

Rehabilitation and utilisation through forest cultivation of degraded lands within the Magura amelioration perimeter

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Abstract

The rehabilitation project of the Magura amelioration perimeter is founded on a comprehensive approach that integrates the geomorphological, climatic, and geological characteristics of the area, along with the urgent need for ecological restoration measures. A detailed environmental assessment has revealed that the lands within the Magura perimeter are at significant risk of erosion and degradation, primarily due to climatic conditions and the geological particularities of the region. The geographical and administrative positioning of the perimeter highlights the strategic importance of the area within both administrative and ecological contexts, particularly given its proximity to protected zones and the necessity for sustainable land management. Moreover, climatic and geomorphological factors are critical drivers necessitating immediate intervention to prevent soil loss and to safeguard local biodiversity. The proposed technical solutions, including afforestation works and the implementation of an ameliorative complex, are essential for restoring the ecological balance of the region. Land mapping and monitoring measures will enable the effective and long-term implementation of restoration works, contributing to sustainable natural regeneration. The necessity of the investment is strongly supported by a cost–benefit analysis, which demonstrates that land rehabilitation efforts will yield multiple advantages—both economic (through improved soil productivity) and ecological (by stabilising ecosystems and preserving biodiversity). In addition, the proposed technical measures are aligned with environmental regulations and will contribute to achieving the European Union’s sustainability objectives. Therefore, the rehabilitation of the Magura perimeter represents a vital investment in environmental protection and the assurance of a sustainable ecological future, delivering substantial benefits to local communities and the wider region.

Keywords: ecological rehabilitation, afforestation, geomorphology, climatic conditions, sustainable investment, soil erosion

Introduction

The amelioration perimeter is located administratively within Caraș-Severin County and, from a forestry management perspective, falls under the jurisdiction of the Otelu Roșu Forest District.

The forests comprising Production Unit IV – Magura are situated in the Tarcu Mountains region, specifically on the north-eastern slope of the right bank of the Bistra Marului Valley.

The territory encompassing the Magura amelioration perimeter is underlain by a lithological substrate consisting of magmatic and metamorphic rocks of various geological ages [1]. In the south-eastern area near Poiana Mărului, the substrate includes ante-Proterozoic mica-schists and paragneisses; the central and northern parts feature Proterozoic quartzitic sericite-chlorite schists; while in the north-eastern section near Maru, the substrate comprises Palaeozoic amphibolites with epidote and granitoids in the central zone [3].

These rock formations give rise to evolved soils, mainly belonging to the Cambisol class (including eutric brunisols and acidic brunisols, generally skeletal in nature) as well as Argiluvissols. The soils are relatively friable and, due to their degradation susceptibility, are classified among easily erodible rock types [10].

Production Unit IV – Magura lies within the alpine-Carpathian geosynclinal province, specifically in the Mega-anticlinal subprovince of the Southeastern Carpathians, in the Southern Carpathians region, within the Râul Șes Complex, Tarcu Highlands District, Tarcu Mountains [2,4]. The relief is mountainous and predominantly comprised of slopes, with an undulating and dissected terrain, featuring mostly steep inclines.

The amelioration perimeter is situated within this unit, in the Bistra Marului Valley basin, at the junction with the piedmont hills area, characterised by broad valleys and dissected by synclinal tectonic depressions [8,11].

The total area of the perimeter is 76 hectares, occupying a slope that has been transformed into a basin by erosion processes [9]. The terrain exhibits an undulating configuration [5,6].

The average altitude of the amelioration perimeter is 470 metres, with a minimum elevation of 410 metres and a maximum of 530 metres [1,12]. The average slope gradient is 30%, with significant variability, ranging from a minimum of 16% to a maximum of 75% [7].

The general aspect of the perimeter is west-facing, though local orientations vary considerably due to the highly fragmented nature of the terrain.

Geomorphological characterisation data are presented in Table 1.

Table 1. Synthesis of Geomorphological Data

Area (ha)	Altitude (m)			Slope (%)			Aspect	
	Minimum	Average	Maximum	Minimum	Average	Maximum	General	Predominant
76	410	470	530	16	30	75	SV	S

Source: [16], 2024

The average annual temperature is approximately 11°C, with yearly temperature extremes varying within a range of 7°C, corresponding to a thermal gradient of 0.44°C per 100 metres of altitude [15].

Springs arrive early, accelerating snowmelt, which in turn intensifies erosion processes. Late frosts occur before the end of the vegetation period, causing damage to seedlings during their initial years of growth [14].

The table 2, below presents the average monthly temperatures as well as the overall annual mean temperature.

Table 2. Average monthly temperatures and annual mean temperature

	Month												Annual
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Average Temperatures (°C)	-1	-1	3	7	9	14	20	21	15	12	5	1	II

Source: [16], 2024

The average annual precipitation in the Magura amelioration perimeter is approximately 724.6 mm [15]. The wettest months are May and June, while the driest months are December and January. The table 3 below, presents the monthly precipitation values recorded within the perimeter.

Table 3. Monthly precipitation values in the Magura amelioration perimeter

	Month												Annual
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Average precipitation (mm)	60	50	67	65	81.1	98	121.2	78	66.2	73	69	50	724.6

Source: [16], 2024

The average number of days with snowfall recorded at the Caransebes meteorological station is 21.9 days per year. Vind regime is presented in table 4.

Table 4. Wind frequency by direction

Direction	N	NE	E	SE	S	SV	V	NV
%	2	1	3	18	5	1	3	5

Source: [16], 2024

The annual frequency of calm days is 41%, and as shown in the table 5, the dominant wind direction is from the southeast (SE).

Table 5. The average wind speed by direction

Direction	N	NE	E	SE	S	SV	V	NV
m/s	2	2	3	5	7	3	4	4

Source: [16], 2024

We can conclude that the highest value of the average wind speed is 7 m/s, coming from the south (S).

Material and Method

The degradation processes within the Magura amelioration perimeter have consequences that can be grouped into the following categories.

Surface erosion removes the soil entirely, or it undergoes a series of modifications (the humic horizon becomes thinner, it loses nitrogen and phosphorus, its structure and texture are altered, and the microbiological activity in the soil decreases or disappears) [13].

The extent of erosion in the Magura amelioration perimeter is calculated using the R. Gaspar - Al. Apostol equation.

$$E=A(ESie_j/S)$$

e - indici medii de eroziune:

E₂ - 10

S - 25

Al - 75

A - The erosion coefficient, which takes into account the percentage of the affected area, is E = 60.4 m³/year/ha.

The undermining of slopes and the occurrence of flash floods may endanger economic objectives or social constructions.

The consequences of gravitational displacement processes are as follows:

The materials dislodged and displaced due to slope undermining obstruct the drainage channels, increasing the intensity of flash flood waves and significantly raising the solid flow rate of torrents.

Degradation of Cultivated Lands:

Especially in the hilly region, the process dislocates and disturbs the soil layer in a relatively short period, forming completely unproductive lands.

Endangerment of Human Settlements, Transport Installations, and Other Economic Objectives.

Due to the ascending dynamic nature of the erosion processes, they gradually intensify until the complete degradation of the territory.

The necessity and opportunity of investment primarily arise from the fact that the perimeter affected by erosion processes poses a real threat to the socio-economic objectives in the area. Given the pronounced dynamics of the erosion process, immediate intervention is required.

The purpose of mapping is to establish operational land groups for which intervention solutions are adopted.

The mapping method used for the lands in the Magura amelioration perimeter is the stationary and unified method.

The stationary unified mapping method for degraded lands emerged from the need to unify the working methods with stationary characteristics developed after 1960. Its foundations were laid within the Faculty of Forestry in Brasov.

This method is stationary because it operates with criteria of a stationary nature, relating to relief, climate, and soil. It is unified because it considers all categories of degraded lands, including those degraded by human activity, operates with the same criteria, and uses the same taxonomic units and notation system.

The criteria considered by the aforementioned method are:

- Nature of degradation
- Category of degraded land
- Phytoclimatic position of the perimeter
- Physiognomy of the land
- Soil conditions

The first three criteria indicate the ecological specificity, while the last two indicate the productive potential. The method delineates the following taxonomic units: class, series, subclass, group, and type of degraded lands, as well as the stationary unit.

The taxonomic units, in descending order, are as follows:

- Station class
- Zonal station series
- Station subclass
- Station group
- Station type
- Stationary unit

Phytoclimatic position, denoted by the initials C, D, M, and M2. In the Magura amelioration perimeter, the following have been identified:

- I. Eroded lands
- II. Rocky lands
- III. Fugitive lands affected by landslides

Results and Discussion

The adoption of a comprehensive set of measures and ameliorative works is required for the implementation of the integrated and sustainable amelioration of the land and stems from the multitude of objectives and issues that need to be addressed.

The components of the ameliorative complex are as follows:

- Stones and boulders, which will later be used for embankments.
- Consolidation of slopes, ravines, and embankments through the construction of terraces.
- Slope stabilization.
- Soil preparation in the hearths.
- Formation of embankments at the upper part of the ravine.
- Amendment of acidic soils.
- Afforestation works.
- Exploitation restrictions.
- Protection, warning works, and fencing.

There is a direct link between the measures derived from the local analysis of the specific situations in the amelioration perimeter. Thus, for the correction of the soil's reaction, the ameliorative complex involves works for the amendment of acidic soils.

By applying this ameliorative complex, the aim is to solve all the existing problems within the perimeter.

The ameliorative complex includes both measures and ameliorative works:

a. Ameliorative measures refer to the Magura amelioration perimeter and aim to limit the extension or reactivation of degradation processes. These measures include:

- Usage restrictions
- Rules for land exploitation
- Protection measures and awareness campaigns

Protection will be carried out by the forester in the respective district, while awareness measures will include actions to sensitize the local population and works to install warning signs.

b. Ameliorative works are technical interventions related exclusively to the Magura amelioration perimeter and aim to restore and utilize degraded land. These works are grouped into four categories as follows:

Depending on the local specifics and the extent of the degradation process, each area requires certain works, with each intervention targeting a different process affecting that area (table 8).

Table 8. Presentation of the works

No.	Name of the Works	UM	Quantities	Location of the Works
1	Stone and Boulder Removal	ha	40,9	T1T2
2	Reforestation Works	ha	76,0	T _b T ₂ , T ₃
3	Fertilization with Topsoil	m ³	4986	T ₂
4	Soil Preparation in Strips	m ²	1508	T ₁ , T ₂
5	Terraces Supported by Small Walls	m	163000	T ₁
6	Terraces Supported by Stone Benches	m	138500	T ₂
7	Levelling and Shaping Works	ha	6,7	T ₃
8	Retaining Walls	m	700	T ₃
9	Fencing	m	5125	T ₁ , T ₂ , T ₃

The effective afforestation area in the Magura amelioration perimeter is 76.0 ha. The trees planted have a mixed role, both protective and productive. The protective role manifests primarily on the soil but also on the water. Forest cultures regulate rainwater runoff, stabilize, restore, and utilize degraded land. The productive role consists of obtaining preliminary products such as firewood, poles, resin, berries, etc.

For the success of the afforestation works, great importance must be given to selecting the tree species, which must be compatible with the station's conditions in the perimeter as well as with the vegetation zone and subzone it is located in.

The main criterion for selecting the species is the station-based one, along with the ecological one. Considering the ecological requirements of the species, the following species were selected for the afforestation of the Magura amelioration perimeter, which satisfy the proposed protection and production requirements: Robinia, Birch, Scots pine, Sea buckthorn, Black locust, Red oak.

The afforestation formulas were established based on the types of stations as follows:

T₁ - 80%Pis 20%Că

T₂ - 80%Sc 20%Me

T₃ - 60%Str 30%Pis 10%Mj

The afforestation schemes, which depict the species association and the arrangement of seedlings, are established for each type of station in a mixed planting pattern. To achieve the proposed ameliorative goal, it is necessary to adopt a successful technique for the installation of the cultures as quickly as possible. For the Magura amelioration perimeter, the planting in pits has been adopted (table 9).

Table 9. Planting in consideration pits for the amelioration perimeter

Stationary type Symbol S		Formula	Mode of association	Working distance Number of seedlings/ha	Afforestation procedure Soil improvement Land preparation
formula	[ha]				
T ₁ ID1a	32,6	80%Pis 20%Că	Rows	2x1 5000	Planting in holes 30x30x30cm, terraces supported by small fences, cleaning of stones and boulders.
T ₂ ID2a	27,7	80%Sc 20%Me	Rows	2x1 5000	Planting in pits 30x30x30cm, Terraces supported by stone benches, Fertilization with vegetal earth, Clearing of stones and boulders.
T ₃ VD1a	15,7	60%Str 30%Pis 10%Mj	Biogroups	2x1 5000	Planting in pits 30x30x30cm, Levelling works - modelling, Restoration of lateral support (retaining walls).

On the lands corresponding to types T₁ and T₂, due to significant nutrient deficiencies, local fertilization with borrowed soil will be done at the planting pit. The lands that, due to steep slopes, sunny exposure, and especially erosion, cannot retain water, will be properly arranged with terraces: simple terraces or terraces supported on lands with strong and very strong erosion will be established.

The seedlings will be installed at a density of 5000 seedlings/ha for types T1, T2, and T3.

Completion and maintenance of the plantations: After the installation of the plantations, a technical-financial reception of the works will be carried out, during which the afforested area, the number of seedlings per hectare, and the extent to which the installation conditions have been followed will be checked.

During the installation period and until the successful establishment of the plantations, an annual control of the plantations will be performed, carried out in autumn (September-October). This operation involves the creation of circular sample areas that will total at least 4% of the afforested area (table 10).

Table 10. Completion and maintenance works

Stationary type		Formula	Preliminary completion volume [%]	Maintenance works		
Symbol Formula	S [ha]			Duration [years]	No.	Staging
T ₁ ID1a	32.6	80%Pis 20%Că	30	4	13	4+4+3+2
T ₂ HD2a	27,7	80%Sc 20%Me	40	5	14	4+4+3+2+1
T ₃ VD1a	15,7	60%Str 30%Pis 10%Mj	40	5	16	3+4+3+2+2+1

In the station type T1, the percentage of replanting is 30%, as the work was carried out under moderate conditions.

In station types T2 and T3, due to harsher vegetation conditions, the replanting percentage is 40% of the area, considering the species used.

The maintenance works, established based on the main species in the culture and the working conditions specific to each area, are scheduled as follows:

- In T1, 13 operations will be carried out over 4 years,
- In T2, 14 operations over 5 years,
- In T3, 16 operations over 5 years.

Soil preparation is done locally, in strips. This operation is performed simultaneously with soil mobilization and represents the first stage of the planting process.

The strips are 0.5 m wide, corresponding to the width of the terrace platforms.

In the Magura amelioration perimeter, fertilization is carried out using topsoil in the T2 station type, only in the planting pit. The volume of soil required is 4,986 m³. For the studied perimeter, topsoil fertilization is adopted, applied locally at the planting pit. To avoid the use of chemical fertilizers, the soil used must contain a minimum of 15% mull humus. The fertilization with topsoil aims to compensate for soil deficiencies, particularly in severely eroded areas, where planting is not possible without this operation. It also addresses the lack of nutrients in the soil. The method involves transporting the topsoil to the base of the slope by trailer, and from there carrying it by stretcher or bucket to the planting pits. The application rate is 10 dm³ per planting pit, thus representing a partial fertilization.

The working technique consists of covering the roots with topsoil and pressing it down to ensure intimate contact between the root and the soil. The fences are made of woven twigs, crafted from stakes of 1.0 m in length and 5–7 cm in diameter, driven 70 cm into the ground, spaced 0.5 m apart (figure 1). Materials used include stakes of pine, oak, and alder, as well as twigs of willow, alder, hornbeam, and also wire and nails.

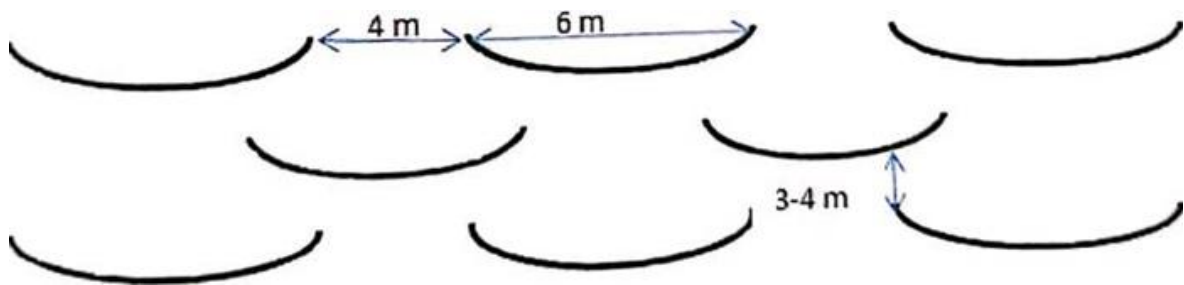


Figure 1. Arrangement in the form

The necessity of carrying out such works arises from the very harsh vegetation conditions, with steep slopes and superficial or non-existent soil. These works (figure 2), are justified by the protection they provide to the seedlings for 5–6 years.

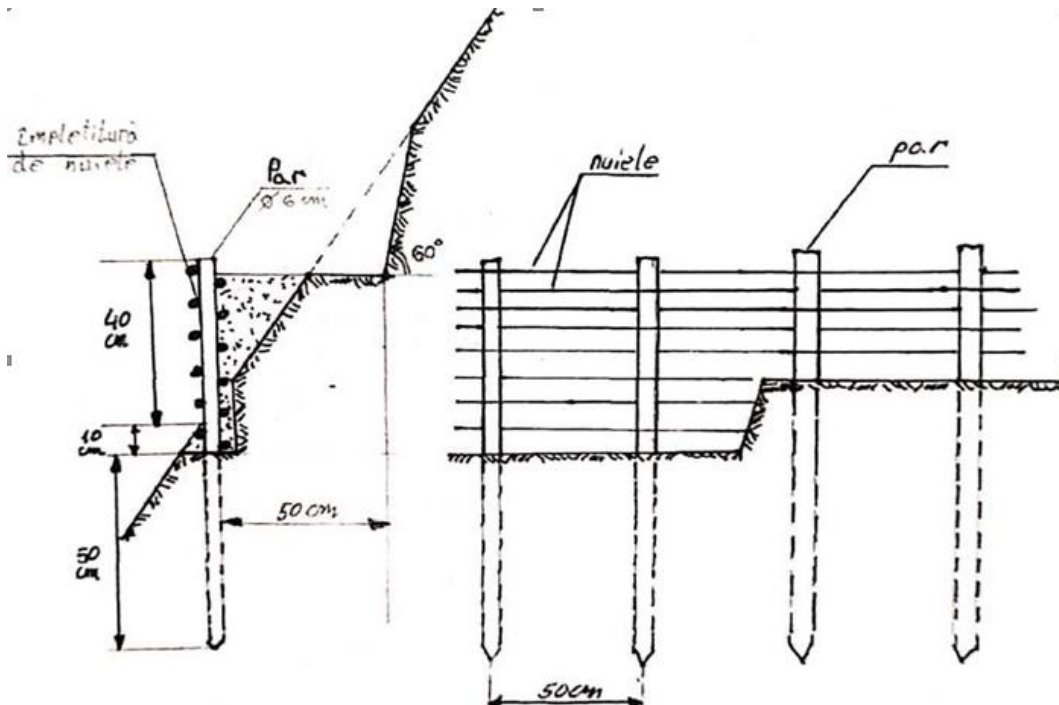


Figure 2. Sketch

Conclusions

The Magura amelioration perimeter represents a compelling example of successful intervention in degraded landscapes, demonstrating that, through the application of sustained silvicultural measures well-adapted to local conditions, it is possible to restore the ecological and protective functionality of land affected by severe degradation processes.

Although the initial target area for rehabilitation was 178 hectares, the works were extended to 223 hectares, reflecting the project's efficient capacity to adapt to field realities. Over 580,000 forest seedlings were planted, using a wide range of species and technologies suited to the edaphic and climatic conditions of the area. This diversity of interventions-including classical afforestation, terracing, and other ameliorative methods-significantly contributed to slope stabilization and the reduction of erosion processes.

The rehabilitation of the perimeter took place over approximately 15 years, a necessary timeframe for the consolidation of vegetation and its integration into a new ecological balance. The success of this intervention validates the importance of long-term approaches and integrated ecological reconstruction strategies, particularly in areas severely affected by human activities or restrictive natural conditions.

Therefore, the Magura perimeter can be considered a model of best practices in the field of degraded land reclamation, offering valuable insights for future similar interventions at the regional or national level.

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