



## Mid-Holocene vegetation history and Neolithic land-use in the Lake Banyoles area (Girona, Spain)



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### ABSTRACT

This paper focuses on high-resolution analysis of pollen and sedimentology and botanical macro-remains analysis in a core from Lake Banyoles (Girona, Spain). The core sequence comprises a high resolution mid-Holocene (ca. 8.9–3.35 cal ka BP) vegetation succession, and sedimentological, geochemical and geomorphological proxies are related to both climatic and anthropogenic causes. Deforestation processes affected natural vegetation development in the Early Neolithic (7.25–5.55 cal ka BP) and Late Neolithic (5.17–3.71 cal ka BP), in the context of broadleaf deciduous forest resilience against cooling and drying oscillations. Changes in sedimentation dynamics and in lake water level caused the emergence of dry land on the lake margin where riparian forest was established from 5.55 cal ka BP onwards. The data show that in the context of an increasing aridification process, Neolithic land-use played an important role in vegetation history and environmental evolution.

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### 1. Introduction

The Holocene, despite being a relatively stable climatic period compared to the previous glacial period, has been punctuated by cooling and drying oscillations recorded in oxygen isotope data of ice cores (Grootes et al., 1993; O'Brien et al., 1995; Grootes and Stuiver, 1997), coral records (Beck et al., 1997), stalagmites (Bar-Matthews et al., 1999; Zanchetta et al., 2007; Boch et al., 2009; Moreno et al., 2010;), marine archives (Sirocko et al., 1993; Bond et al., 1997; Cacho et al., 2001, 2006; Fletcher et al., 2010, 2013), and lacustrine records (Harrison and Digerfeldt, 1993; Magny, 1998; Magny et al., 2003, 2013; Giraudi et al., 2011).

These climatic fluctuations lead to environmental variability. The temperate and humid climate in Early Holocene favoured the

development of deciduous broadleaf forests in southwest Europe (Jalut et al., 2009), vegetation that was frequently dominant in the Mediterranean region of the Iberian Peninsula (Burjachs et al., 1997; Carrion et al., 2010; Pérez-Obiol, 2007; Pérez-Obiol et al., 2011). Afterwards, an increasing aridification process correlated with decreasing insolation and summer temperatures in the Northern Hemisphere (Porter and Denton, 1967; Denton and Karlén, 1973), caused the development of sclerophyllous and evergreen forests following a south–north gradient in different areas of the Mediterranean region (Carrion et al., 2010; Denèfle et al., 2000; Jalut et al., 2000, 2009; Roberts et al., 2001; Sadori and Narcisi, 2001; Sadori, 2013).

Nevertheless, human activities should be considered in order to comprehend environmental changes occurred since Middle Holocene onwards. In fact, some authors place the adoption of farming activities in the onset of the Anthropocene (Ruddiman, 2003; Ruddiman et al., 2015). Thus, the anthropogenic factor should be kept in mind as a relevant element in vegetation evolution from the start of the Neolithic onwards, as shown by several studies in the Mediterranean area (Riera and Esteban-Amat, 1994; Dupré et al., 1996; Carrión and van Geel,

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1999; Sadori and Narcisi, 2001; Yll et al., 2003; Carrión et al., 2009). In this paper we focus on a mid-Holocene pollen record from Lake Banyoles, when the establishment of the first farming societies changed the relationship between humans and environment, resulting in the onset of an increasing process of landscape disturbance.

The Lake Banyoles area is remarkable for its evidence of early farming communities in the Iberian Peninsula, such as those attested at La Draga archaeological site, and also for the possibility it provides of relating the archaeological sites with palaeoecological records obtained from lacustrine and peat deposits in the lake surroundings. Previous palaeoecological analyses have been carried out in the study area (Pérez-Obiol and Julià, 1994; Höbig et al., 2012). Pérez-Obiol and Julià (1994) mainly focused on the Pleistocene records, but they also presented data about the vegetation cover at the onset of the Holocene in Banyoles, showing the dominance of broadleaf deciduous tree forests, especially deciduous *Quercus* and *Corylus*.

La Draga is a waterlogged Neolithic site on the eastern shore of Lake Banyoles. The archaeological research carried out at the site revealed evidence for intensive farming activity during the late 8th and early 7th millennium cal BP (Tarrús, 2008; Palomo et al., 2014). After eighteen years of excavations at the site, a new research project was started in 2008, including a survey of the lake shores (both on land and under water), aiming to locate new evidence of settlement sites and human activity of prehistoric societies (Bosch et al., 2010; Terradas et al., 2013). Holocene sediments were cored at locations placed at regular distances along the lakeshore during the 2008 and 2009 fieldwork seasons.

The reconstruction of past social activities and the impact on the environment requires an interdisciplinary approach in which several fields of research must be combined, such as archaeology, sedimentology and palaeoecology. The main goal of such an analysis should be to reveal the development of the relationship between changing environmental conditions and the factors that control climatic fluctuations, as well as the influence of all this on socioeconomic strategies.

Therefore, the main goals of this study are: i) to comprehend vegetation change patterns and their causes. ii) To evaluate the relationship

between vegetation patterns and sedimentation dynamics and their possible link with environmental changes. iii) To assess the impact on the landscape of the first farming societies.

## 2. Study area

### 2.1. Environmental and geographical settings

The study site is located in the northeastern Iberian Peninsula, 35 km from the Mediterranean Sea and 50 km south of the Pyrenees (Fig. 1). Lake Banyoles is a karst lake associated with a large karst aquifer system located in a tectonic depression, fed by underground water. The lake is approximately 2100 m long and 750 m wide with an average depth of 15 m that in several locations can reach up to 46 m (Casamitjana et al., 2006; Höbig et al., 2012).

The climate in the Banyoles region is defined as humid Mediterranean, with an annual precipitation of 750 mm and a mean annual temperature of 15 °C. The average maximum temperature during July and August is 23 °C, and the minimum average is 7 °C in winter. The minimum monthly precipitation (10 mm) occurs during summer and in December.

Dense vegetation formations in the mountains surrounding Lake Banyoles, are dominated by a mixed forest of evergreen oak (*Quercus ilex*, *Quercus coccifera*, *Rhamnus alaternus*, *Phillyrea media*, *Ph. angustifolia*), deciduous oak (*Quercus humilis*, *Buxus sempervirens*, *Ilex aquifolium*) and pine forest (*Pinus halepensis*) (Fig. 1). In this context, shrublands (*Erica arborea*, *Rosmarinus officinalis*) are well represented. Along the lakeshore, there are helophytic communities represented by *Phragmites australis*, *Typha angustifolia*, *Lythrum salicaria* and several cyperaceous species (Gracia et al., 2001).

### 2.2. Archaeological background

Located half-way along the eastern shore of Lake Banyoles, La Draga is the most important archaeological site in the region, providing a detailed bioarchaeological record that is unique for the Iberian Peninsula thanks to anoxic preservation conditions, with an Early Neolithic

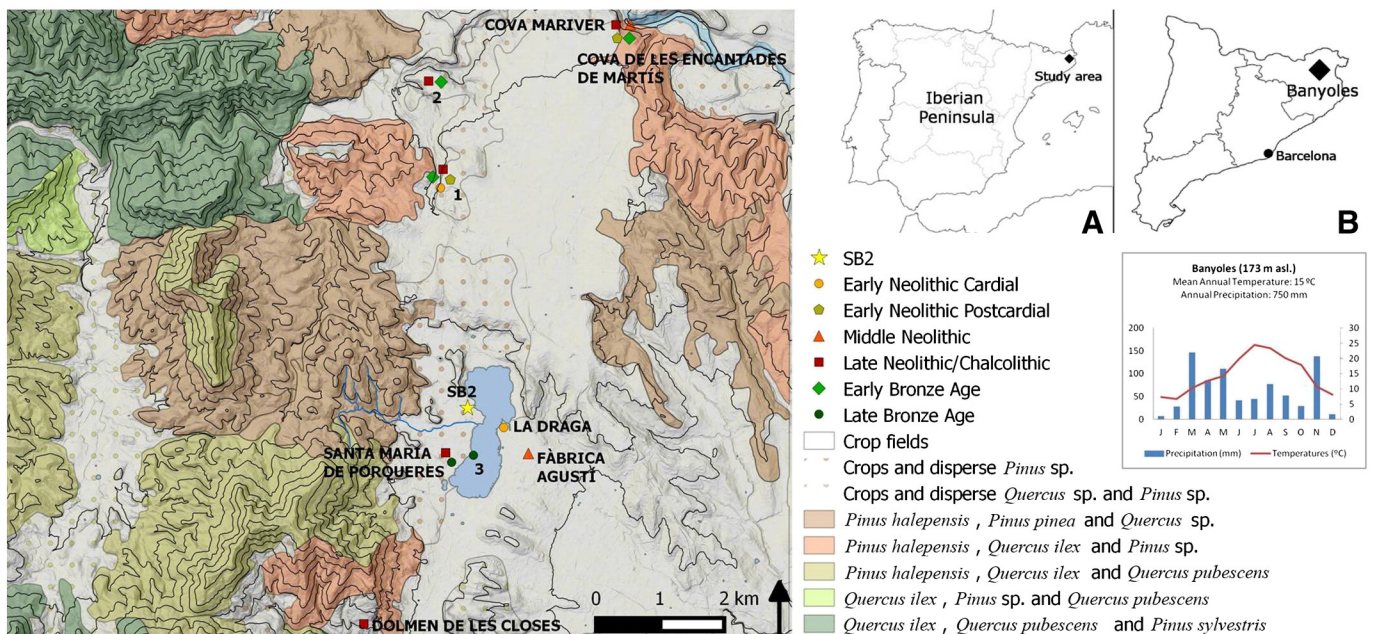


Fig. 1. Location of the coring site and surrounding archaeological sites. Source for vegetation map: Mapa Forestal de España (Zona 10). Climogram: precipitation and temperatures data in 2013 recorded in the station of Banyoles.

1. Cova de Reclau Viver, Cova d'en Pau, Mollet III, Cova de l'Arbreda, Cova d'en Costa, Cau del Roure.
2. Cau d'en Salvador, Cova dels Encantats de Serinyà, Cau d'en Quintana.
3. Worked wooden remains, probably a canoe, recovered by underwater surveying.

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