Forest genetic diversity and restoration

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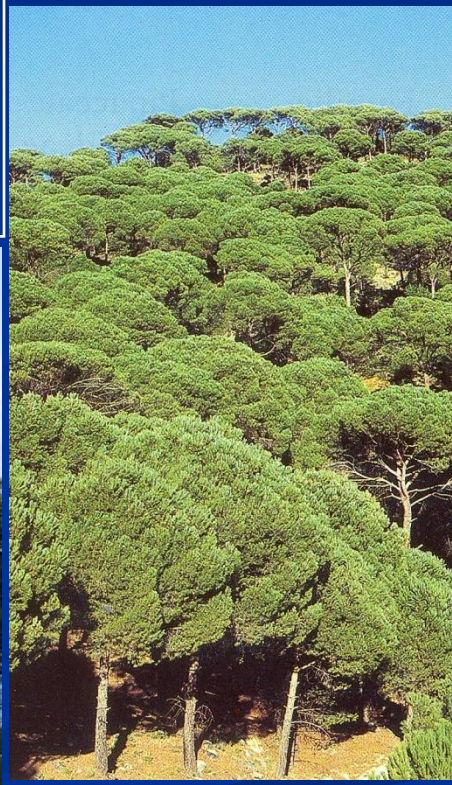
Avignon, France



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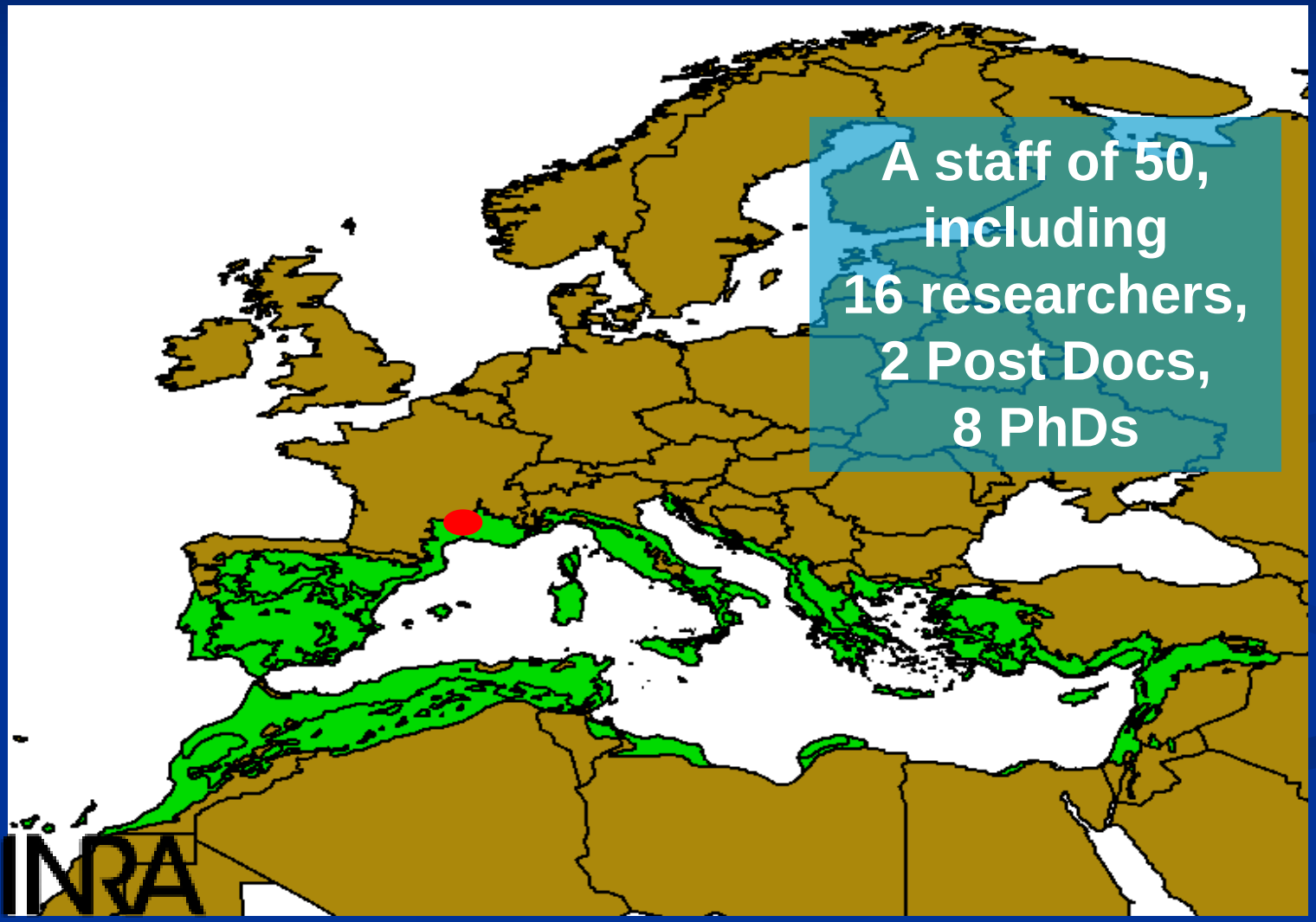
Restoration ecology 2013 – Mediterranean ecosystem restoration
SER Summer school

May 13, 2013
Avignon, France

The INRA – URFM "Ecology of Mediterranean forests" research laboratory



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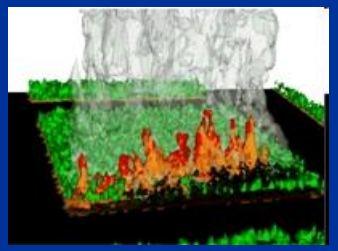
INRA-URFM "Ecology of Mediterranean forests"
3 research groups

Functional Ecology and Community Dynamics



Physics and Ecology of Wild Fires

Population Biology and Evolution:
6 PhDs, 1 Post Doc, 7 researchers,
4 (+3 associated) technicians

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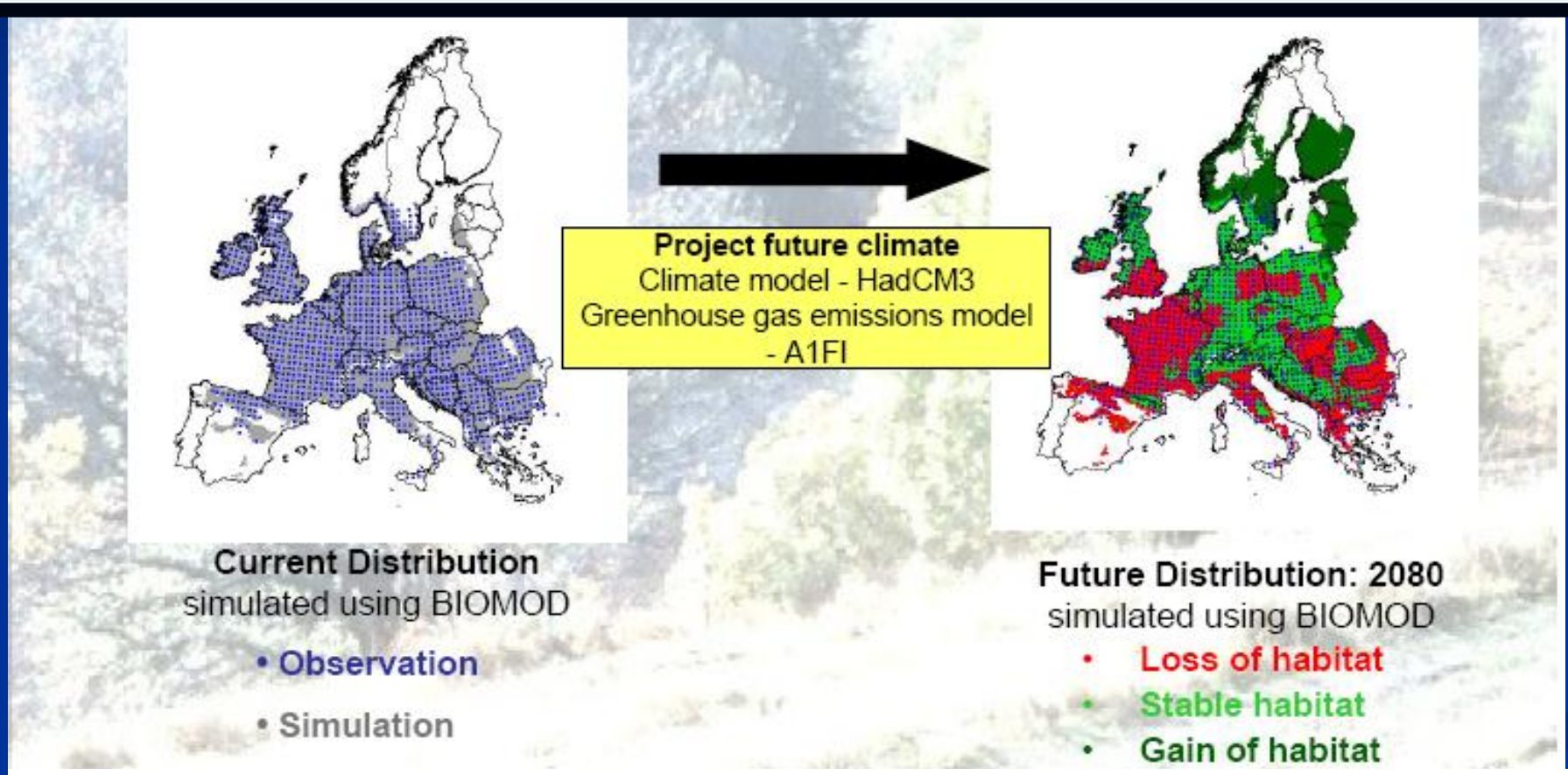
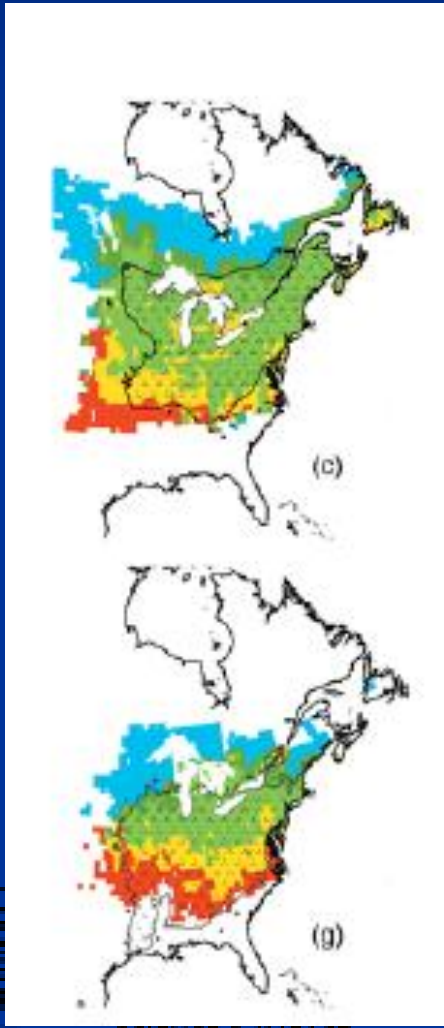
The usual view of species in ecology

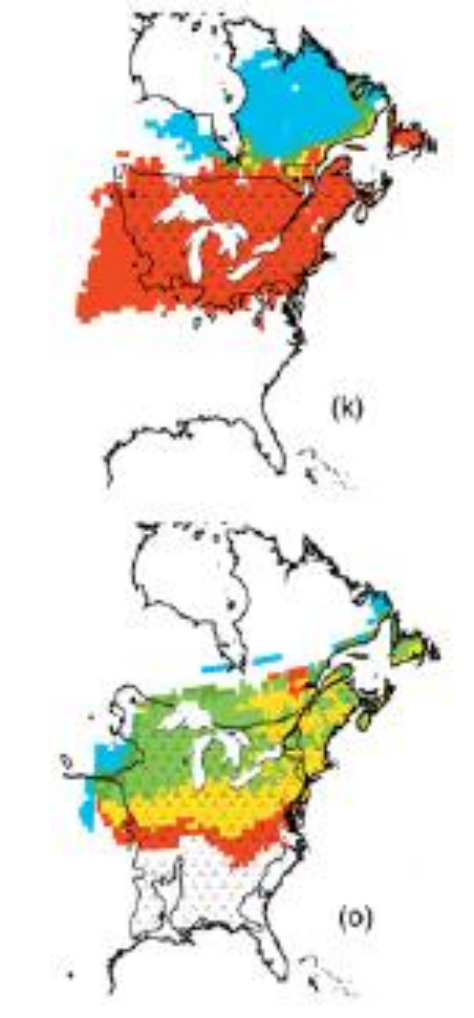


Climate envelope modelling. Changes in habitat suitability for *Quercus petraea* under climate change

Thuiller (GCB) 2003, Thuiller et al. (PNAS) 2005

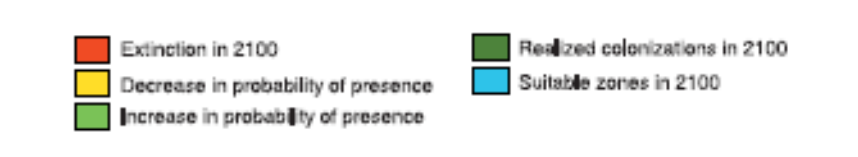
The usual view of species in ecology



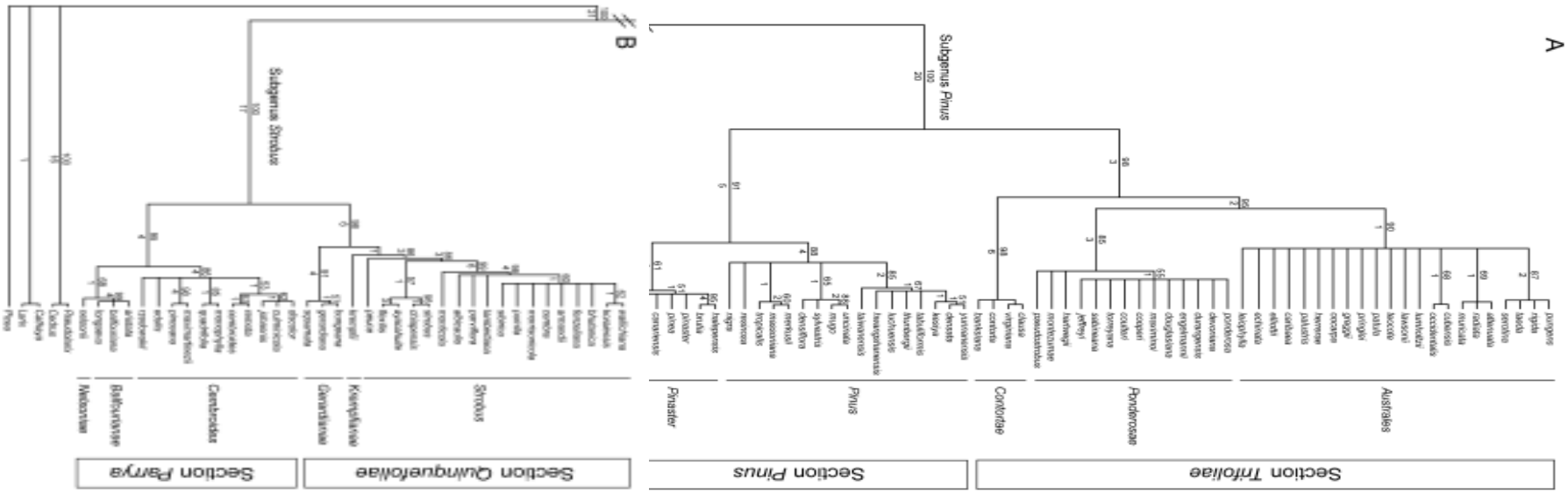


Process-based envelope model including phenology and dispersal. Changes in habitat suitability for:
(c) *Acer saccharun*,
(g) *Carya ovata*,
(k) *Fraxinus nigra*,
(o) *Ostrya virginiana*
under IPCC climate change scenario B2 in 2100

Morin et al. (J. Ecol.) 2008



The usual view of species in ecology



Strict consensus of 55,536 phylogenetic tree for the combined rbcL and matK matrix for the genus *Pinus*

Gernandt et al. (*Taxon*) 2005

Species are far from being homogeneous

- Species are concepts
- Species are made of populations, groups of individuals that exchange genes
- Populations have different evolutionary and adaptive properties (i.e. genetic diversity)
- Genetic diversity cannot be easily predicted

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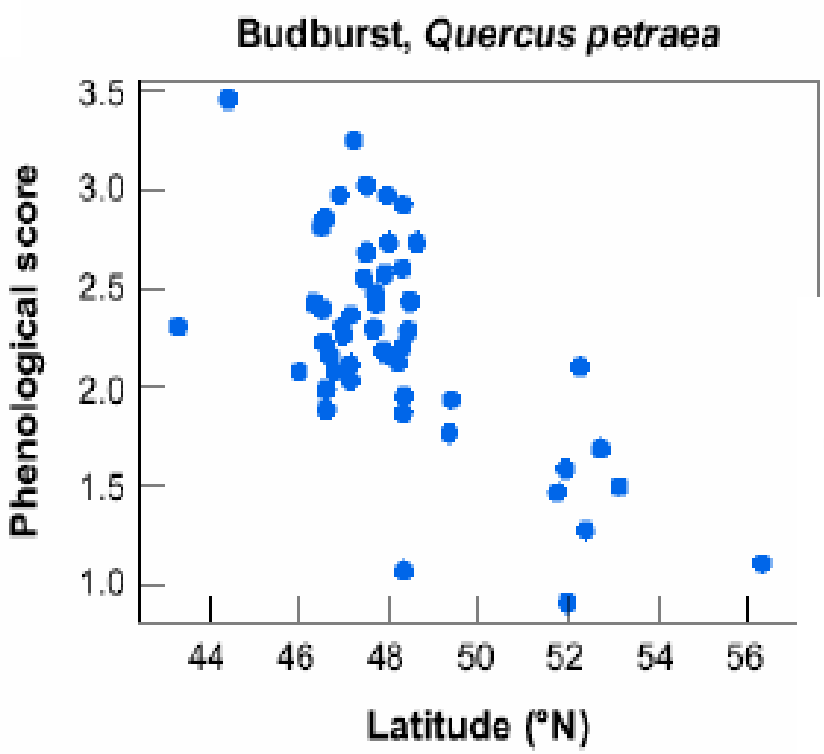
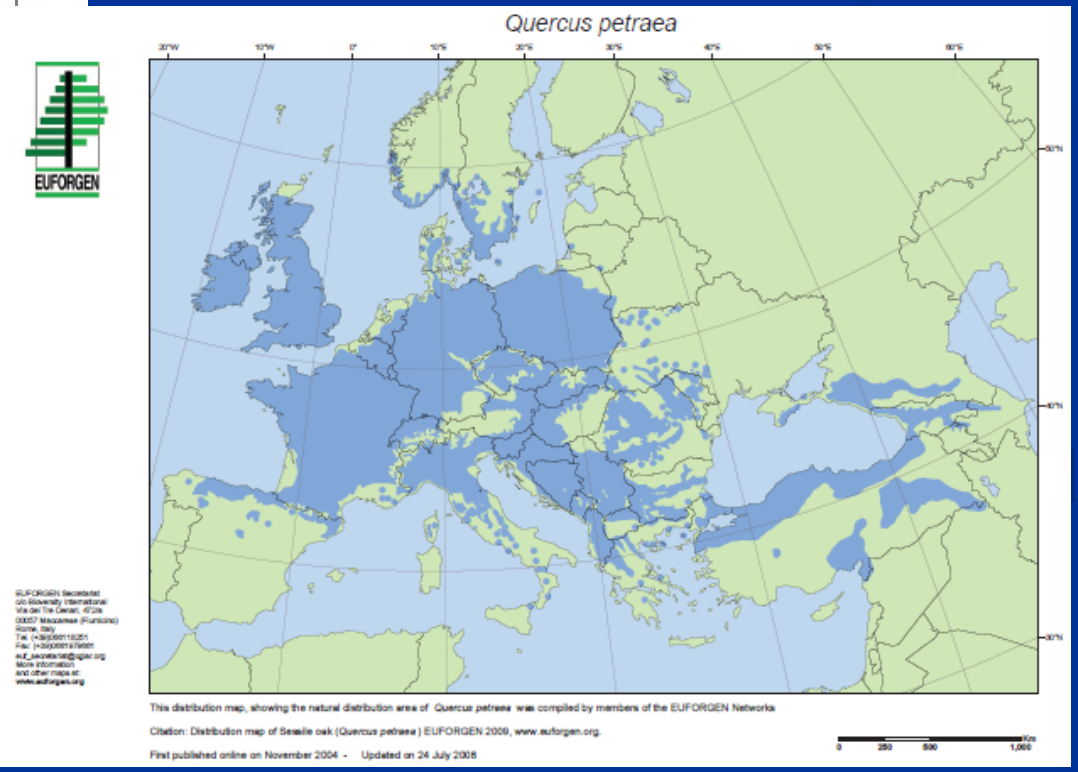
Populations have different adaptive properties



Ducousso et al. (AFS) 1996

A strong link between geographic origin and bud break date in the European oak Quercus petraea (4 common garden experiments)



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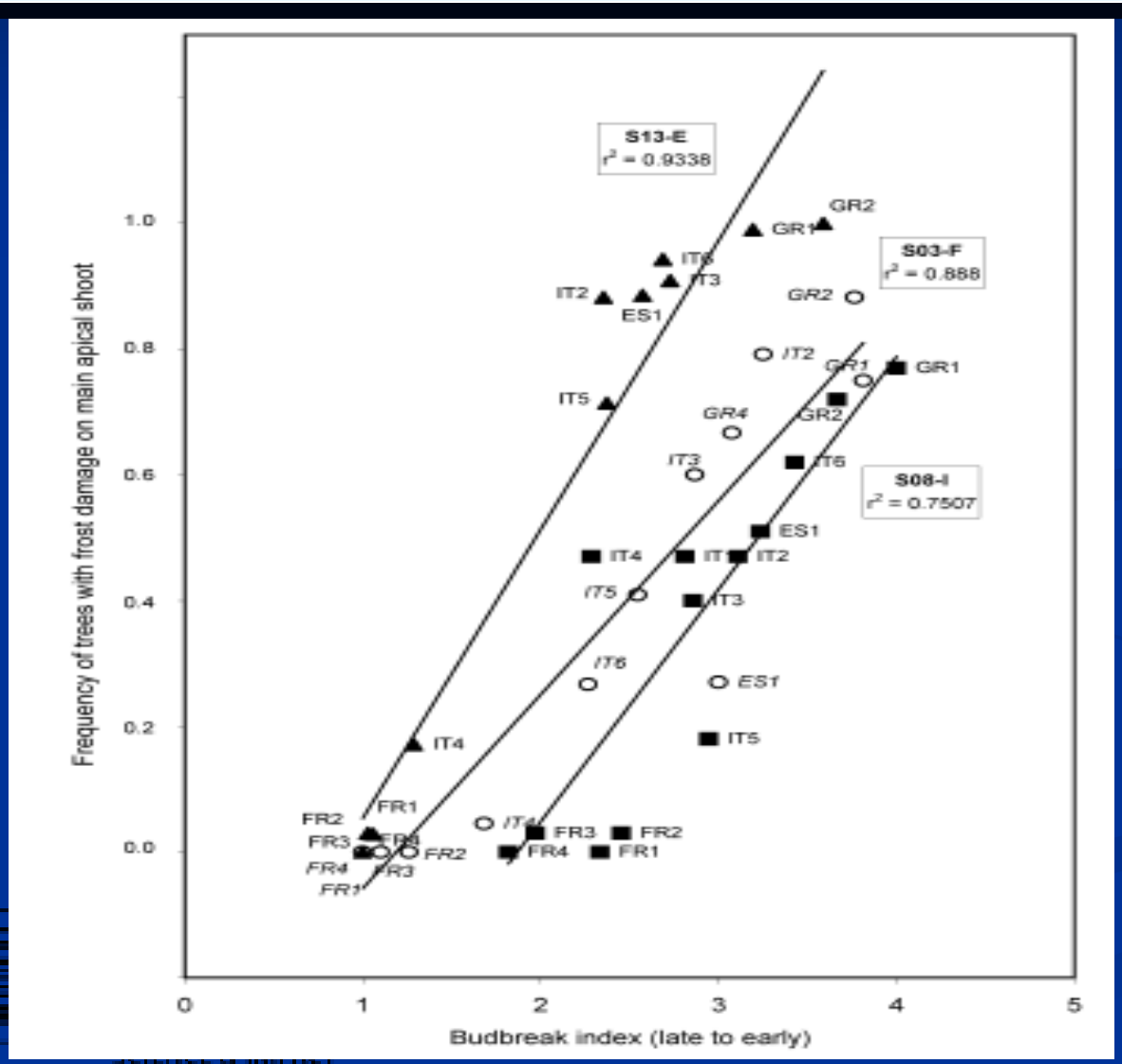
Populations have different adaptive properties

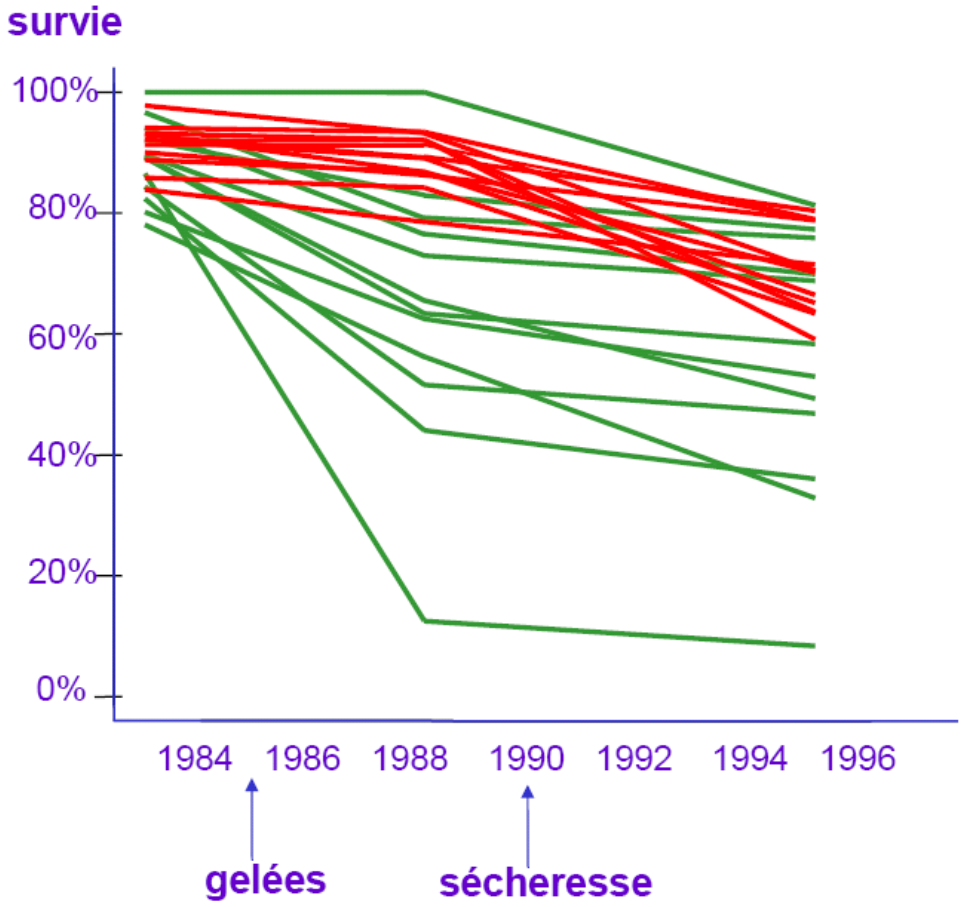


A strong link between geographic origin, bud break date and susceptibility to late frost damage in walnut (Juglans regia) in 3 common gardens

Fady et al. (NeFo) 2003

Diversity among populations within species can be larger than between species

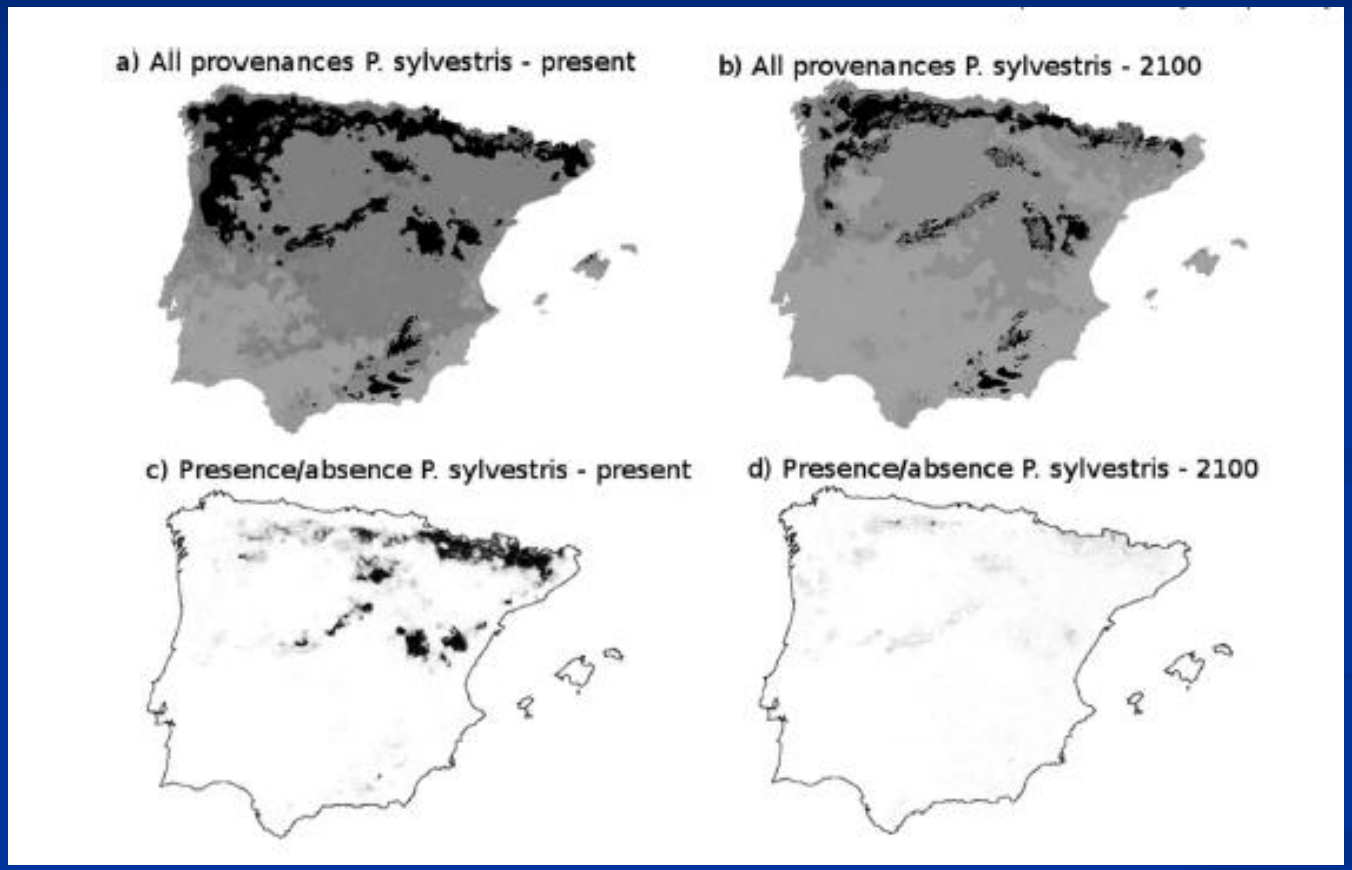
Provenances de ***Pinus halepensis*** et ***Pinus brutia***:
survie en plantation après deux événements climatiques majeurs



Forest tees display a particularly large genetic diversity because of their migration and evolutionary history

Bariteau (AFS) 1992

The consequences of species being non-homogeneous for simulating range changes under climate change



(a) Potential current presence and (b) potential future presence under the genetic model, (c) actual presence and (d) potential presence under the climate envelope model in 2080 for Pinus sylvestris in Spain

A2 scenario, HadCM3

Benito Garzon et al (GEB) 2011

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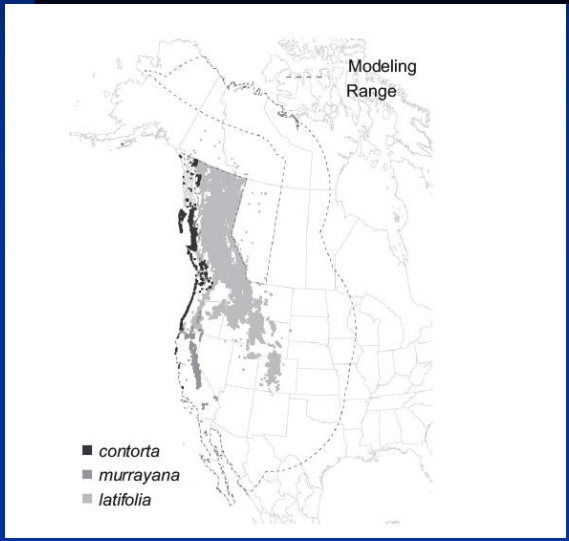
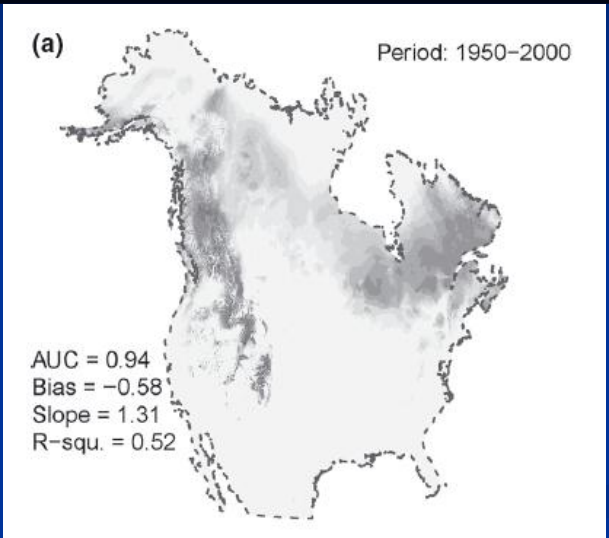
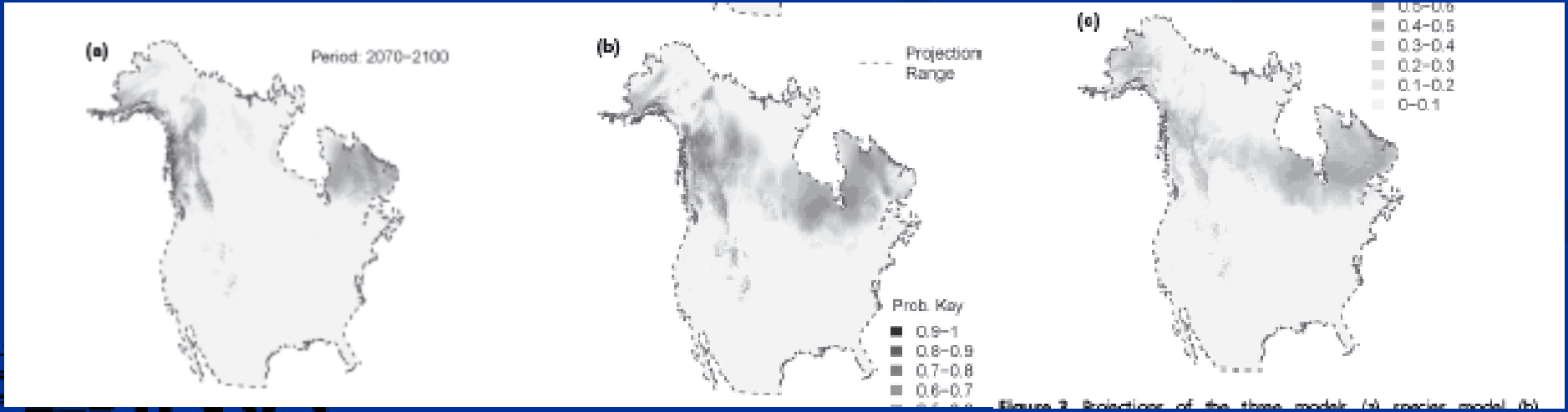
The consequences of species being non-homogeneous for simulating range changes under climate change





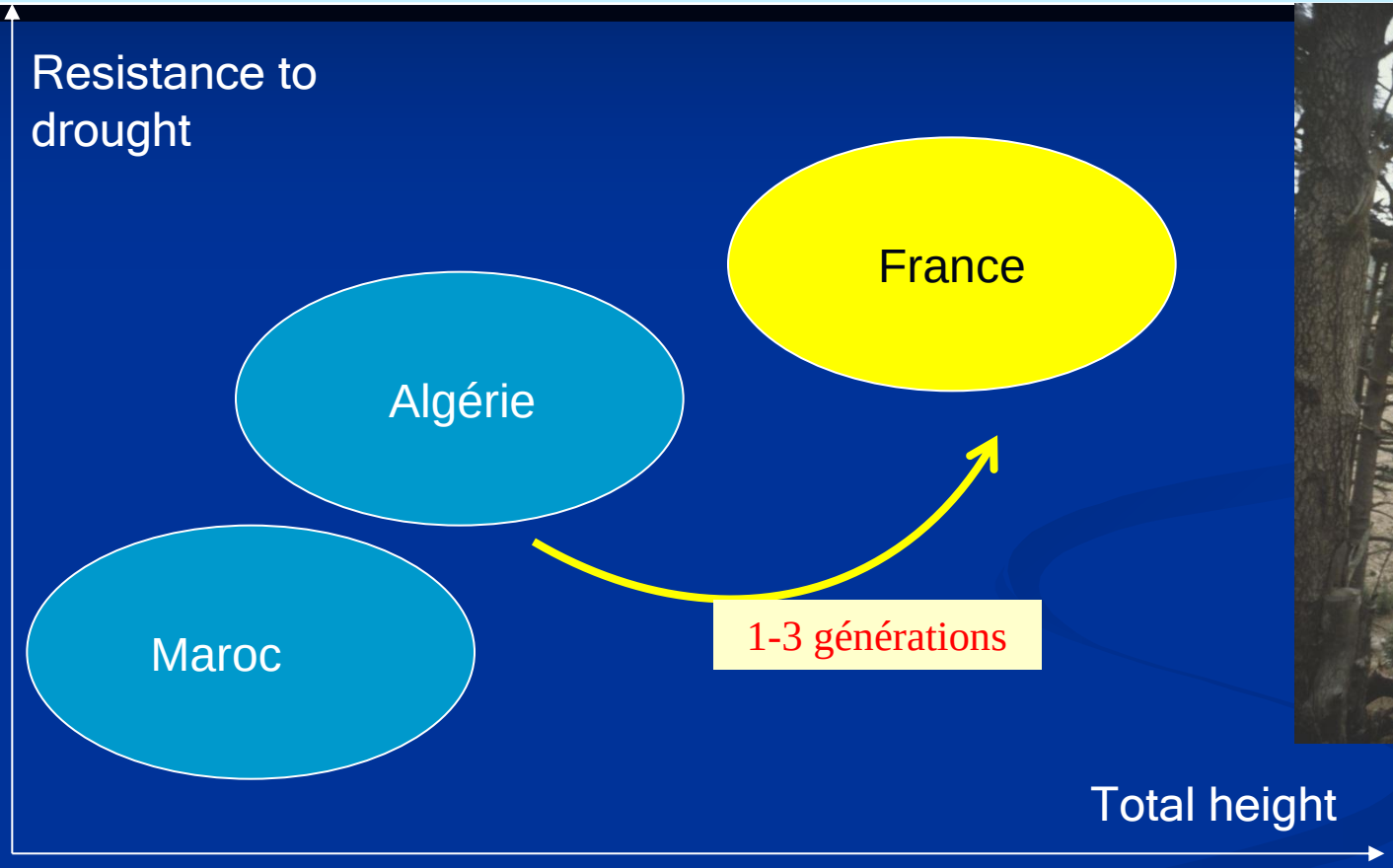
(a) Envelope model, (b) subspecies model and (c) genetic diversity model of Pinus contorta distribution in 2100 in North America

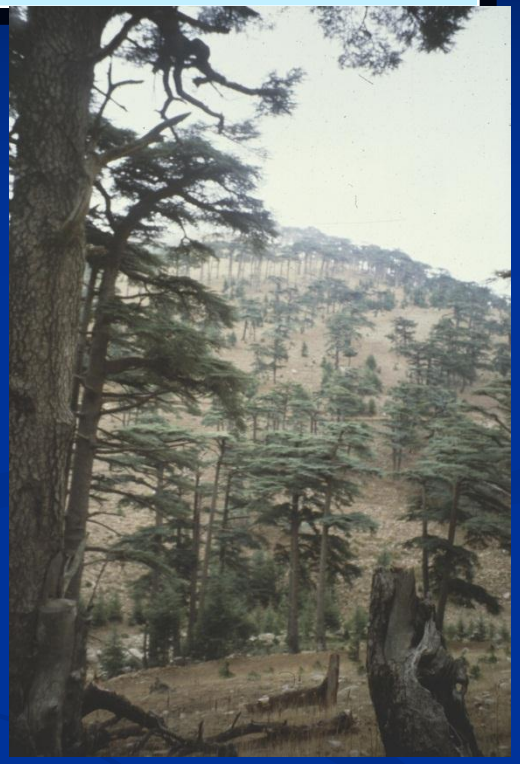


A2a scenario, HadCM3

Oney et al. (Ecol. Evol.) 2013

Populations have different (adaptive and) evolutionary properties



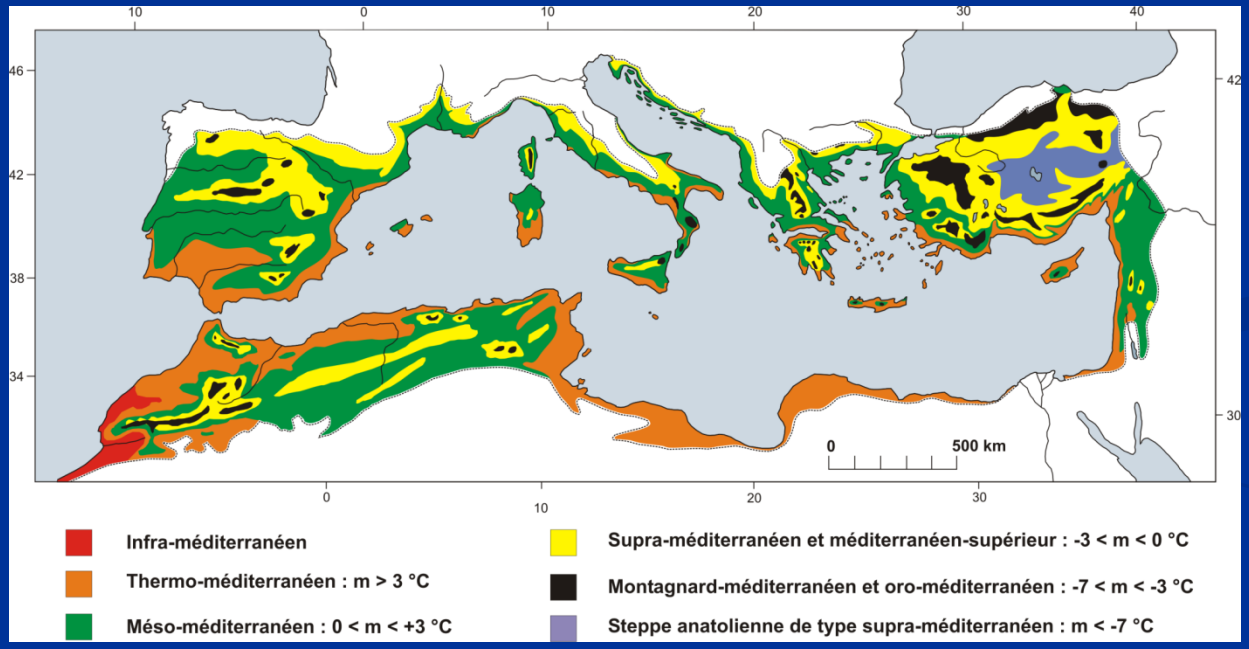


An ecological crisis can trigger rapid genetic adaptation via natural selection (here Cedrus atlantica in France)

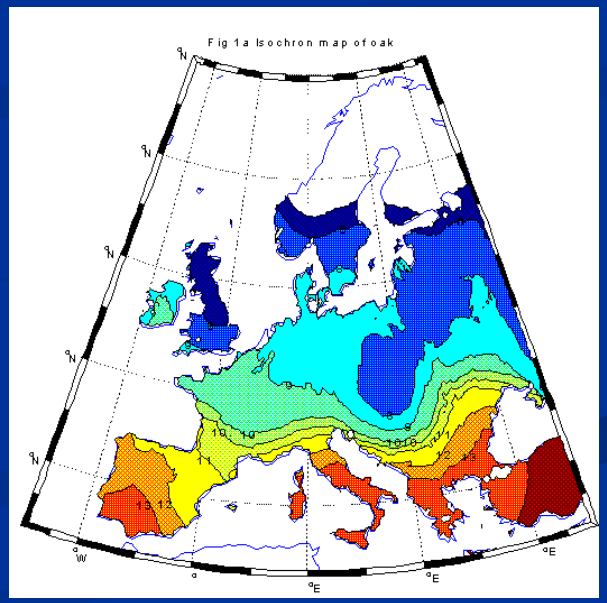
Lefèvre (unpublished)

Genetic diversity and adaptation cannot be easily predicted – where is diversity?

Particularly in ecologically and historically complex regions such as the Mediterranean



Quézel & Médail (Ecologie et biogéographie des forêts du bassin méditerranéen) 2003



Brewer et al. (FEM) 2002

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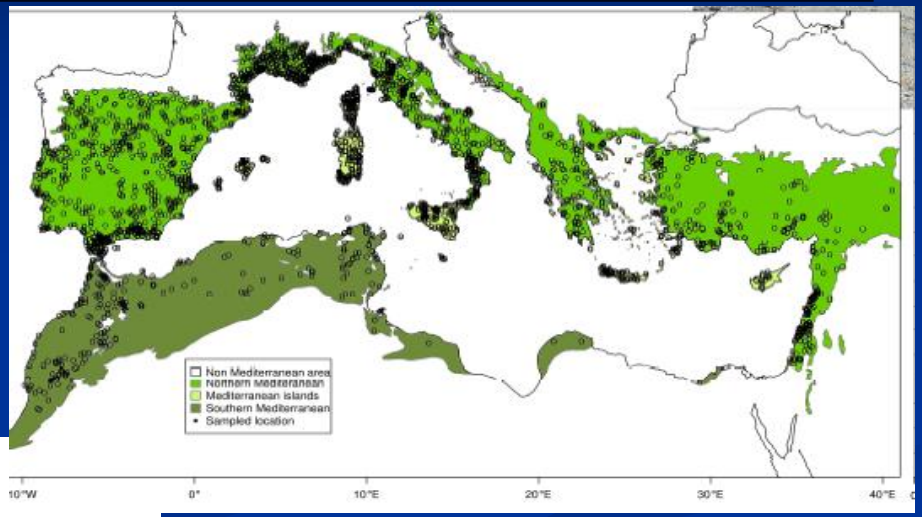
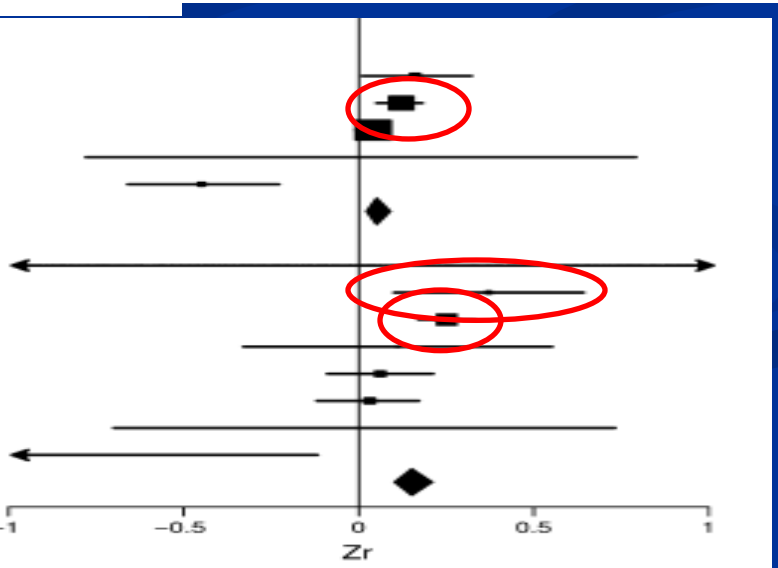
A significant excess of genetic diversity in the Eastern Medit. for trees, arachnids and insects

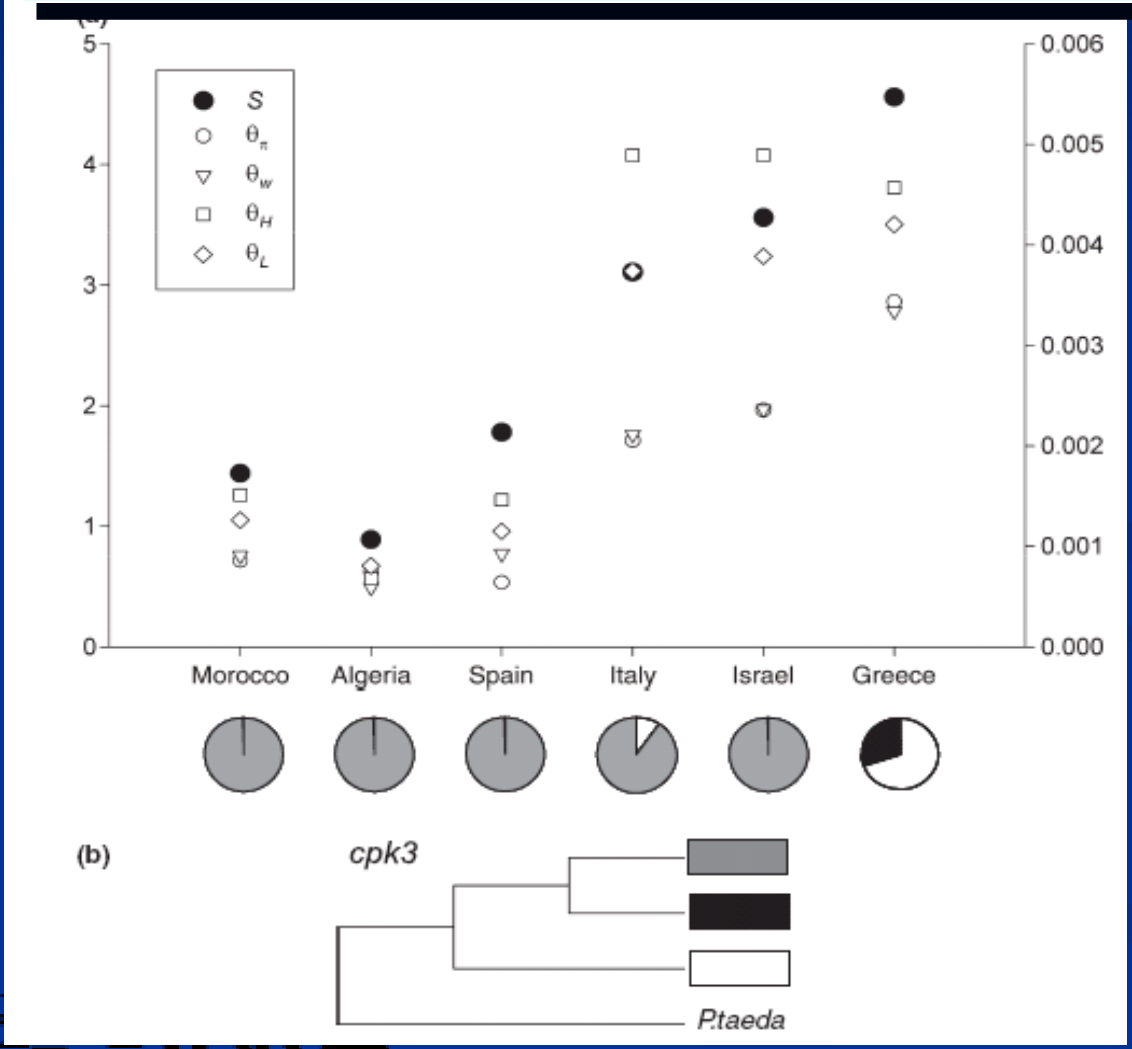
Conord et al. (*Ecol Evoll*) 2012



Dataset	Number of Effect-sizes	Signif. of Q-test	Effect-size
Moderator			
Monocotyledone	14	NS	0.15
Gymnosperm	122	***	0.11
Dicotyledone	121	***	0.03
Pteridophyte	3	NS	−0.01
Bryophyte	9	NS	−0.46
Plants	**269**	***	**0.04**
Crustacea	2	NS	0.56
Arachnida	10	NS	0.36
Insect	69	***	0.24
Reptile	8	NS	0.1
Mammal	33	*	0.05
Amphibian	29	***	0.02
Bird	5	*	0
Gasteropod	3	NS	−0.96
Animals	**159**	***	**0.14**



Diversity among and within populations shaped by recolonization and natural selection



Genetic diversity estimates at 8 nuclear genes involved in drought response in Aleppo pine (Pinus halepensis) across the Mediterranean: recolonization and selection in new habitats

Grivet et al. (*New Phytol*) 2009

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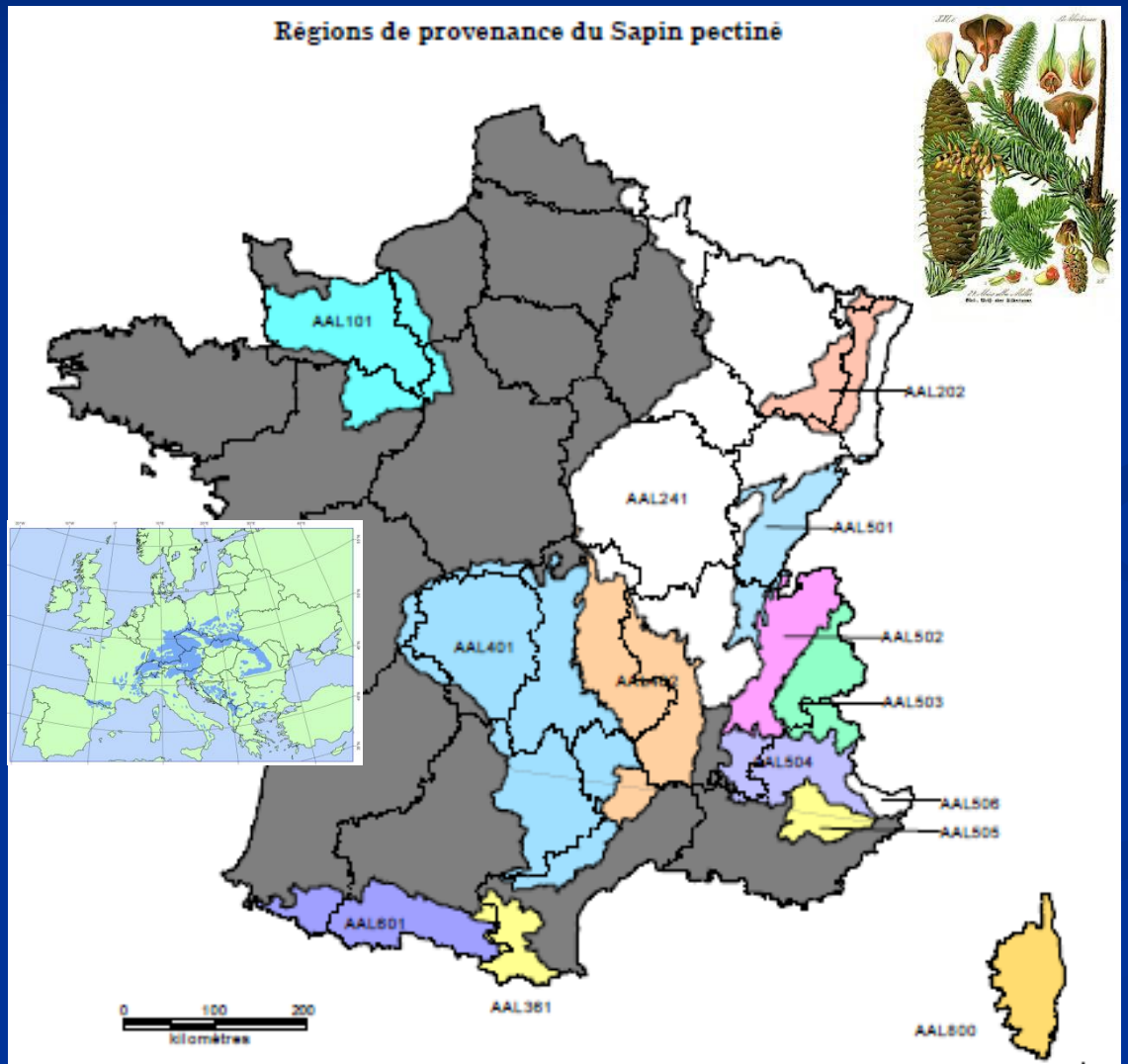
The consequences of species being non homogeneous for restoration ecology and management

Species do not occupy their full potential range for a number of reasons (colonization, competition, land-use, etc);

Because species are made of genetically distinct populations, choosing material from the right origin for restoration projects matters! (e.g. 30 000 ha of frost sensitive maritime pine plantation (introduced from Portugal) destroyed in the Landes during winter 1984-5)

A history of moving forest reproductive material across Europe at least since the early 1850s (see Ventoux outing): exotics as ecological engineers or genetic and community pollutants?

European best practice for reforestation recognizes within species diversity



14 regions of provenance for Abies alba in France: An administrative-ecological- genetic recognition of adaptive differences within species

An example of partially science-driven European regulation: Council Directive 1999/105/EC of 22 December 1999 on the marketing of forest reproductive material

The consequences of species being non homogeneous for restoration ecology and management

Choosing the right origin matters, but is local always best?

Using enough diversity: safeguarding adaptive potentials

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Choosing the right origin: local is not always best!

Massive killing of Pinus contorta by mountain pine beetle in British Columbia, Canada.

Choosing the right origin: local is not always best!

Abies alba and Picea abies decline in Vésubie (Maritime Alps)

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Choosing the right origin: local is not always best!

Abies alba decline in Ventoux (Vaucluse) after the 2003 summer heat wave

Choosing the right origin: local is not always best!

Rehfeldt et al. (GCB) 2002

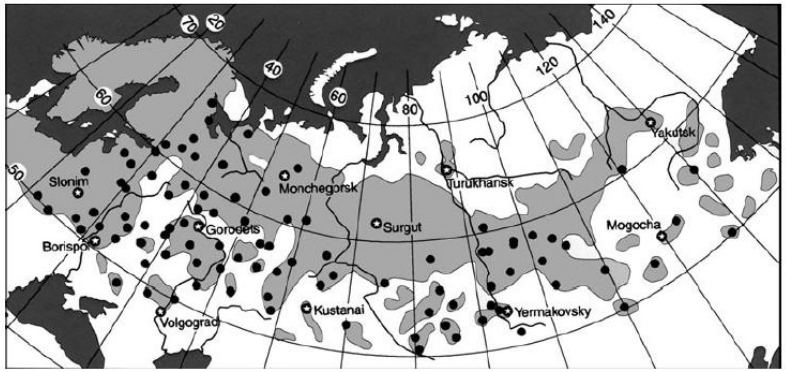


Fig. 1 Distribution (shading) of *P. sylvestris* (after Critchfield & Little, 1966) and location of populations (dots) sampled. Locations that are named are used throughout the paper to illustrate geographical effects.

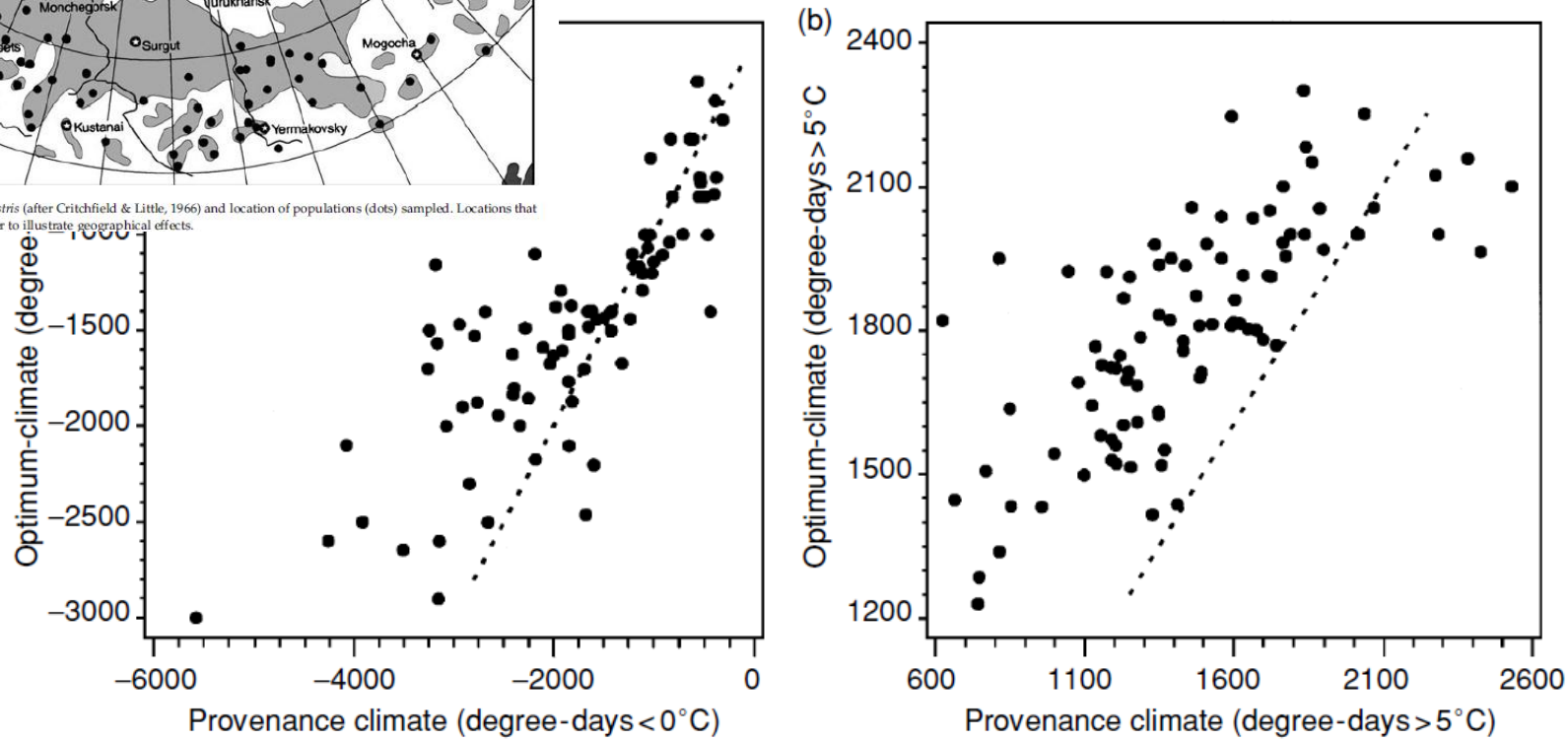


Fig. 5 Relationship between the optimum climate and the provenance climate: (a), degree-days < 0 °C, and (b), degree-days > 5 °C. In both (a) and (b) the hashed line (–) indicates equality of the inhabited and optimal climates. Populations to the left of this line occupy climates colder than their optima while those to the right occupy climates warmer than their optima.

Using enough diversity: safeguarding adaptive potentials

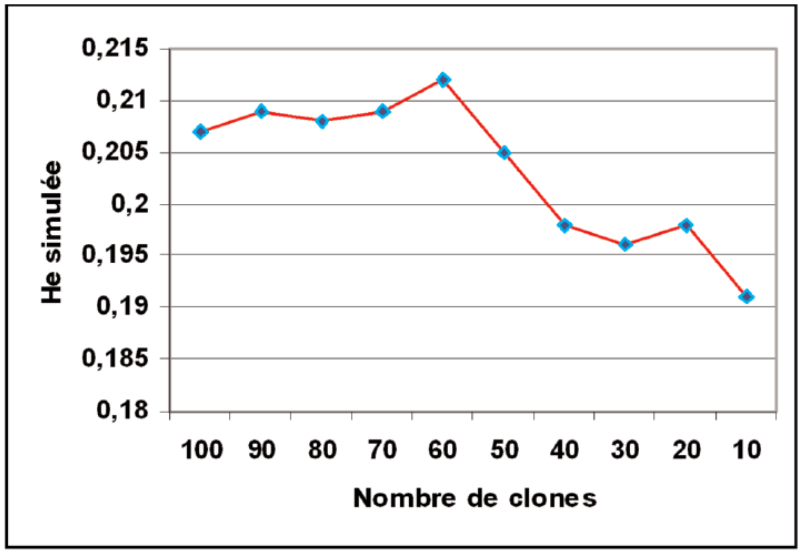
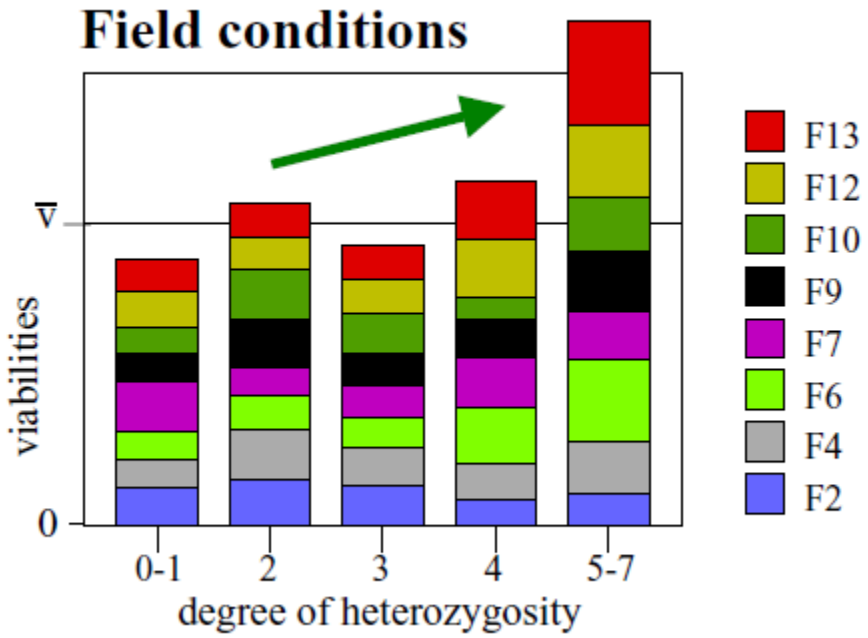


Figure III.10 *: Effets d'une sélection génétique sur la diversité He simulée dans un verger à graines de 100 clones (traduit de Stoehr et al., 1997).*

Effect of number of clones on GD in a seed orchard (Stoehr & El-Kassaby (TAG) 1997

Effect of GD on germination success in Fagus sylvatica (Finkeldey & Ziehe (FEM) 2004



Some genetic background suggestions for ecological restoration

- Choosing the right origin matters! But local is not always best (particularly considering climate change). However, restoration projects can be genetic polluters for neighboring natural habitats (e.g. Pinus nigra in Europe); but also restoration projects can be safe-havens for endangered populations;
- Collecting enough diversity matters, particularly under uncertain climatic future! Diversify / mix sources within a region, sample seeds from as many individuals as possible within population (typically more than 30), write down geographic origin information and failed attempts;
- Adopt forest regulations for large forest restoration projects

Choosing the right origin and safeguarding adaptive potential: key challenges for ecological restoration under global change

Thank you for your attention!