ADAPTIVE MANAGEMENT OF FORESTS AND THEIR GENETIC RESOURCES IN THE FACE OF CLIMATE CHANGE

PROJECT BRIEF

FORGER

TOWARDS THE SUSTAINABLE MANAGEMENT OF FOREST GENETIC RESOURCES IN EUROPE

Decline in health and growth of forests induced by climate change has been reported in different parts of the world. In Europe, low-elevation, drought-prone forests of south and southeastern Europe are particularly exposed to pressures from climate change. In these regions, forests have a significant economic value, and play an important role in the regulation of the hydrological cycle and preservation of biodiversity. A key attribute for tree species to withstand environmental changes is the level of their intraspecific diversity, as that allows adaptation to changes. The conservation and sustainable use of forest genetic diversity have implications with regard to the maintenance of healthy forest ecosystems in the face of environmental changes. Scientists within the EU-funded project FORGER endeavoured to determine the extent to which four widespread forest tree species in Europe may be affected by climatic change, by making use of field trials and modelling tools.

In this brief, recommendations are provided to decision makers on measures to improve the adaptive management of forests and their genetic resources, based on insights on expected responses to future climatic changes in four model tree species studied.

Abies alba at the southern range limit (French Alps) shows widespread signs of mortality after the extreme drought of 2003 (photo B. Fady, INRA).

RESULTS FROM FORGER RESEARCH BASED ON FIELD AND MODELLING STUDIES

Whether adaptability of a forest tree species to climate is narrow and site-specific, or it covers a wide range of conditions, is of primary importance for adaptive forest management.
A key question the FORGER project addressed is *how much capacity to withstand ongoing and projected climatic changes ('buffering capacity') is available in tree species that dominate European forests?* FORGER research focused on developing projections of expected responses to climate change in four tree species (Norway spruce, Scots pine, European beech and sessile oak), based on results from existing long-term field trials and modelling studies.

FIELD STUDIES

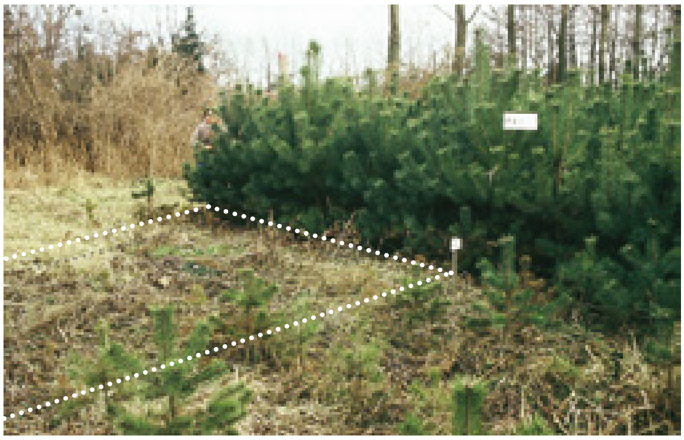
A common practice in forest genetic studies is the planting of trees of different origin in common sites to assess the performance of tree populations across a range of conditions ('provenance trials'). Trees planted at sites with a climate substantially different from their origin are exposed to changes in their environmental conditions that may mimic the effect of climatic changes. Based on the analysis of the performance of tree populations in these trials, FORGER developed projections of future responses of trees to climatic changes. It also tried to determine the species-specific extreme climatic conditions beyond which adaptive management would not be effective. The analysis of field studies allowed the assessment of optimal environmental conditions at species level and also for different populations within the same species, by identifying sites where maximum growth and vitality were recorded.

The following general patterns, common to all four tree species analysed, were observed:

- A significant part of the differentiation between provenances of a species is linked to climatic conditions at origin and is likely the result of climatic selection.
- The asymmetric shape of transfer functions (i.e. maxima of performance shifted away from local origins) indicates that local genetic resources are not necessarily superior.
- Limits of tolerance to climatic extremes are genetically determined.
- When exposed to extreme droughts, vitality of populations declines, particularly at the xeric limit (the low-elevation, low-latitude limit of distribution where moisture supply is the main constraining factor) and may lead to mass mortality. Populations at the lower, xeric limits of the species' distribution are thus more exposed to climate change impacts.

MODELLING STUDIES

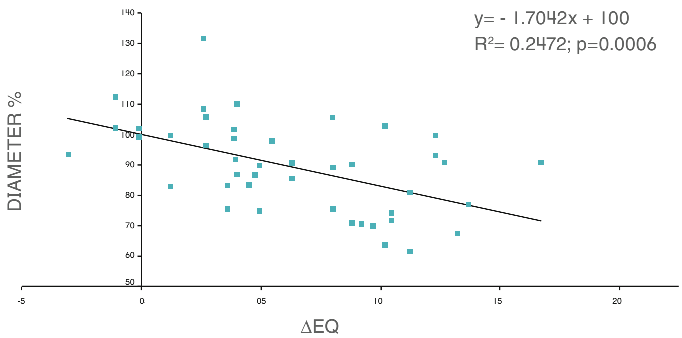
The modelling of tree growth, forest dynamics and forest ecosystem functioning carried out within FORGER included genetic processes. The new model developed enables a projection of the adaptive response and evolution of genetic diversity of forest ecosystems exposed to climate change, expressed through growth and survival under changing environmental conditions. Moreover, the model allows to assess whether the adaptive responses to climate change may be enhanced by particular management practices. The results presented below derive from a modelling study on European beech. The response patterns are true also for the other species, but differ in some details (e.g., differences in drought tolerance and the advancement of bud burst with increasing temperature).



Above: Growth and survival of trees depends on how their climate adaptedness matches actual conditions. In this test site in Hungary, Scots pine from East Siberia, Turkey and Hungary were planted. Due to warmer climate, no trees from Siberia survived (marked plot), the Turkish trees were maladapted (foreground), whereas the Hungarian trees thrived (back right) (photo C. Mátyás).

Above, on the left: Oaks in the Bercé forest in France. Compliance with traditional silvicultural standards for two centuries may not guarantee adaptiveness to projected extreme climate events (photo C. Mátyás).

Figure 1: New climate stress causes growth decline and even mortality. Data of a test in Hungary shows that mean diameter of beech provenances declined with increasing severity of droughts.
Legend: Diameter % = performance in percents of experimental mean; ΔEQ = change of Ellenberg's drought index (Horváth – Mátyás 2014).



Above: Difference in growth of two provenances of 10 year old beech in a continental environment (test site Bucsuta, Hungary). Left: local provenance Magyaregregy (South Hungary), aver. height 3.13 m; right: Atlantic provenance Soignes (Belgium), aver. height 2.62 m (photo C. Mátyás).

Figure 2:

Estimated climatic threats to beech for the next decades, based on projections for moderate climate change. (design: Mátyás – Rasztovits, unpublished).

- Current occurrence
- Threatened in the next 3-4 decades
- Threatened in 1-2 decades
- Presently endangered occurrences
- Approximate northern limit of favourable climate for beech in 3-4 decade

FINAL CONSIDERATIONS

- Populations can to some extent genetically adapt to climate change within 2–3 rotations, though the rate of adaptation is possibly not fast enough to balance the speed of the projected climate change.
- Beside growth, traits that show an adaptive response to climate stress include among others the timing of bud burst and water use efficiency.
- Regular forest management practices, such as sheltercut or group selection system, enhance the rate of adaptation by shortening the rotation period between regeneration and harvest.
- With a 'no-management' approach, genetic diversity is maintained better than with an active management systems. However, the rate of adaptive response to climate change in the former is lower than what is achieved through an active forest management. This is because fewer selection events occur in the no-management system per unit of time, compared to an active management system.
- In populations at the xeric limit, a strong selection pressure, manifested in high mortality in both adult individuals and regeneration, leads to a decline of genetic diversity; however the loss of diversity, particularly evident where climatic conditions are more extreme, at the southern edge of the range of the modelled species, is partly mitigated by the long-distance gene flow, that enables inflow of genetic diversity from neighbouring areas.
- At the northern edge, where growing conditions are expected to improve, the model indicates that external gene flow may reduce the rate of adaptive response, introducing non-adaptive alleles.

KEY RECOMMENDATIONS FOR ADAPTIVE FOREST MANAGEMENT

The project results lead to the following recommendations with regard to management of forest genetic resources to sustain adaptation to climate change.

Current national seed zoning regulations affecting the use of FRM should be reviewed, in light of more recent findings.

- The stable performance of provenances across environmental conditions is of primary importance in the selection of FRM and needs more attention. The selection of provenances should, however, be based also on survival and tolerance to climate extremes, pests and diseases, not on juvenile growth alone.
- Assisted migration is a measure that could help sustaining healthy and productive forests. Some areas though should be left to evolve without such an active management measure, to allow natural selection to operate.
- Provenance trials provide a unique insight to guide management. However, existing provenance trials were not designed to study the effects of climate change, therefore new trials should be established, especially designed to further investigate the effects of climate change on tree species and the use of genetic resources to increase their adaptation.

Professional judgement and local experience are still essential elements in guiding the implementations of the recommendations above, which are based on a combination of findings from long-term field trials, projections of future climatic conditions and modelled responses to these changes.

ANSWERS TO KEY QUESTIONS FOR MANAGEMENT

How will productivity respond to expected climatic warming?

In principle, elongation of the vegetation period may increase productivity. However, populations experiencing warmer (and drier) climatic conditions, react with declining growth and vitality. By approaching the genetically defined tolerance limit for dry conditions, the genetic potential for adaptability fades and mortality increases.

Is there a role for FRM in supporting adaptation of forest tree species to climate change?

Considerations on the use of FRM to foster adaptation of a tree species to climate change depend on the knowledge of whether a particular tree population has sufficient genetic diversity to cope with climatic changes or needs support from active management of FRM.

Present EU regulations on the use of FRM do not mention assisted migration as a measure to sustain future genetic adaptation. Considering that climate change will be a challenge also in future and that it will affect also the next generation of forests, the proper selection of FRM is a crucial issue.

Is local FRM better than FRM introduced through assisted migration?

A high within-population genetic variation observed in all the tree species analysed suggests a high potential of adjust to changing climate conditions in areas where species grow within optimal conditions. In regions nearer to the limits of species distribution, adaptive potential may decline due to strong climatic pressures.

Superior or equal performances of non-autochthonous populations are frequently observed in provenance tests of various species. This may be explained by the simultaneous action of genetic adaptation, gene flow and other genetic effects. This observation indicates the availability of a wider range of options in the choice of appropriate FRM, including use of FRM introduced through assisted migration. It is however important to track the origin of the FRM used.

What traits should be considered in the choice of FRM?

Besides growth and tolerance of biotic and abiotic pressures, stability of performance (i.e. reliability across a wide range of site conditions) should be an important trait for choosing FRM in the face of climate change. Significant within-species differences in performance and higher sensitivity to changing macroclimatic conditions were found in Norway spruce and Scots pine than in beech and sessile oak. In the field tests analyzed within FORGER, the various provenances of beech and sessile oak displayed higher stability and less variation in growth.

This brief presents recommendations that are based on the findings of the final report of the project to be published in 2016.

Reference to the document:
Climate change affects forest genetic resources: consequences for adaptive management

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