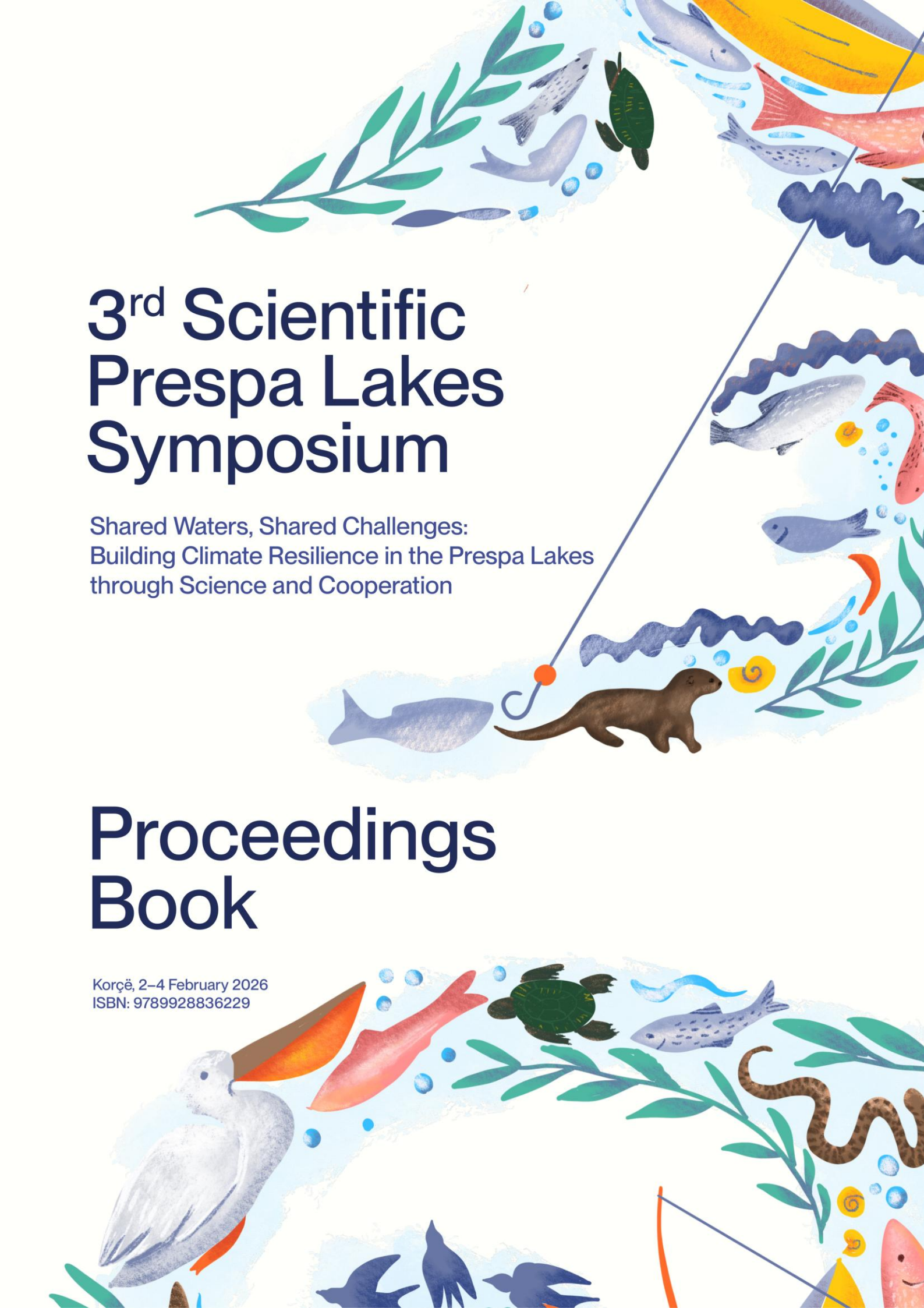


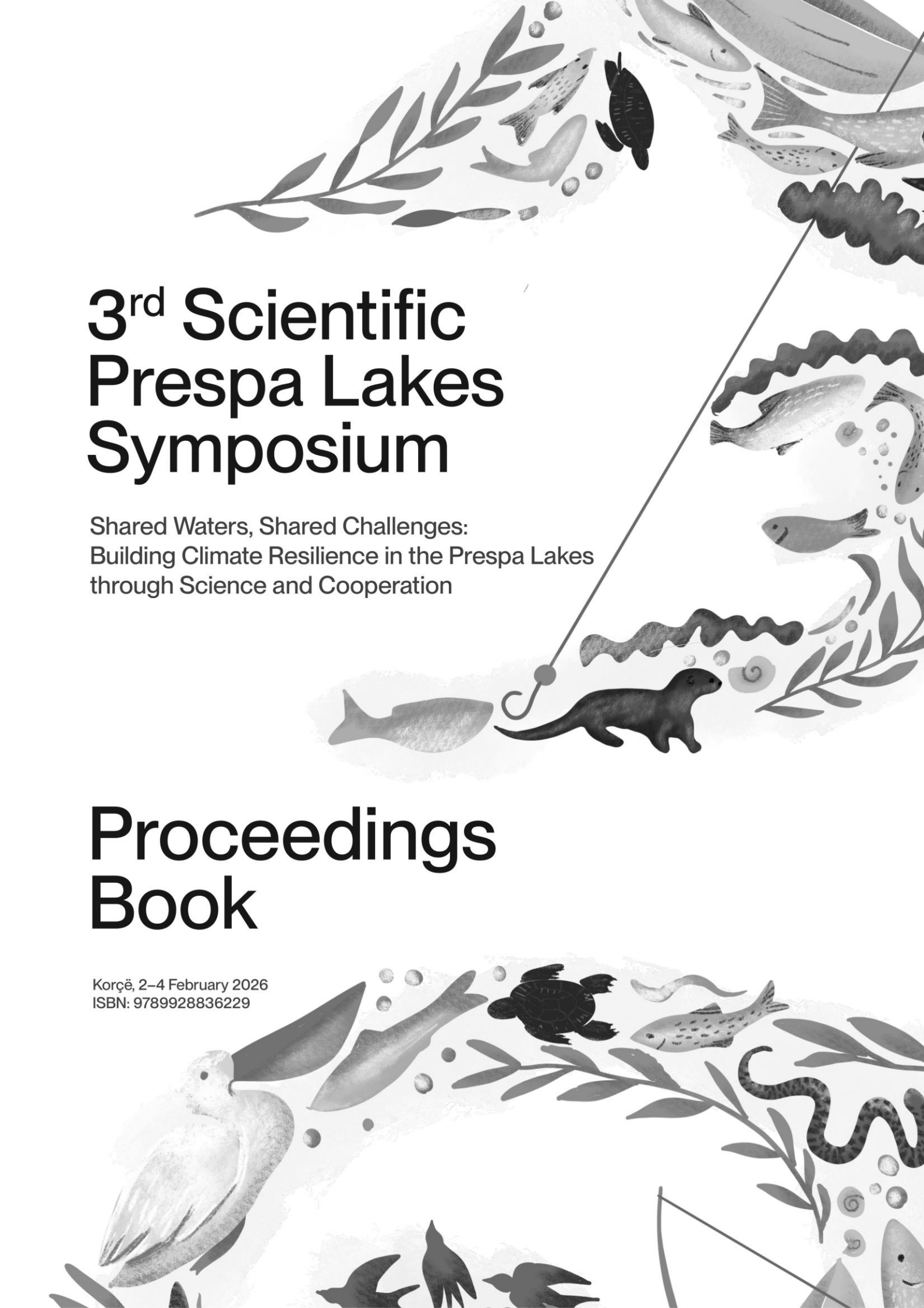
The background of the cover is a vibrant, stylized illustration of a lake ecosystem. It features various aquatic and semi-aquatic life forms: several fish in different colors (blue, red, yellow, green), a green turtle, a brown water snake, and a white bird with a long beak. There are also green reeds, blue bubbles, and a yellow sun-like shape. A thin blue line with an orange dot runs diagonally across the cover. The text is overlaid on the left side of the cover.

# 3<sup>rd</sup> Scientific Prespa Lakes Symposium

Shared Waters, Shared Challenges:  
Building Climate Resilience in the Prespa Lakes  
through Science and Cooperation

## Proceedings Book

Korçë, 2–4 February 2026  
ISBN: 9789928836229



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# About the Symposium

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The 3rd Scientific Prespa Lakes Symposium, held on 2-4 February 2026 at Fan S. Noli University in Korçë, was organised by the Protection and Preservation of Natural Environment in Albania (PPNEA) in collaboration with the Society for the Protection of Prespa, the Macedonian Ecological Society and the PrespaNet partnership, with the support of the Prespa Ohrid Nature Trust (PONT) and EuroNatur.

Entitled “Shared Waters, Shared Challenges: Building Climate Resilience in the Prespa Lakes through Science and Cooperation”, the symposium approached the Prespa Lakes as one interconnected transboundary social-ecological system. Scientists, public institutions, protected-area managers, civil-society organisations and practitioners from Albania, Greece and North Macedonia examined the pressures affecting the basin and the need for coordinated, evidence-based responses across national borders.

The programme combined an opening plenary with thematic sessions on climate change and water management, biodiversity conservation and ecosystem management. It also included a poster session, a joint field excursion in Prespa National Park and a World Café discussion, creating space for scientific exchange as well as practical dialogue between researchers, decision-makers and actors working directly in the landscape.

The contributions gathered in this Proceedings Book reflect the breadth of that exchange. They address changing lake levels, hydrology and water quality, climate impacts on waterbirds and habitats, biodiversity vulnerability, adaptive management, community participation, sustainable use of natural resources and locally relevant conservation solutions. Together, the full papers and poster contributions provide a record of current knowledge and a basis for future cooperation in the Prespa basin.

The symposium reaffirmed that the resilience of the Prespa Lakes depends on sustained monitoring, transparent data exchange, inclusive governance and a stronger connection between science, policy and local action.

## MAIN THEMATIC AREAS:

- Climate-change impacts, water availability and transboundary water governance
- Biodiversity conservation, ecosystem vulnerability and adaptive management
- Cooperation between science, public institutions and local communities
- Practical pathways for long-term ecological and community resilience

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3rd Scientific Prespa Lakes Symposium | 2–4 February 2026 | Korçë, Albania

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Macedonia  
**Session II: Biodiversity Conservation and  
Ecosystem Management**



**Dr. Vivi Roumeliotou**  
Society for the Protection of Prespa (SPP), Greece  
**Session II: Biodiversity Conservation and  
Ecosystem Management**

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3rd Scientific Prespa Lakes Symposium

# FULL PAPERS

Shared Waters, Shared Challenges:  
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through Science and Cooperation

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## **THE ROLE OF LOCAL COMMUNITY PARTICIPATION IN THE EFFICIENCY OF PROTECTED AREAS PROJECTS AND HIGH-NATURAL-VALUE AREAS: A LITERATURE REVIEW**

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### **ABSTRACT**

This study explores community participation in the governance of protected areas in Albania, focusing on the relationship between institutional trust, participatory governance, and conservation effectiveness. Although Albania's environmental legislation formally incorporates mechanisms for public consultation, empirical evidence indicates that community involvement in decision-making processes often remains limited and largely consultative rather than genuinely participatory. The research adopts a mixed-methods approach, integrating quantitative indicators from the Balkan Barometer survey with qualitative analysis of governance practices and comparative regional case studies. To assess the broader institutional context, the study constructs a Composite Institutional Trust Index (ITI) that measures levels of public confidence in key political and administrative institutions across Western Balkan countries. In addition, the study introduces a Community Participation Index (CPI) as a methodological contribution for quantifying the degree of local involvement in protected area management. The CPI evaluates participation across several dimensions, including decision-making authority, institutional representation, economic benefit-sharing, participation depth, and perceived influence. The findings suggest that Albania operates within a low–moderate institutional trust environment, while community participation remains moderate and largely consultative. Strengthening co-management arrangements, economic incentives, and institutional transparency is therefore essential for improving both the legitimacy and sustainability of protected area governance.

**Keywords:** participation, decision-making, representation, index

## 1. INTRODUCTION

Recent Albanian scholarship increasingly highlights the relatively high level of environmental awareness among residents living within protected areas. Data from the Balkan Barometer indicate that a substantial majority of citizens view the designation of “Protected Area” as an important instrument for safeguarding national natural heritage (RCC, 2024). This is aligned with national policy for enhancing the protected areas system in both expansion and management (MoE, 2015) and IUCN (IUCN, 2020). Nevertheless, a notable perceptual asymmetry persists between broader public attitudes and the perspectives of local communities. While the general public tends to frame conservation primarily as an ecological priority, residents of protected territories frequently interpret these policies through the lens of constraints on property rights, land use, and local development opportunities (Avdia and Allka, 2023). Against this backdrop, this study examines community participation in the governance of Protected Areas in Albania, with particular attention to perceptions of decision-making processes and the socio-economic role of rural communities. Drawing on Balkan Barometer survey data and comparative case evidence, the analysis suggests that predominantly top-down governance structures weaken the long-term effectiveness and legitimacy of conservation policies. Without meaningful mechanisms for local engagement and economic inclusion, protected areas risk becoming largely symbolic regulatory frameworks, which scholars often describe as “parks on paper.”

Survey evidence further reveals a pronounced institutional trust deficit in environmental governance. Although Albania’s legal framework formally mandates public consultation in environmental decision-making, local residents frequently report that participation processes remain largely procedural, offering limited influence over actual policy outcomes. Concerns regarding transparency and accountability are particularly evident in relation to large-scale development initiatives, such as tourism infrastructure and resort projects implemented within protected areas with insufficient consultation of affected communities.

At the same time, emerging evidence suggests that ecotourism is increasingly perceived by local populations as a potential bridge between conservation and development objectives. In regions such as the Vjosa Valley and the Albanian Alps, environmental protection is gradually being reframed not as a barrier to economic activity but as a strategic natural asset capable of generating sustainable income through agrotourism and nature-based tourism enterprises.

However, recent legislative amendments concerning development within protected areas have intensified the conservation development dilemma (Shumka et al., 2022). On one side lies the pressing need for investment and employment opportunities in rural regions; on the other, a

growing concern that uncontrolled construction and mass tourism could erode the very ecological landscapes that underpin Albania's emerging nature-based tourism economy. In this context, the long-term effectiveness of protected area governance in Albania depends on a transition from a predominantly state-centered management model toward collaborative co-management frameworks that incorporate local stakeholders as active partners. Existing research suggests that without secure property rights, equitable benefit-sharing mechanisms, and tangible economic incentives for sustainable practices, local resistance is likely to persist, thereby undermining both ecological outcomes and institutional legitimacy.

## **2. LITERATURE REVIEW**

The governance of protected areas has increasingly been examined through the lens of participatory environmental governance, institutional legitimacy, and socio-economic integration. Early conservation paradigms were largely characterized by centralized and exclusionary management approaches, often referred to as “fortress conservation,” where ecological protection was prioritized while local communities were excluded from decision-making processes (Lockwood et al., 2010; Borrini-Feyerabend and Hill, 2015). Contemporary scholarship, however, increasingly conceptualizes protected areas as complex socio-ecological systems, emphasizing that long-term conservation success depends not only on ecological management but also on institutional trust, local participation, and equitable distribution of benefits.

Within the context of post-communist Southeast Europe, the effectiveness of conservation policies is strongly shaped by historical governance legacies and patterns of institutional trust. Research suggests that communities in the region often exhibit persistent skepticism toward central authorities due to administrative traditions inherited from centralized socialist governance systems. In such contexts, the social acceptance of conservation policies is closely linked to their ability to generate tangible economic and social benefits for local populations. Popescu et al. (2014) argue that when conservation initiatives fail to provide visible benefits or compensation mechanisms, they are frequently perceived by rural communities as constraints on livelihoods rather than as collective environmental goods.

Empirical studies across the region also highlight recurring tensions between environmental protection and rural development objectives. Bouriaud et al. (2013), analyzing the implementation of the Natura 2000 framework in Romania, demonstrate that restrictions placed on privately owned land, particularly when not accompanied by adequate compensation schemes, can generate substantial conflicts between conservation authorities and local

landowners. Comparable governance challenges have been observed in Albania, where unresolved property rights and incomplete land registration within protected areas contribute to uncertainty among residents and increase vulnerability to external investment pressures.

Another recurrent theme in the literature concerns the institutional design of protected area management systems, particularly the persistence of centralized decision-making structures. Nita et al. (2018) shows that governance networks within Natura 2000 sites in Romania often remain dominated by governmental actors, limiting the participation of local stakeholders in the formulation of management plans. Such institutional arrangements may weaken policy legitimacy and reduce compliance with conservation regulations. Similar patterns have been documented in Albania, where public consultation procedures are formally embedded within environmental legislation but are frequently perceived by local communities as largely symbolic and lacking substantive influence over policy outcomes.

Tourism development introduces an additional layer of complexity in protected area governance. While tourism is often promoted as a mechanism for supporting rural economies and generating incentives for conservation, poorly regulated development can produce significant ecological and social impacts. The case of Pirin National Park in Bulgaria illustrates these risks. Tomova (2018) documents how the expansion of ski infrastructure within protected zones contributed to habitat degradation and intensified conflicts between conservation objectives and economic interests. These experiences have broader implications for Albania, where tourism development is increasingly positioned as a strategic sector for regional growth, raising concerns about the balance between environmental protection and infrastructure expansion.

Conversely, the literature also identifies examples where integrating conservation with local economic development has produced more positive governance outcomes. Slovenia's Triglav National Park is frequently cited as a successful model in which conservation policies have been combined with regional economic strategies. Through the establishment of a quality certification label associated with the park, locally produced goods and services that comply with environmental standards receive market recognition, allowing communities to capture higher economic value while reinforcing conservation objectives Kuščer et al., (2017). Such initiatives demonstrate how protected areas can function not only as regulatory frameworks but also as drivers of sustainable local development.

The depth and effectiveness of community involvement in environmental governance are often assessed using Arnstein's Ladder of Citizen Participation (1969), a theoretical framework widely employed in governance and planning research. Arnstein conceptualizes participation

as a hierarchical continuum consisting of eight levels grouped into three broader categories: non-participation, tokenism, and citizen power. The framework distinguishes between participatory processes that merely inform or consult citizens and those that enable meaningful power-sharing through partnership, delegated authority, or citizen control.

Empirical studies on participatory governance in Albania consistently suggest that community involvement in environmental decision-making remains concentrated within the lower levels of the participatory spectrum, particularly within the stages of informing and consultation. Research on stakeholder participation in Llogara National Park demonstrates that although Albanian environmental legislation formally requires public consultation during the preparation of management plans, decision-making authority largely remains concentrated within central government institutions Boshnjaku (2015), awhile recently similar conclusions with regards to nature resources management and utilizations has been revealed within Divjakë-Karavasta National Park (Shumka et al., 2023) . Regional analyses of protected area governance in Southeast Europe further identify structural barriers such as administrative centralization, limited local institutional capacity, and fragmented governance frameworks, all of which constrain the development of more collaborative management arrangements (Lovren, 2018; Shumka et al., 2022).

Additional studies examining environmental planning and territorial governance in Albania reinforce these findings. Hoxha et al. (2021) highlight the gap between formal participatory provisions and their practical implementation, noting that public hearings are frequently treated as procedural requirements rather than mechanisms for meaningful policy influence. Similarly, Kaprata (2020) argues that participatory reforms within Albania's territorial governance system have largely remained consultative, with limited institutional mechanisms that enable citizens to exercise real decision-making power. More recent research also suggests that although administrative reforms have increased opportunities for citizen engagement at the local level, the transfer of substantive authority to community actors remains limited (Zaimi, 2023).

Overall, the existing literature suggests that while Albania has formally incorporated participatory principles into its environmental governance framework, the practical realization of collaborative governance remains incomplete. Centralized institutional structures, unresolved property rights issues, and increasing development pressures, particularly those associated with tourism expansion, continue to challenge the effectiveness and legitimacy of protected area governance. Consequently, many scholars emphasize the importance of transitioning toward co-management models that integrate local communities as active partners, thereby strengthening both the ecological sustainability and the socio-economic resilience of

protected area systems.

### 3. METHODOLOGY

This research adopts a mixed-methods design to examine community participation and governance dynamics in Albania's Protected Areas. The integration of quantitative and qualitative approaches enables a more comprehensive assessment of both institutional perceptions and governance practices. The study aims to identify the gap between the formal environmental governance framework in Albania and the socio-economic realities experienced by rural communities living within protected territories. The research is structured as a comparative and exploratory analysis. Quantitative evidence is drawn from the Balkan Barometer survey, which provides regional data on institutional trust, perceptions of corruption in environmental decision-making, and the willingness of rural businesses to transition toward environmentally sustainable economic activities. These indicators are used to contextualize governance legitimacy and public attitudes toward environmental policies. The qualitative component is based on a systematic review of academic literature, institutional reports, and policy analyses related to protected area governance and community participation in Southeast Europe. In order to provide comparative insights, the study analyzes contrasting governance outcomes through selected case studies. Negative governance outcomes are illustrated through examples such as illegal logging in Romania and tourism-related pressures in Bulgaria's Pirin National Park. These cases are contrasted with more collaborative governance approaches observed in Slovenia's Triglav National Park, where community engagement and local economic initiatives have supported conservation objectives. To assess participation more systematically, the study introduces a Community Participation Index (CPI). This composite indicator evaluates the extent of community involvement across five dimensions: decision-making authority, institutional representation, economic benefit-sharing, depth of participation based on Arnstein's Ladder of Citizen Participation, and perceived influence and institutional trust. By aggregating these dimensions into a standardized score ranging from 0 to 100, the CPI provides a structured tool for assessing whether participation mechanisms represent meaningful co-governance or remain primarily consultative. The Community Participation Index (CPI) draws upon empirical findings reported in the studies cited in the literature review, particularly those based on structured survey instruments designed to evaluate community participation and governance perceptions.

The empirical basis of this study relies on secondary quantitative and institutional data related to governance perceptions and participation in environmental decision-making. The primary dataset is drawn from the Balkan Barometer survey, which measures levels of institutional trust, perceived corruption, and citizens' influence in policymaking across Western Balkan countries. These variables are used to construct the Institutional Trust Index (ITI) through a weighted composite of five standardized indicators. Additionally, the study develops a Community Participation Index (CPI) to evaluate local involvement in protected area governance. The CPI integrates institutional, economic, and perception-based indicators, allowing a structured assessment of the depth and effectiveness of community participation. The calculation of the Community Participation Index (CPI) relies on the empirical findings reported in the studies referenced in the literature review, particularly those derived from structured survey instruments used to assess community participation and governance perceptions.

#### 4. DISCUSSION

##### **Construction of the Composite Institutional Trust Index (ITI)**

To evaluate the broader governance context in which environmental decision-making and protected area management occur, this study develops a Composite Institutional Trust Index (ITI) for the Western Balkans. The index is designed to provide a standardized measure of public trust in key political and administrative institutions that shape policy legitimacy and citizen engagement. Institutional trust is widely recognized in governance literature as a critical determinant of policy compliance, collective action, and the effectiveness of participatory mechanisms.

**Table 1.** Index Construction Methodology: Indicators Used (Standardized to 0–100 scale)

| Indicator                     | Weight |
|-------------------------------|--------|
| Trust in National Government  | 25%    |
| Trust in Local Government     | 20%    |
| Trust in Parliament           | 15%    |
| Perceived Citizen Influence   | 20%    |
| Reverse Corruption Perception | 20%    |

**Table 2.** Raw Data Inputs (Balkan Barometer (Regional Cooperation Council, 2023))

| Country              | Nat. Gov. | Local Gov. | Parliament | Influence | Corruption (perceived widespread) |
|----------------------|-----------|------------|------------|-----------|-----------------------------------|
| Albania              | 34        | 38         | 28         | 30        | 64                                |
| Serbia               | 42        | 45         | 38         | 35        | 59                                |
| Montenegro           | 45        | 47         | 40         | 38        | 54                                |
| North Macedonia      | 33        | 36         | 29         | 30        | 61                                |
| Bosnia & Herzegovina | 28        | 32         | 24         | 25        | 70                                |
| Kosovo               | 37        | 40         | 30         | 33        | 65                                |

**Table 3.** Reverse Corruption Score, Calculated by Authors

| Country              | Reverse Corruption Score |
|----------------------|--------------------------|
| Albania              | 36                       |
| Serbia               | 41                       |
| Montenegro           | 46                       |
| North Macedonia      | 39                       |
| Bosnia & Herzegovina | 30                       |
| Kosovo               | 35                       |

The index is constructed using five indicators derived from regional survey data, each standardized on a scale from 0 to 100. These indicators capture different dimensions of institutional legitimacy and citizen–state relations: (1) trust in the national government, (2) trust in local government, (3) trust in parliament, (4) perceived citizen influence on decision-making, and (5) perceptions of corruption within public institutions. Because corruption perception reflects a negative dimension of governance, this variable is transformed into a reverse corruption score, calculated as 100 minus the percentage of respondents who perceive corruption as widespread. This transformation ensures that higher values consistently represent higher levels of institutional trust across all indicators. The Community Participation Index (CPI) draws upon empirical findings reported in the studies cited in the literature review, particularly those based on structured survey instruments designed to evaluate community participation and governance perceptions. Each indicator is weighted to reflect its relative importance in shaping governance legitimacy. Trust in national government receives a weight of 25%, while trust in local government and perceived citizen influence each account for 20%. Trust in parliament is assigned a weight of 15%, and the reverse corruption indicator contributes 20% to the composite score. The final ITI score is calculated using the following weighted aggregation formula:

**Table 4. Final Institutional Trust Index ITI Scores, Calculated by Authors.**

| Ra<br>nk | Country              | ITI<br>Score |
|----------|----------------------|--------------|
| 1        | Montenegro           | 43.8         |
| 2        | Serbia               | 40.6         |
| 3        | Kosovo               | 35.6         |
| 4        | Albania              | 34.9         |
| 5        | North Macedonia      | 33.8         |
| 6        | Bosnia & Herzegovina | 28.4         |

$$ITI = (0.25 \times NG) + (0.20 \times LG) + (0.15 \times PARL) + (0.20 \times INF) + (0.20 \times RC)$$

where NG represents trust in national government, LG trust in local government, PARL trust in parliament, INF perceived citizen influence, and RC the reverse corruption score.

The resulting index enables comparative analysis across Western Balkan countries, revealing differences in governance legitimacy and public trust. Based on this methodology, Albania records an ITI score of 34.9, placing it within the low-moderate trust category. This range corresponds to the “consultation” level within Arnstein’s Ladder of Citizen Participation, indicating that while formal participatory mechanisms exist, citizens’ influence over decision-making remains limited.

**Table 5.** Conceptualize governance effectiveness thresholds:

| ITI<br>Range | Governance Type               | Arnstein Level              |
|--------------|-------------------------------|-----------------------------|
| 45+          | High legitimacy               | Partnership                 |
| 38–45        | Moderate trust                | Placation                   |
| 30–38        | <b>Low–moderate<br/>trust</b> | <b>Consultation</b>         |
| <30          | Structural distrust           | Informing /<br>Manipulation |

From a governance perspective, this score reflects moderate institutional skepticism, relatively weak parliamentary trust, and high perceptions of corruption. In the context of environmental governance and protected area management, such conditions suggest that policy decisions may be perceived as elite-driven, while participatory processes remain largely consultative and enforcement legitimacy remains fragile.

### Community Participation Index (CPI) for Protected Area Governance

In addition to the Institutional Trust Index, this study introduces a Community Participation Index (CPI) as an original methodological contribution designed to measure the extent to which local communities are substantively involved in the governance of protected areas. The CPI aims to operationalize participation beyond formal consultation by capturing multiple institutional, economic, and perceptual dimensions of community involvement. The conceptual foundation of the index draws upon established theoretical frameworks in participatory governance and environmental management, particularly Arnstein's (1969) Ladder of Citizen Participation, Pretty's (1995) typology of participation, Ostrom's (1990) theory of common-pool resource governance, and Borrini-Feyerabend et al.'s (2013) co-management framework. Together, these approaches emphasize that effective environmental governance requires not only procedural participation but also meaningful power-sharing, economic inclusion, and institutional legitimacy. The CPI is constructed as a composite index ranging from 0 to 100, consisting of five analytical dimensions that collectively capture the structural and perceived components of community participation in protected area governance. The first dimension, Decision-Making Power (25%), measures the degree of formal authority granted to local communities in governance processes. It evaluates whether community representatives possess voting rights within protected area management boards, whether legally recognized co-management agreements exist, and whether local actors have influence over budgetary allocations related to conservation or development activities. The second dimension, Institutional Representation (20%), examines the formal inclusion of community actors within governance structures. Indicators include the proportion of management board seats occupied by local representatives, the presence of advisory councils or consultative bodies representing community interests, and the inclusion of diverse social groups such as women and youth.

**Table 6.** CPI Structure: The CPI is composed of five dimensions

| Dimension                        | Weight | Description                                   |
|----------------------------------|--------|-----------------------------------------------|
| D1: Decision-Making Power        | 25%    | Community authority in PA decisions           |
| D2: Institutional Representation | 20%    | Formal representation in PA governance bodies |
| D3: Economic Benefit Sharing     | 20%    | Access to tourism and conservation revenues   |
| D4: Participation Depth          | 20%    | Level on Arnstein's ladder                    |
| D5: Perceived Influence & Trust  | 15%    | Community perception of influence             |
|                                  |        |                                               |

Total CPI Score: 0–100

**Table 7. Indicators & Measurement: D1: Decision-Making Power (0–25)**

| Indicator                           | Scoring |
|-------------------------------------|---------|
| Community voting rights in PA board | 0-10    |
| Legal co-management agreement       | 0-10    |
| Budgetary influence                 | 0-5     |

**Table 8. D2: Institutional Representation (0–20)**

| Indicator                               | Scoring |
|-----------------------------------------|---------|
| % of board seats held by locals         | 0-10    |
| Presence of community advisory councils | 0-5     |
| Gender/youth inclusion                  | 0-5     |

**Table 9. D3: Economic Benefit Sharing (0–20)**

| Indicator                        | Scoring |
|----------------------------------|---------|
| Revenue-sharing mechanism exists | 0-10    |
| Local eco-tourism licenses       | 0-5     |
| Compensation schemes             | 0-5     |

**Table 10. D4: Participation Depth (Arnstein Scale) (0–20)**

| Level           | Score |
|-----------------|-------|
| Informing       | 5     |
| Consultation    | 10    |
| Placation       | 12    |
| Partnership     | 16    |
| Delegated Power | 18    |
| Citizen Control | 20    |

Table 11. **D5:** Perceived Influence & Trust (0–15)

Measured via survey:

% Who believe community influences PA decisions

% Who trust PA management authority

Standardized to 15 points

The third dimension, Economic Benefit Sharing (20%), assesses the extent to which conservation policies generate tangible economic returns for local populations. This includes the presence of revenue-sharing mechanisms derived from tourism or conservation activities, access to local ecotourism licenses, and compensation schemes designed to offset restrictions associated with protected area status. The fourth dimension, Participation Depth (20%), evaluates the qualitative level of community engagement using Arnstein's Ladder of Citizen Participation. Governance arrangements are classified along a continuum ranging from informing and consultation to higher levels of participatory authority such as partnership, delegated power, and citizen control. The fifth dimension, Perceived Influence and Trust (15%), captures the subjective dimension of participation through survey-based indicators measuring whether local residents believe they have influence over protected area decisions and whether they trust the authorities responsible for protected area management.

The CPI score is calculated through a simple additive formula  $=D1+D2+D3+D4+D5$

where each dimension contributes to the final composite score according to its predefined weight. This structure enables the index to combine institutional indicators, economic mechanisms, and perceptual measures into a single analytical framework. The interpretation of CPI scores follows a four-tier classification system that reflects different levels of participatory governance. Scores between 80 and 100 indicate community-led governance, characterized by strong local authority and collaborative management. Scores between 60 and 79 reflect robust co-management structures. Scores between 40 and 59 indicate moderate participation, where formal mechanisms exist but decision-making authority remains largely centralized. Scores between 20 and 39 represent tokenistic participation, while scores below 20 indicate largely symbolic or passive forms of engagement.

**Table 12. Community Participation Index  
Calculation Albania, Calculated by Authors**

| Dimension                    | Max Score  | Observed Score |
|------------------------------|------------|----------------|
| Decision-Making Power        | 25         | 11             |
| Institutional Representation | 20         | 14             |
| Economic Benefit Sharing     | 20         | 11             |
| Participation Depth          | 20         | 11             |
| Perceived Influence & Trust  | 15         | 5.6            |
| <b>Total CPI</b>             | <b>100</b> | <b>52.</b>     |

**Table 13. Community Participation Index  
Calculation Interpretation**

| CPI Score | Participation Level      |
|-----------|--------------------------|
| 80–100    | Community-led governance |
| 60–79     | Strong co-management     |
| 40–59     | Moderate participation   |
| 20–39     | Token participation      |
| <20       | Symbolic/passive         |

Applying this methodology to the Albanian context produces a CPI score of 52, which falls within the category of moderate participation. This result suggests that although formal participatory mechanisms and representation structures exist within protected area governance, substantive decision-making authority remains limited. Decision-making power and economic benefit-sharing mechanisms appear relatively constrained, while perceived influence and institutional trust remain comparatively low. Taken together, the CPI provides a structured analytical tool for evaluating participatory governance in protected areas. By integrating institutional design, economic incentives, and community perceptions, the index allows researchers to assess whether participation mechanisms represent meaningful co-management arrangements or remain primarily consultative in practice.

## 5. CONCLUSIONS

The findings of this study highlight the complex interaction between institutional trust, participatory governance, and conservation effectiveness within Albania's protected area system. The Institutional Trust Index indicates that Albania operates within a low moderate trust environment, characterized by significant public skepticism toward political institutions and widespread perceptions of corruption. Such institutional conditions directly affect environmental governance, as trust deficits tend to weaken the legitimacy of regulatory

decisions and reduce the willingness of local actors to comply with conservation measures. In this context, protected area policies risk being perceived as externally imposed administrative decisions rather than collectively supported public goods.

The Community Participation Index further demonstrates that while Albania has formally adopted participatory provisions within environmental legislation, the depth of community engagement remains limited. A CPI score of approximately 52 places the country within the category of moderate participation, suggesting that participatory structures exist but do not yet translate into meaningful decision-making power for local communities. Institutional representation mechanisms are present in some governance arrangements; however, substantive authority over planning, budgeting, and strategic management remains largely centralized. Similarly, economic benefit-sharing mechanisms linked to conservation and tourism remain underdeveloped, limiting the incentives for local communities to actively support conservation policies.

These findings align with broader patterns observed across post-socialist governance systems, where formal participatory procedures often coexist with highly centralized administrative decision-making structures. In the Albanian case, this institutional configuration creates a structural gap between the legal framework for participation and the practical implementation of collaborative governance. As a result, local communities may experience protected area regulations primarily as restrictions on land use and economic activity rather than as opportunities for sustainable development.

At the same time, emerging evidence suggests that nature-based tourism and local product branding may offer pathways for reconciling conservation objectives with rural economic development. Experiences from comparable European cases demonstrate that when protected areas generate tangible economic value for residents, through tourism revenue sharing, certification schemes, or support for local enterprises, community support for conservation initiatives tends to increase significantly. In Albania, similar strategies could help transform protected areas from perceived regulatory constraints into drivers of regional economic resilience. Additional research is required to more systematically assess the extent of community participation in decision-making processes within protected area governance. Future studies should prioritize the development of aggregated indices and the harmonization of methodological approaches for measuring participatory engagement at the national scale.

## 6. POLICY IMPLICATIONS

From a policy perspective, these findings suggest several priorities for strengthening protected area governance in Albania. First, institutional decentralization and co-management arrangements should be expanded to ensure that local communities have meaningful representation and voting power within protected area management bodies. Second, conservation policies should incorporate economic incentive mechanisms, such as payments for ecosystem services, community-based tourism licensing, and revenue-sharing schemes that directly benefit local residents. Third, improving transparency and accountability within environmental decision-making is essential for rebuilding institutional trust, particularly in relation to large-scale development projects within or near protected areas. Finally, the adoption of analytical tools such as the Institutional Trust Index and the Community Participation Index can support evidence-based policy design by providing measurable indicators of governance quality and participatory depth. By systematically monitoring these dimensions, policymakers and researchers can better assess whether environmental governance reforms are effectively moving toward collaborative and socially legitimate conservation models. In conclusion, the long-term sustainability of Albania's protected areas depends not only on ecological management but also on the strength of participatory institutions and the equitable distribution of conservation benefits. Transitioning toward more inclusive governance frameworks that integrate local communities as active partners is therefore essential for ensuring both ecological integrity and social legitimacy within Albania's environmental policy landscape. The Community Participation Index (CPI) draws upon empirical findings reported in the studies cited in the literature review, particularly those based on structured survey instruments designed to evaluate community participation and governance perceptions. As such, the index may be proposed as a methodological framework for the quantitative assessment of participation at both local and national levels, contributing to the standardization of measurement approaches and calculation procedures in participatory governance analysis.

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## **ADAPTIVE MANAGEMENT OF BIODIVERSITY AND ITS VULNERABILITY IN PRESPA NATIONAL PARK**

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### **ABSTRACT**

Prespa National Park is well known for its natural beauty, rich biodiversity, floristically and faunistically rich and interesting, presence of endemism, and traditional cultural values, due to the geographical and altitudinal extent, geological and soil variability. On the other hand, severe environmental impacts and mismanagement of natural resources have increased the vulnerability of biodiversity, which is now also accelerated by climate change. The most serious threats are felt especially in the Lesser Prespa Lake, as a result of interventions, even surrounding NP territory, within the ecological integrity: Former Maliqi Marsh (reclaimed) - Slopes in the upper course of the Devoll River - the Prespa lakes. Under these conditions, the implementation of adaptive management of the Prespa NP ecosystems and identification of nature-based solutions is a priority. As a good practice, we propose the implementation of MARISCO, as an innovative methodology for managing biodiversity and its vulnerability in conservation sites. MARISCO is an ecosystem-based and participatory approach to nature conservation; as such is needed to understand what the ecosystem actually is. The most innovative definition considers ecosystems as systems that act as a bioreactor that captures the energy of solar radiation and converts it into chemical energy in the form of biomass. The objective of this study was the identification of the systemic interrelationship between stresses, threats, and contributing factors for adaptive management of biodiversity and human welfare objects dependent on biodiversity and ecosystem services. As a conclusion, based on the above-mentioned interrelationships, the Nature-based Solutions measurements are identified.

**Keywords:** Adaptive management, Biodiversity, Human welfare, threats, contributing factors, systemic interrelations.

### **1. INTRODUCTION**

To create and maintain resilient social and ecological systems, protected area management (PAM) must be adapted to rapidly changing environmental conditions (CEEWeb, 2021). Past and present climate has shaped the valued ecosystems currently protected in parks, but future climate change will redefine these conditions. Continued conservation as climate changes will require thinking differently about resource management; we present some logical tools for doing so. Three critical tenets underpin future management plans and activities: (1) climate patterns of the past will not be the climate patterns of the future; (2) climate defines the environment and influences future trajectories of the distributions of species and their habitats; (3) specific management actions may help increase the resilience of some natural resources, but fundamental changes in species and their environment may be inevitable (Baron, Fleishman, & Oropeza, 2009). The most threatening factor for the natural ecosystems in Prespa NP is the eutrophication of the Lesser Lake ecosystems. Eutrophication is becoming increasingly severe,

not only affecting the sustainable development of water resources, leading to degraded ecosystem functions, but also threatening socio-economic development and ecological security (Chang & et al., 2024). Many studies have shown that aquatic macrophytes play a significant role in controlling eutrophication, but only a few of these studies are ecosystem-based (Zhu & et al, 2020). Adaptive management of biodiversity in Prespa's Protected Areas is crucial for maintaining the ecological balance and supporting human survival. The concrete objective is the identification of the main threats, analyzing diagnostically the stresses and management of vulnerabilities of biodiversity, conservation objects and human wellbeing objects, which must be developed according to a consensual management vision. Research objectives of adaptive management planning, related to the diagnostic analysis, are: (i) adapting management practices to rapidly changing environmental conditions and emerging threats; (ii) enhancing resilience of social and ecological systems by integrating different management approaches and perspectives; (iii) improving management effectiveness and financial sustainability; (iv) addressing barriers to improve management effectiveness. The analysis combines elements of a landscape character assessment with those of an environmental impact assessment.

## 2. LITERATURE REVIEW

The adaptive management to climate change in protected areas is grounded in several theories that aim to enhance the effectiveness and sustainability of conservation efforts: (i) resilience theory emphasizes the importance of resilience in protected areas to adapt to changing environmental conditions and maintain ecological functions, facing challenges; (ii) adaptive planning approach involves the systematic application of reliable information to improve management over time, which is essential for addressing the uncertainties and complexities of protected area management; (iii) ecosystem-based approach theory encompasses various frameworks that integrate ecological and social dimensions to address complex environmental issues; (iv) participatory approach theory emphasizes the involvement and empowerment of stakeholders in decision-making processes, fostering inclusivity and collaboration in various fields such as community development.

Prespa National Park is one of the most studied areas in the region. Previous studies in Prespa's National Park are focused on various aspects of the region's biodiversity, cultural heritage, and environmental challenges. Can be mentioned here: ethnobotanical studies, to address the temporal dynamics of local knowledge in response to socio-economic changes; conservation efforts studies, addressing the basin's issues, such as over-abstraction and diversion of water, wetland drainage, deforestation, and overgrazing; water management studies, focused on the water balance of the Prespa's Lakes and its fluctuation, water abstraction for human uses, and the consequences for biodiversity in the catchment basin.

More specific studies are those focused on: the cultural heritage of the Great Prespa Region (Muslli, 2015), Prespa Lakes (shared by Albania, Greece, North Macedonia) (Salathé & al, 2025); Watershed Dynamics in the Prespa Lakes: An Integrated Assessment of Stream Inflow Effects (Markogianni & al, 2026); New additions to the flora of Prespa, Greece (Bergmaier & al, 2020); Prespa Lakes Basin Strategic Action Program (REC, GEF, Prespa, & UNDP, 2010); Development of a transboundary monitoring system for the Prespa Park Area (Germanos , 2010); Management Plan of the Prespa National Park in Albania 2014-2024. (Shumka, Wolfgang, & Dieterich, 2014); Transboundary Biosphere reserve Prespa –Support to the

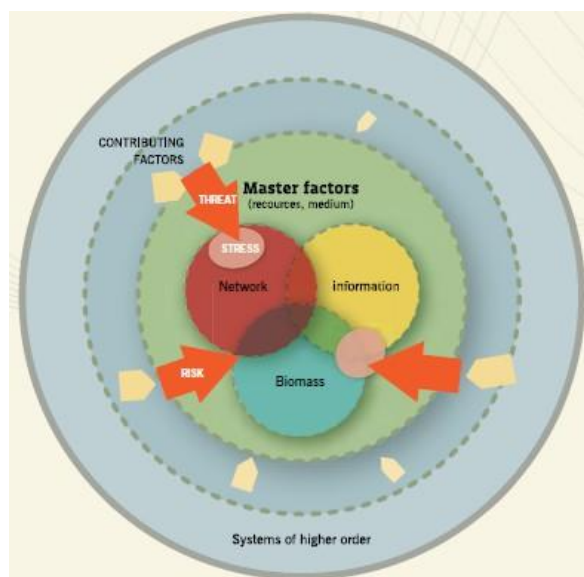
National Park Prespa in Albania (OBf, 2010); Assessment of challenges and opportunities related to non-timber forest products in the wider Prespa area (Rantasa & al, 2019); Additions to the flora of the Prespa National Park, Greece (Strid & al, 2017); Assessment and mapping of the Great Prespa Lake wetland habitat types in Albania (Fotiadis & al, 2020) etc. These studies contribute to a better understanding of the complex interplay between human activities and the natural environment in Prespa's National Park, providing valuable insights for future conservation efforts and management strategies. The article we are presenting here should be considered a continuation of studies and efforts for the management of biodiversity and its vulnerability in the Prespa NP.

The conceptual framework of this case study in Prespa protected areas is designed to address the challenges of managing protected areas in a rapidly changing environment. It emphasizes the importance of integrating different approaches and perspectives to ensure the resilience of social and ecological systems. The framework includes several key components, such as climate adaptation, stakeholder involvement, and monitoring and evaluation.

The research gap in adaptive management on protected areas is significant, particularly in the context of climate change and biodiversity loss. Current studies highlight the need for more comprehensive and integrated approaches to manage protected areas effectively in the face of rapidly changing environmental conditions. In our understanding, the research gap in adaptive management of the Prespa NP primarily revolves around the need for continuous availability of data on current states and trends of nature and threats. This includes biocultural conservation, climate-smart management, and biosecurity approaches to overcome challenges induced by human needs, climate change, and invasive species. Additionally, economic valuation and shifts in funding priorities can boost protected area effectiveness and efficiency. In-situ monitoring techniques, remote sensing, and open data infrastructures can fill data and information gaps for protected area planning and management.

### 3. METHODOLOGY

In this paper, we are presenting the MARISCO method through a case study on Prespa National Park (Ibisch & Hobson, 2014). Principally, MARISCO is an ecosystem-based approach to nature conservation, and the crucial thing is to understand the meaning of an ecosystem. Based on this methodology, ecosystems act as bioreactors that capture radiation energy from the sun and convert it into chemical energy in the form of more or less complex molecules and biomass. At the most basic level, energy is the driver for all of phenomena in nature. Ecosystem functionality depends on the availability of abiotic master factors, as well as on the included biomass, information, and degree of interaction and networking. MARISCO can facilitate adaptation to climate change, but only if it is integrated into a broader concept of ecosystem-based climate management and ecosystem-based sustainable development (Ibisch & Hobson, 2014). Threats degrade the key ecological attributes of ecosystems – biomass, information, network, and master factors – and cause stress in the system. Schematically, the methodological concept in Figure 1 is presented.



**Figure 1.** Ecosystem functionality scheme. (Source: MARISCO. Adaptive Management of vulnerability and Risk at Conservation sites)

Sensitive ecosystems are prone to being impacted by external threats because they lack ‘defense’ mechanisms or a buffering capacity. Based on the MARISCO methodology, man cannot manage the ecosystem better than nature itself does. What man must do is to manage the threats he himself causes to nature, leading to ecosystem vulnerability and degradation processes. Vulnerability has to be understood and analyzed systemically as a phenomenon of complexly interacting processes.

The important initial step has been the creation of a broader database and recordings from collected and secondary data. The database information was focused on topographical, hydrological, ecological, socio-economic, demographic, and biodiversity information (e. g., habitat types, species, distributional maps), natural-resource and biodiversity use, and ecosystem services.

Preparation and initial conceptualization have been the most important phase, focusing on: descriptive analysis, explaining “what happened”, ecosystem diagnostic analysis, delving deeper to answer “why it happened”; determining the biodiversity objects and human wellbeing objects, including ecosystem services.

Systemic vulnerability and risk analysis has been the crucial phase in the establishment of adaptive management of Prespa NP, focusing on: assessment of the current status of the biodiversity objects (key ecological attributes, stresses); ecological variability, which included habitat variability and habitat stresses, threat status; identification of contributing factors, which accelerate the threats, and finally the identification of the NbS measurements.

To facilitate the conceptualization and adaptive management efforts, we have used MIRADI software, which offers a comprehensive suite of features designed to support conservation

processes. This software is being developed by the Conservation Measures Partnership for conservation practitioners going through the adaptive management process outlined in MARISCO. MIRADI software helped us define the project scope, design conceptual models, prioritize threats, develop objectives, identify and prioritize strategies, etc.

#### 4. RESULTS

Based on the primary and secondary ecological, social, and historical data, a detailed “diagnostic analysis” is provided to understand the changes in the ecosystem over time, within the ecological integrity (Former Maliqi Marsh-two Prespa Lakes and surrounding areas-slopes of the upper course of the Devoll River). It should be stressed that the author of this paper has been present for 5 years (1961-1966) and periodically after, in this area, having a clear memory about the changes, in space and in time, of the Prespa NP ecosystems.

Because of the interrelationships between them, the former Maliqi Marsh (after reclamation called Sugar Land), Prespa lakes together with the upper course of Devolli Valley, formed an integral part of the lake system, an “ecological integrity”. Diagnostic analysis is focused on the activities that contributed to the current state of this “ecological integrity”. Diagnostic analysis analyzes the factors and impacts that have led to the degradation of ecosystems in this “ecological integrity”.

Maliqi Swamp has been a rich ecosystem in biodiversity, with important economic value for the rural population, providing fish and eels for the Korca market, and an attractive place for bird watching. After the reclamation, the adverse impacts and threats started very soon (within a decade) as a result of the peat mineralization in contact with O<sub>2</sub>, such as:

- ♣ dropping of the level of the land ground, permanent inundations and the refilling of drain channels; as a result, the need for re-reclamation (several times).
- ♣ deterioration of the soil structure, making it vulnerable to wind erosion in autumn and spring and even self-burning in summer, a serious problem for the health of the rural population.
- ♣ Rapid decline in soil fertility, because of the destruction of the soil structure

In order to keep the peat moist and slow down the rate of mineralization, the government decided to change the bed of the Devoll River towards Lesser Prespa Lake, to use it for irrigating the "sugar land". This process is accompanied by other adverse environmental impacts on the upper part of Devolli Valley, such as massive deforestation and overgrazing of temperate forests (Morava, Q. Zvezdes, Gorice, Vernik, Pustec etc.), to convert them into agricultural and grazing land (by socialist cooperatives); the violent conversion of mountain grasslands into crop land (mainly for potato production) by the so-called Military Agricultural Enterprise (Morava, Mali i Kuq, Qafa e Kazanit, Mali i Thate). These lands are cultivated for only 3-5 years, to be abandoned later. Meanwhile, the dense forests of Morava Mountains were intensively harvested to produce fuelwood to meet the needs of the population and the bakeries built near each agricultural cooperative (especially the southern slope of Morava Mountain, Devolli Valley). Overgrazing and permanently wildfire have been another adverse environmental impact. These activities significantly increased the level of erosion and multiplied the amount of sediment in the Devoll River, which now would have to flow into the Lesser Prespa Lake.

The watery mirror in Lesser Prespa Lake was much wider than the current one, and rich in

standing water habitats, like: Rooted floating vegetation of eutrophic waterbodies (C1.34-EUNIS), *Phragmites australis* beds (C3.21-EUNIS), located only near the lake shore, etc. In the depths of the lake, there were many cold underwater flows and fresh, drinkable groundwater springs (fishermen used for taking drinking water). Distantly from the lake shore were the islands of organic material (kore) that served as nesting grounds for wild birds.



**Figure 2.** Lesser Prespa Lake before 1965 (left) and nowadays (right). The lake shore reached close to the road.

It was very rich in fish species. C.a. 100 fishermen from Treni Village, divided into two teams (every 25 boats), fishing every day for the Korca fish market, and not only. During the fishing season, they produced reed leaves (shavar) for animals, mats (*Typha latifolia* and *Typha angustifolia*), and harrows (*Phragmites australis*), getting more income for their families. Watershed slopes were covered by dense forests and bushes and rich in NFWP (hazelnuts, lime fruits, wild rose fruits, linden flower, whitethorn, thornapple, mountain tea, different medicinal plants, etc.), which are now being drastically collected.

The dynamism of lake eutrophication is influenced by a multitude of factors, including sedimentation, nutrient loading, hydrodynamic characteristics, and biological interactions, which contributed rapidly to the sedimentation of Lesser Prespa Lake. The discharge of water, laden with sediments, also created trouble in the Greek part of Lesser Prespa Lake, which, in the absence of communication and agreement between the governments, opened a channel connecting Lesser Prespa Lake with Gross Prespa Lake. In this way, the Greek side managed the water, while the Albanian side accumulated sediments in the lake.

To be easily analyzed, the determination of conservation and biodiversity objects was done by grouping biodiversity objects logically listed according to landscape ecosystems. Based on bio-ecological factors, more than 30 habitats identified from the secondary data and studies (Fotiadis & al, 2020), are classified in 10 groups,: (i) lakeshore vegetation ecosystem, (ii) reedbed ecosystem, (iii) *Juniperus fetidissima* and *Juniperus excelsa* ecosystem, (iv) Thermophilus ecosystem of broadleaved deciduous woodland, (v) Mesophiles ecosystem of broadleaved deciduous woodland, (vi) Hay meadows (Helleno-Moesian riverine and humid *Trifolium* meadows); (vii) Semi-natural dry grasslands and scrubland areas on calcareous substrates (Festuco-Brometalia); (viii) Shrubby ecosystem and dwarf shrubs of high mountains; (ix) Alpin and sub-alpine dry grassland and mountainous meadows ecosystem, (x) Alpin and calcareous stone with hasmophytic vegetation.

Related to the designation of conservation objects (human welfare objects - dependent on biodiversity), are identified: (i) Economic income and social welfare, (ii) Fuelwood and other biomass energy production for household needs, (iii) Food security and basic materials for a good life, (iv) Pasture lands and biomass providing for the livestock, (v) NTFP for family needs and incomes, (vi) Satisfactory yields in agricultural products, (vii) Fresh and pure water supply, (viii) Security in the face of environmental and climate changes, (ix) Social, traditional and cultural activities for leisure and entertainment (Muslli, 2015).

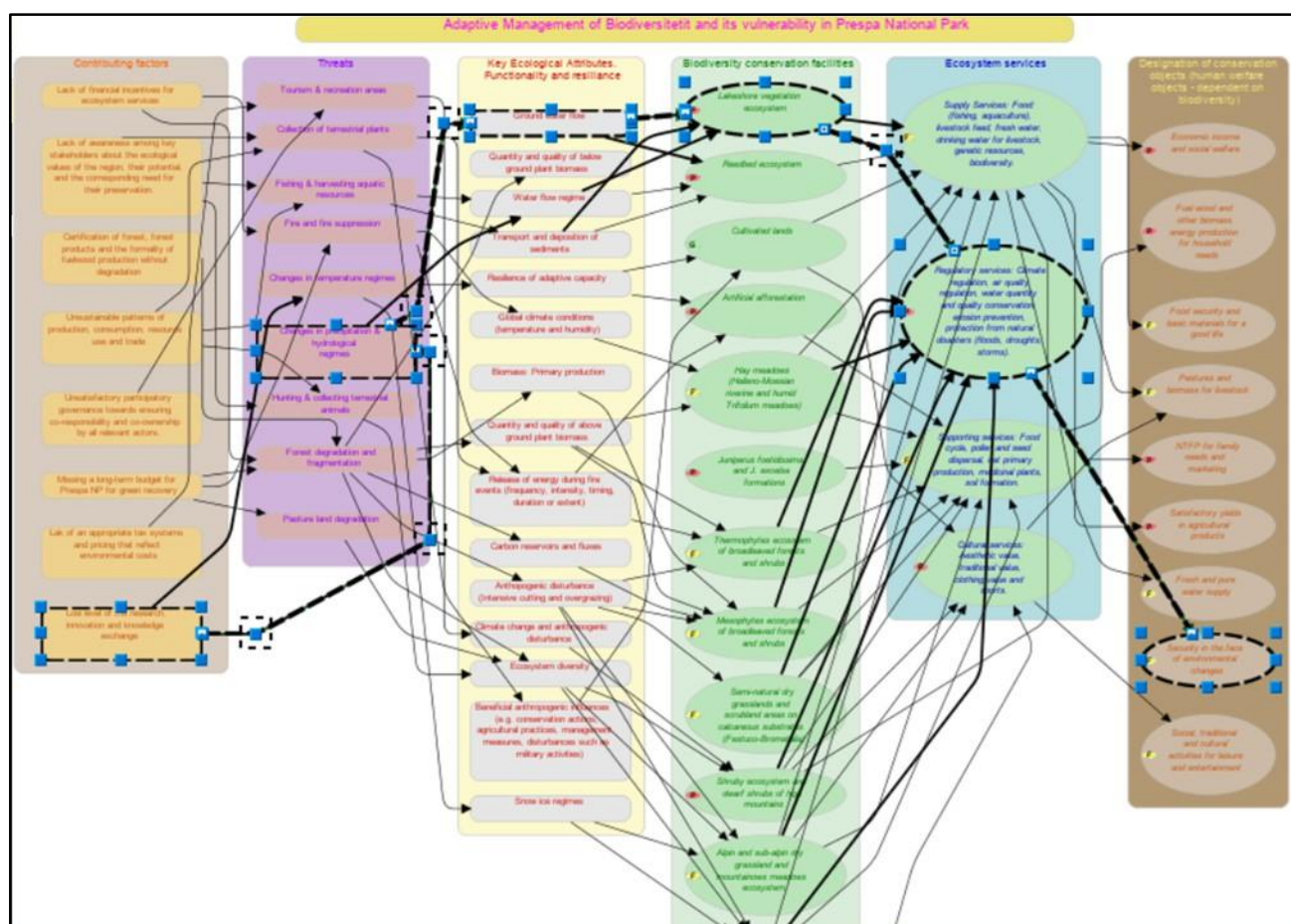
The identification of ecosystem services was essential for the analyses related to human welfare. The depiction of ecosystem services reflects the potential of a given site for ecosystem-based sustainable development. There are analyzed: (i) Supply Services (food: (fishing, aquaculture), livestock feed, fresh water, drinking water for livestock, genetic resources, biodiversity); (ii) regulatory services [climate regulation, air quality regulation, water quantity and quality conservation, erosion prevention, protection from natural disasters (floods, droughts, storms)]; (iii) supporting services (food cycle, pollen and seed dispersal, net primary production, medicinal plants, soil formation); (iv) cultural services (aesthetic value, traditional value, clothing value and sports).

The main issues determined during the systemic vulnerability and risk analysis have been:

- ♣ Stresses (manifestation of a biodiversity object's 'illness' or 'wounds' - the identifiable symptoms of bad health and vulnerability): the manifestations of the degradation of key ecological attributes, caused by the insufficient availability or quality of master factors, manifesting the loss of levels of biomass, information and network, as: loss of connectedness, soil erosion, change in structure and species composition, fragmentation, defoliation, diseases and pests, wild fires, reduced oxygen saturation, low production of biomass, reduced population size, etc.
- ♣ Key ecological attributes and the functionality of the target systems: (i) biomass (primary production, above ground biomass, below ground biomass, aquatic biomass, extent of ecosystems); (ii) information (intraspecific diversity, specific diversity/species richness, morpho-functional diversity, habitat diversity, ecosystem diversity, viable population size, structure and natural population dynamics); (iii) network (connectedness of ecosystems, extent, structure and native species composition, syn-ecological interactions and interdependencies); (iv) resilience and resistance/adaptability. Other key ecological attributes (Master factors) analyzed have been global climate conditions, weather and local climate conditions, hydrologic regimes, physical soil parameters, matter cycle-related processes, matter and water efficiency of ecosystems.
- ♣ Threats: the drivers of stress and the vulnerability they cause to biodiversity objects. They are disturbances that cause negative changes in key ecological attributes and stresses in a bio-ecological system. The threats degrade the key ecological attributes of ecosystems – biomass, information, network, and master factors – and cause stress in the system. Threat is considered a human-induced forcing factor, a direct or indirect impact that will eventually induce a symptom, such as deforestation, degradation, climate change (precipitation patterns, temperature), mining activities, illegal logging and fishing, poaching, intensive use of biological resources, overgrazing, etc.

- ♣ Contributing factors: described as a human action or activity that directly or indirectly results in the emergence of a threat, which then goes on to induce stresses, several components in an ecosystem: (i) bio-physical or natural factors (steep slope, geological instability, climate change, water balance, soil), (ii) natural resource-use related factors (unsustainable forestry, agriculture, hunting practices, NWFP etc.). (iii) institutional factors (lack of financial resources of conservation actors, equipment, capacities), (iv) socio-demographic factors (population growth, emigration, immigration); (v) political or governance related factors (governance, legislative bodies or instruments, lack of regulation, legislation enforcement, administration, corruption); socio-economic factors (needs, poverty, insufficient access to resources, humankind's demand for natural resources, education)

Vulnerability has been understood and analyzed systemically as a phenomenon of complexly interacting processes. Stresses, threats and their contributing factors – whether climate-change-related or not – cannot be understood in isolation. The complexity has facilitated the strategy formulation and prioritization by a diagram provided by MIRADI Software:



**Figure 3.** Diagram of complexity analyses of the factors, provided by MIRADI Software

## 5. DISCUSSIONS

By analyzing the complex relationships of factors in the three right pillars of the diagram (biodiversity conservation objectives, human welfare objectives - dependent on biodiversity and ecosystem services), we can identify the strategies and goals.

By analyzing the complex relationship of the factors in the three left pillars of the diagram (especially threats, key ecological and contributing factors), we can identify the nature-based solutions (objectives and activities), for example:

Goal: Conservation and improvement of the functionality of the conservation objects, ecosystem services and human wellbeing, to climate change adaptation

Objective 1: Forest Land restoration to create sustainable landscapes that are ecologically functional, resilient, productive and beneficial for the environment and people who live in them.

Activities:

- i. mobilization of an innovative nursery,
- ii. reforestation activities, using Macedonian fir, oak species, Black elder, Large-leaved Lime seedlings,
- iii. conversion activities and silvicultural measurements of degraded forests,
- iv. strengthening, regenerating and undertaking biotechnical measures on the slopes of rivers, streams and steep slopes,
- v. implementation of demotivation mechanisms to reduce illegal logging and related trade, as well as forest degradation and fragmentation (traceability, due diligence system, etc.)
- vi. establishing a control system for fire prevention and post-wildfire restoration planning, supporting the PA administration with technology, methodology and training.

Objective 2, on mountainous grassland restoration: Enhancing the ecological diversity of grasslands to support a variety of plant and animal species, creating suitable habitats for endangered species and promoting the conservation of native flora and fauna, implementing practices that benefit local communities to improve food security and provide additional income streams.

Activities:

- i. Mobilisation of shepherds in maintaining biological balances of high-mountain pastures, through promotion of transhumance, livestock movements, removal of infesting bushes, invasive species, etc.
- ii. Undertaking site preparation, revegetation, and post-restoration management of degraded mountain grasslands
- iii. Establishment of an innovative system for grazing permits and activities (fees, permits, management plans, grazing permits, mowing and infrastructure, respecting the traditions and rites of passage and encouraging new livestock farmers)
- iv. Encouraging and supporting beekeepers to stimulate pollination in deeper and more sensitive areas, stationing beehives in nearby areas with increased presence of rare and threatened species.

Objective 3: Enhancing the clarity and health of the lakes by removing pollutants and debris,

restoring and creating the environmental conditions the species need to survive and thrive, stabilizing the shoreline and reducing sediment run-off, involving residents in lake stewardship by strengthening knowledge and skills.

Activities:

- i. Combining restoration techniques in the lake with nature-based solutions in the lakeshore zone (e.g. high-performance buffer zones).
- ii. Reducing external sources of pollution to provide an opportunity for optimising existing solutions.
- iii. Establishment of a holistic approach that encourages society to become actively involved in water monitoring and restoration programs.
- iv. Reduction of “internal supply” by removing nutrient-rich sediments and using them for biomass energy and fertilizer production.

## 6. CONCLUSIONS

It is important, based on actual conditions, to move from classical management to adaptive management to climate change in protected areas. MARISCO method is a highly effective approach for integrating risk and vulnerability perspectives into the management of conservation sites. It is designed to take into account the impact of climate change in the strategic management of protected areas. The method involves a participatory approach where multi-stakeholder groups discuss ecosystem services, likely impacts of climate change, and other direct and underlying threats. This DISCUSSION is supported by scientific data collected beforehand and presented in an easy-to-understand way during the stakeholder get-together.

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## ASSESSMENT OF BIOFUEL PRODUCTION POTENTIALS FROM BIOMASS IN THE KORÇA REGION

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### ABSTRACT

Biofuels represent an increasingly important component of the global transition toward renewable energy sources and environmental protection. Their production from agricultural and biological resources offers significant potential for reducing greenhouse gas emissions, mitigating climate change, and promoting the sustainable management of natural resources. This article examines the role of biofuels in environmental protection, with particular emphasis on their contribution to reducing dependence on fossil fuels and strengthening the principles of the circular economy in the Korçë Region. The study analyzes the potential for biofuel production, primarily from agricultural residues and non-food biomass, highlighting the advantages of using by-products that do not compete with food security. For this purpose, data on cultivated area and total production of agricultural (crop) cultures in the Korçë Region were collected from the Statistical Yearbooks published in 2013, 2018, and 2023. Technical coefficients, such as the dry matter content of energy production substrates and conversion coefficients to KTOE, were obtained from the literature for each crop. Based on the collected data, the cumulative energy production potential was calculated as the potential contribution of overall agricultural activity. The results indicate that biofuels, when produced within sustainable management frameworks, can significantly reduce environmental pressures while simultaneously supporting rural development and increasing energy security.

**Keywords:** biomass, biofuels, Korça region, renewable energy, biomass energy potential.

### 1. INTRODUCTION

Despite the efforts and attention of the 27 European Union Member States (EU-27), energy consumption and production, as well as emission reduction, have not fully met the EU's targets. The impacts of climate change, together with increasing energy demand, volatile oil prices, and energy poverty, have led to the search for energy options that are economically more efficient, socially acceptable, and environmentally sound. One option that has attracted growing interest

from a wide range of stakeholders is the use of biofuels (McKendry, P., 2002). Encouraged by research showing that biofuels can provide significant amounts of energy while simultaneously mitigating climate change, governments in many countries have supported biofuel production in order to increase their use. Farmers view biofuels as a pathway to additional income, and biofuels may have the potential to stimulate rural development and improve access to energy in poorer countries. Industry has made substantial investments in the development of production and technology, and the use of biofuels has been seen as an important pathway toward achieving sustainable transport. Within the global context of concern over climate change mitigation, bioenergy has received increasing attention due to its potential to contribute to the reduction of greenhouse gas emissions. While attention to date has focused mainly on large-scale biofuel production for transport (Ligji nr. 138/2013 and Ligji Nr.9876), modern bioenergy developments encompass a broad range of activities, including the more sustainable cultivation and use of biomass (e.g., firewood and charcoal) for energy at local and broader scales.

### **1.1 The concept of biomass and its energy potential**

Biomass is a term that encompasses a wide range of materials with a highly heterogeneous nature. The term biomass refers to all non-fossil organic matter, that is, all organic materials derived from plants and originating from photosynthetic CO<sub>2</sub> fixation processes (Directive 2009/28/EC, 23 April 2009). It includes all terrestrial and aquatic vegetation, as well as organic residues. According to the definition provided in Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources—also known as the EU Renewable Energy Directive (EU-RED)—biomass is defined as “the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries, including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste” (Christensen, A., & Petrenko, C., 2017). The same definition of biomass is adopted in Albanian Law No. 138/2013 “On Renewable Energy Sources,” which is fully aligned with Directive 2009/28/EC. The relatively short regeneration period of biomass places it among renewable energy sources, since the time required for organic matter utilization is comparable to the time required for its formation.

In addition to crops cultivated specifically for energy purposes, biomass includes all agricultural and forestry products, including residues from agricultural processing and silviculture, residues from agri-food products intended for human or animal consumption, chemically untreated residues from the wood and paper processing industries, all organic products derived from the biological activity of animals and humans, as well as those contained in urban solid waste

(organic fractions).

### **Biomass types**

Since the 1980s, the European Community has promoted various research programs focused on the study of agricultural crops as potential biomass sources for energy production, as well as on the most suitable cultivation and transformation techniques.

### **Types of biomasses**

Biomass usable for energy purposes consists of all organic materials that can be used directly as fuels or transformed into other substances (solid, liquid, or gaseous) that are more easily utilized in conversion facilities. Researchers (**ARSIA, 2004**) characterize different types of biomass in various ways. One possible classification is as follows:

1. Woody biomass

2. Agricultural residues

The main agricultural residues include crop residues, straw, oil cakes, nut shells, etc.

Residues can be divided into two groups:

- (1) materials remaining in the field or orchard after harvesting, such as wheat straw, maize stalks, rice straw, leaves, etc.; and

- (2) processing residues, i.e., materials remaining after processing a crop into a usable resource, such as oil cakes, seeds, roots, etc.

Some agricultural residues can be used as animal feed, for soil management, or for processing. Materials remaining in the field can be collected from existing agricultural land. Traditionally, this biomass has been left in the field or burned. Additional infrastructure is required for its collection and baling. These feedstocks are generally easier to convert into energy compared to woody biomass, possibly due to their lower lignin content.

3. Energy crops

Hybrid poplar, energy cane, and similar crops are grown exclusively for energy production purposes. These crops are fast-growing, have minimal nutrient requirements, and can be cultivated on marginal or non-agricultural land.

4. Waste

Urban solid waste and residues from the paper industry are the main sources of this biomass type. Their high cellulose content and low lignin content make them very suitable substrates for biofuel production. However, due to the presence of significant inorganic additives, pretreatment processes are required prior to enzymatic hydrolysis.

5. Algae

Due to their high efficiency in converting solar energy, algae have attracted attention for fuel

production. Microalgae are fast-growing photosynthetic organisms that can complete their growth cycle within a few days. Algae can contain up to 50% oil by mass. As a result, algal oil production for biodiesel has been extensively studied, and industrial biodiesel plants based on algae already exist. It is estimated that diatom algae can produce up to 40 tons of oil per hectare per year, which is 7–30 times higher than the yields achieved by the best-performing oil palm crops and about 200 times higher than soybean yields.

### **1.2 Benefits of using biomass for energy purposes**

Biomass is widely available and represents a local, clean, and renewable resource. It is one of the most promising solutions in the search for new renewable energy resources in the short and medium term, for at least three reasons:

- the possibility of producing energy with relatively modest investments;
- the provision of an alternative to traditional crops that struggle to compete in an increasingly globalized market;
- the sequestration of significant amounts of carbon in soils (thus qualifying for green certificates and economic benefits arising from the Kyoto Protocol).

### **1.3 Selection of energy crops**

Biomass quality is determined by various factors, the most important of which are moisture content, calorific value, and ash content. The main characteristics of biomass can be defined in terms of particle size, bulk density, moisture and ash content, heating value, molecular composition (e.g., lignin, hemicellulose, cellulose, volatile compounds, proteins), and element composition (e.g., C, O, H, N, S, K, P). The magnitude of these characteristics depends on plant species, pedoclimatic conditions, cultivation practices, and other factors.

### **1.4 Biomass energy potential in Korca region, Albania**

Korça Region covers an area of 3,697 km<sup>2</sup>, corresponding to approximately 370,000 ha, and is located in the south-eastern part of Albania. It borders North Macedonia (formerly the Former Yugoslav Republic of Macedonia) to the east and Greece to the south-east. From an administrative point of view, Korçë is designated as a county (prefecture). The county consists of four districts: Devoll, Kolonjë (Ersekë), Korçë, and Pogradec. Within the Korçë County there are 37 municipalities and communes (16 in Korçë, 5 in Devoll, 8 in Kolonjë, and 8 in Pogradec). The total territorial area of the county is 3,697 km<sup>2</sup>. Mountains occupy 58% of the area, hills 17%, and plains 25%. The highest peak is located in Mount Gramoz (Kolonjë), at an elevation of 2,523 m. The regional climate is Mediterranean–continental, characterized by cold winters and warm, dry summers. The average annual temperature is 10.6 °C, while November is the month with the highest precipitation, with an annual average of 104.9 mm. Northern and south-

western winds are predominant. As noted above, within its administrative boundaries, Korçë County has a total land area of approximately 370,000 ha. Of the total land area, cultivated land accounts for 23.5%, while arable land, amounting to 81,893 ha, represents 95.1% of cultivated land.

Cultivated land is generally located on sloping terrain. For instance, in the Korçë district, approximately 39% of cultivated land lies on slopes exceeding 25%. This proportion is even higher in the Kolonjë district. The areas with the most developed agriculture include the Korçë basin, the Devoll basin and plateau, the Kolonjë plateau, and the lands surrounding Lake Pogradec. The Korçë and Devoll basins are particularly recognized for their advanced agricultural development.

Due to various factors such as altitude, lack of financial resources, and population migration, approximately 16,274 ha of arable land (19.8%) remain unused, while 14,867 ha (18.1%) are classified as abandoned. Relatively larger unused areas are recorded in the Korçë district (10,675 ha) and Kolonjë (3,332 ha).

Water resources include precipitation, surface water, and groundwater. Irrigation mainly relies on surface water, although groundwater use has increased in recent years. More than 39 reservoirs have been constructed, with a total storage capacity of approximately 70 million m<sup>3</sup>. Prior to 1990, about 50% of cultivated land in Korçë County had irrigation potential. Following infrastructure degradation in the early 1990s, irrigated land was reduced to 17,574 ha, or about 20% of cultivated land (Korçë 18.3%, Devoll 23.3%, Pogradec 13.6%, Kolonjë 28.8%). Irrigation disparities among municipalities are significant, and insufficient irrigation remains a major constraint on crop productivity.

Detailed data on land structure in the county are presented in the following table.

**Table nr. 1. Land structure in Korçë County by district**

| No. | District     | Total land (ha) | Cultivated land (ha) | Forests (ha) | Meadows and pastures (ha) | Other land (ha) |
|-----|--------------|-----------------|----------------------|--------------|---------------------------|-----------------|
| 1   | County total | 366,024         | 86,108               | 132,075      | 53,732                    | 94,109          |
| 2   | Korçë        | 172,478         | 44,207               | 54,900       | 23,604                    | 49,767          |
| 3   | Pogradec     | 71,541          | 17,506               | 27,330       | 5,364                     | 21,341          |
| 4   | Devoll       | 41,542          | 13,148               | 15,165       | 3,022                     | 10,207          |
| 5   | Kolonjë      | 80,463          | 11,247               | 34,680       | 21,742                    | 12,794          |

Source: DRBUMK Korçë, 2025.

Traditionally, Korça region has been dominated by agriculture, alongside other sectors such as livestock farming, forestry, and fisheries. A significant number of state-owned industries have been closed over the past decade, and the continued fragmentation of land through privatization

(allocation of agricultural land to farmers) has negatively affected agricultural production. Nevertheless, the small and medium-scale agribusiness sector is currently showing growth.

The main characteristics of private farms include very small land holdings (Korçë 1.24 ha, Kolonjë 1.48 ha, Devoll 1.47 ha, Pogradec 0.54 ha) and internal fragmentation into 4–8 plots, which significantly limits productivity. Along with land, livestock and other assets such as tractors and other inputs were also distributed. The agro-processing industry was entirely privatized. The year 1993 marked the beginning of agricultural production recovery, temporarily interrupted in 1997.

Regarding cultivated areas, structural changes have been evident since 1990. Wheat, maize, vegetables, forage crops, and potatoes have increased in the cropping structure, while industrial crops have generally declined. Compared to 1990, only vegetables, potatoes, and beans show higher production levels, whereas cereal production remains lower, reflecting changes in both cultivated area and yields. Either in local and/or global contexts, biofuels production may lead to indirect land use change and biodiversity implications (Bertzky, M., Kapos, V., Scharlemann, J.P.W., 2011).

## 2. METHODOLOGY

Modern food processing technologies are applied across various sectors, including energy production. In this context, the net energy obtained from crop biomass after food extraction can represent an important source of renewable energy, contributing to environmental protection without compromising food security. This study was based on a quantitative and analytical approach combining statistical data analysis with literature-based energy conversion methods. Data on cultivated area and total crop production were obtained from the Albanian Statistical Yearbooks for the years 2013, 2018, and 2023, focusing on agricultural crops in the Korçë Region. Agricultural biomass availability was estimated by calculating crop residue quantities using residue-to-product ratios obtained from relevant scientific literature. Technical coefficients, including dry matter content and lower heating values, were applied to determine the usable biomass fraction for energy production. Energy potential was calculated in megajoules (MJ).

The cumulative bioenergy potential was calculated as the sum of contributions from all relevant crops for each reference year. Interannual variability was analyzed to identify trends and fluctuations in biomass availability and energy potential. The analysis excluded livestock-related biomass and focused exclusively on plant-based agricultural residues.

### **3. RESULTS AND DISCUSSION**

#### **3.1 Total biomass energy potential**

The main objective of this study was to assess the potential for biofuel production from agricultural biomass in the Korçë Region and to evaluate its contribution to renewable energy production and environmental protection. The specific objectives were to quantify the availability of agricultural biomass derived from crop residues in Korça Region based on statistical data, to analyze temporal changes in biomass availability using multi-year datasets from national statistical yearbooks, to estimate the bioenergy potential of agricultural residues expressed in energy units (MJ and KTOE), to identify the main agricultural crops contributing to biofuel potential and evaluate their relative contributions, to provide a scientific basis for supporting regional bioenergy planning and sustainable agricultural policy development.

The study was based on a quantitative and analytical approach combining statistical data analysis with literature-based energy conversion methods. Data on cultivated area and total crop production were obtained from the Albanian Statistical Yearbooks for the years 2013, 2018, and 2023, focusing on agricultural crops in the Korçë Region. Agricultural biomass availability was estimated by calculating crop residue quantities using residue-to-product ratios obtained from relevant scientific literature. Technical coefficients, including dry matter content and lower heating values, were applied to determine the usable biomass fraction for energy production. Energy potential was calculated in megajoules (MJ).

**Table nr 2 . The calculated bioenergy potential for Korça region for 2013.**

| Nr.      | Description            | Area (ha) | kg DM/ha<br>(kgs of dry matter per hectare) | Heating value (MJ/kg DM) | Potential energy value (MJ) | Conversion coefficient: 1 toe = 41,868 MJ |
|----------|------------------------|-----------|---------------------------------------------|--------------------------|-----------------------------|-------------------------------------------|
| <b>1</b> | Total cereals          | 24300     |                                             |                          |                             |                                           |
|          | Wheat                  | 16300     | 2500                                        | 17.5                     | 713125000                   | 17032.698                                 |
|          | Maize (corn)           | 4100      | 6000                                        | 13.8                     | 339480000                   | 8108.340499                               |
|          | Rye                    | 600       | 3000                                        | 17.5                     | 31500000                    | 752.3645744                               |
|          | Barley                 | 2400      | 3000                                        | 17.5                     | 126000000                   | 3009.458298                               |
|          | Forage crops           | 900       | 3000                                        | 17.5                     | 47250000                    | 1128.546862                               |
| <b>2</b> | Vegetables             | 2500      | 39017                                       | 17.1                     | 1667976750                  | 39838.94024                               |
| <b>3</b> | Beans                  | 2300      | 1883                                        | 17.1                     | 74058390                    | 1768.854256                               |
| <b>4</b> | Fruit trees (orchards) | 36000     | 4000                                        | 18                       | 2592000000                  | 61908.85641                               |
| <b>5</b> | Potatoes               | 1900      | 39470                                       | 17.1                     | 1282380300                  | 30629.12726                               |
| <b>6</b> | Meadows*               | 52000     | 3500                                        | 6                        | 1092000000                  | 26081.97191                               |
| <b>7</b> | Forests*               | 91500     | 30000                                       | 18                       | 4941000000                  | 1180137.575                               |
|          | <b>TOTALI</b>          |           |                                             |                          |                             | <b>1370396.734</b>                        |

**Table nr 3. The calculated bioenergy potential for Korçë County for 2018.**

| Nr.      | Description            | Area (ha) | kg DM/ha<br>(kgs of dry matter per hectare) | Heating value (MJ/kg DM) | Potential energy value (MJ) | Conversion coefficient: 1 toe = 41,868 MJ |
|----------|------------------------|-----------|---------------------------------------------|--------------------------|-----------------------------|-------------------------------------------|
| <b>1</b> | Total cereals          | 21300     |                                             |                          |                             |                                           |
|          | Wheat                  | 13300     | 2500                                        | 17.5                     | 581875000                   | 13897.84561                               |
|          | Maize (corn)           | 4400      | 6000                                        | 13.8                     | 364320000                   | 8701.633706                               |
|          | Rye                    | 300       | 3000                                        | 17.5                     | 15750000                    | 376.1822872                               |
|          | Barley                 | 2300      | 3000                                        | 17.5                     | 120750000                   | 2884.064202                               |
|          | Forage crops           | 900       | 3000                                        | 17.5                     | 47250000                    | 1128.546862                               |
| <b>2</b> | Vegetables             | 3000      | 39017                                       | 17.1                     | 2001572100                  | 47806.72829                               |
| <b>3</b> | Beans                  | 2300      | 1883                                        | 17.1                     | 74058390                    | 1768.854256                               |
| <b>4</b> | Fruit trees (orchards) | 3900      | 4000                                        | 18.0                     | 280800000                   | 6706.792777                               |
| <b>5</b> | Potatoes               | 2200      | 39470                                       | 17.1                     | 1484861400                  | 35465.30525                               |
| <b>6</b> | Meadows*               | 50500     | 3500                                        | 6.0                      | 1060500000                  | 25329.60734                               |
| <b>7</b> | Forests*               | 89300     | 30000                                       | 18.0                     | 4822200000                  | 1151762.683                               |
|          | <b>TOTALI</b>          |           |                                             |                          |                             | <b>1295828.243</b>                        |

**Table nr 4. The calculated bioenergy potential for Korçë County 2023**

| Nr.      | Description            | Area (ha) | kg DM/ha (kgs of dry matter per hectare) | Heating value (MJ/kg DM) | Potential energy value (MJ) | Conversion coefficient: 1 toe = 41,868 MJ |
|----------|------------------------|-----------|------------------------------------------|--------------------------|-----------------------------|-------------------------------------------|
| <b>1</b> | Total cereals          | 22574     |                                          |                          |                             |                                           |
|          | Wheat                  | 13430     | 2500                                     | 17.5                     | 587562500.00                | 14033.69                                  |
|          | Maize (corn)           | 5500      | 6000                                     | 13.8                     | 455400000.00                | 10877.04                                  |
|          | Rye                    | 700       | 3000                                     | 17.5                     | 36750000.00                 | 877.76                                    |
|          | Barley                 | 2844      | 3000                                     | 17.5                     | 149310000.00                | 3566.21                                   |
|          | Forage crops           | 444       | 3000                                     | 17.5                     | 23310000.00                 | 556.75                                    |
| <b>2</b> | Vegetables             | 2990      | 39017                                    | 17.1                     | 1994900193.00               | 47647.37                                  |
| <b>3</b> | Beans                  | 2443      | 1883                                     | 17.1                     | 78662889.90                 | 1878.83                                   |
| <b>4</b> | Fruit trees (orchards) | 3530      | 4000                                     | 18                       | 254160000.00                | 6070.51                                   |
| <b>5</b> | Potatoes               | 2100      | 39470                                    | 17.1                     | 1417367700.00               | 33853.25                                  |
| <b>6</b> | Meadows*               | 49200     | 3500                                     | 6                        | 1033200000.00               | 24677.56                                  |
| <b>7</b> | Forests*               | 87900     | 30000                                    | 18                       | 47466000000.00              | 1133705.93                                |
|          | <b>TOTAL</b>           |           |                                          |                          |                             | <b>1277744.90</b>                         |

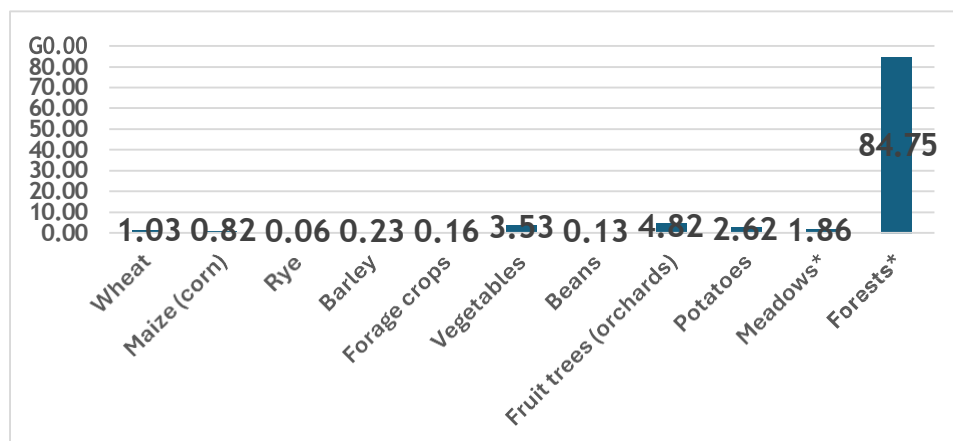
\*All data for meadows and forest surface were collected from Local Directory of Forest and Meadows, Korçë.

The cumulative bioenergy potential was calculated as the sum of contributions from all relevant crops for each reference year. Interannual variability was analyzed to identify trends and fluctuations in biomass availability and energy potential. The analysis excluded livestock-related biomass and focused exclusively on plant-based agricultural residues. The calculated bioenergy potential for Korçë County shows substantial values across all three reference years, 2013, 2018, and 2023, confirming the strategic importance of biomass as a renewable energy resource, as shown above. The total estimated energy potential amounted to 2.28 Mtoe in 2013, decreased to 2.24 Mtoe in 2018, and increased again to 2.41 Mtoe in 2023. The decline observed in 2018 is mainly associated with a reduction in cultivated agricultural areas—particularly cereals and fruit trees—reflecting land-use changes, climatic variability, and ongoing fragmentation of agricultural holdings. The recovery by 2023 suggests partial stabilization of land use and increased contribution from forest biomass and grasslands. Overall, the results demonstrate that biomass energy potential in the region is relatively resilient but sensitive to structural changes in agriculture and forestry management.

### 3.2 Contribution by biomass category

Forest biomass represents by far the largest contributor to total bioenergy potential in all assessed years. Its contribution was decreased from 1.3 Mtoe in 2013 to 1.29 Mtoe in 2018,

reaching 1.27 Mtoe in 2023. This dominance is driven by the extensive forest area and the high dry matter yield (30,000 kg DM/ha), combined with a relatively high lower heating value (18 MJ/kg DM). The increasing contribution of forest biomass highlights both its energetic importance and the need for sustainable forest management to avoid overexploitation and long-term degradation.



**Graphic nr. 1. Share contribution in percentage to total bioenergy potential assessed for 2023**

**Cereals-** Cereal crops (wheat, maize, barley, rye, and barley) constitute the most important agricultural source of biomass energy. Their energy potential declined from 30.0 ktoe in 2013 to 26.9 ktoe in 2018, before increasing again to 29.9 ktoe in 2023. This pattern closely follows changes in cultivated area rather than changes in conversion coefficients, which remained constant. Maize and wheat residues contributed the largest share among cereals, due to their wider cultivation and higher residue production. These residues represent a technically accessible resource for bioenergy, although competing uses such as animal feed and soil amendment must be considered.

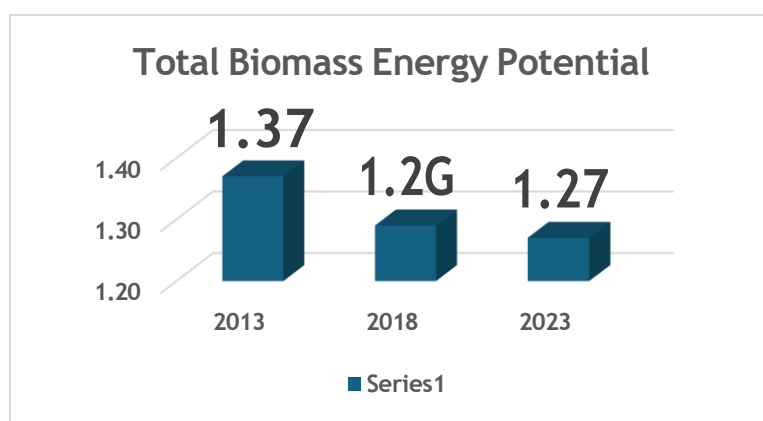
Vegetables and potatoes provided moderate but stable contributions to total energy potential. Vegetable residues contributed approximately 40–48 ktoe, while potatoes ranged between 30–35 ktoe across the studied years. Legumes (beans) showed the lowest contribution, remaining below 2 ktoe, due to limited cultivated area and lower dry matter yields. Although individually modest, these residues can play an important role in decentralized, small-scale bioenergy systems, particularly in agro-industrial or rural contexts.

#### Grasslands (meadows)

Grasslands exhibited a constant decrease in energy potential in 2023, reaching 26 ktoe, compared to around 251 ktoe in 2018 and 24.6 in 2013. This decrease is primarily attributed to the decrease of grassland area rather than changes in energy content, indicating a shift in land use (Bertzky, M., Kapos, V., Scharlemann, J.P.W., 2011), or improved grassland management. The figure illustrates the evolution of total biomass energy potential in the study area over three

reference years (2013, 2018, and 2023 table 2,3,and 4), expressed in toe-equivalent units. The results reveal a non-linear temporal trend characterized by an initial high value in 2013, a noticeable decline in 2018, followed by a significant decrease in 2023.

In 2013, the total biomass energy potential was estimated at approximately 1.37 million toe, reflecting relatively stable agricultural activity and consistent contributions from forest biomass. The decrease observed in 2018 to about 1.15 million toe and to 1.13 million toe in 2023, can be attributed to reductions in cultivated areas, changes in crop structure, or socio-economic factors affecting agricultural production. This decline highlights the sensitivity of biomass availability to land-use dynamics and farming intensity.



**Graphic nr. 2. Total biomass energy potential in MJ estimated for 2013, 2018 and 2023**

By 2023, the total biomass energy potential increases to around 2.41 million toe, exceeding the 2013 level. This recovery is primarily driven by the expanded contribution of forest biomass and grasslands, along with partial stabilization of agricultural residues. The upward trend suggests improved biomass availability and reinforces the role of forestry resources as a stabilizing component of the regional bioenergy supply.

Overall, the figure confirms that while biomass energy potential exhibits interannual variability, the long-term outlook remains positive. These findings emphasize the importance of sustainable land and forest management to ensure a reliable biomass supply and support the integration of bioenergy into regional renewable energy strategies (Çela, R., Himzo, A., 2009).

### 3.3 Temporal trends and variability

The comparison across years reveals that land-use changes are the dominant factor influencing biomass energy potential, rather than variations in calorific values or conversion coefficients, which were taken from the literature. Agricultural biomass shows greater interannual variability compared to forest biomass, which remains relatively stable due to its long regeneration cycles.

The results emphasize the importance of multi-year assessments when estimating bioenergy potential, as single-year analyses may misrepresent long-term availability.

### **3.4 Implications for energy policy and regional development**

The results indicate that biomass could represent a strategic complementary energy source for Korçë County, supporting energy diversification, rural development, and greenhouse gas mitigation. Forest residues and cereal by-products appear to be the most promising feedstocks for bioenergy deployment (Çela, R., Himzo, A., 2009). Targeted investments in biomass collection, logistics, and small- to medium-scale conversion technologies could enhance local energy security while maintaining environmental sustainability.

### **3.5 Overall discussions**

In summary, the analysis confirms that Korçë County possesses a high and relatively stable biomass energy potential, dominated by forest biomass and cereal residues. Although fluctuations occur due to agricultural restructuring and land-use changes, biomass remains a viable renewable energy option. Sustainable management practices and integrated planning are essential to transform this theoretical potential into practical and environmentally sound energy solutions.

## **4. CONCLUSIONS**

The analysis of biomass energy potential for the years 2013, 2018, and 2023 indicates a gradual but consistent decline over the observed period. Total biomass energy potential decreased from approximately 1,370,397 toe in 2013 to 1,295,828 toe in 2018 and further to 1,277,745 toe in 2023. This represents an overall reduction of nearly 6–7% over the decade. The most pronounced decline occurred between 2013 and 2018, while the period 2018–2023 shows a slower rate of decrease, suggesting a partial stabilization phase. Nevertheless, the long-term trend reflects a modest contraction in the available biomass resource base.

Forest biomass constitutes the dominant share of total energy potential throughout the entire study period. In each of the three reference years, forest resources account for approximately 85–90% of total biomass energy. Although the forest-based energy potential remains structurally high, it exhibits a slight but continuous reduction across the decade. Given this overwhelming contribution, any variation in forest area, productivity, or management practices exerts a substantial influence on total biomass energy availability. The results therefore underline the strategic importance of sustainable forest management for maintaining regional bioenergy capacity.

Agricultural biomass contributes a comparatively smaller but still significant share of total potential. Cereals such as wheat, maize, barley, and rye demonstrate moderate fluctuations, largely driven by changes in cultivated surface area and crop structure. While some crops show localized increases in particular years, the aggregate contribution of cereal biomass does not compensate for the decline observed in forest biomass. High-yield crops such as potatoes and vegetables generate considerable energy potential per hectare due to elevated dry matter production; however, their overall share remains limited in relation to forest resources. Meadows and pastures provide a stable contribution over time, though their lower calorific value reduces their relative impact on total energy output.

The overall structural composition of biomass energy potential reveals a strong dependency on forest ecosystems. This dependency increases the vulnerability of the bioenergy sector to factors such as forest degradation, land-use change, wildfires, and unsustainable harvesting. The observed decline in total potential suggests that, without strengthened reforestation programs, improved biomass recovery practices, and enhanced resource efficiency, the downward trend may persist.

In conclusion, the period 2013–2023 is characterized by a moderate but continuous reduction in biomass energy potential, primarily influenced by changes in forest resources. Although agricultural biomass provides complementary energy capacity, it is insufficient to offset forest-related fluctuations. The findings highlight the need for integrated land management strategies, diversification of renewable energy sources, and the implementation of sustainable biomass utilization policies to ensure long-term energy security and environmental sustainability.

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## **CLIMATE CHANGE IMPACTS ON PRESPA BREEDING WATERBIRD POPULATIONS**

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### **ABSTRACT**

We present the major consequences that climate change has brought upon the phenology and behaviour of large waterbirds nesting in Prespa via lowering water levels, higher winter temperatures in northern Greece, and higher spring temperatures in Prespa. Most large waterbirds (herons, pelicans, cormorants) nest at Lesser Prespa Lake in habitats directly surrounded or underlain by water. Lowering water levels have four major impacts on waterbirds: continuous fragmentation and relocation of heron and pygmy cormorant colonies; increased predation by terrestrial mammals accessing colonies via “land bridges”; heron foraging sites shifting continuously to new shallow-water areas; drought-enhanced combustibility of reedbeds and wildfires becoming more catastrophic to colonies. The differential effect of climate change between main wintering and breeding grounds and density-dependent phenomena continue to advance laying dates in the Dalmatian pelican, but breeding is mistimed owing to a mis-match between unavailability of food (fish) in the Prespa lakes during the early breeding period and increased energy needs of early breeders, who are forced to a lower breeding success, caused by abandonment of nests and eggs in search of food in distant, lower-lying wetlands. More hazardously, very early breeding increases the viral exposure window and transmissibility of highly pathogenic avian influenza viruses, which are more dynamic in low temperatures. Furthermore, a few great white pelicans overwintering in Greece start nesting along with early Dalmatian pelican breeders, triggering a split into one resident and one migratory population.

**Keywords:** Lesser Prespa Lake, climate change, breeding waterbirds

## 1. INTRODUCTION

Waterbirds are likely to be amongst the organisms most adversely affected by climate change, as they are associated with a habitat that is very vulnerable to changes in rainfall, evaporation and human demand, and because they migrate between different areas and could thus be deleteriously affected in any one of those areas (Maclean et al. 2007).

Markovic et al. 2017 have found that three biodiversity-rich ancient transboundary Balkan lakes, Lake Ohrid and the two Prespa lakes, are predicted to have ‘very high’ vulnerability to climate change from a combination of ‘low’ resilience, ‘very high’ sensitivity and ‘very high’ exposure.

In this paper, we describe the major consequences that four basic manifestations of climate change have on the phenology, behaviour and breeding performance of the large waterbirds nesting at the Prespa lakes, mainly via impacts on their nesting and feeding habitats: a. Lowering water levels of both lakes; b. Higher temperatures in the waterbirds’ wintering grounds; c. Higher winter temperatures in Northern Greece; and d. Higher spring-summer temperatures in Prespa.

## 2. STUDY AREA AND METHODS

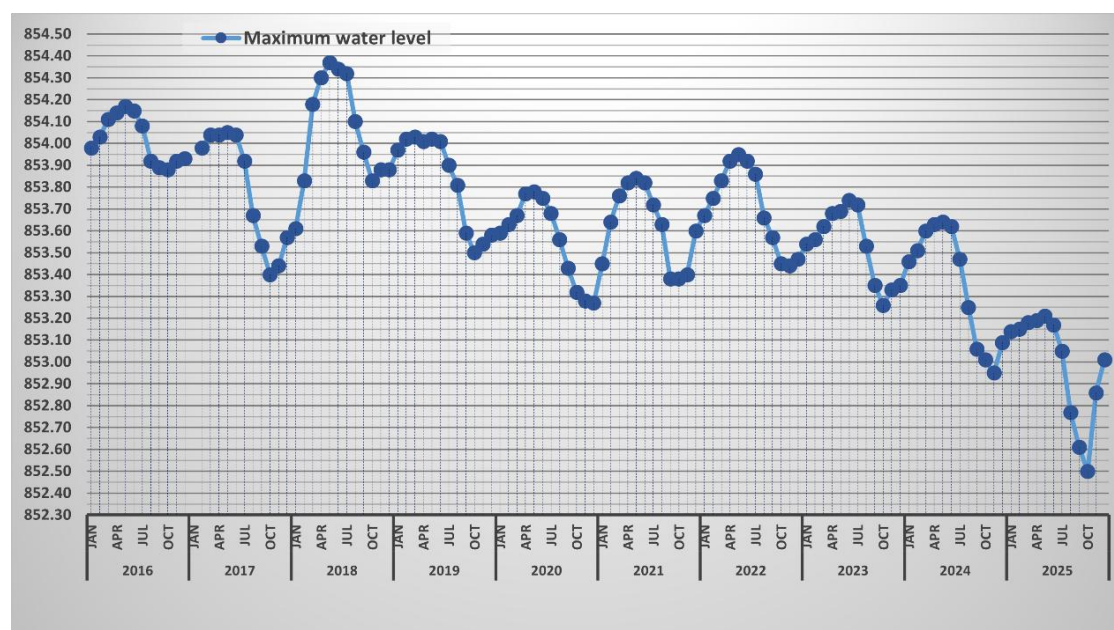
Great Prespa Lake and Lesser Prespa Lake are two adjacent highland lakes in the Western Balkans that are shared by three countries, Albania, Greece and North Macedonia. The area is home to over 160 species of breeding birds and important colonies of waterbirds, including six species of herons (*Ardea alba*, *Ardea cinerea*, *Ardea purpurea*, *Egretta garzetta*, *Ardeola ralloides*, *Nycticorax nycticorax*), the glossy ibis *Plegadis falcinellus*, the pygmy cormorant *Microcarbo pygmaeus*, the great cormorant *Phalacrocorax carbo sinensis* and the two European species of pelican. The colony of the globally Near Threatened Dalmatian pelican (hereafter DP) *Pelecanus crispus* is the largest in the world, while that of the great white pelican (GWP) *Pelecanus onocrotalus* is the second largest in Europe.

Long-term monitoring data, including lake water level, data related to waterbird phenology, location of nesting sites, number of nests, breeding success, and use of feeding sites, as well as observed data, i.e., reedbed fire events, were analyzed to assess climate change impacts on Prespa breeding waterbird populations.

### 3. RESULTS

#### A. Lowering water level

Most large waterbirds in Prespa nest in habitats directly affected, surrounded or underlain by water. The lowering water levels of Lesser Prespa Lake during at least the last ten years (Fig. 1) have had four major impacts on the waterbirds breeding in this lake: a. alterations to nesting sites, b. increased accessibility to predators, c. alterations to feeding sites, and d. the catastrophic potential of wildfires is amplified.

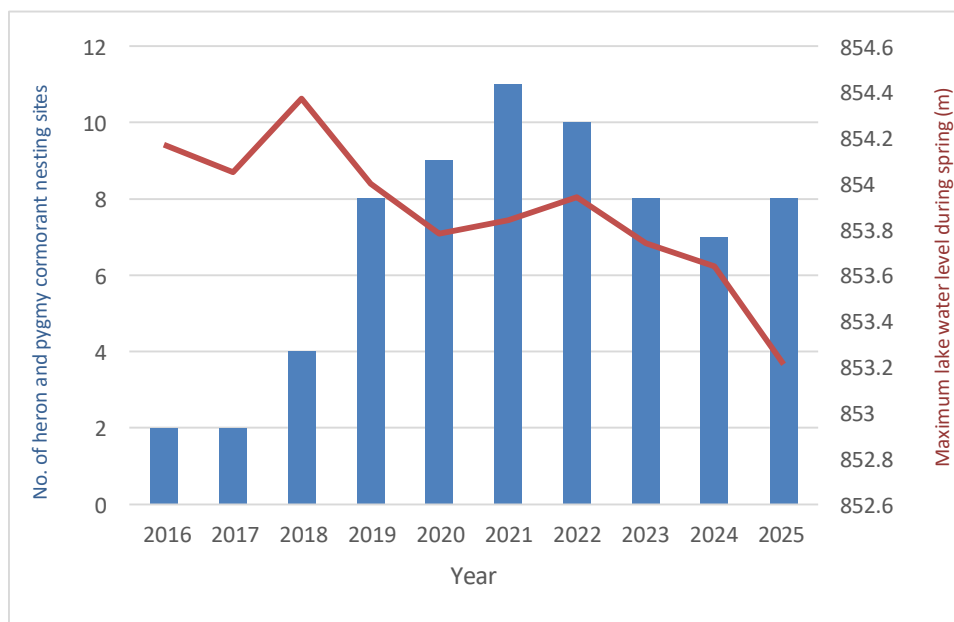


**Figure 1. Lesser Prespa Lake maximum monthly water levels during the period 2016-2025, demonstrating a declining trend as a result of climate change impact.**

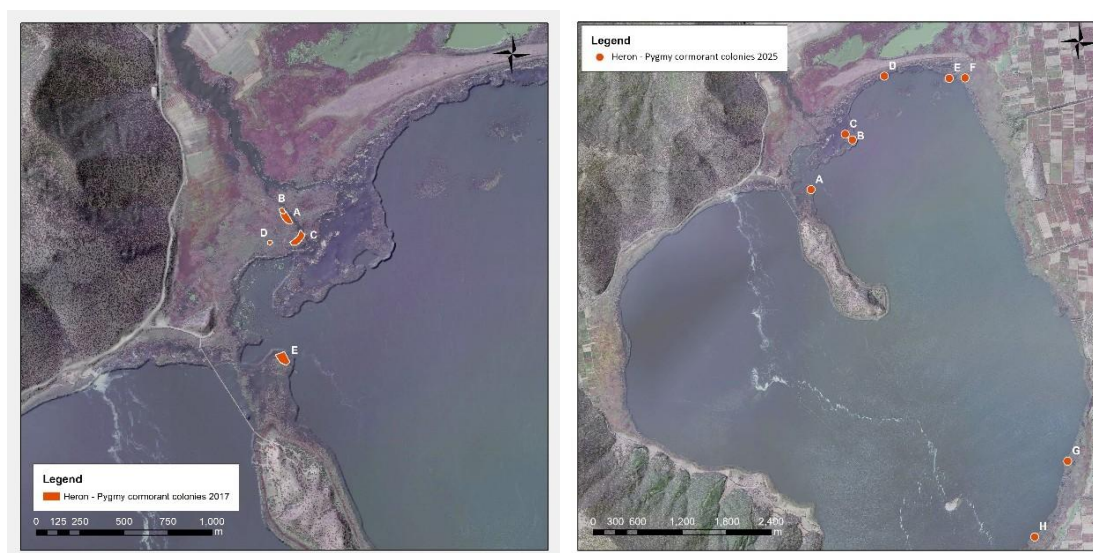
##### A1. Nesting sites

In Lesser Prespa Lake, herons form mixed colonies with pygmy cormorants and glossy ibis, building their nests on trampled reeds in reedbeds over water. Reedbeds cover large parts of the lakeshore, but lowering water levels mean that large parts of the reedbeds remain out of the water and thus past nest sites are not chosen by the birds as they are not flooded. Presence of flooding is apparently the cue used by these birds to accept or reject a nesting site. The same is true of pelicans and great cormorants, which nest on the ground of reed-rhizome islets. The waters around these islets have receded; the birds do not recognise them anymore as safe islets suitable for breeding, and so they do not use them. By itself, this fact decreases the availability of proper nesting sites and lowers the carrying capacity for breeders. After 2014, the drop in water level has resulted in an unusual fragmentation of colonies at Lesser Prespa Lake, as

herons and pygmy cormorants are forced to abandon traditional nesting sites and relocate to other areas with similar features but which are flooded. These colonies are thus scattered in smaller patches across the wetland (Figure 2), because no large areas can be found to fulfil these attributes.



**Figure 2.** Low spring water levels after 2018 have forced herons and pygmy cormorants to relocate to new colony sites, breaking into smaller and different sub-colonies in the Greek part of Lesser Prespa Lake.



**Maps 1 & 2.** Location of heron-pygmy cormorant nesting sites in 2017 (left) and 2025 (right) at Lesser Prespa Lake.

## A2. Predation

Low water levels significantly increase the vulnerability of waterbird colonies to terrestrial predators by reducing the natural water barrier and allowing easier access. Limited nest

abandonment owing to terrestrial predators has been documented in previous years. In 2025, the record-low lake water level allowed substantial predator access to waterbird colonies, and this led to devastating rates of nest abandonment, egg loss, and, for the first time, massive chick predation. During the 2025 breeding period at Lesser Prespa Lake, we estimate that a minimum of 123-140 DP and 95 GWP nestlings were predated, and at least 60 DP and 460 GWP eggs. Predation incidences were first recorded in early April and continued until early July, resulting in a record low breeding success (fledged young per Apparently Occupied Nest) of 0.38 and 0.29 for the DP and the GWP respectively. Moreover, great cormorants nesting on pelican islets also suffered from extensive chick predation, which resulted in a record low breeding success. We estimate that 2-3 foxes *Vulpes vulpes*, 1-2 golden jackals *Canis aureus*, a single brown bear *Ursus arctos*, and an unknown number of wild boar *Sus scrofa*, wild cat *Felis sylvestris* and American mink *Neogale vison* were involved in the predation of pelican colonies. Regarding the latter, it is particularly worrisome that numerous observations have been recorded in the last few years. The American mink is recognized as one of the most harmful invasive alien species in Europe (Goicolea et al. 2023). Originating either from accidental escapes or intentional releases from fur farms, they pose a severe threat to Prespa's wetland ecosystems, particularly to vulnerable ground-nesting waterbirds. Warmer temperatures and changing water resources may have made the Prespa wetlands more hospitable for minks, while drought reduces wetland refuges for biodiversity.

Hérons are not monitored as intensively as pelicans, but in the last 15 years we have often recorded low numbers of nests abandoned a few days after initiation, which we could not attribute to predation, however. In 2026, a whole mixed colony of great white egrets, night herons and pygmy cormorants, with around 150 nests, was abandoned at the egg stage. All nests were found void of any content, although many eggs would already have been laid. This was likely the action of a predator, probably American mink.

### *A3. Impacts to feeding sites*

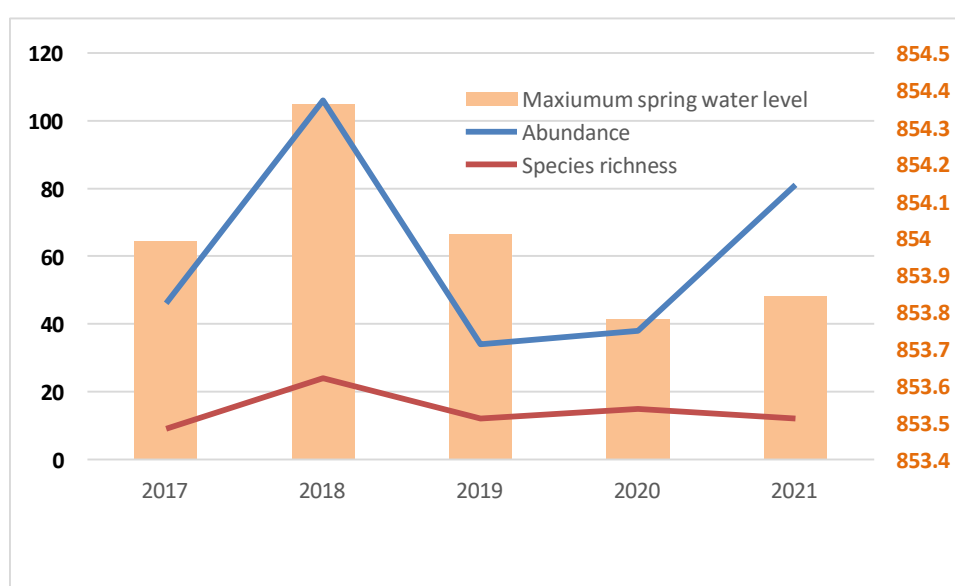
Long periods of drought have a strong impact upon lakeshore habitats, as they reduce seasonal water level fluctuations and force a drop in average lake level. Under such conditions, there is limited or no seasonal flooding of wet meadows and the shallow edges of the lake, which constitute important fish spawning grounds and waterbird foraging areas. Thus, the available open-shallow foraging environments greatly decrease.

In Fig. 3 we depict the variation of the mean total numbers (individuals) of large waterbirds and the number of species recorded feeding in a sample of standard feeding sites around the

shoreline of Lesser Prespa Lake. It is apparent that in 2018, the only relatively wet year of the period, both abundance and species richness are much higher, yet the number of feeding waterbirds does not vary in proportion to the numbers of breeding birds. Other factors, not shown here but potentially affecting the quality of each feeding site are the degree of inundation, as well as the extent of management by humans (e.g. mowing, grazing) or the occurrence of wildfires, etc. Finally, the proximity of each feeding site to the existing breeding colony sites is important for waterbirds and partly dictates both the chosen colony location and the degree of use of each feeding site in a trade-off for balancing costs and benefits in energy consumption terms (De la Cruz et al. 2025).

In the last 10-15 years, as typical wet-meadow and shallow-water feeding sites have dried out due to the falling water levels, the waterline has shifted within the reedbed belts surrounding the lake, and thus there are no longer shallow-water areas free of vegetation to serve the needs of waterbirds as foraging sites. Thus, most historical edge-of-water feeding sites of waterbirds are no longer used by the birds, which are increasingly shifting to new feeding sites on the shore of Great Prespa Lake; i.e., there is a strong relocation of foraging sites, which has remained recorded only at the empirical level, however, and has not been measured quantitatively

In agreement with the above, since ca 2013, two species of herons, the grey heron and the little egret, have started to abandon their historical nesting sites at Lesser Prespa Lake and have moved to nest on Golem Grad Island in Great Prespa Lake, North Macedonia.



**Figure 3. Species richness and mean abundance of all large waterbird species recorded feeding during sampling visits to a standard number of shallow-water feeding sites around the periphery of Lesser Prespa Lake, 2017-2021 in April and May. Also depicted for comparison is the maximum water level of the lake in the middle of May.**

#### *A4. Increasing impact of wildfires*

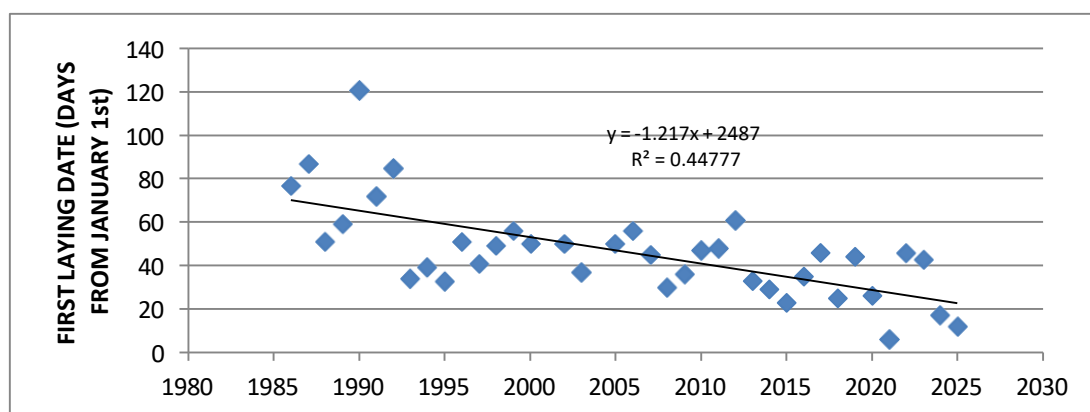
Waterbird colonies located in the reedbeds of Lesser Prespa Lake are vulnerable to uncontrolled wetland fires set by locals, either deliberately to “clear” old-growth reeds that are considered undesirable, or unintentionally, in their attempt to clear the aquatic macrophytes from drainage ditches in early spring. These fires spread to the reedbeds from the drainage ditches, threatening waterbird nests or turning parts of the reedbeds unsuitable for nesting, when they occur shortly before the breeding period. Higher temperatures and prolonged droughts caused by climate change lower the water level and vast areas of dense reedbeds dry out, thus becoming highly flammable, significantly elevating the risk, intensity, velocity and extent of wetland wildfires (Table 1). It is indicative that no fires took place at all in 2018, the wettest year of the decade.

**Table 1. Lesser Prespa Lake burnt reedbed areas during the last decade, 2016-2025.**

| <b>Year</b> | <b>Burnt reedbed area (ha)</b> |
|-------------|--------------------------------|
| 2016        | 198.40                         |
| 2017        | 1.16                           |
| 2018        | 0                              |
| 2019        | 281.31                         |
| 2020        | 53.88                          |
| 2021        | 74.34                          |
| 2022        | 10.36                          |
| 2023        | 55.48                          |
| 2024        | 17.94                          |
| 2025        | 50.01                          |

#### **B. Increase of air temperature in Dalmatian pelican overwintering sites**

Using DP breeding data for the period 1985-2005, Doxa et al. (2012) observed direct climate effects, which resulted in a rapid advancement in the species’ median laying dates by -1.4 days/year. This shift was associated with a. an increase in population size, and b. warmer and wetter winters in the main wintering/stop-over site (i.e. Lake Kerkini, a low-altitude lying wetland in northern Greece). The shift continued for the period 2006-2025, showing an overall advancement of the same magnitude (-1.37 days/year for 1985-2025, Fig. 4). The population increase continued, although it showed signs that has reached a plateau.

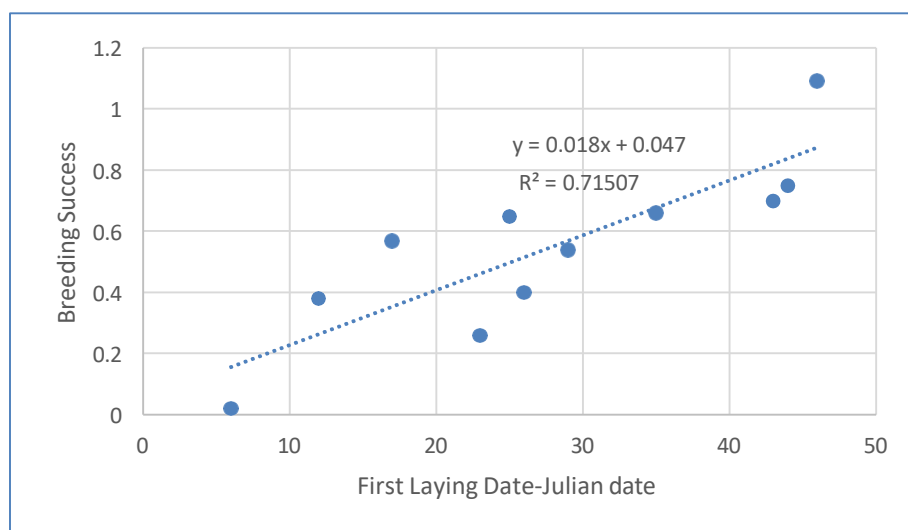


**Figure 4. Advance of 48 days (70 to 22) in 40 years, or -1.37 days/year, in the period 1985-2025 for the first laying date of the Dalmatian pelican in Prespa.**

The average day of initiation is day 35 (4<sup>th</sup> February) for the years 2006-2025 (20 years) and has a strong negative trend. Advancement of breeding has two major consequences that are discussed below: B1. Mismatch with prey availability and B2. Exposure of birds to higher pathogen dynamics.

#### *B1. Mismatch with prey availability*

In contrast to what was happening until 2014, increased frequencies of egg and chick abandonment of early breeders led to extremely low breeding success (BS) in the following years. During 1985-2000, BS of early breeders was consistently higher than that of later breeders, as for most other populations of waterbirds, but in 2014-2019 this was reversed (Fig. 5). In fact, we have been observing a continuation of the advancement that, after a certain threshold, led to the mistiming of the breeding season. We have only empirical data, but we are confident that the over-advancement brought a mismatch between the increased energy needs of incubating and breeding birds and the complete unavailability of fish. The waters of the mountain lakes in Prespa are still very cold in January, February, and March, and fish have not yet started moving to the upper layers of the lake water; therefore, they are unavailable to pelicans.



**Figure 5. Relation between Breeding Success (young per nest) and first laying date for Dalmatian pelicans in Prespa 2014-2025.**

## *B2. Exposure of birds to higher pathogen dynamics*

The 2022 high pathogenicity avian influenza (HPAI) outbreak killed almost 1,800 adult Dalmatian pelicans at the Lesser Prespa Lake colony, ca. 60% of the colony's breeders (Alexandrou et al. 2022). In 2021, another 73 DP had died due to HPAI.

Changes to animal behaviour in response to environmental change can affect pathogen dynamics and disease outcomes. Viruses have more severe impacts on wild bird populations when they are more easily transmitted, and infection lasts longer. Over the last few decades some bird populations, including DP breeding at Prespa, have advanced their spring migration timing (see below). This change in phenology could affect density-dependent transmission processes and increase time spent at their high-altitude breeding grounds, where temperatures are lower and thus environmental virus loads might be higher. In a recent study, Teitelbaum et al. (2025) simulated the effects of climate change on HPAI dynamics, both via viral environmental decay and via changes in bird migration phenology. The results showed that a 9-day advancement in spring migration timing increased the duration of HPAI outbreaks by increasing the time birds spent at their breeding grounds, leading to higher mortality. For the Prespa DP colony, arriving up to 40 days earlier in recent decades has increased their exposure period to HPAI prior to nesting. This extended viral exposure window at the breeding grounds, combined with dense aggregations involved in various nuptial interactions facilitating the spread of HPAI, provides a highly plausible explanation for the severe DP mortality observed in 2022.

### **C. Winter air temperature increases in northern Greece**

Van der Schriek et al. (2023) showed that the wider area of Western Macedonia, and northern Greece in general, is considered to be a hotspot of climate change, with fast rates of increase that are higher than in other areas of the country. Increased mean temperatures, milder winters, prolonged and intensive heatwaves, as well as more frequent stochastic extreme weather phenomena of high intensity and short duration with consequences on both terrestrial and aquatic ecosystems have already been recorded. Prediction models indicate that temperature is expected to increase by 1.5 °C to 3 °C by 2070, while in summer the rise will reach 6 °C. Up to the end of the century, there will be a significant air temperature increase (1-6 °C) and interannual differences in rainfall and drought periods will also increase (van der Schriek et al. 2020). These changes in northern Greece have two major repercussions for the GWP population in Prespa:

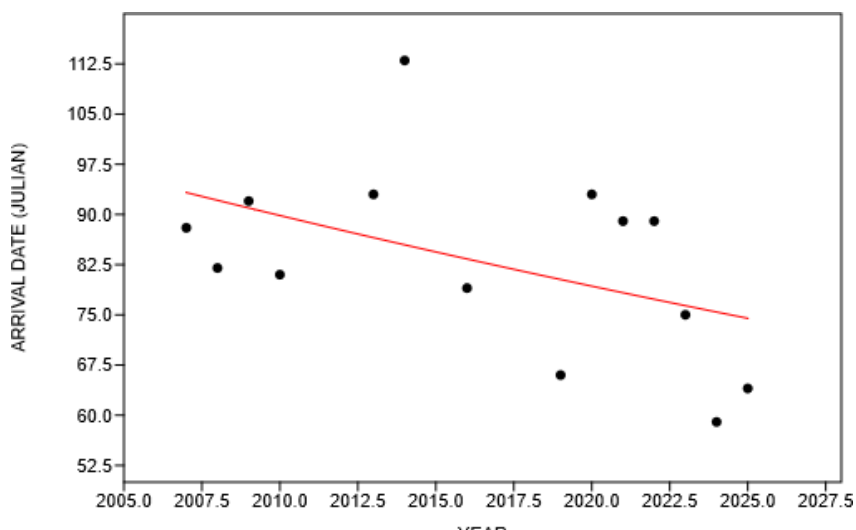
#### *C1. Part of the GWP population is becoming resident*

During the last 30 years, an increasing number of adult and immature GWP have stopped migrating south in the autumn and instead spend the winter in Greece, with increasing numbers of up to 40 individuals counted in Lake Kerkini (Papadopoulos, K. pers. comm.) and up to 140 individuals in Karla Reservoir (Catsadorakis, G. unpubl. data). This phenomenon should probably be attributed to the increasing average winter air (and water) temperatures in northern Greece, where these birds were staging before starting their south-bound migration in the autumn. It thus seems that a separate population is eventually formed with a resident or a short-distance migration behaviour. The implication of this, in combination with higher availability of prey during winter in many lowland wetlands and especially at Lake Kerkini, is that a number of these resident GWP obtain a physical body status suitable for breeding early in the season and very much earlier than the arrival of the migrant part of the population in spring.

#### *C2. Earlier initiation of breeding in Prespa for part of the GWP population*

There are two differences observed in the phenology of GWP in relation to their arrival at their breeding grounds in Prespa in the period 2007-2025: Firstly, there is a marginally statistically significant (GLM, Poisson distribution, log link,  $p=0.009$ , Fig. 6) advancement of the arrival date by -0.0125 % every year between 2007 and 2025 (usually of the first >20 individuals). This advancement can be misleading, however, because of the second phenological issue that has arisen: after 2006, every year less than 10 GWP individuals have arrived very early in Prespa along with the first DP and they start laying eggs between 14<sup>th</sup> January and 30<sup>th</sup> March.

We assume that these are birds that have overwintered in Greece, in lower-lying wetlands, and especially Lake Kerkini, a low-lying, extremely productive lake. Very often it is difficult to say with certainty when exactly the first groups of truly migrant birds arrive, as they are mixed with these birds.



**Figure 6.** Arrival date of the first migratory GWP in Prespa from their winter quarters, 2007-2025 (n=14), there are no data for the years 2011-12, 2015, and 2017-2018.

#### **D. High temperatures in Prespa during spring-summer**

The risk of algal blooms and cyanotoxin outbreak events is higher during prolonged high temperatures, and this can negatively impact all waterbirds in Prespa, as they are subject to higher exposure to various pathogens and there is higher adult mortality (Papadimitriou et al. 2018, Verstijnen et al. 2018). Algal blooms have started appearing in the Prespa lakes since 2010 and re-appeared in 2016 (Moustaka-Gouni et al. 2019) with *Dolichospermum lemmermannii*, *Anabaena* spp., while an *Aphanizomenon flos aquae* outbreak in March 2025 affected a very large part of Great Prespa Lake in all three littoral countries (Tsiaousi 2025).

## **4. DISCUSSION AND IMPLICATIONS FOR CONSERVATION**

Due to falling water levels, all reedbed nesting herons at the Prespa lakes face increasing difficulties in securing proper, flooded nesting sites and open, shallow foraging sites, these latter ideally as close as possible to the former. In the current transitional period of rapidly falling water levels, this lack is amplified by increased predation. Two species (grey heron and little egret) have already started shifting to another nesting habitat (large trees on an island), but this is not feasible for other species with incompatible traits. At the same time, feeding sites in Great Prespa Lake tend to be more distant, and this places energy constraints on all species that nest

in Lesser Prespa Lake. A future shift of heron colonies to reedbeds in Great Prespa Lake cannot be foreseen at present, as all the reedbeds around Great Prespa have dried up due to a rapid fall of water level that has not been matched by an expansion of reedbeds into the receding shallow water line.

Although monitoring of the breeding population sizes of all large waterbirds has been in place for over 40 years in the Greek part of Prespa, to avoid disturbance we have refrained from collecting detailed and systematic data on phenology and breeding success of herons and cormorants. Yet, we do have indications that a large, dense and more compact mixed colony of these birds in a suitable habitat offers more benefits (higher synchronization, higher social stimulation and facilitation, protection against predators, etc.) than costs, and attains higher breeding success than multiple scattered smaller colonies, which lead to a lower annual recruitment and ultimately to a population decrease.

With regard to the Dalmatian pelican, the situation is more complex. Up to 2022, the breeding population showed signs of having reached the carrying capacity of the wetland for breeding. However, climate change and other factors have differentially affected the wintering site (Kerkini, low-lying at 36 m asl, "decision-making site") and the breeding site (Prespa, high-altitude wetland, 854 m asl, "wetland of selection"). The birds have responded to the higher temperatures in Kerkini (which allow sustained activity of fish in winter) and other low-lying wintering sites, and to the population increase, by advancing their laying dates in Prespa (Doxa et al. 2012). The advancement of phenology of arrival in the breeding grounds and laying dates has been documented widely for many bird species (Visser et al. 2004). Temperatures at different locations (wintering versus breeding area) have been shown to change in different ways, as has the fact that climate change is advancing spring phenology, but not all components of food chains shift their phenology at the same rate (Visser et al. 2004).

However, as Visser & Both (2005) showed, when phenological shifts relative to food supply were at stake, the focal species shifted either too little or too much (Maclean et al. 2007). Dalmatian pelicans in Prespa have over-advanced too, mistiming the onset of the breeding season for early breeders. This mistiming was manifested through a mismatch between fish unavailability and the energy demands of the birds; as has been shown in many other cases, food availability is very low to nil for parents, both when incubating and when feeding their young (Sanz et al. 2003).

The over-advancement was likely a product of density-dependence and the mismatch triggered two adaptive responses: while the earliest birds abandoned their nests and eggs to travel outside

Prespa to low-lying wetlands to find food and then most likely made replacement nests, another group of early breeders risked leaving their chicks unattended at a very young age and increased their brooding shift time from 1.5-2 days to 3.5-4 days (a second adaptation trait).

The carrying capacity of Lesser Prespa Lake in pelican nesting habitats will certainly diminish as lowering water levels create “land bridges” and render many of the reed-rhizome islets (on which pelicans nest) unsuitable for nesting. Moreover, the rapidly falling water levels and shifting reedbed edges do not allow the creation of new reed-rhizome islets, and in the near future, available proper nesting sites for the ground-nesting pelicans and cormorants will cease to exist. However, the existing four rocky islands in the lakes might be able to host pelican and cormorant colonies in the future.

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## MONITORING OF THE PHYSICO-CHEMICAL CHARACTERISTICS OF THE GREAT PRESIPA LAKE

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### ABSTRACT

Freshwater ecosystems play a vital role in environmental sustainability, human consumption, and local livelihoods. Prespa Lake, one of the largest freshwater lakes in the region, is an important water resource, yet its quality may be affected by natural and anthropogenic factors. This study aimed to monitor and evaluate the physicochemical characteristics of the Great Prespa Lake to determine its suitability for human use and environmental health. Field measurements were conducted at multiple locations around the lake, including pH, water temperature, conductivity, and dissolved oxygen. Water samples were collected and analyzed in the Analytical Chemistry Laboratory at the Faculty of Human and Natural Sciences, Department of Biology-Chemistry, using standard and currently approved analytical methods. Laboratory analyses included general water hardness (°dH), calcium and magnesium hardness, nitrite, ammonia, and chloride concentrations. The results showed that water hardness ranged from 6.42 to 6.44 °dH, classifying the water as hard and unsuitable for drinking. Calcium and magnesium levels were moderate to low, ammonia was present at trace levels, and nitrite concentrations were generally low but higher near populated areas. Chloride concentrations ranged from 3–10 mg/L, with elevated levels observed in inhabited zones. Water pH varied between 7.22 and 7.68 during the spring season. Overall, these results indicate that while the lake's water may be suitable for limited use, its quality requires careful management to ensure the safety of local populations and the preservation of the aquatic ecosystem.

**Keywords:** The Great Prespa Lake, water quality, physicochemical indicators, water hardness, pH, nitrite, ammonia, chloride

### 1. INTRODUCTION

Water is very widespread in nature: 71% of the surface of the globe, with an area of 361 million [km<sup>2</sup>] and a volume of 1300 million [km<sup>3</sup>], consists of water. Water in nature is divided into two main groups: underground waters and surface waters. Underground waters refer to the water present beneath the Earth's surface, filling the pores and cracks present in rocks. They constitute about 1.7% of the total water present on the planet. They are used mainly for agricultural, communal, and industrial purposes. Underground waters make up about 22% of the water we use. Surface waters and underground waters are connected through the hydrological cycle; most underground waters come from precipitation, which infiltrates beneath the surface and, once the ground becomes saturated, continues to move downward until, at a certain depth, it joins a rock layer.

Surface water is the water found on the surface of the Earth in rivers, streams, lakes, oceans, glaciers, etc. Due to the ease of access, surface water provides about 78% of the fresh water we use. Surface water takes part in the hydrological cycle, which includes the movement of water to and from the Earth's surface; precipitation and runoff feed surface water bodies, while evaporation and infiltration into the ground cause these bodies to lose water. There exist three types of surface water: perennial, transitional, and man-made.

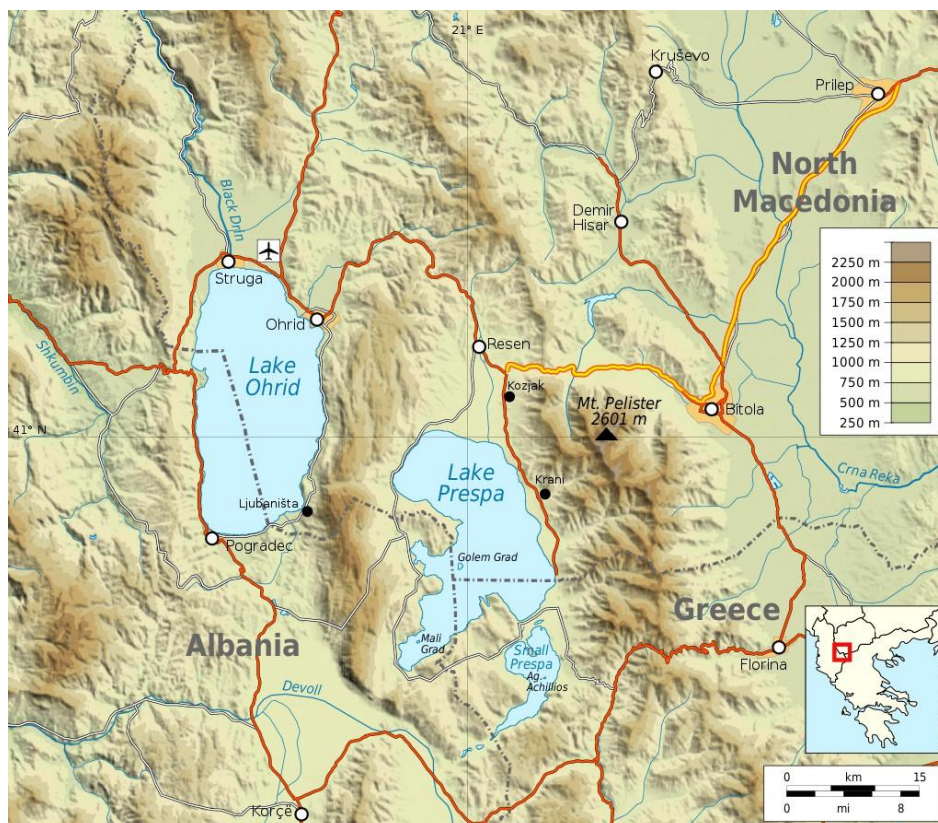
### **Meteoric and telluric waters**

Meteoric waters (from the Greek meteoros, meaning "above the ground") are formed from the condensation of water vapour present in nature, such as rain, snow, hail, dew, etc. Meteoric waters contain a certain amount of dissolved substances, such as oxygen, nitrogen, carbon dioxide, and other atmospheric gases; together with these, meteoric waters also carry various impurities present in the air, including microorganisms. Despite this content of foreign matter, meteoric waters are considered much cleaner than telluric waters. As they fall to the ground, meteoric waters become enriched with mineral salts and other substances depending on the type of soil with which they come into contact.

Telluric waters (from the Latin tellus, meaning "earth") consist of spring waters, well waters, and the waters of rivers, lakes, seas, etc. Telluric waters contain a considerably larger amount of dissolved substances and mechanical impurities than rainwater. Spring waters are good drinking waters and can be used directly for food purposes; depending on the nature of the soil they pass through, they contain varying amounts of dissolved salts and gases and have different temperatures. River and lake waters, when not polluted by industrial discharges or by inhabited centres, usually contain a small amount of salts and organic matter and are characterized by low temporary hardness; with the development of industry and the growth of inhabited centres, these waters have gained great importance as sources of drinking water, and river and lake waters are usually rendered potable after undergoing treatment processes.

### **Lake Prespa**

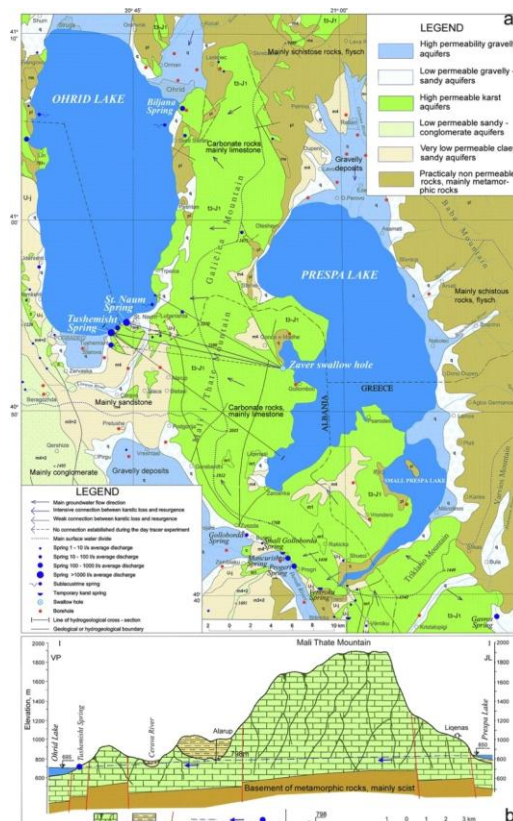
Prespa, or Lake Prespa, is one of the freshwater lakes in Europe, belonging to three countries: North Macedonia, Albania, and Greece, with a total surface area of 318.9 km<sup>2</sup>, of which 190 km<sup>2</sup> belongs to North Macedonia, 84.8 km<sup>2</sup> to Greece, and 38.8 km<sup>2</sup> to Albania. Prespa is the highest tectonic lake in the Balkans, at 853 metres above sea level. Prespa as a whole is divided into two lakes: Great Prespa and Small Prespa, which are the only lakes in the Balkans that have islands.



**Map 1.** Topographic map of Lake Prespa and Lake Ohrid

The first hydrogeological studies of the Prespa and Korça area began in 1960 and have continued since. The dominant ions in the chemical composition of the waters are  $\text{HCO}_3^-$ ,  $\text{Ca}^{2+}$ , and  $\text{Mg}^{2+}$ , although there are also zones with a high content of  $\text{Na}^+$ ,  $\text{SO}_4^{2-}$ , and, more rarely,  $\text{Cl}^-$ . The lake loses its water due to the calcareous character of Mount Galiçica and drains into Lake Ohrid, at Shën Naum and the springs of Bljanë. The lake is fed by underground springs and by several rivers that flow into it. Lake Prespa is between one and five million years old, which makes it one of the oldest freshwater ecosystems on the continent.

The climate of the area is Mediterranean-mountainous (Jaho et al., *Klima e Shqipërisë*, 1975), with a fairly dry and cool summer and a wet and cold winter. The average annual temperature is about 10.7 °C; in summer the average temperature is about 25 to 30 °C, and in winter about 0 to 10 °C. Average precipitation is about 722 mm/year, most of which falls during the winter season (70%).



**Map 2.** Geological map of Lake Prespa

## Characteristics of drinking water and water hardness

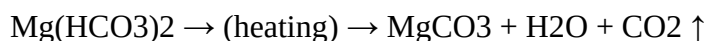
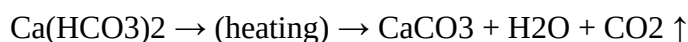
Organoleptic, chemical, and microbiological analyses of water are very important, since without prior knowledge of these properties, water cannot be used in any technological process of the food industry. Among the most important indicators are water hardness and the content of ammonia, nitrite, nitrate, hydrogen sulphide, etc. As regards chemical composition, water hardness is of particular importance, and its determination is essential, especially when the water is to be used to generate steam; water with high hardness forms the so-called "scale" in boilers.

Water hardness is the indicator that shows the amount and type of alkaline-earth salts dissolved in water; quantitatively, hardness is assessed in mg-equivalents/l of alkaline-earth ions. According to degree of hardness, waters can be divided as follows: very soft water, 0-4.2 German degrees (0-1.5 mg-eq/l); soft water, 4.2-8.4 German degrees (1.5-3 mg-eq/l); medium water, 8.4-16.8 German degrees (3-6 mg-eq/l); hard water, 16.8-28.8 German degrees (6-10 mg-eq/l); very hard water, above 28 German degrees (above 10 mg-eq/l).

According to Albanian norms, drinking water permitted for use in the food industry must meet the following physico-chemical indicators: pH between 6.5 and 8.5; temperature 8-15 °C; general hardness 10-20 German degrees; nitrite - not permitted; nitrate up to 45 mg/l; ammonium ions (NH<sub>4</sub>) up to 0.1 mg/l; oxidizability up to 4 mg/l; chloride ions up to 250 mg/l; calcium ions up to 200 mg/l; iron ions up to 0.3 mg/l; sulfate ions up to 250 mg/l; dry residue up to 1 g/l; free chlorine 0.1-0.3 mg/l.

## Types of hardness

Besides the German degree ( $^{\circ}\text{Gj} = 1 \text{ mg CaO}/100 \text{ ml}$ , expressed as ppm  $\text{CaCO}_3$ ), other units are also used in practice to assess water hardness: the English degree ( $^{\circ}\text{A} = 1 \text{ mg CaCO}_3/\text{gallon}$ ) and the French degree ( $^{\circ}\text{F} = 1 \text{ mg CaCO}_3/100 \text{ ml}$ ). By general hardness ( $\text{Ft}$ ) is meant the total quantity of calcium and magnesium salts found in the water. Permanent hardness ( $\text{Fp}$ ) refers to the content of those types of Ca and Mg salts which, during the boiling of water, do not change and do not decompose; this hardness is owed mainly to the carbonates, sulfates, and chlorides of alkaline-earth metals. Temporary hardness ( $\text{Ft}$ ) refers to the content of calcium and magnesium hydrogen-carbonates, together with their carbonates; this hardness is called variable, because the salts that make it up decompose, under high temperature (heating above  $60^{\circ}\text{C}$ ), into carbonates that precipitate,  $\text{CO}_2$  (which escapes), and water, following the reactions:



A second, simplified classification of waters according to hardness, also used in the practical part of this study, divides waters as follows: soft water, 0-3 mg-eq/l; medium water, 3-6 mg-eq/l; hard water, 6-9 mg-eq/l; very hard water, above 9 mg-eq/l.

## Spring, well, and sea waters

Spring waters are good drinking waters and can be used directly for food purposes. Depending on the nature of the soil they pass through, these waters contain varying quantities of salts and dissolved gases and have different temperatures. Some of these waters contain small quantities of salts (under 200 mg/l), while most of them contain 600-1000 mg/l and are considered the most suitable for drinking; waters containing salts above 1000 mg/l have a distinctive taste and are generally not pleasant.

Well waters are drawn from water layers found beneath the ground. According to depth, these waters can be divided into two groups: waters of shallow layers and waters of deep layers. The composition of the shallow well-layer waters (usually a few metres deep) varies according to the nature of the soil and its filtering properties; since these waters, in many cases, can be reached by impurities from drains, waste dumps, etc., measures must be taken to prevent such contamination and to periodically check the water's cleanliness. Waters of the deep soil layers and of artesian wells, several tens or hundreds of metres deep, are microbiologically clean and contain little organic matter, because they are filtered as they pass through the ground; these waters have a constant chemical composition, are rich in minerals and endogenous gases, and are distinguished by their characteristic taste.

Sea waters cannot be used directly as drinking water because they contain large quantities of salts (on average 3-5%, of which sodium chloride accounts for about 2.5%). The water of the Adriatic Sea contains 3.7-3.86% dry matter, of which 2-2.3% is sodium chloride. Today, sea waters, after being purified through treatment plants, also serve as sources of drinking water.

## 2. METHODOLOGY

The analyses were carried out at the Analytical Chemistry Laboratory of the Faculty of Human and Natural Sciences, Department of Biology-Chemistry, Fan S. Noli University of Korça.

### 2.1 Sampling

Water samples were collected from four monitoring points around the Great Prespa Lake: Gorrica e Vogël, the middle of the lake, Gollomboc, and Pustec. Samples were collected in stoppered plastic bottles that had been pretreated for 10 minutes with 20 ml of a saturated potassium permanganate solution and then with 10 ml of concentrated sulfuric acid; the bottles were then rinsed with large quantities of ordinary water until all acidity of the rinse water disappeared, followed by several rinses with distilled water.



*Figure 1. The sampling process*

At the moment of sampling, each bottle was rinsed three times with the water to be analyzed and then filled to the brim, in such a way that, once the stopper was inserted, no air bubble remained inside. A cardboard label was then tied or glued to the neck of the bottle. When river, reservoir, or cistern water was analyzed, the bottle was submerged to a certain distance from the bottom and from the surface, in a zone sufficiently far from the shore, taking care that sediment was not stirred up. If the composition of a water body changes during the day, sampling was repeated several times at set hours so that the sample would correspond to the average composition. Sampling was carried out during the spring season.

## **2.2 Organoleptic analyses**

Determination of odour was carried out both cold and warm. In the cold test, at least 200 ml of

water was placed in a 500 ml stoppered glass bottle; after closing, the contents were shaken vigorously, the stopper was removed, and the water was smelled immediately. The warm test, used especially for waters with a light odour not detectable when cold, was carried out by placing the same volume of water in a stoppered 500 ml glass vessel, immersing it in a warm water bath (about 70 °C) up to the water level inside, and leaving it until the water inside reached 40-60 °C, at which point the temperature was measured with a thermometer while the water was smelled at the same time. Taste was assessed on a roughly 200 ml sample, after first rinsing the mouth, both at the standard temperature and after warming the sample to 30 °C in a water bath.

## **2.3 Determination of general hardness**

Reagents: (a) Eriochrome Black T indicator solution, 4 g/l in ethyl alcohol; (b) buffer solution, prepared by dissolving 5.4 g ammonium chloride and 350 ml of 25% ammonia in a 1-litre calibrated flask, made up to volume with water; (c) 0.2 N Complexon III solution (the disodium salt of ethylenediaminetetraacetic acid), prepared by dissolving 3.72 g of Complexon III in a 1-litre calibrated flask, made up to volume with water. Procedure: a 100 ml sample was taken and heated to about 60 °C; 5 ml of buffer solution and about 15 drops of indicator were added, and the sample was titrated with the Complexon III solution until the colour changed from red to blue-green, confirmed by verifying that one further drop produced no additional colour change. Calcium and magnesium hardness were determined following the same titration principle, using reagents selective for each ion; general hardness was expressed first in French degrees and then converted to German degrees.

## **2.4 Qualitative determination of ammonia**

Reagents and equipment: HgI<sub>2</sub>, KI, NaOH, technical balance, watch glass, dark 100 ml bottle, 50 or 100 ml cylinders. Seignette-salt solution was prepared by dissolving 100 g of Seignette salt in 200 ml distilled water, then adding 10 ml of Nessler's reagent; after 1-2 days the solution was separated from the sediment that formed at the bottom of the vessel. Nessler's reagent itself was prepared by dissolving 10 g HgI<sub>2</sub> and 5 g KI separately in 20-30 ml ammonia-free distilled water, dissolving 20 g NaOH in 70 ml of the same water, then combining the two solutions in a well-stoppered bottle; the reagent is turbid at first and clears after 2-3 days.

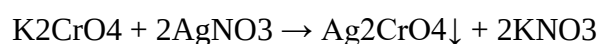
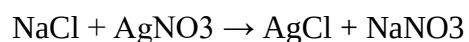


**Photo 1.** Titration process, recording the general hardness results converted to German degrees

Procedure: in a 100 ml round-bottom flask, 20 ml of the water sample to be analyzed was measured with a cylinder; 10 drops of Seignette-salt solution and 3-5 drops of Nessler's reagent were then added with a dropper. In the presence of ammonia, the water takes on a yellow or brownish colour, the intensity of which is proportional to the ammonia content: a light yellow colour indicates 0.2-1 mg NH<sub>3</sub>/l, a light brownish colour indicates about 2 mg/l, a pronounced brownish colour indicates about 3 mg NH<sub>3</sub>/l, and a brownish turbidity indicates an ammonia content above 7 mg/l (requiring dilution for more precise determination). A blank test using ammonia-free distilled water was always carried out alongside the sample for colour comparison.

## 2.5 Determination of chlorides

Qualitative/approximate procedure: to 20 ml of the water sample in a conical flask, 10 drops of dilute nitric acid were added, followed by 1 ml of 0.1 N AgNO<sub>3</sub>. The turbidity produced is proportional to chloride content: opalescence without turbidity indicates 3-10 mg/l Cl; opalescence with slight turbidity, 10-15 mg/l; weak turbidity, 15-20 mg/l; normal turbidity, 20-30 mg/l; heavy turbidity through which objects remain visible, 30-80 mg/l; heavy turbidity through which objects are not visible, 90-150 mg/l; a curd-like precipitate forming with time, 150-300 mg/l; and an immediate compact white curd-like mass, above 300 mg/l. For precise quantitative determination, the Mohr method was used: 20 ml of sample was treated with 5-6 drops of 5% K<sub>2</sub>CrO<sub>4</sub> solution, turning the water yellow, and titrated with 0.1 N AgNO<sub>3</sub> until a persistent light brick-red colour appeared, marking the formation of silver chromate:



Chloride content was then calculated from the volume of AgNO<sub>3</sub> consumed, knowing that 1 ml of 0.01 N AgNO<sub>3</sub> is equivalent to 0.355 mg Cl, using the formula  $X = n \times 0.355 \times 100 / 20$ , where X is the chloride content in mg/l and n is the ml of 0.01 N AgNO<sub>3</sub> used in the titration.

## 2.6 Quantitative determination of nitrite

Reagents: spectrophotometer and 50 or 100 ml flasks (10 pieces); 12% acetic acid solution (120 ml concentrated acetic acid in 880 ml distilled water); sulfanilic acid solution (0.5 g sulfanilic acid dissolved in 150 ml of the 12% acetic acid solution);  $\alpha$ -naphthylamine solution (0.2 g dissolved in 20 g boiling water, filtered, then diluted with 180 ml of the 12% acetic acid solution); standard sodium nitrite solution (0.15 g NaNO<sub>2</sub> dissolved in 1 litre distilled water, of which 25 ml was further diluted to 500 ml, giving a solution in which 1 ml contains 0.0075 mg NaNO<sub>2</sub>). The Griess reagent was prepared, immediately before use, by mixing equal volumes of the sulfanilic acid and  $\alpha$ -naphthylamine solutions.

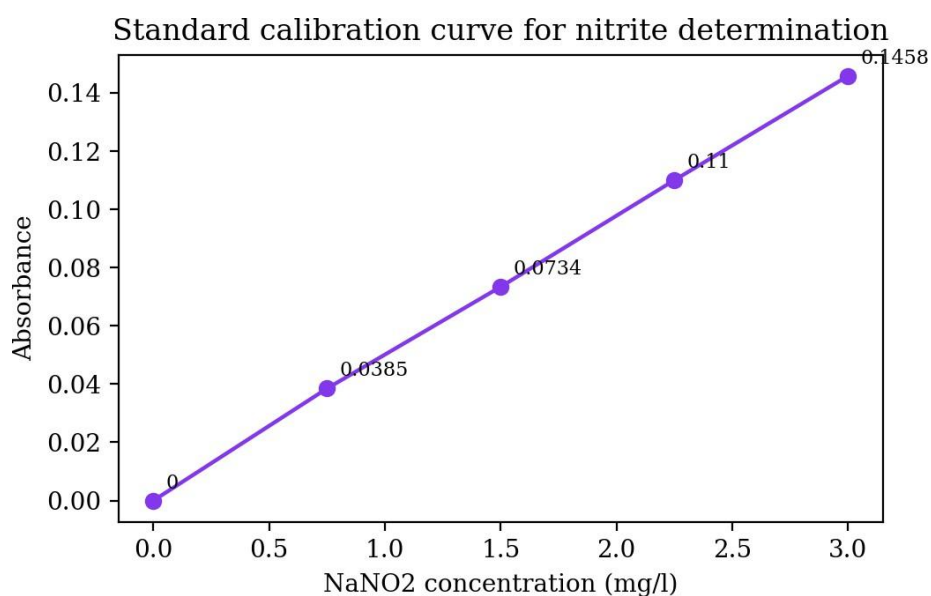


**Photo 2.** Measuring nitrite content in water with the spectrophotometer

Preparation of the standard curve: a series of ten 100 ml flasks was filled with increasing known quantities of the standard nitrite solution (1 mg, 2 mg, 3 mg ... up to 10 mg in the tenth flask), made up to volume with distilled water, and the absorbance of each resulting solution was measured with a photoelectrocolorimeter at a wavelength of 580 nm. The standard curve was then constructed by plotting the known nitrite concentration of each flask against its measured absorbance. A subset of the calibration points obtained is shown in Table 1.

**Table 1.** Standard calibration points for nitrite determination

| Standard sample | NaNO <sub>2</sub> (mg/l) | Absorbance |
|-----------------|--------------------------|------------|
| 1               | 0                        | 0          |
| 2               | 0.75                     | 0.0385     |
| 3               | 1.5                      | 0.0734     |
| 4               | 2.25                     | 0.11       |
| 5               | 3                        | 0.1458     |



**Chart 1.** Standard calibration curve for nitrite determination, built from the data in Table 1

To determine nitrite in the lake water samples, 10 ml of each sample was placed in a 100 ml flask together with 15 ml of Griess reagent, made up to volume with nitrite-free distilled water, and its absorbance was measured against the standard curve; the nitrite content obtained for the 10 ml portion was multiplied by 100 to express the concentration per litre.

## 2.7 Reference standards

The obtained values were compared against the national standards applicable to drinking water in Albania, which set reference limits for pH (6.5–8.5), general hardness (10–20 °dH), nitrite (not permitted), nitrate (up to 45 mg/l), ammonium (up to 0.1 mg/l), and chloride (up to 250 mg/l).

### 3. RESULTS

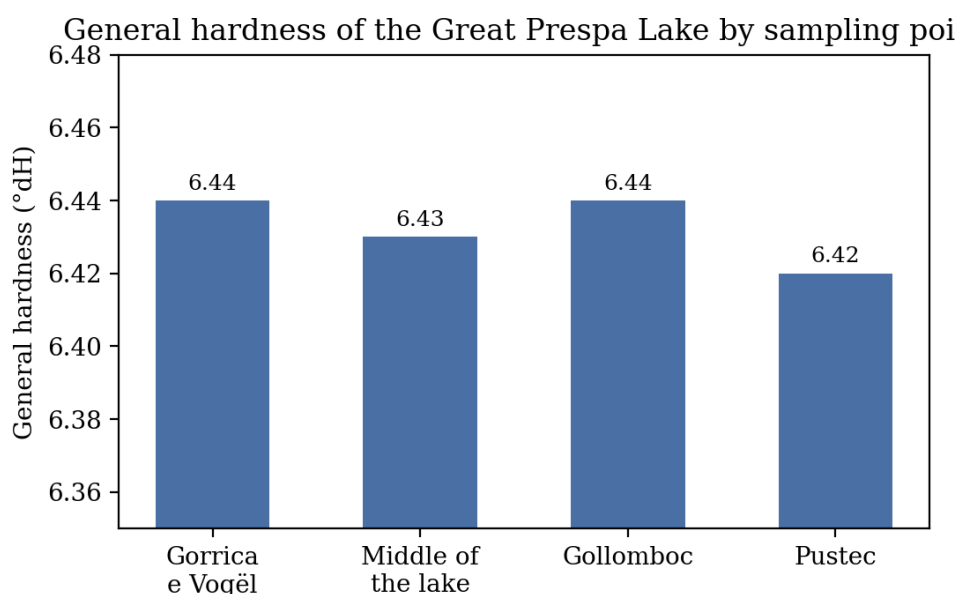
The physico-chemical characteristics measured at the four monitoring points of the Great Prespa Lake are summarized in Table 2.

**Table 2.** Summary of physico-chemical analyses of the Great Prespa Lake waters

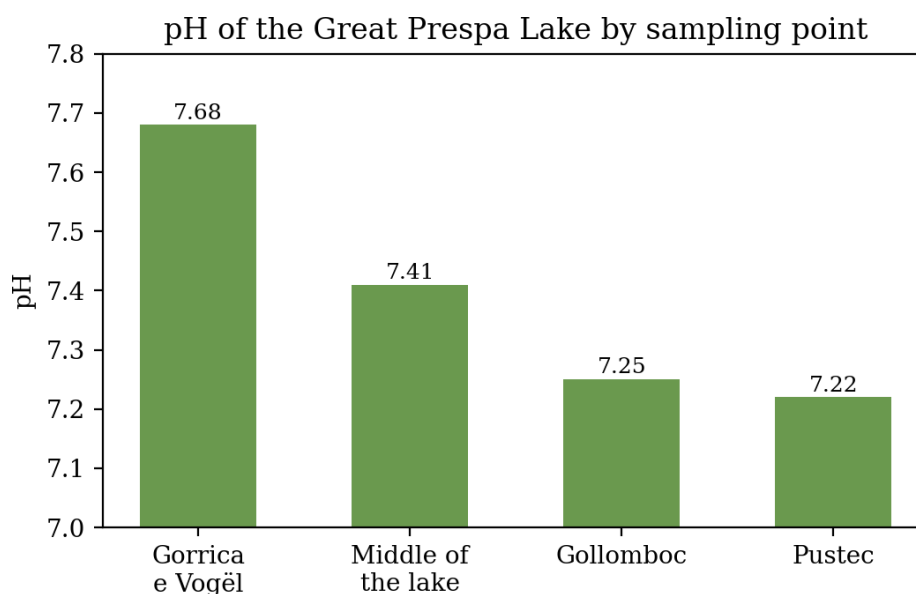
| Parameter                | Gorrica e Vogël | Middle of the lake | Gollomboc | Pustec  |
|--------------------------|-----------------|--------------------|-----------|---------|
| Ph                       | 7.68            | 7.41               | 7.25      | 7.22    |
| Conductivity (µS/cm)     | 278.9           | 263.5              | 276       | 277.6   |
| Dissolved O2 (mg/l)      | 10.2            | 10.6               | 10.3      | 9.7     |
| Temperature (°C)         | 6.8             | 7.2                | 6.8       | 7.8     |
| General hardness (°dH)   | 6.44            | 6.43               | 6.44      | 6.42    |
| Calcium hardness (°dH)   | 4.76            | 4.64               | 4.76      | 4.64    |
| Ca (mg/l)                | 34              | 33.2               | 34        | 33.2    |
| Magnesium hardness (°dH) | 1.68            | 1.8                | 1.68      | 1.8     |
| Chloride                 | trace           | not detected       | Present   | present |
| Nitrite (mg/l)           | 0.0625          | 0.00416            | 0.0187    | 0.09375 |

Additional qualitative observations recorded during monitoring showed that all sampled waters were odourless, colourless, and free of any foreign taste. No ammonium ions were detected in any of the samples. Nitrite ions were detected mainly in samples collected near populated areas along the lake shore. Similarly, chloride content, although present across most samples, was noticeably higher in the samples collected near inhabited zones.

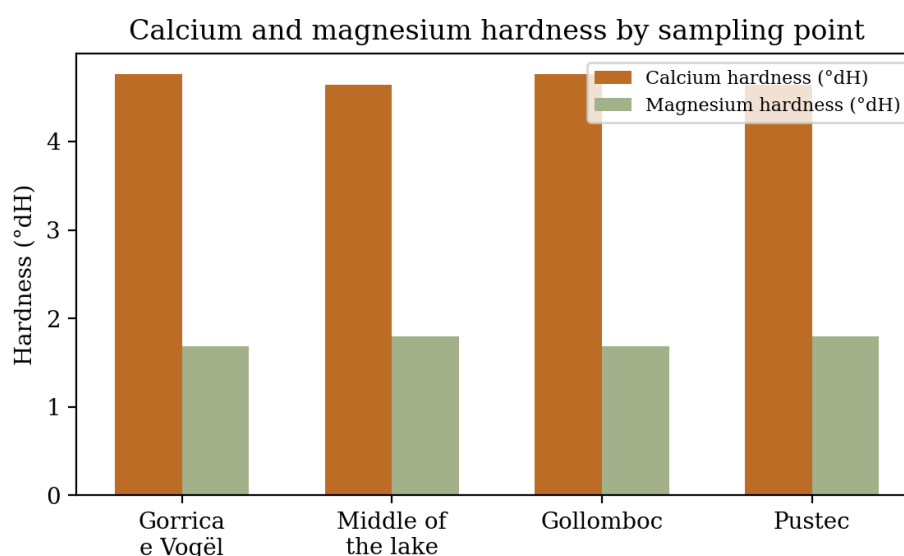
The data in Table 2 are presented graphically in Charts 2-4 below, reconstructed from the titration and field-measurement results.



**Chart 2.** General hardness of the Great Prespa Lake by sampling point, from the titration results



**Chart 3.** pH of the Great Prespa Lake by sampling point



**Chart 4.** Calcium and magnesium hardness of the Great Prespa Lake by sampling point

#### 4. DISCUSSION

The general hardness of the Great Prespa Lake, ranging between 6.42 and 6.44 °dH across all sampling points, falls below the national reference range established for drinking water (10–20 °dH). On this basis, and as also stated in the study's own conclusions, these waters are considered hard waters and are not suitable for drinking. Calcium and magnesium concentrations, which determine this hardness, were found at moderate to relatively low levels, consistent with the geochemical composition of the carbonate-rich watershed that feeds the lake.

The absence of detectable ammonium ions in all samples, together with the trace-level presence of ammonia, indicates a low degree of organic pollution from decomposing proteinaceous matter at the time of sampling. Nitrite concentrations, while generally low across the lake as a whole, were comparatively higher in samples collected near populated shoreline areas such as Pustec, suggesting a localized anthropogenic influence, most likely associated with domestic wastewater discharge or agricultural runoff reaching the lake in these zones.

Chloride concentrations, ranging from 3 to 10 mg/l, remained well below the national limit of 250 mg/l for drinking water; nevertheless, the pattern of higher chloride content near inhabited areas mirrors the nitrite results and reinforces the interpretation that human settlement along the shoreline is exerting a measurable, if still moderate, pressure on water quality. The pH values recorded, between 7.22 and 7.68, fall within the neutral-to-slightly-alkaline range considered acceptable under national standards (6.5–8.5), indicating no evidence of acidification or alkalization of the lake.

Taken together, these findings are consistent with previous physico-chemical assessments of freshwater sources in the Korça region, which similarly identify proximity to human settlement as a key factor influencing water quality indicators, and underline the importance of continued, season-spanning monitoring to capture the full variability of the lake's water chemistry.

## 5. CONCLUSIONS

From the analysis carried out on a number of sites of Lake Prespa, we reached the following conclusions:

- The general hardness for Lake Prespa, as analyzed by us, is  $F_p = 6.42\text{--}6.44$  German degrees.
- These are considered hard waters and are not suitable for drinking.
- From this result we see that the quantity of Ca and Mg salts from the lake has a content that is medium to partially low.
- The ammonia content during monitoring is considered to be at trace levels.
- The pH of the water varies between values of 7.22 to 7.68 (measured during the spring period).
- The nitrite content during monitoring is considered to range from trace levels up to high nitrite levels.  $\text{NO}_2^-$  ions are present.
- The chloride ( $\text{Cl}^-$ ) content during monitoring is considered to be at levels of 3–10 mg/l.
- The safety of the population that uses these sources is not good, with regard to the basic indicators.

## 6. RECOMMENDATIONS

- Fan S. Noli University, Korçë, has a strong laboratory base, both in the Faculty of Natural and Human Sciences and in the Faculty of Agriculture.

- In the university's prospective plans, concrete research work should prevail compared to theoretical work, in coursework, diploma theses, etc.
- Water monitoring with chemical analyses should continue, in other seasons as well.
- Water monitoring with chemical analyses of microelements should continue, in the new scientific laboratory built at the FShNH, etc.
- The regulations in the sanitary zones around the sources should be strictly enforced.
- Cooperation with the local authorities, the Korça Regional Water Supply and Sewerage Company, and other universities within and outside the country should be raised to a higher level, so that the issues in this field, as well as in the field of environmental protection and care, are effective and serve the policies to be applied for the region.

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## **FOOD SAFETY AND MICROBIOLOGICAL QUALITY ASSESSMENT OF RIVER WATER USED FOR IRRIGATION IN THE KORÇA REGION**

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### **ABSTRACT**

Pollution of aquatic ecosystems from various sources constitutes one of the most significant concerns in our society. The quality of river water used for agricultural irrigation is particularly important due to its direct impact on food safety and human health concerns. It is estimated that the primary contamination of agricultural products, especially vegetables, by pathogens originates from water. Microbiological indicators are quite important for assessing water quality for agricultural purposes as well as for identifying various pollutants.

The present study utilized standard analytical and modern (spectrophotometric) methods to evaluate the most important microbiological and physicochemical indicators in the waters of the Devoll and Dunavec rivers. Microbiological indicators included *Escherichia coli* as an indicator of fecal contamination, while physicochemical parameters such as Biochemical Oxygen Demand (BOD<sub>5</sub>), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS), were also determined. Based on the obtained results, the waters of the Devoll and Dunavec rivers were classified as Class II, according to applicable water quality standards. These waters are not suitable for food crops to be consumed fresh, where the edible parts are in direct contact with the water, or for root crops that are consumed raw. Overall, the waters of these rivers are considered suitable for irrigating other crops. The study's reliance on microbiological indicators of the waters of the Devoll and Dunavec rivers identified potential sources of pollution, contributing to determining pathways for improving ecosystems and food safety.

**Keywords:** River water quality; Irrigation water; Microbial contamination; *Escherichia coli*; Physicochemical parameters; Korça region

## 1. INTRODUCTION

Pollution of ecosystems is one of the major global concerns today. The lives of aquatic animals, the irrigation of agricultural crops, the quality of food products, and the soil irrigated by these waters are significantly affected by the quality of river waters.

The study focused on assessing the microbiological and chemical indicators of the waters of the Devoll and Dunavec rivers for agricultural purposes and identifying the sources of pollution. Korça field is traversed by two main rivers: the Devoll River and the Dunavec River.

The Devoll River (196 km) is one of the main rivers in Albania. Its waters are used to irrigate approximately 10,000 hectares of land in the Korça region. The Dunavec River is the main river in the southern part of Korça's field. It flows through the field from south to north for about 15 km until it meets the Devoll River near Maliq.

Agriculture is a sector significantly impacted by pollution. The most important microbiological and chemical indicators regarding water quality for irrigation of crops include: *Escherichia coli*, Biochemical Oxygen Demand (BOD5) Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and chloride content (Cl<sup>-</sup>). Flowing water absorbs oxygen from the atmosphere. Various chemical reactions and the decomposition of organic materials consume oxygen. Wastewater contains organic materials decomposed by microorganisms, which use oxygen in the process. River water is widely used for agricultural irrigation in many regions, but its microbiological quality is a critical factor for **food safety and public health**. (Food Safety Book Ian. C. Shaw., 2010)

Contaminated irrigation water can serve as a direct source of pathogenic microorganisms, facilitating their transfer to crops and soil and increasing the risk of foodborne diseases. (Anh et al., 2023). Cl<sup>-</sup> in river waters plays an important role in reducing the content of *Escherichia coli* (Abnavi et al., 2021; Owoseni et al., 2017).

Hence, indicators such as Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD5), Total Suspended Solids (TSS), and chloride content serve as indirect markers for evaluating river water quality from a microbiological perspective.

The anthropogenic factor is considered the main contributor to the deterioration of water quality in Albania (Hoxha et al., 2009; Sulçe et al., 2018). Surface water pollution in Albania has increased in recent years (Bardhi et al., 2014; Lushaj et al., 2011). Numerous studies have been conducted to assess the microbial quality of drinking water and the impact of agricultural activities on ecosystem pollution. Recently, several researchers have focused their research efforts on evaluating the microbial quality of irrigation water used for agricultural production, particularly for vegetables (Gemmell & Schmidt, 2012; Omolola et al., 2022; Steele et al., 2005).

Water can be a direct source of contamination in the production of fresh crops. Many researchers identify irrigation water as a source of pathogenic microorganisms in agricultural production (Olaimat & Holley, 2012; Pachepsky et al., 2011; Park et al., 2012). Although viruses and parasites are of great importance and can be transmitted to fresh produce through irrigation water, this paper focuses mainly on pathogenic bacteria. The primary document used as a basis for assessing the microbiological quality of the waters of the Devoll

and Dunavec rivers for agricultural purposes is EU Regulation 2020/741 of the European Parliament and Council on minimum requirements for water reuse. It aims to establish standards for water quality for agricultural purposes. This regulation specifies quality requirements for several parameters, including *Escherichia coli*, Oxygen Demand (BOD<sub>5</sub>), Chemical Oxygen Demand (COD), and Total Suspended Solids (TSS). Pathogenic microorganisms in water used for irrigating crops pose the most significant risk for contamination of fresh produce and human and animal health (European Commission, 2017; FAO, 1995; WHO, 2006).

To evaluate water suitability, it is essential to compare microbiological indicators with minimum requirements based on the "fit for purpose" approach (Helmecke, Fries & Schulte, 2020). The main health risk is the consumption of vegetables irrigated with contaminated water, especially by microorganisms (Alegbeleye & Sant'Ana, 2023; Allende & Monaghan, 2015). The study applies standardized scientific methods to evaluate the microbiological and chemical quality of irrigation water from the Devoll and Dunavec rivers, identify pollution sources, and assess associated food safety risks. The results provide a scientific basis for sustainable water management and safe agricultural production in the Korça region.

## 2. METHODOLOGY

Water samples were collected at the entrances of the irrigation schemes: Zemblak dam (Devoll river → Korçe field N 40°42'9.1152" and the dam near Voskop bridge (Dunavec river → Bulgarec field N 40°37'20.55" E 20°44'14.3052"). Sampling sites were chosen where water mixing is optimal. Analyses were performed at the Chemistry-Food Technology and Microbiology laboratories of the Faculty of Agriculture, "Fan.S.Noli" University of Korçë. Sampling followed ISO 5667-3:2024 and was conducted monthly from July to September 2025. The analyzed indicators of the Devoll and Dunavec river waters are presented in Table 1.



**Fig. 1.** View of the monitoring sites along the Devoll and Dunavec rivers

**Table 1:** Analyzed Indicators of the Waters of the Devoll and Dunavec Rivers

| Indicators                                                     | Description                                                                                                                                                      |
|----------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Escherichia coli</i><br>cfu/100 ml)                         | Fecal contamination microorganism. Sanitary index.                                                                                                               |
| Biochemical oxygen demand NBO5<br>(Oxygen Demand (BOD5) (mg/l) | The concentration of dissolved oxygen consumed under specific conditions with biochemical oxidation of organic and/or inorganic substances in water over 5 days. |
| Chemical oxygen demand (COD) (mg/l)                            | The concentration of oxygen consumed through chemical oxidation.                                                                                                 |
| Total Suspended Solids (TSS) (mg/l)                            | The solid substances remain on the filter after filtration under specified conditions.                                                                           |
| Cl <sup>-</sup> (Chloride) (meq/l)                             | The concentration of Cl <sup>-</sup>                                                                                                                             |

Standard analysis methods were used to assess the microbiological quality of the waters of the Devoll and Dunavec rivers, comparing them with the standard water values for irrigation according to EU Regulation 2020/741. This regulation defines various water quality parameters for different categories of crops, which depend on the potential contact between water and the crop, the final use of the crop (e.g., raw consumption, food processing, industrial uses), and the irrigation method, as shown in Table 2.

**Table 2.** Method for measurement and Standard values for irrigation water

| Nr | Indicators                                               | Method for measurement | Units      | Standard values for irrigation water |
|----|----------------------------------------------------------|------------------------|------------|--------------------------------------|
|    | <i>Escherichia coli</i> (cfu/100 ml)                     | ISO 10523:2012         | cfu/100 ml | 0-1000                               |
|    | Biochemical oxygen demand NBO5<br>(Oxygen Demand (BOD5)) | ISO 5813-1983          | mg/l       | 0-18                                 |
|    | Chemical oxygen demand (COD)                             | ISO 6060-1989          | mg/l       | 4-7                                  |
|    | Total Suspended Solids (TSS) (mg/l)                      | ISO 11923:1997         | mg/l       | 25-50                                |
|    | Cl <sup>-</sup> (meq/l)                                  | SSH ISO 9297:2000      | meq/l      | 0-30                                 |

The integrated use of microbiological indicators of river water quality determines the quality class. This is a quite meaningful indicator. This classification, according to EU Regulation 2020/741, is presented in Table 3.

**Table 3.** Limit values of chemical parameters in rivers according to the EU Water Framework Directive (WFD)

| Indicators              | Units      | Limit values of microbiological parameters |                          |                                  |                          |                       |
|-------------------------|------------|--------------------------------------------|--------------------------|----------------------------------|--------------------------|-----------------------|
|                         |            | High status,<br>Class I                    | Good status,<br>Class.II | Moderate<br>status Class.<br>III | Poor status<br>Class. IV | Bad status<br>Class.V |
| <i>Escherichia coli</i> | cfu/100 ml | ≤ 10                                       | ≤ 100                    | ≤ 200                            | ≤ 500                    | ≤ 1000                |
| COD                     | mg/l       | >7                                         | >6                       | >5                               | >4                       | <3                    |
| BOD5                    | mg/l       | <2                                         | <3.5                     | <7                               | <18                      | >18                   |

### 3. RESULTS

The section of the Devoll River where we conducted analyses covers approximately 7,200 hectares. The main crops cultivated in this area include cereals, legumes, potatoes, sugar beet, vegetables, medicinal plants, fruit trees, and others. These crops exhibit different responses to the microbiological indicators of the irrigation water content. Microbiological analyses of the Devoll River water, conducted throughout the entire irrigation season based on standard methods, are presented in Table 4.

**Table 4.** Microbiological analyses and chemical irrigation characteristics of the Devoll River (FAO standard values accordins to Ayers and Westcot in 1985)

| Nr | Indicators              | Units                               | Standard values for irrigation water | The time when the analysis was performed |             |                |
|----|-------------------------|-------------------------------------|--------------------------------------|------------------------------------------|-------------|----------------|
|    |                         |                                     |                                      | July 2025                                | August 2025 | September 2025 |
|    | <i>Escherichia coli</i> | cfu/100 ml (colony forming unit/ml) | 0-1000                               | 48                                       | 27          | 21             |
|    | Total Dissolved Solids  | mg/l                                | 0 – 2000                             | 160                                      | 80.6        | 24.8           |

|  |                 |                         |          |      |        |       |
|--|-----------------|-------------------------|----------|------|--------|-------|
|  | Solid matter    | mg/l                    | 0 – 2000 | 325  | 330    | 354   |
|  | COD             | mg/l                    | 4-7      | 13   | 7      | 4     |
|  | BOD5            | mg/l(miligram/l)        | 0-18     | 7,37 | 3,8194 | 2,829 |
|  | Cl <sup>-</sup> | meq/l(miliequivalent/l) | 0-30     | 1,6  | 1,6    | 0,9   |

The assessment of the microbiological quality of river waters is determined based on a comparison with the allowable standards set in the EU Water Framework Directive (WFD). Based on the analysis data, it is concluded that the waters of the Devoll River are within the allowable standards regarding the indicators of *Escherichia coli* content and Biochemical Oxygen Demand (BOD5). The Chemical Oxygen Demand (COD) exceeds the permissible standards in July. The content of Cl<sup>-</sup> is above the permissible standards. The high presence of Cl<sup>-</sup> is linked to water pollution from human activity. The use of detergents and Cl<sup>-</sup> for disinfecting drinking water through wastewater is discharged into the Devoll River. According to the content of *Escherichia coli*, the main microbiological indicator, the waters of the Devoll River are classified as Class 2. These waters are not suitable for food crops that are consumed fresh, where the edible part comes into direct contact with water, or for root crops consumed raw. In an integrated manner, the waters of this river are considered good for irrigating other crops. The microbiological analyses of the water from the Dunavec River, carried out throughout the irrigation season, based on standard methods, are presented in Table 5.

**Table 5.** Microbiological analyses and chemical irrigation characteristics of the Dunavec River (FAO standard values according to Ayers and Westcot in 1985)

| Nr | Indicators              | Units      | Standard values for irrigation water | The time when the analysis was performed |             |                |
|----|-------------------------|------------|--------------------------------------|------------------------------------------|-------------|----------------|
|    |                         |            |                                      | July 2025                                | August 2025 | September 2025 |
|    | <i>Escherichia coli</i> | cfu/100 ml | 0-10000                              | 48                                       | 36          | 32             |
|    | Total Dissolved Solids  | mg/l       | 0 – 2000                             | 60                                       | 40.4        | 19.8           |
|    | Solid matter            | mg/l       | 0 – 2000                             | 328                                      | 330         | 325            |
|    | COD                     | mg/l       | 4-7                                  | 23                                       | 11.5        | 8.2            |

|  |                 |                         |      |      |     |      |
|--|-----------------|-------------------------|------|------|-----|------|
|  | BOD5            | mg/l(miligram/l)        | 0-18 | 5,72 | 4,4 | 2,9  |
|  | Cl <sup>-</sup> | meq/l(miliekuivalent/l) | 0-30 | 1    | 0.6 | 0.85 |

#### 4. DISCUSSION

The present study demonstrates that the Devoll and Dunavec rivers exhibit microbiological and chemical limitations that may compromise their suitability for agricultural irrigation.

The deterioration in their quality indicators is a result of ecosystem pollution. Improving the quality of river waters requires intervention in wastewater treatment, reforestation, the INTRODUCTION of biological methods for plant cultivation, and ecological awareness within communities.

Based on the analyzed data from the river ecosystem, the presence of pathogenic microorganisms in water used for irrigation mainly comes from fecal contamination, a conclusion supported by a range of research (Helmecke et al., 2020; Partyka et al., 2018; Reynolds et al., 2021). *Escherichia coli* is part of the coliform bacteria group and is considered an indicator of contamination from sewage. Many researchers have used *E. coli* and coliform populations as indicators for assessing microbiological safety (Delair et al., 2024; Some et al., 2021; Solaiman et al., 2020). The study confirmed significant relationships between indicators such as Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD5), Total Suspended Solids (TSS), and the microbiological content of river waters. This is also confirmed by the above-mentioned researchers.

## 5. CONCLUSIONS

Microbial pollution of freshwater ecosystems in rivers, as a result of human activity, is one of the most significant concerns regarding the sanitary quality of water used for agricultural purposes. The presence of pathogenic bacteria in river water represents the primary route for the contamination of agricultural products. Protozoa and viruses are serious threats to human health. Based on the analyzed data of microbiological indicators, the waters of the Devoll and Dunavec rivers are classified as Class 2. These waters are unsuitable for crops that are consumed fresh, where the edible parts are in direct contact with water, and for root crops that are consumed raw. The installation of wastewater treatment plants is essential for improving the quality of the ecosystem and ensuring safe food products.

This finding suggests that improving irrigation quality in the region requires an integrated approach, combining wastewater treatment, sustainable agricultural practices, ecological land management and enhanced community awareness. The results provide a practical framework for policymakers and stakeholders to prioritize water quality management strategies that safeguard both crop safety and environmental health.

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## IMPACTS ON THE DECREASING WATER LEVEL TREND OF THE GREAT PRESPIA LAKE

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### ABSTRACT

North Macedonia is part of the Balkan Peninsula. The Biggest issue concerning water scarcity is the Prespa Lake Issue. Jointly with Lake Ohrid, it forms a unique hydrological system, which transfers water naturally from the Prespa Basin, downstream 150 m, through the karst into the Ohrid Lake. Lake Ohrid is 2 million years old and is the most significant water ecosystem on the continent, but without Lake Prespa, Ohrid will never survive “aging” without Prespa’s pure karst water. Lake Ohrid and the City of Ohrid are under UNESCO Protection since 1979. What about Prespa?

Human activities directly and indirectly influenced the rapid lowering of the water level in Lake Big Prespa. There is no evidence that the karst discharge into Lake Ohrid has increased.

Climatic impacts with: Increased air temperatures accelerating the evaporation process, which leads to the rapid loss of large amounts of water; a decreasing trend of the precipitation in addition disturb Water Balance process. Hydrological and Meteorological measurements and data exchange for analyzing the water balance are crucial.

In October 2025, the level of Lake Big Prespa was 840.87 m, - abs. measured minimum.

Only with Hydrological and Meteorological monitoring on the Prespa Lakes, monitoring of water use, data exchange, and protection by all three states can Lake Big Prespa be saved from agony, but only if all three states want that.

**Keywords:** hydrology, water level, lake, water balance, climate, precipitation

## 1. INTRODUCTION

As everywhere in the Region, N Macedonia is faced with water scarcity. One of the biggest issues is the situation with Lake Prespa (Figure 1). Jointly with Lake Ohrid, Lake Prespa is part of the Unique Hydrological System, which transfers water naturally from the Prespa Basin, downstream 150 m, through the Galicica and Suva Gora karst into Lake Ohrid (Crn Drim Spring at St. Naum - Figure 2). Lake Ohrid is 2 million years old, one of the oldest lakes in Europe, and from a biological point of view, is the most significant preserved water ecosystem on the continent, but without Lake Prespa, Ohrid will never survive “aging”; pure Karst water is the secret of the lake's long life. Lake Ohrid and the City of Ohrid have been under UNESCO Protection since 1979.

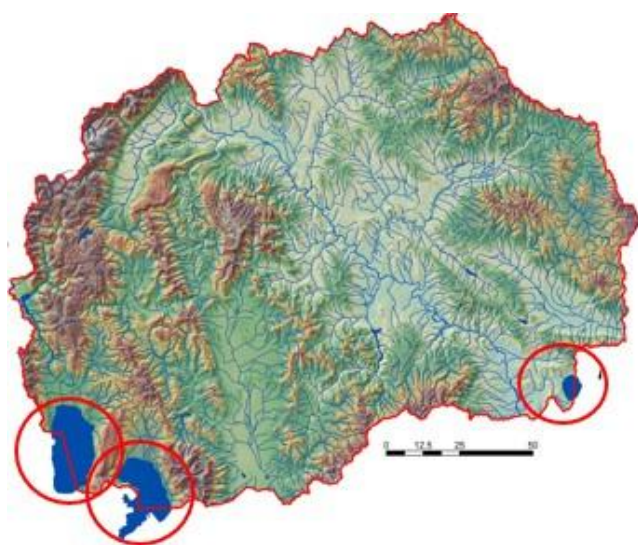


**Figure 1.** Lake Prespa



**Figure 2.** Crn Drim Spring at St.Naum

## 2. Lakes in general



There are over 160 lakes in North Macedonia. Fifty of them are natural. The three largest natural lakes on the territory of the state, Lake Dojran, Lake Prespa, and Lake Ohrid (Figure 3), according to the way their basins were formed, are of a tectonic type. A common characteristic of tectonic lakes is that they age naturally. The term “aging” means filling their volume space with sediment and reducing their water content. Therefore, these lakes should be under constant monitoring and protection.

**Figure 3.** Location of the three tectonic Lakes

### 2.1 General Hydrological Analysis of the Lake Prespa Water Reserves

The water levels of Lake Prespa (Figure 3), which was once (in the Neogene) part of the Great Neogene Lake (Figure 4), and then part of the Great Desaret Lake, are constantly decreasing. According to geologists, this Lake, like other lakes from the Region, has long been involved in an "aging" process. The former Great Desaret Lake was reduced within the borders of the Prespa, Ohrid, Korca and Bilista Basins, as shown in Figure 5. The "aging" process continued, and time took its toll. The last remains of the Great Desaret Lake are the Ohrid and Prespa Lakes.

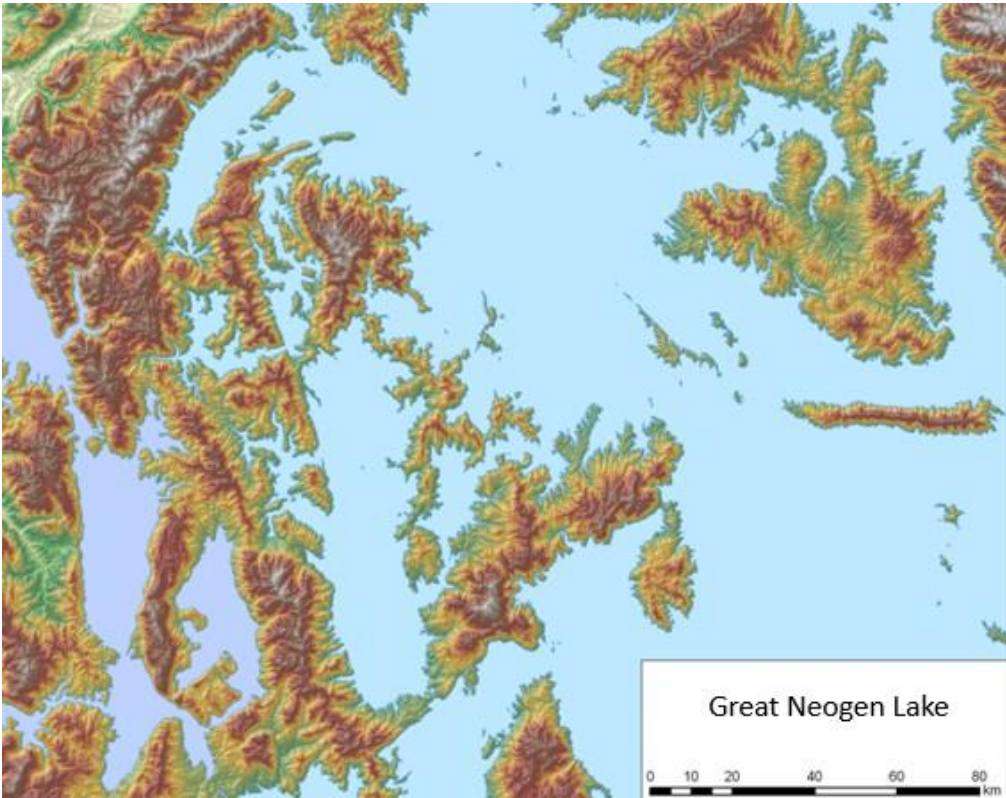


Figure 4.The Great Neogene Lake



Figure 5. Remains of the Great Desaret Lake

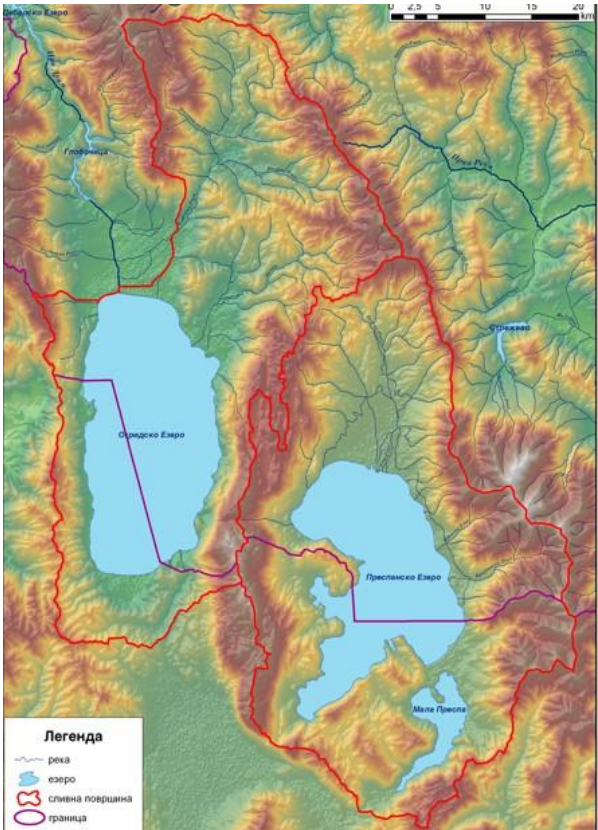


Figure 6. Lakes Ohrid and Prespa

Lake Prespa contains the Big and the Small Lake. Until recently (last century), these two lakes communicated with each other (Figure 7).



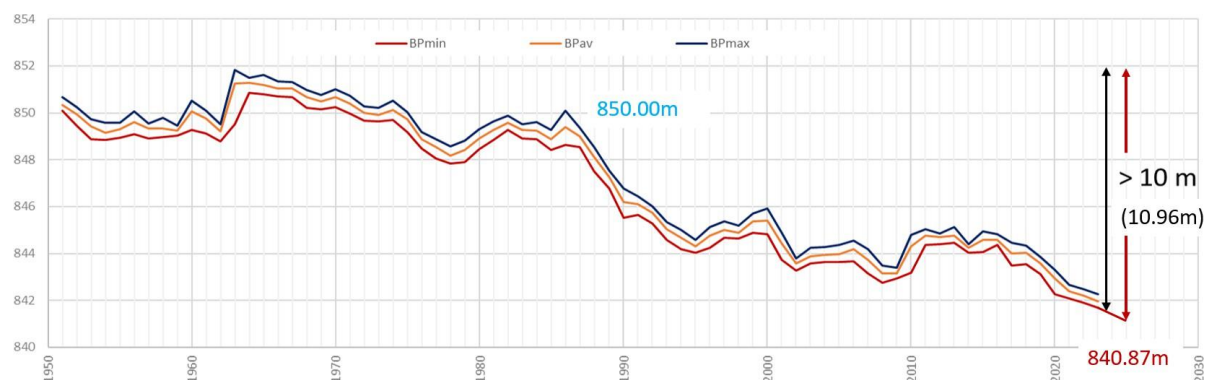
**Figure 7.** Surface water bodies in Prespa sub-basin/Greece

Source: Special Secretariat of Water, Ministry of Environment and Energy – Greece (2014)

We have witnessed that in the last more than 37 years Lake Prespa has been suffering a great loss of its water reserves, but according to certain information, this lake was at this level at other times in the past. Namely, in Albania near Zavir, an anthropogenic building has come to light which, according to the assumptions, dates from a thousand years ago.

What changes the lake is undergoing can be checked from the hydrological monitoring, from which you can get some idea of what is happening with Lake Prespa. The level of the lake has been measured since before the Second World War, but there has been constant monitoring organized by the Hydrometeorological Service since 1947.

After an analysis of the hydrological parameters, it can be said that the absolutely observed maximum water level at Lake Prespa was registered on July 15, 1963, at an elevation of  $H=851.83$  m, while the absolutely observed minimum water level is at an elevation of  $H=840.87$  m, registered in October, 2025. Under such circumstances, the absolute amplitude is 1096 cm.



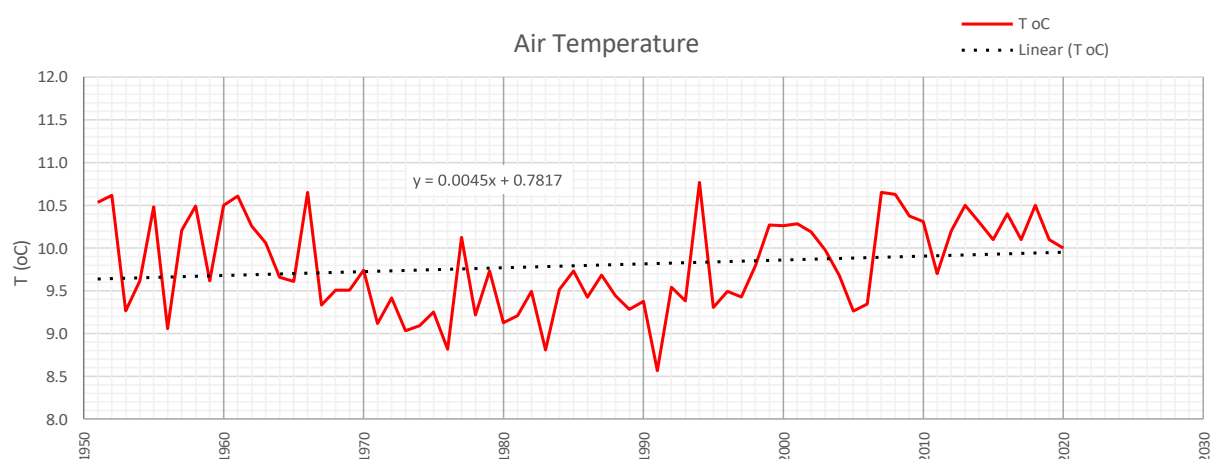
**Figure 8.** Multiannual oscillations of the characteristic water levels of Lake Prespa

### 3. Impacts on the Lake Prespa water

What is the cause of water loss? Naturally, Lake Prespa discharges around 8.00 m<sup>3</sup>/s of water through karst into Lake Ohrid. Because of climatic impacts and increasing temperature through evaporation and evapotranspiration, Lake Prespa is losing around 19.0 m<sup>3</sup>/s of water during the year. Humans, depending on wet or dry years, use a huge amount of Lake Prespa water reserve, directly and indirectly.

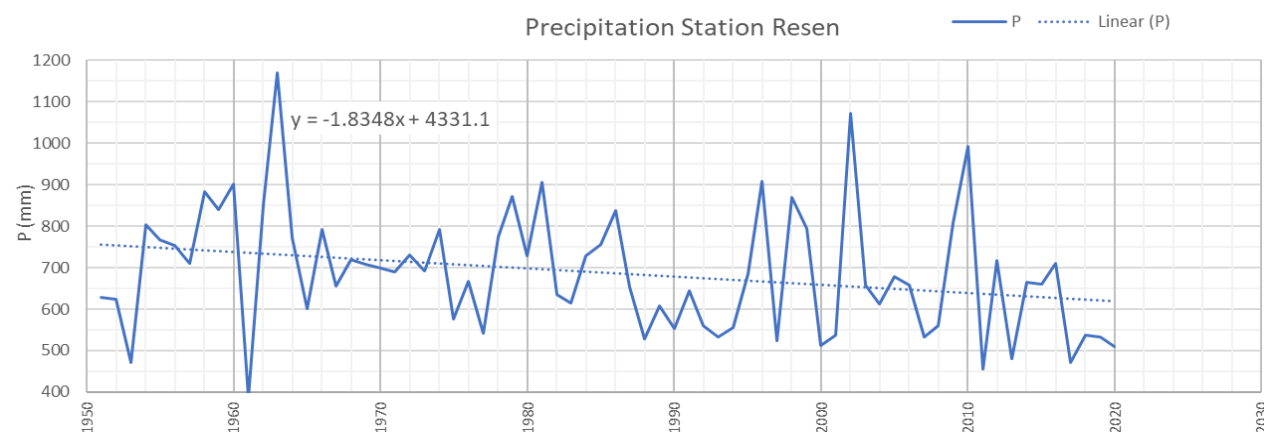
#### 3.1 Impacts to the Lake Prespa Water

Climate change plays a major role in lowering water levels, both directly and indirectly. High temperatures (Figure 9) increase the evaporation of water from the lake and in that way, lake loses directly large amounts of water, and on the other hand, the rise in air temperatures increases the need for water for irrigation, so the population of the three states with the use of water from the basin of the lake and from the lake, indirectly and directly affect the reduction of water levels of the lake.



**Figure 9.** Multiannual oscillations of the air temperature (Climate Station Resen)

Meteorological parameters show a trend of increasing air temperatures, decreasing relative humidity, and increasing evaporation (Figure 9).



**Figure 10.** Multiannual precipitation oscillations (Climate Station Resen)

Precipitation plays a significant role in the water balance of the lake. During snow-rich winters, the lake level rises over a longer period of time than in snow-free winters. In rainy years, the use of water resources is reduced, and this affects the lake level positively. Looking at the sequence of precipitation, a decreasing trend can be observed (Figure 10). If we look at the period from 1987 to 1995, we can notice a period with a small amount of precipitation, and it is precisely in that period that the largest drop of 5 m in the water levels of Lake Prespa occurs. The increased evaporation, demand for irrigation, and the small amounts of precipitation have caused a drastic drop in water levels. A continuous downward trend of precipitation and increased water demand additionally affects the reduction of water levels. It is obvious that the balance is disturbed and there are no conditions to replenish Lake Prespa water naturally.

### 3.2 Anthropogenic Impacts

The population living in the Prespa Region, whether from the side of Macedonia, Greece or Albania, has always used the water from the Lake Prespa basin to irrigate their agricultural lands. As in the past, so to these days, the local dams and canals are used to bring the water from the upper reaches of the rivers to their farmlands and orchards with apples and other fruits around the lake by gravity.

1) According to the study by KfW Bank (Project Preparation & Development of the Transboundary Prespa Park Project), the Albanian Government in 1953 created a system for using the water from Lake Small Prespa and connecting it to the Korca irrigation system,



whereby annually they used 20 to 45 million m<sup>3</sup> of water. The use of the water officially lasted until 2004, but according to some information, due to the high water level of Lake Small Prespa, the leakages through the locality called Grlo (Figure 9) continue even further.

**Figure 9.** Location of the water outlet from Small Prespa and the irrigation system in Albania (source: Prespa National Park 2013). Surface water bodies in Prespa sub-basin/Albania.

2) Since 1959 (Project Preparation & Development of the Transboundary Prespa Park Project), on the Macedonian side, organized pumping of water from Lake Prespa has been started; pumps were installed at the village of Asamati and the village of Sirhan ( $1.0+0.8=1.8\text{m}^3/\text{s}$  or 16 million m<sup>3</sup> yearly), from where the pumped water was thrown into the irrigation system leading to Resensko Pole. This system, with the great drop in the water level (in the 90s of the last century), is not in operation due to the very low level of the lake.

3) The agricultural areas around Lake Small Prespa (Greece) use irrigation water from the lake and from the German (Germanos) River. In 1969, an artificial dam (a concrete channel with a culvert whose threshold was at an elevation of 849.60 masl) was installed on Lake Small Prespa (Final report of the assessment of habitat vulnerability to climate change (LIFE15 NAT/GR/000936) to regulate the flow of water from the small lake to the big lake (Figure 10).

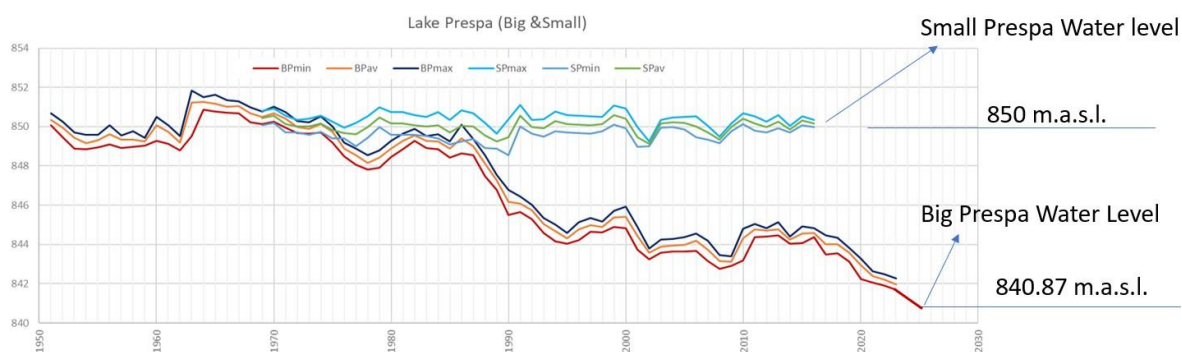


**Figure 10.** Location of the Small Prespa Dam (Google Earth)

4) While in summer the water was used for irrigation in the Korca irrigation System (Albania), in winter, the excess water from the river Devol (since 1976) was thrown into the lake as compensation. Without considering the consequences, large amounts of sediment were thrown into Lake Small Prespa, which practically led to the acceleration of the eutrophication process of this part of Lake Small Prespa (Figure 11).



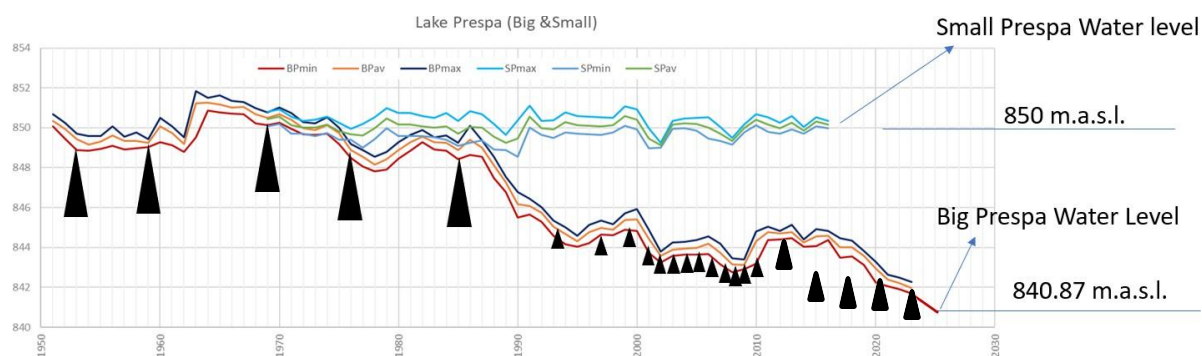
**Figure 11.** Location of the exit of the water from Lake Small Prespa towards Albania-Grlo (Google Earth)



**Figure 12.** Multiannual oscillations of the characteristic water levels of Lake Prespa (B&S)

5) In 1985, tabular closures were placed on the Dam of Lake Small Prespa, which control the

discharge even when higher water levels occur on the Lake Small Prespa (Figure 12), thus maintaining high water levels (in contrast to the Lake Big Prespa) and allowing the flooding of the shores of the lake, with certain amounts of water flowing out uncontrollably towards the basin of the river Devol (Figure 11) – Grlo - area - Albania.



**Figure 13.** Human impacts on the water reserves of the lake - period 1951-2025 and multiannual oscillations of the water levels of the Lake Prespa (Big&Small)

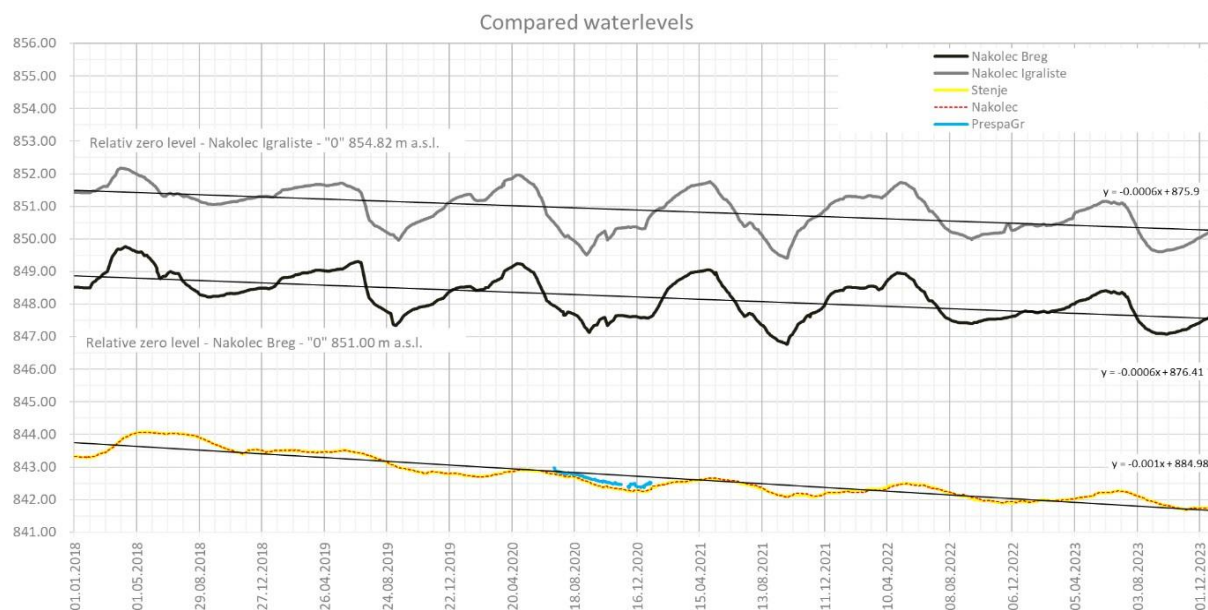
6) As a replacement for the old pumping system in North Macedonia, in the 90s, and especially in the beginning of the 21st century onwards, a large number of pumps for pumping groundwater have been included in the basin of Lake Prespa on the side of North Macedonia, the number of which is increasing day by day.

All mentioned anthropogenic activities directly affect the lowering of the water level of Lake Prespa.

#### 4. Needs of continuous Hydrological and Meteorological Monitoring

As part of the HMS hydrological monitoring system, occasional monitoring of 16 groundwater stations has recently been carried out in Lake Prespa, and from 2018 regular monitoring of groundwater is carried out at the village and near the village of Nakolec (Water level Stations Igraliste and Breg). With the help of these data, we can confirm that the groundwater has a decreasing tendency (Figure 14).

In order to be able to confirm what the real situation is with Lake Prespa, we really need continuous joint hydrological and meteorological monitoring by all three. Only joint action has a chance to do proper monitoring of Lake Prespa.



**Figure 14.** Water level stations on Lake Prespa and groundwater stations at Nakolec

## 5. Water Balance

To analyze water balance, we need to know what is happening with the water. Concerning Karst discharge to Lake Ohrid it is no evidence that the discharge has increased; that is mean the discharge is generally constant. All these human activities directly and indirectly influenced the rapid lowering of the lake's level, and in addition, the decreasing trend, increased air temperatures, reduced air humidity, and winds accelerate the evaporation process, which leads to the rapid loss of large amounts of water.

Realistically, on an annual basis, the anthropogenic impacts such as pumping groundwater from Resensko Pole for irrigation, preventing runoff from the Small to Big Prespa, the discharging to Albania seem minor and many experts reject these figures in the overall water balance equation of water resources, but if analyzed these numbers for longer period of years will show that they also influence what has been happening to Lake Big Prespa for the past 37 years and more.

According to Table 1, where the elements of the water balance equation for Lake Big Prespa (1951-2020) are shown, Lake Prespa annually has a deficit of 53 M m<sup>3</sup>, which means a discharge of  $Q = 1.68 \text{ m}^3/\text{s}$ .

**Table 1.** Elements of water balance equation for Lake Big Prespa (1951-2020)

Stojov 2024

| Elements of Water Balance equation | Inflow (m <sup>3</sup> ) | Outflow (m <sup>3</sup> ) | Difference (m <sup>3</sup> ) | Changes in discharges (m <sup>3</sup> /s) | Changes in Water level (m) |
|------------------------------------|--------------------------|---------------------------|------------------------------|-------------------------------------------|----------------------------|
| Precipitation (lake)               | 189,081,000              |                           |                              | 5.99                                      | 0.71                       |
| Precipitation (land)               | 609,514,800              |                           |                              | 19.3                                      | 2.27                       |
| Inflow (into lake)                 | 228,559,753              |                           |                              | 7.24                                      | 0.85                       |
| Evaporation (land)                 | 380,955,047              |                           |                              | 12.1                                      | 1.42                       |
| Evaporation (lake)                 |                          | 222,606,000               |                              | 7.05                                      | 0.83                       |
| Karst outflow into Lake Ohrid      |                          | 248,042,736               |                              | 7.86                                      | 0.92                       |
| Total                              | 417,640,753              | 470,648,736               |                              |                                           | 1.56                       |
| Water deficit                      |                          |                           | (53,007,983)                 | (1.68)                                    | (0.20)                     |
| In total for 37 years              |                          |                           | (1,961,295,371)              | (62.1)                                    | (7.31)                     |

How much water was used outside the Prespa Basin into the Korca, how much water was retained in the Basin of Lake Small Prespa, how much water was used for irrigation in the Big Prespa Basin, and so on, remain a matter of assumption. With the available data, it is not possible to prove it in detail, but if we determine that the average water level - heigh loss of the lake is somewhere between 7 and 8 m, we can determine that in the past 37 years the lake has lost 1.961.000.000 m<sup>3</sup> of water, almost 2 Billons m<sup>3</sup> of water, which amounts equal to a loss of 53 M m<sup>3</sup> of water on an annual level, which is equal to an insignificant 20 cm loss.

However, to confirm these numbers, Hydrological and Meteorological monitoring by all three states and control of all water is required. Without continuous hydrological and meteorological monitoring and monitoring of water use, it is difficult to draw up a balance of the water in the Prespa Basin and in the lake itself.

## 6. CONCLUSIONS

All the anthropogenic activities directly and indirectly influenced the rapid lowering of the water level in Lake Big Prespa.

There is no evidence that the karst discharge into Lake Ohrid has increased.

Climatic impacts with:

- increased air temperatures, reduced air humidity, and winds accelerate the evaporation process, which leads to the rapid loss of large amounts of water
- decreasing trend of precipitation, in addition disturb Water Balance process.

Hydrological and Meteorological measurements and data exchange for analyzing the water balance are crucial.

In October 2025, the lake reached the new absolute measured minimum of 840.87 m.

After a rainy autumn, in February 2026 the lake increased its water levels by 80 cm up to 841.67 m, but from July 2026 the lake water levels will start to decrease again. The problem with Lake Big Prespa will not disappear without joint protection from the three states. In November 2026, it is expected that the new absolute measured water level will drop below an elevation of 840.67 m. This means an additional 20 cm or a new 53 M m<sup>3</sup> of water loss from Lake Big Prespa.

Only with Hydrological and Meteorological monitoring on the Prespa Lakes, monitoring of water use, and protection by all three states can Lake Big Prespa be saved from agony, but only if all three states want that.

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3rd Scientific Prespa Lakes Symposium

# POSTER CONTRIBUTIONS

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Korçë, Albania | 2-4 February 2026

Proceedings Book

## ADVANCING CONSERVATION EFFORTS OF BLACK ALDER (*Alnus glutinosa* (L.) Gaertn.) POPULATIONS NEAR LAKE PRESPA VIA SEED ANALYSIS

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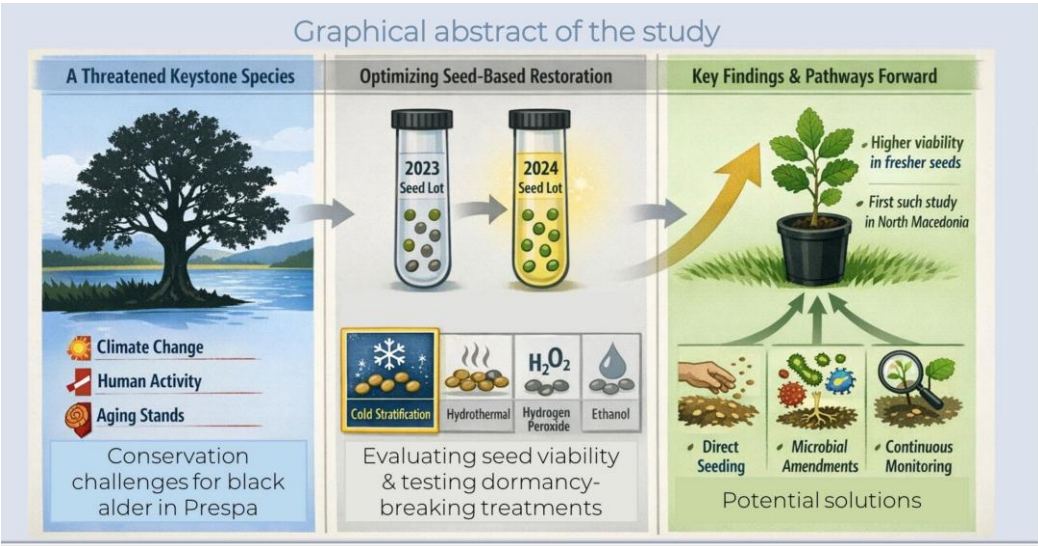
### ABSTRACT

Black alder (*Alnus glutinosa* (L.) Gaertn.) is a keystone riparian species in the Prespa region of North Macedonia, where its fragmented and ageing populations are increasingly affected by climate change, human activity and limited natural regeneration. This study evaluated locally collected seed lots from 2023 and 2024 and tested five pre-sowing treatments intended to overcome deep seed dormancy and improve nursery propagation. The 2024 seed lot showed higher purity, thousand-seed weight, and vitality than the 2023 lot. Cold stratification produced the strongest germination response, while hydrothermal and hydrogen peroxide treatments had only limited effects; ethanol and water soaking were ineffective. The findings provide practical guidance for black alder reforestation in the Prespa region and support the adoption of cold stratification as a standard nursery treatment. Continued annual monitoring of seed quality, diversification of mother-tree sources, field testing of direct seeding, and investigation of microbial amendments are recommended to improve restoration success.

**Keywords:** *Alnus glutinosa*; black alder; seed viability; seed dormancy; cold stratification; reforestation; Prespa.

### 1. BACKGROUND AND OBJECTIVES

Riparian forests provide essential ecosystem services, including bank stabilisation, nutrient retention, habitat provision and water-quality protection. In North Macedonia's Prespa region, black alder forms ecologically important but fragmented and ageing stands. Agricultural expansion, invasive species and changing climatic conditions have reduced natural regeneration, creating a need for active restoration. Because successful reforestation depends on viable reproductive material and reliable nursery protocols, the study focused on the quality of locally sourced seeds and on methods for overcoming the species' deep dormancy.



**Figure 1.** Graphical overview of the conservation challenge, seed-treatment assessment and proposed restoration pathways.

**The study had three objectives:**

1. To compare the physical properties and viability of black alder seeds collected in 2023 and 2024.
2. To evaluate five pre-sowing treatments for breaking dormancy and promoting germination.
3. To identify a practical treatment that can improve nursery seedling production for conservation forestry.

**2. MATERIALS AND METHODS**

Seed samples from two consecutive collection years (2023 and 2024) were assessed in accordance with the International Seed Testing Association sampling criteria. The analysis covered seed purity, thousand-seed weight, germination percentage, germination energy, practical seed value and seed vitality. Five pre-sowing treatments were tested under controlled conditions.

**Table 1.** Physical seed properties of *Alnus glutinosa* in 2023 and 2024

| Code | Treatment              | Protocol                                                                                                           |
|------|------------------------|--------------------------------------------------------------------------------------------------------------------|
| T1   | Cold stratification    | Seeds were conserved in moist sand and cold-stratified at 4 °C for 49 days.                                        |
| T2   | Ethanol soak           | Seeds were soaked for 24 hours in 35% ethanol at room temperature (20-25 °C).                                      |
| T3   | Hydrogen peroxide      | Seeds were kept in darkness for 7 days in 1% H2O2 at room temperature.                                             |
| T4   | Water soak             | Seeds were soaked in water for 35 days at room temperature; water was changed every 48 hours.                      |
| T5   | Hydrothermal treatment | Seeds were placed in boiling water (100 °C) for 10 seconds and then soaked in room-temperature water for 24 hours. |

Statistical analysis: Physical seed properties were compared descriptively. Germination variables were analysed using two-way ANOVA (Treatment x Year) followed by Tukey HSD tests. Vitality categories were compared using Fisher's exact test and two-sample proportion tests. Statistical significance was set at  $p < 0.05$ , and analyses were conducted in R 4.3.0.

3. RESULTS

All measured physical seed properties were higher in the 2024 lot. Seed purity increased from 59.51% in 2023 to 74.00% in 2024, while thousand-seed weight increased from 1.165 g to 1.725 g. Seed vitality also improved significantly: the proportion of healthy seeds rose from 18.5% (74 of 400 seeds) to 36.25% (145 of 400 seeds;  $p < 0.05$ ).

Table 2. Seed vitality results of *Alnus glutinosa* in 2023 and 2024

| Seed lot | Purity (%) | Thousand-seed weight (g) | Healthy seeds (n/400) | Healthy seeds (%) |
|----------|------------|--------------------------|-----------------------|-------------------|
| 2023     | 59.51      | 1.165                    | 74                    | 18.50             |
| 2024     | 74.00      | 1.725                    | 145                   | 36.25             |

The ethanol (T2) and water-soak (T4) treatments produced no germination and were therefore excluded from the comparative analysis. Among the active treatments, cold stratification (T1) was clearly superior, producing the highest germination percentage (27.1%), germination energy, and practical seed value. All pairwise differences among T1, T3 and T5 were statistically significant ( $p < 0.05$ ), and treatment performance was strongly influenced by seed-lot year (Treatment x Year interaction,  $p < 0.001$ ). The benefit of cold stratification was greatest in the higher-quality 2024 seed lot, where germination percentage increased by 12.7 percentage points and practical seed value by 12.3 percentage points relative to 2023. In 2024, practical seed value reached 24.7% under cold stratification, compared with 0.9% under hydrogen peroxide treatment.

4. CONCLUSIONS AND RECOMMENDATIONS

The study provides the first targeted assessment of black alder seed quality and germination treatments in North Macedonia. Locally sourced seeds showed generally low viability, but seed quality varied substantially between years, with the 2024 lot performing considerably better. Cold stratification was the only consistently effective dormancy-breaking treatment and should be adopted as the standard pre-sowing protocol for nursery production. Hydrothermal and hydrogen peroxide treatments showed limited potential, while ethanol and prolonged water soaking were ineffective.

- 1. Monitor seed quality annually:** because purity, vitality and germination performance can vary markedly between collection years.
- 2. Use cold stratification as the standard treatment:** to improve germination and nursery efficiency.
- 3. Diversify seed sources:** by collecting from multiple healthy mother trees and, where necessary, assessing reproductive material from other regions.

- 4. Test restoration methods under field conditions:** including autumn direct seeding and the use of symbiotic microbial amendments such as Frankia.
- 5. Link seed research with tree-health monitoring:** including phenology, disease status and the long-term condition of remnant alder stands.

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## IMPACT OF AGRICULTURAL ACTIVITIES ON THE CHEMICAL COMPOSITION OF WET MEADOW SOILS IN PRESPIA

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### ABSTRACT

Wet meadows in the Prespa region provide essential ecosystem services, including water-flow regulation, nutrient retention, carbon storage, soil formation and biodiversity support. Despite their ecological importance, these habitats have declined considerably because of conversion to agricultural land, especially apple orchards, and the occurrence of wildfires. This study examined local fertilizer-use practices and assessed how mineral fertilization affects the chemical composition of wet meadow soils in the Ezerani protected area. The research combined 39 anonymous, in-person interviews with local farmers and a pilot in-situ experiment using 18 plastic lysimeters containing intact soil and vegetation. Experimental plots were assigned to fertilized and unfertilized treatments. Survey results indicated that NPK fertilizers, particularly formulations similar to 8:16:24, were most frequently used, with an average application rate of approximately 700 kg ha<sup>-1</sup>. Chemical analyses showed that fertilization altered soil properties, including a reduction in pH and increases in nitrogen, phosphorus, and potassium. The findings demonstrate the capacity of wet meadow soils to retain nutrients derived from mineral fertilizers, while also indicating that acidification may increase the mobility of selected heavy metals. Sustainable fertilizer management is therefore important for protecting wet meadow functions and reducing nutrient pressures on the Prespa ecosystem.

**Keywords:** wet meadows; mineral fertilizers; soil chemistry; nutrient retention; Ezerani; Prespa

### 1. BACKGROUND AND OBJECTIVE

Wet meadows are transitional ecosystems that connect agricultural landscapes with aquatic habitats. Their soils and vegetation can retain nutrients before they reach surface waters, making them particularly relevant in intensively cultivated areas surrounding Lake Prespa. The study aimed to document fertilizer practices among local farmers and to test whether mineral fertilizer application changes the chemical characteristics of wet meadow soils.

## 2. STUDY DESIGN

The study combined a farmer survey with a controlled field experiment. Thirty-nine farmers were interviewed in person about fertilizer type, quantity and frequency of application. The experimental component was established in May 2022 in a wet meadow within the Ezerani protected area. Eighteen plastic lysimeters, each 15 cm deep and covering 0.15 m<sup>2</sup>, were filled with intact soil and aboveground vegetation and installed in excavated plots. The lysimeters were divided into fertilized and unfertilized treatments. Based on the survey findings, an NPK fertilizer corresponding to common local practice was applied in June 2022. Soil and plant material were sampled before fertilization, and soil was sampled again at the end of August.

## 3. METHODOLOGY

Laboratory analyses included soil organic matter, pH, total nitrogen, total phosphorus, calcium, sodium, potassium, magnesium, zinc, manganese, iron, and selected heavy metals, including copper, lead, nickel, and cadmium. Fertilized and unfertilized treatments were compared using t-tests, with statistical significance assessed at  $p < 0.05$ .



**Figure 1.** Fieldwork and experimental setup in the Ezerani wet meadow: (a-b) farmer interviews and questionnaire administration; (c-e) excavation and installation of plastic lysimeters.

## 4. FARMER SURVEY RESULTS

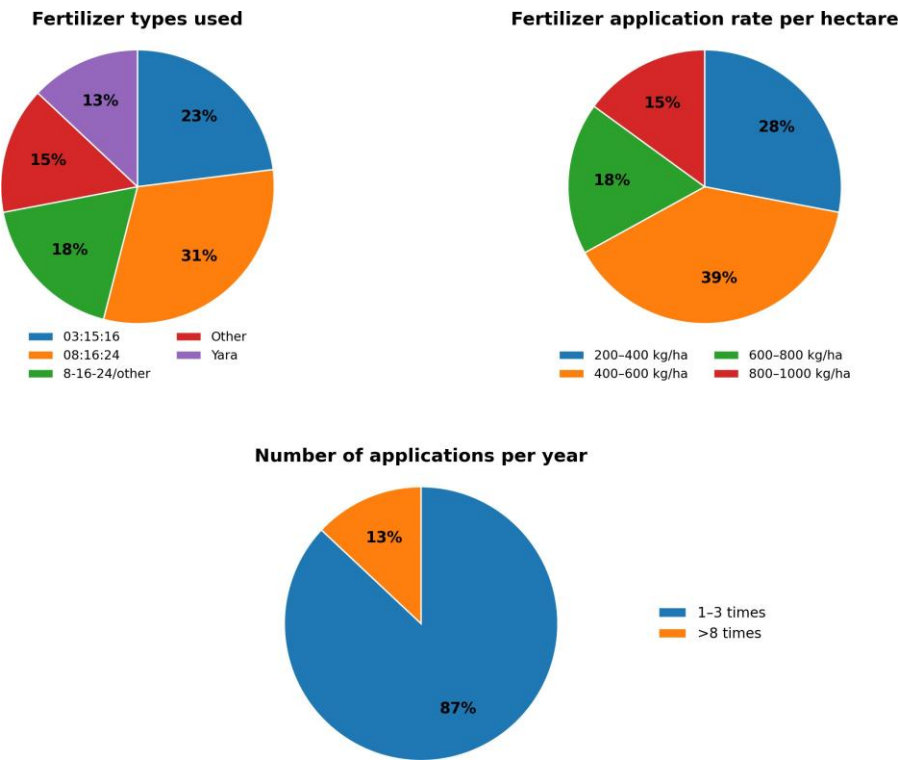
The survey showed that farmers used several fertilizer formulations, with NPK 8:16:24 or comparable products being the most common. The largest share of respondents reported applying 400–600 kg ha<sup>-1</sup>. Considering all responses, the estimated mean application rate was approximately 700 kg ha<sup>-1</sup>. Most farmers reported one to three fertilizer applications per year.

**Table 1.** Summary of fertilizer-use patterns reported by surveyed farmers in the Prespa region.

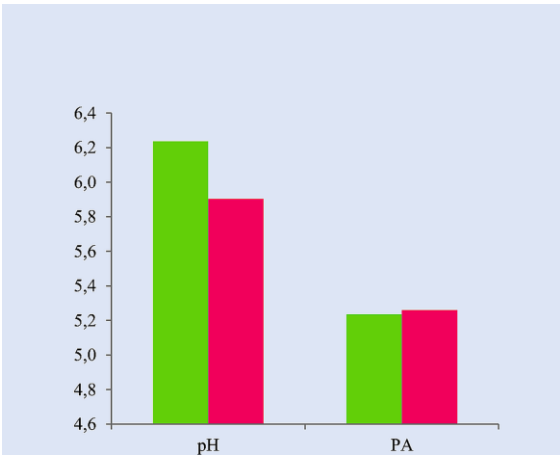
| Survey indicator                   | Main result                       | Reported share / value                |
|------------------------------------|-----------------------------------|---------------------------------------|
| Fertilizer formulation             | NPK 8:16:24                       | 31% of respondents                    |
| Application-rate category          | 400–600 kg ha <sup>-1</sup>       | 39% of respondents                    |
| Estimated average application rate | All fertilizer practices combined | Approximately 700 kg ha <sup>-1</sup> |
| Applications per year              | 1–3 applications                  | 87% of respondents                    |

5. EFFECTS ON SOIL CHEMICAL COMPOSITION

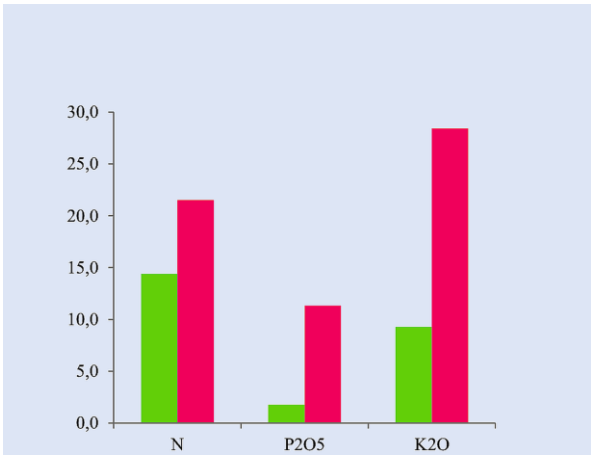
Comparison of fertilized and unfertilized plots showed clear treatment-related differences. Mineral fertilizer application reduced soil pH and increased the concentrations of major plant nutrients. Statistically significant differences were reported for pH, nitrogen, phosphorus and potassium (t-test,  $p < 0.05$ ). Changes were also observed for several trace elements and heavy metals, but these differences were not consistently statistically significant. The reduction in pH is environmentally relevant because lower pH can increase the mobility and bioavailability of some metals in soil.



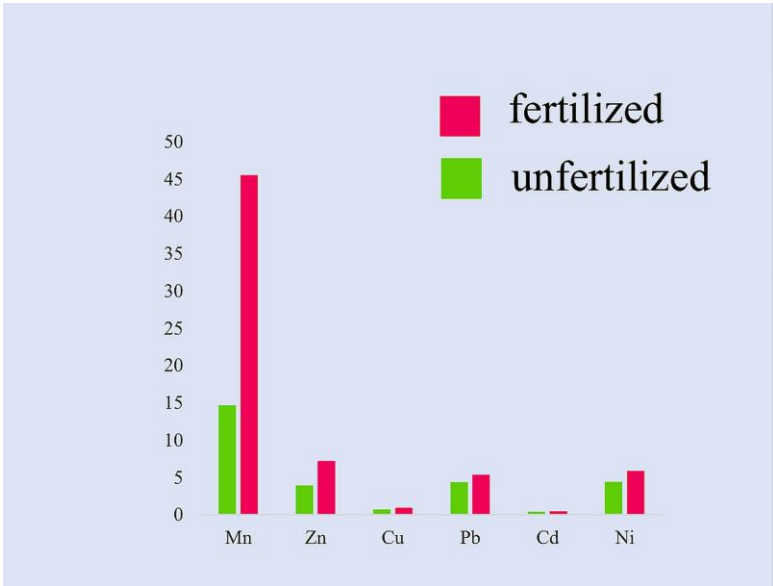
**Figure 2.** Fertilizer formulations, application-rate categories and annual application frequency reported by farmers.



**Figure 3a.** Mean pH and PA values. Green: unfertilized; magenta: fertilized.



**Figure 3b.** Mean N, P<sub>2</sub> O<sub>5</sub> and K<sub>2</sub> O values. Green: unfertilized; magenta: fertilized.



**Figure 3c.** Mean concentrations of selected trace elements and heavy metals. Green: unfertilized; magenta: fertilized.

**Table 2.** Direction and interpretation of changes in selected soil parameters following mineral fertilizer application.

| Parameter      | Direction after fertilization | Interpretation                                                   |
|----------------|-------------------------------|------------------------------------------------------------------|
| pH             | Decrease                      | Statistically significant; indicates soil acidification          |
| Total nitrogen | Increase                      | Statistically significant; nutrient retention in wet meadow soil |

| Parameter                                   | Direction after fertilization | Interpretation                                                     |
|---------------------------------------------|-------------------------------|--------------------------------------------------------------------|
| Phosphorus (P <sub>3</sub> O <sub>5</sub> ) | Increase                      | Statistically significant; accumulation following fertilizer input |
| Potassium (K <sub>3</sub> O)                | Increase                      | Statistically significant; direct response to NPK application      |
| Selected trace elements / heavy metals      | Generally higher values       | Differences were not consistently statistically significant        |

## 6. CONCLUSIONS AND IMPLICATIONS

- The average mineral fertilizer application reported by local farmers was approximately 700 kg ha<sup>-1</sup>, with NPK 8:16:24 or similar formulations used most frequently.
- Mineral fertilization altered the natural chemical composition of wet meadow soils, particularly by reducing soil pH and increasing nitrogen, phosphorus and potassium.
- Wet meadow soils retained nutrients derived from fertilizer inputs, confirming their role as natural filters within the Prespa landscape.
- Fertilizer management should be adjusted to crop needs and monitored carefully, because soil acidification may increase the mobility of heavy metals and contribute to downstream ecological pressure.

## KEY RECOMMENDATIONS

- Reduce unnecessary fertilizer inputs by matching application rates to soil tests and crop nutrient requirements.
- Preserve and restore wet meadows as nutrient-retention zones between agricultural land and Lake Prespa.
- Continue long-term monitoring of soil pH, nutrients and metal mobility in fertilized and unfertilized meadow plots.
- Promote farmer guidance on fertilizer timing, dosage and environmental risks in the Prespa basin.

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## **EFFECTS OF FERTILIZATION, MOWING AND BURNING ON THE MINERAL COMPOSITION OF SOIL WATERS IN WET MEADOWS OF THE PRESPA REGION**

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### **ABSTRACT**

Wet meadows in the Prespa region provide important ecosystem services, including nutrient retention, water purification and biodiversity support. At the same time, these habitats are increasingly exposed to intensive agricultural practices, excessive fertilization and inappropriate management. This study examined the combined effects of mineral fertilization and three meadow-management regimes - mowing, non-mowing and burning - on the mineral composition of soil water in Nature Park Ezerani. An ex-situ lysimeter experiment with 18 intact soil-vegetation monoliths compared fertilized and non-fertilized treatments. Soil water was collected on three occasions and analysed for nitrite, nitrate, major cations and selected metals. Fertilization altered soil-water chemistry, but the magnitude of the response depended strongly on meadow management. Burned and fertilized plots showed the greatest accumulation of sodium, potassium and nitrate, whereas non-mowed and non-fertilized plots generally retained lower levels of inorganic nitrogen. The findings underline the importance of sustainable fertilizer use, traditional mowing and effective fire prevention for maintaining wet-meadow functions and reducing eutrophication pressure on Lake Prespa.

**Keywords:** wet meadows; mineral fertilization; mowing; burning; soil water; nutrient retention; Ezerani; Prespa

### **1. BACKGROUND AND OBJECTIVE**

Wet meadows form a natural buffer between intensively cultivated land and aquatic ecosystems. Their soils and vegetation can retain nutrients, regulate water movement and limit the transfer of agricultural pollutants into lakes. In the Prespa region, these functions are especially important because apple production and other agricultural activities occur close to sensitive wetland habitats. The objective of the study was to assess how mineral fertilization interacts with mowing, non-mowing and burning to influence the mineral composition of soil water in a wet meadow within Nature Park Ezerani.

2. EXPERIMENTAL DESIGN

The research was implemented in three phases: fieldwork, laboratory analysis, and statistical processing. In May 2022, eighteen plastic lysimeters were installed in an ex-situ experiment using intact soil and vegetation monoliths. Each lysimeter was approximately 15 cm deep and represented an area of 0.15 m<sup>2</sup>. Three meadow-management designs were established: mowed meadow with the aboveground biomass removed, non-mowed meadow, and meadow with burned aboveground biomass. Each management design was tested under both fertilized and non-fertilized conditions. The fertilized treatments received NPK 8:16:24 at an application rate of approximately 700 kg ha<sup>-1</sup>. Soil water was collected in June 2022, October 2022, and March 2023.

**Table 1.** Experimental treatments used to assess the combined effects of meadow management and mineral fertilization.

| Code | Meadow-management regime | Fertilization  |
|------|--------------------------|----------------|
| KG   | Mowed meadow             | Fertilized     |
| KN   | Mowed meadow             | Non-fertilized |
| NG   | Non-mowed meadow         | Fertilized     |
| NN   | Non-mowed meadow         | Non-fertilized |
| ZG   | Burned meadow            | Fertilized     |
| ZN   | Burned meadow            | Non-fertilized |

3. LABORATORY AND STATISTICAL METHODS

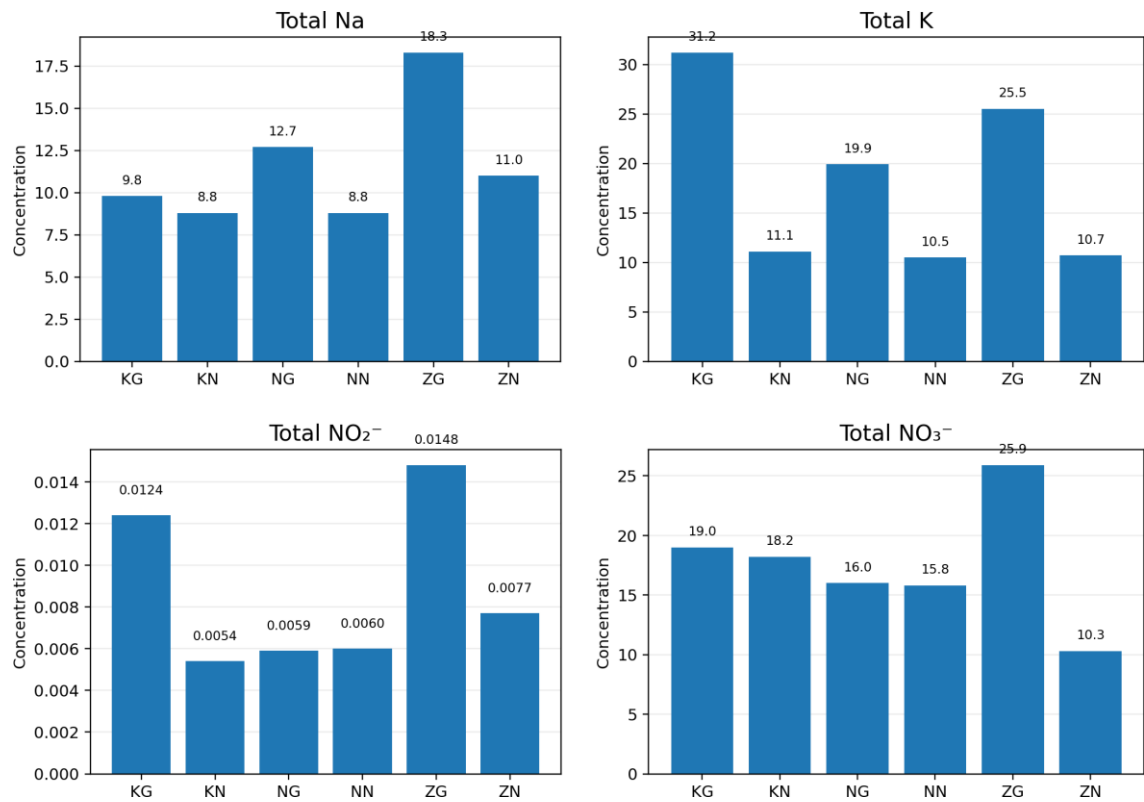
Nitrite and nitrate concentrations were determined using spectrophotometric methods. Major cations - potassium, calcium, magnesium and sodium - and selected metals, including iron, manganese, zinc and copper, were analysed by atomic absorption spectroscopy using Agilent 55 and Agilent 240Z instruments. Both filtered and digested samples were assessed to distinguish soluble and total element concentrations. Statistical processing was conducted in Microsoft Excel, and treatment effects were evaluated using t-tests.



**Figure 1.** Lysimeter installation and laboratory procedures used for soil-water collection and chemical analysis.

#### 4. RESULTS

Nutrient concentrations responded clearly to both meadow management and fertilization. The burned and fertilized treatment (ZG) consistently recorded the highest total sodium and nitrate concentrations and also showed elevated potassium and nitrite values. This pattern indicates that the combination of nutrient input and disturbance caused by burning increased nutrient release and mobility. Mowed and fertilized plots also showed relatively high concentrations of selected elements, particularly potassium. By contrast, non-mowed and non-fertilized treatments generally showed lower levels of inorganic nitrogen, indicating greater nutrient retention under less disturbed conditions.



**Figure 2.** Total sodium, potassium, nitrite and nitrate concentrations across mowed, non-mowed and burned treatments, with and without mineral fertilization.

**5. CONCLUSIONS AND MANAGEMENT IMPLICATIONS**

Wet-meadow management strongly influenced the effect of mineral fertilizers on soil-water chemistry. Burning combined with fertilization produced the clearest nutrient enrichment, while non-mowed and non-fertilized conditions showed stronger retention of inorganic nitrogen. The results support reduced and carefully targeted fertilizer use, maintenance of appropriate mowing regimes and effective prevention of uncontrolled fires. Further research should examine plant nutrient uptake and long-term soil-water interactions to quantify the role of wet meadows as natural filters and their contribution to limiting eutrophication in Lake Prespa.

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## **APPLICATION OF THE MARK-RELEASE-RECAPTURE METHOD IN THE STUDY OF THE BIODIVERSITY OF THE ORDER LEPIDOPTERA IN ALBANIA**

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### **ABSTRACT**

The Mark-Release-Recapture (MRR) method was applied during July 2024 to investigate the population structure and short-term recapture dynamics of the vulnerable butterfly *Pseudochazara tisiphone* in the Korçë region of Albania. Fieldwork was conducted in the Bredhi i Drenovës area following the principles of the European Butterfly Monitoring Scheme. Individuals were captured with aerial entomological nets, marked using non-toxic identifiers, and released at the capture site. A total of 164 butterflies were marked, and 17 were subsequently recaptured, corresponding to a recapture rate of approximately 10.4%. Of the recaptured individuals, 11 were female and six were male. The species showed rapid flight, strong camouflage and a preference for rocky, shaded microhabitats, often near *Acantholimon albanicum*. The study confirms that MRR is a practical, non-invasive approach for monitoring butterfly populations and provides baseline information for continued research and conservation planning.

**Keywords:** Mark-Release-Recapture; *Pseudochazara tisiphone*; butterflies; population monitoring; Bredhi i Drenovës; Korçë; conservation

### **1. BACKGROUND AND OBJECTIVE**

*Pseudochazara tisiphone* is classified as Vulnerable in Albania and has a restricted distribution associated with rocky and dry habitats. Its populations may be affected by habitat change, human disturbance and climatic conditions. The objective of this study was to examine population structure, movement and behavioural characteristics through the application of the Mark-Release-Recapture method in the species natural habitat.

2. STUDY AREA AND METHODOLOGY

The study was carried out in the Bredhi i Drenovës area in the Korçë region during July 2024. Field procedures followed the general principles of the European Butterfly Monitoring Scheme. Butterflies were captured using aerial entomological nets, individually marked with non-toxic identifiers and released at the original capture location. Subsequent sampling visits recorded recaptured individuals, sex and field observations on flight behaviour, resting sites, habitat use and association with vegetation.



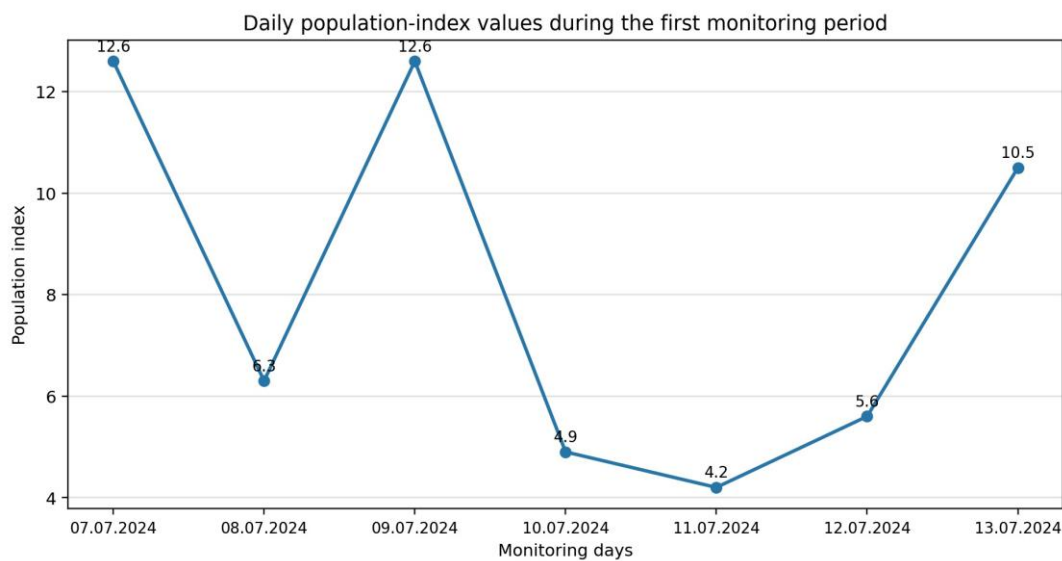
**Figure 1.** Field application of the MRR method: marked individuals of *Pseudochazara tisiphone* and non-toxic marking during monitoring in Bredhi i Drenovës.

3. RESULTS

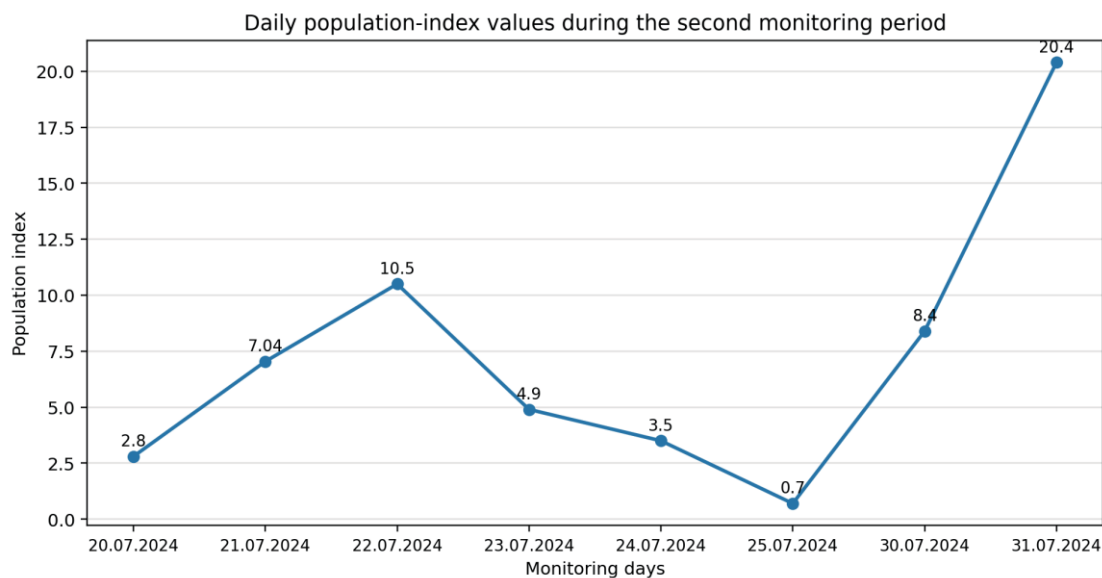
During the monitoring period, 164 individuals were marked and 17 were recaptured. The overall recapture rate was approximately 10.4%. Females represented 64.7% of recaptures, while males represented 35.3%. The highest numbers of marked individuals were recorded on 7, 9 and 31 July, whereas recapture events were more frequent on 12 and 31 July. Daily population-index values varied between sampling dates, indicating short-term fluctuations in detectability and local activity.

**Table 1.** Summary of marked and recaptured *Pseudochazara tisiphone* individuals during July 2024.

| Indicator              | Number | Share / rate                |
|------------------------|--------|-----------------------------|
| Individuals marked     | 164    | 100%                        |
| Individuals recaptured | 17     | 10.4% of marked individuals |
| Recaptured females     | 11     | 64.7% of recaptures         |
| Recaptured males       | 6      | 35.3% of recaptures         |



**Figure 2a.** Daily population-index values recorded during the first monitoring period in July 2024.



**Figure 2b.** Daily population-index values recorded during the second monitoring period in July 2024.

**4. BEHAVIOURAL AND HABITAT OBSERVATIONS**

Individuals displayed fast flight and were difficult to capture because they frequently rested on rocky surfaces or directly on the ground. The species was most often observed in areas with sparse vegetation and along gravelly roads. Butterflies regularly selected shaded sites and avoided prolonged exposure to excessive heat. When their wings were folded, their coloration provided effective camouflage against the surrounding rocks. Several individuals were observed close to *Acantholimon albanicum*, an endemic perennial plant characteristic of rocky and arid habitats.

## 5. CONCLUSIONS AND NEXT STEPS

The Mark-Release-Recapture method provided useful baseline information on abundance, sex structure, behaviour and short-term recapture dynamics. Although the number of recaptures was limited, the results demonstrate that MRR can be applied as an efficient and non-invasive monitoring method for vulnerable butterfly populations. Continued surveys are recommended to generate a longer time series, estimate population size and survival more robustly, examine movement between habitat patches and identify the natural and anthropogenic factors influencing the species. The monitoring programme is expected to continue in 2026.

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# 3<sup>rd</sup> Scientific Prespa Lakes Symposium

Shared Waters, Shared Challenges:  
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in the Prespa Lakes  
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