BOOK OF ABSTRACTS

This Book of Abstracts provides a comprehensive overview of the session content and is structured into three main sections:

I. Session Description – an introduction to each session, including its objectives and expected outputs
II. Session Program – a detailed schedule for each session, including speakers and timing
III. List of Abstracts – a complete compilation of all accepted abstracts

I. SESSION DESCRIPTION

ID: B2

Freshwater Ecosystem Services for Restoration, Management, and Policy: linking restoration, valuation and nature-based solutions for research and decision-support

Hosts:

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Host (s):	Juan Pablo Pacheco	Aarhus University, Denmark	jp@ecos.au.dk
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Abstract:

Freshwater ecosystems provide essential services that underpin environmental health, human well-being, and sustainable development, including water quality regulation, flood mitigation, climate regulation, carbon sequestration, and diverse cultural and relational values. However, despite their critical role, knowledge of Freshwater Ecosystem Services (FES) remains fragmented and underrepresented, which limits their effective integration into water management, restoration, and policy frameworks.

This session brings together three complementary themes: assessing and managing FES for integrated watershed protection, quantifying the biophysical and socio-economic benefits of freshwater restoration to support nature-based solutions, and applying the ecosystem services concept to meet the objectives of the EU Water Framework Directive. It seeks to foster stronger inter- and transdisciplinary collaboration among researchers, water managers, policymakers, and other stakeholders to address knowledge gaps, share methodological advances, and identify best practices for integrating FES into decision-making.

Through case studies and conceptual presentations, followed by a joint discussion, this session focuses on holistic and systemic approaches to FES, including advancing nature-based solutions, multi-service assessments, modelling and valuation approaches, restoration actions, and strengthening science-policy interfaces for integrated watershed management to support environmental conservation and human well-being.

The session will result in two main outcomes: a peer-reviewed synthesis of FES research and methods, and the launch of a thematic interdisciplinary working group to coordinate research, inform policy, and guide sustainable freshwater conservation and management across scales and sectors.

Goals and objectives of the session:

This session aims to advance the understanding, assessment, and practical application of Freshwater Ecosystem Services (FES) as a common framework for research, management, and policy. We welcome studies encompassing multiple ecosystem services, habitat types, geographical contexts, and diverse analytical approaches, including empirical studies, reviews, modelling exercises, and concept-based discussions. We also welcome analyses of decision-making contexts that shed light on the role of FES in conservation, restoration, prioritisation, and management strategies supported by nature-based solutions, particularly those drawing on European and comparative international case studies addressing service quantification, valuation, and trade-offs.

We seek to bring together diverse FES approaches to integrated research, water management, ecosystem restoration, and the implementation of the EU Water Framework Directive, the Nature Restoration Law, and related environmental goals, and to serve as a starting point for an interdisciplinary community on FES that integrates scientific research, management, and policy.

Specific Objectives:

1. Synthesize current knowledge and approaches on freshwater ecosystem services, including water quality and quantity regulation, erosion and flood control, nutrient retention, climate regulation, carbon sequestration, and habitat provisioning, while highlighting both well-established and emerging or underrepresented services.

2. Identify main knowledge and implementation gaps in FES research and management, with a particular focus on strategies for protecting and restoring freshwater ecosystems and their services, while aligning with broader goals of nature conservation, climate resilience, and sustainable development goals.

3. Explore decision-making contexts and knowledge needs that support prioritisation of freshwater restoration and the efficient allocation of resources to nature-based solutions, and to share examples of best practice in applying the ecosystem services concept to water management planning to support the objectives of the Water Framework Directive.

4. Establish a thematic interdisciplinary working group dedicated to the research and management of freshwater ecosystem services, promoting collaboration across scientific, management, and policy domains to co-produce knowledge, bridge research–practice gaps, and guide coordinated action for the conservation and sustainable use of freshwater ecosystems

Planned output / Deliverables:

The session is expected to create a collaborative space for researchers, policymakers, and practitioners to share approaches and experiences, and identify knowledge and implementation gaps in assessing and integrating FES into watershed management, conservation, and sustainability planning and decision-making, with attention to both tangible and less tangible services.

Key outcomes of this session include a joint peer-reviewed publication summarising current FES research and management perspectives & scope, potentially including a synthesis of methodological advances in modelling and valuation that link ecosystem services assessment to policy and management decisions, as well as practical guidance on FES in line with the EU Water Framework Directive.

The session will also initiate a thematic interdisciplinary working group on FES to coordinate research, support knowledge transfer, and inform policy and management, while contributing to ESP working groups (BWG 2a and BWG 2b) and supporting ongoing European initiatives on upscaling nature-based solutions.

Session format:

Standard session composed of three sub-sessions:

- Sub-session 1. Freshwater ecosystem services for integrated watershed management and protection – *Juan Pablo Pacheco, Bence Decsi, Pablo E. Prado Velasco, Marcus Ming Fricke, Zsolt Kozma, Kenneth M. Persson, Linus Zhang*
- Sub-session 2. Quantifying the biophysical and socio-economic benefits of freshwater ecosystem restoration: understanding knowledge needs for up-scaling nature-based solutions - *Xavier Garcia, Sien Kok, Nicolas Grondard, Kerry Waylen, Sebastian Birk*
- Sub-session 3. Support of the fulfilment of the objectives of the European Water Directive through the implementation of ecosystem services concept to water management planning - *Jiri Schneider, Jiri Jakubinsky, Martin Pawel*

Each sub-session will include oral presentations of 10 minutes, followed by 5 minutes for questions, in 15-minute slots.

The sub-sessions will conclude with a joint discussion of 30 minutes, focused on establishing the basis for the working group on Freshwater Ecosystem Services and identifying the main components to include in the perspective paper. Overall, the session is expected to last 5 hours

Related to ESP Working Group:

BWG 2 – Freshwater systems

II. SESSION PROGRAM

Room: A1
Date of session: Tuesday, 19 May 2026
Time of session: 11:00 – 19:15

Timetable speakers:

Sub-session 1:

Freshwater ecosystem services for integrated watershed management and protection

Time	First name	Surname	Organization	Title of presentation
11:00	Juan Pablo	Pacheco	Session's organizers	Introduction to the session
11:05	Priya	Sharma	University of Eastern Finland	Reviving pondscapes: a spatial approach to assess biodiversity and cultural services
11:18	Linda	Rogge	TUD Dresden University of Technology, International Institute (IHI) Zittau	Payments for Environmental Services in carp pond farming: Rewarding results for biodiversity conservation
11:31	Pablo Edmundo	Prado Velasco	Lund University, Sweden	Modelling Willingness to Pay for Freshwater Ecosystem Services in the Central Andes
11:44	Fábio André	Matos	University of Aveiro, Portugal	Assessing the effects of green roofs on freshwater quality and ecosystem service values: the case of green roofs in Tampere, Finland
11:57	Celina	Aznarez	Center for Desertification Research (CIDE), CSIC-UV-GVA, Spain & Aarhus University, Denmark	Ecosystem services mismatches in a socio-ecological system under chronic hydrological stress: a Water-Energy-Food Nexus approach in the Segura River Basin, Spain
12:10	Javier	Senent Aparicio	Center for Desertification Research (CIDE), CSIC-UV-GVA, Spain	Coupling SWAT+ and GOTM-WET Models to Assess Climate Change Impacts on Ecosystem Services in the Mar Menor Coastal Lagoon
12:30	Lunch break			
14:00	Máté	Chappon	Széchenyi István University Győr, Hungary	Considering environmental flow requirements in the Water Value Flow framework – an ES valuation study in the Lake Velence catchment, Hungary
14:13	Zsolt	Kozma	Budapest University of Technology and Economics, Hungary	How hydrological models can support ecosystem services mapping

Sub-session 2:

Quantifying the biophysical and socio-economic benefits of freshwater ecosystem restoration: understanding knowledge needs for up-scaling nature-based solutions

Time	First name	Surname	Organization	Title of presentation
14:26	Pinar Pamukcu	Albers	University of Bonn, Germany	How effective is urban river and floodplain renaturation for enhancing ecosystem services and water management?
14:39	Sien	Kok	Wageningen University & Research, Netherlands	Integrated hydrologic- economic assessment of upstream afforestation strategies in Sorraia watershed, Portugal

14:52	Lydia	Olander	Duke University, United States of America	Creating a Data Exchange to Evaluate Hazard Attenuation Benefits of Nature-Based Solutions: Freshwater and Coastal System Examples
15:05	Francesc	Comalada i Pla	Catalan Institute for Water Research (ICRA), Spain	Monetary valuation of river Cultural Ecosystem Services to support restoration prioritization in Europe
15:18	Henriette	John	Leibniz Institute of Ecological Urban and Regional Development, Germany	Using ecosystem service assessment to valuate effects of small-scale nature-based solutions in urban stream restoration
15:30	Coffee break			
16:00	Emilio	Politti	International Institute for Applied Systems Analysis, Austria	Basin Scale Hydrological Modelling of Channel and Forest Restoration in the Danube Basin
16:13	Saadet Gökçen	Karaduman	Izmir Katip Celebi University, Türkiye	Interconnected Histories of Lakes, Deltas, and Lagoons: Assessing Freshwater Ecosystem Service Trade-offs and Nature-Based Restoration Pathways in Türkiye
16:26				

Sub-session 3:

Support of the fulfilment of the objectives of the European Water Directive through the implementation of ecosystem services concept to water management planning

Time	First name	Surname	Organization	Title of presentation
16:39	Jiří	Schneider	Mendel University in Brno, Czech Republic	Linking Freshwater Ecosystem Services and Policy: Evidence from Water Framework Directive Implementation in Europe
16:52	Annija	Danenberga	Baltic Studies Centre, Latvia	From Biophysical to Behavioural: Integrating Socio-Economic Indicators into Ecosystem Service Assessments for River Basin Nutrient Management
17:05	Bence	Decsi	Budapest University of Technology and Economics, Hungary	Decoding Water Quality Across the Danube River Basin - Evidence from stressor-based watershed typologies and ecosystem service potential assessments
17:18	Ján	Babej	Global Change Research Institute, Czech Republic	Integrating Ecosystem Service Assessment within River Basin Planning: Insights from a Czech Case Study
17:30	Coffee break			
17:45	Máté	Chappon	Széchenyi István University Győr, Hungary	Quantifying benefits of large-scale floodplain restoration using the River

				Ecosystem Service Index (RESI) in the Szigetköz-Danube, Hungary
17:58	Kinga	Krauze	European Regional Centre for Ecohydrology PAS, Poland	Bringing Freshwater Ecosystem Services into Practice: Methods, Challenges, and Nature-Based Solutions
18:11	Elina	Klodane	Association Baltic Coasts, Latvia	Assessment of Freshwater Ecosystem Services for Achieving Good Status in Vulnerable Water Bodies
18:24	Elena	Preda	Bucharest University of Economic Studies, Romania	Leveraging Regional Attractiveness as a Strategic Catalyst for Ecosystem Restoration in the Danube Region
18:37	Elisa	Marsicovetere	University of Basilicata, Italy	From Ecosystem Service Assessment to Results-Based Payments: A Policy-Oriented Framework for Nutrient Regulation
18:50 – 19:15	General Discussion: central issues for a perspective paper			

III. ABSTRACTS

The first author is the presenting author unless indicated otherwise

1. Reviving pondscapes: a spatial approach to assess biodiversity and cultural services

***First author*:** Priya Sharma
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Man-made aquatic systems, such as freshwater fishponds, are an important yet often overlooked part of European watersheds. Prominent in Central and Eastern Europe, these pondscapes support local food production while delivering broader ecological and cultural benefits. However, assessing services like habitat maintenance and cultural values remains challenging because they stem from complex, long-term interactions between ecosystems and human activities. Traditional biophysical assessments often fail to capture these dimensions, leaving gaps in evaluation methods for fishpond landscapes.
To address this, we applied an Ecosystem Service (ES)-in-Planning approach that integrates spatial indicators with ES concepts. Our case study focused on 25 pondscapes across Hungary, combining landscape structure metrics such as fractal dimension, edge density, and connectivity with cultural and recreational indicators, including land-cover diversity, naturalness, accessibility, and tourist attractions. This framework allowed us to link ecological complexity and human influence on service delivery and trade-offs across regions and pond types.
Results revealed clear patterns that irregularly shaped, heterogeneous pondscapes with higher edge density and connectivity supported greater biodiversity and cultural services, including recreation and aesthetic value. In contrast, compact, homogeneous ponds with high hemeroby indicated stronger human influence and reduced ecological integrity. Road density varied regionally, improving accessibility but also increasing fragmentation, highlighting a trade-off between recreational potential and habitat quality.
Our findings demonstrate that spatial indicators can turn complex landscape patterns into actionable insights for sustainable pondscape management. We recommend a multi-pronged strategy including preventing abandonment through periodic management, restoring degraded ponds by resetting successional stages, and reviving ghost ponds to unlock historic seedbanks for rapid biodiversity

recovery. Combined with ES indicators, these measures enable targeted planning, enhance connectivity, and secure long-term freshwater ES in agricultural landscapes.

Keywords: Pondscapes, Fishponds, Spatial indicators, Habitat maintenance, Cultural ecosystem services

2. Payments for Environmental Services in carp pond farming: Rewarding results for biodiversity conservation

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Carp pond farming has led to the creation of large, interconnected pond landscapes that constitute cultural landscapes and biodiversity hotspots. A substantial number of these ponds are part of the EU's Natura 2000 network. Carp is predominantly reared in extensive polyculture, which is considered a sustainable form of aquaculture compared to more intensive fish farming systems. In order to preserve these ponds as habitats, continuous maintenance is required. Therefore, pond farmers play an active role in biodiversity conservation and the provision of further environmental services. To support extensive carp pond farming and incentivise conservation-oriented practices, German states offer aquacultural funding programmes. These programmes fall under the broader scope of Payments for Environmental Services (PES). In terms of their design and purpose, aquacultural funding programmes are comparable to agri-environment schemes, where the question of how to effectively incentivise biodiversity conservation has long been debated. Payments of such schemes can be distinguished in action-based and result-based payments, with the latter generally being deemed more environmentally effective.
To assess how pond farmers are currently rewarded for biodiversity conservation, we selected aquacultural funding programmes in German states with a substantial pond-farming area (< 500 ha). Our analysis of six programmes from five different states revealed that five out of six programmes are action-based. Programmes tend to be complex and inflexible in design, increasing existing tensions between fish production and nature conservation. In our review, we discuss the potential for integrating result-based payments into aquacultural funding programmes. Building on insights from agri-environment schemes, we outline objectives, indicators, and further design features for result-based payments in carp pond farming. Our approach emphasises the need for a more flexible governance framework to inform the design of policy instruments and facilitate the alignment of production and conservation in pond farming.

Keywords: Carp pond farming, biodiversity conservation, PES, result-based payments

3. Modelling Willingness to Pay for Freshwater Ecosystem Services in the Central Andes

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Freshwater ecosystems in the central Andes provide critical ecosystem services (ES), including water purification, baseflow regulation, groundwater recharge, and cultural and recreational benefits. However, these high-mountain systems are increasingly threatened by changing land use, climate variability, and accelerating pressure on water resources. Understanding local willingness to pay (WTP) for conservation and improved water quality is essential for designing effective management and payment schemes for ecosystem services. This study integrates hydrological modeling, remote sensing, and socio-economic analysis to evaluate the determinants of WTP for freshwater ES in Andean headwaters. Biophysical variables were derived from the InVEST Seasonal Water Yield model, producing spatially explicit indicators of precipitation, baseflow, quickflow, curve number (CN), local and upslope recharge, and recharge contribution. These hydrological indicators were linked with in situ water quality measurements and landscape variables. Survey data collected from local and downstream population recorded WTP for water conservation initiatives along with socio-demographic variables such as education level and age

groups. Machine-learning classifiers (Random Forest and Extreme Boost Gradient) were applied to identify the socio-environmental predictors of WTP. Results indicate that both socio-economic characteristics and spatial hydrological conditions significantly shape WTP. Education levels, access to freshwater sources, and age exhibited higher influence in contributing financially, while hydrological stressors, such as distance to water (streams, lakes, wetlands, etc), elevation, runoff potential (CN) and baseflow, were associated with greater support for conservation efforts. The integration of hydrological modeling with social perception valuation provides a robust framework for understanding how environmental conditions influence public support for freshwater ES, offering evidence-based guidance for watershed restoration programs, payment schemes and land planning in the central Andes

Keywords: Freshwater Ecosystem services, Willingness to pay, Central Andes

4. Assessing the effects of green roofs on freshwater quality and ecosystem service values: the case of green roofs in Tampere, Finland

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Urban ecosystems face multiple and increased pressures from anthropogenic action and climate change. Urban freshwater ecosystems are particularly sensitive to environmental pressures, while the services and values derived from them are invaluable to society. To effectively manage freshwater ecosystems and potentiate the services they provide, it is crucial to assess their ecosystem service values. By using environmental valuation methods, it is possible to estimate natural values in monetary terms that can be more easily communicated to and understood by policy makers which, in turn, contributes to better informed decision-making processes. Nature-based solutions (NBS) can be strategically implemented across urban and peri-urban areas to mitigate the negative effects of human activities and climate change. Several studies have assessed the flood mitigation impacts and benefits, while the water quality improvement impacts — particularly the benefits — have received little attention. In this paper we assess the water quality impacts, costs and benefits from NBS across urban and peri-urban landscapes under current and future climate conditions, with a case study for green roofs in Tampere (Finland). Hence, an integrated hydro-economic modelling approach is developed, which combines climate scenarios (2020; 2050), a water systems model (MIKE+), and meta-analytic function transfer. Results show that under current conditions, urban freshwater ecosystems provide large provisioning and cultural ecosystem service values. Under future climate conditions (2050), these values decrease by 10–15%. Depending on the magnitude and location of implementation, green roofs can halt and reverse these future urban freshwater ecosystem service value losses. Results from this study contribute to the growing body of evidence on i) the substantial ecosystem service values from urban freshwater systems and ii) the effectiveness of NBS in the management of urban freshwater ecosystems and ecosystem service values.

Keywords: Nutrient pollution, Sediment transport, Ecosystem service valuation, Nature-based solutions, Hydrological modelling

5. Ecosystem services mismatches in a socio-ecological system under chronic hydrological stress: a Water-Energy-Food Nexus approach in the Segura River Basin, Spain

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This study examines synergies, trade-offs and mismatches in the supply and demand of ecosystem services (ES) in the semi-arid Segura River Basin, a region marked by intense competition among water,

energy, and food (WEF) demands. We assessed the spatial dynamics and interrelations of four key ES: sediment retention, carbon sequestration, food provisioning, and water provisioning. Focusing on four key ES (sediment retention, carbon sequestration, food provisioning, and water provisioning), we applied a spatially explicit, integrative modelling
framework that combines the Soil and Water Assessment Tool (SWAT+) for hydrological simulation with the ARIES platform (via k.LAB) for AI-driven semantic modelling of ES. Our findings reveal clear synergies and trade-offs shaped by land-use patterns and ecosystem condition. Natural areas, particularly forested and protected zones, function as ES hotspots,
critical for regulating services like sediment retention and carbon sequestration, underscoring their importance in WEF sustainability and conservation. Conversely, agricultural and urban areas showed pronounced mismatches: intensive agriculture exacerbates soil degradation and carbon loss, while urban areas place pressure on rural ecosystems where their high demands for provisioning ES are constrained by a limited capacity for regulating ES. By identifying spatial hotspots of intervention this research highlights the value of spatially explicit assessments for understanding ES interactions. The results underscore the importance of integrating ES interdependencies into land and resource management to mitigate trade-offs, strengthen synergies, and enhance resilience in WEF nexus decision-making under climate and socioeconomic pressures.

Keywords: Segura River Basin; Water management; Ecosystem services mismatches; Synergies; Trade-offs

6. Coupling SWAT+ and GOTM-WET Models to Assess Climate Change Impacts on Ecosystem Services in the Mar Menor Coastal Lagoon

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Coastal lagoons are highly vulnerable to climate change, particularly when they are embedded in intensively managed and anthropized catchments. The Mar Menor (southeastern Spain), one of the largest hypersaline coastal lagoons in Europe, has undergone severe ecological degradation over recent decades due to nutrient enrichment, hydrological alterations, and extreme weather events. This study presents an integrated modelling framework based on the coupling of the SWAT+ hydrological model and the GOTM-WET aquatic ecosystem model to assess the impacts of climate change on key regulation ecosystem services in the Campo de Cartagena basin and the Mar Menor lagoon.
SWAT+ was applied to simulate catchment-scale hydrology, sediment transport, water availability, and nutrient exports, while GOTM-WET represented the lagoon's physical, chemical, and biological dynamics, including water temperature, oxygen concentration, nutrient cycling, and phytoplankton biomass. Bias-corrected climate projections from five CMIP6 global climate models were considered under two shared socioeconomic pathways (SSP2-4.5 and SSP5-8.5) for mid-century and late-century periods.
The results project a consistent increase in air and water temperatures (up to ~3.7 °C by the end of the century) and a decrease in average precipitation, together with an intensification of torrential rainfall events. These changes lead to reduced green and blue water availability, altered runoff patterns, increased phosphorus inputs, and decreased nitrogen loads from groundwater. In the lagoon, warming and changes in nutrient dynamics promote higher chlorophyll-a concentrations, more frequent algal blooms, and an increase in hypoxic events, indicating a progressive deterioration of water quality regulation services.
The coupled SWAT+–GOTM-WET approach proves effective in capturing land–sea interactions and climate-driven pressures on ecosystem services. The findings highlight the need for integrated, climate-adaptive management strategies at both catchment and lagoon scales to preserve ecosystem functioning and resilience in vulnerable coastal systems.

Keywords: Climate change, ecosystem services, SWAT+, GOTM-WET, Mar Menor

7. Considering environmental flow requirements in the Water Value Flow framework – an ES valuation study in the Lake Velence catchment, Hungary

First author: Máté Chappon
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Determining environmental flow requirements is an increasingly important component of water resources management as water scarcity intensifies globally. This research presents a hydrologically based, standardizable method for estimating minimum ecological flows and maximum utilizable water resources and an application of this new methodology.
The proposed method relies on two monthly indicators defined as functions of catchment size: (i) natural water resources during low flow conditions – represented by runoff with 80% exceedance probability, and (ii) minimum ecological flow values. The difference between these indicators defines the utilizable water resources, representing the maximum volume available for societal use and serving as an upper abstraction limit.
The approach ensures that ecological flow requirements are composed of two components: a static part that is equal to the monthly minimum ecological flow value, and a dynamic element corresponding to the actual runoff exceeding the 80% probability threshold. As a result, ecosystem water availability varies consistently with natural hydrological conditions rather than being constrained by fixed annual or monthly limits, thereby preserving the natural intra-annual dynamics of each hydrological year.
The method is applied to the water scarce catchment of Lake Velence, Hungary's third largest lake. Using the Water Value Flow framework, the research examines how water allocation patterns and the monetary values of ecosystem services would change if environmental flow requirements were incorporated into water management practice. The evaluation covers the period 2015–2024 and focuses on ecosystem service valuation under constrained water availability.
The results are compared with a previous assessment of reservoir operation scenarios in the same catchment that did not account for environmental flow requirements. Overall, the research demonstrates the capability of the Water Value Flow framework to integrate environmental flow constraints and to assess the hydro-economic implications of sustainable water management measures, thus supporting transparent decision-making, stakeholder dialogue, and conflict resolution.

***Keywords*:** Environmental Flow Requirements, water scarcity, ES valuation, Water Value Flow, Lake Velence

8. How hydrological models can support ecosystem services mapping

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Assessing ecosystem services (ES) as a function of different environmental factors is essential for effective spatial planning and scenario analysis. Among these drivers, water availability represents a complex challenge, as the hydrological processes influencing the quantity and quality of water utilizable by ecosystems exhibit strong spatio-temporal variability and involve several state variables that may be relevant for ecosystem functioning.
Here, we present case studies from the Danube River Basin region to illustrate how distributed hydrological models can support ES assessment and mapping. With this, our goal is to initiate discussion among hydrological and ES experts from diverse disciplinary backgrounds on the potential and limitations of hydrological models for supporting ES assessment.
The models selected for demonstration are the MIKE She and the CWatM, both capable of simulating surface water and groundwater processes and the hydraulic relationship of the two, including river discharge, actual evapotranspiration and storage in e.g. soil, groundwater, snow, reservoirs at daily time step over multiple decades and varying spatial resolution. Using these models to process environmental

information on meteorology, terrain, soil, land use, and water management enables the assessment of the hydrological regime under different climatic forcing and landscape alterations. Though there are rigorous calibration-validation methodologies to provide reliable hydrological simulations, one must understand the limitations of cell-based models and that the abundant model outputs are always biased with uncertainties.
The simulated hydrological variables were subsequently linked to ecosystem service assessments, either as direct forcing inputs for ecosystem and crop models or through the derivation of indicators relevant for regulating services, such as runoff generation or flood mitigation by wetlands. Overall, the case studies demonstrated that distributed hydrological models can provide a coherent and transferable basis for integrating water availability into ecosystem service assessments. At the same time, the results highlighted the need for transdisciplinary collaboration across hydrology, ecology, agriculture, and water management sectors to ensure that model outputs are meaningfully interpreted and jointly applied in ecosystem service assessments, planning, and decision-making.

Keywords: Hydrological modelling, Mike She, Community Water Model, Danube River Basin

9. How effective is urban river and floodplain renaturation for enhancing ecosystem services and water management?

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The Emscher region in Germany represents one of Europe's most ambitious examples of urban river and floodplain restoration, illustrating how large-scale renaturation can enhance ecosystem functioning and support sustainable water management. The renaturation transformed a formerly canalised river system into near-natural floodplains, generating measurable socio-ecological benefits.

This study quantifies key ecosystem services (ESs) associated with the renaturation, including crop yield potential, grassland biomass, flood and low-flow regulation, habitat provision, landscape aesthetics, nutrient retention, and carbon storage. We applied the River Ecosystem Service Index (RESI), integrating hydromorphological, ecological, and land-use indicators across 161 river segments. Detailed analyses were conducted for two renatured floodplains (Dortmund-Mengede and Dortmund-Ellinghausen) to assess local-scale responses to renaturation interventions.

Results show that renatured floodplains exhibit increased hydromorphological diversity and enhanced river–floodplain connectivity, leading to improved ecosystem services compared to non-renatured segments. RESI revealed trade-offs and synergies among services, particularly those associated with land-use, floodplain structure, and implemented nature-based solutions. Despite some data limitations, the analyses highlight the clear benefits of renaturation in enhancing flood regulation, habitat provision, nutrient retention, carbon storage, and landscape aesthetics, with further improvements expected as vegetation and soils develop and ecosystem functions strengthen.

Overall, the findings underscore floodplain renaturation as a multifunctional nature-based approach and show how integrated ecosystem service assessments can inform renaturation planning, supporting sustainable water management and climate resilience. These assessments can be integrated into river basin management and restoration frameworks to guide evidence-based decision-making and contribute to the objectives of the EU Water Framework Directive by prioritizing restoration measures, improving ecological status, and promoting multifunctional management of rivers and floodplains.

Keywords: Floodplain renaturation, ecosystem services, River Ecosystem Service Index (RESI), nature-based solutions, sustainable water management

10. Integrated hydrologic- economic assessment of upstream afforestation strategies in Sorraia watershed, Portugal

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Across Europe, watersheds face growing pressures from pollution, hydrological alteration, abstraction and climate change, with many surface waters failing to achieve good ecological status. Southern Europe is particularly vulnerable due to seasonal water scarcity, highly variable rainfall, erosion-prone soils and intensive land use. Afforestration of upstream watersheds can mitigate erosion, regulate runoff and enhance base flows by increasing infiltration; however, the hydrological and economic implications of afforestation depend strongly on species, landscape and climate context. This study presents an integrated hydrological–economic assessment of afforestation scenarios in support of integrated river basin planning, using the Sorraia basin in Portugal as case study. We apply SWAT to evaluate impacts of expanding eucalyptus plantations (EUCINT) versus restoring native cork-oak forests (RESTOAK) under current and mid-century climate, focusing on reservoir inflows, sediment loads and total phosphorus loads (TP), and corresponding economic implications for agricultural production, reservoir sediment management, water quality and water-based recreation.
Results show that afforestation effects on streamflow are modest compared to literature, likely due to limited soil depth and precipitation in the study area. Sediment and TP dynamics exhibit stronger land-cover effects: EUCINT substantially increases sediment loads, whereas RESTOAK slightly reduces sediment loads. TP loads decline in both scenarios due to reduced grazing inputs, despite higher erosion under EUCINT. In correspondence, initial results indicate that implications of hydrological changes for agricultural production are limited, reservoir management costs under EUCINT increase substantially and both afforestation scenarios contribute to improved water quality.
Our methodology highlights the value of basin-scale analyses that jointly consider hydrological changes and economic trade-offs of upstream land cover change. While land-cover change might not be able to offset projected climate-driven hydrological changes, targeted oak restoration efforts may enhance seasonal flow resilience, whereas continued eucalyptus expansion risks reduced inflows and higher sediment management pressures in Mediterranean reservoirs.

Keywords: upstream afforestation; hydrological-economic assessment; integrated river basin management; ecosystem services

11. Creating a Data Exchange to Evaluate Hazard Attenuation Benefits of Nature-Based Solutions: Freshwater and Coastal System Examples

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In the United States decision makers, engineers, regulators and project planners often claim that evidence on the effectiveness (performance and reliability) of nature-based solutions (NBS) in achieving benefits, particularly hazard attenuation, is insufficient to inform project planning, support development of design and engineering standards, and conduct benefit-cost and return on investment analyses. Recent attempts at systematic review of NBS effectiveness for coastal protection (hazard attenuation) found heterogeneity in metric reporting, a lack of information on critical metrics, and insufficient detail about NBS type and design, making it impossible to assess effectiveness (Bredes et al. 2024, Huynh et al. 2024). Similarly, a systematic review of studies on ecological outcomes from NBS projects found heterogeneity in assessment metrics, with more holistic assessments significantly more likely to show negative or mixed outcomes than solely positive outcomes or no effect (Key et al. 2022). Despite a vast number of restoration and nature-based projects installed in the U.S. over the last few decades, project-level data collected by funders and projects are insufficient for many of the same reasons (Warnell and Olander 2024).
Evaluating effectiveness requires consistent, comprehensive data on NBS project design, setting and

context, performance, and outcomes, including data on baseline conditions or at a reference site, many of which are not consistently collected. Our team has developed two examples – one for coastal protection projects and one for inland water management projects - showing what data needs to be collected to evaluate hazard attenuation (flood, erosion, drought) and biodiversity impacts, and how it needs to be organized to enable evaluation and synthesis. We have also convened a network of funders, practitioners, researchers, and data users to design a NBS Effectiveness Data Exchange (NEDE) to create the data infrastructure (e.g., standards), host the primary database, maintain it, and support related research.

Keywords: Metrics, Performance, Hazard Attenuation, Biodiversity

12. Monetary valuation of river Cultural Ecosystem Services to support restoration prioritization in Europe

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River Cultural Ecosystem Services (CES) are increasingly recognized as key drivers of public support for conservation, yet they remain underrepresented in restoration planning because their benefits are rarely quantified in monetary terms. We address this gap by monetizing river-related CES across the EU-27 and estimating the economic benefits that ecological restoration could generate. We analyze geolocated Flickr data (2022–2024), classify river photos into five CES categories using a deep learning model (F1 = 0.92), and infer user home locations at NUTS-3 level. Driving distance is used to compute round-trip travel costs for 91,570 observed day trips. A user–site travel cost model estimates a mean consumer surplus of €61 per visit. A spatial environmental demand model (negative binomial GLM, spatial cross-validated RMSE = 1.05) predicts CES use as a function of ecological status, naturalness, accessibility to large cities, and recreational infrastructure across 6,650 river segments. Predicted use is calibrated with official visitation data from 175 freshwater landscapes (R^2 = 0.60), enabling the conversion of social-media activity into real visits. Welfare benefits vary markedly across Europe: the top 10% of river segments concentrate over half of the total estimated economic benefits. River segments located near large population centers generate up to five times higher welfare gains than similarly improved sites in low populated areas, suggesting accessibility as a key determinant of restoration returns. Across scenarios, one-class ecological status improvements yield aggregate recreational welfare gains between ~€60k and ~€170k per year under current use levels, demonstrating that restoration interventions produce quantifiable economic benefits at continental scale. These findings demonstrate that combining social-media data with economic valuation provides a practical decision-support framework to prioritize river restoration where societal returns are greatest.

Keywords: Cultural Ecosystem Services; travel cost model; river restoration; monetary valuation; European Union

13. Using ecosystem service assessment to valuate effects of small-scale nature-based solutions in urban stream restoration

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Streams in cities are often heavily anthropogenically modified, straightened or forced into an artificial bed. As a result, they can only provide ecosystem services (ES) to a very limited extent. However, for adapting cities to climate change, increasing biodiversity and improving the quality of life in cities, multiple ES would be particularly important. The restoration of streams could therefore offer a number of benefits to cities and their inhabitants.
But the planning and implementation of large-scale stream restoration projects can face many obstacles and challenges, including the lack of space, ownership rights to neighbouring properties, differing

interests among stakeholders, a low level of acceptance and very time-consuming planning procedures. In contrast, minor measures in the form of small-scale nature-based solutions can be implemented relatively quickly as part of watercourse maintenance with appropriate participation processes. But this raises the questions of what measures are necessary at which locations in order to maximise the provision of ES and how the improvement can be measured.
We will present a methodological approach based on stream structural mapping, public surveys and some additional data to evaluate ecosystem services in the current state as well as in the future after implementing small-scale nature-bases solutions. We adapted existing methodologies for the assessment of regulating and cultural ES to the urban context. Regarding provisioning ES, which are mostly underrepresented or even neglected in urban ES studies, we developed a new methodology especially for the provision of edible plants by streamside green spaces for healthy food and a re-connection of people with nature.
In addition, we provide information on how ES can be used for communication purposes to increase acceptance of restoration measures, and how ES can become relevant to policy in the form of policy briefs.

Keywords: urban stream restoration, edible plants, nature-based solutions, participation, communication

14. Basin Scale Hydrological Modelling of Channel and Forest Restoration in the Danube Basin

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Basin-scale hydrological modelling of Nature-Based Solutions (NBS) is currently shifting from experimental, site-specific pilots to integrated, catchment-wide strategies. While NBS such as reforestation, wetland restoration, and runoff attenuation are seen as vital for climate resilience, modelling them at the scale of an entire river basin presents a unique technical challenge.
With this work, we attempt to provide a first, scenario-based hydrological assessment of the potential of large-scale channel and floodplain restoration in the Danube basin.
The modelling covers the entire Danube basin and uses the hydrological model CWatM at a 5-degree resolution. The simulated NBS include restoration of the floodplain forest and channel restoration. The first was simulated by changing the land-cover inputs in CWatM, while the latter was simulated by increasing channel width and depth. The NBS were simulated with three progressive degrees of restoration intensity (i.e., from intensive to limited). The simulation spanned several decades, and the effectiveness of the NBS was assessed by comparing hydrological variables (e.g., runoff, groundwater storage) between a baseline scenario (i.e., without restoration) and the restoration scenarios.
The results show a sensible change in the hydrological variables between baseline and scenarios.

Keywords: basin scale modeling, natural based solution, CWatM, hydrological model

15. Interconnected Histories of Lakes, Deltas, and Lagoons: Assessing Freshwater Ecosystem Service Trade-offs and Nature-Based Restoration Pathways in Türkiye

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Freshwater lagoon ecosystems constitute highly dynamic social–ecological systems that provide essential freshwater ecosystem services, while remaining particularly vulnerable to hydrological alterations, coastal interventions, and land-use pressures. In Türkiye, many lagoon and lagoon–lake systems have undergone profound transformations over recent decades due to changes in lake–lagoon connectivity, water management infrastructure, and climate variability. This study aims to assess historical changes in freshwater lagoon ecosystem services by explicitly linking hydrological connectivity, human interventions,

and biodiversity responses, with a particular focus on endangered fish species.
Five representative freshwater lagoon and lagoon–lake systems across different coastal regions of Türkiye were selected to capture a gradient of hydro-ecological conditions and management contexts. Long-term remote sensing data (Landsat and Sentinel series) were used to analyse historical changes in water surface extent, hydroperiod, wetland vegetation dynamics, lagoon–sea connectivity, and water quality proxies such as turbidity and chlorophyll-related indices. These indicators were integrated with fisheries data derived from provincial statistics, fishing gear inventories, and cooperative records to quantify changes in provisioning ecosystem services. Species-specific catch-per-unit-effort (CPUE) metrics and a weighted endangered fish index were developed to track temporal trends in threatened fish populations and to relate biological responses to habitat and hydrological changes.
Quantitative analyses were complemented by semi-structured stakeholder interviews with fishers, local authorities, and protected area managers to document perceived ecological changes, key intervention periods, and governance challenges. By triangulating remote sensing indicators, fisheries data, and stakeholder knowledge, the study identifies intervention-driven regime shifts and their impacts on provisioning, supporting, and regulating freshwater ecosystem services.
Building on this integrated assessment, the study develops a framework for designing context-specific, stakeholder-accepted Nature-based Solutions aimed at restoring hydrological connectivity, improving habitat quality, and enhancing freshwater ecosystem services. The results support evidence-based restoration planning and decision-making, contributing to the integration of ecosystem services into freshwater management and restoration strategies in line with emerging European water and nature restoration frameworks.

Keywords: Lake–lagoon connectivity;Water allocation trade-offs, Nature-based Solutions (NbS); Integrated watershed management

16. Linking Freshwater Ecosystem Services and Policy: Evidence from Water Framework Directive Implementation in Europe

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The EU Water Framework Directive (WFD) introduced an ecosystem-based framework for freshwater management aimed at achieving good ecological and chemical status of surface and groundwater bodies. Increasingly, ecosystem services (ES) approaches are promoted as complementary tools to support WFD implementation by linking ecological status, human well-being, and decision-making. This study provides a cross-country review of how ES concepts and methods have been integrated into WFD implementation across EU Member States.
We conducted a systematic review of 120 peer-reviewed studies published between 2015 and 2025, analysing the role of ES in freshwater assessment, management planning, restoration prioritisation, and policy support under the WFD. The results reveal substantial heterogeneity in the depth and form of ES integration among Member States. The most advanced applications are reported from the United Kingdom, Germany, Italy, Spain, and Greece, where ES frameworks have been used to support pressure prioritisation, assess trade-offs among management options, and monetise benefits of water quality improvements through natural capital accounting.
Across countries, ES approaches contribute to WFD implementation by strengthening links between ecological objectives and socio-economic benefits, supporting stakeholder engagement, and informing river basin management planning. However, persistent barriers limit wider uptake, including legal and institutional ambiguities, methodological inconsistencies, data constraints, and limited administrative capacity. We identify key pathways to enhance ES integration in future WFD cycles, including the development of standardised freshwater ES assessment frameworks, improved cross-sectoral coordination, and explicit incorporation of ES indicators into River Basin Management Plans. The findings highlight the potential of ES-based approaches to support freshwater restoration, adaptive management, and evidence-informed water policy in Europe.

Keywords: ecosystem services, Water Framework Directive, freshwater management; river basin planning, policy support

17. From Biophysical to Behavioural: Integrating Socio-Economic Indicators into Ecosystem Service Assessments for River Basin Nutrient Management

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Effective nutrient management in river basins is shaped by biophysical conditions as well as socio-economic factors that influence how management measures are adopted and implemented. Although widely recognised, these socio-economic factors are rarely translated into indicators that can be consistently applied alongside biophysical indicators in river basin assessments, including within integrated decision-support tools. In this context, the ENGAGE project proposes a framework for integrating selected socio-economic elements into ecosystem service (ES)–based nutrient management assessments. The framework focuses on socio-economic factors such as behavioural change, affordability, access to data and information, and technological uptake, and explicitly treats these conditions as decision-relevant system drivers rather than contextual background factors, drawing on both qualitative and quantitative project evidence.

The selected socio-economic factors are translated into a set of socio-economic indicators capturing observable behaviours and responses, incentives, adoption levels, and capacities relevant to nutrient management. Examples include adoption rates of nutrient-reduction measures (%), availability and level of financial incentives or subsidies (€/ha), and monitoring coverage (% of farms or area monitored). The indicators are linked to river ecosystem service (ES) categories, including regulating services (e.g. nutrient retention and water purification, reflected in changes in nitrogen and phosphorus loads), provisioning services (e.g. water abstraction for irrigation and agricultural production), supporting services (e.g. nutrient cycling and habitat maintenance linked to soil and aquatic ecosystem functioning), and cultural services (e.g. recreational use and aesthetic value, reflected through bathing-water status, visitation, or perception-based indicators of water quality).

The resulting indicator set is designed for direct integration into the ENGAGE decision-support tool, supporting farmers, river basin managers, and policymakers in evaluating nutrient management options under different socio-economic scenarios. This work contributes to river basin planning under the EU Water Framework Directive by strengthening the representation and understanding of social and economic contexts influencing nutrient management decisions.

Keywords: River basins; Nutrient management; Socio-economic factors; Socio-economic indicators; Ecosystem services; Decision support tool

18. Decoding Water Quality Across the Danube River Basin -Evidence from stressor-based watershed typologies and ecosystem service potential assessments

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Across Europe, freshwater ecosystems were simultaneously shaped by climate variability, land-use intensification, and accelerating socio-economic pressures, yet their combined effects on surface water quality and freshwater ecosystem service (FES) potential remained poorly understood at large spatial scales. While individual stressors were often examined in isolation, their interaction across heterogeneous watersheds produced complex and spatially differentiated outcomes that challenged effective river basin management.
The objective of this study was to disentangle the coupled environmental and socio-economic controls shaping surface water quality and freshwater ecosystem service potential, and to define watershed types

according to the dominant stressors governing their provision. We analyzed more than 1,000 watersheds of the Danube River Basin by integrating multiple categories of spatial data representing landscape structure, hydroclimatic conditions, and human pressures, together with indicators of water quality and ecosystem condition.
We applied principal component analysis followed by K-means clustering to identify dominant gradients and co-variability within this heterogeneous dataset. The results revealed strong, interpretable gradients associated with hydroclimatic regimes, land-use intensity, and topographic context, highlighting their central role in structuring water quality patterns and FES potential. Based on these gradients, three distinct watershed types emerged: hydroclimatically driven systems dominated by climatic constraints; land-use–dominated basins shaped primarily by agricultural and urban pressures; and complex socio-ecological landscapes where human activity, topography, and climate interacted to produce hybrid stressor regimes. These typologies clarified where water quality degradation and reduced ecosystem service potential were predominantly linked to human pressures rather than natural hydroclimatic constraints. The results suggested that the approach was transferable to other regions and spatial scales, with potential for comparison against hydrological and ecosystem service modelling results. Moreover, the framework appeared suitable for delineating intervention target zones and supporting decision-makers in prioritizing measures aimed at improving water quality and enhancing freshwater ecosystem service potential.

Keywords: Water quality, Freshwater ecosystem services, Watershed typology, Human pressures, Danube River Basin

19. Integrating Ecosystem Service Assessment within River Basin Planning: Insights from a Czech Case Study

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The ecosystem services (ES) framework provides essential information about the functions and structures of the landscape from which humans derive benefits. This approach supports both effective ecosystem protection and the establishment of long-term sustainable management aligned with human needs and landscape function preservation requirements. Although references to ecosystem services increasingly appear in river basin management plans across European Union member states, a more comprehensive and integrated application is lacking. This gap limits their practical translation into water management strategies. To address this, river basin authorities consider the necessity of complementing ES assessment with so-called engineered services – services provided by constructed infrastructure – to capture the full spectrum of benefits in river systems and identify meaningful compromises between competing objectives. This integrated approach is not a return to purely anthropocentric water management paradigms but rather an attempt to recognize all services available in river ecosystems while pursuing sustainable utilization pathways. Many river basin managers have predominantly technical or engineering backgrounds, and gaining their confidence requires that ES assessments explicitly incorporate engineered services, even where these may create tensions with conservation objectives. Adopting this pragmatic perspective is essential to ensure that the ES concept is actively applied in water-planning processes. Simultaneously, ES assessment concepts must be simplified to be accessible to water basin managers, with complex analytical steps supported by user-friendly decision-support tools or software. Additionally, ES assessment should maximize the use of existing data already employed in river basin management planning, particularly ecological status assessment datasets. From a practical perspective, our study tackles three key questions: (1) Which data sources and datasets are most appropriate? (2) Which ES assessment approach best supports adoption and usability by water resource managers? (3) How can ES assessment be effectively embedded as a planning instrument to strengthen its integration into river basin management plans and improve its role in designing and prioritizing environmental measures?

Keywords: Engineered Services, River Basin Management, Water Resources Planning

20. Quantifying benefits of large-scale floodplain restoration using the River Ecosystem Service Index (RESI) in the Szigetköz-Danube, Hungary

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Large-scale river regulation and hydropower development have profoundly altered floodplain ecosystems along the Danube, with substantial consequences for the delivery of ecosystem services (ES). This research applies the River Ecosystem Service Index (RESI) methodology to quantify long-term changes in multiple ESs in the Szigetköz floodplain (north-western Hungary), with a specific focus on the effects of floodplain restoration measures. The research integrates biophysical and spatial indicators to evaluate eight key ESs: arable crop production, grassland plant biomass production, flood risk regulation, timber production, greenhouse gas retention and carbon sequestration, local temperature regulation (cooling), habitat provision, and water-related cultural activities.
The study considers four distinct time periods reflecting major socio-hydrological transitions: (i) the 1950s which was later considered as the reference period for restoration planning; (ii) the 1980s, prior to the diversion of approximately 80% of the Danube discharge to the Gabčíkovo hydropower plant; (iii) 1993–1994, following the diversion but before large-scale floodplain restoration; and (iv) 2015–2022, after the implementation of restoration measures aimed at increasing water levels and re-establishing hydrological connectivity and ecological functions.
RESI scores indicate partial recovery of provisioning ecosystem services, substantial improvements in habitat provision and cultural services, and mixed responses in regulating services, including flood risk regulation, greenhouse gas retention, and local temperature regulation. Comparison of reference, degraded, and restored system states provides an integrated quantification of restoration outcomes, indicating achieved benefits. The findings support evidence-based river management, inform future floodplain restoration planning, and demonstrate the applicability of RESI for long-term, multi-service research in large European floodplains.

***Keywords*:** Floodplain restoration; ecosystem services; River Ecosystem Service Index (RESI); Danube River; Szigetköz

21. Bringing Freshwater Ecosystem Services into Practice: Methods, Challenges, and Nature-Based Solutions

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In 1997, Zalewski et al. first introduced the concept of using ecosystem properties as management tools into the strategic documents of UNESCO IHP Phase V. The objective was twofold: (i) to improve water security through low-cost, high-efficiency measures, now recognised as Nature-Based Solutions (NBS), and (ii) to emphasise the need for holistic and cross-sectoral management approaches. Central to this concept was the recognition of the role of regulating ecosystem services in enhancing the resilience of socio-ecological systems, and thus the need not only to monitor ecosystem state but also to quantify the underlying processes.
The Water Framework Directive (WFD), adopted in 2000, provided a legislative and operational framework for the assessment of freshwater systems; however, it largely overlooked these functional ecosystem aspects. In 2020, the Polish Ministry of Climate and Environment supported the first attempt to complement freshwater status indicators with ecosystem service indicators through the EEA-funded ECOSERV_POL project.
A central challenge of the project was to move beyond the conventional approach of modelling ecosystem services and presenting resultant maps to decision-makers, and instead to develop methods based exclusively on publicly available data, accessible and understandable to non-scientific users. The overarching aim was to create pragmatic tools capable of integrating ecosystem services into spatial

planning. Over the three-year period, our freshwater research team developed an assessment framework for 38 ecosystem services (regulating, cultural, and provisioning) delivered by rivers and streams, wetlands, and lakes and ponds.
This presentation reflects on the practical and methodological challenges encountered, particularly the gaps and inconsistencies within what is often considered established knowledge. With a specific focus on water-related risk management, we also draw upon insights from the H2020 RECONECT project, which facilitated co-production of knowledge across European countries on research–practice, practice – policy, and knowledge – practice gaps. We discuss pathways for operationalising freshwater ecosystem services (FES) through targeted education, ecosystem restoration, and the implementation of Nature-Based Solutions.

Keywords: ecosystem services, knowledge co-creation, service assessment, spatial planning, Poland

22. Assessment of Freshwater Ecosystem Services for Achieving Good Status in Vulnerable Water Bodies

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The abstract presents an interim, science-based assessment of freshwater ecosystem services to evaluate the effects of implemented and demonstrated management measures at water bodies at risk in Latvia. The demonstration measures were implemented in framework of the LIFE GoodWater IP project, Implementation of River Basin Management Plans of Latvia towards Good Surface Water Status. The assessment focuses on changes in ecosystem diversity, ecological quality, and the capacity of freshwater ecosystems to deliver services that support environmental objectives, local economies, and community well-being.
It quantifies both actual and potential ecosystem service provision using biophysical baseline (zero) values and interim values, enabling the identification of trends attributable to management interventions. In total, six ecosystem services are assessed through twenty-one indicators, which are systematically described in nineteen indicator data sheets.
To capture socio-economic implications, biophysical ecosystem service values are translated into monetary terms, allowing for the evaluation of benefits and losses associated with ecosystem service changes. This integrated approach supports an improved understanding of the links between ecological restoration measures, ecosystem service delivery, and their impacts on local communities and economic activities. The interim results are further complemented by findings from the Ecosystem Services Provision and Socio-Economic Impact Assessment Questionnaire conducted within the project.
The report is structured around an inventory of ecosystem service values based on the Burkhardt matrix and supported by cartographic materials illustrating spatial patterns of service provision. Detailed annexes document indicator-specific calculation procedures, consolidated methodological descriptions, and expert interpretations of observed changes between the initial and interim assessments. An extensive image gallery provides visual evidence of biophysical conditions and includes documentation from expert field surveys conducted during both assessment phases. Together, these components ensure methodological transparency and provide a robust foundation for evaluating progress toward good surface water status.

Keywords: freshwater ecosystem services, vulnerable water bodies, socio-economic implications, biophysical ecosystem service values

23. Leveraging Regional Attractiveness as a Strategic Catalyst for Ecosystem Restoration in the Danube Region

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The Danube Region is a vital complex ecological system facing significant degradation from intensive land use, fragmentation, and climate change. Historically, restoration efforts have struggled to secure long-term funding and political priority, as they are often viewed as secondary to industrial and urban development. There is a critical need to bridge the gap between conservation goals and economic growth. The paper aims to repurpose the Regional Attractiveness Assessment, traditionally a tool for investment promotion, into a smart tool for ecological recovery. By quantifying the direct correlation between high-functioning ecosystem services (such as flood regulation, carbon sequestration, and recreational value) and the region's ability to attract talent, tourists and sustainable investment, the paper seeks to promote the ecological restoration as a primary driver of territorial competitiveness.
The paper integrates ecological data with socio-economic indicators for identifying the attractiveness gaps where ecosystem degradation is causing capital flight or talent loss. Also, by suggesting an interactive dashboard to visualize the Return on Investment (ROI) of nature-based solutions, it is expected to boost the engagement of local authorities and private investors.
The anticipated result is a fundamental shift in regional governance. By positioning restoration as an attractiveness asset, we expect to unlock private funding and increase local political will for "green-blue" infrastructure. Ultimately, the paper intends to demonstrate that a healthy Danube ecosystem is not a luxury, but a prerequisite for a resilient, competitive, and attractive European macro-region.
By integration of such smart approach in the elaboration of the national restoration plans we can contribute to securing regional funds and private investment, turning the ecosystem into a primary economic asset rather than a regulatory burden.

Keywords: Regional attractiveness, ecosystem restoration, sustainable investments, ecosystem services

24. From Ecosystem Service Assessment to Results-Based Payments: A Policy-Oriented Framework for Nutrient Regulation

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Over recent decades, ecosystem services assessment has generated a substantial body of biophysical and economic knowledge aimed at guiding public decision-making; however, its uptake into operational policy instruments remains limited (Turner et al., 2014; UN SEEA-EA, 2021).
This study addresses this gap by proposing a policy-oriented and results-based framework that translates biophysical ecosystem service flows into a Payments for Ecosystem Services (PES) scheme explicitly linked to nutrient regulation outcomes, tested in the Basento River basin (southern Italy).

The framework integrates four sequential phases. First, water-quality regulation services are estimated through the InVEST Nutriment Delivery Ratio model (Sharp et al., 2020).
Second, the economic valuation of the service is conducted using a replacement cost approach (OCSE, 2018; Johnston et al., 2015), understood as the avoided cost of achieving equivalent nutrient removal through engineered treatment solutions, providing a transparent and directly implementable economic basis for defining performance-based incentives.
Third, a spatially explicit 2×2 matrix integrates ecosystem service capacity (C) and the flow-to-demand ratio (R), consistent with MAES and SEEA-EA accounting frameworks. The matrix classifies territorial units into four functional categories: excellence (high C; R ≥high), untapped potential (high C; R low), marginal/resilient systems (low C; R ≥ high), and deficit (low C; R < low); thereby supporting spatial prioritisatio and the calibration of results-based policy instruments (Burkhard et al., 2012; Grêt-Regamey et al., 2017).
Finally, the framework converts biophysical results into operational PES, where payments to land managers are proportional to verified ecosystem outcomes measured as marginal nutrient load reductions (e.g., kg of N or P retained annually), ensuring alignment between biophysical performance and economic incentives. This design enhances PES credibility for managers and delivers society verifiable water quality improvements, nutrient reductions, and greater efficiency in public spending for the community.
Keywords: results-based PES, nutrient retention, water quality regulation, InVEST NDR, ecosystem accounting