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Climate factors and oak decline based on tree-ring analysis. A case study of peri-urban forest in the Mediterranean area

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ABSTRACT

The main objective of this research was to investigate climate-growth relationships and if climate is a possible cause of oak decline in a very representative peri-urban forest in the Mediterranean area. The dendrochronological behaviours of healthy trees and declining trees were compared according to compromised vitality as assessed by crown defoliation. The analysed parameters were ring and latewood widths. The results showed that ring widths and latewood depended directly on spring precipitation (April-May-June) and, inversely, on spring-summer temperature (April-May-June-July). The growth histories of healthy and declining deciduous oaks in Castelporziano, as evaluated by their crown vitality, were very similar. The onset of decline dates back to the middle of the 1940s, and a further irreversible growth depression was based on the increase in temperature in the 1980s. This climatic change is reflected roughly 13 years later in declining trees, 17 years later in the healthy ones, in a strong growth depression that appears very exacerbated by the recurrent warm extreme events after the 2000s. Latewood in our study did not add more to the total ring-width measurements, potentially because of a high state of tree suffering. Declining trees were in general older than healthy ones, but in this study, the difference in age was not different from a statistical point of view.

1. Introduction

Deciduous oaks can be considered one of the most important groups of species of the genus *Quercus*. They characterise the landscape of the Mediterranean area both in forests and in urban and peri-urban woods. Currently, their health and survival are seriously at risk because oak decline has increased over the last two decades and mortality has been documented in forests worldwide (Allen et al., 2010; Ibáñez et al., 2017; Gentilesca et al., 2017). Forest decline and mortality have been ascribed more frequently to various causal factors that result from the interaction of predisposing (e.g., low site productivity, advanced tree ages), inciting (e.g., climatic changes, insect defoliation, droughts) and contributing factors (e.g., poor forest management practices, bark beetles) (Manion, 1991).

Generally, the symptom of oak decline that alerts foresters and society as being predictive of mortality is the abundance of crown defoliation that is also represented by dead branches (Drobyshev et al., 2007a; Tulik, 2014; Čater, 2015; Tulik and Bijak, 2016). However, crown vitality is not always necessarily an indicator of an irreversible decline of the tree. Another indicator which shows significant promise in this respect is tree-ring width. Comparison of tree-ring series according to variations in the severity of symptoms of crown defoliation and the to-date pattern of radial growth that precedes tree mortality can be particularly useful (Lombardi et al., 2008; Cailleret et al., 2016). Furthermore, tree-ring analysis detected climatic change as one of the most important drivers of forest decline (Di Filippo et al., 2010; Andersson et al., 2011). One important contribution, which can act in a complementary manner with dendrochronology, is the use of aerial photographs in a GIS environment. With a diachronic approach, the latter can help reconstruct the ecological dynamics of the landscape and changes in canopy cover. Studies on oak decline using tree-ring analysis in the Mediterranean area have been performed mainly on forest coppice stands (Corona et al., 1995; Amorini et al., 1996; Di Filippo et al., 2010) and it is necessary to enlarge the case studies to high volumes of forest seriously threatened. Climate change is rapid and extreme in the Mediterranean basin and its deleterious effects are even more abrupt in urban areas (Ordóñez and Duinker, 2014). Urban forests are crucial as they have a "pillow" function by providing a multitude of ecosystem services (Manes et al., 2012). Therefore, when there is a phenomenon of dieback, as in Castelporziano, it is necessary to understand the cause of

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decline and any possible solution to enhance the resilience of the ecosystem.

With these assumptions in mind, the work presented here seeks to investigate the declining status of monumental oaks in a very representative peri-urban forest of the Mediterranean area, specifically the estate of Castelporziano located approximately 20 km from the Metropolitan area of Rome. The estate of Castelporziano is a true hotspot of biodiversity and, owing to it being an ecosystem at very high risk, its conservation is a priority.

The specific aims of this investigation were:

1. To establish climate-growth relationships and assess whether climate is a possible cause of oak decline; and
2. To compare the dendrochronological behaviours of healthy trees and declining trees according to compromised vitality as determined by crown defoliation and dead branches.

2. Materials and methods

2.1. Study area

The Presidential Estate of Castelporziano (41°41′54,56″ N; 12°21′9,50″ E) covers an area of roughly 6000 ha. It is well-known internationally because it is the summer residence of the President of the Republic; therefore, it is highly protected and included in the Natura 2000 network.

The soils are primarily made up of stabilised old sand dunes and contain a free water table with the presence of a superficial groundwater table in most of the investigated land. The area has been inhabited for a very long time with evidence of strong activity dating back to Roman times and even before. Anthropogenic activity lasting for such a long time has deeply modified the landscape of the area. At present, the site is burdened with very strong urbanization with about 200 inhabitants per square kilometre, and it is jeopardised by elevated anthropogenic pressures which have greatly accelerated the degradation processes (Trotta et al., 2015).

From a climatic point of view, the site is classified as Mediterranean, referring to the climatic data of Rome—Collegio Romano, with a hot and dry period between May and September (Fig. 1). The mean annual total precipitation in Rome (1862–2013) is 711 mm, while the mean annual temperature is 16.1 °C.

The landscape represents a typical Mediterranean forest ecosystem along the Tyrrhenian coast with relicts of mixed deciduous and evergreen woods, Mediterranean shrubland, xeric vegetation of pastures, wetlands, and dunes. The most represented vegetative type is the mixed deciduous oak species. The oak high forest can be classified as mature, and over the last 50 years, it has not been subjected to any more silvicultural treatment.

2.2. Sampling and tree-ring measurement

The samples for dendrochronological analysis were collected in the spring of 2014.

In total, 38 trees were sampled with a diameter at breast height (DBH) spanning from 27 cm up to 103 cm and an age range between 52 to 215 years in different zones of the estate. It was allowed to collect no more than one core for each tree.

Core sampling was performed on selected healthy trees and on the declining ones according to their crown defoliation. It was decided to assess decline status in the tree only when there was an estimation of at least 20% of defoliation in the crown using the same criterion adopted by Tulik (2014) (Fig. 2). The sampled trees belong to deciduous species, such as English oak (*Q. robur* L.) and Turkey oak (*Q. cerris* L.), but also downy oak (*Q. pubescens* Willd.) and Italian oak (*Q. frainetto* Ten.). Some of the sampled trees did not demonstrate discretely clear species characteristics, so they may be regarded as hybrids. The main characters of age and DBH are reported in Table 1, dividing the subgenus', *Quercus Oersted* (Q. *robur* L.) and *Cerris* (Spach) Oersted (Q. *cerris* L.), according to Schweingruber (1990).

Diameter at Breast Height and Age of the investigated trees classified according to the vigour class.

Ring-width (RW) series and latewood (LW) width series were measured at 1/100 of mm by the LINTAB system (Rinn Tec) and classical dendrochronological analysis was carried out (Romagnoli and Codipietro, 1996; Corona et al., 1995).

It was decided to work with two mean curve representatives of the Castelporziano site (healthy and declining) because it was not permissible to sample a higher number of trees that could be used to build a mean chronology representing ecological behaviour at the species level and because of a very robust inter-tree synchronization. Among the 38 sampled trees only 26 were included in the mean curves due to broken cores or to a very poor inter-synchronization

The boundary between earlywood and LW was established at the end of the vessels in the porous zone of the ring, which in some cores was represented by one-two rows of vessels while in other samples, extended up to the third row of vessels. It was decided to not take into account earlywood in the following analysis because earlywood chronological series were not so well synchronized to each other. The most important dendrochronological parameters, i.e., mean value, standard deviation, coefficient of variation, and mean sensitivity, were calculated based on the raw values of RW and LW in healthy and declining trees. In order to verify the relationships with climatic parameters, mean inter-correlation and EPS were also elaborated. Using Kruskal-Wallis test (statistical programs: R package, version 4.0), a

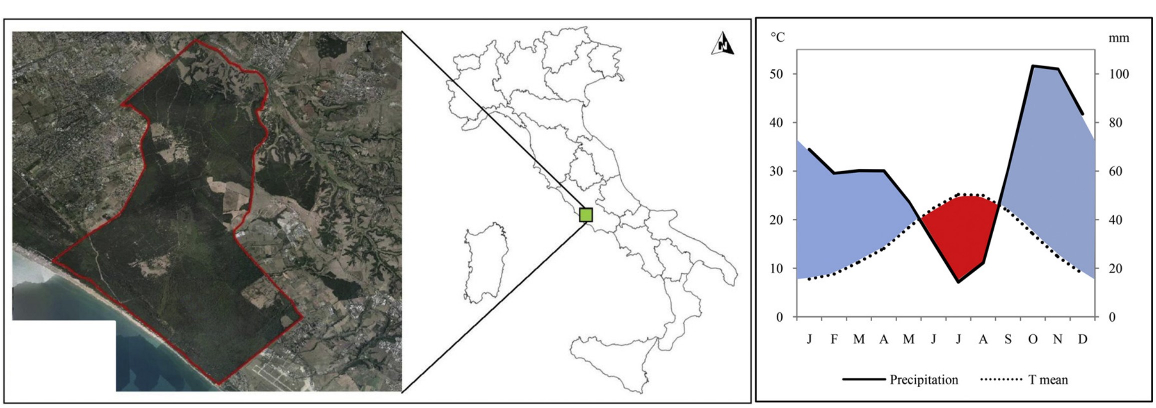

Fig. 1. Study area and meteorological data. *Left*: Local overview of sampling areas within the Presidential Estate of Castelporziano (*red contour on colour orthophoto*). *Right*: Bagnouls-Gaussen's diagram for the period 1862–2013 deriving from the data of the meteorological station of Collegio Romano (Rome). The sum of monthly precipitation (mm) and mean monthly temperatures (°C) are reported.