The forest resistance to droughts differentiated by tree height in Europe

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Abstract

More frequent droughts are altering the dynamics and function of the European forest ecosystem, which is deeply connected to the global carbon cycle. Tree height is an important structural feature of forests; however, how it regulates the response of forests to droughts remains controversial. By comprehensively examining the variations of satellite-based vegetation greenness with drought evolution in Europe, we observed apparent height-dependence forests’ resistance to drought. Short trees show lower resistance to drought than tall trees, demonstrating earlier and larger negative vegetation anomaly. However, short trees present more rapid recovery when released from the drought. Although tall trees are more resistant to short-term water stress, prolonged drought may cause more serious damage. The observed resistance differences can be attributed to the differences in the capacity for water absorption and regulation among forests of different heights. These findings are critical to our understanding of the response of forests under drought stress.

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1. Introduction

Forests play a critical role in regulating the global hydrological and carbon cycles (Dixon et al. 1994; Pan et al. 2013). Globally, drought has been identified as the most widespread stress factor that pushes trees to their physiological threshold and causes irreversible damage (Allen et al. 2010; McDowell et al. 2008). Recently, Europe has experienced frequent devastating droughts and heatwaves, which have led to increased concern regarding the stability of local forest ecosystems and regional carbon cycles (Ciais et al. 2005; Fischer et al. 2010; Seneviratne et al. 2006; Zaitchik et al. 2006). European productive temperate forests have been significantly affected by these extreme drought events, and it is estimated that the droughts caused a mean reduction in net primary productivity (NPP) of 16 gC m⁻² month⁻¹ in the summer of 2003 (Ciais et al. 2005). More frequent droughts can be expected as the climate warms (Meehl et al. 2004; Schär et al. 2004). Therefore, understanding the resistance of forests to drought is critical if we are to accurately forecast future forest dynamics in Europe.

Previous studies have reported a height-dependence with respect to the resistance of forests to drought (Bennett et al. 2015; Lindenmayer et al. 2012; Lutz et al. 2012; Phillips et al. 2010). It has been suggested that, under drought conditions in Europe, tall vegetation experiences relatively less browning and a smaller reduction in gross primary productivity (GPP), which indicates less water stress and drought impacts on tall vegetation (Bevan et al. 2014). However, some other studies indicate large trees are more likely than small trees to succumb to extreme drought (Bennett et al. 2015; McDowell et al. 2015). For example, large trees die at twice the rate of small trees in conifer-dominated forest in the Southwest of North America from 2009 to 2016 (Stovall et al. 2019, 2020). These findings are surprising, and it is unclear why large trees experience less variability in greenness during drought, but have a higher risk of
Text S1: Sample method based on a greedy algorithm

We randomly sampled n samples (X₁, X₂, … Xₙ) to fit by linear regression. If the P-value of the slope of the regression equation is greater than 0.05, this samples is selected. Otherwise reselect. Then we randomly sampled a point (Xₙ₊₁) to fit with (X₁, X₂, … Xₙ). If the P-value of the slope of the regression equation is greater than 0.05, the number of total samples plus one. Otherwise, this random sample is discarded and the number of total sample grid cells is unchanged. If the number of total samples reaches the maximum, then stop and finish.