# Arboretums, common gardens and forest tree resilience

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This manuscript is a preliminary version of a paper now published under the reference:

**Fady, B., Rihm, G. Arboretums, common gardens and forest tree resilience. New Forests (2022). https://doi.org/10.1007/s11056-022-09908-y**

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**Abstract:**

Climate change triggered forest die-back is a huge concern worldwide. Arboretums and common gardens comparing geographic origins within species can provide a large body of valuable information and material usable to increase their resilience. Common gardens have been foundational in demonstrating the existence of genetic diversity, local adaptation and phenotypic plasticity. They have also been instrumental for forest management and policy, *e.g.* for guiding seed transfer rules and their marketing. While the current generation of common gardens has seen a renewed interest for developing process-based niche models or genome-trait-environment association studies, they are too limited in the number of species, provenances and habitats they sample in the context of climate change and novel bioeconomy focus. A new generation of common gardens is now needed.

**Short abstract:**

Common gardens are needed more than ever for developing climate-smart forestry

**Keywords:**

Breeding; Climate change; Genetic diversity; Local adaptation; Natural selection; Niche modeling.

**Acknowledgements:**

This research was part of the GenTree project which has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement # 676876.

**Main Text:**

In the December 2021 issue 6572 of Science, Gabriel Popkin presents an all too true story about forest dieback. Climate change triggered forest dieback is a huge concern worldwide, disrupting biodiversity and long-established businesses and jeopardizing the potential of forests for mitigating greenhouse gas emissions. The author suggests that an arboretum established in the 1800s could offer "a rare opportunity to assess how the mature trees are handling climate change".

A single arboretum alone, cannot provide even hints on resilience. Many are needed, testing varied environments. And not just arboretums comparing species, but also common gardens comparing geographic origins within species, so called provenances, which often demonstrate that diversity within-species is as large as that among species. Europe is fortunate enough to hold a wealth of arboretums and common gardens, some indeed dating back to the 19th century (Langlet 1971).

Common gardens have demonstrated the existence of genetic diversity, local adaptation and phenotypic plasticity. Replicated across well-characterized environments, they provide much-needed reliable information for forest management (Fady et al. 2020). They have been instrumental for policy, guiding seed transfer rules across regions and have served as the basis for Directive 1999/105/EC on Forest Reproductive Material, which has governed the marketing of seeds in the European Union since 1999.

Considered old-fashioned and outdated in the omics era, funding for common garden maintenance and monitoring decreased regularly during the past three decades. Scientific interest for common gardens has remained intact, though, *e.g.* for developing process-based niche models or genome-trait-environment association studies (Martínez-Sancho et al. 2021; Prasad and Leites 2021). Forest owners and managers are aware of the importance of selecting genetically appropriate material for plantation success (Vinceti et al. 2020). Yet, with climate change and a novel bioeconomy focus, current data and estimations show that long-established common gardens are limited to too few species and provenances, and cover too few habitats (Fady et al. 2020; GEN4X 2021). New types of common gardens are needed for testing material from currently underused native and exotic species (Figure 1). They are also needed for testing a wider range of populations from commonly used native and exotic species, in a wider range of habitats, including currently marginal habitats likely to become widespread in our climate change future (Figure 2). Early stage tests in nurseries offer the possibility of repeated, comparatively inexpensive evaluations of the germination and seedling niches under environments of varying severity. At the other end of the life cycle, compiled data from wider-scale forestry operations that have used identified material repeatedly could be harnessed to "assess how the mature trees are handling climate change" (Popkin 2021). Funding for these new types of common gardens and data archiving is needed both for better understanding the limits to adaptation and for expanding options available for forest managers to increase forest resilience.

## References and Notes


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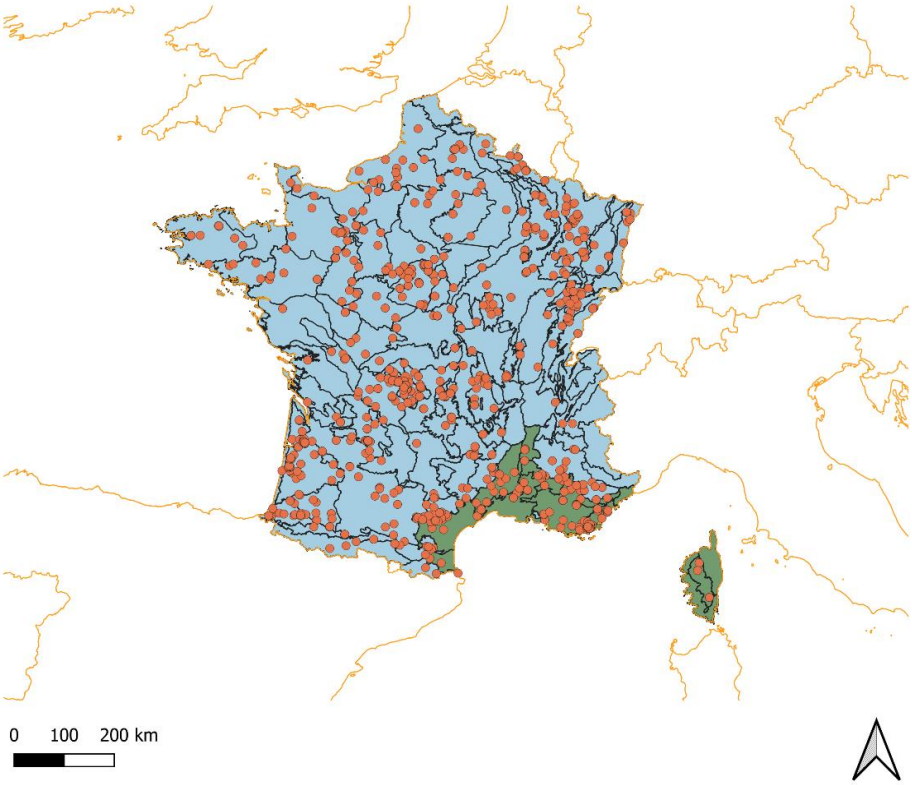
Figure 1: A partial view of the Saint Lambert (southern France) common garden which tests different provenances of *Abies cephalonica* Loud., a rarely used exotic Mediterranean fir of potential interest for plantation and restoration in France and other temperate countries with climate change related die-back. The seed crop from common gardens can also be used to provide new genetic material having passed a first step of selection under climate conditions different from those of the original habitat of the provenances.

Figure 2: distribution of the 1208 forest tree common gardens of the French GEN4X network (panel A, common gardens appear as orange dots). While common gardens are planted in almost all ecological regions of the French territory (panel A, ecological regions are delineated by black lines), Mediterranean tree species, of potential value under changing environmental conditions towards a drier and hotter climate in France, are tested in only 185 sites, in too few habitats outside of the Mediterranean bioclimate region (panel B, common gardens containing at least one Mediterranean tree species (*sensu* Médail et al. 2019) appear as orange dots and the part of France under Mediterranean climate appears in green).

**A**



**B**