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CASE STUDY

Kalimanci Water Reservoir: Biotechnical Works and Afforestation for Catchment Protection (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.

The Kalimanci Reservoir catchment, located in northeastern North Macedonia, is a large water management system covering approximately 1,135 km² within the Bregalnica River basin. Constructed in 1969 with a storage capacity of 127 million m³, the reservoir was developed to provide irrigation water, support hydropower production, and improve regional water security. However, high erosion rates in the catchment threatened reservoir functionality through increased sediment accumulation. To address this challenge, integrated erosion-control measures were implemented, combining biotechnical structures and afforestation. A total of 1,544 erosion-control structures were constructed, including check dams and dry-stone masonry barriers, while approximately 5,710 ha were afforested to stabilise slopes, reduce runoff, and improve vegetation cover. These interventions decreased sediment transport, reduced land degradation, and extended the operational lifespan of the reservoir. The restored catchment improved ecosystem services, including soil conservation, water regulation, and landscape stability, while supporting local livelihoods through reliable irrigation for agriculture and hydropower generation. The Kalimanci case demonstrates the effectiveness of combining engineering measures with nature-based solutions for sustainable watershed management.

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[Afforestation with black pine (Pinus nigra) on the immediate slopes of the reservoir - Source: I. Minchev, I. Blinkov, A. Trendafilov, B. Trendafilov (2023)]

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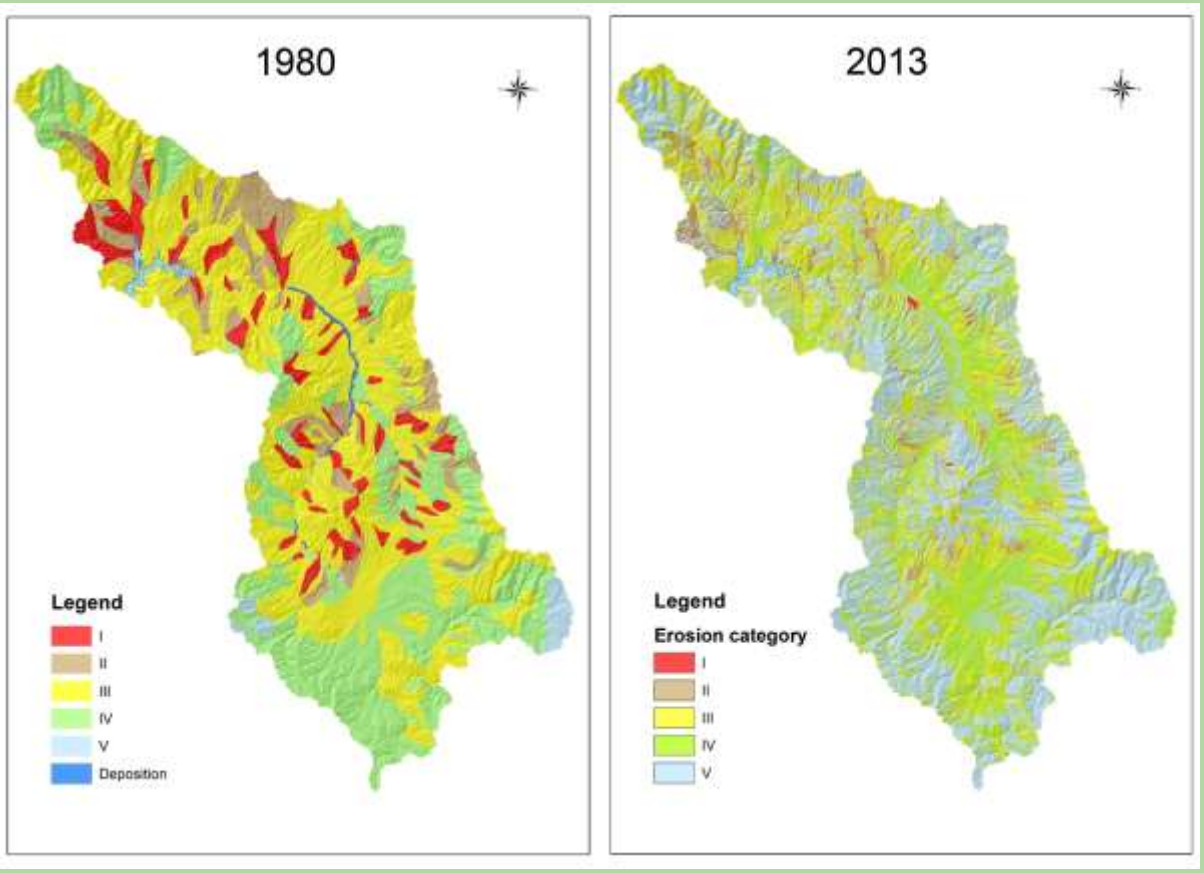

[Erosion map of the catchment of Kalimanci 1980 vs. 2013. Width and spacing between the tree windbreaks in the Ovche Pole Region - Source: Onchevski & (Mihara, 2026)]

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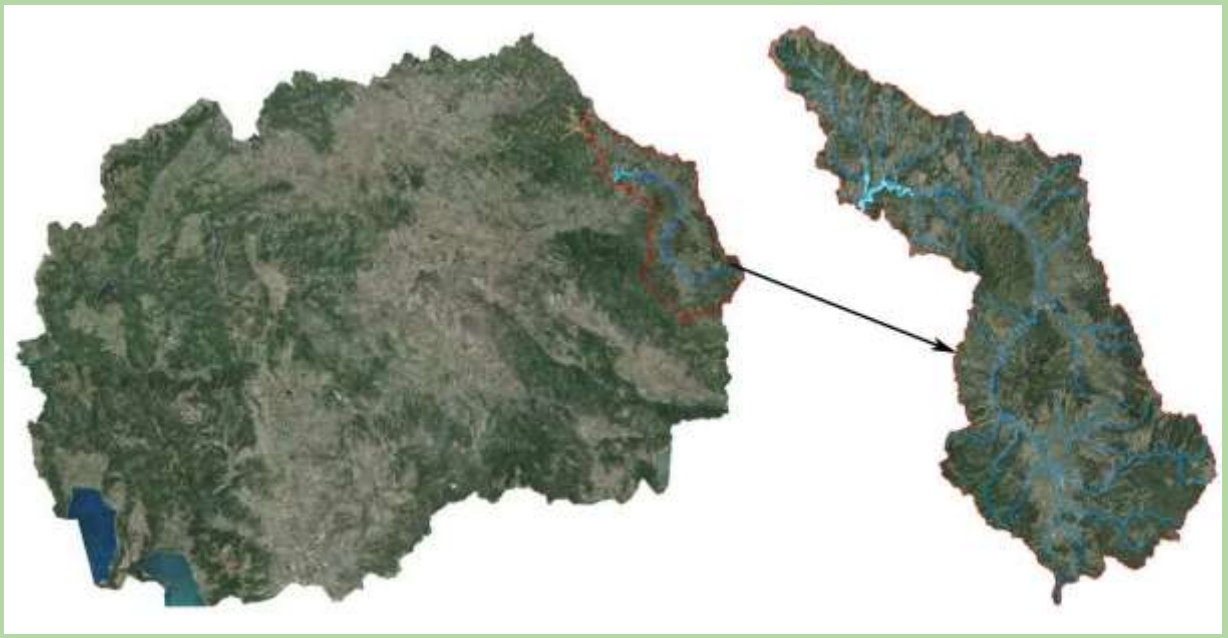
2. CONTEXT

2.1 LOCATION

Country: North Macedonia. Region: Eastern part of North Macedonia. Province: Northeastern part of the Republic of North Macedonia. Site: Kalimanci Water Reservoir catchment (middle and upper catchments of the Bregalnica River). Approximate GPS coordinates: Latitude 41.994° N; Longitude 22.602° E.



[Location of the Kalimanci catchment within the Republic of North Macedonia - Source: I. Minchev, I. Blinkov, A. Trendafilov, B. Trendafilov (2023)]

2.3 LANDSCAPE TYPE

Forestland. Croplands.

2.4 LAND DEGRADATION CHALLENGE

Soil erosion. Land degradation.

2.5 BASELINE DATA

Land condition	• Site: Kalimanci Water Reservoir catchment, including the middle and upper catchments of the Bregalnica River, northeastern North Macedonia.

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	• Soil: the catchment is affected by erosion processes, with historical erosion assessments used as indicators of land condition. Systematic erosion data before dam construction were not available; baseline conditions are represented by erosion estimates from the early 1980s. • Vegetation cover: afforestation interventions were implemented in the catchment area, with some measures initiated before the dam construction (1969). The effects of afforestation are considered significant after approximately 20 years of vegetation development. • Erosion status: the erosion map from the early 1980s estimated an average erosion coefficient (Z) of 0.54, with average erosion production of approximately 1200 m^3/km^2/year. By 2013, erosion levels had decreased, with an average Z coefficient of 0.31 and erosion production of 486 m^3/km^2/year, indicating improved erosion control.
Environmental context	• Climate: the catchment is influenced by regional climatic conditions that affect water availability, vegetation development, and erosion processes. • Hydrology: the Kalimanci Reservoir regulates water flow within the Bregalnica River catchment. Sediment accumulation was monitored through historical surveys (1969–1997) and bathymetric measurements (2013). Sedimentation decreased from 467,686 m^3/year during 1969–1985 to 214,325 m^3/year during 1985–2013. • Biodiversity: Biodiversity is influenced by the dominance of agricultural land, degraded forests, and limited natural vegetation. Shelterbelts provide additional habitat structures within the agricultural matrix. • Ecological pressures: the main environmental pressures include soil erosion, sediment transport, and sediment accumulation in the reservoir, which threaten water storage capacity and catchment stability.
Socioeconomic context	• Population: the area is mainly rural, with settlements dependent on surrounding natural resources and catchment management activities. • Livelihoods: local livelihoods are mainly linked to agriculture, forestry, and the use of water resources provided by the reservoir system. • Land management: catchment management included afforestation and erosion-control interventions aimed at reducing sediment production and protecting the reservoir. These measures were implemented in relation to dam operation and long-term watershed management.

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	• Resource dependency: the area depends on the reservoir system for water regulation and associated ecosystem services.
Policy and governance	• Institutional framework: the management of the Kalimanci catchment is linked to water infrastructure planning and long-term erosion control strategies. Afforestation and biotechnical interventions were implemented as part of integrated catchment protection measures associated with reservoir management.

3. INTERVENTION

3.1 TIMEFRAME

The biotechnical works were done in the period of 1959-1974. The afforestation works started from 1950 and they continue up to 1990. The major afforestation works were done in the 1980's.

3.2 TYPE OF INTERVENTION

Reforestation. Afforestation. Soil restoration. Erosion control.

3.3 IMPLEMETING ORGANISATIONS

The works were carried out by the Public Enterprise for Water Economy "Bregalnica" – Kochani, with the involvement of the Water Economy Institute of Macedonia.

3.4 FUNDING SOURCES

The financing of the biotechnical work was included in the budget for the dam construction and they were government funded through the established public enterprises (PE). Some of the afforestation works were community based where the PE were providing seedlings for afforestation and the private land owners together with the PE were planting on their land. The public land afforestation was done solely by the PE.

3.5 IMPLEMENTATION ACTIONS AND MEASURES

Following the construction of the Kalimanci Reservoir, a series of bio-ameliorative and anti-erosion measures were implemented throughout the reservoir catchment to reduce soil erosion, limit sediment transport, decrease reservoir sedimentation, and extend the operational lifespan of the reservoir. The interventions included the construction of 1,544 transverse erosion-control structures, consisting of 160 check dams, 1,308 dry-stone masonry check dams, and additional smaller erosion-control works. In parallel, anti-erosion afforestation was carried out over approximately 5,710 ha, aiming to stabilise degraded slopes, improve vegetation cover, reduce surface runoff, and enhance catchment resilience. These combined structural and

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ecological measures contributed to a significant reduction in sediment yield and improved long-term protection of the reservoir system.

4. IMPACT

4.1 ENVIRONMENTAL IMPACT

☑ Improved soil health or reduced soil erosion. ☑ Improved water quality. ☑ Reduced land degradation. ☑ Improved ecosystem services.

The main focus of the intervention measures and works were in line with stopping filling the reservoir with sediment. That means decreasing soil erosion and land degradation with bio-technical works. The results of the sedimentation of the reservoir show a decrease of the sedimentation by 2,5 times. In the first period from 1969–1985 the sediment transport in the reservoir was 467,686 m^3/year and in the second period from 1985–2013 was 214,325 m^3/year. Improvement of biodiversity and access to water also provided improved ecosystem services: flood regulation, irrigation, improved animal husbandry, recreational values of the reservoir (scenic values, fishery..). On the other hand the water is used for production of electricity. The hydro-electric plant was put into operation in 1969 with an installed capacity of 12.5 MW and is part of the "Bregalnica" hydro system. The main purpose of the reservoir is to irrigate about 28,000 ha, mainly rice fields in the Kochani Valley, but also part of the arable land in Ovche Pole. For this purpose, two canals were built, the right one is 98 km long and carries water to Ovche Pole, and the left one is 36 km long and irrigates the areas in Kochansko Pole. This means reduced sediment equals to sustainable provision of water volume for irrigation and electricity production.

4.2 COMMUNITY IMPACT

☑ Increased household income. ☑ Job creation or new livelihood opportunities. ☑ Improved food security. ☑ Improved water access. ☑ Strengthened community resilience.

The construction of the water reservoir secured water availability for irrigation in the Kochani Valley and surrounding areas, extending towards Shtip and Sveti Nikole. This significantly improved community resilience by providing a more reliable water supply for agricultural activities. The increased availability of water supported agricultural productivity, contributed to higher household incomes, and created new employment opportunities in the wider surrounding area.

4.3 INSTITUTIONAL IMPACT

☑ Strengthened institutional coordination. ☑ Increased community participation in decision-making. ☑ Establishment of new management structures or partnerships. ☑ Capacity building for institutions or communities.

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The establishment of the hydro system involved local communities in the management and decision-making processes, supporting the development of policies for the sustainable use of the system and ensuring a more equitable distribution of irrigation water.

4.4 SUSTAINABILITY OF THE RESULTS

☑ Long-term funding mechanisms. ☑ Integration into policies or development plans. ☑ Institutional support or partnerships. ☑ Local technical capacity for maintenance.

The management system is based on the cooperation between public institutions and local communities. All water users (mainly private agricultural landowners) pay for water use, and these funds are allocated for the maintenance of the irrigation network and the reservoir infrastructure managed by the Public Water Economy Enterprise. In the past, the afforested areas within the catchment were also managed by the Water Economy Enterprise, ensuring that their protective function was integrated into overall catchment management. However, following institutional restructuring and the separation of water management and forestry enterprises, forest areas were transferred to the Forestry Public Enterprise. This change created management challenges, as the main objective of the Forestry Enterprise is oriented towards economic forest production, while the forests within the reservoir catchment primarily serve a protective function, such as erosion control and sediment reduction, with limited direct economic returns.

5. CONCLUSION

- **Community relevance:** fully.
  The intervention addressed a critical community need by securing reliable water availability for irrigation and supporting agricultural production. It improved resilience of local communities by enabling more stable farming practices, increasing productivity, and contributing to regional energy security through hydropower generation.

- **Technical effectiveness:** partially.
  The intervention effectively reduced erosion and sedimentation risks through afforestation and biotechnical anti-erosion structures, improving catchment stability and reservoir longevity. However, some ecosystem pressures remain due to ongoing erosion risks and the need for continuous maintenance of protective measures.

- **Economic efficiency:** fully.
  The reservoir system provided long-term economic benefits by ensuring irrigation water supply and electricity production. The management system, including water-use

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payments, supported maintenance of the infrastructure and contributed to the financial sustainability of the reservoir and associated services.

- **Institutional support:** fully.
  The intervention was strongly supported by public institutions through government-led planning, funding, and implementation. Cooperation between water management institutions and local communities enabled operation, maintenance, and long-term management of the reservoir system.

- **Innovation:** partially.
  The intervention applied an integrated approach combining water infrastructure, afforestation, and erosion-control measures. While these techniques were established practices, their coordinated application at the catchment scale represented an effective model for sustainable reservoir protection.

- **Replication & Scaling Potential:** fully.
  The approach can be replicated in other erosion-prone catchments where reservoirs require long-term protection. Combining afforestation, biotechnical measures, and sustainable water management supports soil conservation, sediment reduction, and improved water security while maintaining ecosystem functions.

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