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Short communication

Regional patterns of fire recurrence effects on calcareous soils of Mediterranean *Pinus halepensis* communities

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Abstract

The effects of fire recurrence on soils were studied on calcareous sites of Mediterranean *Pinus halepensis*-dominated communities in Catalonia (NE Iberian Peninsula). Soil organic horizons and mineral soils of 15 sites consisting in two adjacent areas, one burnt only once (in 1994) and the other burnt twice (in the same 1994 fire but also once before, from 1975 to 1993) were surveyed 9 years after the last fire. Fire recurrence decreased the occurrence and dry mass of soil organic horizons. Total nitrogen concentration in L organic horizon was higher in less recurrently burnt areas. No other significant difference between once- and twice-burnt areas was found for any studied chemical parameter either in organic L and FH horizons or in mineral soils. The present study underlines the fact that fire effects on soil organic horizons are accumulated through consecutive fires.

Keywords: Calcareous soils; Fire regimes; Mediterranean-type communities; *Pinus halepensis*; Regional patterns

1. Introduction

Fire is a dominant ecological factor in Mediterranean-type ecosystems, and changes in fire regimes – temporal and spatial patterns of fire occurrence (Gill, 1975) – can have important consequences for the conservation of Mediterranean landscapes. In fact, shifts in historical fire regimes have been observed both in Southern California and the eastern coast of the Iberian Peninsula, which result from changes in land use, policies, and an increasing climatic fire risk (Minnich, 1983; Moreno et al., 1998; Piñol et al., 1999; Pausas, 2004). Among those, the increase of fire recurrence – number of fire events that occur at a site along a given period of time – is of special concern. Firstly, because most wildfires are not lighted by natural but by anthropogenic causes, so fire recurrence can reach extremely high values in certain areas. Along the last decade in Catalonia (a 32,000 km^2 region in the NE Iberian Peninsula), 17% of summer fires were caused by lightning, 12% by unknown causes, and the rest were all anthropogenic; the 30% of the total were intentionally lighted. For the rest of the year, percentages were 4%, 12%, and 22%, respectively (Departament de Medi Ambient i Habitatge, 2005). Consequently, some areas in the region have burnt six times along 1975–1998 (Díaz-Delgado and Pons, 2001), i.e., average fire interval (*sensu* Johnson, 1992) was shorter than 4 years. Secondly, it has been pointed as having the most relevant ecological consequences (Keeley et al., 1999). Recurrent fires can lead to long-term cumulative effects on some ecosystem properties, such as vegetation regeneration (Zedler et al., 1983; Díaz-Delgado et al., 2002). In a previous study, Eugenio and Lloret (2004) found that in Catalonia, *Pinus halepensis* communities affected by two fires along a 20-year-long period showed less developed structure and lower fuel amounts than those burnt only once along the same time period, despite time since last fire was the same for both types of areas. Thus, a loss of plant productivity after recurrent fires was evidenced, which could lead to shifts in community types.

If cumulative effects are evidenced at plant community level, it is likely that they also occur in soils. The loss of plant productivity should be caused by a reduced availability of nutrients in mineral soils, and should result in reduced organic matter inputs to soil organic horizons. Moreover, direct effects of reburning should be evidenced on soil organic horizons, especially on those that need long periods of time to recover,

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Fig. 1. Location of Catalonia in the Mediterranean Basin.

such as humiferous layers (Ferran and Vallejo, 1992). Given that soil organic horizons play a main role in nutrient cycles and mineral soil fertility (O'Connell, 1989), and considering that soils of Mediterranean-type ecosystems usually show nutrient deficits, especially of phosphorous and nitrogen (Carreira et al., 1997), such reduction would be deleterious, and support a shift to less productive types of plant communities. Soil studies in the Mediterranean Basin have focused on the effects of a single fire, dealing with short-term nutrient dynamics in mineral soils (Kutiel and Kutiel, 1989; Carreira et al., 1997; Gimeno-García et al., 2000; Romanyà et al., 2001), newly developed water repellence in mineral soils (Alcañiz et al., 1994; DeBano, 2000), soil erosional responses, especially after the occurrence of rainfall events (Rubio et al., 1997; Cerdà, 1998; Andreu et al., 2001; De Luis et al., 2003; Pardini et al., 2004), and to a lesser extent, recovery of organic horizons (Ferran and Vallejo, 1992; Serrasolses and Vallejo, 1999), and depletion of soil microbial populations (Dumontet et al., 1996; Hernández et al., 1997; Radea and Arianoutsou, 2000). Moreover, most approaches to the study of fire effects on soils have been local, on a single study site or stand, and thus, no conclusions have been obtained on patterns occurring at wider spatial scales, i.e., over a range of geomorphic and climatic conditions.

2. Materials and methods

In the present work, fire recurrence effects on soils were studied at a regional level in Catalonia (Fig. 1). We selected 15 study sites by conducting spatial analyses on digital maps of substrate (''Geological Data Base 1:50,000'' (ICC, 2002)), vegetation (digitized over the source maps ''Mapa Forestal de Catalunya 1:100,000'' (DARP, 1996) and ''Mapa de Cultivos y Aprovechamientos 1:50,000'' (MAPA, 1980; Díaz-Delgado and Pons, 2001)), and fire history for the period 1975–1998[1] (generated by applying a semi-automatic methodology for mapping fire scars larger than 30ha (Salvador et al., 2000) that used a time series of remote sensing data, and by completing that information with available cartography (Díaz-Delgado and Pons, 2001)) (Fig. 2). All study sites corresponded to *P. halepensis* forests located on calcareous substrates. We focused on communities dominated by the tree seeder species *P. halepensis* (Aleppo pine) because it is one of the most abundant trees in the Mediterranean Basin (Quézel, 2000), and particularly in the Eastern Iberian Peninsula. In a recent forestry and ecological inventory conducted on 10,600 stations distributed all over the forest surface of Catalonia (CREAF, 2003), more than 181 millions of individuals were recorded, whose canopy covered 50% of the total surveyed surface. The soils of selected sites developed on sedimentary calcareous rocks; about half of sites were formed by soft rocks (marls, clays, argillites, mudstones), and the rest were formed by consolidated hard rocks resulting in very stony soils (dolomites, limestones, conglomerates). Each site consisted of two adjacent areas that suffered a common last fire in 1994: (1) an area that burnt only in 1994 (once-burnt, hereafter), and (2) an area that burnt twice, once between 1975 and 1993, and afterwards in 1994 (twice-burnt, hereafter). Fire interval (Fox and Fox, 1987) at twice-burnt areas ranged from 1 to 16 years. Study sites were located in the field by means of a global positioning system (GPS), and in addition, once- and twice-burnt areas were recognized according to the presence of field indicators of burning history. One stand of 1 ha was selected in each area, in such a way that paired once- and twice-burnt stands were as

[1] No spatial records of fires occurring before 1975 are available for the region.