 13th International Conference on Mine Closure, pp. 123–132, DOI: 10.36487/ACG_rep/1915_11_Mitchell.

[5] **Suh J., Kim S.M., Yi H., Choi Y.,** 2017
An Overview of GIS-Based Modelling and Assessment of Mining-Induced Hazards: Soil, Water, and Forest, International Journal of Environmental Research and Public Health, vol. 14, no. 12, article 1463, DOI: 10.3390/ijerph14121463.

[6] **Ioniță M.F.,** 2024
Critical Analysis of Contaminated Sites Resulting from Mining Activities, with Examples from Closed Mining Perimeters in the Jiu Valley, Ph.D. Thesis, University of Petroșani, Petroșani, Romania.

[7] **Ioniță M.F., Radu S.M., Dunca E.C.,** 2024
Research on the Identification of Inactive Mining Sites with the Potential for Soil Contamination in the Jiu Valley – Case Study Balomir Tailings Dump, Mining Revue, vol. 30, no. 2, pp. 53–59, DOI: 10.2478/minrv-2024-0015.

[8] **Ioniță M.F., Radu S.M., Dunca E.C.,** 2024
Researches on the Mobility and Toxicity of Heavy Metals from Balomir Tailings Dump – Uricani Jiu Valley, Mining Revue, vol. 30, no. 2, pp. 44–52, DOI: 10.2478/minrv-2024-0014.

[9] **Dunca E.C., Ioniță M.F., Radu S.M.,** 2025
Soil Contamination and Related Ecological Risks: Complex Analysis of the Defor Petrila Tailings Dump, Romania, Land, vol. 14, no. 7, article 1492, DOI: 10.3390/land14071492

[10] **Bradshaw A.,** 1997
Restoration of Mined Lands—Using Natural Processes, Ecological Engineering, vol. 8, no. 4, pp. 255–269, DOI: 10.1016/S0925-8574(97)00022-0

[11] **Wong M.H.,** 2003
Ecological Restoration of Mine Degraded Soils, with Emphasis on Metal Contaminated Soils, Chemosphere, vol. 50, no. 6, pp. 775–780, DOI: 10.1016/S0045-6535(02)00232-1

[12] **Tordoff G.M., Baker A.J.M., Willis A.J.,** 2000
Current Approaches to the Revegetation and Reclamation of Metalliferous Mine Wastes, Chemosphere, vol. 41, no. 1–2, pp. 219–228, DOI: 10.1016/S0045-6535(99)00414-2.

[13] **Ali H., Khan E., Sajad M.A.,** 2013
Phytoremediation of Heavy Metals—Concepts and Applications, Chemosphere, vol. 91, no. 7, pp. 869–881, DOI: 10.1016/j.chemosphere.2013.01.075.

[14] **Baker A.J.M., Brooks R.R.,** 1989
Terrestrial Higher Plants Which Hyperaccumulate Metallic Elements: A Review of Their Distribution, Ecology and Phytochemistry, Biorecovery, vol. 1, pp. 81–126.

[15] **Lasat M.M.,** 1999
Phytoextraction of Metals from Contaminated Soil: A Review of Plant/Soil/Metal Interaction and Assessment of Pertinent Agronomic Issues, Journal of Hazardous Substance Research, vol. 2, article 5, pp. 1–25, DOI: 10.4148/1090-7025.1015