Journal of Arid Environments 104 (2014) 116–123

Contents lists available at ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Fire history of Atlas cedar (*Cedrus atlantica* Manetti) in Mount Chélia, northern Algeria

S. Slimani [a,d,*], R. Touchan [b], A. Derridj [a], D. Kherchouche [c], E. Gutiérrez [d]

[a] Faculty of Biological Sciences and Agronomy, The University Mouloud Mammeri, Tizi Ouzou 15000, Algeria
[b] Laboratory of Tree Ring Research, The University of Arizona, 1215 E. Lowell St. Bldg. 45B, Tucson, AZ 85721, USA
[c] Department of Agronomy, Institute of Veterinary Science and Agronomy, The University Hadj Lakhdar, Batna 05000, Algeria
[d] Department of Ecology, Faculty of Biology, The University of Barcelona, Barcelona 08028, Spain

ARTICLE INFO

Article history:
Received 24 October 2013
Received in revised form
31 January 2014
Accepted 14 February 2014
Available online 15 March 2014

Keywords:
Aurès Massif
Dendrochronology
Fire regime
Fire scars

ABSTRACT

The first fire history of the *Cedrus atlantica* forest of Chélia in northern Algeria is reconstructed from samples of 14 and 12 dead fire-scarred trees from lower and upper elevation stands respectively. Superposed epoch analysis is applied to summarize mean climate conditions before, during, and after sets of fire years in both stands. Prior to 1850, *C. atlantica* forests in both sites were characterized by high frequency and low intensity fire regimes. The sharp decline in the fire frequency after the mid-nineteenth century coincided with the promulgation of the first laws governing land and forest use in Algeria. Most fire events occurred in the summer, during the latter part of the growing season. No significant relationships were found between an October–June precipitation reconstruction and fire events. This could be due to anthropogenic and topographic factors. The findings of this study provide baseline knowledge on the ecological role of fire in the *C. atlantica* forest. This information is vital to support ongoing ecosystem management efforts in the region.

1. Introduction

In Mediterranean-type ecosystems, fire is a natural and regular process that plays a major role in shaping vegetation communities and landscapes, and controls plant species age structure and diversity (Trabaud, 1994). The present landscapes of most Mediterranean ecosystems are the result of a long evolution, during which plants evolved mechanisms to overcome the effects of fire and adapt to it (Ne'eman et al., 2004; Trabaud, 1994).

Forest fires represent a serious environmental issue in the Mediterranean region and other regions that are characterized by Mediterranean climate such as California, central Chile, southern and southwestern Cape Province of South Africa, and southwestern parts of Australia (Montenegro et al., 2004). According to Fernandes and Botelho (2004), wildfires burn an estimated average of 700,000–1,000,000 ha of land every year in the Mediterranean Basin.

In Algeria, about 41,644 declared fires burned 1,162,484 ha between 1979 and 2009 (Bekdouche, 2010). Algeria has a long history of forest fires. National fire statistics cover about 160 years, dating back to 1853 (Meddour-Sahar et al., 2013). However, the data are more or less fragmentary. Meddour-Sahar et al. (2008, 2013) documented the fire history in Algeria over the French colonization and post-colonial periods. The authors noted that, despite the increase in concern for environmental issues, fire frequency continued to increase over time, while the area burned tended to decrease slightly.

Long-term fire history data constitute a valuable tool in understanding present-day vegetation structure and composition for forest management and sustainability. Most of the studies on wildfires in Algeria were carried out in post-fire dynamics investigations (Bekdouche, 2010; Lounis, 1998; Slimani, 2002), and data on Atlas cedar forests are rare (Meddour, 1992).

Trees are excellent recorders of environmental changes and are well-suited to investigating past fire activity (Fulé et al., 2008; Swetnam and Baisan, 1996; Touchan et al., 1995). Varied techniques are used for reconstructing fire history. However, the most accurate records of actual fire events of the past are those from fire-

* Corresponding author. Present address: Department of Ecology, Faculty of Biology, The University of Barcelona, Barcelona 08028, Spain. Tel.: +34 934 037 143; fax: +34 934 111 438.
E-mail addresses: slimanisaid@yahoo.fr (S. Slimani), rtouchan@ltrr.arizona.edu (R. Touchan), aderridj@yahoo.fr (A. Derridj), d.kherchouche@yahoo.fr (D. Kherchouche), emgutierrez@ub.edu (E. Gutiérrez).

http://dx.doi.org/10.1016/j.jaridenv.2014.02.008
0140-1963/

scar data, which provides "point" fire frequencies with annual to seasonal resolution (Henderson, 2006).

In this first fire-history study in North Africa, we investigated the long-term fire regime of lower and upper elevations of the Atlas cedar forest of Mount Chélia, northern Algeria. We employed dendrochronological methods to determine exact fire dates. Fire history data, observations of site characteristics, and independent dendroclimatic reconstruction (Kherchouche et al., 2012) were used to assess associations between fire regimes and environmental factors (Baisan and Swetnam, 1990; Touchan and Swetnam, 1995; Touchan et al., 1996).

2. Material and methods

2.1. Study area

Our study area is located on Mount Chélia in the heart of the Aurès Massif, between the cities of Khenchela and Batna, northeastern Algeria (Fig. 1). The area encompasses two adjacent sites, which are stands of Atlas cedar of about two hectares each: Oued Tider (OUT) and Thniet Zemroune (THZ) (Fig. 2). The two sites differ in elevation by 110 m. OUT, the lower stand, has north- to northwest-facing aspects, whereas THZ is positioned at the top of the hill, and has a south-facing aspect. The mean slope at both sites is about 25° (Table 1). The soil is well-drained and derived from sandstone and dolomite (Faurel et Laffite, 1949 in Belloula, 2011). The study area is characterized by a semi-arid Mediterranean climate with two contrasting seasons: wet and cold first season reaching a mean minimum temperature of −1 °C in January; and a hot and dry second season extending from mid-May to late-September, with a mean maximum temperature of 33 °C registered in August. The total annual precipitation is 388 mm (Beghami, 2010). The snow-cover period, with 10–15 snowy days per year, lasts from January to March (Bensid, 1996 in Belloula, 2011); whereas the frost period, with an average frequency of 38 frost-days per year, is longer and lasts from November to April (Belloula, 2011).

The study area is an open forest consisting of almost pure stands of Atlas cedar with minor occurrence of *Quercus ilex* and *Juniperus oxycedrus* trees. The vertical structure of the vegetation is simple with a low understorey cover of herbs, shrubs and tree saplings that undergoes intense and continuous pressure from grazing. The main understorey plant species are *Berberis hispanica*, *Bupleurum spinosum*, *Aegilops triuncalis*, *Cytisus balansae*, *Teucrium chamaedrys* subsp. *chamaedrys*, *Ampelodesma mauritanica*, *Asphodelus ramosus*, *Calycotome spinosa*, *Genista pseudopilosa*, *Anthemis monilicostata*, *Thymus munbyanus*, *Sedum acre* subsp. *neglectum*.

2.2. Fire-scar sampling and analyses

In September of 2012, we collected fire-scarred samples from stands at the lower and upper elevations, OUT and THZ respectively. The sampling procedure concentrated on the available dead material. Fourteen and twelve fire-scarred samples from OUT and THZ, respectively, were collected from stumps and logs using a chainsaw (Table 1). One criterion for sample-tree selection was the presence of well-preserved scars showing evidence of fire by the number of healing ridges observed on the scarred surface ("cat face") (Baisan and Swetnam, 1990). In the laboratory, the samples were glued onto plywood, fine-sanded and crossdated using dendrochronological techniques (Stokes and Smiley, 1996). The FHX2 software program (Grissino-Mayer, 2001) was used to compute descriptive statistics. FHX2 is designed to analyze the fire history of forest ecosystems, and provides a means for entering, archiving, storing, editing, and manipulating fire history information from tree rings. FHX2 creates fire charts displaying fire chronologies for individual trees or for individual sites. It has powerful statistical functions for analyzing the temporal changes in fire regimes, seasonality of past fires, and spatial differences in fire occurrence between sites (Grissino-Mayer, 1995).

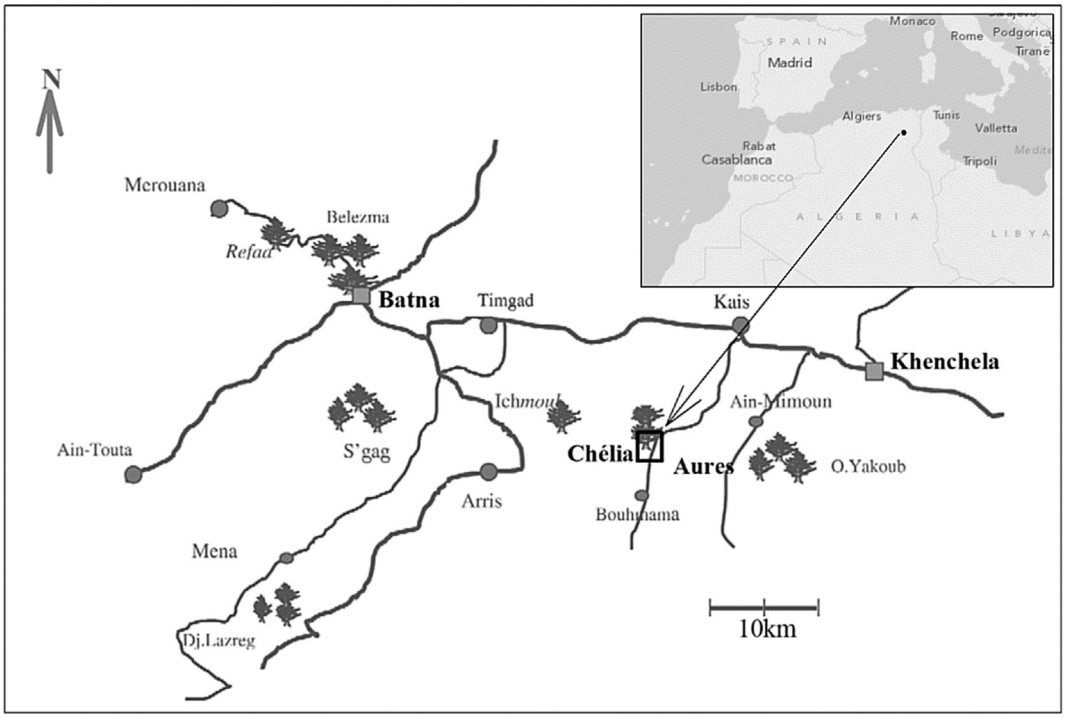

Fig. 1. Location of the study area. Map redrawn from Bentouati (2008).