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CLIMATE CHANGE MITIGATION OF THE OHRID - PRESPA REGION BY A STAKEHOLDER ENGAGEMENT

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Abstract:
Climate change, economic growth, and demographic shifts create complex, long-term challenges, particularly for water-dependent sectors such as agriculture, energy, tourism, and environmental systems. Traditional, isolated management approaches are increasingly ineffective, especially in transboundary regions where shared water resources face mounting pressures. Addressing these challenges requires innovative, multidisciplinary solutions that engage stakeholders and decision-makers across all affected sectors.
The H2020 ARSINOE project is tackling these issues in the transboundary Ohrid and Prespa Lakes region, shared by North Macedonia, Albania, and Greece. By applying System Innovation and Frame Design Thinking methodologies, the project fosters collaboration through national working groups and transboundary living labs. These participatory tools enhance communication, facilitate problem identification, and drive solution development—integrating research, planning, and citizen innovation.
This approach supports sustainable, climate-resilient water management by promoting cooperation among the three countries, ensuring continuous monitoring, and implementing adaptive strategies across sectors. Key outcomes include: improved understanding of lake interconnections, integrated data analysis (hydrology, economy, demography) and prioritization of water users and feasible climate resilience strategies.
The project delivers policy and management recommendations to ensure long-term sustainability - balancing water use with economic growth while protecting the environment. Given the region's UNESCO heritage and Biosphere Reserve status, ARSINOE aims to safeguard its ecological and cultural significance for future generations.

Keywords: *Climate resilience and adaptiveness, water scarcity, System Innovation Approach, Frame Design Innovation Thinking, stakeholder engagement, Ohrid and Prespa Lakes.*

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Introduction

Climate change, alongside economic growth and demographic shifts, is intensifying long-term challenges, particularly for water-dependent sectors such as energy, ecosystems, biodiversity, agriculture, fisheries, tourism, and cultural heritage. Traditional, sector-specific, and nationally focused water management approaches are proving increasingly inadequate. They fail to address the interconnected nature of water resources, especially in transboundary regions where multiple stakeholders depend on shared water bodies. Conventional strategies struggle to ensure sustainable water availability, highlighting the urgent need for a more holistic and integrated approach.

To effectively address these challenges, multidisciplinary and innovative solutions are essential. These approaches must foster collaboration among stakeholders and decision-makers, integrating insights from all affected sectors. By promoting cooperation and innovation, can be developed resilient strategies to tackle water scarcity, enhance climate adaptation, and ensure sustainable resource management—particularly in regions where water sources extend across national borders.

As part of the Climate Resilient Regions through Systemic Solutions and Innovations (ARSINOE) project (https://arsinoe-project.eu/), a transboundary stakeholder engagement model has been introduced in the case study of Ohrid and Prespa Lakes. Given the complexity of the challenges faced in this shared water ecosystem between North Macedonia, Albania, and Greece, an innovative approach is essential to ensure effective collaboration and decision-making. To enhance stakeholder engagement and address the specific needs of the region, the project implemented a System Innovation Approach combined with Frame Design Innovation Thinking. This methodology aims to foster cross-border cooperation, align policy-making efforts and develop systemic solutions that support climate resilience and sustainable water management in the transboundary lake region.

The Ohrid-Prespa Lakes system is a unique, interconnected freshwater ecosystem of global significance. Lake Ohrid, shared by North Macedonia and Albania, receives water through natural underground flows from Prespa Lake. Together, these lakes form one of the most recognizable UNESCO-listed regions, designated as a Mixed World Heritage Site. The area is also home to six protected areas, three internationally recognized wetlands under the Ramsar Convention, and a UNESCO Biosphere Reserve, underscoring its ecological and cultural importance.

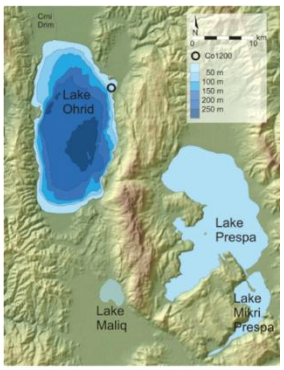

Figure 1. *Map of Ohrid and Prespa Lakes*

Figure 2. *Ohrid Lake*

Beyond its environmental value, the region supports hydropower production on the Crn Drim River, a thriving tourism sector, and industries such as textiles, food, and construction materials. However, climate change is disrupting the delicate water balance, posing serious risks to ecosystems, agriculture, energy production, and tourism. Research highlights the urgent need for climate adaptation strategies, emphasizing sustainable water management, improved governance, and cross-border collaboration among North Macedonia, Albania, and Greece.

The North Macedonian part of the Prespa and Ohrid Lakes watershed includes of Ohrid and Prespa Lakes. A superlative natural phenomenon, Lake Ohrid provides a refuge for numerous endemic species of freshwater fauna and flora dating from the Tertiary period. Situated on the shores of the lake, the town of Ohrid is one of the oldest human settlements in Europe. Built mainly between the 7th and 19th centuries, it has the oldest Slav monastery (St Pantelejmon) and more than 800 Byzantine-style icons dating from the 11th to the end of the 14th century. In the shallow waters near the shores of the lake, three sites testify to the presence of prehistoric pile dwellings, and the small Lin Peninsula is the site of the remains of an Early Christian church founded in the middle of the 6th century (https://whc.unesco.org/en/list/99/, accessed on 25.2.2025). Ohrid Lake together with Prespa Lake make the Ohrid –Prespa region to be one of the most recognizable UNESCO regions, as mixed world heritage site.

Collaborative Approach to Sustainable Water Governance

Through the Ohrid and Prespa Lakes case study, stakeholders in the ARSINOE research and innovation project are developing a

comprehensive, climate-resilient water governance framework. This initiative ensures sustainable water use, ecosystem conservation, and economic stability while addressing climate challenges in the transboundary lake system. By fostering cross-border cooperation, the project seeks to balance social, economic, and environmental interests for long-term regional sustainability.

To engage stakeholders effectively, the project established national working groups and transboundary living labs in North Macedonia, Albania, and Greece. These participatory platforms enabled: collaboration and problem identification – bringing together motivated stakeholders to define challenges and explore solutions, future scenario development – using research and participatory tools to anticipate climate impacts and propose strategies and integrated planning and innovation – merging analysis, research, design, and citizen-driven solutions. Over the first two years, national working groups and transboundary living labs were successfully launched in all three countries. These simultaneous sessions facilitated direct engagement with stakeholders, leading to the development of mental maps that captured local perspectives on challenges, opportunities, and long-term sustainability in the Ohrid-Prespa region. By fostering regional cooperation, this initiative lays the foundation for a sustainable future, ensuring that the Ohrid-Prespa Lakes remain a resilient and thriving ecosystem for generations to come.

Stakeholders were selected and identified from different sectors (water, agriculture, tourism, fishery, energy, academy, culture), categories (government/municipalities, academia, NGOs/associations, business and local citizens), and scale levels (local, regional, national). All three North Macedonian national working groups took place in the Skopje, with the presence of all local and national stakeholders.

First National Workshop: The first national workshop took place in June 2022. During this workshop: key climate change indicators were identified, including temperature and precipitation variations, water body status, sectoral vulnerabilities, and the causes and consequences of water scarcity. Discussions highlighted the interconnected impacts of climate change on water quantity and quality, environmental and economic sector dependencies, demographic and socio-economic changes, water pollution sources and poor groundwater management. The most affected sectors include water management, biodiversity and ecosystems, human health, hydropower and renewable energy, agriculture, fishery, and forestry, tourism and cultural heritage and small and medium-sized enterprises

(SMEs). Key challenges identified were inefficient water use and the need for climate-adaptive strategies, lack of innovation and business models for sustainable water management and insufficient collaboration and information - sharing across sectors and countries.

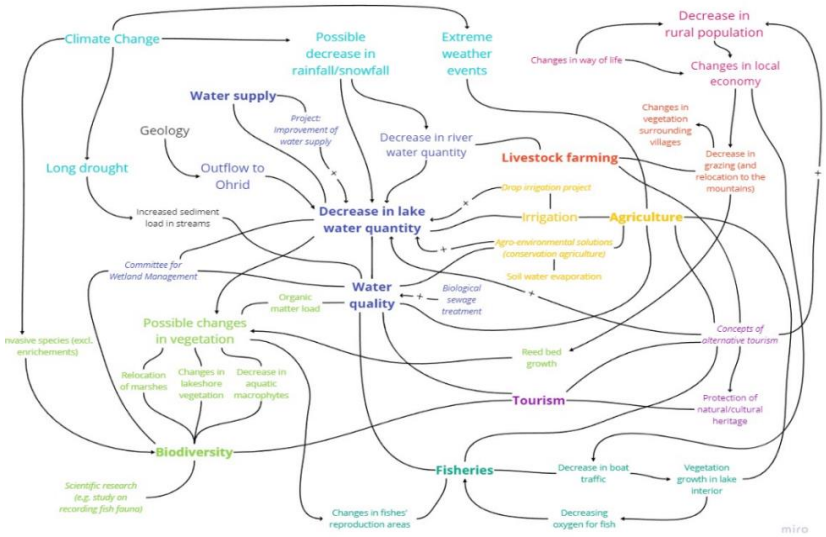

Figure 3. *Map of relevant users and stakeholders of the Ohrid and Prespa Lakes*

Second National Workshop: The second national workshop took place in January 2023 and it was named Future narratives and vision for the Ohrid-Prespa region. The second national working groups gathered stakeholders from North Macedonia to discuss future narratives and a shared vision for the Ohrid and Prespa Lakes region. At the workshop's outset, stakeholders identified major challenges: fragmented sectoral strategies leading to inefficient water use, endangered ecosystems due to inadequate conservation measures and lack of water measurement and monitoring, affecting long-term water management. The main sectors analyzed included water management, biodiversity, human health, hydropower, agriculture, fisheries, tourism, industry (SMEs), and cultural heritage. New drivers influencing climate resilience were identified, such as forest management, wildfire risks, renewable energy installations, and sustainable tourism planning. After discussions, stakeholders reached a consensus on the core climate adaptation priorities: integrated climate-adaptive actions across all sectors, symbiotic water use strategies and improved water measurement and monitoring for sustainable management.

Figure 4. *Second National Workshop with the stakeholders*

Third National Workshop: The third national workshop took place in June 2023 and was implementing the methodology of back casting to the future vision. Stakeholders outlined key milestones by working backward from 2050 to the present to realize the future vision established in the second workshop. They then identified the necessary innovations to achieve these milestones. The stakeholders contributed the potential innovative solutions for climate adaptation in the Ohrid and Prespa Lakes region, further strengthening the region's long-term resilience.

Figure 5. *Third National Workshop with the stakeholders*

As part of the methodology, a SWOT analysis was conducted for the Ohrid and Prespa Lakes case study, applying a strategy of problem posing and solving that leverages strengths to maximize opportunities. Key findings from the SWOT Analyses are the strengths: strong awareness and concern among stakeholders about water status, responsibility, interest, and willingness to take action, existing and emerging initiatives for water and environmental management, and sectoral and national strategies aligned with regional plans. The following weaknesses were presented, limited

communication and information sharing across sectors, lack of awareness about funding opportunities for innovation, unexplored business models that could support sustainable water management, and insufficient monitoring networks for water quality and quantity, limiting future scenario forecasting. The following opportunities were identified, availability of funding for climate adaptation initiatives, strong capacity within social and scientific communities, established long-term collaboration among institutions from all three countries, and growing trends in innovation for climate resilience. The following threats were identified climate change impacts on water resources, threats to biodiversity and ecosystems, and risk of failing to restore lakes and environmental systems to their natural state.

Results and discussion

At the conclusion of the First National Workshop, stakeholders identified a core problem statement: biodiversity, agriculture, fisheries, tourism, and cultural heritage are increasingly vulnerable to climate change impacts, particularly water scarcity. While existing institutions and projects are addressing these challenges, stakeholders emphasized the need for further support, expansion, and innovation to strengthen climate adaptation. There was a consensus on the urgency of transitioning to climate-adaptive water management and acknowledging national and local action plans already in place. The key differences identified were that each sector focused on different issues with varying levels of detail, reflecting national priorities and stakeholder structures, policy discussions varied across groups, with some topics receiving more emphasis in certain countries, climate projections were analyzed with different time horizons (2050, 2070, and 2100), with each sector employing unique methodologies. Identified Gaps were the stakeholders sought clearer insights into the CS4 objectives, expected impacts, and their role in implementation, key stakeholders were absent from initial workshops due to scheduling conflicts, the transboundary significance of the case study was not sufficiently emphasized and should be prioritized in future sessions, and envisioning a sustainable future for the Ohrid - Prespa Region.

During the Second National Workshop, stakeholders collaborated to define a shared long-term vision for the Ohrid - Prespa region, emphasizing sustainability, resilience, and cross-border cooperation. The Future vision was identified as through scientific research and cross-border collaboration, a deeper understanding of the hydrological connections between the three lakes has been achieved, leading to reversed water level declines in Large Prespa Lake and improved water quality. Local authorities and citizens demonstrate high environmental awareness,

supported by social innovations, capacity building, and citizen science applications. Community-driven initiatives, such as local incubators, empower residents to adopt resilient practices and pass this knowledge on to future generations. Efforts to conserve biodiversity and restore ecosystems extend beyond lakes and wetlands, incorporating surrounding forests and landscapes. A joint transboundary coordination mechanism ensures seamless cooperation across national, regional, and local levels, bringing together stakeholders from multiple sectors. The natural and cultural heritage of the UNESCO Ohrid - Prespa region is actively protected, ensuring that tourism remains sustainable while minimizing human impact on water sources, lake ecosystems, and surface water regimes. By fostering cross-border collaboration, leveraging research and innovation, and strengthening governance mechanisms, this initiative paves the way for a climate-resilient and sustainable future for the Ohrid - Prespa Lakes region. Through ongoing stakeholder engagement and adaptive strategies, the region can serve as a model for transboundary climate action and water management.

Stakeholders have established key principles for sustainable development in the transboundary Ohrid - Prespa region, focusing on water quality and reducing untreated wastewater, enhancing water-use efficiency across sectors, strengthening transboundary cooperation for integrated water management, protecting and restoring water-related ecosystems, investing in clean energy technologies and sustainable tourism, promoting cultural and natural heritage conservation and building resilience to climate-related hazards. Stakeholders envisioned a thriving and sustainable Prespa region by 2050, characterized by reversed negative demographic trends, green job opportunities for youth in tourism, agriculture, fisheries, and clean industries: sustainable economic growth through scientific research, technology, and transboundary synergies, climate-adaptive agriculture, integrating diverse crops, modern technology, and efficient irrigation and balanced tourism development, respecting carrying capacity and seasonal distribution. They also envisioned a transboundary economic strategy, including common product labeling and improved infrastructure and robust water monitoring systems, ensuring long-term water quality and availability. Also the region will create a transboundary Crisis Management Plan, with early warning systems for droughts, wildfires, and ecosystem threats, strengthened protection of UNESCO heritage, eliminating anthropogenic pressures on water bodies and sustainable tourism and cultural heritage preservation, ensuring long-term economic and environmental balance.

The Third National Workshop brought together the results from previous two national workshops, integrating insights into a common

back-casting funnel. Twenty stakeholders from North Macedonia participated in person, engaging in-group discussions to refine and improve the proposed strategies. Stakeholders identified twelve priority themes, each linked to critical sectors influencing the Ohrid - Prespa region's sustainability: institutional-legal framework and policy, education and social cohesion, water management, environment and biodiversity, tourism and cultural heritage, agriculture, fisheries, forests and wetlands, infrastructure and renewable energy and funding schemes and transboundary innovation hubs.

Through collaborative discussions, stakeholders agreed on key milestones to be achieved between 2025 and 2050. Identified urgent priorities focused on transboundary challenges were common monitoring methodology – establishing standardized approaches for data collection and analysis, historical water level survey – documenting long-term changes to inform sustainable water management. The following milestones were detected defining key actors – mapping relevant institutions and stakeholders for coordinated action and climate-resilient infrastructure – developing structures to withstand extreme weather events linked to climate change. To achieve these milestones, stakeholders identified key technological and social innovations, aligning them with sectoral needs. Examples include: advanced transboundary monitoring systems and management plans, smart sensor-based water management, raindrop collection technologies for water efficiency, new and rediscovered crop varieties for climate-adaptive agriculture, sustainable farms linked to tourism for economic diversification, and multifunctional hubs integrating education, innovation, and capacity-building. The draft innovation pathways were shared with stakeholders for feedback, with opportunities to add innovations and refine existing ones. Stakeholders also identified existing innovations – connecting with initiatives that are already being implemented, innovation gaps – highlighting areas lacking sufficient development, barriers and enablers.

The results of this Living Lab serve as a strategic foundation for advancing transboundary cooperation, driving policy action, research, and investment in sustainable innovations. By aligning efforts across sectors, the Ohrid - Prespa region is positioning itself as a model for climate resilience, environmental conservation, and cross-border collaboration.

Conclusion

The stakeholder engagement methodologies implemented in the Ohrid - Prespa region aim to provide sustainable results by enhancing climate resilience and sustainability across the transboundary region,

strengthening cross-border collaboration, fostering further research, innovation, and result deployment, establishing a new model for transboundary cooperation, enabling continuous monitoring, evaluation, and improvement of climate adaptation across sectors. Also, they will deepen understanding of the hydrological connections between the lakes and pressures impacting water resources, integrating diverse datasets (hydrological, economic, demographic) from partner countries and prioritizing water users and their needs, particularly environmental ecosystems, while identifying feasible climate-resilient alternatives for water use.

The study contributes to provide innovations pathways for policy and management recommendations to ensure a climate-adapted transboundary region with a balanced approach to water use and sustainable sectoral growth. Ultimately, the Ohrid and Prespa Lakes case study aims to establish a long-term sustainable water balance, factoring in climate change, demographic shifts, and sectoral growth (agriculture, industry, fisheries, tourism, and hydropower), while ensuring environmental protection and biodiversity conservation.

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