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Insights about past forest dynamics as a tool for present and future forest management in Switzerland

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ABSTRACT

Mountain forest ecosystems in central Europe are a product of millennia of land use and climate change, and this historical legacy shapes their vulnerability to projected climate change and related disturbance regimes (e.g. fire, wind throw, insect outbreaks). The transitional and highly dynamic state of present-day forests raises questions about the use of modern ecological observations and modeling approaches to predict their response to future climate change. We draw on records from the different subregions (northern, central and southern Alps and their forelands) in and around the Swiss Alps, which has one of the longest evidence of human land-use in Europe, to illustrate the importance of paleoecological information for guiding forest management and conservation strategies. The records suggest that past land use had different impacts on the abundance and distribution of woody species, depending on their ecology and economic value. Some taxas were disadvantaged by intensified burning and browsing (e.g. *Abies alba, Ulmus, Tilia, Fraxinus*, *Pinus cembra* and the evergreen *Ilex aquifolium* and *Hedera helix*); others were selected for food and fiber (e.g. *Castanea sativa, Juglans regia*) or increased in abundance as consequence of their utility (charcoal, acorns, litter and other products) or resistance to disturbance (e.g. *Picea abies*, *Fagus sylvatica*, *Pinus sylvestris*, and deciduous *Quercus*). Another group of trees increased in distribution as an indirect result of human-caused disturbance (e.g. *Betula*, *Alnus viridis*, *Juniperus*, and *Pinus mugo*). Knowledge of past species distribution, abundance and responses under a wide range of climate, land use and disturbance conditions is critical for setting silvicultural priorities to maintain healthy forests in the future.

1. Introduction

Present-day Alpine forest ecosystems and their dynamics are fundamentally different from those of the past. In particular, a long human history has had irreversible consequences on Alpine forest ecosystems (e.g. Tinner et al., 2005; Carcaillet et al., 2009; Blarquez et al., 2010; Valsecchi et al., 2010), decoupling natural vegetation-climate relationships in many regions and maintaining plant communities in a non-equilibrium state with climate and disturbance regimes (Svenning et al., 2015). In recent decades, reduced management and abandonment of remote mountain areas have led to expansion of forest cover and loss of high-diversity meadows (Gehrig-Fasel et al., 2007; Loran et al., 2016). The transitional and highly dynamic state of Alpine forests challenges forest managers tasked with assessing the local consequences of climate change on forests and developing adaptive and restorative silvicultural plans to ensure near-to-nature conditions and continued delivery of ecosystem services in the future (Lindner, 2000; Schmid et al., 2015). However, the strong human signature on present-day forest composition, structure and dynamics in many regions raises concerns about the use of short-term ecological observations and standard modeling approaches (Iverson and Mckenzie, 2013) to predict forest responses to future climate change (Ibanez et al., 2006; Williams and Jackson, 2007; Dawson et al., 2011; Tinner et al., 2013). To understand present-day relationships between climate, humans, vegetation and disturbance requires information on the causes and consequences of ecosystem change in the past. This information is especially critical for forests in the Alpine region of Switzerland, where present-day ecosystem dynamics are conditioned by historical legacies and altered disturbance regimes, and the abundance and distribution of current forest types and taxa

Abbreviations: Cal yr BP (years before present), years before 1950; BCE, before Common Era; CE, Common Era.

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are a product of both anthropogenic manipulation and climate change, which are difficult to disentangle.

In this paper, we review and describe the influence of past changes in climate, land use and disturbance on the development of Swiss mountain forest ecosystems and the history of selected woody species. Representative sites with good chronological control (i.e. multiple radiocarbon dates) and taxonomical resolution are selected along a strong north-to-south environmental gradient in the Alps to compare forest history in different settings. The time span of interest is the last ~20,000 years, which covers the period from the end of the last glaciation to the present day. Special focus is on the last 7500 years starting with the onset of the Neolithic period and the progressive human alteration of land cover and forest composition. The specific aim of the paper is to show how knowledge of Alpine forest history can inform management efforts that seek to (1) assess forest sensitivity to future climate change; (2) choose between different management options (e.g. preserving close-to-nature conditions, maintaining cultural landscapes, protecting species of special concern, maximizing biodiversity); and (3) maintain forest capacity to provide important ecosystem goods and services.

We first briefly describe the Holocene climate history of the study area and the main responses of tree species to these changes. Second, we discuss the main human impacts since the onset of the Neolithic period. Finally, we examine the usefulness of this type of paleoecological information as a baseline for making local forest management decisions in the face of global change.

2. Material and methods

2.1. Study area

Three subregions in Switzerland (southern Alps and their forelands, central Alps, and northern Alps and their forelands) constitute a representative environmental transect through central and southern European mountain ecosystems (Fig. 1). The southern Alps and their forelands are the warmest subregion displaying warm-temperate climate conditions in the low-elevation lake area (Insubria). The elevation ranges from 200 m asl (Lago Maggiore Locarno) to 3402 m asl on the Adula Peak in northern Ticino, and about half of the southern subregion lies above 1500 m asl, where mean annual temperature is correspondingly low (e.g. 3.9 °C in San Bernardino at 1639 m asl.). Average (1981–2010) annual temperature for the subregion is ~12–13 °C (e.g. Swiss Meteorological Station Locarno-Monti) and annual precipitation ranges from 1300 mm in the west (e.g. meteorological station Acquarossa) to 1900 mm in the east (Locarno-Monti). In winter, the climate is dry and mild and summers are humid (June-September 800–1200 mm of precipitation), with thunderstorm events alternating with periods of drought. Present-day forests are organized by elevational belts (Fig. 2). *Castanea sativa* (sweet chestnut) dominates low-elevation forests (up to 900–1000 m asl). These closed forests, which occur in other regions of southern Europe (e.g. Apennines, Pyrenees, the Balkans), occasionally support other thermophilous broadleaved species, such as *Tilia cordata* (small-leaved linden), *Quercus petraea* (sessile oak), *Q. robur* (common oak), and (*Q. pubescens* (downy oak), *Alnus glutinosa* (common alder), *Prunus avium* (sweet cherry), *Acer* spp. (maple), and *Fraxinus* spp. (ash). At middle elevations (900–1400 m asl), forests consist of mostly pure stands of *Fagus sylvatica* (European beech), and at higher elevations, forests are dominated by *Picea abies* (Norway spruce) and at upper treeline by *Larix decidua* (European larch). On south-facing slopes, beech forest is sometimes absent, and *Abies alba* (silver fir) is present in small patches on north-facing slopes in the central part of the subregion. *Pinus sylvestris* (Scots pine) grows on dry south-facing slopes, and *P. cembra* (stone pine) occurs in the most continental settings at high elevations (Ceschi, 2014).

The central Alps subregion, including the Valais and Engadine, displays a markedly continental climate characterized by low

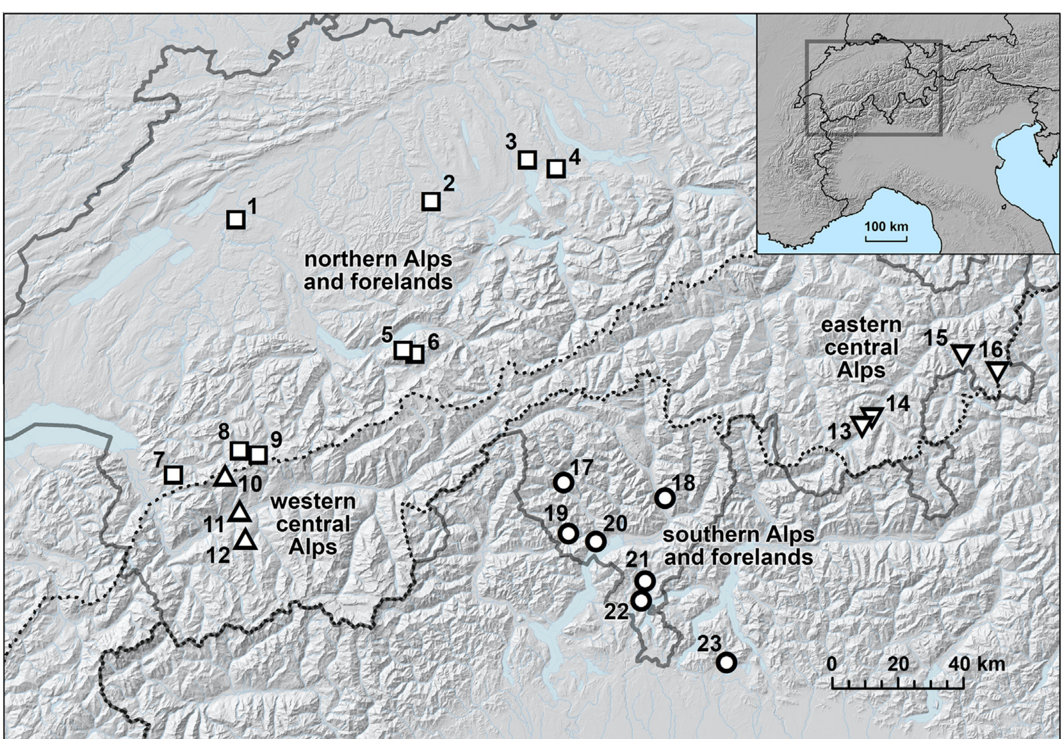

Fig. 1. Study area with detailed location of subregions and study sites: Northern Alps and forelands (1. Lobsigensee, 2. Soppensee, 3. Bibersee, 4. Egelsee, 5. Sägistalsee, 6. Bachalpsee, 7. Lac de Bretaye, 8. Lauenensee, 9. Iffigsee); Central Alps (western part: 10. Sanetsch, 11. Lac du Mont d'Orge, 12. Gouillé Rion; eastern part: 13. Lej da Champfér, 14. Lej da San Murezan, 15. Il Fuorn, 16. Fuldra/Palü Lunga); Southern Aps and forelands (17. Piano, 18. Guér, 19. Segna, 20. Balladrum, 21. Origlio, 22. Muzzano, 23.Segrino).

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