Can Silviculture Foster Forest Genetic Evolution? A Demo-Genetic Modelling Approach Accounting for Within-Stand Individual Variability Estimated from ICP Forest Data

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A modelling approach

Our knowledge of the rate at which forests can naturally evolve towards adaptation and the extent to which silviculture can influence this natural adaptation remains limited.

To address these questions, we developed an individual-based demo-genetic model (DG-ABM): *Luberon2* (**Fig. 1**). The model integrates forest dynamics processes driving survival and mating success, including tree growth, competition, disturbances and regeneration, with genetic diversity in quantitative traits related to these processes.

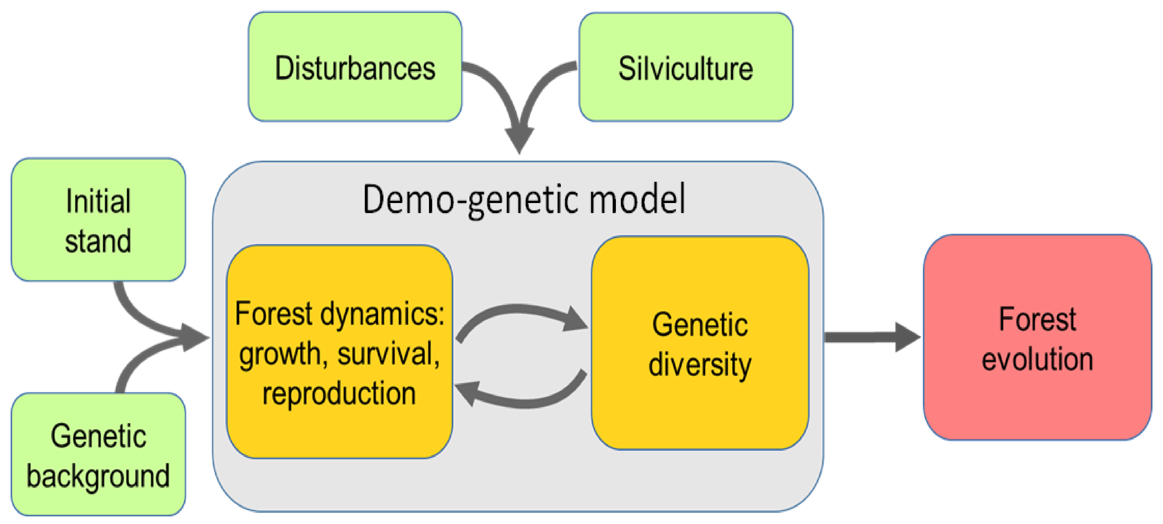

***Figure 1.** Main components of the Luberon2 demo-genetic individual based model: inputs (green boxes) including initial stand description, genetic background, disturbance regimes and silvicultural scenarios; demo-genetic processes (grey box) resulting from the coupling of a forest dynamics model with a genetic diversity and inheritance model (orange boxes); outputs (red box) including stand- and tree-level dynamic variables regarding the demography, performances and genetic diversity.*

The adaptive potential of forest tree populations heavily relies on their intra-population genetic diversity. Therefore, meaningful predictions require careful consideration of plausible values for genetic parameters for the studied quantitative traits.

To go further on DG-ABMs (Lamarins et al., 2022)

Within-Stand Individual Variability

We focused on two fitness-related traits: vigour, determining growth potential, and growth sensitivity to drought stress. We used dendrochronological data collected within stands of the French RENECOFOR network (ICP Forests Level II network) to estimate the vigour and sensitivity of individual trees (**Fig. 2,3**).

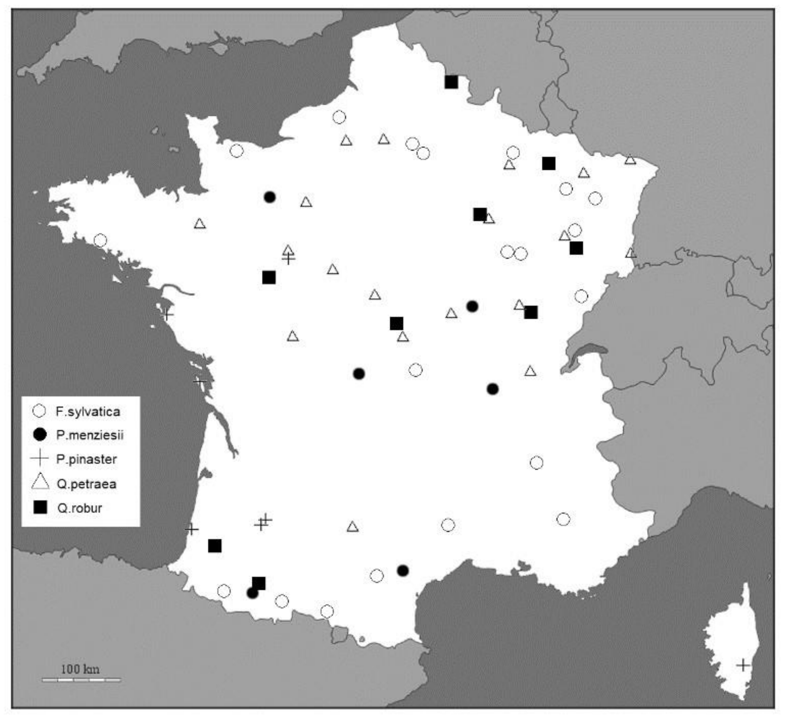

***Figure 2.** Geographical position of the 61 forest stands (5 species) studied. The plots are part of the RENECOFOR network (ICP Forests Level II network).*

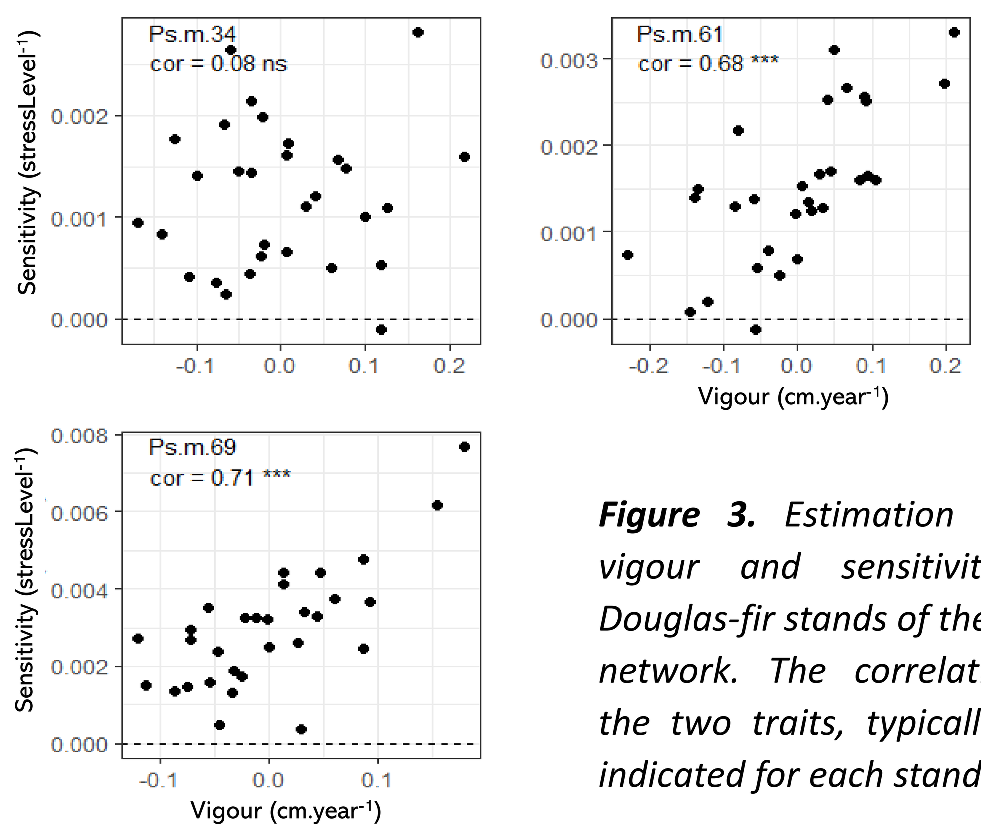

***Figure 3.** Estimation of individual vigour and sensitivity in three Douglas-fir stands of the RENECOFOR network. The correlation between the two traits, typically positive, is indicated for each stand.*

Using realistic heritability assumptions, we inferred genetic diversity from these empirical estimates. For reference, we considered the case where the two traits are not correlated.

Link to the article (Fririon et al., 2023)

Evolutionary impacts of non-selective thinning

Using *Luberon2* to simulate non-selective silviculture over four non-overlapping generations of trees under drought-free conditions, we characterized and quantified the effect of thinning frequency and intensity on viability selection through competition and fecundity selection.

The predicted evolutionary rates from *Luberon2* aligned with observed microevolutionary rates documented for wild plant and animal populations, providing double validation of the model and the genetic diversity estimated from ICP Forest Data.

The thinning regimes had a drastic long-term effect on the evolutionary rate of vigour over generations, potentially reaching 84% reduction, depending on management intensity (**Fig. 4**).

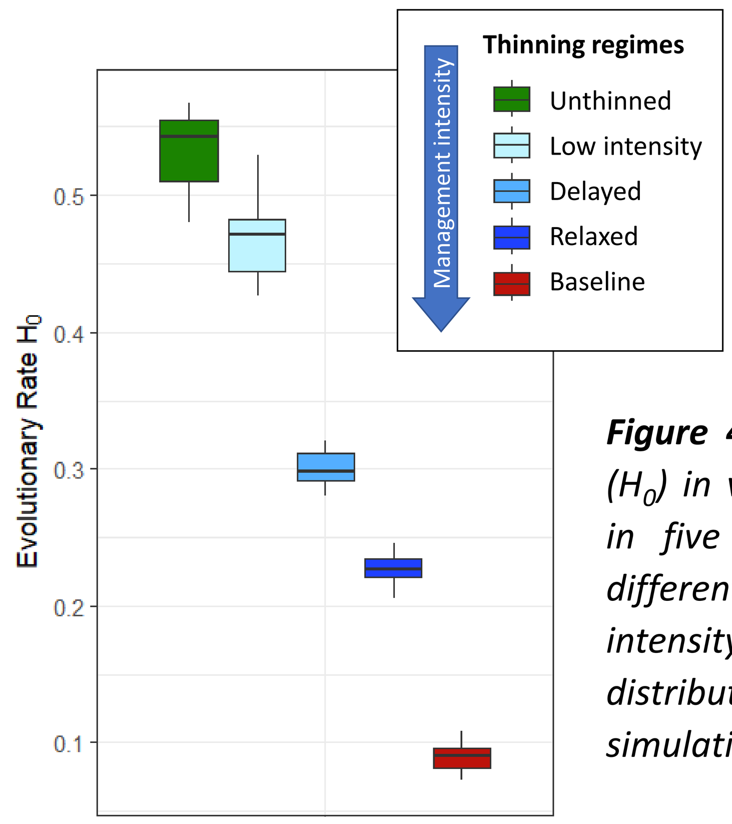

***Figure 4.** Average evolutionary rate (H_0) in vigour after four generations in five silvicultural scenarios with different levels of management intensity. The boxplots illustrate the distribution of values over 10 simulation replicates in each case.*

In conclusion, the evolutionary consequences of management do not only result from specific anthropogenic selection, not considered here, but globally from the partial substitution of human interventions for natural evolutionary processes.

Link to the article (Godineau, Fririon et al., 2023)

Silviculture to foster genetic adaptation

Using *Luberon2* to simulate selective silviculture over three non-overlapping generations of trees under drought conditions, we characterized and quantified the effect of four different "thinning from below" scenarios on the level of drought stress and on the selection of resistant genotypes.

Compared to no thinning, introducing anthropogenic selection in the same direction of natural selection increased the genetic gain in vigour and less sensitivity by up to 30% (**Fig. 5**).

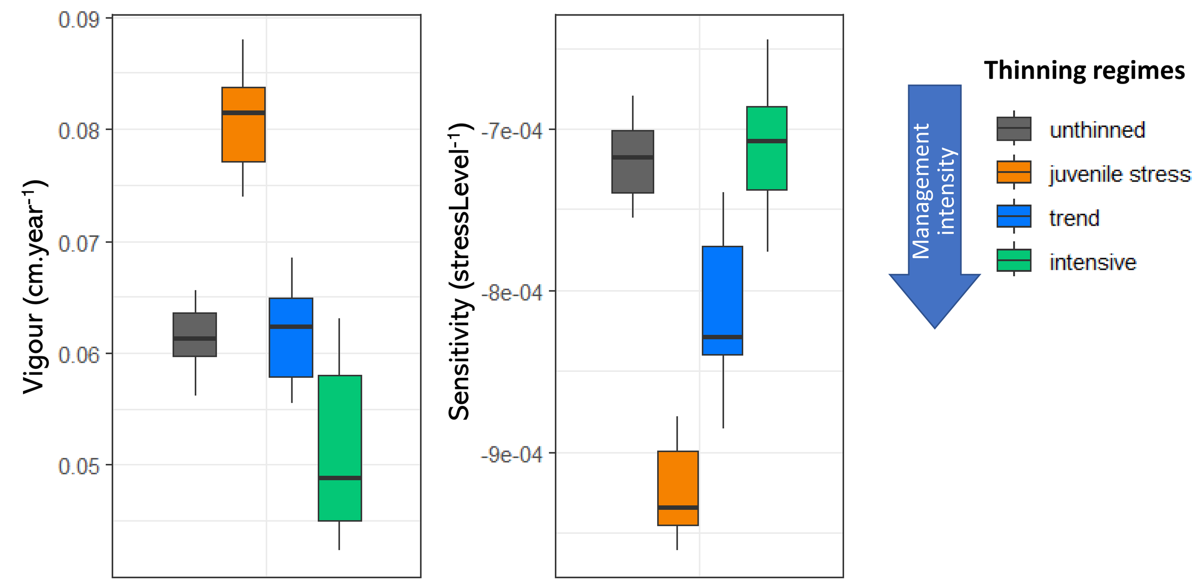

***Figure 5.** Genetic gain in vigour and less sensitivity after three generations in four different "thinning from below" silvicultural scenarios. The boxplots illustrate the distribution of values over 10 simulation replicates in each case.*

A scenario designed to foster genetic evolution by avoiding early and non-selective thinnings (*juvenile stress scenario*), thereby promoting both natural and anthropogenic selection successively, resulted in better stand performances than a scenario focused solely on drought stress reduction trough density reduction (*intensive scenario*), while maintaining long-term evolvability.

In conclusion, integrating eco-evolutionary considerations into adaptive management thinking could be useful in balancing drought stress mitigation and genetic adaptation.

Fririon et al., submitted