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UNIVERSITY OF IASI
GEOGRAPHY AND GEOLOGY FACULTY
DOCTORAL SCHOOL OF GEOSCIENCES

Analysis of factors influencing ecosystem services in the Natura 2000 Site ROSCI0434 Siretul Mijlociu

SUMMARY OF THE DOCTORAL THESIS

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Abbreviations used

WBA	Water Basin Administration
ANANP	National Agency for Protected Natural Areas
APM	Environmental Protection Agency
CICES	Common International Classification of Ecosystem Services
CLC	CORINE Land Cover
EEA	European Environment Agency
EUNIS	the European Nature Information System
EA	Appropriate assessment
GPS	Global Positioning System
NIS	National Institute of Statistics
InVEST	Integrated Valuation of Ecosystem Services and Tradeoffs
IPBES	Intergovernmental Platform on Biodiversity and Ecosystem Services
MA	Millennium Ecosystem Assessment
MAES	Mapping and Assessment of Ecosystems and their Services
MEFP	Ministry of Environment, Waters and Forests
UN	United Nations
OSPA	Office of Pedological and Agrochemical Studies
ROSCI	Site of community importance, integrated into the Natura 2000 ecological network
ROSPA	Special bird protection area, integrated into the European ecological network Natura 2000
WWTP	Wastewater treatment and purification station
TEEB	The Economics of Ecosystems and Biodiversity
EU	European Union
QGIS	Quantum Geographic Information System

Keywords

Ecosystem services, regulating services, supply services, cultural services, Natura 2000, ROSCI0434 Siretul Mijlociu, species of community interest, aquatic habitat, riparian habitats, conservation tools, CICES classification, hierarchical model, "cascade" model, pollution, water footprint, InVEST, habitat fragmentation, anthropogenic activities, water quality, ecosystem, biodiversity, resilience, conservation of natural capital, EU Biodiversity Strategy, ecosystem approach, agriculture and water use, sustainable development, ecological connectivity, integrated management, territorial planning, adaptation to climate change.

Introduction

In recent decades, the issue of ecosystem services has gained major importance in environmental sciences, especially in the context of the sharp degradation of natural capital and the intensification of anthropogenic pressures. Natural ecosystems provide essential benefits for society like food, water, climate regulation, air and water purification, recreation, but these services are often undervalued in the decision-making process.

The Natura 2000 network, established at European level, represents the most important instrument for biodiversity conservation, integrating habitats and species of community interest. In Romania, this network expanded after 2007, but Natura 2000 sites face a lack of management plans, insufficient data and difficulties in harmonizing conservation with socio-economic development.

The general objective of the work is the complex and correlative assessment of ecosystem services and anthropogenic pressures within the Natura 2000 site ROSCI0434 Siretul Mijlociu, in order to understand the interdependencies between them.

The specific objectives aim to:

- mapping habitats and species of conservation interest;
- qualitative and quantitative assessment of ecosystem services;
- analysis of the relationships between the state of ecosystems and human activities;
- identification of vulnerable areas and monetary assessment through InVEST modeling;
- formulating proposals for sustainable management and integrated territorial planning.

The research aims to provide an integrated approach, capable of capturing the complexity of the relationships between biodiversity, ecosystem services and human activities, with the aim of proposing solutions for the conservation of natural capital and the sustainable use of resources.

Chapter I. Methodology

The concept of ecosystem services was established internationally with the Millennium Ecosystem Assessment (United Nations, 2005), which demonstrated the fundamental dependence of human well-being on the functioning of ecosystems. Ecosystem services have been grouped into four broad categories:

1. supply services
2. adjustment services
3. cultural services
4. support services.

Ecosystems provide essential habitats for the life cycle of species, and the conservation of genetic diversity supports their adaptability and resilience, with some areas being recognized as biodiversity "hotspots". In this context, European and international policies have integrated the concept of ecosystem services into conservation strategies, an important moment being the launch of The Economics of Ecosystems and Biodiversity (TEEB, 2010).

For standardization and comparability between assessments, the Common International Classification of Ecosystem Services (CICES) was created, developed by the European Environment Agency, which in its updated version (V5.2) classifies ecosystem services into three broad categories:

1. supply (food, water, wood),
2. regulation and maintenance (climate regulation, pollination),
3. cultural (recreation, symbolic values).

The European Environment Agency (EEA) published in 2018 a map of ecosystems and habitats in 39 European countries (EUNIS classification), a step forward in achieving defined and standardized approaches for identifying ecosystem services.

Within the MAES initiative, a methodological guide was developed that proposes a unitary classification of ecosystems as systems made up of biotic and abiotic components, grouped into three broad categories: terrestrial, marine and freshwater. Their delimitation is

based on ecological and geographical criteria, and the methodology allows for uniform application in all EU countries.

In the context of the diversity of existing systems, the need for a unified characterization and correlation of habitats, including those in the Natura 2000 network, is emphasized to ensure data comparability and integration.

In Romania, ecosystem mapping was carried out by correlating CORINE Land Cover Classes (CLC) with ecosystem types identified according to the EUNIS classification and by integrating them with the Land Parcel Identification System (LPIS), providing a unified framework for analysis and comparability.

The methodology of this paper is based on these international frameworks (MA, TEEB, MAES, CICES) and combines qualitative and quantitative methods to capture the relationships between ecosystem state, anthropogenic pressures and benefits provided, providing an integrated framework adapted to the national and local context.

I.1. Spatial delimitation of the research: ROSCI0434 Siretul Mijlociu

I.1.1. Spatial and normative context of the study area

The study area is represented by the ROSCI0434 Siretul Mijlociu site, designated in 2016 and located in the north-east of Bacău County. It includes riparian habitats of community interest (92A0 Zăvoaie with Salix alba and Populus alba) as well as fauna species of conservation interest, including: fish (serpentine, barbel, wrasse, gerbil, scaly wrasse), reptiles (European turtle) and mammals (otter).

The site fulfills multiple functions: habitat for species of community interest, source of natural resources (water, mineral aggregates, fish resources) and area with recreational potential, being relevant for the analysis of interactions between human activities and biodiversity conservation.

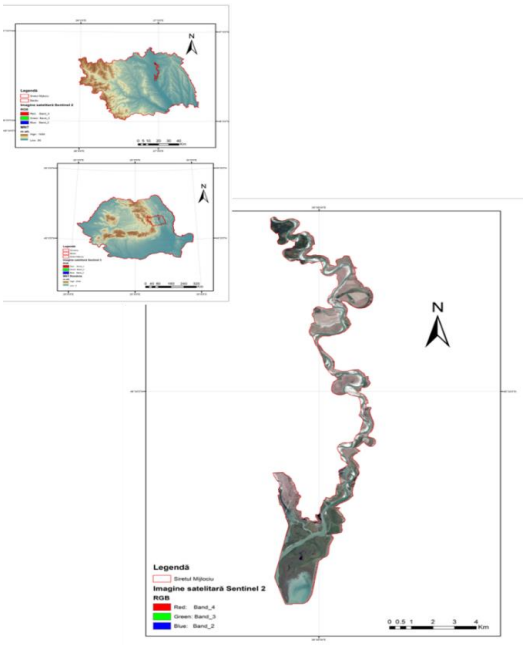

Fig. I.1. Location of ROSCI0434 Siretul Mijlociu

I.1.2. Materials used

Direct field observations (2021–2023), GPS mapping equipment and cameras, local interviews, and a variety of documentary sources and institutional databases (Environmental Protection Agency, National Agency for Protected Natural Areas, Water Basin Administration, National Meteorological Administration, CORINE Land Cover data, the official spatial data platform published by the Ministry of Environment, Waters and Forests) were used to conduct the research.

I.1.3. Research and evaluation methods

The assessment of ecosystem services at the ROSCI0434 Siretul Mijlociu site was based on internationally recognized conceptual frameworks, in particular the "Cascade" model and DPSIR (Driving forces-Pressures-State-Impact-Responses), which allow the integration of the relationships between the state of ecosystems, anthropogenic pressures and the benefits provided to society. The analysis had as its starting point the assessment of the state of habitats and species, considered direct indicators of the capacity of ecosystems to provide services.

Areas of interest were identified and analyzed according to the official boundaries of the protected area, including adjacent ecologically relevant areas. Field activities aimed at identifying habitat 92A0 Zăvoaie with Salix alba and Populus alba and monitoring species of community interest, through direct observations, identification of microhabitats and data collection from monitoring reports and local sources.

To capture the relationship between anthropogenic pressures and the state of ecosystems, spatial analysis techniques and the "dose-response" method were applied, which allows quantifying the effects of environmental changes on biodiversity. Data collected in the field (2021–2023) were correlated with information from institutional databases, thus building an integrated picture of the functionality of ecosystems and their capacity to provide ecosystem services.

I.2. Collection of data on ecosystem services

The collection of data necessary for the assessment of ecosystem services was carried out through a mixed approach, which combined primary and secondary data sources, in order to ensure rigorous coverage and a rigorous methodological foundation.

I.2.1 Materials used and data sources

Primary data were obtained through direct observations and photographic documentation, GPS mapping of areas of interest and the application of a questionnaire addressed to the local population.

Secondary data came from specialized scientific literature, European and national strategic and legislative documents, official statistical data (National Institute of Statistics), geospatial databases (CLC (Corine Land Cover), orthophotomaps, Natura 2000 boundaries), guides and monitoring reports published by the National Agency for Protected Natural Areas, as well as from information provided by the Siret Water Basin Administration, the National Meteorological Administration and the Bacau Environmental Protection Agency.

The selected ecological parameters targeted forest and aquatic habitats, fish species (Aspius aspius, Romanogobio vladykovi,Cobitis taenia, Sabanejewia balcanica), reptiles (Emys orbicularis) and mammals (Lutra lutra), being correlated with the ecosystem services provided and the ecological state of the ecosystems.

I.2.2. Ecological parameters and database

An integrated database was established, including biotic and abiotic components, local economic activities, water resource use and relevant hydrological characteristics (precipitation, flow).

The ecological indicators used were extracted from official documents regarding the conservation objectives of the ROSCI0434 Siretul Mijlociu site and served as benchmarks for assessing the functionality of ecosystems and the ecosystem services provided.

I.2.3.Data collection and analysis methods

The social component of the research consisted of applying a standardized questionnaire to assess the level of knowledge, perception and attitude of the local community towards the protected area and ecosystem services.

The questionnaire, applied to a sample of 850 people from the localities surrounding the site, targeted: the level of knowledge of protected areas, perceptions of benefits and attitudes towards biodiversity conservation. The data obtained were statistically analyzed and correlated with ecological indicators, contributing to the integration of the social dimension in the assessment of ecosystem services.

This approach allowed for the complex characterization of the relationship between the state of ecosystems and the benefits offered to the local community by the ROSCI0434 Siretul Mijlociu site.

I.3. Analysis of factors influencing ecosystem services

The analysis aimed to identify and evaluate the main natural and anthropogenic factors that influence the capacity of ecosystems in the ROSCI0434 Siretul Mijlociu site to provide ecosystem services, using an integrated methodology that combines ecological, hydrological, pedological and socio-economic data.

I.3.1. Materials and data sources used

The analysis was based on a diverse set of climatic, hydrological, pedological, ecological and socio-economic data, obtained from direct observations, questionnaires applied to locals and institutional sources (National Meteorological Administration, Siret Water Basin Administration, Bacău Pedological and Agrochemical Studies Office), complemented with Corine Land Cover geospatial data and information from strategic documents and scientific sources.

I.3.2. Methods used for analysis

The analysis integrated spatial methods (Inverse Distance Weighting interpolation, Corine Land Cover classification, GIS mapping), ecological and chemical analysis methods (dose-response method, water quality assessment, biotic indices, InVEST – Habitat Quality model, water footprint calculation) and institutional qualitative analysis methods (content analysis of strategic and legislative documents), to assess the relationships between anthropogenic pressures, the state of ecosystems and the services provided.

I.4. Research limits

The research was affected by: the lack of a functional system for monitoring illegal activities, the absence of a standardized framework for collecting environmental data, the shortage of updated information on species of community interest, limited access to some institutional databases and a relatively high degree of subjectivity of certain direct observations.

Chapter II. Characterization of the natural factors of the Natura 2000 site ROSCI0434 Siretul Mijlociu and the surrounding area

The assessment of ecosystem services is based on the natural setting of the site: habitat types, specific biodiversity, climatic regime and local edaphic and hydrological conditions, geology, relief. Together, these explain the capacity of ecosystems to provide provisioning, regulating and supporting and cultural services.

II.1. Habitat types in the Natura 2000 site

The ROSCI0434 Siretul Mijlociu site, with an area of 2,969 ha and a length of about 26 km, is located in the continental biogeographic region and includes a diversity of habitats: aquatic ecosystems (rivers and lakes: 43.04%), wetland ecosystems (swamps and peatlands: 21.91%), pastures (18.68%), agricultural lands (10.5%) and deciduous forests (5.4%).

The habitat of community interest 92A0 Zăvoaie with Salix alba and Populus alba is representative for the site, being located in the northern sector (Schineni and Prăjești) on low fluvial banks (156–160 m), periodically subject to flooding. It develops on alluvial deposits with fertile soils and well supplied with water, having a structure dominated by white poplar (50–70%), associated with black poplar, willow and other deciduous species. The shrub and herbaceous layer are well developed, including numerous species characteristic of wetlands.

This habitat has a high conservation value, providing essential microhabitats for aquatic and semi-aquatic fauna. Currently, the conservation status is assessed as average to unfavorable, in the context of hydromorphological and anthropogenic pressures.

II.2. Analysis of abiotic and biotic components in the ROSCI0434 Siretul Mijlociu area

II.2.1 Local climate and natural conditions

Climate. The climate of the studied area is temperate-continental, with summer precipitation maxima and pronounced thermal seasonality; active wind regime, generally with moderate intensities.

Precipitation regime and specific climatic characteristics.The climatological analysis for Bacău (1992–2022) highlights a rainfall regime with a summer maximum and high seasonal variability, characterized by abundant precipitation and extreme phenomena in the warm months, average relative humidity of about 66% and the occurrence of a water deficit at the end of the vegetation season.

Aeolian regime.The wind regime in the Bacău area is active, dominated by frequent winds from the north, northwest and south, with moderate intensities (1.2–4.1 m/s) and maximums in winter, when the snowdrift contributes to the soil moisture deficit by reducing air humidity and intensifying evapotranspiration.

Relief. The relief of the ROSCI0434 Siretul Mijlociu area is predominantly low plain, with altitudes between 122 and 250 m, characterized by meadows and weakly fragmented slopes, while to the east and west there are hilly units reaching up to 717 m, creating a morphological contrast useful in the analysis of geomorphological processes and the ecological potential of the site.

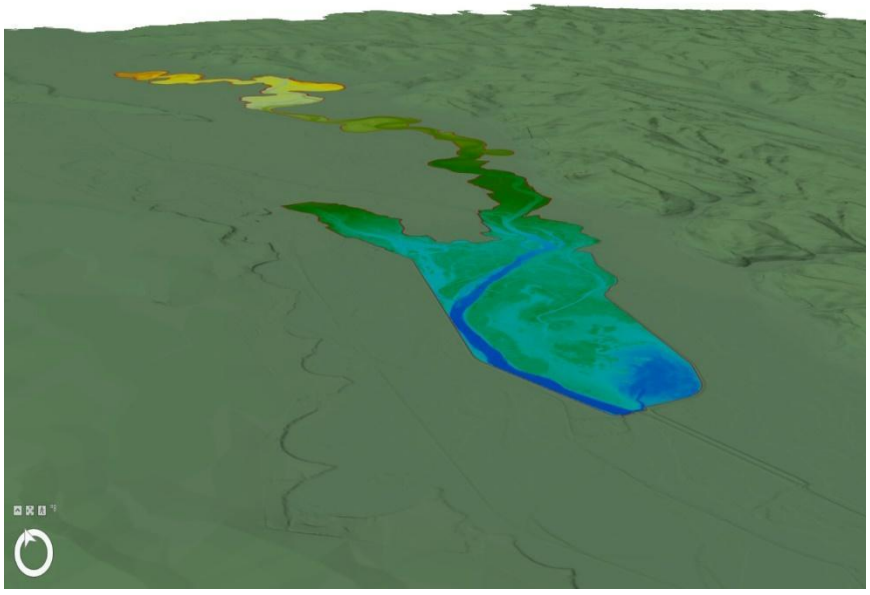

Fig.II.1.Three-dimensional model of the studied area

The landscape from the ROSCI0434 Siretul Mijlociu is shaped by the natural dynamics of rivers, characterized by the alternation of erosion and deposition processes, which generate a diversity of habitats. This landscape structure has a multidimensional dimension, defined by: the continuity of the watercourse from source to outlet, the lateral transition between the aquatic and terrestrial environment (including the floodplain), the vertical exchanges of water, sediments and organisms between the riverbed and the subsoil, as well as the temporal variability induced by floods and droughts, which influence the hydrology, vegetation and fauna of the area.

Geology, geomorphology. The ROSCI0434 Siretul Mijlociu site is located in the Moldavian Platform, part of the Central Moldavian Plateau, and overlies Neogene and Quaternary sedimentary deposits. From a geomorphological point of view, it is located in the Roman-Adjud corridor, a depressional area shaped by the Siret River, characterized by low-lying meadows, fluvial terraces and glaciations, which reflect the processes of erosion, sedimentation and recent morphogenetic evolution of the area.

Hydrology. The protected natural area is located in the Siret river basin, the largest in Romania, which collects about 17% of the country's water resources and has the Danube River as its emissary. The hydrographic network of the studied area is dominated by the Siret river and its main tributary, the Bistrița River, complemented by surface water bodies (lakes, reservoirs) and the ROSI03 groundwater body, developed in porous-permeable alluvial deposits. Hydrological analyses indicate a good ecological status, but also active processes of transport and sedimentation of alluvium, while the physicochemical and biological parameters (phytoplankton, macroinvertebrates) reflect a relatively fragile balance, influenced by both natural processes and anthropogenic pressures, with direct implications for water quality and aquatic biodiversity.

Soil cover. In ROSCI0434 Siretul Mijlociu alluvial soils, luvosols and preluvosols, with sectors of chernozems, dominate; humus is low–medium (≈1.5–3.3%), the pH is generally neutral–weakly alkaline (with acidic spots in the W–SW), and the higher permeability in the meadow favors percolation to the groundwater. Heavy metal loading is moderate and below alert thresholds (with local increases in Cu, Pb, Co, Ni), while P and N are higher in the proximity of agricultural and urban areas (Bacău, Traian, Cleja), which makes the soils remain, overall, favorable for conservation and ecosystem services.

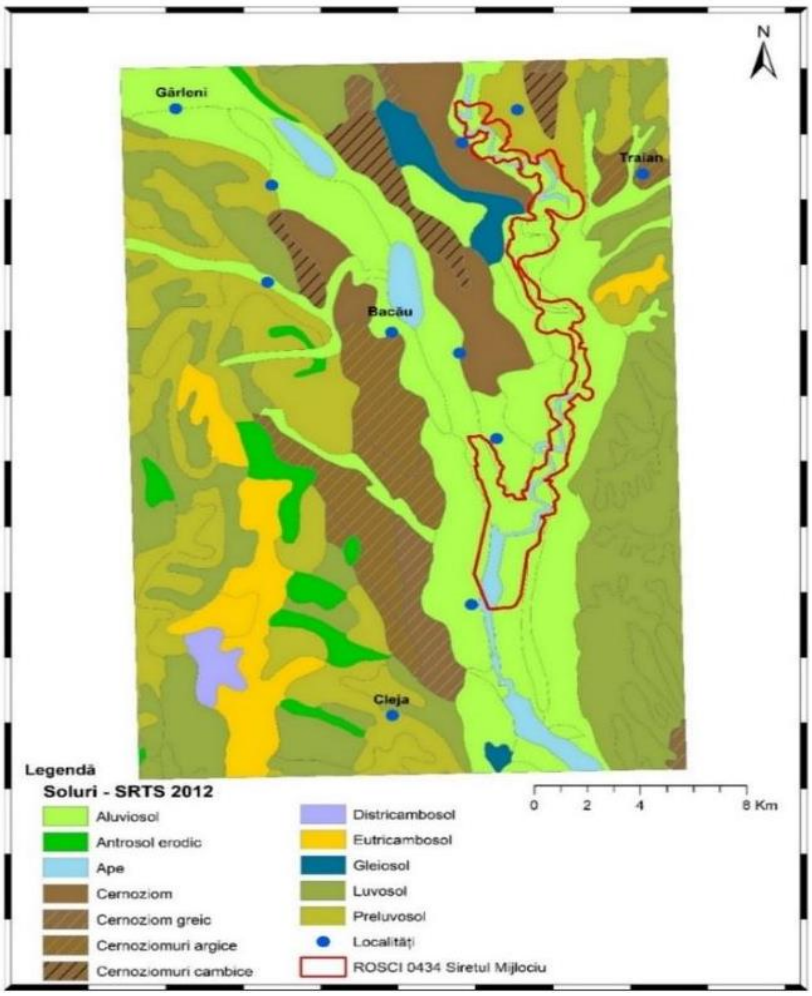

Fig. II.2. Distribution of soil types in the protected natural area ROSCI0434 Siretul Mijlociu

II.2.2. Biodiversity of present species

Aquatic ecosystems (rivers and lakes) dominate the ROSCI0434 Siretul Mijlociu site, covering over 43% of the surface and providing habitat for species of community interest, such as the otter (Lutra lutra), the European water turtle (Emys orbicularis) and several protected fish species (Aspius aspius, Barbus petenyi, Cobitis taenia, Romanogobio kesslerii, Sabanejewia balcanica, Rhodeus amarus). The site also overlaps with an avifaunal migration route of continental importance, being frequented by aquatic and marsh species from the families *Ardeidae, Threskiornithidae, Anatidae, Rallidae, Charadriiformes, Laridae* and *Sternidae*.

Monitoring data highlight variations in the population dynamics of ichthyofauna during 2020–2021, suggesting an increased sensitivity of certain species (e.g. Aspius aspius, Sabanejewia balcanica) to habitat changes. In contrast, species such as Rhodeus amarus and

Cobitis taenia show constant abundances and high frequency values, supporting the hypothesis of relative stability of aquatic communities.

The presence of the otter and the European water turtle underlines the conservation value of the site, as they function as indicator species of habitat quality.

Thus, the high biodiversity and complexity of the biological communities in the site reflect the interdependence between abiotic factors, habitat structure and ecosystem functions, strengthening the role of the area as an area of ecological and conservation importance at national and European level.

Chapter III. Anthropogenic factors influencing ecosystem services

III.1. Human activities in the area

Over a length of approximately 26 km, the ROSCI0434 Siretul Mijlociu site is strongly influenced by human activities, which generate pressures on habitats and species of community interest. Among these, the most significant is the exploitation of mineral aggregates (ballast in the riverbed and terrace), which affects the morphology of the riverbeds, the dynamics of sediments and the trophic resources of the ichthyofauna. Other major pressures are intensive agriculture, with the input of nutrients and pesticides, recreational fishing (over 23,000 kg annually), urban expansion and infrastructure projects (e.g. the Bacău Bypass), which fragment habitats and reduce ecological coherence.

In addition, the waste treatment and treatment plants (Tamași WWTP, Letea Veche TMB) contribute to point and diffuse pollution risks, and the change in land use category amplifies the site's vulnerability to urbanization. Although inclusion in the Natura 2000 network requires protection measures, anthropogenic pressures remain considerable, requiring constant monitoring and integrated strategies to maintain the functionality of ecosystems and associated ecosystem services.

III.2. Environmental pollution and degradation

An image of all human activities carried out in the protected natural area is shown below.

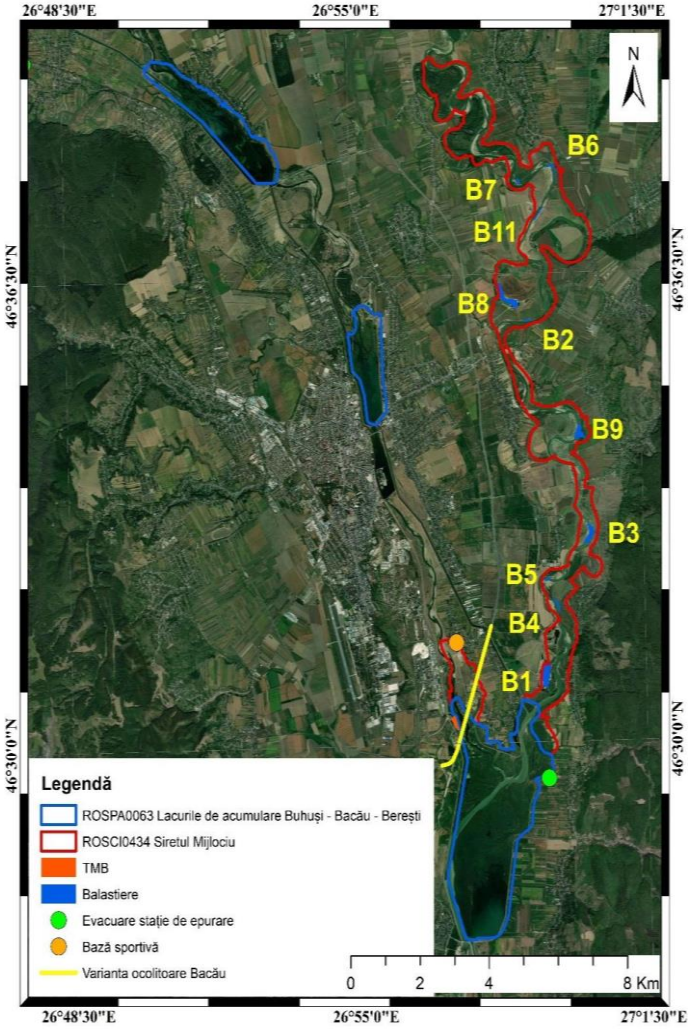

Fig. III. 1. Map of activities with environmental impact on the area

Anthropogenic activities carried out in the ROSCI0434 Siretul Mijlociu site, in particular the exploitation of mineral aggregates, agriculture, road infrastructure and urbanization, generate complex forms of environmental pollution and degradation. The ballast beds in the minor and terraced riverbed affect water quality, the hydrological regime and the stability of the substrate, leading to the loss of aquatic and terrestrial biodiversity. Infrastructure projects (e.g. Bacău Bypass, sports base) fragment habitats and reduce ecological connectivity, while waste treatment and treatment plants contribute to risks of point and diffuse pollution.

Intensive agriculture and recreational fishing amplify pressures through nutrient inputs, overfishing and food web disruption, which affects ecosystem services that support, regulate and provide food. The overlap of these pressures in the adjacent urbanized areas increases the vulnerability of the site, requiring monitoring and integrated management measures to maintain environmental quality and conserve biodiversity.

III.3. Water footprint and impact on ecosystems

The water footprint, a concept introduced by Arjen Hoekstra in 2002, in the context of analyzing the consumption of "virtual water" associated with the production and global trade of goods, defined by the blue, green and grey components, is an essential tool for assessing the sustainability of the use of water resources and the impact of human activities on aquatic and terrestrial ecosystems. In the ROSCI0434 Siretul Mijlociu site, the water footprint analysis for the period 1992–2022 highlights an increase in direct and indirect water consumption, determined by population expansion, intensification of agricultural practices and changes in food preferences.

The results indicate that the grey water footprint, associated with nutrient and wastewater pollution, exerts the greatest impact on the water quality of the Siret River and, implicitly, on the conservation status of species and habitats of community interest. Climatic variability and extreme hydrological episodes increase pressures on water resources, and maintaining ecological balance depends on integrated management that ensures both the needs of local communities and biodiversity conservation objectives.

III.4. Conservation and protection measures applied

Anthropogenic activities with potential environmental impact in the ROSCI0434 Siretul Mijlociu site are regulated by a complex legal framework, based on environmental notices, agreements and permits, as well as on the mandatory appropriate assessment for projects that may affect species and habitats of community interest. The conservation objectives aim to maintain ecological connectivity, limit turbidity, protect riparian vegetation and ensure biological and abiotic parameters favorable to protected species.

The measures applied include: restrictions on the exploitation of mineral aggregates (limitation of working periods, prohibition of deforestation and invasive species), rules for fish farming (planting only with native species, control of discharged waters), strict conditions for infrastructure and urban works (ecological passages, vegetation restoration, pollution prevention), as well as the regulation of recreational fishing by respecting the prohibition and limiting catches. For priority habitat 92A0 and species of community interest (Lutra lutra, Aspius aspius, Emys orbicularis, etc.), specific prohibitions and measures are provided to prevent irreversible degradation of ecosystems.

The results obtained argue for the need to strengthen protection measures and implement adaptive management, based on scientific data, which ensures the maintenance of the favorable conservation status of habitats and species, in parallel with the sustainable use of natural resources.

Chapter IV. The impact of anthropogenic factors on ecosystem services

In the Natura 2000 site ROSCI0434 Siretul Mijlociu, aquatic, riparian and forest ecosystems provide essential services for water quality, biodiversity, carbon storage and cultural benefits. Anthropogenic activities, mineral aggregate exploitation, agriculture, infrastructure and urbanization, reduce the capacity of ecosystems to support these functions. Through integrated approaches, including InVEST modelling and monetary valuations, vulnerable areas were identified and losses generated by habitat degradation were quantified.

IV.1. Assessment of the quality and quantity of ecosystem services

In the Natura 2000 site ROSCI0434 Siretul Mijlociu, the quality of ecosystem services is influenced by the efficiency, continuity and resilience of aquatic and riparian habitats, but also by the generally low perception of the local community. Analyses showed reduced nutrient filtration and vulnerability to climatic and hydrological variations, which affects the self-regulation capacity of ecosystems.

From a quantitative point of view, regulating and supporting services are affected by flow variability, increased nutrient concentrations, thermal stress that can alter vegetation development cycles and contribute to the loss of sensitive species or the emergence of drought-tolerant species and the loss of sensitive species, while provisioning services include fisheries resources, mineral aggregates and water for consumption and agriculture.

Cultural services, although present, are poorly valued due to low population awareness. Natural and anthropogenic pressures act cumulatively, diminishing both the quality and quantity of ecosystem services.

IV.2. Identification of the most vulnerable ecosystem services

The most vulnerable ecosystem services in the protected natural area are those of regulation and support, dependent on water (filtration and purification, regulation of the hydrological regime, maintenance of wetland habitats). These are affected by pollution, exploitation of mineral aggregates, lowering of the water table and fragmentation of habitats.

Supply services (water for consumption and irrigation, fisheries) and cultural services (recreation, landscape value) are also under pressure, in the context of the forecasted increase in water demand and infrastructure development. Planned interventions, such as the expansion of sewage networks or the modernization of treatment plants, can bring benefits for water quality, while dams and ballast water exploitation can reduce hydrological connectivity and the resilience of wetland habitats.

Thus, the water factor remains the critical element of ecosystem vulnerability in the site, directly influencing the stability and functionality of the services provided.

IV.3. Approaches and tools for assessing ecosystem services

Using the InVEST-Habitat Quality model, a habitat ecological quality score was calculated, which is an indicator of the ecosystem's capacity to provide services in general. The total ecosystem value of the ROSCI0434 Siretul Mijlociu site was estimated at approximately 2.37 billion lei/year, an indicative value, assigned according to the habitat quality score, and in the case of this model it is an aggregate monetary estimate of the ecological potential, but not equivalent to a complete assessment of all ecosystem services provided by a site.

An example is the value of the ecosystem service associated with the fishery resource, with a potential value of approx. 362.7 million lei/year, but reduced by anthropogenic pressures by over 500,000 lei/year. These values are indicative, but clearly highlight the economic importance of natural capital and the need to conserve habitats.

IV.4. Integrating ecosystem services into public policies and opportunities for ecological restoration

SEuropean and national strategies (Biodiversity 2030, European Green Deal, National Strategy for Biodiversity Conservation and Action Plan) recognize the central role of ecosystems in well-being and economy, promoting green infrastructure and ecological restoration objectives.

In practice, however, the integration of ecosystem services into sectoral policies remains limited, and in ROSCI0434 Siretul Mijlociu the lack of management based on this concept reduces the efficiency of conservation.

Instruments such as payments for ecosystem services (PES), green infrastructure and integrated spatial planning can link nature protection with benefits for communities. Integrating these services into public policies transforms Natura 2000 areas from constraints into valuable natural assets for sustainable development.

IV.5. Recommendations for improving site management

To maintain ecosystem services and ecological resilience in ROSCI0434 Siretul Mijlociu, an integrated governance model, based on multidimensional assessments, is necessary.

The priorities aim to: reduce pressures from aggregate extraction through closure periods and ecological reconstruction; sustainable management of water resources through integrated monitoring, extended treatment and payments for ecosystem services; preserve

habitat of community interest and connectivity through invasive species control and creation of ecological corridors; limit anthropogenic expansion through cumulative impact assessment and integration of green infrastructure into planning.

At the same time, the involvement of local communities through education, ecotourism and participatory governance is essential for strengthening social capital. The implementation of these measures, supported by instruments such as InVEST, CICES and MAES, can transform the site into an example of good practice for conservation based on ecosystem services.

The integrated analysis suggests that the maintenance of ecosystem services in ROSCI0434 Siretul Mijlociu is conditioned by the reduction of anthropogenic pressures and a better integration of the value of nature in public policies, aspects that will be developed in the general conclusions of the thesis.

Conclusion

The analysis carried out in the Natura 2000 site ROSCI0434 Siretul Mijlociu confirmed the high value of biodiversity and the role of aquatic, riparian and wetland ecosystems in providing ecosystem services. Habitat 92A0 Zăvoaie with Salix alba and Populus alba, together with species of community interest, constitute key elements for maintaining ecological functionality.

Qualitative and quantitative assessments, however, showed increased vulnerability, driven by anthropogenic pressures (aggregate exploitation, urbanization, infrastructure) and natural factors (climate change, invasive species). InVEST modeling results and field monitoring indicate moderate ecological functionality, with average efficiency in water purification and low resilience.

The working hypothesis, that increasing anthropogenic pressures reduce the functionality of ecosystems and their capacity to provide ecosystem services, was confirmed.

Differences in water physicochemical parameters and biological indices, as well as imbalances identified by the water footprint, highlight the decline in regulatory and supporting capacity. At the same time, the analysis of supply services has shown the imbalance between the exploitation of mineral resources and the sustainability of fisheries resources.

The results of the questionnaire highlight a predominantly negative public perception of protected areas, caused by low levels of information and lack of trust in responsible

institutions. This indicates the need for a reconnection between communities and natural values, through education and active involvement.

The conclusions confirm that maintaining ecosystem services depends on reducing anthropogenic pressures, integrating natural capital into public policies and applying innovative mechanisms, such as payments for ecosystem services or investments in green infrastructure. At the same time, the results can be used by authorities, protected area managers, NGOs and communities for strategic planning and strengthening site management.

Thus, the paper demonstrates that the Natura 2000 site ROSCI0434 Siretul Mijlociu has a significant, but vulnerable, ecosystem potential, and that its protection and valorization is an essential condition for biodiversity conservation and sustainable development.

Directions for future research and conservation actions

Future research in the ROSCI0434 Siretul Mijlociu site should include quantitative and monetary assessments of ecosystem services, useful for management plans and PES-type mechanisms. Monitoring the impact of aggregates exploitation and expanding water footprint analysis are priorities, in the context of climate change and pressure on water resources. Integrating natural capital into sectoral policies, along with the involvement of local communities through education and ecotourism, can ensure the long-term conservation of the 92A0 habitat and species of community interest.

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