THE Science BREAKER
SCIENCE MEETS SOCIETY

January 21, 2022

Plant Biology

Can forests survive climate change?

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This Break was edited by Ilaria Di Meglio, Senior Scientific Editor - TheScienceBreaker

ABSTRACT
Human-induced (anthropogenic) climate change is exposing forests to a growing risk of drought-induced tree mortality. Replacement patterns following drought related mortality indicate that predrought dominant tree species have limited short-term persistence, highlighting the likelihood for major ecosystem reorganization and its implication to changing forest biodiversity in the coming decades.

Many forests across the globe are experiencing tree mortality episodes as a consequence of long, intense drought periods, likely associated to anthropogenic – human-caused, as opposed to natural – climate change. To date, most research has focused on plant mortality processes during drought, and the way in which forest communities recover following drought mortality, which is key for the fate of these key ecosystems, remains mostly unknown. This knowledge gap represents a major limitation to our understanding of the ecological consequences of climate change.

We performed field campaigns to study the short-term (range 1 to 23 years after tree mortality) dynamics of forests after drought-induced mortality. Although we inevitably need to wait several decades to accurately know the final fate of these forests, the long-lived nature of trees allows us to expect that, in the absence of further disturbance, the current patterns of species persistence, which is their ability to stay in the disturbed site, will remain for decades.

In our study, we assessed 131 forest and woodland sites from dry tropical to temperate and boreal systems, excluding species-rich tropical forests. We quantified the composition of woody species after drought mortality to evaluate: the degree of self-replacement of the predrought dominant tree species (i.e., replacement with itself), replacement of the dominant species by other woody species including trees and shrubs, or the lack of replacement by woody vegetation. This approach allows us to assess forest resistance, which is the ability of a forest to resist disturbances and maintain its structure and function or, alternatively, conversion of forest to other vegetation types. Replacement patterns following drought were then examined in relation to drought characteristics, forest management, and biotic disturbances (including insects and pathogens). We also assessed the bioclimatic preferences, that is the climate conditions (e.g., arid or humid environments) where species thrive, of predrought dominant and postdrought replacing species.

We found that in 69% of the study sites trees affected by drought mortality were replaced by other tree and shrub species, and in 10% of the cases no replacement by woody vegetation (i.e., forest collapse) prevailed up to ~20 years following drought. Therefore, drought episodes are likely to cause forest species turnover and promote structural change, strongly influencing short-term ecosystem resilience. We found that changes in species composition were stronger under drier conditions after drought, which given the increasing aridity trends in many regions, highlights the likelihood of important ecosystem reorganizations due to these events in the coming decades. Importantly, under high management intensity, irrespective of management type, and when fungi and other pathogens were concurrent with the drought, we observed the highest levels of tree replacement by shrubs. Overall, these results highlight that interacting disturbances (anthropogenic and natural) can disrupt forest resistance and, therefore, amplify processes that lead to forest collapse.

Across the multiple forest types that we assessed, drought-related mortality mostly promoted replacement by species with a higher tolerance to arid conditions (drought-tolerant). This is the case behind some of the iconic cases of forest transformations reported to date, such as Scots pine replacement by pubescent oak in central Europe, pinyon pine replacement by juniper species and bitterbrush in North America, and jarrah replacement by marri tree in Australia. However, in some cases, we observed replacement by species characteristic of less arid climates or no change in the species' bioclimatic characteristics (i.e., climatic preferences) following drought. These changes were driven, respectively, by replacement by species exhibiting higher climatic tolerances, such is the case of stone pine replacement by holm oak in Mediterranean landscapes, or by turnover of species with equivalent climatic preferences, such as silver fir replacement by European beech and mountain ash in the Pyrenean range.

Drought may not necessarily lead to different ecosystem trajectories if compared to vegetation changes that follow other disturbance types like fires or pests. But drought-induced tree mortality could accelerate the rate and geographical extent of vegetation turnover (e.g., replacement of trees by shrubs), and this has broad ecological impacts. In spite of the general patterns we described, we found that both short-term forest replacement patterns and the associated shifts in the bioclimatic characteristics of the species varied greatly. This variability indicates that multiple ecological processes including the characteristics of drought itself, land-use changes, management history, and other past or concurrent disturbances modulate ongoing changes in species composition associated with drought events. These changes have important implications for future forest biodiversity and ecosystem services and merits further monitoring.