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Effects of thinning on litterfall were found after years in a *Pinus halepensis* afforestation area at tree and stand levels

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ABSTRACT

Little is known about the litterfall dynamics and the effects of stand-management practices under semi-arid Mediterranean conditions. Our aim was to provide data on the annual amount and the seasonal distribution of litterfall in a 15-year-old afforestation area of Aleppo pine under three different intensities of thinning applied 5 years before the study, and to analyse the relationships between litterfall and tree and stand characteristics. Three different but typical overstory thinning regimes [75% of mean basal area removed (T75), 60% (T60), and 48% (T48)] were performed on 16 randomly established 20 × 20 m plots [4 per treatment + 4 control unthinned plots (T0)]. Two trees per plot (8 trees per stand) were randomly assigned for monthly litterfall measurements from June 2009 to May 2010. In each tree, three circular traps were hung in random positions below its canopy. In total, 32 trees were monitored by means of 96 traps (24 traps per stand). Annual litterfall showed two seasonal peaks, ranging from 0.95 Mg ha^{-1} yr^{-1} in T75 to 2.28 Mg ha^{-1} yr^{-1} in the unthinned control stands (T0). However, at the tree level, litterfall ranged from 4.0 kg per tree yr^{-1} of total litterfall in T75 to 2.0 kg per tree yr^{-1} for T0. Trees in T0 tended to shed more needles and twigs measured per m^{-2} yr^{-1} than those at low densities, despite having less mean crown projection (T75 = 86 g m^{-2} yr^{-1}; T60 = 91 g m^{-2} yr^{-1}; T48 = 94 g m^{-2} yr^{-1}; T0 = 102 g m^{-2} yr^{-1}). Also, control trees shed a greater proportion (%) of needles and twigs with respect to the total amount of litterfall, mainly from August to November in all cases. Annual litterfall and needle fall showed a significant linear relationship with regard to tree size and stand density, canopy cover, basal area, and annual biomass production. Although only one year of data are shown and relative caution should be taken into account until further research is concluded, our results show that greater needle fall could be stimulated at high tree densities by tree competition for resources. Thus, this data may be used for planning forest management within a context of global change.

1. Introduction

The amount and quality of litterfall provides valuable information on the productivity and dynamics of nutrient cycling in forest ecosystems. Together with fine-root turnover, it is one of the main pathways that transfers annual organic matter and nutrients to forest soils (Hennessey et al., 1992; Agren and Knecht, 2001; Berg and Meentemeyer, 2001; Ukonmaanaho et al., 2008), so that litterfall dynamics is strongly linked to soil-carbon sequestration. Thus, real data on litterfall inputs are needed for modelling (e.g. models RothC, CENTURY, DAISY, CANDY, NCSOIL, and DNDC) in order to improve predictions for carbon balance under different scenarios and to develop and adapt sustainable forest-management practices for a changing world (see Smith et al., 1997 for a comparison of nine soil organic-matter models).

It is widely assumed that the amount and quality of litterfall depends, from a global perspective, on such factors as latitude and climate (Meentemeyer et al., 1982; Albrektson, 1988; Berg and Meentemeyer, 2001). However, these effects can be altered at a regional scale by other factors, such as: altitude; exposure; soil type; nutrient and water availability; interseasonal and interannual climatic variability; strong storms, winds, snow, and other disturbances; and pests and diseases (Bray and Gorham, 1964; Pausas, 1997; Li et al., 2005; Martínez-Alonso et al., 2007). In addition to these natural causes, forest composition, local-scale stand

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structure, and forest-management practices including thinning, pruning, fertilisation or irrigation may affect litterfall production, nutrient concentration, and cycling (Trofymow et al., 1991; Finér, 1996; Kavvadias et al., 2001; Blanco et al., 2008; Inagaki et al., 2008; Kunhamu et al., 2009).

Thinning is a routine silvicultural practice intended to improve growth in the remaining trees and gain higher lumber values. It is known that the environmental changes after canopy removal not only alter litter decomposition and nutrient-cycling processes (Shure and Phillips, 1987; Yin et al., 1989; Klemmedson et al., 1990), but also affect site productivity and the diversity of understory vegetation (Beatty and Sholes, 1988; Facelli and Pickett, 1991; Navarro et al., 2010). This is because changes in the canopy significantly influence seasonal and annual contributions of organic debris, potential nutrient returns, and initial litter-decomposition rates (Caldentey et al., 2001).

Most researchers agree that clearing vegetation reduces litter inputs until the canopy regrows (e.g., Huebschmann et al., 1999; Chertov et al., 1999; Caldentey et al., 2001; Blanco et al., 2006a), but the relations between stand characteristics and litterfall inputs are still not clear. Blanco et al. (2006a) proposed that tests in different types of forests and geoclimatic conditions are needed for a more accurate characterisation of forest response. In any case, all these studies were conducted at the stand level and very few studies have examined thinning effects at the tree level (for exceptions, see Miyaura and Hozumi, 1985; Adu-Bredu et al., 1997).

Pinus halepensis Mill. is a native tree of the western and central Mediterranean Basin, which has been used extensively in afforestation programmes in dry and semiarid areas for many decades (Maestre and Cortina, 2004). Its drought tolerance has led to its use in high-density plantations for controlling soil erosion in degraded lands and recently for converting cereal crops and old fields into forests via the European Farmland Afforestation Programme promoted by the Community Agrarian Policy (CAP).

However, as the Mediterranean Basin climate is becoming warmer and drier (IPCC, 2007), increased drought-induced mortality of pine plantations is expected (Sarris et al., 2010; Sánchez-Salguero et al., 2012). In this case, thinning can also help to prevent wildfires and enhance resource uptake by the remaining trees. Thinning in dry and semiarid forest is known to decrease competition among trees, enhancing soil–water availability and boosting individual growth (Aussenac, 2000; Misson et al., 2003; Navarro et al., 2010). However, little is known about litterfall production in Mediterranean forests or plantations under dry and semiarid conditions, especially in *P. halepensis* afforestation stands, and nothing is known about thinning effects.

This study was conducted as part of an overall project to evaluate the effects of forest-management practices on the ecology of Aleppo pine stands in the semiarid environments of south-eastern Spain. The objectives were as follows: (i) to provide data on the annual amount and seasonal distribution of litterfall in an Aleppo pine afforestation under semiarid Mediterranean conditions (only one-year data); (ii) to evaluate the effect of different thinning intensities; and (iii) to analyse the allometric relationship between the annual amount of litterfall as well as tree and stand characteristics.

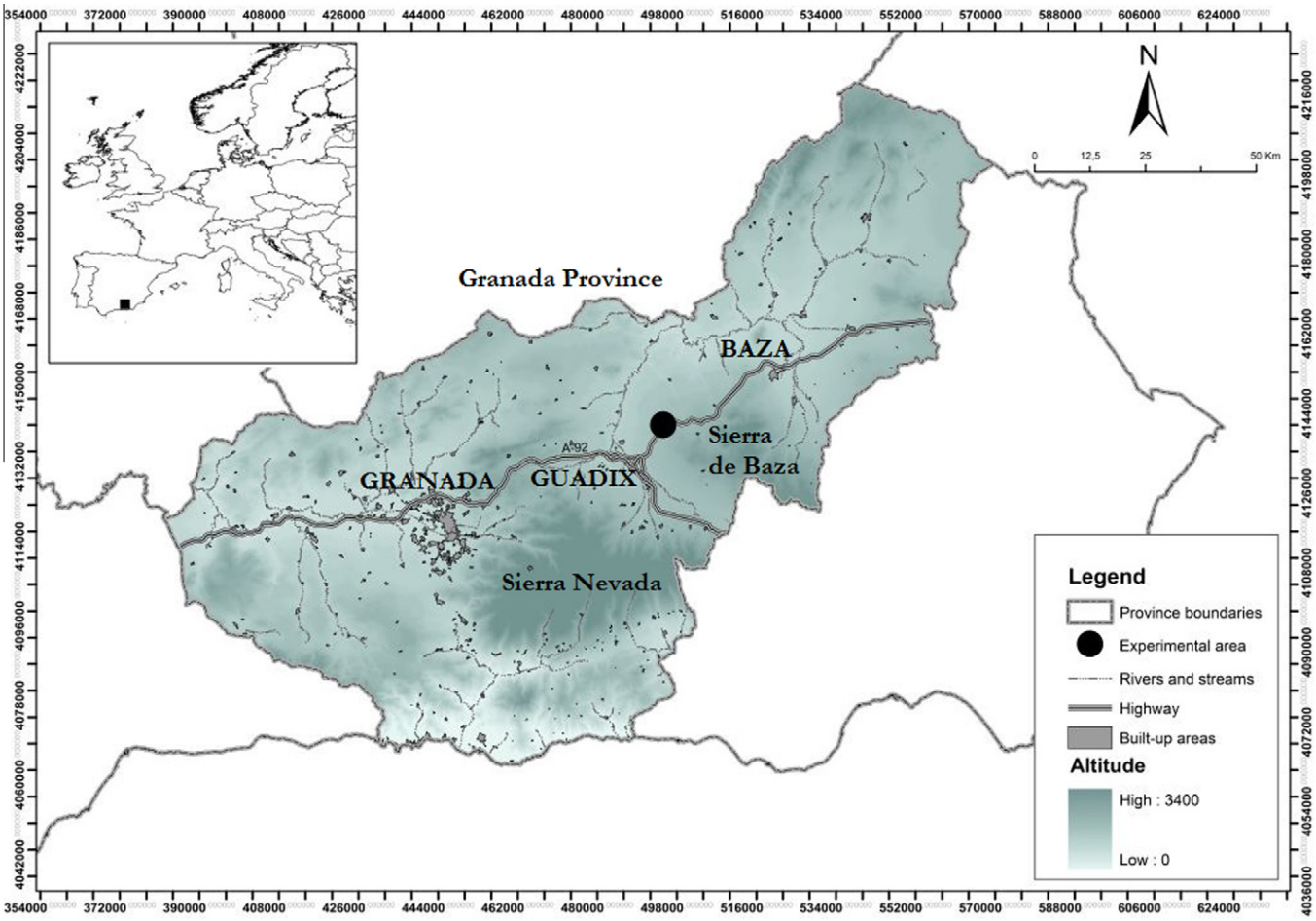

Fig. 1. Location of the study site in SE Spain.