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CASE STUDY

Integrated land management of Mount Vodno (North Macedonia)

Project full title: Enhancing Technical and Vocational Skills for Implementing Nature-Based Solutions (NbS) to Combat Land Degradation
Project acronym: NbS4LD
Project number: 2025-1-TR01-KA220-VET-000357096
Project activity: WP2 Developing Educational Resources on NbS for Combating Land Degradation

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1. INTRODUCTION

This case study has been analysed by REFORD - Regional Center for Forestry and Rural Development, a non-governmental, non-profit organization registered in North Macedonia in 2010, which is a partner organisation of the NbS4LD project. REFORD aims to contribute to rural development by providing support to rural communities in their efforts to use natural resources in a sustainable manner, mainly through: sharing of new technologies, experiences and work methods; increasing and strengthening the awareness, social and economic power of the rural population; building the capacities of local organizations and institutions in the region; collaboration and networking with similar organizations, individuals, donors and institutions in order to achieve its mission and goals. REFORD provides support in the networking of the private forest owners in the Balkans, through its "Balkan Network" cooperation platform. Currently, 6 national organizations of forest owners from the Balkans participate in the "Balkan Network": Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, North Macedonia and Bulgaria. From 2024, REFORD became a national body for administration of the PEFC system in North Macedonia.

Mount Vodno, located in the Skopje Region of North Macedonia, is a 4,573 ha forest landscape historically affected by severe deforestation, soil erosion, and torrential floods. Before the 1950s, degraded and barren slopes generated uncontrolled runoff that threatened Skopje's population and infrastructure, with the most destructive flood recorded in 1951.

A large-scale restoration programme was initiated after World War II, combining nature-based solutions and technical measures. Between 1954 and 1969, extensive afforestation, construction of approximately 30 check dams, and more than 6 km of regulated channels were implemented to stabilize slopes, reduce sediment transport, and control torrent flows. Later interventions expanded forest restoration across the mountain, resulting in improved vegetation cover, reduced land degradation, and increased ecosystem resilience.

The restored forest ecosystem now provides important environmental and social benefits, including improved biodiversity (over 1,100 plant taxa), carbon storage, air-quality improvement, flood protection, and recreational opportunities. Mount Vodno has become a key green infrastructure element for Skopje, supporting hiking, cycling, tourism, and public well-being. The intervention is managed through long-term forest management plans involving the City of Skopje, the Ministry of Agriculture, Forestry and Water Economy, and Public Enterprise "Parks and Greenery". Despite its success, increasing urban pressure and construction on mountain slopes remain major challenges requiring continued protection, monitoring, and maintenance.

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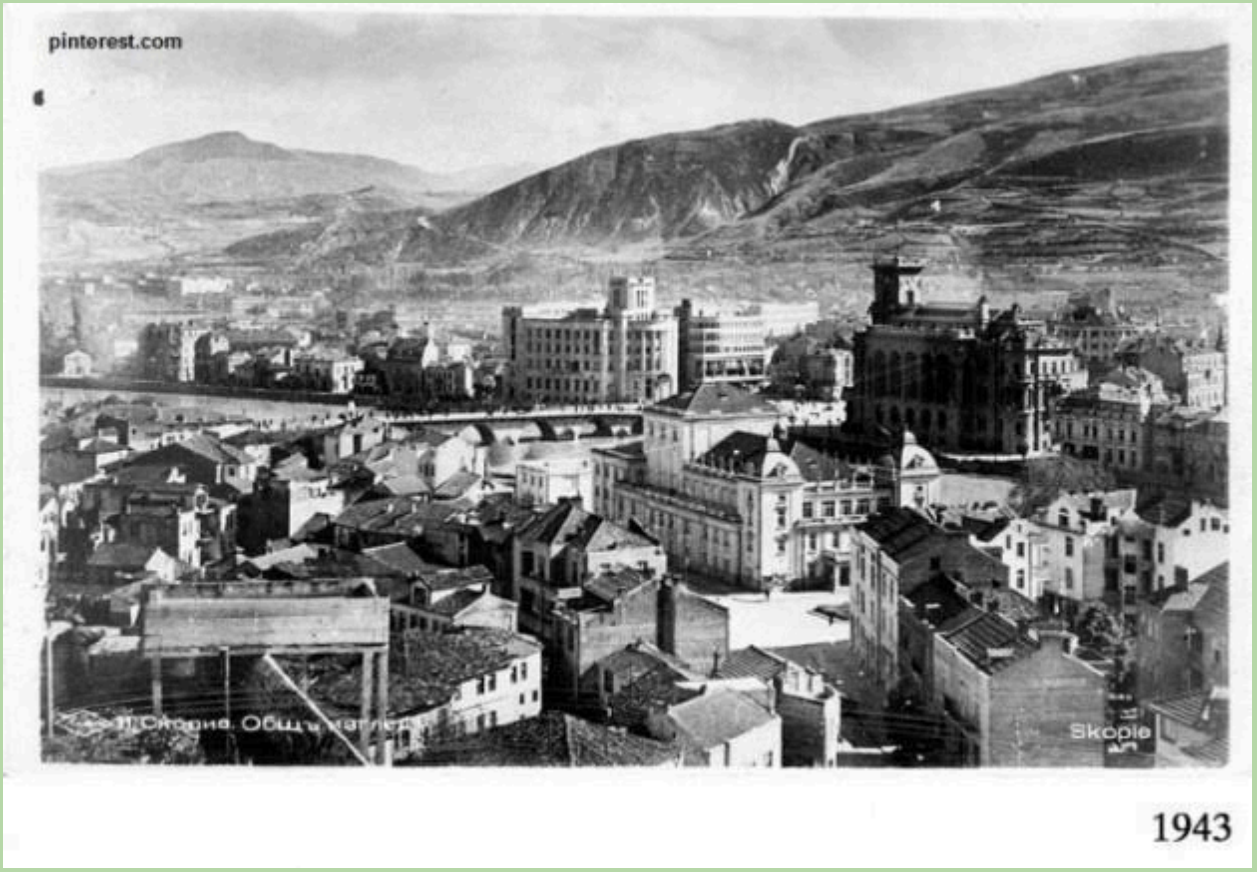

[Vodno Mountain before the reforestation in 1943 - Source: Dana Dina KolevskaIvan BlinkovPande Trajkov Vladimir Maletić (2016)]

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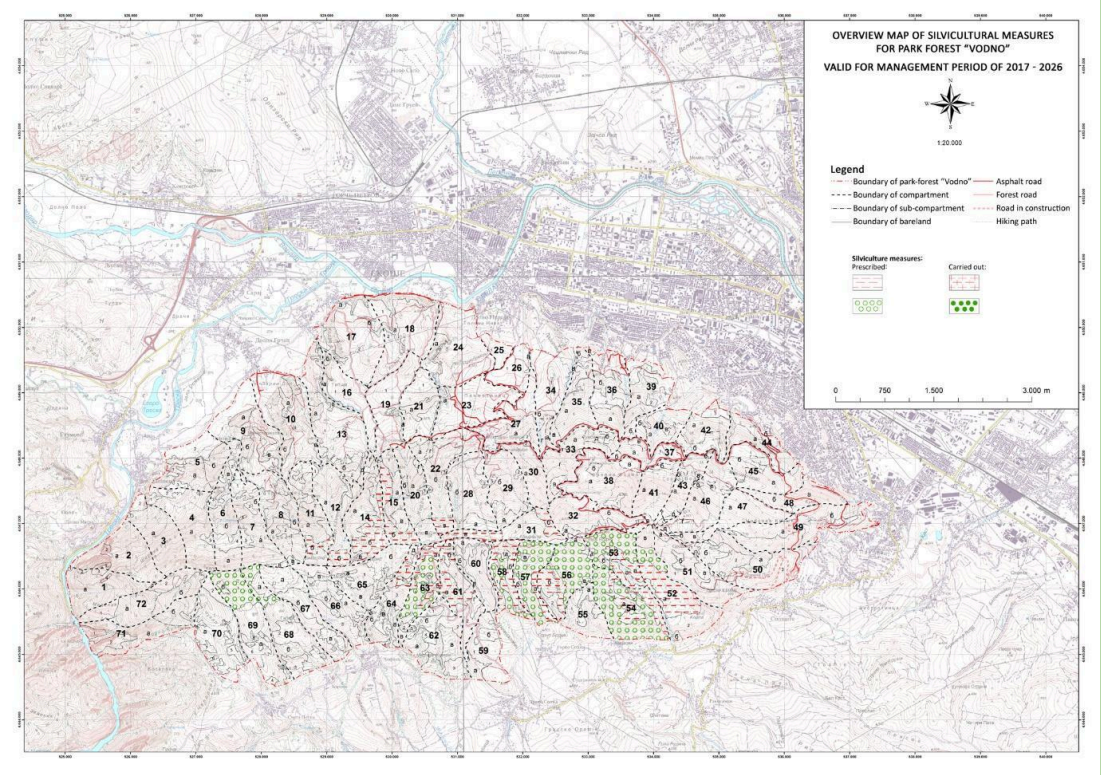

[Overview map of silvicultural measures for Park-Forest "Vodno" (2017-2026), integral part of the management plan - Source van Blinkov (2022)]

[Skopje panoramic mountain view. Skopje city and suburbs seen from above in a mountain view]

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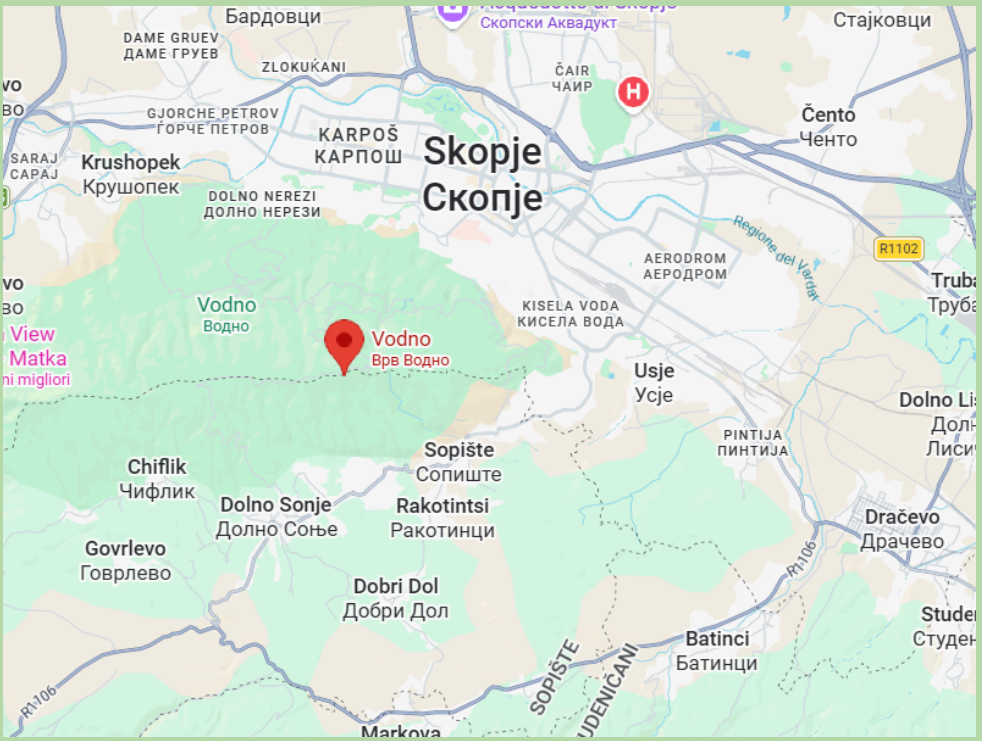
2. CONTEXT

2.1 LOCATION

Country: North Macedonia. Region: Northern part of North Macedonia. Province: Skopje Region (immediately south of Skopje). Site: Vodno Mountain. Approximate GPS coordinates (central area): Latitude 41.972° N; Longitude 21.371° E.



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2.3 LANDSCAPE TYPE

Forestland.

2.4 LAND DEGRADATION CHALLENGE

Soil erosion. Vegetation and ecosystem degradation. Urbanisation/land conversion.

2.5 BASELINE DATA

Land condition	• Site: Park-Forest Vodno, located south of Skopje, North Macedonia, covering approximately 4,573 ha. The terrain ranges from 266 to 1,066 m above sea level and is predominantly steep, with slopes frequently exceeding 45%. • Soil: The geological substrate consists of sandstones and marl clay (5%), sands and sandy clay (30%), plumbago-sericite schists (10%), and marbles, phyllite-mica schists, and cipolin on southern slopes (55%). According to the WRB classification, the dominant soil types are Rendzic Leptosols (49.3%), complexes of Chromic Luvisols and Vertisols (30.4%), complexes of Chromic Luvisols, Humic Calcaric Regosols and Vertisols (16.5%), Fluvisols (2.6%), and Leptosols (0.9%). • Vegetation cover: forest land occupies approximately 80.9% of the area, including 47.4% forest stands and 33.5% pastures and bare land. Agricultural land covers 17.5%, while other land uses account for 1.6%. The vegetation is highly diverse, with 1,124 recorded plant taxa distributed among 11 plant communities. Forests are dominated by the *Querco-Carpinetum orientalis* association, while pastures are characterized by *Helianthemo-Euphorbietum thessalae*. Black pine (*Pinus nigra*) plantations established through afforestation efforts are also widespread. • Erosion status: historically, extensive deforestation left large areas barren, resulting in severe soil erosion and frequent torrential flooding in Skopje. The most destructive flood occurred in 1951. Although large-scale afforestation and erosion-control measures have significantly improved slope stability, numerous small and large torrents remain present throughout the mountain, indicating continued susceptibility to erosion processes.
Environmental context	• Climate: the area experiences a continental-sub-Mediterranean climate characterized by hot, dry summers and cold winters. Climatic conditions vary with elevation. Mean annual temperatures decrease from approximately 11.2°C below 500 m to 8.8°C above 750 m,

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	while annual precipitation increases from about 565 mm to 696 mm. Drought intensity decreases with altitude, reflected by increasing De Martonne drought index values from 27 to 37. • Hydrology: the mountain contains numerous seasonal torrents, ephemeral streams, and springs but lacks permanent watercourses. Surface runoff is strongly influenced by steep topography and episodic rainfall events. • Biodiversity: Mount Vodno supports high biodiversity, with 1,124 recorded taxa, including 1,010 plant species and 114 subspecific units. Of these, 868 are native species and 142 are introduced. Vegetation is organized into 11 phytocenoses, providing diverse habitats and important ecological functions within the Skopje region. • Ecological pressures: wildfire risk, erosion on steep slopes, urban expansion from the Skopje metropolitan area, recreational pressure, habitat fragmentation, and the impacts of climate change, including increased drought frequency and extreme weather events.
Socioeconomic context	• Population: the site is located adjacent to Skopje, the capital and largest urban center in North Macedonia. The wider metropolitan area has an estimated population exceeding 600,000 inhabitants, creating significant pressure on surrounding natural resources and recreational areas. • Livelihoods: the regional economy has evolved from trade and craftsmanship to industrial production and, more recently, service-oriented activities. Current livelihoods are primarily based on services, commerce, banking, public administration, construction, and manufacturing, with Skopje functioning as the country's principal economic center. • Land management: multifunctional use of the Park-Forest Vodno, including forest conservation, erosion and torrent control, biodiversity protection, wildfire prevention, recreation, and environmental education. Forest and pasture management are integrated within long-term ecological planning frameworks. • Resource dependency: the mountain provides critical ecosystem services to Skopje, including erosion control, flood mitigation, air quality improvement, biodiversity conservation, and recreational opportunities. The city depends on regional water and energy networks, while Vodno remains an important ecological buffer supporting urban resilience.

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Policy and governance	• Institutional framework: nanagement is based on a coordinated governance system involving the City of Skopje, the Ministry of Agriculture, Forestry and Water Economy, and the Public Enterprise “Parks and Greenery.” Since the establishment of erosion and torrent control institutions in the mid-20th century, management has evolved toward a multifunctional ecosystem approach guided by forest management plans, biodiversity conservation objectives, wildfire protection measures, and inter-agency cooperation for emergency response and long-term ecological restoration.

3. INTERVENTION

3.1 TIMEFRAME

The degradation of Mount Vodno occurred gradually over several centuries, leaving large areas barren and highly susceptible to erosion. Initial afforestation efforts were undertaken in 1928 and included experimental approaches involving different tree species, seedling types, soil preparation methods, planting techniques, and post-planting management practices.

Major restoration interventions were implemented after the Second World War, particularly during the 1950s and 1960s, following the establishment of specialized institutions and enterprises dedicated to erosion and torrent control. A significant milestone was the adoption of three key laws on 23 April 1957 (Official Gazette of the People's Republic of Macedonia No. 11/57):

- The Law on Protection of Steep Lands from Erosion and Torrent Control, which expanded the scope of an earlier 1952 law focused primarily on agricultural land;
- The Law on Forests, regulating forest management and protection;
- The Law on Waters, regulating water resource management.

Additional afforestation activities were carried out during the 1970s. Subsequently, the introduction of the first Forest Management Plan in 1993, followed by revised plans in 2005 and 2016, established a systematic framework for afforestation, forest melioration, erosion control, and ecosystem restoration activities. Since then, management interventions have been implemented in accordance with the objectives and prescriptions defined in these plans.

3.2 TYPE OF INTERVENTION

Reforestation. Afforestation. Soil restoration. Erosion control.

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3.3 IMPLEMETING ORGANISATIONS

The restoration, afforestation, and erosion control activities on Mount Vodno have been supported by a succession of specialized institutions since the mid-20th century. Key historical organizations included the Institute of Forestry (established in 1944), the Faculty of Agriculture and Forestry (1947), the Republic Directorate for Torrents, and the "Vodno" Enterprise for Afforestation and Torrent Control (1950), which led large-scale erosion control and afforestation works following severe flooding and land degradation.

Today, management is governed through Forest Management Plans approved by the Ministry of Agriculture, Forestry and Water Economy. The City of Skopje provides strategic oversight, policy direction, and financing through annual operational programs. The Public Enterprise "Parks and Greenery" serves as the principal implementing agency, responsible for afforestation, forest maintenance, erosion control, biodiversity conservation, wildfire prevention, and monitoring activities within Park Forest Vodno. Operational support is provided by other municipal public enterprises, including water supply, sanitation, and communal services, particularly during emergency situations such as forest fires and extreme weather events.

3.4 FUNDING SOURCES

Funding for afforestation and erosion control on Mount Vodno has evolved from direct state investment and voluntary labor campaigns in the 1950s–1970s to more diversified financing mechanisms. Historically, large-scale restoration works were financed through government budgets and the national Fund for Afforestation of Bare Lands. Today, management activities are primarily funded through annual municipal budgets allocated by the City of Skopje and state forestry programs administered by the Ministry of Agriculture, Forestry and Water Economy. Additional support for large-scale environmental restoration, climate adaptation, and green infrastructure projects is provided through international donors and financing institutions, including EU funds, UNDP, and the European Bank for Reconstruction and Development (EBRD).

3.5 IMPLEMENTATION ACTIONS AND MEASURES

The implementation of afforestation and erosion control measures on Mount Vodno was carried out progressively from the 1950s onward, following severe land degradation, widespread erosion, and recurrent torrential flooding affecting the City of Skopje. The first and most important phase was implemented between 1954 and 1969 on the northern slopes of the mountain, which directly overlook the urban area and represented the highest-risk zone for flood generation and sediment transport.

This phase combined large-scale afforestation with extensive bioengineering and civil engineering works. Approximately 30 check dams (barrages) were constructed, together with more than 6 km of regulated channels designed to slow surface runoff, trap sediment, stabilize

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torrent beds, and reduce flood peaks reaching the city. The structures were strategically located within the catchments of the most active torrents, including the Usje, Kisela Voda, Cvetovo, Kapištec, Kozle, Taftalidze, and Dolno Nerezi systems.

Most check dams were built from stone masonry or concrete and positioned within deeply incised gullies and torrent channels. Over time, many of these structures became filled with sediment, demonstrating their effectiveness in retaining eroded material, reducing downstream sediment transport, and stabilizing slopes. The regulated channel network safely conveyed excess runoff toward the Vardar River while protecting residential areas, transport infrastructure, and industrial zones.

Following the successful stabilization of the northern slopes, afforestation activities were extended during the 1970s to the southern and eastern slopes of Mount Vodno. These interventions focused on restoring vegetation cover, improving soil stability, increasing forest cover, and reducing erosion risks across the entire mountain. Since the adoption of the first Forest Management Plan in 1993, and subsequent plans in 2005 and 2016, afforestation, forest melioration, and ecosystem restoration measures have been implemented according to long-term management objectives aimed at maintaining the mountain's protective, ecological, and recreational functions.

4. IMPACT

4.1 ENVIRONMENTAL IMPACT

☑ Improved soil health or reduced soil erosion. ☑ Increased vegetation cover or habitat restoration. ☑ Improved biodiversity. ☑ Improved water quality or water availability. ☑ Reduced land degradation. ☑ Increased carbon sequestration or storage. ☑ Improved ecosystem services.

The implementation of afforestation and erosion-control measures, including check dams and regulated drainage channels, has significantly reduced erosion, controlled torrential runoff, and improved flood protection for the City of Skopje. These interventions have enhanced the safety of both the population and urban infrastructure and contributed to the stabilization of the northern slopes of Mount Vodno.

Afforestation has also improved biodiversity and ecosystem health by restoring forest cover and reducing land degradation. Areas that were once barren and highly susceptible to erosion now provide effective protection against sediment transport and localized flooding in downstream settlements.

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While the erosion-control infrastructure remains largely effective, regular maintenance of channels and drainage systems, including the removal of accumulated sediment and vegetation, is required to ensure their continued functionality.

Beyond its protective role, Mount Vodno now provides important ecosystem services and serves as a major recreational area for residents and visitors. The mountain attracts hikers, cyclists, and nature enthusiasts throughout the year, while the cable car connecting the middle slopes to the summit has improved accessibility and increased tourism potential.

4.2 COMMUNITY IMPACT

☑ Job creation or new livelihood opportunities. ☑ Improved food security. ☑ Increased local capacity or skills. ☒ Conflicts over land or resources.

The socio-economic impact of the mitigation measures represents one of the most significant long-term benefits of the restoration of Mount Vodno. While the primary objective was to reduce land degradation, control erosion and torrential processes, and protect the City of Skopje through afforestation, check dams, and drainage channels, these interventions have generated substantial social and economic benefits for local communities.

Today, Mount Vodno is one of the main recreational and tourism destinations in the Skopje region. Numerous hiking and mountain biking trails of varying difficulty have been developed across the mountain, attracting residents and visitors throughout the year. The construction of the cable car has further expanded access to the mountain, particularly for elderly visitors and people with limited mobility.

The restored forest ecosystem provides valuable recreational opportunities and important cultural ecosystem services. The mountain offers areas for leisure, relaxation, and outdoor activities, serving as a natural refuge from summer heat and, increasingly, from poor air quality in the Skopje Valley caused by a combination of industrial emissions, traffic, and unfavorable climatic conditions. As a result, Mount Vodno has become an important contributor to the quality of life and well-being of the city's residents.

The negative consequences of the successful mitigation measures are mainly related to increased development pressure on Mount Vodno. The stabilization of the mountain has reduced immediate risks and, in some areas, encouraged intensive urban expansion, including the construction of residential and commercial buildings. This has resulted in conflicts over land use, including disputes and legal cases related to the occupation of forest and protected areas.

Despite the improvements achieved through erosion control and afforestation, Mount Vodno and its torrent systems remain dynamic natural processes that require continuous monitoring and maintenance. Neglecting the management of forests, drainage channels, and erosion-control

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structures could increase vulnerability to future erosion and flooding, repeating the risks experienced in the past.

4.3 INSTITUTIONAL IMPACT

☑ New or improved environmental policies. ☑ Establishment of new management structures or partnerships. ☑ Integration into local or national planning. ☑ Capacity building for institutions or communities.

After the Second World War, Mount Vodno was considered a major environmental threat to the population and infrastructure of Skopje due to severe erosion, degraded land, and uncontrolled torrential flows. This led to the establishment of specialized institutions during the 1950s, including the "Vodno" Enterprise for Afforestation and Torrent Control and the "Vardar" Water Economy, which were responsible for implementing erosion-control, afforestation, and water management measures.

Following the independence of the Republic of Macedonia, management responsibilities were gradually transferred to the City of Skopje and local municipalities, including Kisela Voda, Centar, and Karposh. Today, the Public Enterprise "Parks and Greenery" serves as the main operational body responsible for managing Mount Vodno. Management is guided by ten-year Forest Management Plans, supported by annual operational programs.

The involvement of local authorities in Vodno's management has also strengthened public participation, with citizens increasingly involved in discussions on development priorities, protection measures, and policy decisions through public consultations, city meetings, and stakeholder discussions.

4.4 SUSTAINABILITY OF THE RESULTS

☑ Integration into policies or development plans. ☑ Institutional support or partnerships.

The interventions implemented on Mount Vodno during the 1950s and 1960s, combining afforestation with technical torrent-control measures, have demonstrated strong long-term effectiveness. These interventions transformed a highly degraded and erosion-prone landscape into a more stable forest ecosystem that continues to provide protective and ecological functions.

The restoration measures significantly reduced erosion and torrential flood risks affecting Skopje by stabilizing slopes, regulating runoff, and reducing sediment transport. The establishment of extensive forest cover has improved ecosystem resilience, enhanced biodiversity, contributed to air quality improvement, carbon storage, and provided important habitat for more than 1,100 plant taxa.

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The restored landscape has also generated long-term socio-economic benefits by transforming Mount Vodno into a major recreational area and an important green infrastructure element for Skopje. The forest ecosystem contributes to climate adaptation by reducing heat stress, improving urban environmental conditions, and buffering the impacts of extreme rainfall events.

However, the sustainability of these achievements is increasingly challenged by urban expansion, construction pressure, and land-use conflicts along the mountain slopes. Maintaining the long-term benefits requires continued implementation of management plans, protection of forest areas, regular maintenance of erosion-control infrastructure, and effective enforcement of conservation regulations.

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5. CONCLUSION

- **Community relevance:** fully.
  The intervention directly addressed a major community challenge: severe erosion, uncontrolled torrential flows, and flood risks threatening the population and infrastructure of Skopje. Through afforestation and torrent-control measures, the mountain was transformed from a degraded landscape into a protective and recreational area providing long-term benefits to residents.

- **Technical effectiveness:** mostly.
  The combination of nature-based solutions and technical measures, including afforestation, check dams, and regulated channels, has effectively reduced erosion, stabilized slopes, and controlled torrential processes. The restoration of more than 2,500 ha of forest has improved ecosystem functions and biodiversity. However, continued maintenance and protection are needed to preserve long-term effectiveness.

- **Economic efficiency:** mostly.
  The intervention has proven highly cost-effective, as the long-term benefits from reduced flood risks, avoided damages, ecosystem services, and recreational value significantly exceed the initial restoration costs. Continuous investment is required for maintenance and management of the infrastructure and forests.

- **Institutional support:** fully.
  Strong institutional support was established through dedicated organizations such as the "Vodno" Enterprise for Afforestation and Torrent Control and "Vardar" Water Economy. Today, management is supported by the City of Skopje, Public Enterprise "Parks and Greenery," and relevant state institutions through long-term management plans.

- **Innovation:** fully.
  The intervention was innovative for its time by integrating biological restoration (afforestation) with engineering measures (torrent-control structures) at a mountain-wide scale. The approach combined ecosystem restoration, flood protection, and social participation, creating a multifunctional landscape model.

- **Replication & Scaling Potential:** mostly.
  The Mount Vodno approach can be replicated in other urban mountain environments facing erosion and flood risks. Its success depends on adapting measures to local ecological, hydrological, and socio-economic conditions while maintaining the principles of nature-based solutions.

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