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Spatio-temporal patterns of Holocene environmental change in southern Sicily

Camilla Calò [a,*], Paul D. Henne [a], Brandon Curry [b], Michel Magny [c], Elisa Vescovi [a], Tommaso La Mantia [d], Salvatore Pasta [e], Boris Vannière [c], Willy Tinner [a]

[a] Oeschger Centre for Climate Change Research & Institute of Plant Sciences, University of Bern, Altenbergrain 21, CH-3013 Bern, Switzerland
[b] Illinois State Geological Survey, Institute of Natural Resource Sustainability, UIUC, 615 E. Peabody Dr., Champaign, IL 61820, USA
[c] Laboratoire de Chrono-Environnement, UMR 6249 du CNRS, UFR des Sciences et techniques, 16 route de Gray, F-25030 Besançon, France
[d] Dipartimento di Colture Arboree, Facoltà di Agraria, Viale delle Scienze 11, I-90128 Palermo, Italy
[e] Via V. F. 19 n_ 60/A, I-90126 Palermo, Italy

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ABSTRACT

Few examples of natural forest remain near the Mediterranean coast. Therefore, it is difficult to study how coastal forests respond to climatic change or their resilience to human impact.
We developed new sedimentary record of Holocene vegetation and fire history at Lago Preola, a coastal lake in southwestern Sicily (Italy). In order to verify the existence of forest at large scale on the coast, we compare pollen from Lago Preola, a medium-sized lake (33 ha), to Gorgo Basso, a small lake (3 ha) located nearby with the aim of separating local from extra-local vegetation dynamics through time using pollen percentages and influx. We then compare Lago Preola pollen to the record from Biviere di Gela, a large lagoon (120 ha) situated 160 km to the east in southern Sicily, to examine differences in vegetation dynamics between the two coastal areas during the Holocene. Lake-level reconstructions and ostracode analyses from Lago Preola provide vegetation-independent evidence of climate change, and help to disentangle human and climatic impacts on vegetation. Pollen data indicate *Pistacia*-dominated shrublands replaced open grasslands in the region surrounding Lago Preola by 9500 cal yr BP. This change coincided with rising lake levels and the development of an ostracode fauna typical of fresh waters. Evergreen forest dominated by *Quercus ilex* and *Olea europaea* started to expand by 7000 cal BP and consolidated at 6500 cal yr BP, when lake levels were near their Holocene high. Similarities between pollen from Lago Preola and Gorgo Basso demonstrate that forest was the dominant vegetation type in coastal Sicily during the middle Holocene at both regional and local scales, and even developed in the drier climatic setting around Biviere di Gela. Lake levels fell at Lago Preola after 7000 cal yr BP, with a strong decline accompanied by increasing salinity after 4500 cal yr BP. However, no transition in vegetation matched these inferred hydrological changes. Instead, forests persisted in the surrounding region until 2200 cal BP when human disturbance intensified. We propose that different climatic factors control lake levels and vegetation in coastal Mediterranean ecosystems. Whereas lake levels are most sensitive to the abundance of winter precipitation, coastal forests depend on spring precipitation and are limited by the length of summer drought. Moisture availability remained suitable for evergreen forests in coastal Sicily during the late Holocene, and humans, not a drier climate drove the regional forest decline.

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1. Introduction

Ecosystems in the Mediterranean basin have been shaped by millennia of intense landuse. Consequently, it is difficult to distinguish the impacts of human disturbance and climatic change on past vegetation dynamics, or even what vegetation types would be dominant on a regional scale in the absence of frequent disturbance (Allen, 2003; Vogiatzakis et al., 2006). Paleoecological reconstructions provide a means to assess the natural dynamics of Mediterranean ecosystems, and to investigate how these systems respond to climatic change and human disturbance. For example, pollen-inferred vegetation reconstructions indicate that closed forests grew at low altitude near the Mediterranean coast during the mid-Holocene in areas that are currently dominated by *maquis*, (i.e., evergreen shrublands; Carriòn, 2002; Colombaroli et al., 2007; Colombaroli et al., 2009).These studies are consistent with the only two records from coastal Sicily, Gorgo Basso and Biviere di Gela (Noti et al., 2009; Tinner et al., 2009;). At Gorgo Basso, closed evergreen forests replaced *maquis* around 7000 cal yr BP, probably due to increasing regional moisture. The presence of a forest around Gorgo Basso was inferred from high percentage and influx values of pollen from evergreen trees (i.e., *Quercus ilex*, *Olea europaea*, AP > 60% at

* Corresponding author. Tel.: +41 31 631 35 97; fax: +41 31 631 49 42.
E-mail address: camilla.calo@ips.unibe.ch (C. Calò).

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5000 cal yr BP) when compared with the very low abundances for the last 2100 years (Tinner et al., 2009). Tree abundance was also high at Biviere di Gela between 7000 and 2500 cal yr BP (AP > 60% at ca 5500 cal yr BP), although the surrounding landscape was probably more open.

The disappearance of forests at Gorgo Basso and decline in trees at Biviere di Gela after 2500 cal yr BP was interpreted as a consequence of increasing human disturbance and fire activity, suggesting that forests could persist under the current climate (Noti et al., 2009; Tinner et al., 2009;). However, the decline of forests during the middle and late Holocene is observed throughout the Mediterranean region, and some authors attribute this change to a regional decline in moisture availability (Sadori and Narcisi, 2001; Roberts et al., 2011). Furthermore, it is unclear whether the closed forest near Gorgo Basso during the mid Holocene resulted from a favorable local microclimate due to moist conditions near the lake, or if the regional landscape was more open like at Biviere di Gela. Additional paleoecological reconstructions are needed to resolve what vegetation types were dominant on a regional scale near the Mediterranean coast during the Holocene, and to evaluate how climatic change and human impacts affect these ecosystems.

In this paper, we present a pollen-inferred vegetation reconstruction from Lago Preola in southwestern Sicily. This new lake-sediment pollen record allows us to examine human and climatic impacts on vegetation dynamics during the Holocene in Sicily on three spatial scales. We first separate local and landscape-scale vegetation dynamics by comparing the pollen of Lago Preola, a medium-sized lake (ca. 33 ha surface area) with pollen from Gorgo Basso (Tinner et al., 2009), a small lake of ca. 3 ha only 1 km away. The pollen source area of a lake varies with lake size. Therefore, adjacent lakes with different sizes may be used to separate local and regional vegetation dynamics (Jackson, 1990; Sugita, 1994; Conedera et al., 2006; Hofstetter et al., 2006;). Because of the proximity of Lago Preola and Gorgo Basso, differences in pollen assemblages should relate to local vs. regional-scale differences in vegetation, not climate or disturbance history. Although the shape of a lake also affects pollen accumulation (Sugita, 1993), we assume that the 10-fold difference in surface area between Gorgo Basso and Lago Preola is more important than differences in the shapes of these lakes. We also evaluate regional variation in vegetation dynamics by comparing pollen from Lago Preola to Biviere di Gela, a large lagoon (120 ha) situated 160 km to the east on the southern Sicilian coast (Noti et al., 2009). Our comparison between these sites allows us to extend the implications of our findings to a broader spatial scale. We also compare our new Lago Preola pollen record to proxies for hydrological change from the same sediments. A lake-level reconstruction (Magny et al., 2011) and new ostracode analysis, presented here, provide vegetation-independent evidence of changes in moisture availability. Our integrative, multi-proxy approach allows us to identify the past distribution of coastal forests (e.g., restricted to favorable local habitats vs. regional distribution), and evaluate the importance of human and climatic impacts on vegetation change at multiple scales.

2. Material and methods

2.1. Study area

Lago Preola is a medium-sized lake of ca. 33 ha, located near the southwestern coast of Sicily (37°37 N, 12°38 E, 6 m a.s.l.; Fig. 1). The lake has no surface inlet or outlet, and is part of a chain of karstic depressions that are separated from the Mediterranean Sea (1.5 km away) by a calcareous ridge ca 30–40 m high (Fig. 1). The area is an important refuge for various endangered animals, and is part of a WWF protected area, "Riserva Naturale Integrale Lago Preola e Gorghi Tondi." Lago Preola has a typical Mediterranean climate, with hot, dry summers and mild, moist winters. Mean annual air temperature at the nearby weather station in Mazara del Vallo (5 km from Lago Preola) is 18.2 °C, with 26.3 °C in August, and 11.4 °C in January (source: Osservatorio delle Acque, Regione Siciliana; Bonaccorso et al., 2003). Precipitation is most abundant during the fall and winter (177 mm), and little precipitation falls during the summer months (16 mm; Fig. 2). Two other lakes are considered in the present study. The nearby lake, Gorgo Basso (6 m a.s.l.), is much smaller, with a surface area of ca 3 ha, and is part of the same chain of karstic depressions as Lago Preola (Tinner et al., 2009). Biviere di Gela is a large coastal lagoon (120 ha, 7 m a.s.l.) located 160 km to the southeast (Noti et al., 2009).

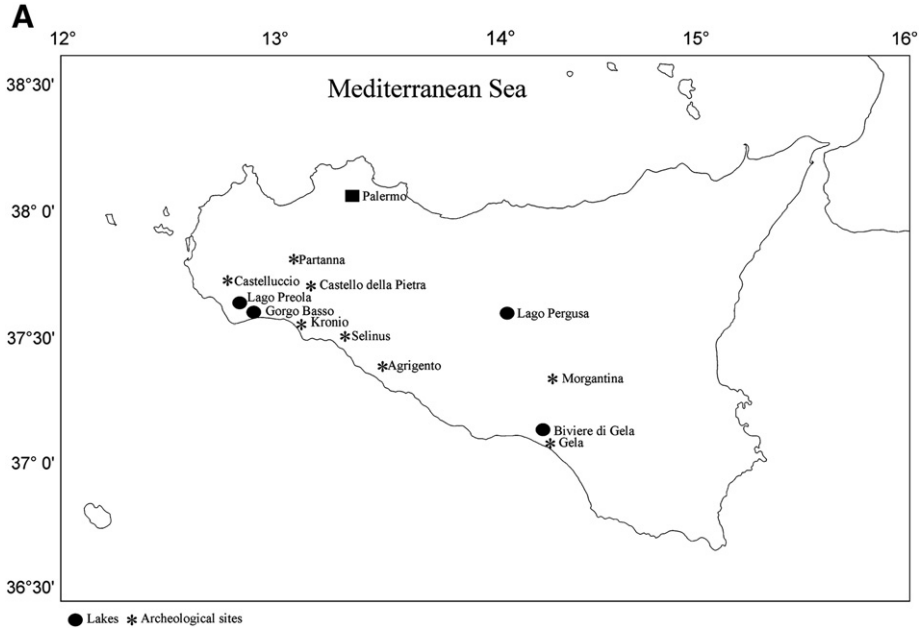

Fig. 1. A. Map showing Sicily with the location of study sites and archeological sites mentioned in the text. B. Local vegetation around Lago Preola and Gorgo Basso. Modified from Brullo and Ronsisvalle, 1975 and from Tinner et al., 2009.

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