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Climatic and anthropogenic forcing of prehistorical vegetation succession and fire dynamics in the Lago di Como area (N-Italy, Insubria)

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ABSTRACT

Combined pollen, charcoal and modeling evidence from the Insubria Region suggests that fire was a major driver of late Holocene vegetation change. However, the extent and timing of fire response dynamics are not clear yet. We use lacustrine sediments from Lago di Como (N-Italy, S-Alps) to assess if the reconstructed vegetation and fire dynamics were relevant at large scales and if they coincided in time with those observed at smaller sites. The lake, due to its size (142 km^2) and economic potential, was very attractive for early land use and human presence in this area is well documented since ca. 10,000 yrs ago (Mesolithic). We used pollen, plant macrofossils and charcoal to reconstruct the vegetation composition and fire activity. During the Younger Dryas and the Early Holocene until ca. 8000 cal BP natural dynamics prevailed. Subsequently, land use and slash-and-burn activities increased at the Mesolithic-Neolithic transition and became widespread around ca. 6500 cal BP. Microscopic charcoal and numerical analyses demonstrate that anthropogenic fires had a determinant influence on long-term vegetation dynamics at regional scales in Insubria. Microscopic charcoal and pollen and spores indicative of land use show that human pressure intensified after ca. 5300 cal yr BP and even more since ca. 4300 cal yr BP. Our results suggest that important species which disappeared or were strongly reduced by land use and fire (e.g. *Abies alba, Tilia, Ulmus*) will potentially reestablish in the Lago di Como area and elsewhere in Insubria, if land abandonment initiated in the 1950s will continue.

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1. Introduction

The use of paleolimnology and palaeoenvironmental proxies provides valuable knowledge about long-term climate-fire-vegetation linkages and their ecological effects on ecosystem dynamics at different spatial and temporal scales (e.g. Swetnam et al., 1999; Heyerdahl and Card, 2000; Whitlock and Larsen, 2001). In an attempt to assess the relative contributions of climate and anthropogenic forcing on vegetation and fire, independent climatic proxies are needed to assess climate impacts on both vegetation and the fire regime, while archaeological or historical records as well as cultural indicators (e.g. pollen of crops and weeds, spores of coprophilous fungi) may be used to evaluate anthropogenic impact. Since burning is considered a major driver of vegetation changes across different biomes (e.g. Tinner et al., 1999; Whitlock et al., 2010; Conedera et al., 2009; Colombaroli et al., 2014; Hu et al., 2015), a better knowledge of past fire dynamics is a key factor in

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preserving and managing biodiversity and ecosystem functions (e.g. Bengtsson et al., 2000; Pignatti et al., 2002; Bowman et al., 2011; Colombaroli et al., 2013; Colombaroli and Tinner, 2013).

Insubria is a Southern European area with particular climatic and vegetation conditions (e.g. Mayer, 1984; Ozenda, 1988; Ellenberg, 1996, 2009) occurring in the region of the large Prealpine lakes, in the Italian regions of Piedmont and Lombardy and the Swiss Cantons Ticino and Grisons (Fig. 1b, e and f; Cotti et al., 1990; Maggini and Spinedi, 1996; Tinner et al., 2000; Pautasso, 2013). Insubrian climate differs significantly from the adjacent central European and Mediterranean climates, being more related to summer-wet subtropical conditions as observed e.g. in Japan (Cotti et al., 1990). Together with warmer temperature, this special climatic setting is favoring ongoing invasions by Eastern Asian subtropical species such as Chinese windmill palm (*Trachycarpus fortunei*) and camphor laurel (*Cinnamomum camphora*) (Conedera et al., 1998; Carraro et al., 1999; Walther et al., 2002). The effects of this ongoing species-reassemblage over fire dynamic in the next decades are still largely unknown (Walther et al., 2002). Similarly, special climatic conditions in Insubria may have triggered prehistorical fire dynamics different from those observed in other areas e.g. in the Northern or Central Alps (Zumbrunnen et al., 2009, 2011).

Fire is pervasive in Insubria during the dry winter season (e.g. Conedera et al., 1996; Conedera and Tinner, 2000). Indeed, well-dated high-resolution lowland records from Southern Switzerland and Northern Italy (Table 1; Fig. 1b) suggest that fire was a major driver of Holocene vegetation change in this area, a finding which is supported by dynamic vegetation modelling experiments (Keller et al., 2002; Wick and Möhl, 2006). Nevertheless, the number of high resolution, multi-proxy palaeoecological sites is not sufficient to assess whether local vegetation and fire patterns at specific sites (e.g. Lago di Annone, Lago del Segrino, Lago di Muzzano, Lago di Origlio, Balladrum mire; see Table 1) are representative for entire Insubria or whether they reflect more local conditions. Lago di Como offers an ideal setting to address this question. It lies between the Lugano and Brianza areas (Fig. 1b) and has a large surface area, which by far exceeds those ones of the previously analyzed sites. The large size of Lago di Como provides the advantage that the reconstructed environmental dynamics may be representative of several tenths of km^2 providing a more regional picture of vegetation history (e.g. Sugita, 1994, 2007; Conedera et al., 2006; Gaillard et al., 2008) of Insubria. Palaeobotanical data at regional scale are particularly important because these can be used to detect large-scale patterns, such as vegetation dynamics driven by climatic change or excessive biomass burning. Additionally, human presence in this area is attested since ca. 60,000–50,000 BP and is well documented since the Mesolithic (ca. 11,200–7500 cal BP) by numerous archaeological data and plant macrofossil analyses, making this site particularly suited to assess the long-term effects of climate and/or human impact over the millennia in Insubria.

The town of Como is located at the tip of the hydrologically closed branch of the lake (Fig. 1b). We conducted new detailed palynological and microscopic charcoal analyses from the samples collected at the Piazza Verdi drilling site, located in the Como downtown area (Fig. 1d) and revised the previous sedimentological, geotechnical and macrofossils data (Morselli, 2006; Comerci et al., 2007; Capelletti, 2008; Motella, 2009; Ferrario et al., 2015a). In this study, we focus on the following issues:

(1) determining the regional vegetation composition (Lago di Como area) under natural or quasi natural conditions, i.e. before agricultural activities started (Neolithic, ca 5500 BC);
(2) analysing the extent to which anthropic activities, especially fire-use, played a role for long-term vegetation dynamics and estimating the qualitative and quantitative differences with other Insubrian sites at local to extra-local scales, to check existing paleoecological and modelling interpretations;
(3) assessing how our data can be used as a reference baseline for nature protection and conservation of the Como area under future warmer conditions (e.g. Willis and Birks, 2006; Jackson and Hobbs, 2009). In particular, we aimed at verifying new projections that suggest that *Abies alba* (silver fir) and other trees will expand in lowland Insubria under global change conditions (Bugmann et al., 2014).

We focus on radiocarbon dated palustrine-lacustrine sediments, preserving pollen and plant macrofossils, dating back to the period between the Younger Dryas and the onset of the Bronze Age (ca. 12,600-4000 cal BP), when primeval Holocene forests established to be later converted into secondary woodlands, shrublands and agricultural openlands.

2. Lago di Como region and study site

Lago di Como (198 m a.s.l.) is located in N-Italy, Lombardy, in the Insubrian Southern Alps and Prealps (Fig. 1a and b), and its surface is 142 km^2. The lake is composed of three branches (Fig. 1c): the northern, the western (Como branch) and the eastern (Lecco branch). The Lago di Como catchment includes two main valleys, Valtellina (Adda River) and Valchiavenna (Mera River), and is very wide, ca. 4522 km^2 (Fig. 1a and b). The Adda River is the main tributary, reaching the lake in the N-sector, and is also the only emissary, outflowing at the end of the Lecco branch. The bedrock around the N-branch is mainly composed of metamorphic rocks (e.g. Siletto et al., 1990), whereas calcareous rocks characterize the Como and Lecco branches (Servizio Geologico d'Italia, 2015). The lake strongly affects climatic conditions along the shores and in surrounding valleys (Giacomini, 1958). The scarce occurrence of fog and chill days and the low thermal excursion (Belloni, 1983) make hilly areas characterized by a humid submediterranean climate. The present day vegetation in the region (Fig. 1f; Oberdorfer, 1964) is characterized by Insubrian communities (e.g. *Castanea sativa* Mill. - chestnut - forests with *Quercus petraea* Liebl. - sessile oak, *Fraxinus excelsior* L. - common ash, *Tilia cordata* Mill. - small-leaved lime, *Fagus sylvatica* L. - beech) on siliceous soils (on metamorphic and crystalline bedrocks) in the Northern Lago di Como catchment (Fig. 1a), and sub-Mediterranean communities on carbonatic soils, e.g. *Quercus pubescens* Willd. - downy oak, *Ostrya carpinifolia* Scop. - European hop-hornbeam, *Fraxinus ornus* L. - manna ash (on sedimentary bedrocks) in the southern lake catchment (Oberdorfer, 1964; Reisigl, 1996; Ellenberg, 2009).

The two hills surrounding the town of Como are the so-called Spina Verde in the SW and Brunate Mountain in the NE (Fig. 1b). The slope of Spina Verde facing Como is characterized by *Castanea sativa* forests, mixed *Quercus* (oak) woods and non-native *Robinia* (false acacia) (Pirola, 1976; Testori, 1988). The slope of Brunate facing Como with high insolation is covered by xero-thermophilous woods (Testori, 2004; Comune di Brunate, 2013) with e.g. *Quercus pubescens*, *Ostrya carpinifolia* and *Fraxinus ornus*. *Picea abies* H. Karst. (spruce) had been introduced particularly between 1950 and 1960 for a partial reforestation of cleared areas.

2.1. Archaeological findings around Lago di Como

Human presence in the Lago di Como area (Fig. 1g; Uboldi, 1993; Casini, 1994; De Marinis, 1994) is testified since ca. 60,000–50,000 cal BP by worked flints found in a cave close to Lago del Segrino (see Fig. 1b), at 700 m a.s.l., and in a site in Brianza (Cremaschi et al., 1990). Human frequentation of mountains (ca. 2200 m a.s.l.) during the Mesolithic is documented in Valchiavenna

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