

Mountain forests at risk: dieback, fire, and erosion - synergistic interactions

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Abstract

Sustainable development of mountain forests and watersheds deserves and requires a prominent position on the European and International agenda. An interdisciplinary *Project Centre on Mountain Forests* (MOUNTFOR) has been established to emphasize the regional/European/global role and outreach of EFI (European Forest Institute). MOUNTFOR aims to contribute to the development of transboundary research plans and infrastructures, synthesizing empirical and modelled results, to foster adaptive management strategies in mountain territories and to restore important environmental functions of mountain forests (e.g., halting soil erosion, balancing water cycle, increasing carbon sequestration, preserving biodiversity, contributing to healthy lifestyle), with focus on water issues. Mountain ecosystems provide unique goods and services, including water, timber, and biodiversity, but their responses to climatic changes are complex and uncertain. MOUNTFOR aims to work closely with policy makers and forest managers to craft and implement site-specific adaptation strategies in order to fulfil ecosystem services, preserving water resources. The dilemma of assigning value to ecosystem services in a market economy stems from the fact that there is no clear market relation between provider and customer. Water may be the single one commodity that has the most direct economic value. In contrast to the widely held view that forest management should emphasize providing water for downstream uses, maintaining forest health in the context of a changing climate may require focusing on the forests themselves and on strategies to reduce their vulnerability to increasing water stress. At present there is no institution at the European level with the capacity to take over and lead the work on forests and water. MOUNTFOR in partnership with the European Forestry Commission Working Party on the Management of Mountain Watersheds could help address the definition of cross-sectoral measures and institutional reorientation, raise awareness, building capacities and link science to policies and practices, and facilitate synergies and exchanges of experiences in the ecosystem services.

Extended version

Sustainable development of mountain forests and watersheds deserves and requires a prominent position on the European and International agenda. An interdisciplinary *Project Centre on Mountain Forests* (MOUNTFOR) has been established to emphasize the regional/European/global role and outreach of EFI (European Forest Institute). The EFI is a non-governmental organization conducting research to promote the conservation and sustainable management of European forests, and providing policy advice on issues related to forests. MOUNTFOR aims to contribute to the development of transboundary research plans and infrastructures, synthesizing empirical and modelled results, to foster adaptive management strategies in mountain territories and to restore important environmental functions of mountain forests (e.g., halting soil erosion, balancing water cycle, increasing carbon sequestration, preserving biodiversity, contributing to healthy lifestyle), with focus on water issues.

Mountain ecosystems provide unique goods and services, including water, timber, and biodiversity, but their responses to climatic changes are complex and uncertain. Moreover, other ecological disturbances such as insect outbreaks and biological invasions interact synergistically with warmer temperatures and land abandonment accelerating ecosystem changes. Mountain ecosystems of Europe are ideally suited to address ecological questions associate with climate change. They have compressed biogeographic zones in different corners of the continent, records of past environmental changes and consequent ecosystem responses, and common ecological and anthropogenic drivers that facilitate comparisons across ecosystems. Because European mountain systems, particularly those within protected areas, have experienced relatively less human disturbance in comparison with nearby lowlands, effects of environmental changes on ecosystems can be inferred with fewer confounding influences than on

intensively managed lowlands. Decades of research on mountain areas, particularly the Alps, provides the foundation for broad syntheses of existing knowledge. MOUNTFOR explores the effects of climate and global change on ecological disturbance, responses of forest vegetation, mountain hydrology, and the coupled hydro-ecological responses that determine vulnerability of mountain ecosystems to change. Building on the strengths of regionally focused projects, MOUNTFOR emphasizes synthesis across sites and regions.

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MOUNTFOR is built upon the experience and structures of a core network of research institutes, which are Associate Members of EFI: the Agricultural Research Council of Italy (CRA), the University of Molise, the University of Tuscia, the Centre for Research and Innovation of Edmund Mach Foundation (CRI-FEM), the University of Trento, and the Free University of Bozen-Bolzano. Core Partners are those committed with some in-kind and/or in-cash contribution to the activities of MOUNTFOR. The institutions involved in the core network supporting the MOUNTFOR initiative have a long-term experience in forest research and advanced learning. MOUNTFOR is hosted by the FoxLab, research unit of the Edmund Mach Foundation of San Michele all'Adige (Italy). Like the cross section of a tree trunk, MOUNTFOR is made of interacting circular concentric rings, including the core, network and support partners. MOUNTFOR will have an open access policy for prospective new partners with competency in related research matter committed to contribute actively to implement the work plan. New members may enter MOUNTFOR at any given time, if accepted by the Consortium and EFI.

Energy and water can be limiting factors in forest ecosystems, depending on inputs of temperature and precipitation. Increases in the frequency, duration, and/or severity of drought and heat stress associated with climate change could fundamentally alter the composition, structure, and biogeography of forests in mountain systems. Reforestation and afforestation may sequester carbon and reduce erosion and managing extreme ecological perturbations, but the albedo and evaporative influences of mountain forests are unclear. In this sense, an integrative perspective requires interdisciplinary studies, effective policy across spectrum of scales, and sustainable management for the long-term. There are multiple potential interactions between drought (low water availability and high temperature), plant hydraulics, carbohydrate and defense metabolism, and population dynamics of biotic agents. Testing of the rates and interdependencies of critical functional and structural thresholds is needed. Future regional climates are likely to accelerate the rate of each process and interdependency, resulting in increased mortality for plants that fail to acclimate. Disturbances interact with each other in ways that are complex and often difficult to predict. When observations of tree mortality in association with a higher frequency and intensity of droughts and increased temperature are combined with forecasts of rising global temperature, declining regional precipitation and more extreme droughts, a scenario emerges in which mountain forest communities could be pushed past their mortality thresholds in coming decades. The increased tree mortality may increase or decrease the risk of severe fires, and accelerate soil

erosion. Tree mortality results in loss of canopy cover, which directly alters evaporation, transpiration, and canopy interception and indirectly alters other watershed hydrologic processes, including infiltration, runoff, groundwater recharge, and streamflow. MOUNTFOR addresses the extent to which climate drivers are mediated by regional- or watershed-scale controls on ecosystem processes, thus quantifying vulnerability in mountain ecosystems.

Italy is predominantly mountainous with the Apennines as the inner backbone and the arc of the Alps all along its Northern border. Hydro-geologically Italy is a country at risk. Since 1923, a specific “hydrogeological law” has been focusing on the protection of vulnerable soils that are identified within watersheds and submitted to limitations of use and obligations of actions. Almost one century after, this law remains a national cornerstone. Nevertheless hydrological, soil, ecosystems and social changes in Italy, mostly man-driven, have led to the development of locally (regional) adapted institutional approaches to and initiatives on risk management, which progressively integrate the ecological, social and economic priorities. As an example, since 2005 the Autonomous Province of Trento has been combining hydrology, soils, forests and grasslands using standard GIS methods, and linking to socio-economic dimensions (social audit). The Italian case shows the importance of dealing with the dynamic of interactions of hydrology, soils, ecosystems, society and economy, when managing natural disaster risk in mountain areas. The major changes taking place and modifying these interactions, and, consequently, the way to deal with these risks are changes in hydrology caused by global (e.g., climate) and local (e.g., dams) changes, changes in soils caused by physical (e.g., roads, pavements, loss of soil), chemical (e.g., nitrate pollution) and microbiological (e.g., biogeochemical cycles) alteration, changes in vegetation cover and ecosystem structure and function (land use is permanently under change and all ecosystems are under succession and disturbance; biodiversity is dynamic and balances with loss trends rather than increase, and changes in society and economy, including culture (decline of rural society, urbanization, recreation and tourism, labour cost, decreasing public budgets, passive environmental protection, conservationism and environmentalism, all concurred to deep changes).

The largest land cover changes in the European mountains between 1990 and 2006 are related to artificialization of soils on one side, and to forestry and agriculture, on the other side. The observed land-use transitions, including agricultural intensification or abandonment, urbanisation, and agricultural development, and the population density changes indicate increasing human pressures on mountain ecosystems in the past decades. Together with climate change impacts, these may have a serious impact on biodiversity, and consequently on risks. The EU and USA are currently building consensus upon “green infrastructure” policy. The underlying principle of Green Infrastructure is that the same area of land can offer multiple benefits if ecosystems are in healthy state. Green infrastructure investments are generally characterized by a high level of return over time, provide job opportunities, and can be a cost-effective alternative or complementary to 'grey' infrastructure and intensive land use change. Natural disaster risk management in mountain areas, in its historical development, goes towards this green infrastructure perspective in view of investing sustainably, though public funding for reducing risks of natural hazards is getting scarcer. Investing on healthy ecosystems on the long run can do much to prevent, mitigate and manage risk.

The management of forest ecosystems requires planning for the long term. Different types of adaptive, active or passive measures can be approached. Cross-sectoral approaches should move to cross-sectoral partnerships and actions among institutions, public and private actors, researchers and practitioners, including local communities and people, using existing instruments (e.g., rural development plans, structural funds and cohesion funds, European economic interest grouping, public–private partnership, consortia, research and development projects, among others). Perspectives, visions and targets, partnerships as human capital pools, need to be supported by proactive work of institutions and concrete proposals, including identification, quantification and mapping of risk-related ecosystem services (provision and support) under different conditions (e.g., abandonment, succession, disturbances, multifunctional management), financial and economic evaluation of services with comparative advantages to non-ecosystem services, including the maintenance costs, and definition of mechanisms for payment of risk-related ecosystem services. At present there is no institution at the European level with the capacity to take over and lead the work on forests and water. MOUNTFOR in partnership with the European Forestry Commission Working Party on the Management of Mountain Watersheds could help address the definition of cross-sectoral measures and institutional reorientation, raise awareness, building capacities and link science to policies and practices, and facilitate synergies and exchanges of experiences in the ecosystem services.