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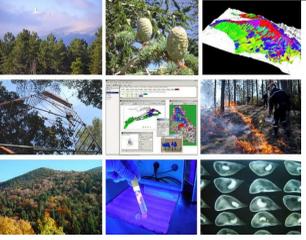
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Local adaptation to climatic gradients: application of a Physio-Demo-Genetics simulation model to European Beech populations



Écologie des Forêts Méditerranéennes INRA Avignon



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Predicting the response of trees, the keystone elements of forests, to ongoing climate change is a critical issue.

Forests are the most important terrestrial ecosystems, providing 75% of the terrestrial biomass and several ecosystem services. Climate change has already taken its toll on forests and the future of forests is unforeseen. Trees are key drivers of ecosystem processes and stability in forests, directly sustaining diverse plant and animal communities, and mediating nutrient and water ecological cycles. Over the past two decades, extensive forest tree mortality triggered by droughts and extreme climatic conditions has been documented all around the world. Nonetheless, tree populations response to climate is still not sufficiently well understood to be able to make reliable predictions for the future. Besides migration, Forests response to climate will be determined by a combination of factors such as phenotypic plasticity and adaptive capacity that are largely unknown for many tree species.

Here we develop a new simulation approach to investigate the evolutionary potential of forest trees to adapt to ongoing climate change. We build an individual based model that accounts explicitly for the effect of individual genetic variability and climate on the variation of tree physiological traits. Selection is acting on functional traits involved in response to climate, such as the timing of budburst (TBB). We illustrate how this tool can be used to investigate the rate of evolutionary change in tree populations evolving for few generations along an environmental gradient.

The physio-demo-genetic model

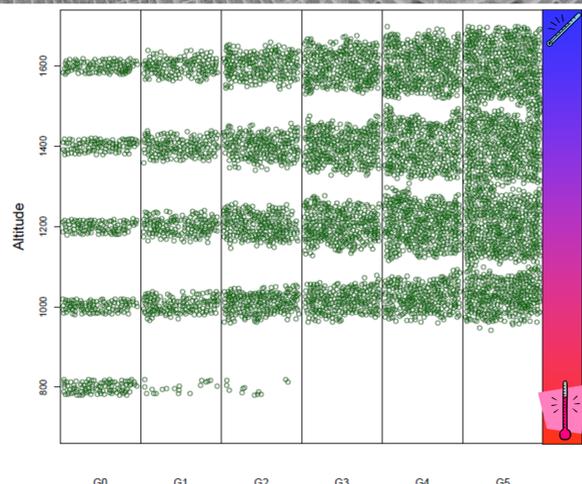
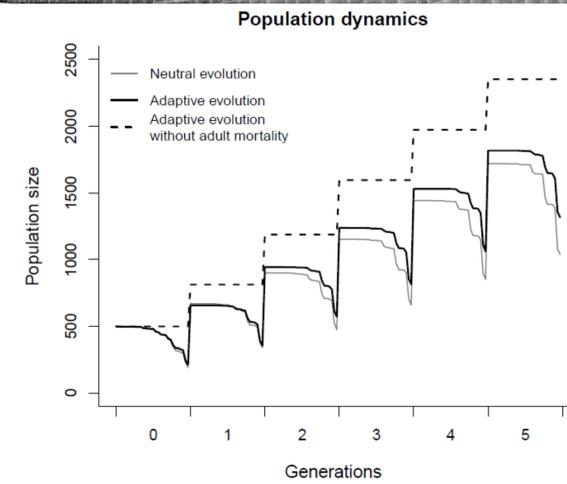
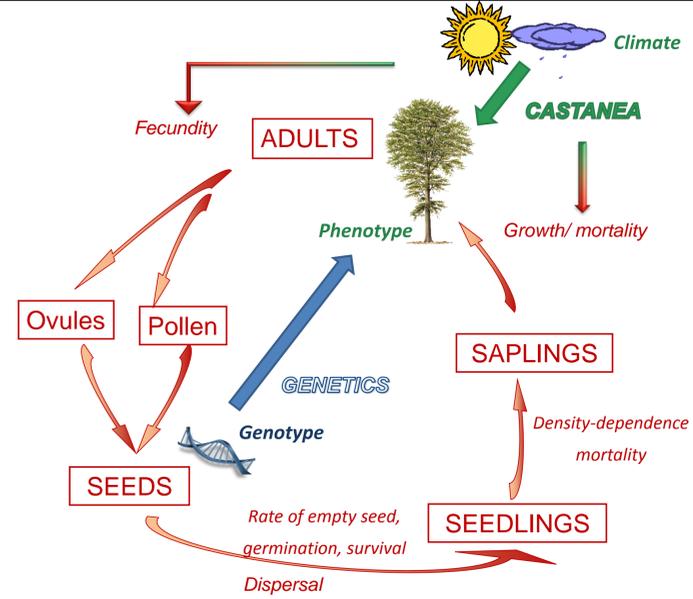
We propose a new Physiological-Demographic-Genetic (PDG) coupling:

1) an **eco-physiological and physical module (CASTANEA)** simulating carbohydrate and water fluxes at tree-level based on daily climate observations (real or simulated).

2) a **population demographic module** converting carbohydrate reserves into demographic rates for adult tree (growth, mortality and seed production) and simulating ecological processes across the life cycle (including seed and pollen dispersal, germination success, density-dependent mortality of seedlings).

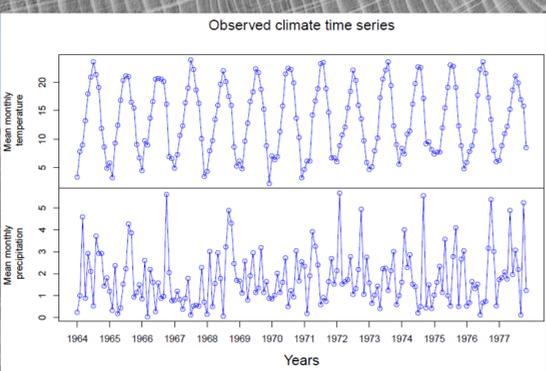
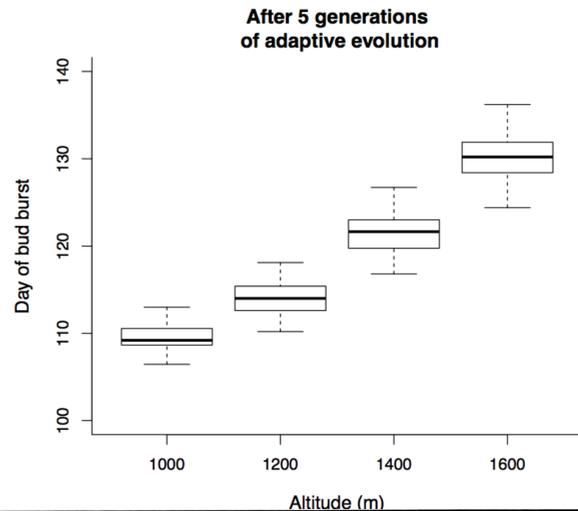
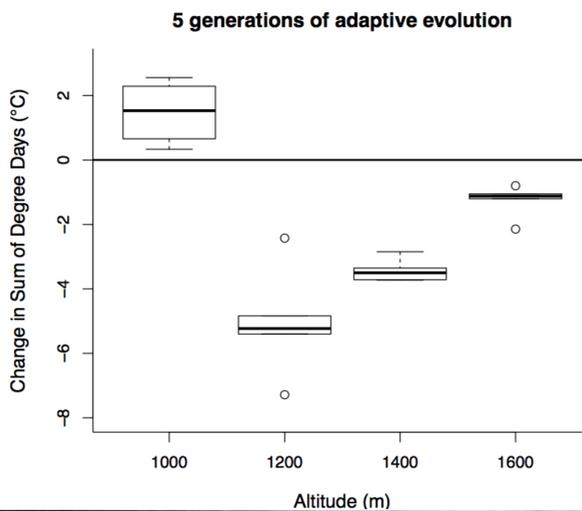
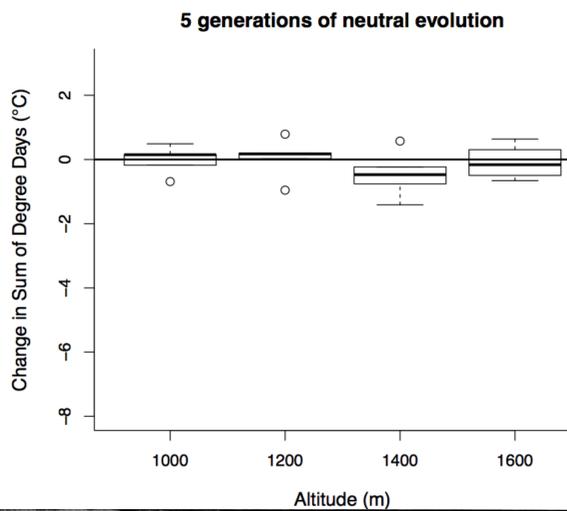
3) a **quantitative genetic module (GENETICS)** relating the genotype at quantitative trait loci (QTLs) to the phenotype of one or more functional traits, accounting for environmental effect. Individual fitness is an output of the model, calculated as the life time reproductive success resulting from a combination of functional traits.

Here we consider only the **Timing of Budburst (TBB) = f (Sum of degree days, Temperature)**



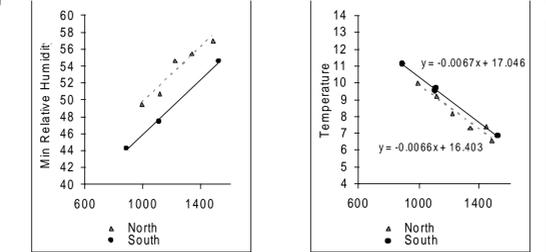
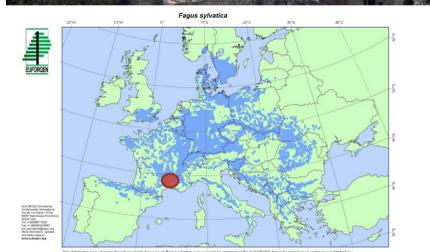
Results

- 1) Five generations are enough for natural selection to result in genetic differentiation for the timing of budburst (TBB)
- 2) Phenotypic variation of TBB due to plasticity (20 days from 1000 to 1600 m) is higher than due to genetic adaptation (2 days from 1000 to 1200m).
- 3) In the presence of genetic adaptation population size is higher than without adaptation.
- 4) The patterns of phenotypic (TBB) and genotypic (Sum of degree days) variation across altitudes are not monotonic.

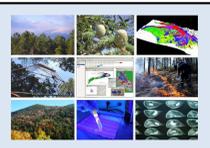


Case study
We parameterized the PDG model on a European beech (*Fagus sylvatica*) population colonising an altitudinal in South East of France on Mount Ventoux. Among the various traits contributing to fitness along the altitudinal gradient, we focussed on the timing of budburst (TBB) because:

- 1) TBB is a life history trait known to affect individual fitness in *F. sylvatica*: an earlier budburst extends the time during which photosynthesis occurs but it also increases the risk of late frosts.
- 2) TBB exhibits genetic differentiation across altitude in *F. sylvatica*: in common gardens trees from higher altitude budburst earlier



Project links



LINKTREE & TIPTREE projects <http://capsis.cirad.fr/> <http://www4.paca.inra.fr>
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