How Europe's forests regenerate—without any human interference

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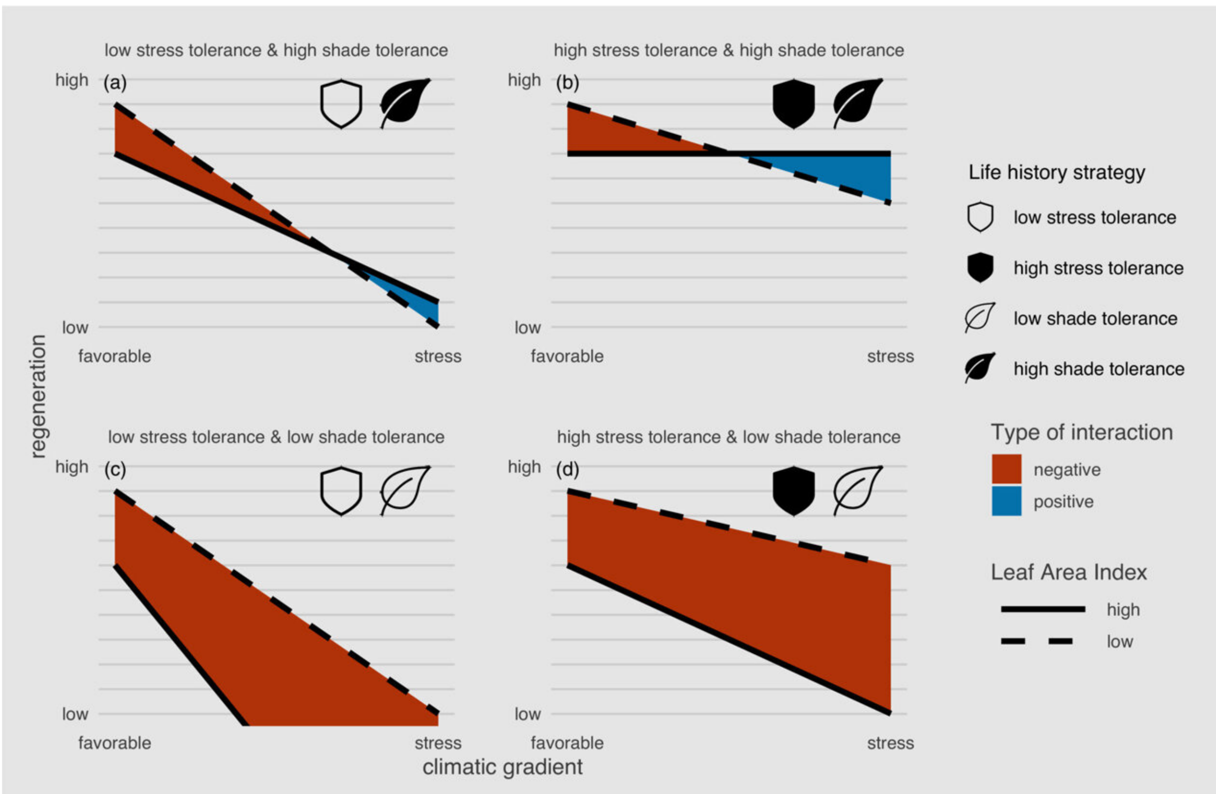

Modification of the Stress Gradient Hypotheses (SGH) based on Life History Strategies (LHS). The SGH states that (i) abiotic factors (e.g. climate or soil) determine species performance at the edges of climatic gradients, (ii) negative interactions (competition) determine performance under favorable climatic conditions, and (iii) positive interactions are more likely under stressful climatic conditions (Bertness & Callaway, 1994; Callaway & Walker, 1997). Thus, the original SGH (a) predicts reduced performance with increasing climatic stress, with effects of neighbors (here captured as Leaf Area Index (LAI): high LAI [solid line] vs. low LAI [dashed line]) transitioning from negative interactions (competition) under favorable conditions to positive interactions under stressful conditions—as in (a, b). LHS traits can modify the nature of this relationship. For example, traits conferring shade tolerance can lead to lower negative effects of climatic stress, especially in the absence of competition (a) (e.g. *Tsuga heterophylla* in Ettinger & HilleRisLambers, 2017). Species that are shade-tolerant and tolerant to climatic stress exhibit both reduced effects of stress on recruitment and high effects of competition across the entire climatic gradient (b) (e.g. *Abies amabilis* in Ettinger & HilleRisLambers, 2017). Lower shade tolerance is expected to heighten competition effects across the entire climatic gradient, reducing the likelihood of positive interactions (c) (cf. Körner (2021) for potential mechanisms that limit species distribution range under cold stress) but climatic stress tolerance can still lower the combined negative effects of competition and climatic stress (d) (Maestre et al., 2009). Shade-induced stress is possible along entire climatic gradients, whereas cold and drought stress appears toward their ends. Thus, according to the SGH varying levels of species tolerance to shade (upper vs. lower panels) and climatic stress (left vs. right panels) are expected to systematically modulate the interaction between trees along climatic gradients. These different trait configurations may translate into different strategies for one species, depending on the type of climatic stress. For example, *Fagus sylvatica* is highly tolerant to shade but sensitive to low temperatures and drought (a). *Quercus* spp. is shade-intolerant and tolerant to drought (d) but intolerant to cold conditions (c). The opposite is true for *Picea abies*, which is considered tolerant to shade and low temperatures (b) but not to drought (a). Other species with very low shade tolerance, such as *Betula* spp. and *Pinus sylvestris*, are tolerant to cold or to cold and drought, respectively (d). Consequently, shade-tolerant and shade-intolerant species may feature different strategies depending on the type of climatic stress (i.e. horizontal switches between panels). Credit: *Journal of Ecology* (2023). DOI: 10.1111/1365-2745.14181

Yannek Käber, a doctoral student in the Professorship of Forest Ecology at ETH Zurich, and his colleagues from ETH and WSL together with the European Forest Research Initiative (EuFoRIa), have taken a look at regeneration in protected European forests for the first time.

In a new study recently published in *Journal of Ecology*, the researchers show how natural regeneration develops without human influence. To this end, they investigated the emergence of young trees in just under 300 natural forest reserves all across Europe. They analyzed how regeneration of the forest works under a wide range of environmental conditions. This involved examining the complex interplay between the different features of the tree species, forest density, disturbances and climate.

Water scarcity leads to fierce competition

One of the most important processes for forest regeneration is competition. What strategies trees use depends on their species. This study shows that positive interactions between trees only occur in a few species, and are therefore rarer than previously assumed. The features of the species concerned and the varying stress factors determine whether trees protect each other from cold or dry conditions during regeneration or whether they compete with each other instead.

Cold stress tends to lead to more protective interactions from other trees than drought stress does. The researchers explain this result by pointing out that low temperatures do not trigger competition for limited resources. Scarcity of water, on the other hand, leads to fierce competition. This can lead to smaller trees being suppressed.

Waiting for gaps

The study also shows what strategies the various tree species use to regenerate. Some are particularly successful in dense forests. Others wait for disturbances such as fire or storms that create gaps in the canopy. As soon as enough light becomes available, these species grow quickly.

In mixed forests, the varying strategies of the different species interact. This means these forests are better placed to react to climatic stress, in that more species emerge that can cope with drought and heat, for example. This changes not only the composition of the forest, but also its structure—in other words, the mix of trees of different sizes and ages. And forest structures form that can only arise in undisturbed and protected forests.

More information: Yannek Käber et al, Sheltered or suppressed? Tree regeneration in unmanaged European forests, *Journal of Ecology* (2023). DOI: 10.1111/1365-2745.14181

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