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An Overview of Extreme Years in *Quercus* sp. Tree Ring Records from the Northern Moldavian Plateau

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Abstract: In this study, we made use of a regional oak tree-ring network from six stands that cover the northern Moldavian Plateau (eastern Europe) to analyze how different tree ring parameters (i.e., early wood tree-ring width, late wood tree-ring width, and total tree-ring width) of *Quercus* sp. are influenced by the occurrence of extreme climatic events (e.g., long-lasting drought events). In order to explore the influence of extreme hydroclimatic events on tree ring width, we have selected each of the six most extreme positive and negative years of tree growth and addressed the seasonal cycle of tree growth in comparison with the main climatic parameters, then evaluated both the current and lagged consequences of extreme hydroclimatic events on tree ring width and the capacity of trees to recover. Our results indicate that the variability of oak tree ring width from the Moldavian Plateau is mainly influenced by the availability of water resources, and that an important limiting growth factor for *Quercus* sp. is the occurrence of long-lasting drought events, e.g., at least two years in a row with severe drought conditions.

Keywords: extreme climatic events; tree-ring width; *Quercus* sp.; dendrochronology; Moldavian Plateau; superposed epoch analysis; drought

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1. Introduction

Extreme climatic events (e.g., droughts, heatwaves, floods) have a strong impact on different sectors including society, biodiversity, the economy, the environment, forestry, water management, and agriculture [1–4]. Forest ecosystems are directly affected by the variability of major climatic parameters (e.g., temperature, precipitation, radiation) via their impact on the tree's physiological processes, for example, photosynthesis and water transport [5]. Thus, extreme climatic events can cause severe damage to trees in the form of forest fires, drastic reduction in tree growth rates, dieback events, and even tree mortality [5–8]. Numerous studies have reported a significant decline in the growth of oak trees during severe drought conditions or extreme climatic events [9–13].

Trees respond to climatic conditions through variations in tree ring parameters (e.g., tree ring width, maximum wood density, and stable isotopic composition in tree ring cellulose, among others) [14,15]. The variations in tree ring width represent an efficient indicator that can quantify the influence of climate (including drought conditions and climatic extreme events) on the growth of trees [11,16]. Extreme climatic events (e.g., droughts, heatwaves, floods) have a strong impact (e.g., via significant changes in resource availability) on tree growth in the year of the extreme climatic event, as well as during the post-event recovery time. The overall availability of water resources is recorded by the sequence of wider or narrower tree ring width [16,17]. Additionally, during extreme drought conditions, trees become more vulnerable to pathogen attacks, forest fires, and insect outbreaks [18].

Recent studies have shown that as a consequence of the ongoing climate change we are facing an increase in mean global/regional temperatures, changes in precipitation patterns, and more frequent and more intense extreme climatic events [3,19–21], including over Romania [22,23], where our tree ring network is located. The observed record-breaking heat waves, droughts, and floods over the last several years have cost hundreds of millions of Euros in damage and have led to significant impacts at the social, economic, and ecological levels [4,24–26]. Moreover, climate models predict that temperature will continue to increase in the next decades, and that the associated climatic extreme events will increase in both frequency and intensity [21,27], causing even greater socio-economic and ecological damages. Therefore, it is expected that the associated risks and impacts of climate change will increase significantly in the coming years and even decades.

Considering the economic and ecological importance of forests, a better understanding of the relationship between the variability of tree ring width and extreme climatic events is essential for ensuring reliable provisioning of forest ecosystem services in the face of climate change [24]. The recent extreme drought events which have affected large parts of Europe over the last decade [3,20,28,29] have allow for investigation of the short-term consequences of extreme drought on tree growth in temperate European forests [18,24,30]; however, such studies are limited for the eastern part of Europe. Furthermore, it is of great interest to study the potential impact of extreme climatic events on forestry (especially tree growth) and related services for human societies in order to help mitigate negative effects.

Here, we employ a regional oak tree ring network from six stands covering the northern Moldavian Plateau (eastern Europe) to present an overview of how tree ring width is affected by extreme hydroclimatic events, with a special focus on long-lasting droughts. The aim of this paper are: (i) to analyze the climate–growth relationship between different parameters of tree rings of *Quercus* sp. from the northern Moldavian Plateau (the northeastern part of Romania and the northern part of the Republic of Moldova) along with the main climatic parameters; (ii) to investigate how the tree ring network reflects the spatial extent of extreme climatic events and climatic extremes over the analyzed region; (iii) to address the seasonal cycle of tree growth variability during the most extreme years; and (iv) to evaluate both the immediate and lagged consequences of extreme climatic events on tree growth and on their capacity to recover.

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