

Data-driven decisions: Enhancing mountain ecosystem management through the integration of long-term data

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Context and objectives

With their diverse habitats and microclimates, mountain ecosystems host a wide range of flora and fauna and provide many ecosystem services, including water supply, fuel provision, grazing systems and spaces for recreational activities. However, mountains worldwide face growing threats from climate change and land-use transformations that are further exacerbated by human behavior (e.g. Dullinger et al. 2012; Engler et al. 2011; Paulsen and Körner 2014; Payne et al. 2020; Steinbauer et al. 2018; Vitasse et al. 2021). The PAGES DiverseK working group addresses ecological challenges by emphasizing the value of a long-term perspective, spanning decades to millennia in this case, to enhance our understanding of climate and ecosystem dynamics in mountain regions. By translating paleoinsights into actionable knowledge, DiverseK aims to collaborate with stakeholders and policymakers to drive informed and meaningful decisions.

The major objective of the workshop was to integrate long-term ecological data into strategies for managing mountain ecosystems. By bringing together 56 participants from 20 countries across the globe, the workshop facilitated an interdisciplinary dialogue among scientists, stakeholders and policymakers. This hybrid event featured 36 presentations and interactive discussions, creating a platform for knowledge exchange. The discussions focused on understanding the legacy of past climate and land-use changes on present ecosystems, offering insights for sustainable land-management and biodiversity conservation. A variety of stakeholders were present in person at the workshop. Specifically, these participants came from the industrial and energy sectors (e.g. Swarovski Optik and Energieagentur

Tirol), professional associations and networks (e.g. International Mountain Guides Federation and International Mountain Museums Alliance), governmental and land-management bodies (e.g. Kyrgyzstan's Forestry Department and the Mongolian Land Management Association), and environmental and agricultural organizations (e.g. Naturpark Karwendel and Tyrol Chamber of Agriculture). Key research initiatives, such as GEO Mountains and the Mountain Research Initiative, also contributed to the discussions.

Key insights

The workshop addressed diverse themes, offering global, regional and local insights into mountain ecosystem challenges and opportunities. Highlights included:

- Monitoring and management: long-term monitoring projects, protected-area management strategies and sustainable land-use practices
- Climate and vegetation dynamics: environmental changes over decades to millennia, the role of fire in forest dynamics, alpine plant responses to warming, and treeline changes due to glacier fluctuations
- Stakeholder engagement and outreach: role of businesses in biodiversity conservation, insights into mountain livelihoods from mountain guides and local stakeholders, and public awareness
- Global perspectives: case studies from the European Alps, Himalayas, Andes and African highlands in particular, illustrated common and region-specific challenges

Collaborative process and outcomes

A key outcome of the workshop was the collaborative drafting of a policy brief to guide

climate adaptation and mitigation efforts in mountain ecosystems through the foundation of robust scientific evidence. The workshop encouraged active participation through guided discussions to initiate the draft of a policy brief. The draft outlines the challenges, including accelerated rates of change, ecosystem vulnerability and socioeconomic impact, alongside examples of current mitigation measures such as sustainable tourism, forest management and conservation efforts. Key recommendations focus on enhancing biodiversity monitoring, promoting adaptive management locally and regionally, fostering global cooperation and raising awareness. A shared document now serves as a living draft for the policy brief, incorporating input from all participants. This collaborative effort aims to finalize the brief by mid-2025 and disseminate it through the expanded network of stakeholders, policymakers and practitioners present during the workshop. A brief communication is also planned for submission to *Nature Sustainability* by the end of 2025.

Key takeaways and next steps

This DiverseK workshop demonstrated the potential of interdisciplinary collaboration and stakeholder engagement in addressing the pressing challenges of mountain-ecosystem management. By integrating historical, present-day and predictive data, the workshop laid a strong foundation for management strategies to enhance the resilience and sustainability of mountain landscapes.

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Figure 1: A view of the diverse mountain landscapes in the Austrian Alps (Seefeld, Tyrol) symbolizing the DiverseK workshop focus on fostering sustainable and resilient mountain ecosystems through interdisciplinary collaboration and stakeholder engagement. Artwork credit: Laurent Marquer.