

Genetic diversity and ecological niche assessment of silver fir (*Abies alba* Mill.) conservation resources in the Sudetes

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The silver fir (*Abies alba* Mill.) restoration program in the Sudetes (S-W Poland) was initiated 28 years ago following a dramatic decline of the species caused by industrial pollution and inappropriate forest management. Initially, the program focused on safeguarding remnant genetic resources through ex-situ collections. This resulted in the selection of 1,839 conservation trees, which served as the basis for establishing conservation clonal seed orchards (CCSOs). These orchards were designed to fulfil two primary functions: to act as a reservoir of genetic diversity and to provide high-quality forest reproductive material (FRM) for ongoing restoration efforts. Despite nearly three decades of implementation, a comprehensive evaluation of whether these CCSOs effectively capture the genetic and ecological variability of the native Sudeten populations has not been conducted.

In this study, we provide a comprehensive assessment of the restoration strategy's effectiveness. We investigated the genetic and ecological representativeness of 11 CCSOs using nuclear microsatellite markers (nSSRs) and ecological niche comparison. Our analysis identified a subtle east–west genetic differentiation across the Sudetes. This spatial structure is a crucial finding for forestry practice, as it provides a clear scientific basis for defining seed zones and guiding FRM deployment to minimize the risk of maladaptation. Notably, the genetic diversity within the CCSOs was found to be lower than that of natural populations. This likely reflects a genetic bottleneck in the Sudeten gene pool, shaped by a complex historical legacy of population fragmentation and decline.

On the ecological side, niche overlap analysis demonstrated that the current CCSO network adequately represents the species' ecological diversity within the region. Furthermore, climate change projections suggest that while the current geographic genetic structure might diminish over time, some expansion of suitable habitats for silver fir is possible. These findings offer strategic guidance for the next phases of the restoration program. Future restoration efforts should therefore prioritize adaptive genetic variation to enhance the long-term resilience of silver fir under ongoing climate change.

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