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EDITORIAL

Title: Plant community responses to climate change: the importance of ecological context dependencies

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Climate change is considered one of the most important threats to biodiversity (IPBES 2019; Montras-Janer et al. 2024). It was a topic in 22% of scientific articles focusing on biodiversity (Clarivate, Web of Science) and the focus of several special issues in ecological journals during the last five years (e.g., Malhi et al. 2020; Kéfi et al. 2024).

This Special Issue « Plant Community Responses to Climate Change » focuses on community, rather than species-specific, responses and the importance of ecological context dependencies. Most ecological studies assessing the effect of climate change on biodiversity have focused on individual species responses, such as changes in geographical distributions with consequences for biodiversity at the regional scale (e.g., Thuiller et al. 2005; Parmesan 2006; Lenoir et al. 2020; Lynn et al. 2021). Beyond the question of scale in ecology, this might be due to the traditional view in the scientific literature that species are independent of each other (Whittaker 1956) and, thus, that we should expect species-specific (or functional group-specific) responses to climate change (Chapin and Shaver 1985). However, differing species-specific ecological requirements and niche positions in the ecological space do not preclude species interdependencies in plant communities (Callaway 1997). Species interdependencies and ecosystem-engineering effects by foundation species (Wilson and Agnew 1992) may contribute to explaining lag dynamics in species responses to climate change (Bertrand et al. 2011; Dullinger et al. 2012; Alexander et al. 2018; Rumpf et al. 2019). For example, Lenoir et al. (2017) have stressed that the microclimatic buffering effect of canopy trees in forest ecosystems contributes to explaining why most plant species have shown limited migration towards colder latitudes or elevations. This is due to the pronounced difference in temperature and relative humidity between the near-ground surface of open habitats and the understory of mature forests from wet and warm climates (De Frenne et al. 2019). Therefore, there is an urgent need to integrate plant-plant interactions and a community-scale perspective into climate change studies to increase the accuracy of our

predictions (Sanczuk et al. 2024) and the efficiency of mitigation strategies (e.g., assisted migration; Michalet et al. 2024).

Ecological context dependencies at the level of individual species and communities can strongly affect biotic responses to climate change (Lenoir 2020), a phenomenon prevalent at different spatial extents and resolutions. At the regional level, for example, changes in alpine plant community composition depend not only on the regional climate and changes therein but also on more local features such as elevation, slope, aspect and bedrock types (Winkler et al. 2006; Niklas et al. 2021; Steinbauer et al. 2022). This is not only caused by differences in stress conditions and species strain (i.e., the physiological stress experienced by a particular species in a specific habitat, Choler et al. 2001; Liancourt et al. 2017; Lynn et al. 2021) but is likely also due to varying plant-plant interactions and, thus, to changes in the buffering capacity of different vegetation types along environmental gradients (Brooker 2006; Michalet et al. 2014; Bektas et al. 2024). At the local level, mesotopographic variation due to the terrain roughness (e.g., depressions vs. ridges in alpine landscapes, Billings and Bliss 1959) contributes to inducing strong differences in soil conditions, snow cover duration and microclimate, and, therefore, supports the occurrence of microrefugia (Wipf et al. 2009; Scherrer and Körner 2011; Choler 2018; Liancourt et al. 2020). These finer-scale habitat differences also affect plant-plant interactions and, in turn, contribute to inducing contrasting changes in community composition depending on local habitats (Wipf et al. 2006; Saccone et al. 2009; Helm et al. 2024, but see Chytrý et al. 2023). Finally, at the proximal level (i.e., within plant communities), individual species responses to temporally or spatially varying climatic conditions are highly dependent on the identity of the neighbouring plant individuals via competition and facilitation (Alexander et al. 2015; Jiang et al. 2018; Losapio et al. 2021).

The Special Issue “Plant Community Responses to Climate Change” features studies from different parts of the world (Europe, South and North America) with a focus on different

study systems (from alpine summits to coastal communities) and a variety of approaches, including manipulative experiments and vegetation surveys. In this editorial, we briefly summarize the six large-scale studies that included variation in climate and bedrock types, the five local-scale studies that considered variation in mesotopography, soil types and snow cover duration, and the four studies that focused on the effects of climate change at very fine scales using manipulative experiments.

2 | OVERVIEW OF STUDIES IN THIS SPECIAL ISSUE

Among large-scale studies assessing the influence of climate conditions, van den Brink et al. (2024) found in Chile that unidirectional climate manipulation experiments (e.g., a warming or drying experiment) not testing for the opposite manipulation (i.e., cooling and wetting, respectively) may not be able to capture the complex nature of biotic responses of plant communities to climate change. Tracking historical microclimatic variation under anthropogenic climate change is challenging due to the paucity of data on long-term past microclimatic measurements. However, Gril et al. (2024) found that the capabilities of plant ecological indicator values (EIVs) to infer microclimate conditions was inconsistent and that refined EIVs tailored for microclimatic variables are needed to capture forest microclimates and reconstruct forest microclimate changes as experienced by understory species under anthropogenic climate change. Similarly, Rumpf et al. (2025) found asymmetric and independent changes in soil and community properties in resurveyed plant communities, following four decades of environmental change in the montane and subalpine grasslands of the Swiss Alps. Joelson et al. (2024) assessed changes in the elevational ranges of temperate mountainous forests and shrublands from the Andes, Argentina, over the last five decades. They found contrasting changes between generalists and shrubland resprouters arising from complex interactions between land-use changes, fire disturbance and climate changes. Using data spanning over two decades from the Swiss Alps, Mayo de la Iglesia et al. (2024) found a

decrease in bryophyte communities but an increase in lichen communities. Finally, Michalet, Delpy et al. (2024) found a decrease and an increase in species richness, in a sunny continental subalpine site from the Alps and a cloudy site on volcanic soils from the Massif Central, respectively.

Among the different studies that investigated the roles of local-scale factors such as mesotopography, soils and snow cover duration, Jiménez-Alfaro et al. (2024) found that the microclimatic variation in topsoil temperature was larger in space than in time at the Picos de Europa (Spain). By using spatial gradients of primary succession at the forefront of four glaciers in the Italian Alps, Khelidj et al. (2024) showed how glacier retreat has heterogeneous impacts on plant functional diversity, with the effects varying depending on traits and duration since glacier retreat. Michalet, Touzard et al. (2024) found an overwhelming effect of decreasing snow cover duration over time, at a subalpine site from the French Alps. In a study from the Sudetes Mountains (Poland), Reczyńska & Świerkosz (2024) showed that rocky plant communities remain very stable over time, in contrast to other community types. Ross et al. (2024) showed a significant halophyte encroachment due to sea-level rise in the Southeast Saline Everglades, Florida (USA).

Finally, among the studies relying on manipulative experiments, Haider et al. (2024) found important changes in the functional characteristics of a highland turf community transplanted to a low-elevation common garden in the German Alps. Warming and drying a *Carex curvula* alpine grassland in the Italian Alps, Forte et al. (2024) found no significant changes in the cover of the most dominant species but an overall decline in chionophilous species. Taber and Mitchell (2024) showed that climate change will have little effect on plant community composition relative to high-severity fire in *Pinus ponderosa* forests from Northern Arizona (USA). Finally, De Pauw et al. (2024) showed how forest fragmentation

near large cities in Europe increases the exposure of understory plant communities to local warming caused by the urban heat island effect.

3 | CONCLUSIONS AND PERSPECTIVES

This Special Issue emphasizes the importance of ecological context dependencies and the relative resistance of plant communities to climate change in the absence of disturbance (e.g., Reczyńska & Świerkosz 2024). Studies in this Special Issue that assessed changes in plant species diversity provided contrasting results depending on the regional and local context as well as the taxonomic group investigated (e.g., De Pauw et al. 2024, Mayo de la Iglesia et al. 2024), with either slight increases or decreases (e.g., Michalet, Delpy et al. 2024) or no significant changes due to contrasting species-group changes in species richness (e.g., Forte et al. 2024). This highlights a consistent lack of strong evidence that climate change has induced a significant general erosion of diversity in terrestrial plant communities (Lenoir 2022), as opposed to animal communities and marine or freshwater systems (Bellwood et al. 2004; Albert et al. 2021). In contrast, most studies in this special issue showed important variation in the functional composition of plant communities in response to climate change (e.g., Khelidj et al. 2024). Climate change induces a functional homogenization (e.g., Jiménez-Alfaro et al. 2024; Ross et al. 2024) and an increase in generalist species (e.g., de Pauw et al. 2024) and of traits associated with competitive ability (e.g., Haider et al. 2024; Michalet et al. 2024) that may have immediate or delayed consequences for plant species richness. This highlights the crucial importance of long-term monitoring studies for assessing climate change consequences on the diversity of terrestrial plant communities. Additionally, several studies in this issue also identify the dominant influence of spatial environmental variation and changes in disturbance regimes over temporal climatic changes (e.g., Jiménez-Alfaro et al. 2024). This suggests that preserving stable ecosystems should be a key component of our climate change mitigation strategies.

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