Fir decline and necrosis: the role of climate change and forest fires

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Abstract Chronologies of tree-ring widths of living and dead trees were analyzed from a stand of Cephalonian fir, located in an adjacent to a burned by a forest fire area. The purpose of the research was to investigate, from a dendroecological point of view, the fir forest dieback phenomenon, but also the role of forest fires in the evolution of the phenomenon. The results show that the dead fir trees lag in tree-ring width growth. The abrupt growth change in tree-ring width in the dead trees 1-2 years before necrosis, indicates that forest fires accelerate the evolution of the phenomenon. It seems that forest fires, besides the immediate destruction of fir forests, accelerate the necrosis of fir trees, which is primarily caused by the observed increase in drought and temperature due to climate change.

Keywords: dendroecology, tree-rings, *Abies cephalonica* fir decline, forest fires, climate change.

1. Introduction

Fir forests dieback and necrosis is a problem that occurs in Greece in the recent decades, some years with higher intensity and is attributed to a combination of biotic and abiotic factors (Tsopelas et al. 2001, Papadopoulos et al. 2007). Increased droughts seem to be the primary cause that reduces trees' strength which are subsequently affected by fungi and insects leading to their necrosis. However, in addition to climatic induced fir decline and necrosis, there are also other biotic and abiotic factors (Schweingruber 1996) that further increase trees' stress and further weaken them, such as forest fires (Michaletz and Johnson 2007, 2008, Bär et al. 2019, Halofsky et al. 2020).

2. Materials and Method

The study area is located in Gorianades, Municipality of Karpenissi, Evritania-Greece (38º54΄23.63΄΄ N, 21º47΄10.38΄΄ E and 842 m a.s.l.). Tree ring samples were taken from living and dead trees in September 2019. The samples were collected and prepared using dendrochronological technics (Stokes and Smiley 1968) and the tree-rings were cross-dated (Fritts 1976) and measured in 0,01 mm using the WinDendro system (Régan 2007). Twenty (20) chronologies were obtained from tree-rings widths from living and dead trees. Monthly precipitation and mean monthly temperature were derived for the years 2017, 2018 and 2019, from daily data from the meteorological stations of the Athens Observatory network: a) Karpenisi (city) (38º54΄59.23΄΄ N, 21º47΄17.92΄΄ E, 990 m a.s.l.) and b) Karpenisi (Voutiro) (38º52΄08.49΄΄ N, 21º 45΄09.57΄΄ E, 700 m a.s.l.). Based on these data we calculated the average monthly values of precipitation and mean temperature which are representatives of the study area located between these two meteorological stations.

3. Results - Discussion

The period covered by the average time series of living and dead trees, extends to 63 (1957-2019) and 61 (1958-2018) years respectively. The average tree-rings' widths, derived from raw data of the living trees (2.48 mm) and dead trees (2.01 mm), are significantly different ($p<0.01$). The average tree-ring widths' curves of the living and dead trees (Fig. 1), show a similar inter-annual variability, as expected since the trees grow in the same position. The same is observed in the overall growth tendency, with the exception of the first decade where a different trend is observed between the living and dead trees (mean tree-ring width 2.94 mm and 1.34 mm respectively). The different growth trend of living and dead trees at the beginning, could be mainly explained by the competition between trees in the stand, which then gradually decreases until it became proportional for the two groups of trees. It should be noted the sharp decrease in ring width of the dead trees in the last year before the year of necrosis.

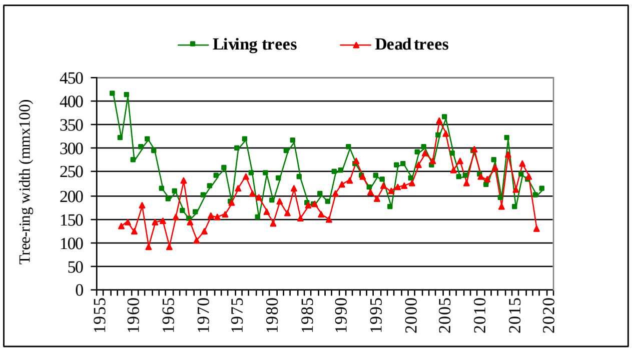

Figure 1. Mean chronologies of raw data tree-ring width for living and dead fir trees.

Research in the wider study area (Papadopoulos et al. 2007, Papadopoulos 2014) have shown that necrosis is preceded by a period of 3-30 years where the width of the rings is very small (less than 1 mm).

In general, dead trees, although offsetting the difference in growth from living trees in the last decades, appear to maintain a tendency to decrease in tree-ring width under stress (Bigler and Bugmann 2004, Cailleret et al. 2017).

According to Cailleret et al. (2019), the declining growth trend may be a precursor sign of tree necrosis. It should be noted that lately, fir forests' necrosis is primarily attributed to the negative effect of high summer temperatures and drought (Papadopoulos et al. 2007, Papadopoulos et al. 2011). In the present study, the period of short increase is only 1-2 years before necrosis, which presupposes another abrupt factor that in addition with the high temperature stress and summer drought led to greater strain and eventual necrosis of the weakest trees. This factor could be the forest fire that occurred in October 2017, in an adjacent location to the research area. This fire, likely related to the heatwave in 2017, potentially resulted in more sensitive trees, that subsequently had a more abrupt necrosis. In particular, 8 of the 10 trees died after forming minimal early wood in 2018 and the 2 trees in 2019 in the phase of early wood formation.

After examining drought by the ombrothermic diagram of the years 2017, when the forest fire occurred, and the years 2018 and 2019, when fir trees necrosis appeared in the study area, it seems that the intense and prolonged summer drought, which occurred with greater duration and intensity, could have played a decisive role in the October 2017 fire (Fig. 2).

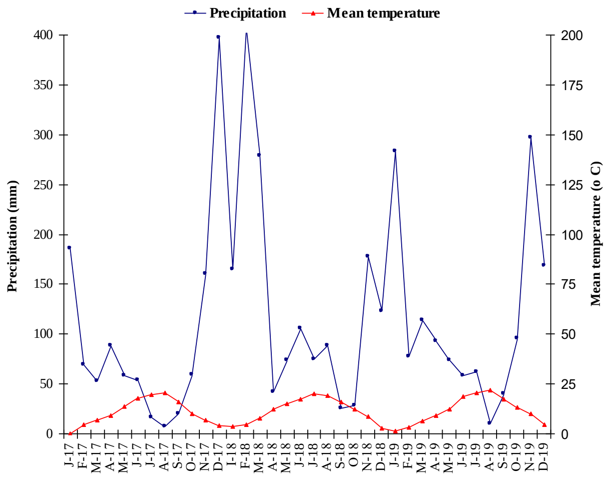

Figure 2. Ombrothermic diagram of years 2017, 2018 and 2019 for the study area.

Given that, even with the mildest climate change scenarios, extreme climate conditions and global warming will affect fir-tree populations in the Mediterranean region (Sánchez-Salguero et al. 2017), it is reasonable to expect that decline and necrosis factors of fir forests will intensify in the future as well as forest fires in the fir zone (Bank of Greece 2011), which requires immediate measures to reduce these factors and adapt fir forest's management to climate change.

4. Conclusions

Apart from the role of climate change, which primarily affects the decline and necrosis of the remaining fir trees, a key role is played by the previous stress posed to these trees by forest fires, accelerating the development of necrosis.

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