

Research on the ecological restoration of degraded lands in the Ostrovul Moldova Veche rehabilitation area

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Abstract

The paper presents research conducted on the ecological reconstruction of degraded lands within the Ostrovul Moldova Veche rehabilitation perimeter, located on the Danube River, downstream from the locality of Moldova Veche, Caraș-Severin County. The island, covering an area of approximately 345 hectares, is part of the Iron Gates Natural Park — a protected area classified as Category V by the IUCN — and holds significant ecological, landscape, and cultural value. The study is based on a complex analysis of geomorphological, geological, hydrological, and climatic conditions, highlighting the impact of degradation processes such as deflation, waterlogging, and bank erosion on ecosystem productivity and soil stability. The research findings indicate that the island's lands, significantly affected by multiple forms of degradation, require ecological reconstruction interventions based on forestry technologies adapted to local conditions. In this context, the use of native forest species, particularly *Salix alba*, is proposed to restore the hydrological balance and stabilize the sandy and rocky soils. The reconstruction project aligns with the general objectives of the Iron Gates Natural Park, focusing on landscape conservation, biodiversity protection, and sustainable development through environmentally compatible traditional activities. The study provides a solid scientific foundation for developing management plans and technical rehabilitation measures, contributing to the conservation of natural heritage and the restoration of ecological functions within the wetland ecosystems of Ostrovul Moldova Veche.

Keywords: ecological reconstruction, degraded lands, Ostrovul Moldova Veche, deflation, waterlogging, biodiversity, Iron Gates Natural Park

Introduction

Located within the riverbed of the Danube, south of the locality of Moldova Veche and approximately three kilometers from the port, Ostrov Island spans an area of roughly 345 hectares. Its sandy-stony relief is interspersed with patches of forest vegetation, predominantly white willow (*Salix alba*), a species emblematic of wetland ecosystems [1, 20, 21]. This natural configuration supports a biodiversity adapted to riparian zones, characterized by specific ecological interactions.

The island stretches over approximately six kilometers, although its current dimensions are the result of significant anthropogenic transformations [17, 19]. Following the construction of the Iron Gates I hydropower plant in 1970, Ostrov was partially flooded—a process that coincided with the disappearance of Ada Kaleh Island, located about 70 kilometers downstream. These interventions profoundly altered the fluvial landscape and generated new habitat conditions.

Ostrov Island lies within the boundaries of the Iron Gates Natural Park, a protected area classified under Category V of the International Union for Conservation of Nature (IUCN), which emphasizes landscape conservation and the facilitation of recreational activities. According to national regulations (Government Emergency Ordinance no. 57/2007, as amended by Law no. 49/2011), natural parks are

defined as spaces where the historical interaction between humans and nature has generated landscapes of remarkable ecological, cultural, and aesthetic value.

Table 1. Surface area of degraded lands in the Ostrov rehabilitation area and types of degradation

No	Surface area of degraded lands			
	Total	River bank degradation	Deflation	Marshmallowing
1	2,9	1,11	1,0	0,80
2	15,0	1,36	10,49	2,15
3	1,5	1,50	-	-
4	2,5	-	9,59	-
TOTAL	29,0	3,97	21,08	2,95

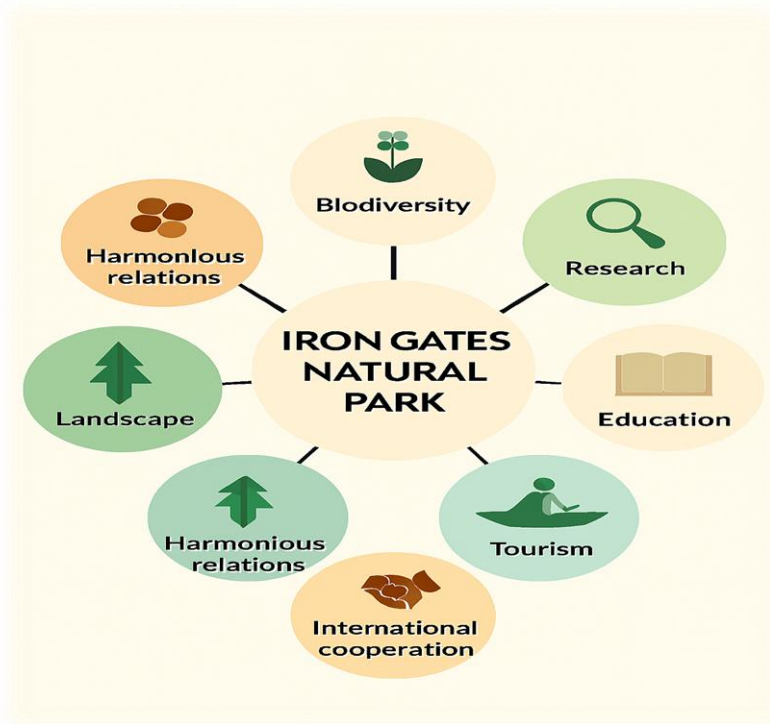


Figure 1. The central objectives of the Iron Gates Natural Par

The distinctive natural agent was on the most of the surface wind, which under the impact of brutal human intervention, through deforestation and intensive cultivation, together with the presence of deposits of fine, non-cohesive sands led to the scattering of sands and the formation of dunes. It is worth nothing that in 64 days the wind speed in the perimeter of the island exceeds 25m/s at certain hours, while, for the scattering of sands, a wind blowing at a speed of 4.5m/s is sufficient. This means that the probability of deflation on lands not covered with vegetation or covered with sparse and poorly developed vegetation is on average 37.5 days per year. The categories of degraded lands are shown in the table below.

The forestry improvement of degraded lands included in the improvement perimeters is carried out on the basis of improvement projects whose technical solution establishes what kind of works are to be carried out, where, how and when they are to be carried out, the costs and efficiency of these works.

The uniformity of the relief together with that of the climatic conditions determines the weak diversity of the station conditions encountered in the Ostrov improvement perimeter. The microstationary differences that appear are mainly related to the level of the groundwater which in settled places ends up forming permanent lakes [15, 16].

Important for each resort is the excess water in the soil determined by the elevation of the land in relation to the level of the Danube. The quality of the resort is imprinted by the higher humus content compared to the surrounding lands.

Table 2. Statistics of degraded lands in the improvement perimeter

No.	Degraded land category	Surface	
		Ha	%
1	Undermined banks	3,97	11,69
2	Sandy lands	21,08	78,69
3	Marshlands	2,95	9,62
	TOTAL	29,00	100

The limits of the resorts generally follow the levels of the groundwater, as a compensating factor for the poverty in humus and nutrients of the soil. The special characteristics of the land in the improvement perimeter did not allow us to assimilate it, even partially, with types of stations in the forest fund.

The description of the stationary units is made in relation to all three groups of criteria, starting with the geomorphological, hydrological and geological criteria, continuing with the main pedological criteria and ending with the secondary pedological criteria. Each stationary unit is characterized by a stationary formula consisting of numbers and letters.

The grouping of the stationary units into types of stations is done according to the stationary formulas, in a stationary type entering all the stationary units in the perimeter characterized by the same stationary formula

On the ground, two stationary groups with three stationary types were separated.

For mapping the degraded lands in the Ostrovul Moldova Veche improvement perimeter, we opted for the method of mapping degraded lands by units and station types.

The park's management plan supports the continuation of traditional activities by local communities, provided they align with conservation principles. Its major objectives include:

- Protecting biological, cultural, and ethno folkloric diversity, as well as landscape components;
- Promoting a functional balance between resource use and environmental protection by encouraging sustainable traditional practices;
- Developing responsible tourism and recreational activities compatible with conservation;
- Stimulating ecological education and public awareness;
- Facilitating scientific research and ecological monitoring;
- Strengthening international cooperation, particularly with Djerdap National Park in Serbia and other protected areas across Europe.

Complementarily, the conservation strategy of the Iron Gates Natural Park aims to:

- Maintain the natural and anthropogenic landscape in a state of ecological balance;
- Ensure the protection of species and habitats of national and community interest;
- Valorize cultural heritage and local ethnic traditions;
- Foster a favorable attitude toward natural values through education, information, and community involvement;
- Promote the sustainable use of resources and eliminate activities with negative impacts on biodiversity and geodiversity;
- Create conditions for ecological tourism and responsible recreation;
- Ensure efficient management by mobilizing necessary resources and recognizing the park's value at local, national, and international levels.

From a geomorphological standpoint, Moldova Veche Ostrov is situated on the largest island within the depression bearing the same name, bounded by the Rillii Valley and Coronini on the left bank, and by the Morava and Pek rivers on the right bank. The islands west of the Babacaia area were formed on the crystalline substrate of the Locvei Mountains, which is in tectonic contact with the Mesozoic sedimentary deposits of the Reșița–Moldova Nouă series. This geological configuration has resulted in an elongated plateau approximately 7 km in length and between 2 and 3 km in width, which, prior to the rise in water level caused by the reservoir, formed the Babacaia cataract. Upstream of this point, the reduced flow

velocity of the Danube (1.0–1.3 m/s) has favored the accumulation of alluvial deposits behind the Coronini barrier.



Figure 2. Ostrov Island

The island's relief is generally flat or gently undulating, with mild slopes descending toward the interior lakes and Danubian zones, where the gradient does not exceed 15%. A notable exception is the southwestern extremity, an erosion remnant originating from the second and third terraces of the Danube, where elevation reaches 102.88 meters and the slopes on the northern and western flanks exceed 75%, as illustrated in Figure 2. The average elevation of the island is approximately 70 meters, with relative variations from the Danube's water level ranging between -0.5 meters and 33 meters. The undulating relief is the result of mobile sand dune formations, and the general exposure is sunny, with minor variations determined by their orientation.

From a geological perspective, the Moldova Veche Depression developed over a former Miocene basin connected to the Pannonian Sea. On the Serbian bank, it partially encompasses the basins of the Morava, Mlava, and Pek rivers, while on the Romanian side, Neogene formations appear as a narrow strip, transgressively and discordantly overlying the crystalline schist's of the Locvei region. The local stratigraphy includes Quaternary deposits (gravels, cobbles, sands) and Pannonian formations (marls, marine clays, grey marly sands), with surface materials composed of fine to medium sands, sandy and clayey dust, followed at depth by coarse alluvium.

The origin of these deposits is mixed: on one hand, crystalline material derived from the erosion of the Locvei Mountains and Romanian tributaries (Rilii, Radimna, Valea Mare, Moldova); on the other hand, sedimentary material—Paleozoic, Miocene, and Pliocene—transported by rivers on the Serbian side (Morava, Mlava, Pek), which contribute a significant volume of alluvium due to the extensive size of their drainage basins.

Moldova Veche Ostrov is located within the homonymous depression and occupies approximately 450 hectares within the Danube riverbed. In this sector, the river exhibits an average discharge of around 5,400 cubic meters per second, with a longitudinal slope of 0.04%. The hydrological dynamics are marked by distinct seasonal variations: minimum water levels occur from the last ten days of July through the second half of October, corresponding to a significant decrease in precipitation in the upper Danube basin, with average discharges between 4,200 and 5,000 m^3/s . In contrast, peak levels are recorded in spring—

April, May, and June—when snowmelt coincides with abundant rainfall, and the Danube's discharge frequently exceeds 7,000 m³/s. Between these extremes, a period of elevated levels is observed, driven by massive runoff from the Tisza, Drava, and Sava basins.

The phreatic aquifer layer, essential for maintaining insular vegetation, is directly influenced by the river's water level. It is naturally bounded between the Danube and the slopes of the gorge, and fluctuations in river level are transmitted to the aquifer with a slight delay. In the current context, the hydrological regime is artificially regulated by the Iron Gates dam, making groundwater levels dependent on the energy demands of the hydroelectric system. In low-lying areas below 64 meters elevation, the average phreatic level is -0.5 meters, while in dune crest zones it may reach depths of 3 to 7 meters.

Climatically, Moldova Veche Ostrov falls within province 1Bp3, characterized by a moderately continental climate typical of western piedmonts, with Banat influences. The topoclimate is shaped by the Danube corridor and gorge, where fragmented relief generates a diversity of local atmospheric processes influenced by air circulation and orographic disturbances.



Figure 3. The highest area of Ostrov (133 m), completely degraded by wind erosion and landslides

The thermal regime displays regional particularities. In winter, warm tropical air advections are frequent, while cold air incursions are limited, moderated by heat exchange with the river waters. Thus, the multiannual average temperature for January is -1.2°C, and February and December maintain positive values. Spring begins early, with a sharp thermal increase in April, when the monthly average is 11°C higher than in February—the highest national value for that month. Summer temperatures range between 19.9°C and 22.2°C, with a multiannual average of 21.3°C. In autumn, maritime air influences from the southwest mitigate radiative cooling and invasions of continental or arctic air, conferring relative thermal stability compared to other regions of the country.

The annual average temperature is approximately 11.5°C, with a thermal amplitude of 23.4°C. Between 1970 and 1978, Moldova Veche recorded extreme temperatures of 37.6°C (absolute maximum) and -14.5°C (absolute minimum). Frost days represent an average of 3% of the year, while tropical days account for about 2%, confirming the temperate and favorable nature of the local climate for vegetation development and agro-pastoral activities.

The climate of Moldova Veche Ostrov is defined by a bimodal pluviometric regime, with peaks in May–June and October–November. The annual average precipitation is 786 mm, with 128 rainy days, although a decline to 651 mm was recorded during the 1970–1979 decade. The 24-hour precipitation extreme was 135.1 mm (July 1917). Snowfall occurs between November and April, with an average of 35–38 days and a snow cover persistence of approximately 30 days.

Relative air humidity is high, with an annual average of 75.5%, influenced by western advections and evaporation from the reservoir. In summer, values drop to around 65%, and phenomena such as dew, fog, and frost are frequent.

The average annual cloudiness is 5.9 tenths, with 102 clear days and 140 overcast days. The minimum is recorded in September (4.3 tenths).

The potential evapotranspiration reaches 820 mm annually, with a peak between May and July (up to 140 mm/month), while actual evapotranspiration does not exceed 550 mm during the warm season.

The wind regime is active, with 209 windy days per year. Dominant directions include E–W–NW and SE, with the southeastern “Coșava” wind occasionally reaching speeds of up to 120 km/h. Winds are generally humid and contribute to the regional precipitation input. Extreme weather phenomena such as hail, hoarfrost, and ground frost are rare, while fog is frequent during the cold season.

The Martonne aridity index (36.6) indicates a forest-type climate, with semiarid tendencies during the summer months - characteristic of steppe transition zones.

The Moldova Veche Ostrov area experiences a moderately continental climate with western influences. Precipitation is concentrated in May–June and October–November, with an annual average of 786 mm. Relative humidity is high (75.5%), and fog, dew, and frost occur frequently. The sky remains overcast for more than 140 days per year. Actual evapotranspiration does not exceed 550 mm. Predominant winds originate from the east and southeast, including the high-intensity “Coșava.” Summers are semiarid, and the Martonne index confirms a transitional climate between forest and steppe.

Material and Method

Moldova Veche Ostrov, once covered by diverse forest stands, has undergone significant transformation due to deforestation, cultivation, and grazing, leading to soil degradation through waterlogging, wind erosion, and bank undermining. Wind action, combined with the sandy texture of the soil and lack of vegetation cover, promotes deflation, occurring with an average frequency of 37.5 days per year.

The total degraded area amounts to 29 hectares, of which 78% consists of sandy soils, 12% of undermined banks, and 10% of waterlogged zones. Restoration efforts are based on site mapping using the Chirita–Ceuca method, which classifies land according to relief, soil type, climate, and moisture regime.

Two site groups have been identified:

- SG I: areas affected by wind erosion, with psammonic soils extremely poor in humus and nutrients, and a phreatic level below 2 meters.

- SG II: areas with excess moisture, weakly alkaline soils with relic gleization, located at or below the Danube's water level.

Mapping was conducted on homogeneous site units, described through synthetic formulas reflecting soil texture, depth, humic horizon, and dominant moisture regime. These parameters form the basis for silvicultural interventions aimed at ecological restoration of the perimeter.

The rehabilitation of degraded lands within the Ostrov perimeter represents a critical phase in the ameliorative complex, ensuring the necessary conditions for forest vegetation establishment [4, 6, 7]. Proposed interventions include clearing, leveling, stabilization of unstable slopes, sand fixation, and local drainage [8,9].

The eastern side of the island, continuously affected by wave erosion, requires protective works using fascine fences (wattle-work) and gabions. Fascine fences are installed on low banks (below 1.20 m), while gabions are used on high banks and can be stacked. The structure of fascine fences involves 2.5-meter stakes driven deep into the ground, reinforced with boulders and accompanied by willow bundles woven with rods up to ground level. Above this, rods from native species harvested before the vegetation season are used.

The entire assembly is embedded into the banks and supplemented with transverse willow fascines, forming a living barrier capable of stabilizing the banks, reducing erosion, and contributing both aesthetically and ecologically to landscape restoration [11, 13].

For the protection of high banks exposed to erosion, steel wire gabions with small mesh and fine stone fill are proposed, being easy to handle. At the base, fascines are added for stabilization until natural consolidation occurs through sediment deposition [10].

Afforestation works aim to ecologically and productively valorize degraded lands, taking into account pedological and hydrological constraints. Species are selected based on their adaptation to local conditions, with roles in erosion control, soil improvement, and high biomass potential.

Species that existed or exist in the area of the improvement perimeters and that have established themselves in similar conditions through their ecoprotective and ecoproductive value as well as their rapid growth in youth was chosen [12, 14].

The acacia, a spontaneous species, grows in some resorts in southern Oltenia much more vigorously than in its country of origin. It is the species that on the arid sands of the Oltenia plain, on the dunes in the northwest of the country but also on other excessively degraded lands where it was planted since 1983-1900, has shown great vitality, a special anti-erosion efficiency and a high productivity of plant biomass. As a consequence of its remarkable ecological plasticity, it is the species that ensures the fixation of mobile sands by developing a strong root system whose area exceeds the crown projection by 2-5 m. In depth on light sandy soils, the roots can reach over 2 m. In this way, it can exploit groundwater, managing to overcome critical moments marked by long periods of drought.

Black locust (*Robinia pseudoacacia*) is preferred for mobile sands due to its deep root system and efficiency in soil stabilization.

Black poplar (*Populus nigra*) adapts well to moist alluvial soils, with rapid growth and valuable timber.

Black alder (*Alnus glutinosa*) is suitable for waterlogged areas, resistant to stagnant water and capable of improving soil through nitrogen fixation.

Ash (*Fraxinus excelsior*) is recommended for soils with temporary water and salt input, due to its ecological plasticity and resilience to hydric fluctuations. Its great ecological plasticity, highlighted in relation to soil and atmospheric humidity, with the ability to achieve normal growth on lands with a total soluble salt content of up to 115-130 mg and especially with the characteristic of the root system to adapt to the periodic play of the groundwater level, recommends it as a native species of great interest for these resorts. In the seasonal conditions in which the ash was proposed, it will produce a large amount of superior wood. The seasonal conditions require the planting of the ash ecotype with the sharp leaf which exhibits great resistance to frost (so it does not freeze) is more resistant to pest attacks and tolerates drought better [2,3,5].

In the case of beatings up, the regeneration compositions are adopted that incorporate usable natural seedlings, after which the afforestation formula is established.

In the afforestation compositions, local species, resistant and adapted to the micro-stationary conditions of the lands included in the improvement perimeters, were proposed, which by association would create stands with optimal structures under compositional ratio. Each species was promoted in its favorable station, following anti-erosion, improvement, climatic, hygienic-sanitary or aesthetic criteria, as well as silvoproductive [18].

In the proposed afforestation compositions, acacia predominates, considered the most efficient species in terms of the capacity to capitalize on the energy, trophic and water resources at its disposal, introduced purely or, as the case may be, associated with some shrub species with a soil protection role in the first years after planting.

On small areas, depending on the existing stationary conditions, acacia, black poplar (white poplar or willow), alder and ash were proposed as the main basic species.

The support species and shrubs proposed in association with the base species are exclusively forest species identified, observed and analyzed in the area.

In order to ensure optimal conditions for the success and maintenance of the planted seedlings, as well as for their proper development and the achievement of the massif state within the planned deadlines, the plantations will be subject to maintenance works for a period of 4-5 years, depending on the species,

the seasonal conditions of the lands on which they were introduced and the climatic conditions of the area [12, 14].

The development of degraded lands represents a basic link in the amelioration complex, on which the success of the improvement action depends in many cases. These works have a special character and they raise the cost of the investment, but they ensure the action an increase in safety, as a result of improving the conditions for the installation of forest crops. Land development basically represents the action of preparing the lands, and the development works have the role of making the respective lands suitable for afforestation, by remedying some inadequate conditions. The role of the development of degraded lands refers, in detail, to the cleaning and leveling of the lands, to the consolidation of the lands, to the stabilization of the lands and to the drainage of the lands. In relation to this role, landscaping works are also divided into land clearing and leveling works, consolidation works of eroded slopes, ravines, embankments and ravine beds, stabilization works of runaway and sandy lands and local drainage works [6, 8].

Results and Discussion

The complex analysis of the Ostrov Moldova Veche perimeter reveals an advanced state of pedological and ecological degradation, with direct implications for land stability, agro-pastoral productivity, and natural regeneration capacity. The total affected area is 29 hectares, predominantly impacted by wind deflation (78.69%), followed by undermined banks (11.69%) and marshy zones (9.62%). These processes are intensified by the sandy texture of the soil, the lack of protective vegetation, and wave action, especially along the direction of prevailing winds.

Station-based mapping, conducted using the Chirita–Ceuca method, allowed the delineation of two distinct ecological groups:

- GS I: lands with typical psamosols, exposed to deflation, with groundwater level below 2 m, soils extremely poor in humus and nutrients, with sandy texture and slightly alkaline reaction.
- GS II: low-lying lands with excess water, gleysolic and gleyed soils, weakly humiferous, with high groundwater level and frequent stagnation.

The proposed interventions include bank arrangement and protection works using brushwood fascines and gabions, with vegetal materials (willow, hazel, field maple) and mineral materials (stone, fascines), aimed at stabilizing the banks and reducing erosion. Brushwood fascines are adapted to low banks, while gabions are intended for high-elevation areas, being constructed from steel wire and filled with small-sized stones, easy to handle.

For the restoration of forest vegetation, three afforestation compositions have been proposed, each adapted to station-specific conditions:

- 50% black locust, 50% sea buckthorn – on uneven terrain with poor soils, for sand fixation and soil improvement. Alternating row planting promotes rapid canopy closure.
- (50% black poplar, 50% bird cherry – as a protective belt along the Danube banks, with an anti-erosion role. Poplars will be planted at 4×2 m spacing, using seedlings of at least 2 m in height.
- 50% black alder, 50% ash – on marshy lands with high groundwater, for biological drainage and soil improvement.

The selected species have been ecologically validated under similar conditions and are notable for their adaptive plasticity, anti-erosion capacity, high productivity, and ameliorative role. Black locust efficiently stabilizes mobile sands, black poplar reinforces banks and produces valuable timber, while black alder contributes to lowering water levels and enriching the soil with nitrogen. Ash, with high tolerance to hydric and salinity variations, completes the composition on soils with temporary water input.

Conclusions

The current condition of the Moldova Veche Ostrov perimeter reveals severe soil and ecosystem degradation, with dominant processes including wind deflation, bank erosion, and waterlogging. These phenomena compromise land stability, hinder natural regeneration capacity, and reduce the productive potential of the area.

Site mapping has enabled the precise delineation of ecological units, providing a robust scientific foundation for selecting appropriate ameliorative interventions and forest compositions. The differentiation

between sandy soils prone to deflation and low-lying areas with excess moisture has led to a tailored, efficient, and ecologically justified approach.

The proposed protective works—such as fascine fences and gabions—are essential for bank stabilization and the prevention of land loss. The use of both vegetative and mineral materials contributes to the creation of living, durable, and environmentally sound structures.

Afforestation compositions were selected based on site-specific conditions and the ecological roles of the species. The pairing of black locust with sea buckthorn, black poplar with bird cherry, and black alder with ash reflects an integrated strategy aimed at soil stabilization, improvement of pedological conditions, and restoration of the ecological functionality of the perimeter.

The proposed forest species are notable for their ecological plasticity, anti-erosion capacity, and high productive potential. They contribute to landscape restoration, biodiversity enhancement, and the reintegration of degraded lands into the silvoproductive cycle.

The Moldova Veche Ostrov amelioration project stands as a model of integrated ecological intervention, with broad applicability in fluvial areas affected by degradation. It demonstrates the importance of aligning site diagnosis, stabilization works, and the rational selection of forest species.

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