Forest Ecology and Management 412 (2018) 21–28

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Recent growth trends of black pine (*Pinus nigra* J.F. Arnold) in the eastern mediterranean

Ellen Janssen[a], Vincent Kint[a], Jean-Daniel Bontemps[b], Kürşad Özkan[c], Ahmet Mert[d], Nesibe Köse[e], Bilgin Icel[f], Bart Muys[a,*]

[a] Department of Earth and Environmental Sciences, University of Leuven, Celestijnenlaan 200E Box 2411, 3001 Leuven, Belgium
[b] IGN, Laboratoire de l'Inventaire Forestier, 14 rue Girardet, 54000 Nancy, France
[c] Department of Forest Engineering, Faculty of Forestry, Suleyman Demirel University, 32260 Isparta, Turkey
[d] Department of Wildlife Ecology and Management, Faculty of Forestry, Suleyman Demirel University, 32260 Isparta, Turkey
[e] Istanbul University, Faculty of Forestry, Forest Botany Department, 34473 Bahçeköy, Istanbul, Turkey
[f] Department of Forest Products Engineering, Faculty of Forestry, Suleyman Demirel University, 32260 Isparta, Turkey

ARTICLE INFO

Keywords:
Tree ring analysis
Radial growth
Basal area increment
Growth trend
Turkey
Climate change

ABSTRACT

Past and present environmental changes cause significant changes in tree growth in many parts of the world, where both decreasing and increasing growth trends have been detected over the last decades. The Mediterranean basin is especially sensitive to climate change and subsequent tree growth declines. In this article, we present the first study on recent tree growth trends in Turkey. *Pinus* nigra is a drought-sensitive species and one of the most common and economically important native conifers to Turkey. Tree-ring cores were taken from 61 *Pinus nigra* plots spread over the entire Lakes District (Southwest Turkey), near the species' southern range limit. The samples cover the 1839–2013 time period. We apply the Regional Curve Standardization technique and statistical modeling to the tree ring width data to investigate long-term growth trends. Both methods show remarkably similar results: a slowly increasing growth trend until the 1970s, followed by a decreasing trend. This recent negative trend is highly correlated with increased temperature and drought in summer, which suggests that it is likely caused by climate change.

1. Introduction

Increased forest growth over the 20th century is well documented for many parts of the world (Spiecker, 1999; Vejpustková et al., 2004; Martínez Vilalta et al., 2008; Salzer et al., 2009). In addition, other studies also observed recent decreasing trends in forest growth (Dittmar et al., 2003; Jump et al., 2006; Piovesan et al., 2008; Bontemps et al., 2010; Charru et al., 2010; Kint et al., 2012; Liu et al., 2013; Aertsen et al., 2014; Liang et al., 2016). Different environmental changes have been brought forward to explain the observed growth trends, including (1) increased atmospheric CO_2 concentration (Martínez Vilalta et al., 2008); (2) climatic changes (Dittmar et al., 2003; Jump et al., 2006; Macias et al., 2006; Sarris et al., 2007; Piovesan et al., 2008; Kint et al., 2012) and (3) increased nitrogen deposition (Nellemann and Thomsen, 2001; Mellert et al., 2008; Braun et al., 2010; Bontemps et al., 2011; Kint et al., 2012).

In the Mediterranean basin, mainly growth declines due to increased temperature and drought have been reported (Jump et al., 2006; Macias et al., 2006; Sarris et al., 2007; Piovesan et al., 2008), although unexpected recent growth increases have also been found (Koutavas, 2013; Tegel et al., 2014). While temperate forests can often still benefit from warmer temperatures, at least in the short-medium term, the productivity of Mediterranean forests is expected to decline due to strongly increased droughts and fire incidence (Schröter et al., 2005; Lindner et al., 2010; Charru et al., 2017).

In Turkey, growth changes over the last century have not been investigated so far. However, data obtained from meteorological stations (Tayanç et al., 2009) show a continued annual warming trend in Southern Turkey since 1950. Southwestern meteorological stations show a cooler period between 1971 and 1993, especially in the Antalya station. All weather stations of Turkey together show a clear temperature increase since 1993. Significant decreases in precipitation since 1950 were identified in the western parts of the country. Additionally, a twentieth century warming trend was identified in tree-ring width data

Abbreviations: BAI, basal area increment; SM, statistical modelling; RCS, Regional Curve Standardization; AD, average distance of the six closest trees to the sample tree; PDSI, Palmer Drought Severity Index; SPEI, Standardized Precipitation-Evapotranspiration Index; AIC, akaike information criteria; RSE, residual standard error; Adj. R^2, adjusted R^2

* Corresponding author.
E-mail address: bart.muys@kuleuven.be (B. Muys).

https://doi.org/10.1016/j.foreco.2018.01.047
Received 29 November 2017; Received in revised form 27 January 2018; Accepted 28 January 2018
0378-1127/

(Köse et al., 2017).

One of the most widespread pine species in the Mediterranean is black pine (*Pinus nigra* J.F. Arnold), with Turkish black pine (*Pinus nigra* subsp. *nigra* var. *caramanica)* covering 4.2 million hectares in Turkey (Köse et al., 2012). It is one of the most common and economically important native conifers to Turkey (Atalay and Efe, 2012). Black pine is also the most commonly used species in dendroclimatological studies in Turkey (Akkemik and Aras, 2005; Touchan et al., 2005; Akkemik et al., 2008; Köse et al., 2011; Köse et al., 2012; Mutlu et al., 2012; Köse et al., 2013; Köse et al., 2017). It is a drought sensitive species (Martín-Benito et al., 2008a; Köse et al., 2012) affected by climate change during recent decades and in future projections (Andreu et al., 2007; Martin-Benito et al., 2011; Sánchez-Salguero et al., 2012). Our study area, the Lakes District in South-west Anatolia, is situated near the species' southern range limit. Climate change, and lower water availability in particular, is expected to reduce productivity at these equatorial range edges (e.g. Sarris et al., 2007) and distributions are expected to shift poleward and upward as the climate warms (Hickler et al., 2012; Rabasa et al., 2013), although range-edge decline is not ubiquitous (Chen et al., 2010; Cavin and Jump, 2017; McCullough et al., 2017).

In this paper, we present the first study on recent growth trends of black pine in Turkey. Our research objective was to examine whether recent growth changes occur in Southwest Turkey as they have been reported from Europe and other parts of the world. Based on tree-ring width data, we used the Regional Curve Standardization approach and statistical models to investigate long-term growth trends of *Pinus nigra* in Southwest Turkey. Our second objective was to assess which climate factors are driving these growth trends.

2. Material and methods

2.1. Study area and sampling design

Data were collected in the Lakes District (South-west Anatolia) during September 2014, between 30°30′–31°16′ longitude and 37°33′–38°04′ latitude. The region is characterized by a sub-humid Mediterranean climate with pronounced winter precipitation and summer drought (see Table 1 in the Appendix for climate normals). Limestone is the predominating parent material (Kint et al., 2014). Locally also conglomerates and sandstones are present. Soil depth, moisture regime and stoniness vary with topography. Most soils can be classified as leptosols, regosols or cambisols (FAO classification), depending on shallowness and stoniness (Fontaine et al., 2007).

Table 1
Parameter estimates of the base model and model statistics of the base and year model for log(BAI + ε) of Pinus nigra in Southwest Turkey.

Variables[a]		Estimates[b]
Intercept		6.19e − 01[*]
D_p		6.59e − 02[***]
D_p2		− 7.11e − 04[***]
Surface2		− 3.17e − 01[***]
Surface3		4.19e − 01[***]
Surface4		4.27e − 01[***]
TPI		− 1.19e − 02[***]
AD		3.88e − 04[***]
Statistics[c]	RSE	Adj. R^2
Base model	0.6411	0.2669
Year model	0.6293	0.2936

[a] Intercept and coefficients for D_p (previous year sample tree diameter, cm), Surface (categorical variable for the topsoil), TPI (Topographic Position Index) and AD (average distance of the six trees closest to the sample tree).

[b] Significance levels (p-values):[***]: < 0.001; [**]: < 0.01; [*]: < 0.05.

[c] : RSE: residual standard error; Adj. R^2: adjusted R squared.

61 plots were established in near-homogeneous even-aged managed high forest stands of black pine (see Fig. 1). All plots are situated in normally stocked productive stands of the valleys and lower mountain slopes, between 900 and 1700 m above sea level. The plots were selected so as to cover a maximal range of site productivity (determined as site index, method in Section 2.2) and tree age/size. Special attention was given to the inclusion of as many combinations of site productivity and tree age/size as possible.

All plots were centered around a vital and dominant tree without apparent stem damage, further called the sample tree. From the central sample tree, a tree ring core was taken with a 5 mm increment borer at breast height. Ring width chronologies were measured using a Lintab measuring platform at a measurement resolution of 0.01 mm and recorded with the TSAP-Win program (Rinn, 2015). Measurement accuracy and crossdating were verified using the COFECHA program (Holmes, 1983; Grissino-Mayer, 2001). Cambial age at breast height was estimated from ring counts, although this ignores the years a tree needs to reach breast height and is thus a slight underrepresentation of tree age. Samples from 61 trees were successfully measured and crossdated. The dataset covers the period 1839 through 2013, but only the 1879–2013 time period was used for further analysis due to low sample depth in the earlier period. The expressed population signal (EPS, based on between-tree correlations and sample replication) was calculated to determine this reliable time period, with a threshold of 0.85 as often cited as adequate (Wigley et al., 1984). All samples were taken in September 2014.

2.2. Growth-trend detection method

One of the main issues when analyzing long-term growth trends is disentangling the age/size trend in the growth curve of individual trees from the long-term growth trend in the tree population, and a variety of methods exists to deal with this challenge (Bontemps et al., 2009; Bontemps and Esper, 2011; Peters et al., 2015). Conventional dendrochronological standardization techniques were not performed on our data as these techniques tend to remove not only the age/size trend but also the long term trend in growth that we are interested in (Peters et al., 2015).

Instead, a combination of different methods was applied. First of all, trees of different ages (varying between 30 and 177 years old) and sizes (diameters between 20 and 88 cm) were sampled (Untheim, 1996; Bontemps et al., 2009), allowing the comparison of the growth of small/young trees with that of large/old trees when they were small/young. Adding young trees to the dataset is crucial, since it is very difficult to disentangle a possible decreasing growth trend from the natural age-related decrease in growth when only old trees are sampled.

Second, basal area increment (BAI) was used as the response variable. The basal area increment of tree "i" in year "y" was calculated as:

$$BAI_{i,y} = \pi*(R_{i,y}^2 - R_{i,y-1}^2)$$

With R the radius of tree "i" at the end of the growing season and y the year of ring formation. BAI was chosen over ring width, as it shows a much smaller decreasing trend with age compared to ring width, as such partly avoiding the confounding with individual tree age/size related growth trends. This so-called Basal Area Correction method even assumes that BAI shows no age trend in mature trees, but more often the conversion does not suffice to remove the age/size trends. The remaining age/size trends were therefore accounted for by introducing tree diameter as an explanatory variable. Tree diameter was preferred over cambial age since tree growth of mature trees is driven by tree size rather than tree age (Mencuccini et al., 2005; Bontemps and Esper, 2011). A lower cambial age limit of 30 years was applied to exclude juvenile growth and minimize the effect of off-pith coring.

Finally, we applied two different statistical methods to our data: Regional Curve Standardization (Becker, 1989) and a statistical