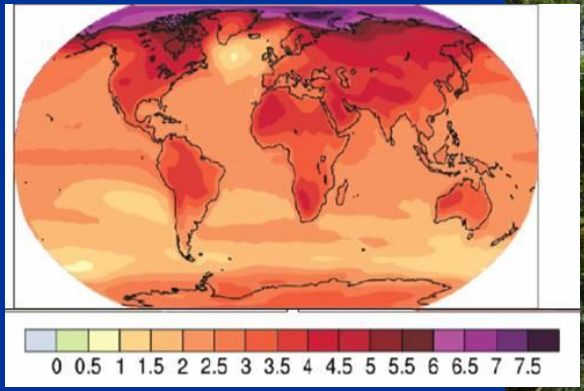
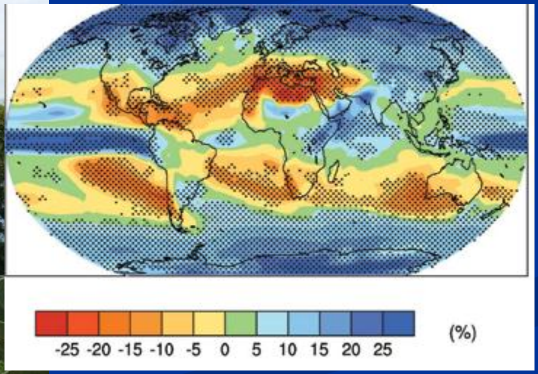
Climate change and forest genetic resources (FGR): state of knowledge, risks and opportunities

Bruno Fady
INRA – URFM, Ecologie des Forêts Méditerranéennes, Avignon

Judy Loo, Ian Dawson, Barbara Vinceti and Giulia Baldinelli
Bioversity International, Rome, Italy
World Agroforestry Centre (ICRAF), Nairobi, Kenya



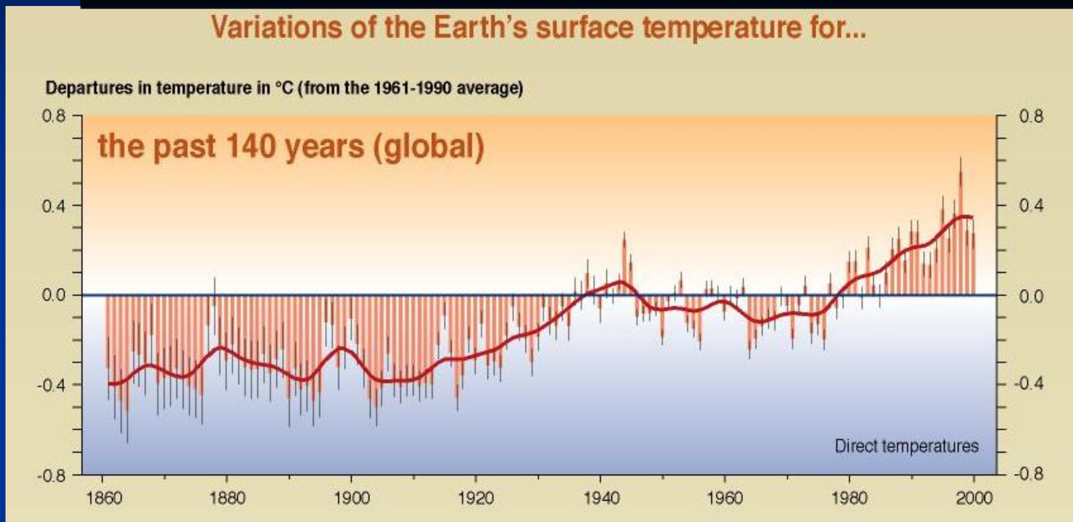


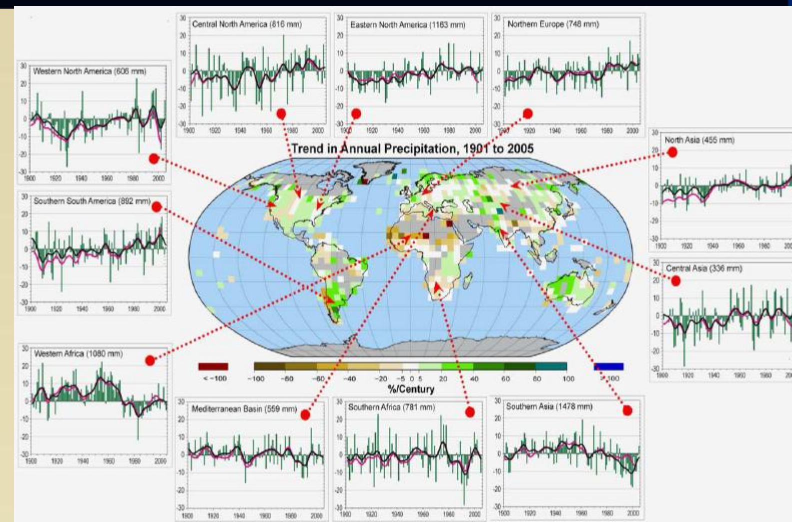
Tours 2012:
Faire face au changement climatique :
la contribution de la science forestière

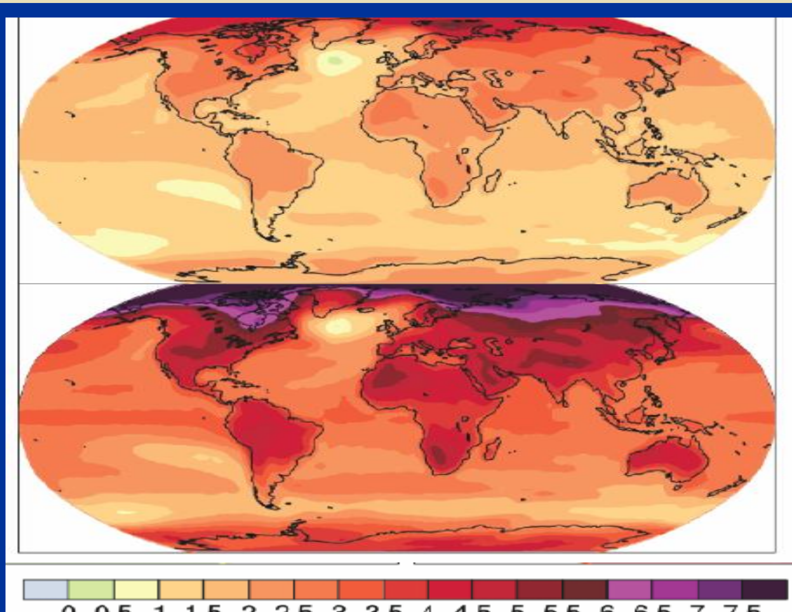
FAO SoW FGR 2013

Bioversity International
World Agroforestry Centre
INRA

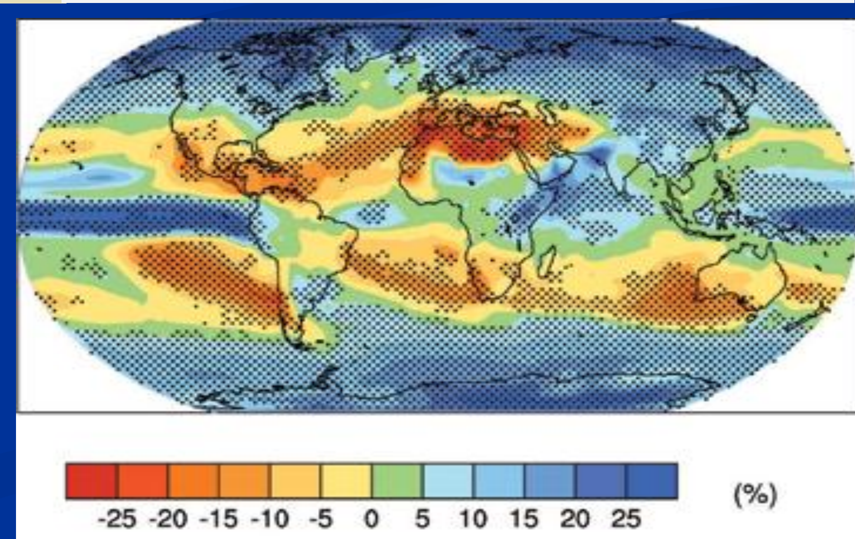
Climate change is here and now! It has happened and is predicted to continue to do so.





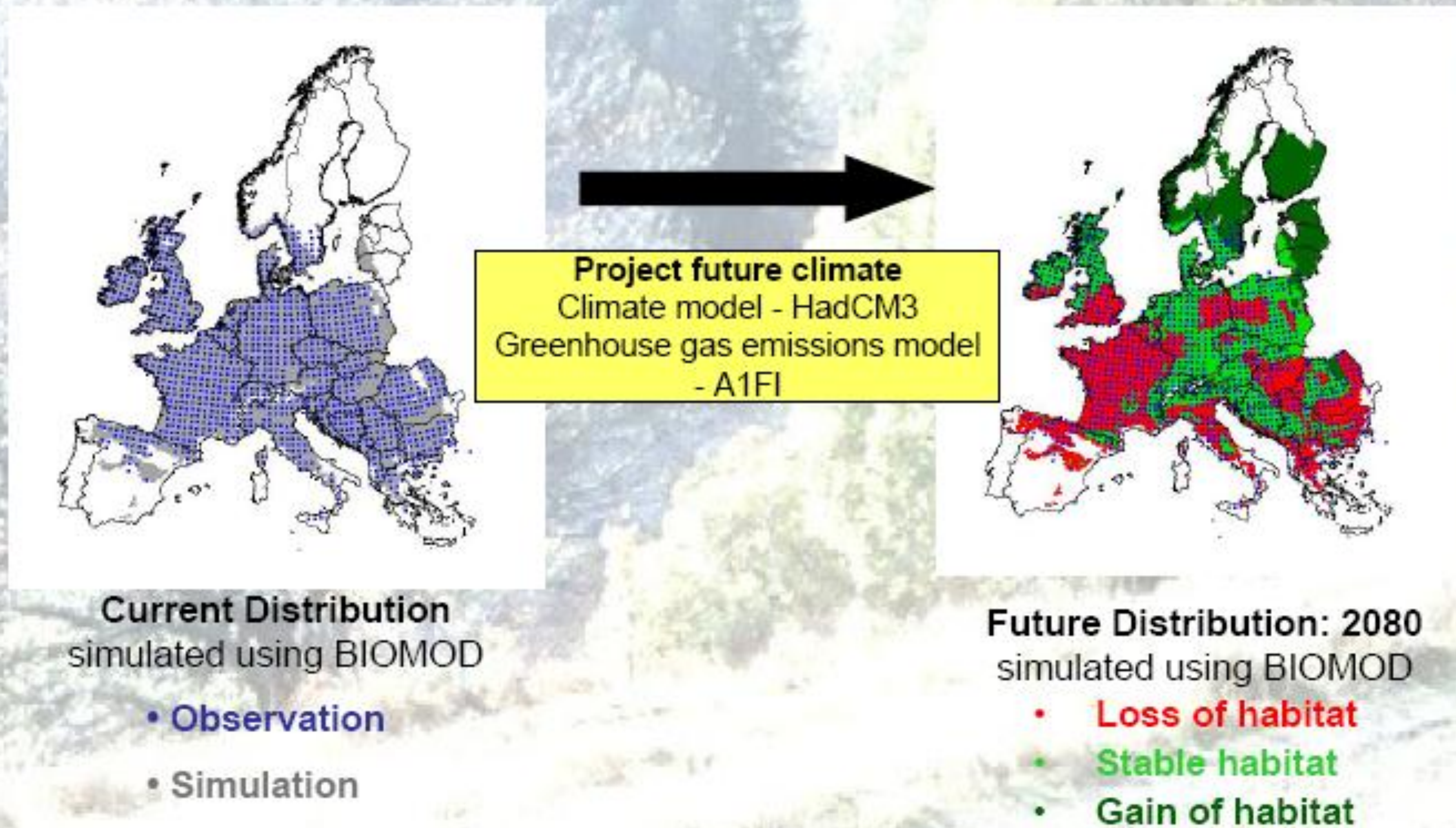


http://www.ipcc.ch/graphics



Bioversity International
World Agroforestry Centre
INRA

Climate change will modify the location of suitable bioclimates for tree species



Quercus petraea, Thuiller GCB 2003, Thuiller et al. PNAS 2005

What are Forest Genetic Resources (FGR)?

Species are not homogeneous entities, they are genetically diverse

FGR: Genetic variation in forest trees, of potential or present benefit to humans (FAO, 1989).
=> From species to populations and individuals

Opportunities offered by FGR for trees to cope with climate change

Genetic variation plays an important role in responding to global challenges. Tree species (mostly undomesticated, with high genetic diversity) have 3 mechanism for responding to climate change:

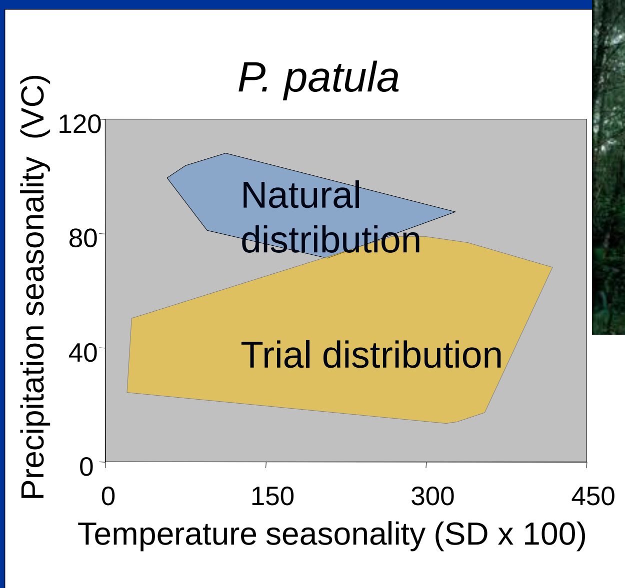
- **Phenotypic plasticity / acclimatization** (trees will continue to survive, grow and reproduce locally because their biological requirements are flexible) – individual (to population) level

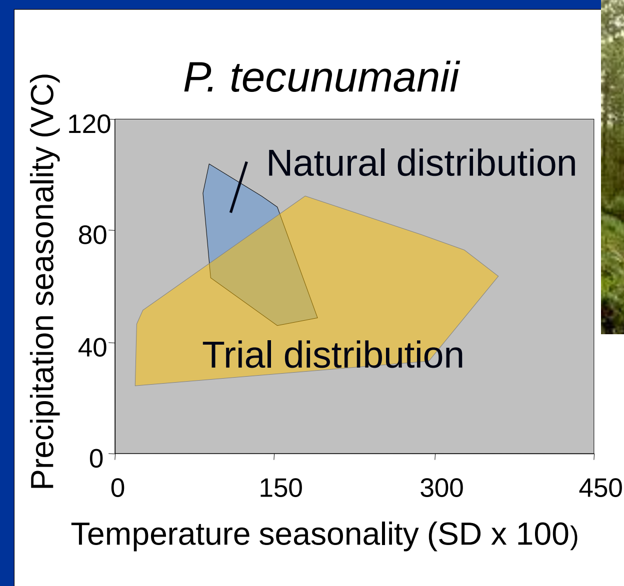
- **Adaptation** (selection of the best fitted progeny) – population level

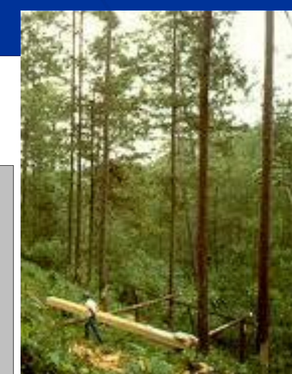
- **Migration** through seed and pollen dispersal (regeneration under friendlier environments after long distance dispersal or hybridization) – population and species levels

Phenotypic plasticity: current knowledge

Trees can survive and grow outside their natural distributions. *Pinus patula* and *P. tecunumanii*: environmental conditions of natural distributions and worldwide provenance trial sites







van Zonneveld et al. (2009) *Forest Ecology and Management*

Bioversity International | World Agroforestry Centre | INRA

Phenotypic plasticity: current knowledge

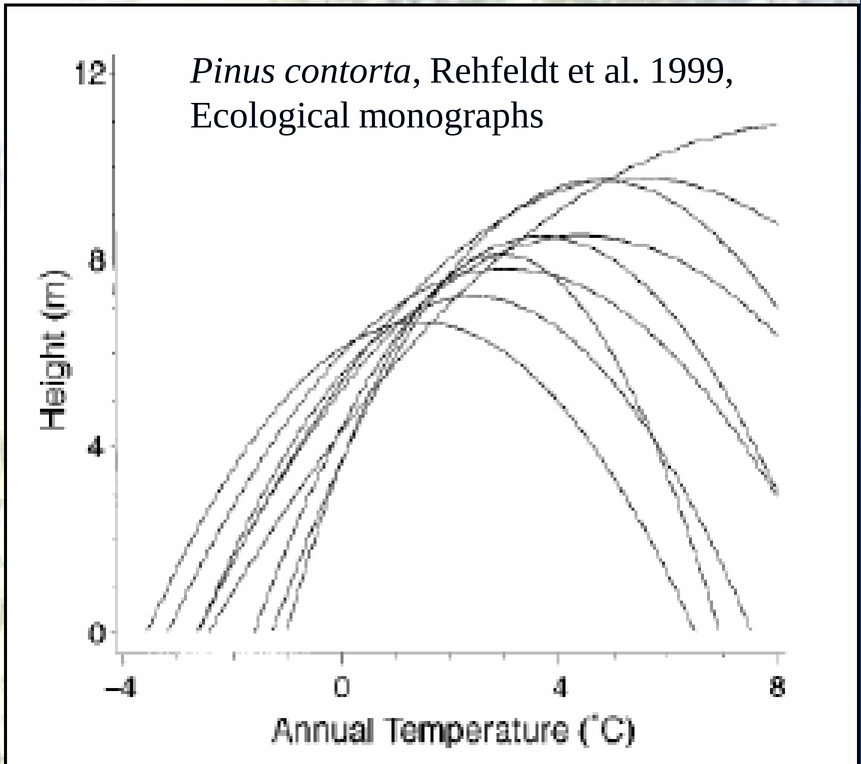


FIG. 8. Response functions using mean annual temperature as a predictor of height for nine populations that represent a variety of responses for ssp. *latifolia.*

Phenotypic plasticity under increasing temperature and drought: yes but… **up to a certain point!!**

Phenotypic plasticity:
Gaps in knowledge and priorities for research

An example of knowledge gap for phenotypic plasticity: epigenetics.

Epigenetic effects:
heritable changes in phenotype that are the result of the modification of DNA expression but not sequence.

Norway spruce can adjust its bud phenology over a single generation after transfer, by a kind of long-term memory of temperature sum and (probably) photoperiod from the time of its embryo development.

(see review by Johnsen et al. 2009).

Phenotypic plasticity: Gaps in knowledge and priorities for research

- Underlying genetic basis of phenotypic plasticity (epigenetics)?
- How flexible are local / indigenous varieties / clones under climate change? Long term monitoring of phenotypic plasticity at individual level in pilot forests (e.g. using tree rings and phenology indicators);
- Is phenotypic plasticity preventing local adaptation?
- etc.

Bioversity International
World Agroforestry Centre
INRA

Adaptation (genetic): current knowledge

Resistance to drought

France

Algeria

Morocco

1-3 generations

Height growth

(*Lefèvre et al., in prep*)

Adaptation (genetic) under strong selection pressure:

….. a fast mechanism!

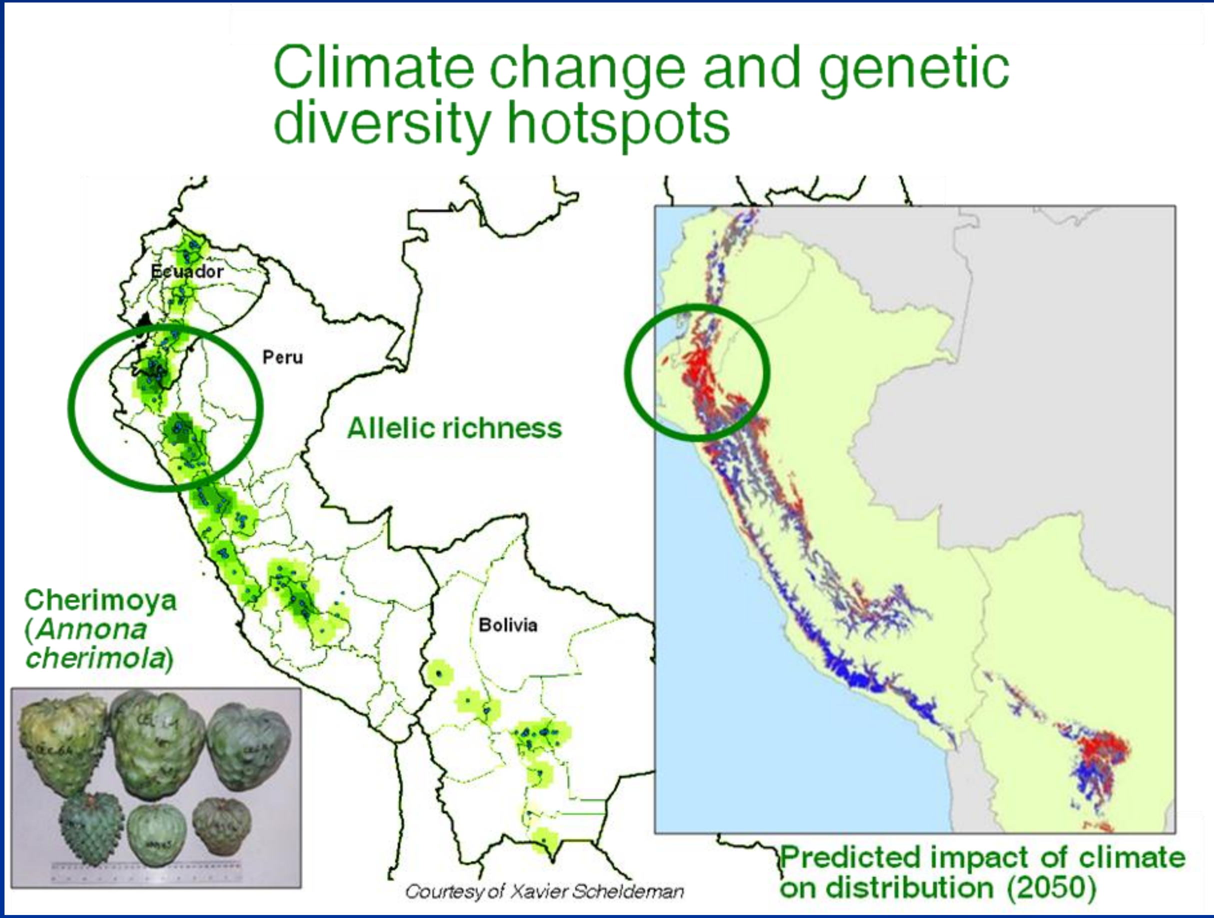
Adaptation (genetic): current knowledge

Abies alba dieback in Mont Ventoux (south eastern France) following 2003 summer heat wave

… **But not fast enough!!** (e.g. at range edges where local adults disappear and recruitment fails)

Adaptation (genetic):
Gaps in knowledge and priorities for research

An example of knowledge gap for adaptation: Where are the areas of high adaptive potential and high conservation value?



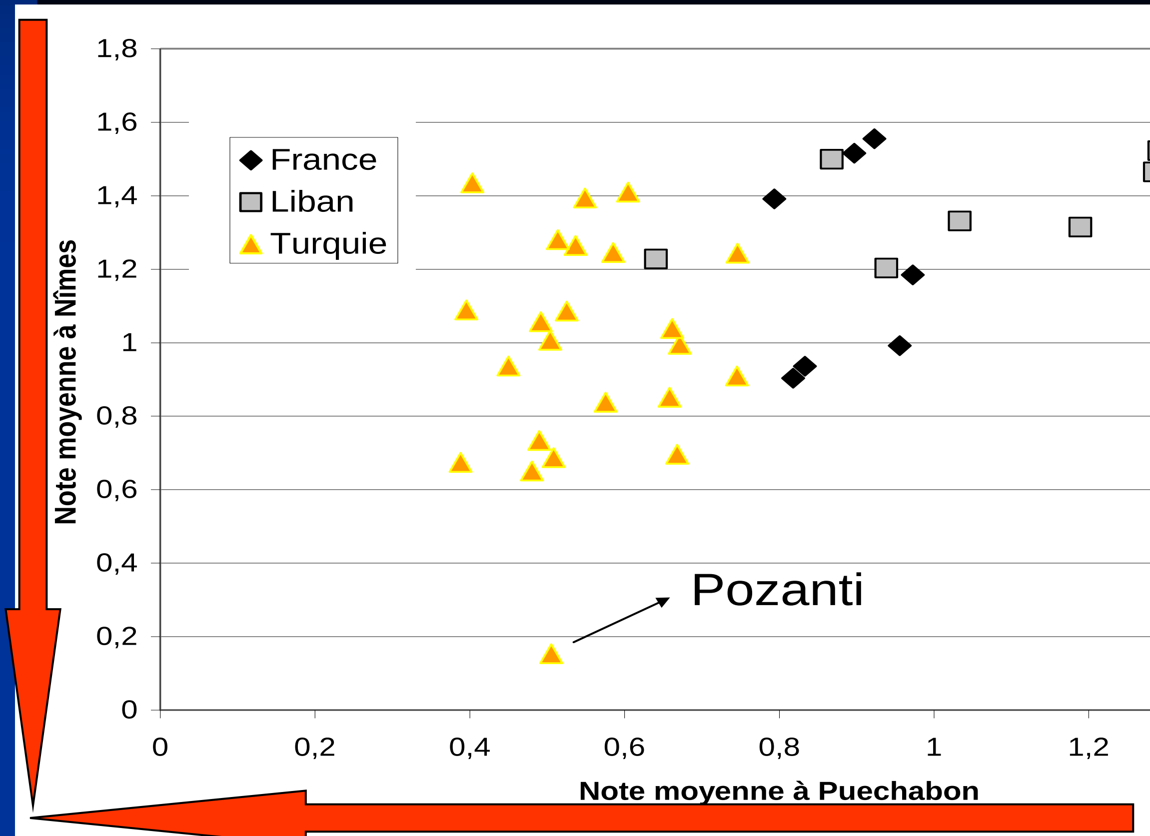
Cherimoya (*Annona cherimola* Mill.), a semi-domesticated fruit tree species from Andean valleys. Climate simulations indicate that the area with the highest risk of species displacement is exactly where the genetic diversity is highest

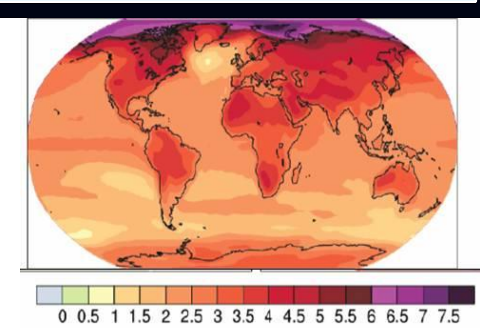
(Van Zonneveld et al. 2011)

Few such studies are yet available. Is highest adaptive potential where highest diversity is?

Bioversity International | World Agroforestry Centre | INRA

An example of knowledge gap for adaptation: What is the extent of standing genetic variation within species?





Bariteau et al. (For Entr) 2007

Resistance to drought (2003) in Cedrus libani

“Common garden” (provenance) tests rarely include marginal populations and habitats. They are also rarely analyzed range-wide.

Adaptation (genetic): Gaps in knowledge and priorities for research

- Where are the areas of high adaptive potential and high conservation value?

- What is the extent of standing genetic variation (a need to evaluate common garden tests range-wide)?

- How is standing genetic variation structured locally / within forests (a need for reciprocal transplants)?

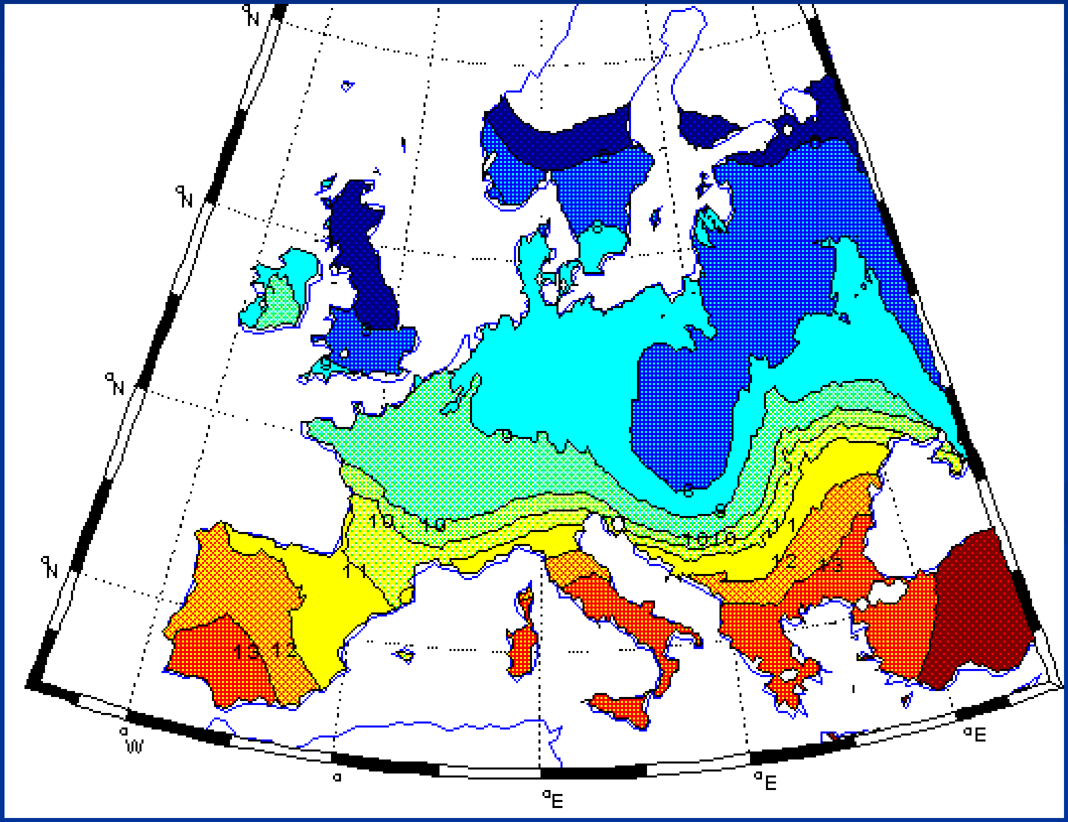
- Genetic correlations between traits within and among species (from breeding programs to disturbance and community ecology)?

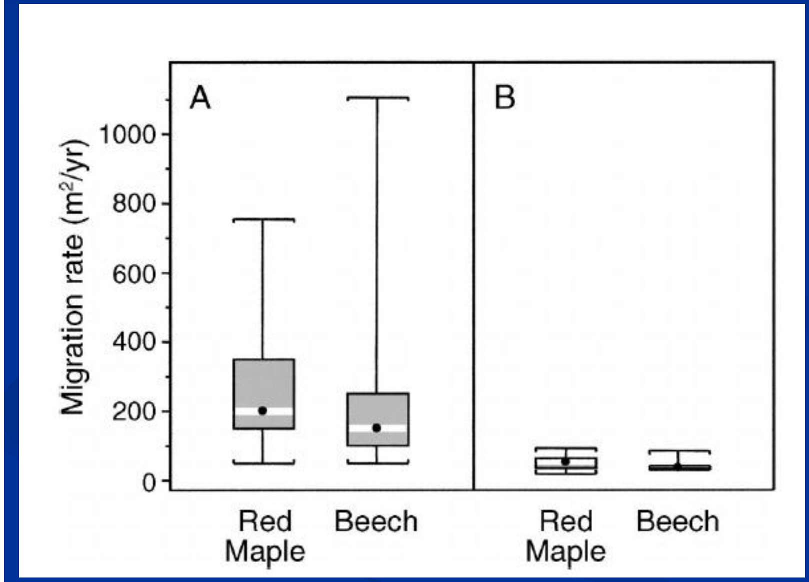
- Genomics of adaptation and reproduction in forest trees (beyond wood characteristics).

- etc.

Migration: current knowledge

European oak isochronal pollen map (www.pierroton.inra.fr/Fairoak/)





McLachlan et al. Ecology 2007
(A: pollen data; B: molecular markers)

Migration of trees can be fast (100-500 m / year during the last 12000 years in Europe)… **fast enough?**

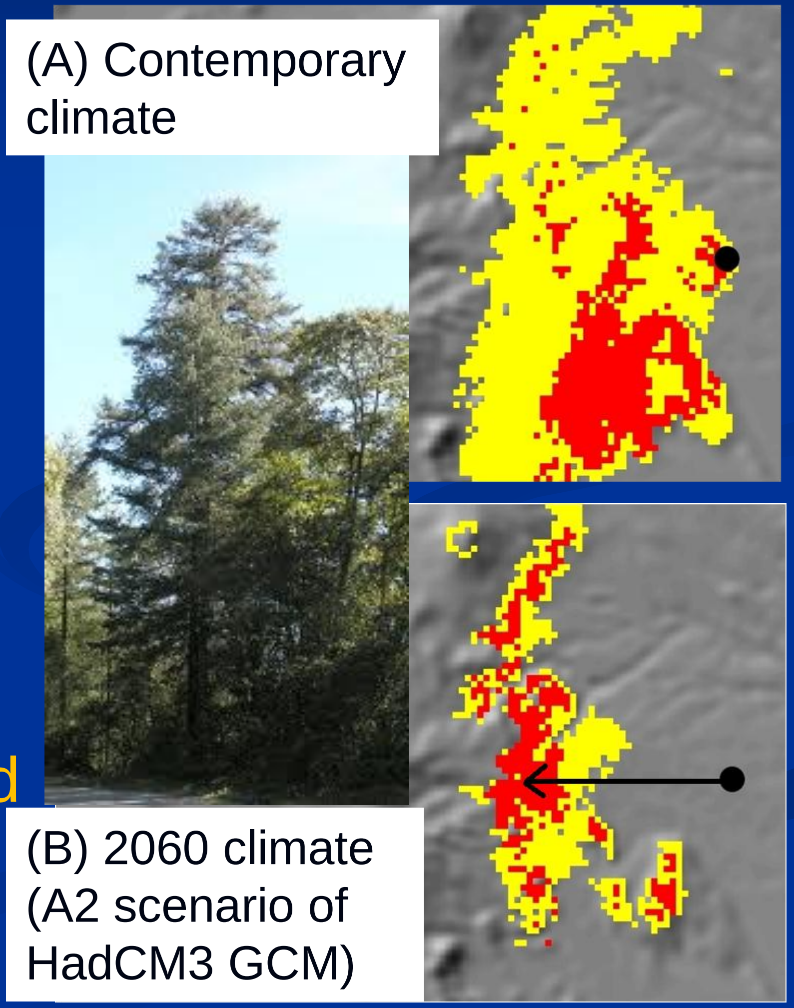
Bioversity International
World Agroforestry Centre
INRA

Migration: Gaps in knowledge and priorities for research

An example of knowledge gap for migration: Geographic distribution of future suitable habitats and dispersal rate

Pinus chiapensis, a rare endangered endemic of Sierra Madre Oriental, Mexico. Probability of suitable current (A) and predicted (B) climatic habitat in the Citlaltépetl range.

yellow > 50%
red > 80%
filled circle: actual population.



Dispersal rate is not fast enough (and seed production large enough) for matching habitat suitability change. Assisted migration required.

Sáenz-Romero et al (2010).

Migration:
Gaps in knowledge and priorities for research

- Geographic distribution of forest tree species (including remote sensing strategies) to model future suitable habitats;

- Improving estimates of long distance dispersal (LDD);

- A better understanding of past migration rates (high spatial resolution paleoecological maps, location of cryptic refugia, combining genetic and ecological tools);

- Understanding contemporary landscape fragmentation and community effects on migration;

- Genetic diversity and genomics of reproduction and LDD;

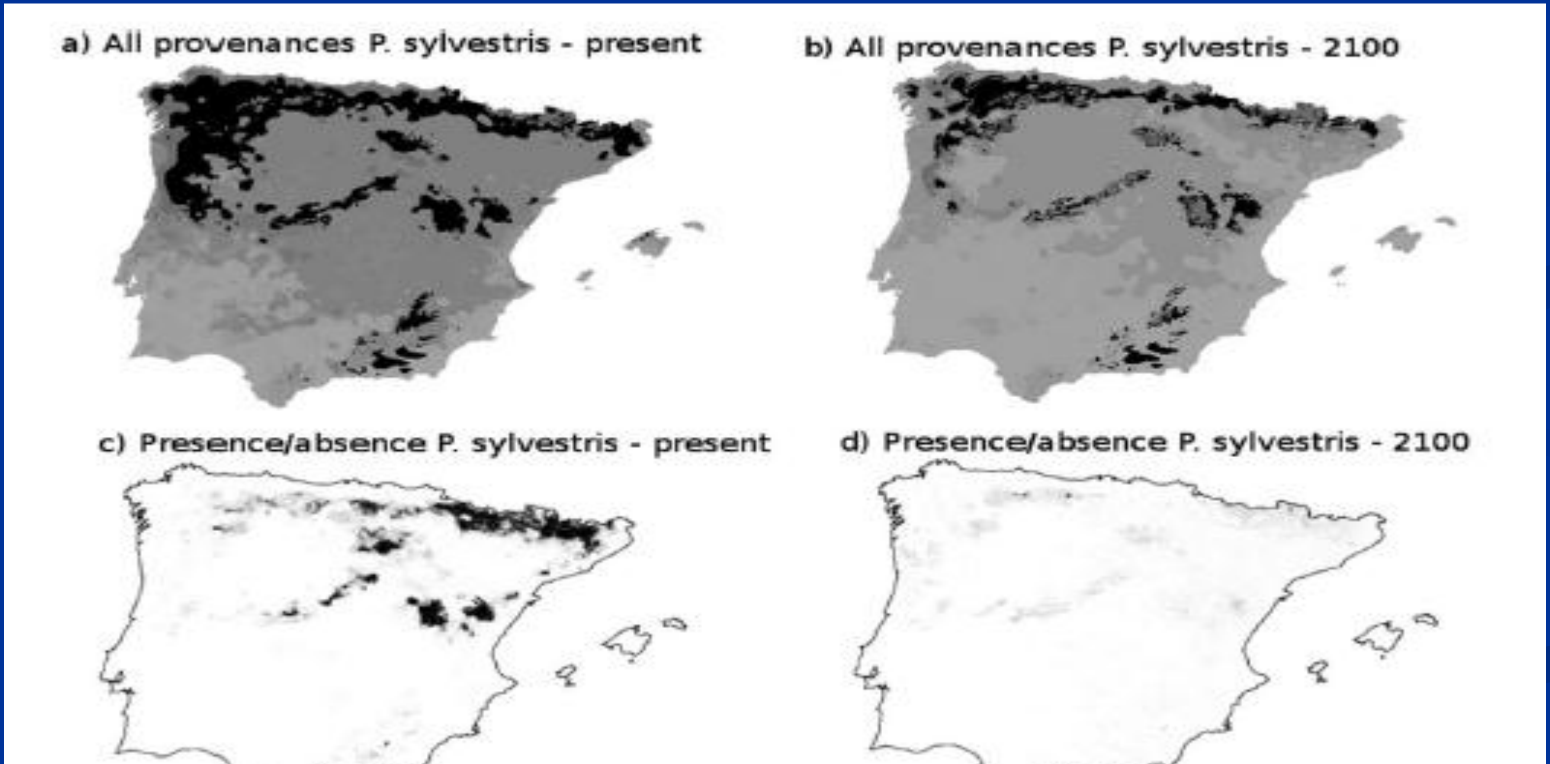
- etc.

Bioversity International
World Agroforestry Centre
INRA

FGR for mitigating and adapting to climate change: priorities for action world-wide

Despite limitations, FGR have an "option value" for mitigating climate change effect on forests

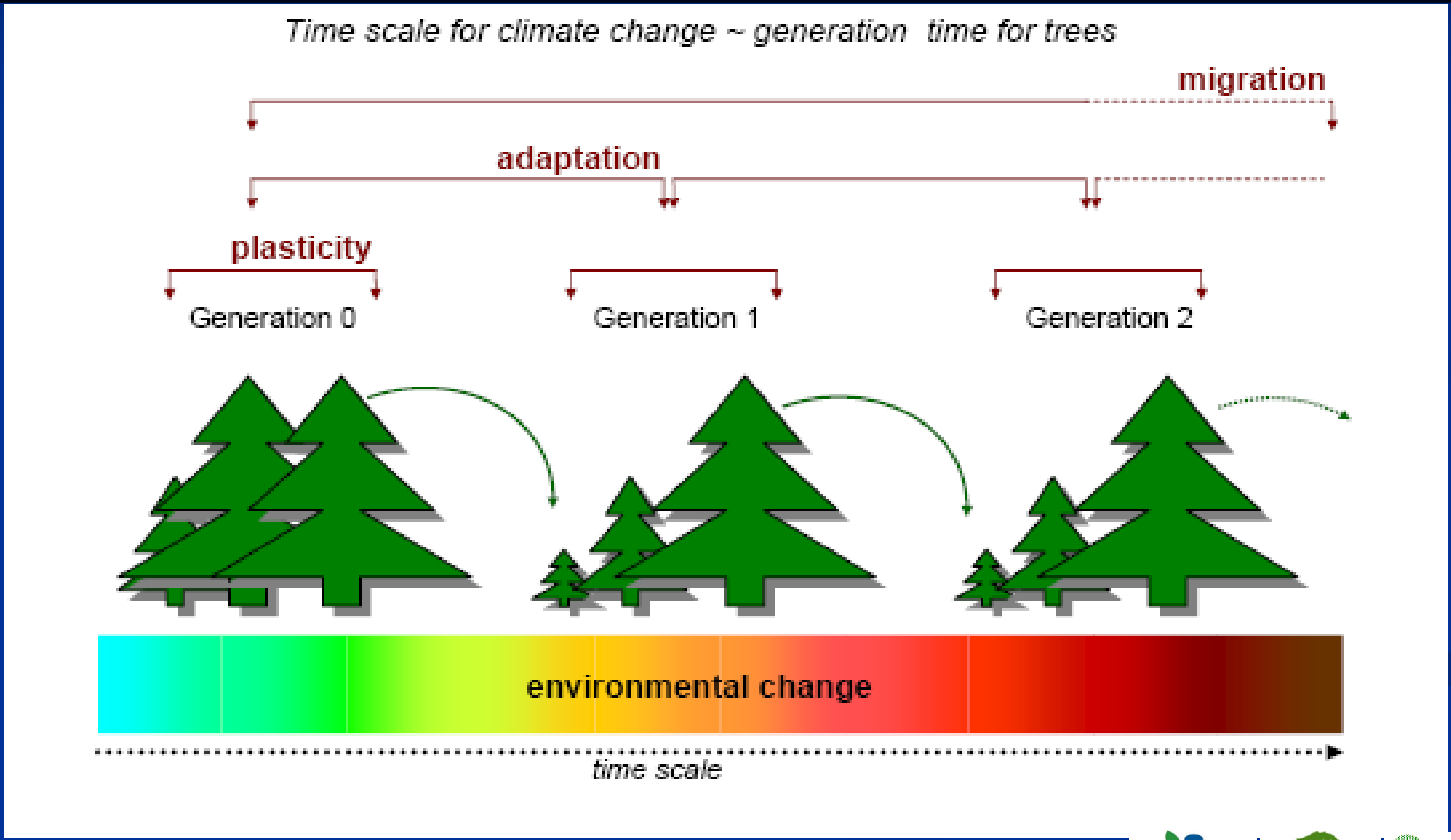
Species distribution models calibrated using intra-specific variability and plasticity (a) predict less reduction in area of occupancy (b vs d) than presence / absence models (c) under climate change



(*Benito Garzon et al. GEB 2011)*

A2 scenario
HadCM3
GCM

Opportunities and risks offered by FGR for trees to cope with climate change: Managing uncertainties in time and space



(Lefèvre et al., unpublished)

Bioversity International
World Agroforestry Centre
INRA

The “option value” of FGR for mitigating and adapting to climate change: priorities for action

-1) Forest species inventories and mapping (including remote sensing);

-2) FGR characterization, conservation, multiplication and delivery (Nagoya 2010 protocol).

-3) Intensify conservation actions for FGR (legal protection, valuation, etc), including marginal populations;

-4) Maintain high diversity FGR for afforestation and reforestation (policy / legal aspects for collection, large breeding program portfolios, assisted migration within species, etc);

-5) Maintain high diversity FGR in naturally regenerated forests (silviculture for a diverse natural selection, large portfolio approach, etc).

Using current knowledge on FGR "option value" to promote management strategies for forest ecosystems under climate change

Forestry Commission
231 Corstorphine Road
Edinburgh
EH12 7AT
www.forestry.gov.uk

The Role of Forest Genetic Resources in Helping British Forests Respond to Climate Change

INFORMATION NOTE

BY JASON HUBERT AND JOAN COTTRELL OF FOREST RESEARCH — JUNE 2007

SUMMARY

This Note provides an overview of the issues surrounding the use of genetic resources in British forestry and presents possible strategies to help forests and woodlands adapt to the effects of climate change through the use of such resources. Ongoing discussions surround the choice of appropriate genetic resources for reducing the impacts of climate change on British forests and this uncertainty is leading to delays in the formulation of a definitive strategy. The objective here is to present the issues surrounding this debate by providing responses to the most commonly asked questions. The information in this Note is based on summaries of genetic population theory, recent research findings and current ideas on these topics circulating within the European research community. The Note does not provide a statement of policy.

INTRODUCTION

Both the Helsinki guidelines (MCPFE, 1993) and *The UK Forestry Standard* (Forestry Commission, 2004) encourage the use of local stock for planting native species, especially in existing and new native woodlands (Figure 1). The UK Woodland Assurance Standard (UKWAS) also encourages use of local provenance (UKWAS Steering Group, 2006). These guidelines are based on the principle that locally sourced planting stock is likely to represent the best-adapted material available for a site. The use of non-local planting material raises concerns that it is likely to be poorly adapted to local conditions. In addition, there are anxieties that the offspring resulting from interbreeding between local and introduced individuals will have reduced fitness compared with the truly local parents (Wilkinson, 2001).

Figure 1
Ancient semi-natural woodland in southeast England. Woodlands such as this will be increasingly affected by climate change.

The scale at which 'local' is meant is often poorly understood for tree species however, and some interpretations take it to mean that adaptation occurs over very short distances. Much of the supporting research for such narrow-scale adaptation is based on short-lived plant species, many of which are insect pollinated or predominately self pollinated. Under these conditions local populations can become genetically isolated and selection pressures can quickly lead to the development of an optimal range of genotypes. In some cases this can lead to very fine-scale population structures. For example, *Delphinium nelsonii*, a perennial herb pollinated by bees and humming birds in the mountains of western USA, appears to show adaptive variation over distances of as little as 50 m (Waser and Price, 1985). However, it has been suggested that the situation for long-lived, open pollinated species, such as many native British tree species, is different and the assumption that local is best has been questioned in these circumstances (Wilkinson, 2001) (Figure 2). Yet, there is a long history of provenance research in forestry that has demonstrated instances of failure due to movement of plant material over large distances (Figure 3). Such examples can also be found in commercial forestry, where failure has often occurred many years after establishment (Johnson *et al.*, 2004; Randall and Berrang, 2000). The key challenge is to define the spatial scale over which forest tree species can be moved without suffering maladaptation. The choice of suitable planting stock may be unnecessarily restricted if the safe transfer distance is larger than the existing seed zone. There is also a possibility that simple geographic proximity is a poorer predictor of success than ecological site matching. In addition, many of the guidelines that emphasise the use of local stock were developed before the likely rate and magnitude of climate change were fully appreciated.

Commission Ressources Génétiques Forestières

DGPAAT/SOUS-DIRECTION DE LA FORÊT ET DU BOIS

Préserver et utiliser la diversité des ressources génétiques forestières pour renforcer la capacité d'adaptation des forêts au changement climatique

De façon générale, la notion de "ressources génétiques" recouvre une part de la biodiversité directement utile pour l'Homme. En forêt, la diversité génétique des arbres est aussi un facteur qui favorise la biodiversité globale de l'écosystème, facteur déterminant de son fonctionnement. Cette diversité, qu'il n'est pas toujours facile d'observer au sein des espèces, est en perpétuelle évolution, elle n'est pas figée. Suivant les lois de la génétique, elle est façonnée par la dynamique des peuplements, par les flux de graines ou de pollen entre peuplements et par la sélection, qu'elle soit naturelle ou d'origine anthropique. Dans le contexte du changement climatique, préserver durablement ce patrimoine sur le long terme est un enjeu global essentiel, étroitement lié à la gestion locale des forêts.

Nous abordons ici la gestion de la diversité génétique au sein de chacune des espèces, sachant que les stratégies de mélanges d'espèces sont bien sûr aussi pleinement justifiées pour une gestion durable dans le contexte du changement climatique.

Nous proposons quelques grandes recommandations générales, sans traiter systématiquement de chaque mode de sylviculture individuellement. Dans beaucoup de cas, plusieurs options sont possibles, il n'y a pas de réponse unique.

Parallèlement à ces recommandations générales de gestion forestière courante, des actions spécifiques de conservation et de transfert expérimental de ressources génétiques seront conduites par la recherche, notamment à l'initiative de la CRGF.

Commission Ressources Génétiques Forestières (*)

(*) Cette commission, constituée de scientifiques, de gestionnaires forestiers publics, privés et d'un représentant du réseau "forêt" de France Nature Environnement, propose au MAP et met en place une stratégie d'évaluation et de conservation de la diversité génétique des espèces d'arbres forestiers en France.

Président : François Lefèvre (Courriel : francois.lefevre@avignon.inra.fr), Secrétaire : Eric Collin (Courriel : eric.collin@cemagref.fr)

Bioversity International — World Agroforestry Centre — INRA

FGR and climate change: risks, opportunities and already some tools for action

Research shows that forest trees can naturally:

- acclimatize through phenotypic plasticity
- adapt under natural selection,
- migrate to more suitable locations …

… but with some limitations!

Integrating FGR into forest management is an asset to alleviate (“option value”) these limitations.





Loo J., Fady B.et al. 2011. FAO Background Study Paper n°56