

## 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

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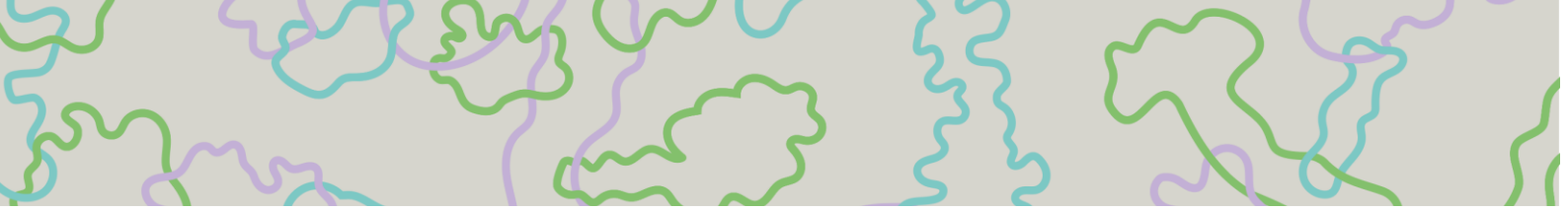
#### Mountain landscapes and ecosystem services: resilience, challenges, and solutions

##### Hosts:

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##### Abstract:

Mountain landscapes, particularly forested regions, are vital socio-ecological systems that provide essential ecosystem services supporting both upland and lowland communities. Covering nearly 27% of



the Earth's land surface, these ecosystems supply a wide range of benefits - from wood and non-wood forest products, freshwater, and hydrological regulation to biodiversity conservation, carbon storage, recreation, and cultural values. Their influence extends far beyond their rugged slopes, nurturing life, livelihoods, and cultural heritage.

However, mountain ecosystems are increasingly challenged by profound environmental and socio-economic transformations. Climate change, altered disturbance regimes, shifting land use, depopulation, disrupted forest-value chains, weak governance systems, and insufficient investment are undermining their resilience and functionality. The rapid pace of climate change in particular threatens to outstrip ecosystems' adaptive capacity, amplifying risks such as floods, landslides, and wildfires, while diminishing the flow of critical ecosystem services.

This session explores how mountain regions can better cope with these mounting challenges by understanding and strengthening the intricate connections between people, communities, and nature. We will examine trade-offs and synergies among ecosystem services, focusing on innovative management, restoration, and governance strategies that enhance resilience and adaptive capacity across mountain landscapes. Special attention will be given to:

1. Managing and restoring mountain forests under changing climate and disturbance regimes to sustain and enhance the flow of ecosystem services;
2. Reconciling competing demands-such as timber production, wildfire risk reduction, biodiversity conservation, recreation, water regulation, and social well-being-through context-sensitive planning, governance innovation, and policy co-design; and
3. Building resilience through participatory approaches that integrate traditional knowledge, scientific insights, and stakeholder collaboration.

Using an interactive, cross-disciplinary format (including World Café discussions), the session will bring together researchers, practitioners, administrators, and policy makers from diverse fields: ecology, forestry, agriculture, economics, geography, and social sciences to exchange knowledge and identify actionable solutions. By fostering dialogue across sectors and scales, this session aims to advance the governance and operationalization of nature-based solutions, strengthen the resilience of mountain socio-ecological systems, and contribute to Europe's ambition for a nature- and people-positive future.

### **Goals and objectives of the session:**

We expect contributions particularly focused on:

- Modelling, mapping and simulation tools, techniques, approaches and frameworks mainly oriented to simulate trade-offs and synergies among conflicting ecosystem services (e.g. timber provision vs. biodiversity conservation) in mountain forested landscapes in Europe, especially in areas / regions under rapidly changing environmental conditions
- Implementing, testing and demonstrating sites showing the effectiveness of nature-based solutions, and climate-smart / biodiversity-smart forestry practices in addressing mountain forests' resilience and adaptation to enhance their beneficial role (i.e. goods and services provision)
- Innovative, trans-disciplinary, comprehensive, multi-scalar studies / research activities targeting the assessment of the suitability / viability of restoration and rewilding strategies / practices in re-establishing the mountain forests' functionality and associated ecosystem services flow, with a specific focus on actions at landscape / watershed scale
- Trans-boundary governance and policy recommendations that empower forests' benefits in European mountains, while balancing environmental, economic and social sustainability. Emphasis is given to unlocking the potential of co-designed and participatory planning, climate and biodiversity finance, innovative and business models for sustainable productions and consumptions throughout the forest-value chain
- Future research directions and operational guidelines in management and planning to empower place-based innovation for a nature- and people-positive mountain forest governance

### Planned output / Deliverables:

Upon acceptance, we will propose a dedicated Special Issue to peer-reviewed, indexed and impacting journals in the following fields: ecology, agriculture and forestry, planning, land use policy

### Session format:

40-minute presentations (10 minutes each) + 2-3 presentations in PechaKucha format (15-20 min) + World Cafe discussion for 25-30 min and final discussion for 10 min

Related to ESP Working Group:

TWG 14 – Application of ES in Planning & Management

## II. SESSION PROGRAM

**Room: C2**

**Date of session: Friday 22, May 2026**

**Time of session: 11:00 – 12:30**

### Timetable speakers:

Time	First name	Surname	Organization	Title of presentation
11:00-11:10	Stefano	Sala	UNIMONT – University of Milan	Mapping Nature-based Solutions in mountain regions: geographic patterns, environmental priorities, and research gaps
11:10-11:20	Ana	Stritih	University of Freiburg	Governance of mountain forests as nature-based solutions for disaster risk reduction
11:20-11:30	Aaron	Westhauser	Albert-Ludwigs-Universität Freiburg, Germany	Changing Climate and Disturbance Impacts on Mountain Forest Ecosystem Services: A Multi-Scenario Modelling Framework
11:30-11:40	Anabela	Paula	University of Coimbra, Portugal	Integrating Ecosystem Services into Regional Planning: A Co-creation Approach to Sustainable Development in Portugal's Beira Interior region
11:40-11:50	Jie	Gong	Lanzhou University	Pattern and spillover effects of ecosystem services in the Jialing River Basin, China: A supply-flow-demand perspective
11:50-12:00	Maria	Felipe-Lucia	Instituto Pirenaico de Ecología, CSIC	Looking at the future from the heart of depopulated rural mountain areas in Spain
12:00-12:10	Beatrice	Mosso	Politecnico di Milano	Multifunctional Green and Blue Infrastructure design in the province of Sondrio. Insights from the PlanToConnect project
12:10-12:20	Fabiana	Figurati	Parthenope University of Naples	A Spatially Explicit Modelling Framework to Quantify PM <sub>10</sub> and O <sub>3</sub> Removal by the Alpine Forests in the Province of Trento (Italy)
12:20-12:30				Discussion

### III. ABSTRACTS

*The first author is the presenting author unless indicated otherwise*

#### 1. Mapping Nature-based Solutions in mountain regions: geographic patterns, environmental priorities, and research gaps

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Nature-based Solutions (NbS) are increasingly promoted as essential strategies for strengthening the resilience of mountain socio-ecological systems, despite their application remains under-documented. This contribution presents preliminary results from a systematic review of 194 peer-reviewed studies, inspired within the framework of MountResilience project, focusing exclusively on NbS in mountain regions worldwide. The analysis reveals a sharp rise in scientific interest in recent years and a markedly uneven global distribution: Europe leads overall production, with Italy particularly active, while several major mountain areas remain significantly underrepresented, indicating persistent financial, linguistic, and logistical barriers. Environmentally, NbS applications were grouped into 10 sectors (9 main sectors and "others"), with the most represented relating to forest management, ecosystem restoration, biodiversity conservation, water regulation, and soil and agricultural practices, reflecting the ecological sensitivity and functional importance of mountain landscapes. Forest-based NbS emerge as dominant approaches, due to their role in stabilising slopes, enhancing carbon storage, and mitigating natural hazards. Similarly, water-related NbS emphasize the pivotal hydrological services provided by mountain ecosystems. Despite these advances, significant knowledge gaps remain: some sectors are still scarcely studied, and a strong European research bias highlights a clear disparity between European regions and those in other parts of the world in adopting the "NbS approach". Beyond summarising global research patterns and sectoral trends, this contribution also aims to provide useful reflections for restoration strategies, forestry applications, and water management practices that can enhance mountain resilience.

**Keywords:** nature based solutions, mountains, resilience, mountresilience

#### 2. Governance of mountain forests as nature-based solutions for disaster risk reduction

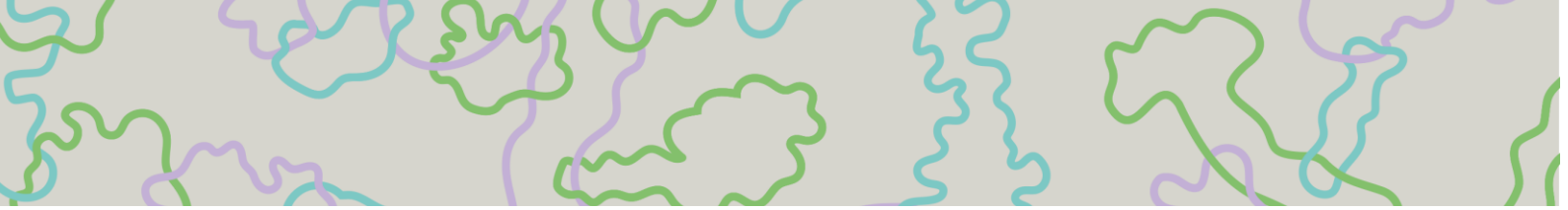
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Forests in steep terrain provide protection from natural hazards, an essential ecosystem service for the safety of people and infrastructure in mountain areas. Many countries recognize the role of mountain forests as nature-based solutions for disaster-risk reduction and have created institutions (such as regulations, incentives, traditions, or norms) to safeguard their protective effect. However, the design and effectiveness of such governance arrangements vary widely, influencing the resilience of both the mountain forests and the communities that depend on them. To map this diversity, we conducted a global survey of forest-governance mechanisms that specifically address protection from natural hazards in mountainous regions. With responses across 78 countries across 6 continents, our results indicate that either formal or informal institutions related to ensuring forests' protective effect exist in most mountain regions, although not all of these institutions are perceived as effective. Increasing natural disturbances, such as forest fires, are seen as a widespread risk for protective forests. At the same time, we also identify a pattern of institutional learning triggered by extreme events, where major flood and landslide events act as windows of opportunity for changes in forest governance, such as regulatory reform, new incentive mechanisms, and broader multi-stakeholder coordination. Our findings can serve as a valuable



resource for learning from best practices in countries with a longstanding tradition of managing forests for protection from natural hazards, and offer insights on how extreme events can serve as opportunities for institutional change toward more resilient disaster risk reduction strategies.

**Keywords:** protective forests, natural hazards, disaster risk reduction, forest management, institutional learning

### 3. Changing Climate and Disturbance Impacts on Mountain Forest Ecosystem Services: A Multi-Scenario Modelling Framework

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Mountain landscapes provide a range of vital ecosystem services, which are increasingly threatened by climate change, rising disturbance regimes, and growing societal demands. Understanding how these services respond to future environmental changes is crucial for supporting forest owners and decision-makers in developing resilient management strategies.

The aim of this study is to demonstrate how the future provision of essential ecosystem services like timber production, carbon sequestration, soil protection, and recreation, is influenced by changing climate conditions, alternative management targets, and increasing wind disturbance patterns.

We assess current and future forest ecosystems' functionality and the flows of associated goods and services in five mountain landscapes in Europe. Using the spatially explicit, individual-based landscape and disturbance model iLand, we quantify present and projected ecosystem services' provision under three climate scenarios (RCP2.6, RCP4.5, and RCP8.5) and a set of alternative management pathways specifically designed to enhance resilience against climate- and disturbance-induced damages while targeting diverse ecosystem services with varying priorities. Particular attention is given to integrating the wind disturbance module by simulating both historic disturbance patterns and additional scenarios reflecting an increased likelihood of future storm events under climate change.

Results from this modeling framework illustrate how different climate and disturbance trajectories, combined with diverse management objectives, shape trade-offs and synergies among potentially competing ecosystem services across multiple spatial and temporal scales. The cross-regional comparative approach reveals distinct regional sensitivities to climate change and disturbance patterns, providing actionable insights for context-sensitive forest management planning.

**Keywords:** Landscape & disturbance modelling, Ecosystem services, Mountain forests

### 4. Integrating Ecosystem Services into Regional Planning: A Co-creation Approach to Sustainable Development in Portugal's Beira Interior region

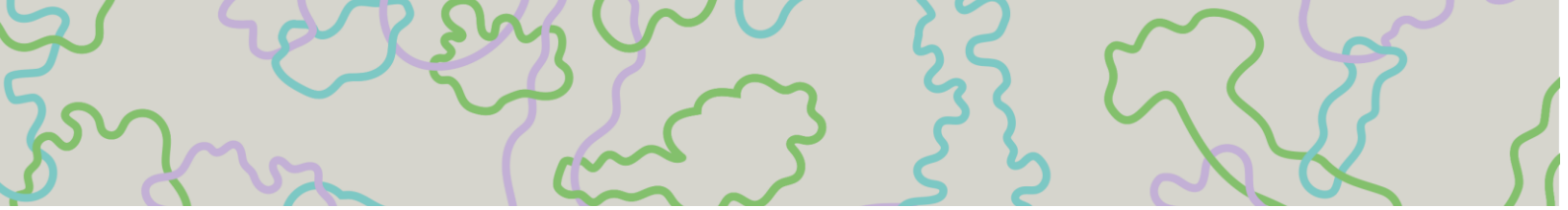
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The Beira Interior region of Portugal, a rural area facing significant socio-economic challenges and increasing wildfire risks due to agricultural abandonment, provides a critical case study for integrating ecosystem services (ES) into regional planning. This study employed a co-creation approach to map nine key ES—provisioning (crops, livestock, biomass), regulating (soil quality, climate regulation, fire protection), and cultural (recreation, cultural landscapes, legacy)—using ES mapping and hot/cold spot analysis. A cluster analysis of landscape typologies, based on land use, diversity, and configuration



metrics, revealed strong associations between traditional agricultural landscapes and provisioning and cultural services, as well as between forested areas and climate-regulating services. Our findings highlight the multifunctionality of heterogeneous landscapes, such as agricultural mosaics and agroforestry systems that integrate traditional agriculture with native forests. These landscapes were identified as critical for balancing multiple ES, enhancing landscape resilience, and providing co-benefits for climate adaptation and rural livelihoods. Stakeholder engagement through co-creation workshops enabled the identification of strategic priorities via a SWOT–TOWS methodology, which validated these findings and emphasized the need for innovation and the valorisation of cultural landscapes.

*Keywords:* Ecosystem services, co-creation, regional planning, landscape resilience

## 5. Pattern and spillover effects of ecosystem services in the Jialing River Basin, China: A supply-flow-demand perspective

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Intensifying human activities have disrupted the balance between the supply and demand of ecosystem services (ESs), leading to exacerbated regional mismatches. As the critical link connecting supply and demand areas, the flow of ESs offers valuable insights into regional sustainable development when its spatial patterns are analyzed. Focusing on the Jialing River Basin (JRB), this study examines water yield (WY), carbon sequestration (CS), and food production (FP) through a systematic investigation from the supply-flow-demand perspective. First, this study quantitatively assesses the supply and demand of ESs from 2000 to 2020 and employs the Optimal Parameters-based Geographical Detector model to identify social-ecological factors influencing the supply-demand relationships. Furthermore, by integrating supply-demand status, the study comprehensively applies the hydrological flow model, breakpoint-field strength model, and Gaussian two-step floating catchment area method to simulate the spatial flow direction and magnitude of ESs, thoroughly exploring their cross-regional spatial spillover effects. The results reveal significant ESs supply-demand imbalances in the JRB, which are jointly driven by social and ecological factors. Additionally, the findings underscore the crucial role of the spatial flow of ESs in spatial mismatches between supply and demand, as well as the practical value of potential spatial spillover effects at larger scales. Grounded in the perspective of ESs supply, demand, and spatial flow, this study provides valuable insights to guide the cross-regional collaborative management of ESs.

*Keywords:* ecosystem services; supply-demand relationship; spatial flow; cross-regional management

## 6. Looking at the future from the heart of depopulated rural mountain areas in Spain

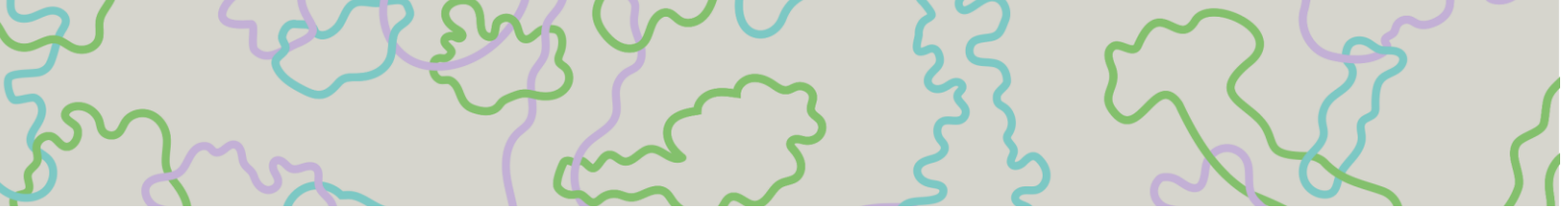
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Rural depopulation is increasing across European – especially Mediterranean – countries, with consequences such as land use change following agricultural abandonment, changes in biodiversity and loss of social structure and public services. Few research has investigated the challenges and opportunities of restoring depopulated rural areas in a sustainable way. In this study, we asked inhabitants of restored after abandonment and permanently inhabited rural settlements in three regions of Spain about their preferences for ecosystem services and quality of life through a survey. In addition, we developed participatory workshops to identify the main drivers of rural depopulation and actions to revert this trend. Independently of the type of settlement, respondents identified habitat and biodiversity as the preferred ecosystem service, together with cultural services in restored settlements. Our results show that inhabitants of rural areas perceive their life as satisfactory in terms of safety and access to basic needs, but not regarding accessibility and health services. Finally, lack of housing and administrative support were identified as the main drivers of current depopulation trends, both of which could be addressed through increasing communication with the different administrative levels.



Our research unveils the perceptions of local communities and can shed light to decision-makers when planning policy and management actions in rural depopulated areas. Aligning those actions with local worldviews and ways of living can foster local support and avoid social rejection and conflicts.

**Keywords:** Depopulation, rural areas, land abandonment, public participation in decision-making

## 7. Multifunctional Green and Blue Infrastructure design in the province of Sondrio. Insights from the PlanToConnect project

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Mountain regions are complex socio-ecological systems characterized by high ecosystem and landscape value, yet increasingly vulnerable to human pressures and the amplified impacts of climate change. The PlanToConnect project, funded under the Interreg Alpine Space program, seeks to develop a transnational vision of ecological and multifunctional connectivity, positioning Green and Blue Infrastructure (GBI) as a strategic priority for Alpine territorial cohesion.

This contribution presents an innovative approach to territorial planning applied to the Province of Sondrio, integrating ecosystem services (ES) mapping and assessment to guide interventions that improve the delivery of diverse ecosystem services across the landscape. By overlaying biotic and abiotic spatial information, the project enables a multidimensional understanding of landscape dynamics, identifying areas for soil and habitat protection as well as zones most vulnerable to climate and anthropogenic pressures.

The methodology defines three strategic frameworks: conservative, aimed at preserving existing ecological functions; multifunctional, focused on enhancing ecosystem services while balancing multiple benefits; and regenerative, targeting the restoration of degraded areas to maximize ecological, social, and cultural values. Each framework is associated with specific territorial priorities and governance objectives, offering actionable guidance for local administrations involved in planning and implementation.

The Sondrio pilot demonstrates how multifunctional GBI can support adaptive territorial strategies, balancing ecosystem service provision, climate resilience, and human well-being. It highlights trade-offs and synergies across forest management, water regulation, biodiversity conservation, recreation, and cultural heritage, emphasizing participatory planning processes that combine scientific evidence with stakeholder knowledge.

By operationalizing ES-driven GBI in mountain landscapes, PlanToConnect provides a practical model for integrating ecological connectivity, climate adaptation, and sustainable territorial development. This approach illustrates how strategic planning in alpine contexts can enhance resilience, foster multifunctional landscapes, and inform policy and governance innovations to address the challenges posed by environmental change.

**Keywords:** Alpine space, Green & Blue infrastructure, multifunctionality, spatial planning, Interreg

## 8. A Spatially Explicit Modelling Framework to Quantify PM<sub>10</sub> and O<sub>3</sub> Removal by the Alpine Forests in the Province of Trento (Italy)

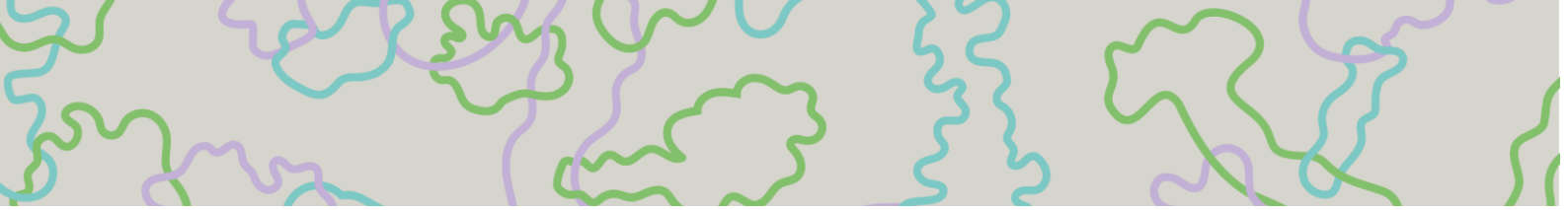
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Mountain forests play a key role in delivering regulating ecosystem services, including the mitigation of air pollution. In complex alpine environments, however, the effectiveness of this service strongly depends on forest structure, phenology, and morphological traits, which remain insufficiently integrated into ecosystem service assessments. This study evaluates the contribution of forest ecosystems in the Province of Trento (Italy) to the removal of particulate matter (PM<sub>10</sub>) and ground-level ozone (O<sub>3</sub>). Forest stands were classified as coniferous evergreen or deciduous broadleaved based on their morpho-functional traits. PM<sub>10</sub> removal was modelled through dry deposition on foliage, while O<sub>3</sub> uptake was



estimated based on stomatal conductance, accounting for vegetation functional differences in ecosystem services supply potential.

A spatially explicit modelling framework integrating land-cover data, remotely sensed Leaf Area Index, and gridded air pollution datasets was applied to estimate seasonal removal efficiency ( $\text{kg ha}^{-1}$ ) and total pollutant removal (Mg) across the landscape. The economic value of air purification was quantified using avoided damage costs derived from European Environment Agency externality estimates.

Results reveal trade-offs between removal efficiency and total uptake across forest types. Deciduous broadleaved forests show higher  $\text{PM}_{10}$  ( $6.98$  vs  $4.66 \text{ kg ha}^{-1}$ ) and  $\text{O}_3$  ( $14.41$  vs  $3.20 \text{ kg ha}^{-1}$ ) removal efficiencies than conifers; however, due to their larger spatial extent, coniferous forests account for higher total  $\text{PM}_{10}$  removal ( $4,206.55$  vs  $3,864.31 \text{ Mg}$ ). In contrast,  $\text{O}_3$  removal is dominated by deciduous stands, with a total uptake of  $5,997.98 \text{ Mg}$  compared to  $2,195.05 \text{ Mg}$  in conifers. The associated economic benefits amount to  $\text{€}1,245.58$  million for  $\text{PM}_{10}$  and  $\text{€}291.65$  million for  $\text{O}_3$ .

These findings highlight the role of alpine forests in reducing atmospheric pollutants and provide actionable insights for strategic forest management, supporting the resilience and multifunctionality of mountain landscapes. The integration of biophysical modelling and monetary evaluation informs sustainable decision-making for mountain forest governance.

*Keywords:* Ecosystem services, Nature-based Solutions, Air quality mitigation, Alpine forests