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Landscape dynamics of *Abies* and *Fagus* in the southern Pyrenees during the last 2200 years as a result of anthropogenic impacts

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ABSTRACT

The vegetation landscape dynamic is derived from the relationship established between a society and its environment through time, and the current landscape has never been seen in the previous 2000 years. The pollen study of a core from a peat bog in València d'Àneu (Lleida, NE Iberian Peninsula) shows a maximum extension of *Abies alba* forest about 2200–2000 cal. yr BP. Later on, there is evidence of selective actions affecting this forest and the expansion of *Fagus sylvatica* at about 2000–1300 cal. yr BP. Beginning in 1300 cal. yr BP, deforestation due to agricultural activities expanded and beech definitively disappeared at 800 cal. yr BP. Natural and human disturbances affected the dynamics of *A. alba* and *F. sylvatica* from their first appearance to the current vegetation landscape. Human impact on the silver fir forest, which reached its maximum in the last millennium, favoured the beech population. Pollen data from this region support our finding that human impact, not climate, is the most important influential factor in the development of beech forests.

1. Introduction

The current discussion concerning the dynamics of the vegetation landscape is rooted in the reasons for change over time and in the weighting of natural and human factors in its evolution (Galop and Jalut, 1994; Esteban et al., 2003; Riera et al., 2004; de Beaulieu et al., 2005; Riera et al., 2006; Pèlachs et al., 2007). Although climatic factors have a very important role in the development of vegetation, palaeobotanic studies have demonstrated the importance of taking into account the role played by human society. Therefore, the primary objective of this study is to determine the extent to which the human imprint has affected the current vegetation landscape, focussing on the dynamics of *Abies* and *Fagus* forests in the Pyrenees.

1.1. Colonization of Abies alba and Fagus sylvatica: the current state of affairs

An explanation of the plant colonization of the Pyrenees from the beginning of the Holocene can be undertaken on the basis of pollen analyses available from the Pyrenees mountain range (Jalut et al., 1998). It is impossible to interpret which factors affect this evolution without taking into account at least three variables: the location of refuge zones, the development of climatic factors and the edaphic dynamics of the soils (Pèlachs, 2005).

In recent years, the study of *Abies alba* dynamics in Europe (Terhürne-Berson et al., 2004; Liepelt et al., 2009) has been associated with other species, such as *Fagus sylvatica* (Tinner and Lotter, 2006). This area of study has developed from a series of interpretations based on the study of climate change, migratory change, unequal growth of species, and the effects of human disturbances and forest fires (Tinner and Lotter, 2006).

In this sense, phylogenetic studies reveal how the *Abies* populations in the Pyrenees were isolated from the rest of Europe (Konnert and Bergmann, 1995). This argument was definitive in defending the proximity of the Pyrenees to *Abies alba* refuge zones, based on plant macroremains and pollen data (Terhürne-Berson et al., 2004; Liepelt et al., 2009). The hypotheses about distribution from the glacial refuges based on isoenzyme studies and other genetic markers (El Mousadik and Petit, 1996) seem to substantiate the existence of five areas of *A. alba* refuge and recolonization: the Pyrenees, central and eastern France, central Italy and the southern Balkans. Pollen and genetic data indicate clearly that the *A. alba* and *Fagus sylvatica* refuges in the Pyrenees have suffered the "bottleneck" phenomenon during their history and that recolonization was not produced exclusively from refuge populations. This theory is well supported because of the low allelic levels, which can be correlated to the current distribution of silver fir in the Pyrenees, with populations that are not extensive in comparison with the rest of Europe.

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Palaeobotanical and genetic data for *Fagus sylvatica* (Magri et al., 2006) have been used to evaluate the genetic consequences in Europe of long-term survival in refuge areas and postglacial spread. The largely complementary palaeobotanical and genetic data indicate that *F. sylvatica* survived the last glacial period in multiple refuge areas. The central European refuges were separated from the Mediterranean refuges, which did not contribute to the colonization of central and northern Europe. Likewise, some populations expanded considerably during the postglacial period (Magri, 2008), while others experienced only limited expansion. According to Ninyerola et al. (2007a), inferences from more than a few studies lend credibility to the presence in the Mediterranean of deciduous taxa such as *Fagus* during the early and mid-Holocene. The climatic suitability of *Fagus* during the early Holocene has been shown by Lozano et al. (2002), who identified *Fagus* and dated it at c. 17,895 cal. yr BP in Urdaibai (Basque County) or López-Merino et al. (2008) in Sierra de Neila at c. 15,600–13,700 cal. yr BP. This led them to suggest the northern Iberian Peninsula as a possible refuge zone (Hewitt, 1999). In the Balearic Islands, the available data (Ninyerola et al., 2007a; Pérez-Obiol and Sadori, 2007) seem to indicate that *Fagus* had refuge in some concave areas during the upper Pleistocene and the Holocene. The presence of small stands of *Fagus* in Majorca, before the colonization from the Pyrenees took place, makes this a credible hypothesis. Similarly, examining the Iberian Peninsula, Pott (2000) indicates that over the last 9000 years *Fagus* has colonized northern areas from diverse Pleistocene Mediterranean refuges.

In the Iberian Peninsula, evidence exists (Costa et al., 1998) of the presence of *Fagus sylvatica* in the Basque Country (Saldropo) and Tramacastilla more than 4000 and 7000 years ago, respectively, which would confirm the presence of various refuge zones in the southern slope of the Pyrenees (Montserrat, 1992). This pattern of colonization

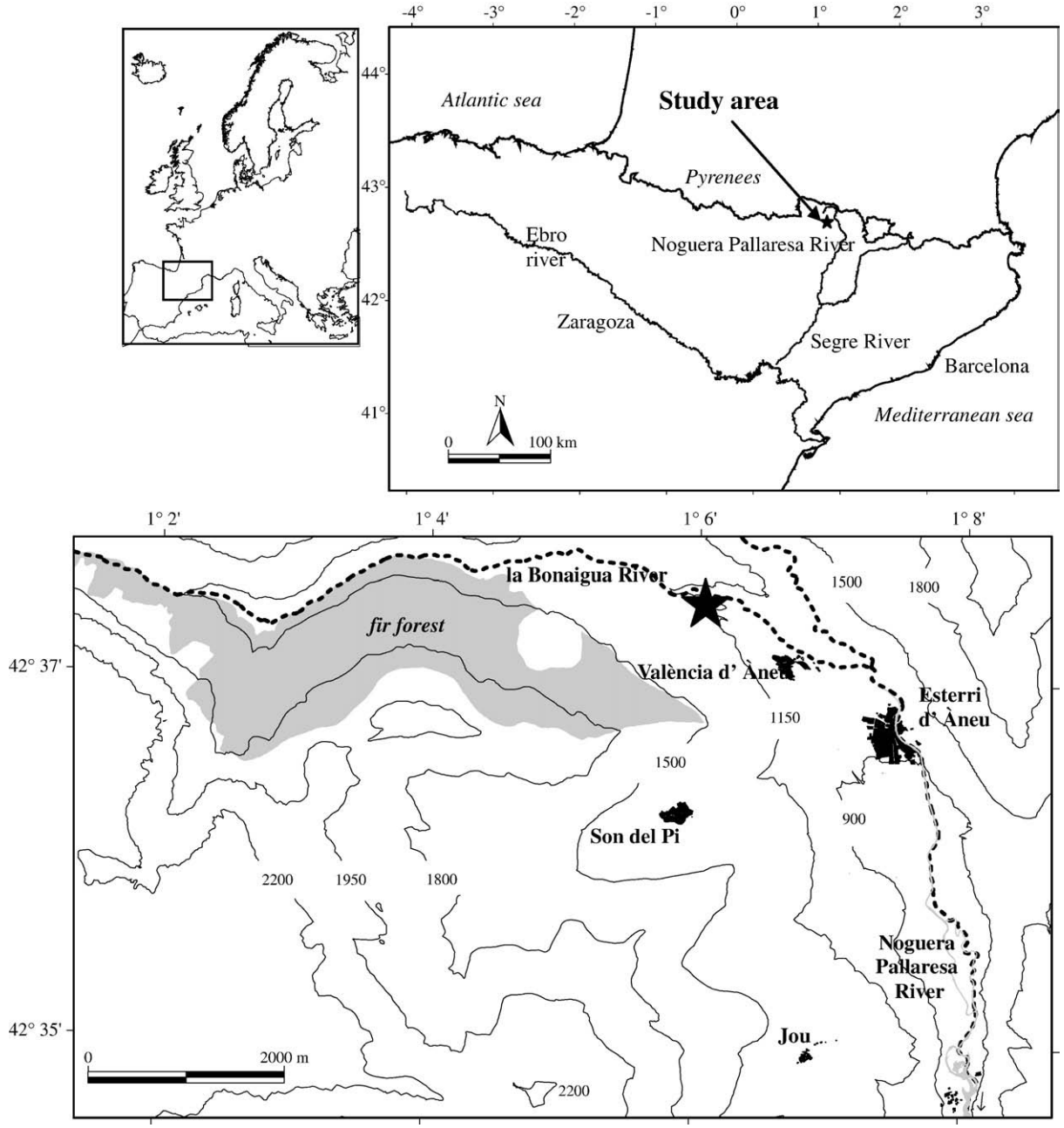

Fig. 1. Location of the València d'Àneu (VAL-III) peat bog (star) and fir forest (in grey) in the Pyrenees.