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Commentary

Mountain Biodiversity Is Central to Sustainable Development in Mountains and Beyond

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Rich biological diversity in mountains provides ample benefits to people locally and beyond. However, mountain biodiversity is decreasing rapidly, often as a result of geographically distant demands. We can achieve the transition to sustainable development only by accounting for the drivers and benefits of mountain biodiversity from a local to global level.

Growing evidence shows that people depend on well-conserved and sustainably managed biodiversity for their well-being.[1,2] With that in mind, the conservation, sustainable use, and restoration of biodiversity are key components of the United Nations Sustainable Development Agenda.[3] In many developing countries, biodiversity and healthy ecosystems are the "wealth of the poor,"[4] providing basic resources (such as trees, fish, or arable land) that are essential to subsistence activities. Accordingly, we can eliminate poverty only if we conserve and sustainably use biodiversity. Similarly, given that diverse and intact mountain ecosystems provide food, domestic crops, and ecosystem functions that underpin food production (e.g., pollination), they play a critical role in achieving food security.[3] Despite biodiversity's importance to sustainable development, most contemporary development and economic agendas threaten it by ignoring it or supporting activities that endanger it.[5]

Mountains host biodiversity that is critical to humankind and to achieving a sustainable future in mountains and beyond. Yet, human pressure on mountains (e.g., through land-use change and unsustainable exploitation of mountain resources) is growing, and mountain ecosystems are increasingly degraded. Concomitantly, we are rapidly losing mountain biodiversity and with it the ability to provide water, safety, and food for communities in mountains and in vast lowland areas.

In this commentary, we first illustrate the importance and challenges of safeguarding healthy mountain ecosystems. We then outline how integrated strategies that enable transformative changes across socio-economic sectors and segments of society can place well-conserved mountain biodiversity at the core of a just, equitable, and sustainable world.

Importance of Mountain Biodiversity

Species diversity is exceptionally high in mountains, which (depending on how they are defined[6]) cover 12%–30% of Earth's land surface outside of Antarctica. Mountains are cradles and sanctuaries of the world's biodiversity[7] and home to around half of the world's "biodiversity hotspots"—areas of particularly rich, unique, and threatened biodiversity—and about 30% of the world's "key biodiversity areas," sites that contribute significantly to the global persistence of biodiversity.[8] With an estimated 4,300 known varieties of potatoes in the central Andes alone[9] and about 5,000 varieties of wild Arabica coffee (*Coffea arabica*) in the Afromontane cloud forests of southern Ethiopia,[10] mountains are also the origin and living museums of genetic diversity for many crop species farmed and consumed all around the world.

Mountain biodiversity is important to people who live there and far beyond in the lowlands. Locally, mountain biodiversity is often indispensable as a source of income, food, medicinal products, energy, and building materials. In the cloud forests of Ethiopia, for example, local peoples' livelihoods depend on the harvesting and local sale of wild-growing coffee cherries, lianas, commercially valuable spices, and wild bee honey.[10] The inhabitants of Mount Kilimanjaro (Tanzania) depend on mountain forests for fuel and medicine.[11] Intact mountain ecosystems also enhance resilience to climate change both locally by stabilizing soils and globally by sequestering carbon. By absorbing and filtering water, intact mountain ecosystems are crucial to water regulation and provision both within mountains and far into the surrounding lowlands. For example, the over 1.5 million inhabitants of Ecuador's capital, Quito, derive most of their water from the mountainous Condor Bioreserve.[12]

Despite their importance, mountain ecosystems remain largely under-protected, and we are not on track to meet the 2030 goal of "ensuring the conservation of mountain ecosystems, including their biodiversity, to enhance their capacity to provide benefits which are essential for sustainable development" as set out in the United Nations Agenda 2030. In the European Alps, for instance, where the Alpine Convention offers a rigorous framework for nature protection and sustainable development and where 35% of the area has some protection status, the existing protected areas still cover only about 70% of the key biodiversity areas (Figure 1). Extents of environmental degradation and levels of species declines in mountains are enormous. Deforestation has left just 20% of the original forest cover in the East African Mountains of Tanzania and Kenya and destroyed about 38% of the habitat of 162 endemic plant and vertebrate species in the Albertine Rift Mountains.[9] Cropping and pastures have transformed around 16%

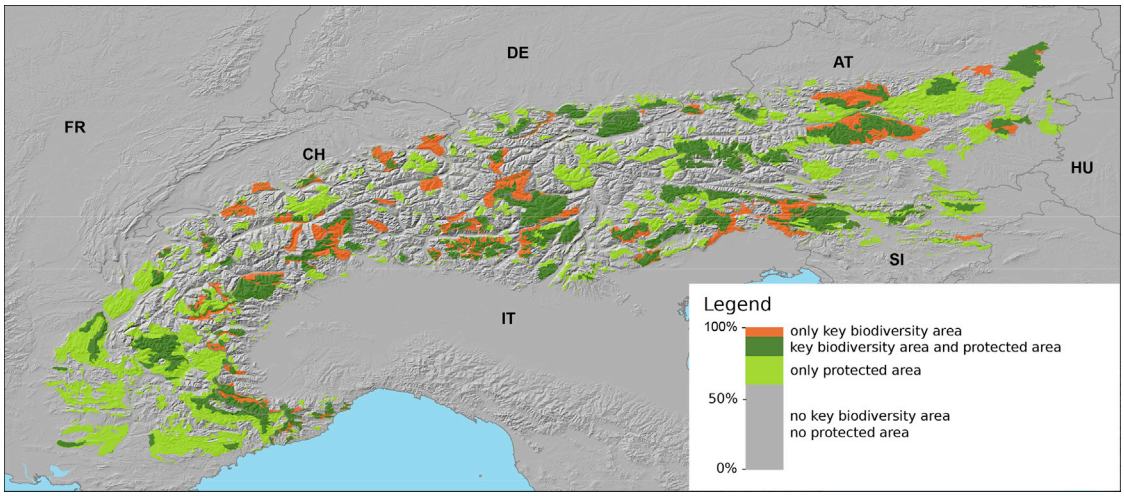

Figure 1. Key Biodiversity Areas and Their Protection in the European Alps

Key biodiversity areas (KBAs, orange), protected areas (PAs, light green), and their overlap (dark green) in the European Alps. The map shows that, although about 35% of the Alps are protected, these PAs still cover only about 70% of the KBAs. It also illustrates regional differences in PA coverage of KBAs. Sources: Key Biodiversity Areas,[15] World Database on Protected Areas,[16] and Global Multi-resolution Terrain Elevation Data 2010 (https://catalog.data.gov/dataset/global-multi-resolution-terrain-elevation-data-2010-gmted2010).

of the species-rich grasslands of Colombia (páramos), and 20 years of agriculture and afforestation have modified 26% of the Jalca grasslands of Peru with profound consequences for local livelihoods.[13] Current models estimate a 30%–40% loss in suitable habitats for northern Andean birds,[13] and within just over a decade, bird populations in four major European mountain regions have declined by 7%.[14] Iconic and already critically endangered species, such as the mountain gorilla (*Gorilla beringei*) and eastern chimpanzee (*Pan troglodytes schweinfurthii*) in Africa and the snow leopard (*Panthera uncia*) in the Himalayas, are on the verge of disappearance.[9]

Mountain biodiversity has been shaped by a range of environmental factors, of which pronounced elevational gradients, rapid change in climatic conditions with elevation across very short geographical distances, and strong contrasts in life conditions with varying topographies are the most obvious. Because of its critical importance for human livelihoods and well-being, it is increasingly shaped by the actions of people both in mountains and beyond. Population increases in many mountain regions—such as Rwanda, where the population living in mountains increased by 45% in only 5 years[17]—have increased the pressures on mountain biodiversity. So too have distant economic pressures. Demand for mountain biodiversity—for traditional medicines, crops (e.g., coffee), and roundwood across the world—can extend many thousands of kilometers away from the source. As the world economy becomes more interconnected and its ecological footprint becomes larger, mountain ecosystems are increasingly shaped by factors such as the unsustainable extraction of biodiversity; land-use change to meet growing crop, wood, and energy demands; nitrogen deposition from lowland fertilizer use; and climate change.

The central challenge to conserving and sustainably using mountain biodiversity is that the benefits from biodiversity, the costs of conserving it, and the forces driving changes in biodiversity all originate or accrue in different communities and places. Many mountain communities depend economically on local mountain biodiversity, often to meet distant demands for products and services, including water, recreational opportunities, food, and medicinal products, such as the African cherry (*Prunus africana*), whose bark is widely used to treat prostate cancer.[10] These demands can create pressures to unsustainably extract biodiversity in the short term, creating economic booms but undermining the long-term opportunities for sustainable development and ultimately harming communities who depend on mountain biodiversity for their survival. For instance, the harvest of caterpillar fungus (*Ophiocordyceps sinensis*, used in traditional Chinese medicine for the treatment of various ailments ranging from cancer to impotence) in Nepalese mountains currently provides up to 65% of the income of poor households.[9] Yet, although high demand from distant regions is likely to keep supporting a highly profitable retailer market, ongoing declines in fungus populations in response to overharvesting and climate change[18] put local livelihoods at risk. Conversely, non-local pressures to conserve mountain biodiversity—for example, to protect water supplies and threatened ecosystems—could also impose costs on mountain communities, particularly in terms of the opportunity costs of prohibited economic activities.

Biodiversity-Related Pathways to Sustainability

Our current trajectory of unsustainable mountain development will continue to harm nature and people alike. To achieve sustainable development, we need to do something radically different. Because biodiversity ultimately underpins human well-being, sustainable development in mountains requires integrated strategies for people and nature centered around the conservation, restoration, and sustainable use of biodiversity (Figure 2).

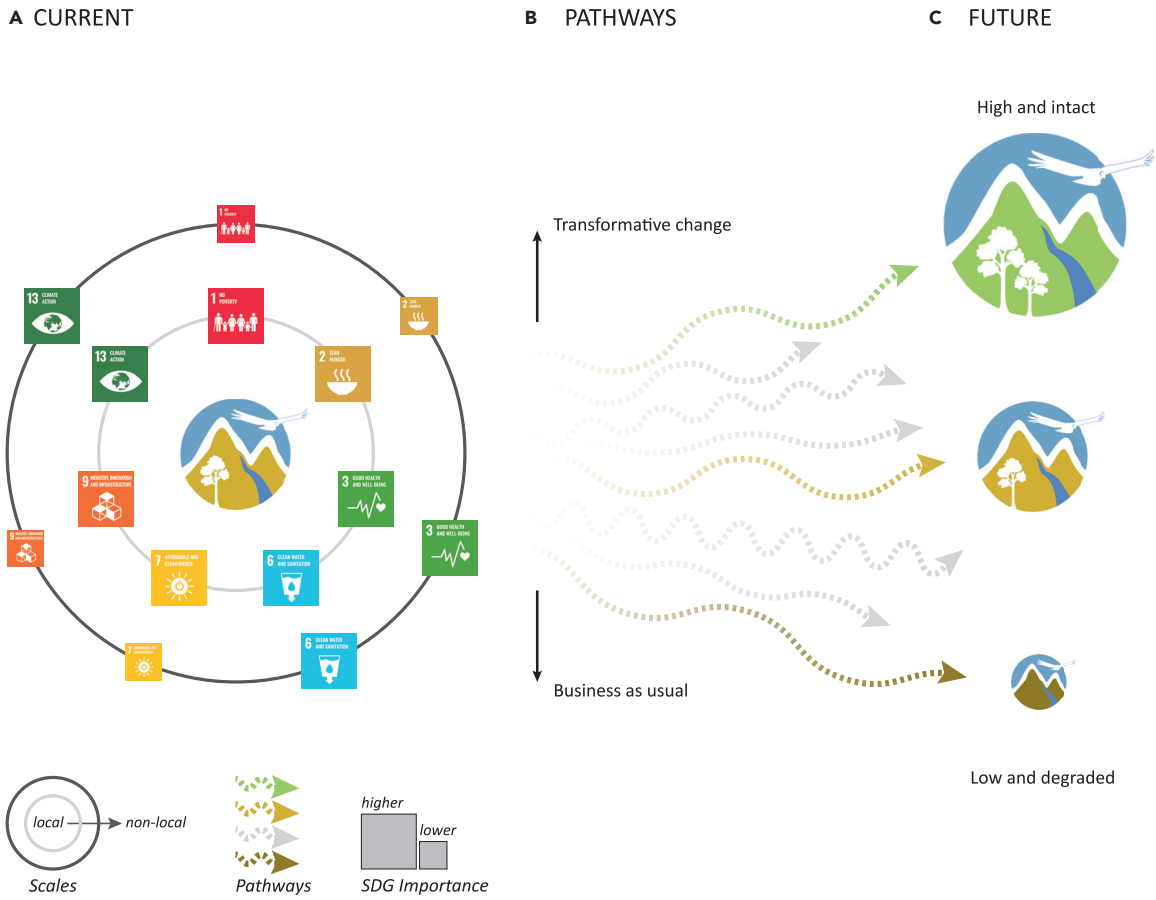

Figure 2. Biodiversity-Related Pathways to Sustainability

(A) The importance of mountain biodiversity for selected Sustainable Development Goals at different scales. Mountain biodiversity loss and degradation are currently ongoing.

(B and C) Different pathways (B) lead to different mountain biodiversity futures (C): "business as usual" (bottom) leads to low and degraded mountain biodiversity and exacerbates the negative effects of differences between scales; "transformative change" can lead to high and intact mountain biodiversity and reconcile scales. Between a no-change and a transformative-change scenario, a continuum of pathways leads to different states of and trends in mountain-biodiversity intactness and in intermediate social and ecological achievements (middle).

These strategies must acknowledge the manifold interactions between nature and people across a wide range of spatial scales and account for them by promoting measures and instruments to conserve and sustainably manage and use biodiversity in ways that are tailored to the relevant scales.[19]

Recent assessments of the state of and trends in biodiversity and ecosystems worldwide have taught us that transformative change is most likely to happen if diverse actors prioritize a common set of entry points for interventions.[1,19] These actors include intergovernmental and non-governmental organizations, governments, citizen and community groups, Indigenous peoples and local communities, donor agencies, science and educational organizations, and the private sector. A key entry point is addressing the mismatch between the places that benefit from biodiversity and those that bear the costs of conserving it. This must be accompanied by the adoption and fostering of responsibility, stewardship and care for nature both locally and at a distance with changing behaviors and actions, the embrace of diverse visions of a good life without high environmental impacts, and the acceleration of education and knowledge generation and sharing. Most importantly, from our point of view, addressing cross-scale interactions requires that local mountain dwellers be recognized and valued as indispensable partners and custodians of biodiversity who strongly depend on it for their livelihoods and visions of a good life. The effective and inclusive conservation and sustainable use of mountain biodiversity are possible only through the inclusion of mountain communities and their values in planning, financial rewards, compensation schemes, or conservation funds. The FONAG fund in Ecuador, as one example, collects payments from water users in Quito and surrounding lowlands and channels the money to protect the Condor Bioreserve watersheds.[12] Such incentives and arrangements allow distant beneficiaries of environmental services (e.g., watershed protection for clean water, forest conservation for disaster risk reduction, carbon sequestration, and cultural and spiritual services) to reward and engage with the custodians of the land providing these services and to improve their livelihoods. Such arrangements appear as a fundamental component of

biodiversity-related pathways for sustainable development in mountains.

A Mounting Challenge

For all that we know about the importance of mountain biodiversity, both for its own sake and for its importance to people in mountains and beyond, conserving it remains increasingly challenging. We argue that the key challenge we need to resolve is that benefits and costs of conserving mountain biodiversity are often spatially mismatched. What happens in the lowlands and in places far removed from mountains can dramatically affect mountain biodiversity and the benefits that mountain communities gain from it. Conversely, short-term economic gains from unsustainable development in mountains locally can ultimately impair people both in mountains and far beyond. We urgently need to follow pathways of conserving, sustainably using, and restoring biodiversity in mountains in a way that respects and preserves the diverse values—including cultural, spiritual, and economic—that people living in and beyond mountains share. However, achieving sustainability while safeguarding mountain biodiversity requires more than individual initiatives and the scaling up of what we have already been doing. It requires the strategic action of a diversity of important actors integrating multiple values and objectives and seizing opportunities for transformative change from cities to untouched ecosystems and from mountaintops to the lowlands. Such strategies are necessary for inspiring and realizing transformations that halt mountain biodiversity loss and ecosystem degradation, reconciling the scales at which mountain biodiversity matters for people, and thus enabling sustainable development in mountains and beyond.

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