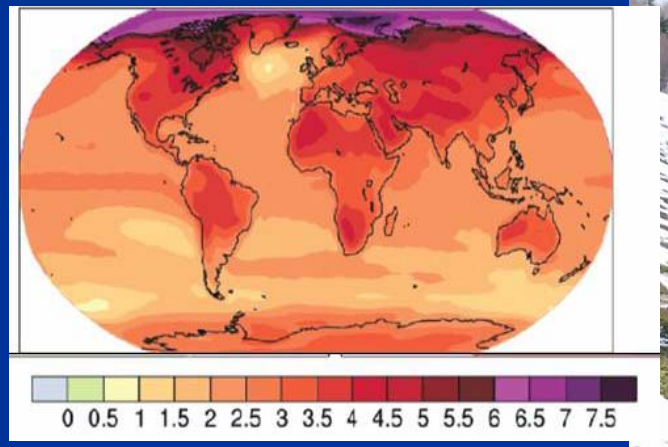
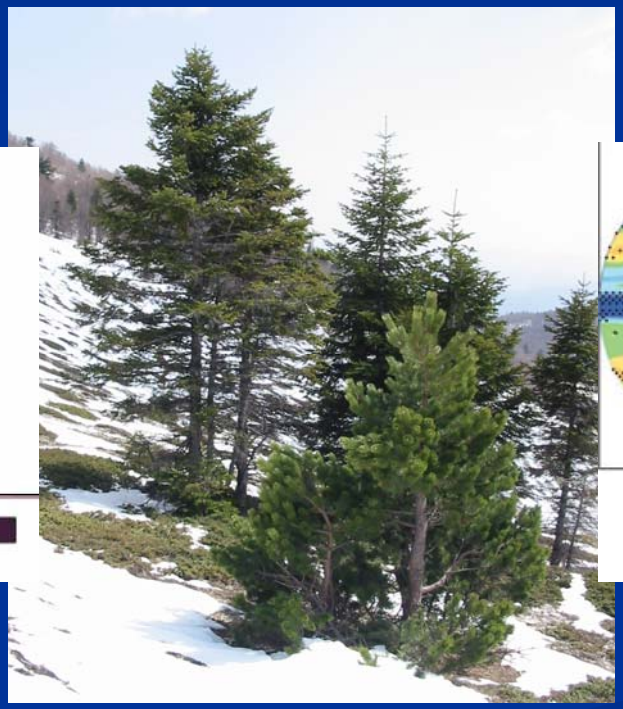
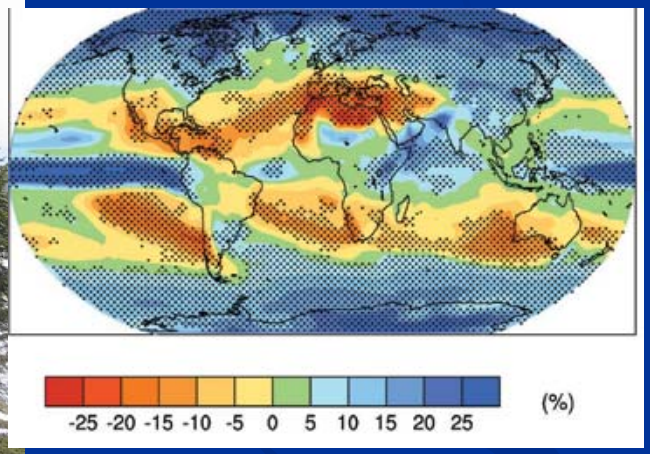
Adaptation of European forest trees to climate change

Bruno Fady
INRA – URFM, Avignon, France







European Forest Week
"Adaptation of forest trees to climate change: what are the implications for sustainable forest management in Europe?"
FAO headquarters, Rome, Italy, 21 October 2008

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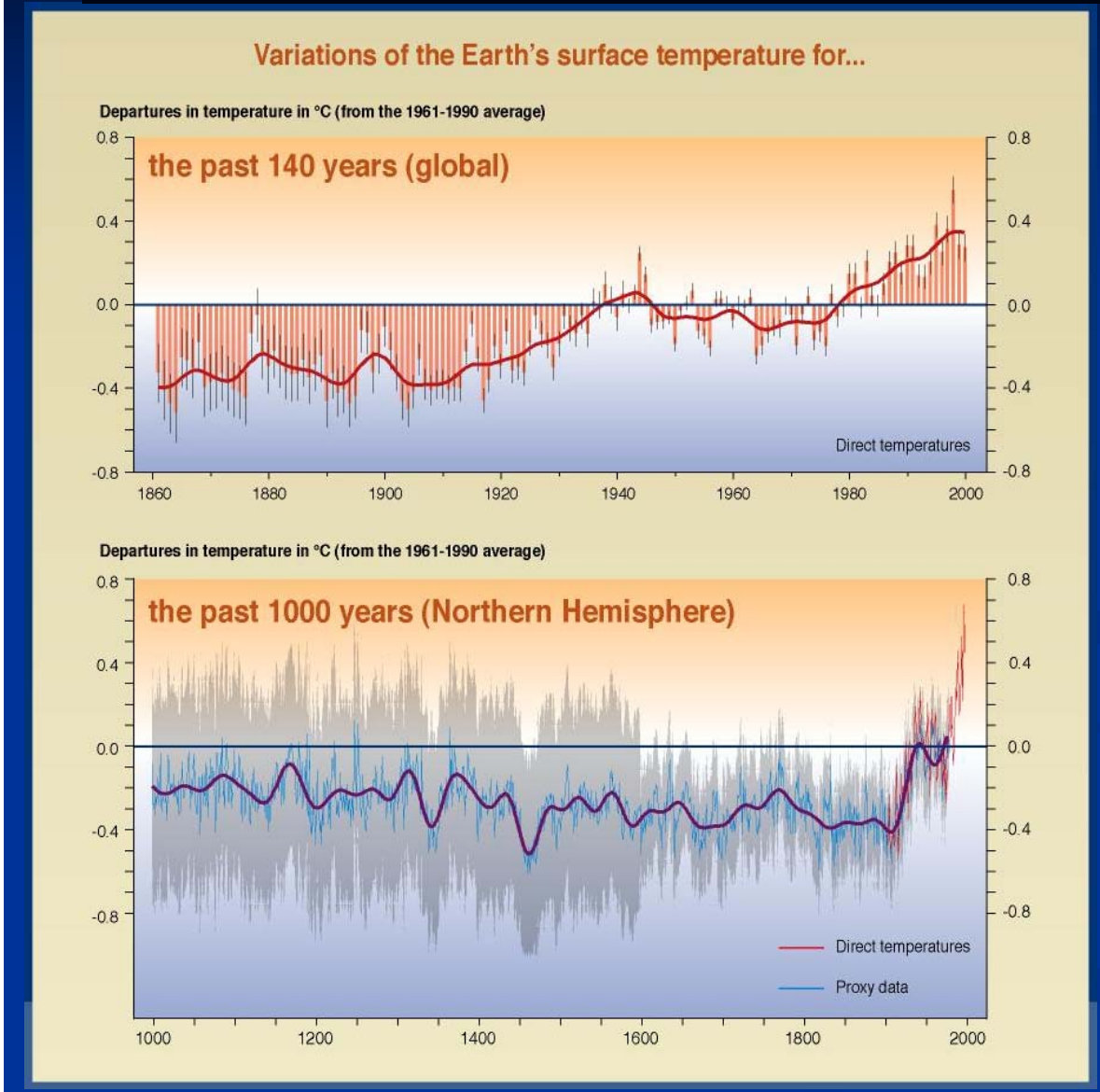
Adaptation of European forest trees to climate change

FAO headquarters, Rome, Italy, October 21, 2008

Climate change is now a reality. Climate change is here and now. It has happened and is predicted (with the highest level of confidence) to continue to do so for centuries to come.

What will its effect be on trees and forest ecosystems? What can **they** do to cope with change? What can **we** do to preserve our forests?

Climate change: What has already happened.



- Mean increase of 0.4°C compared to 1961-1990 average
- Widespread changes in extreme temperatures
- Cold days, cold nights and frost less frequent
- Hot days, hot nights, and heat waves more frequent
- Warming in the Arctic is double that of the globe over past 200 years

(All graphics on climate change are from http://www.ipcc.ch/graphics)

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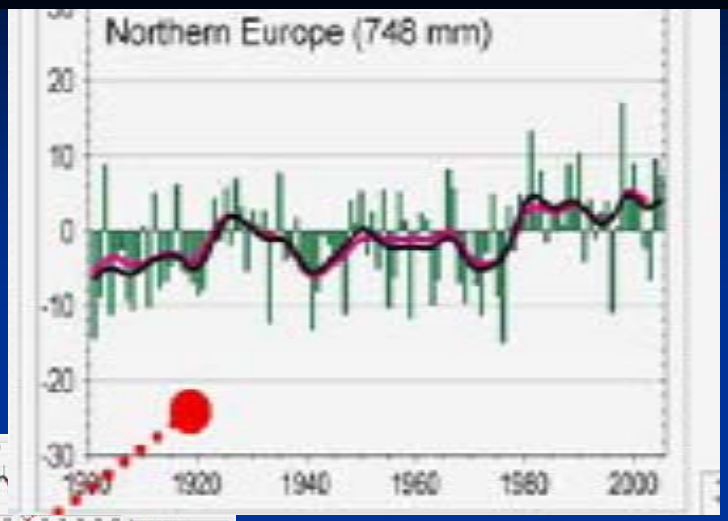
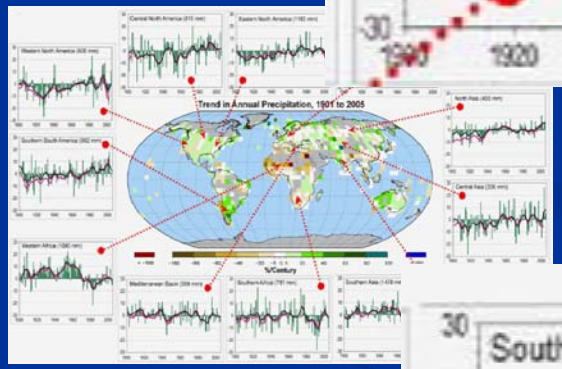
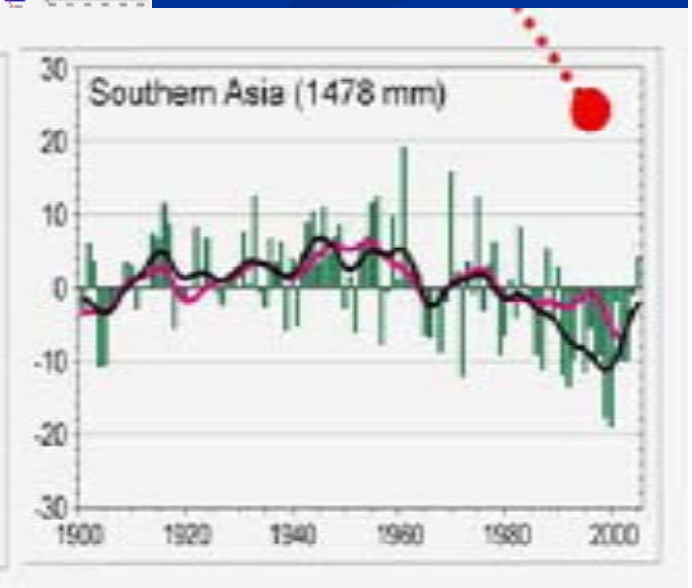
Climate change: What has already happened.

- Land precipitation is changing significantly over broad areas.
- Increased precipitation in parts of North and South America, northern Europe and northern and central Asia.
- Decreased precipitation in Africa, the Mediterranean and south-east Asia.
- The frequency of heavy precipitation events has increased over most land areas.





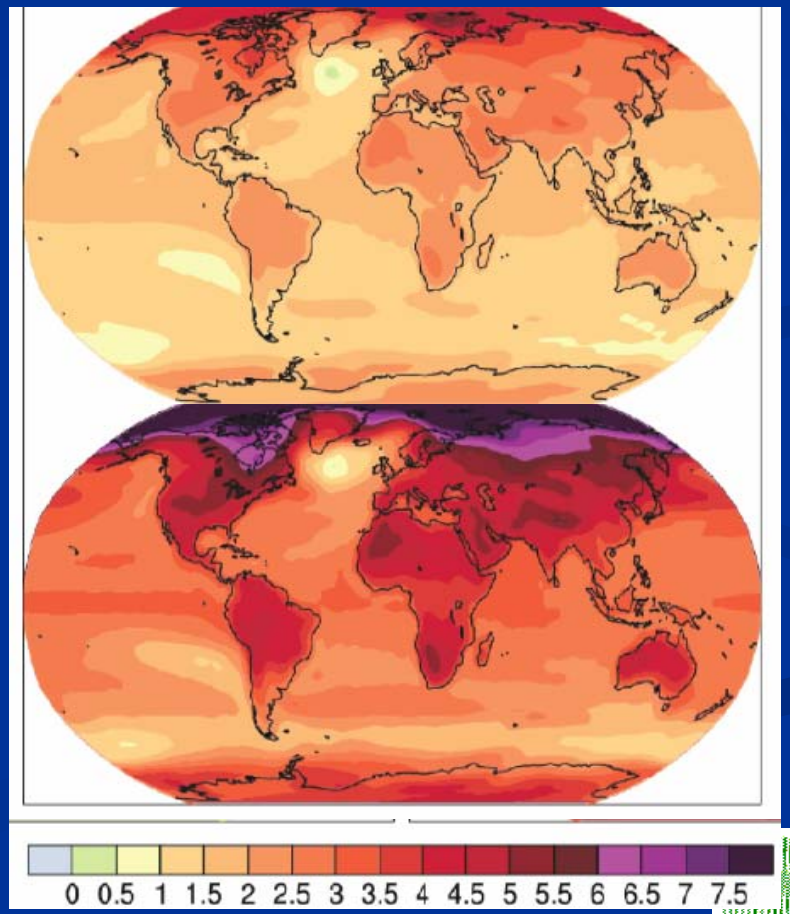


Climate change: What will happen soon

Projected warming in 21st century expected to be ***greatest*** over land and at northernmost latitudes and ***least*** over the Southern Ocean and parts of the North Atlantic Ocean

Best estimate for low scenario (B1) is 1.8°C (*likely* range is 1.1°C to 2.9°C),

and for high scenario (A1FI) is 4.0°C (*likely* range is 2.4°C to 6.4°C).



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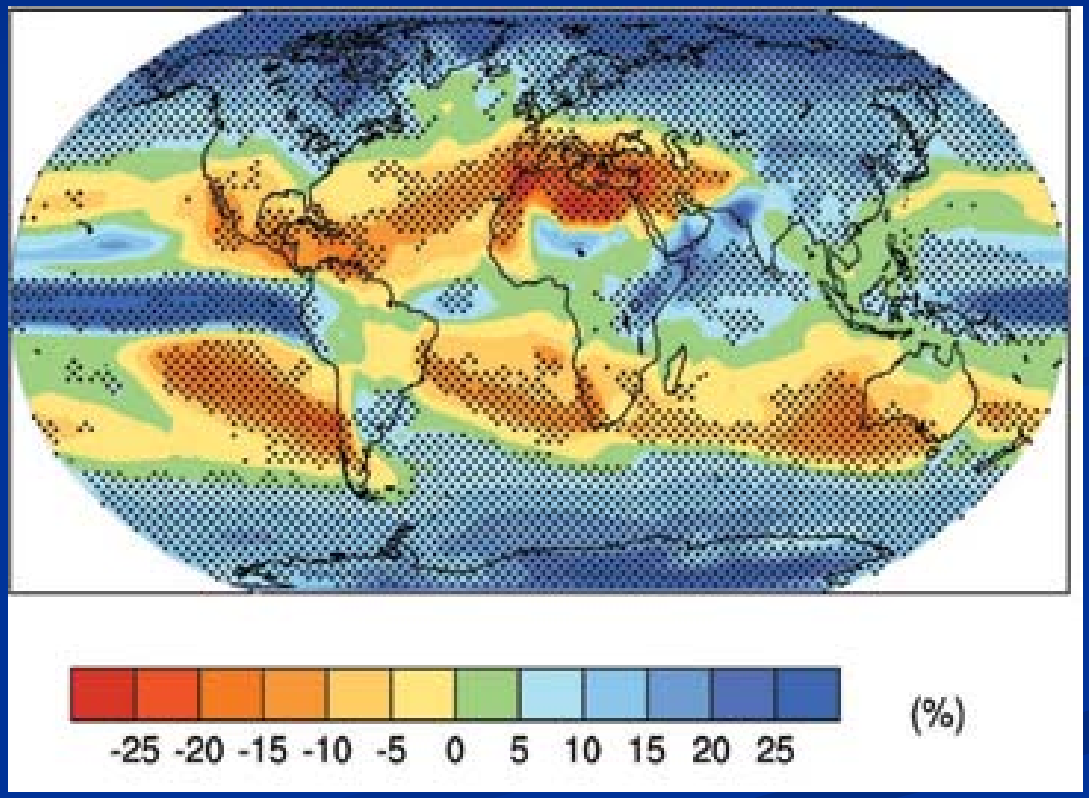
Climate change: What will happen soon

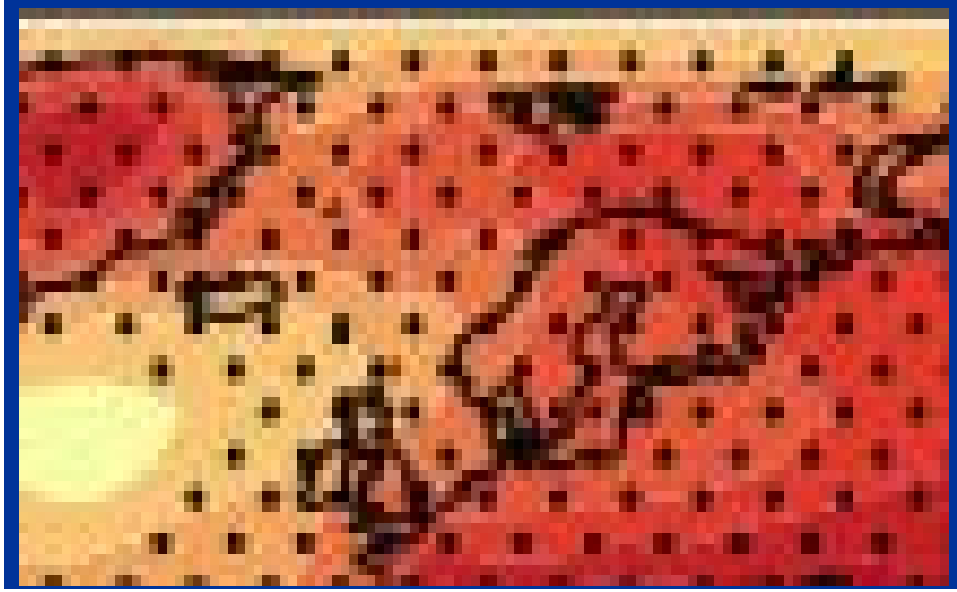
- Precipitation increases *very likely* in high latitudes
- Decreases *likely* in most subtropical land regions.

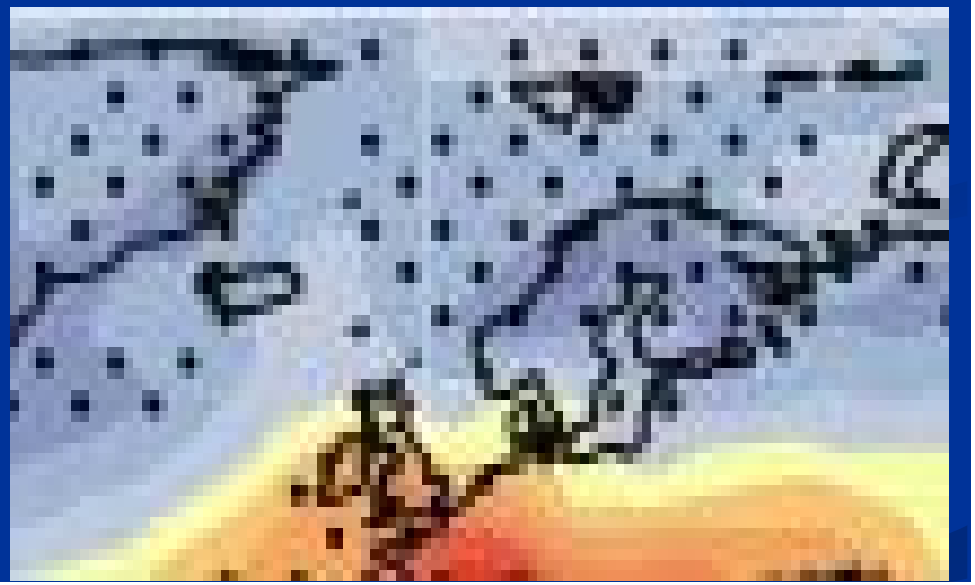
Worldwide mean: -0.2 to -0.4 mm per day.

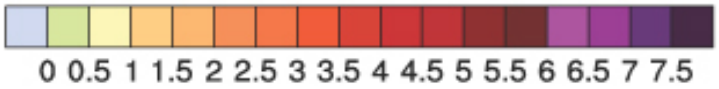


Nordic scenario (A1B, JJA 2080-2099)

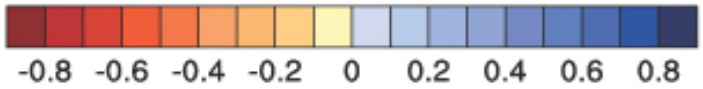
= increased *summer* heat (+2 to 4.5°C) and rainfall (+0.1 to 0.3 mm / day)!







(°C)



(mm day^{-1})

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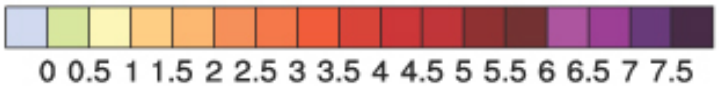
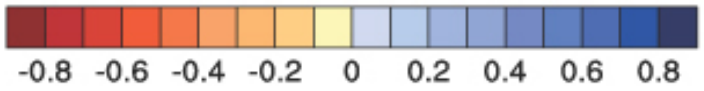
Nordic scenario (A1B, DJF 2080-2099)

= increased *winter* heat (+2 to 7°C) and rainfall (+0.1 to 0.4 mm / day)!





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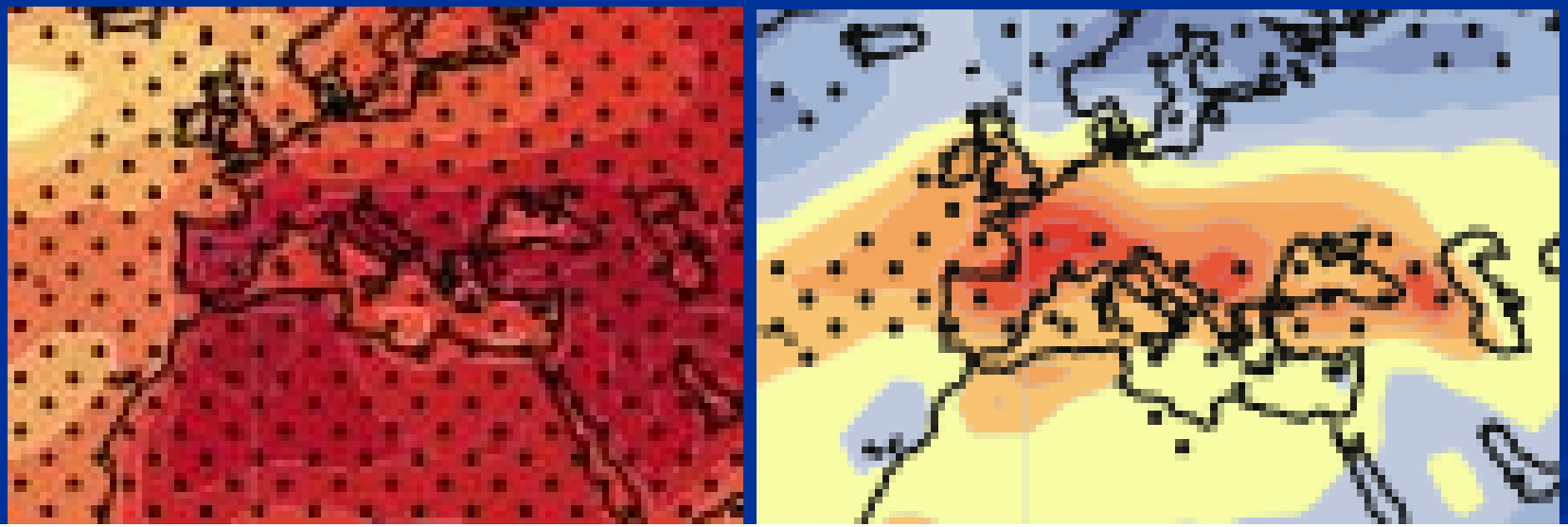
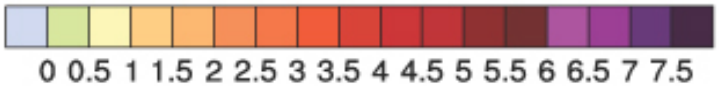
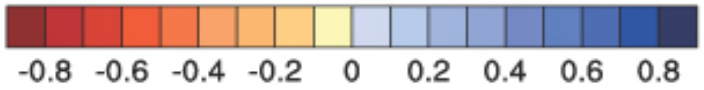
Mediterranean scenario (A1B, JJA 2080-2099)

= increased *summer drought*
(+3 to 5°C; -0.1 to -0.4 mm/day)!





(°C)



(mm day^{-1})

Climate change and forest trees

=> Significant changes in temperature and precipitation regimes

=> Significant consequences on survival and distribution (adaptation) of forest tree species and ecosystems

What can trees do to cope with climate change ?

Trees may use 3 strategies (adaptation *sensu lato*) to face any ecological change:

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

- **adaptation** *sensu stricto* (selection of progeny with highest fitness)

- movement through **dispersal** (regeneration under friendlier environments after long distance dispersal or hybridization)

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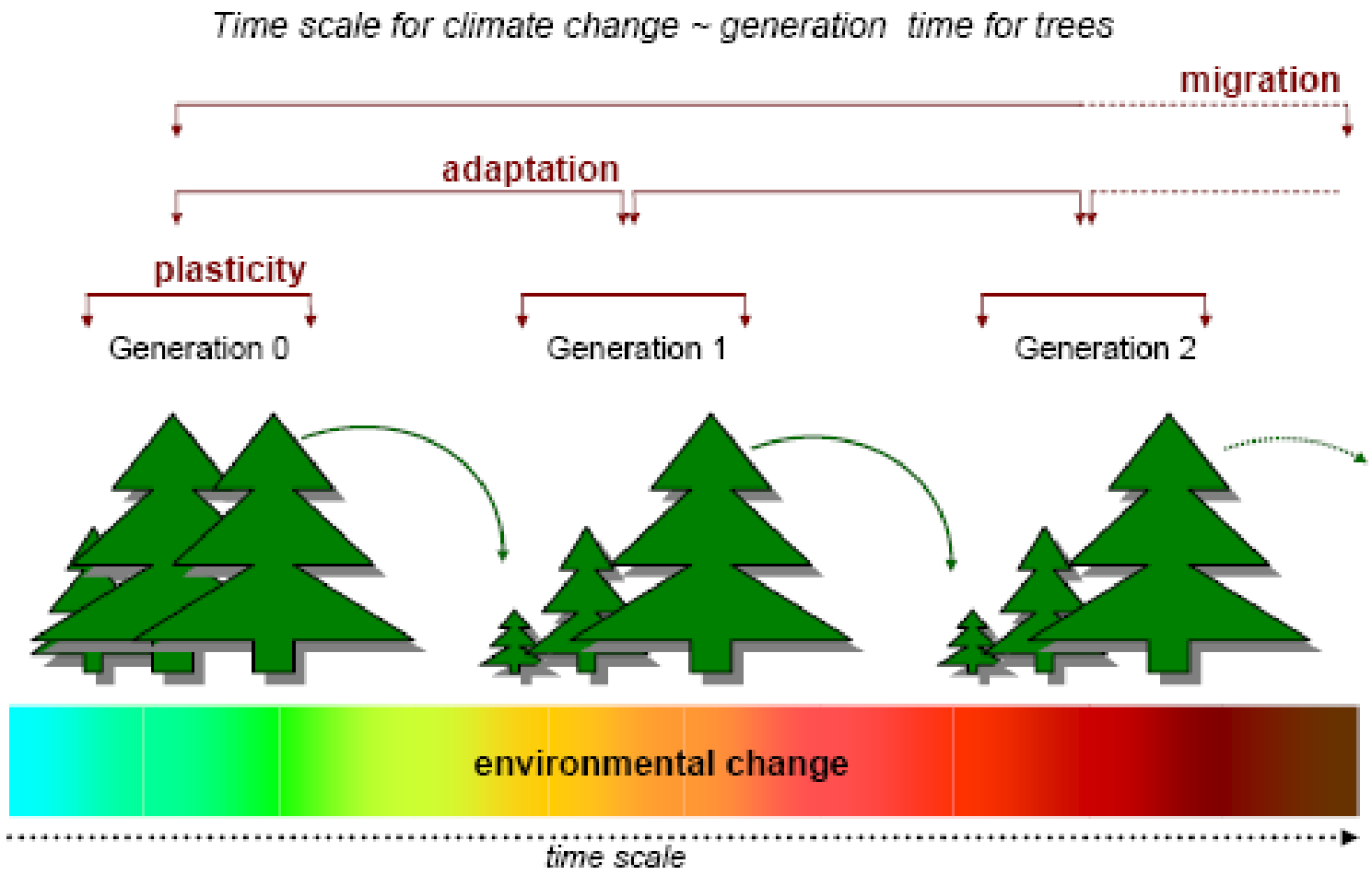
What can trees do to cope with climate change?
A question of time



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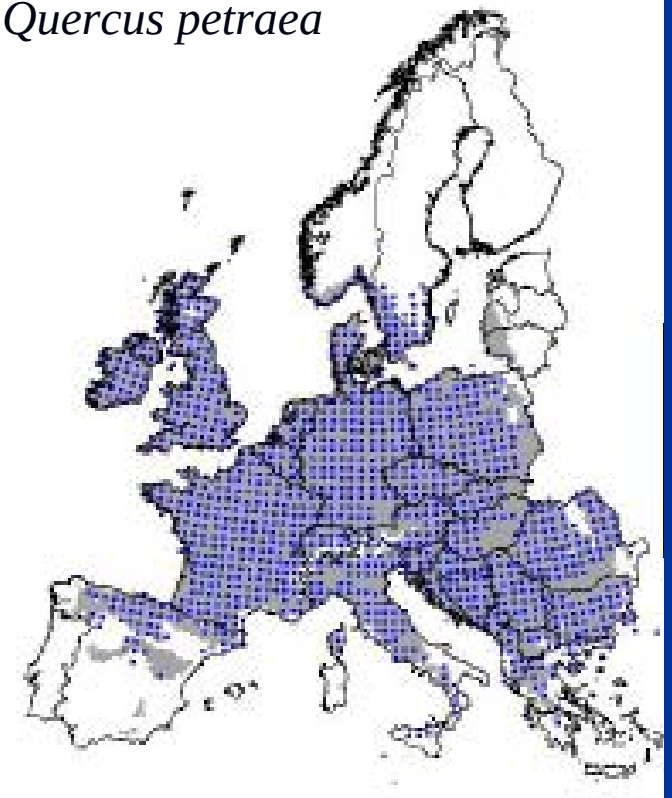
What will happen to trees that are present in the areas where ecological conditions are no longer optimal?

Phenotypic plasticity

Quercus petraea



Phenotypic plasticity (among other factors) determines the ecological niche and the geographic distribution of a species

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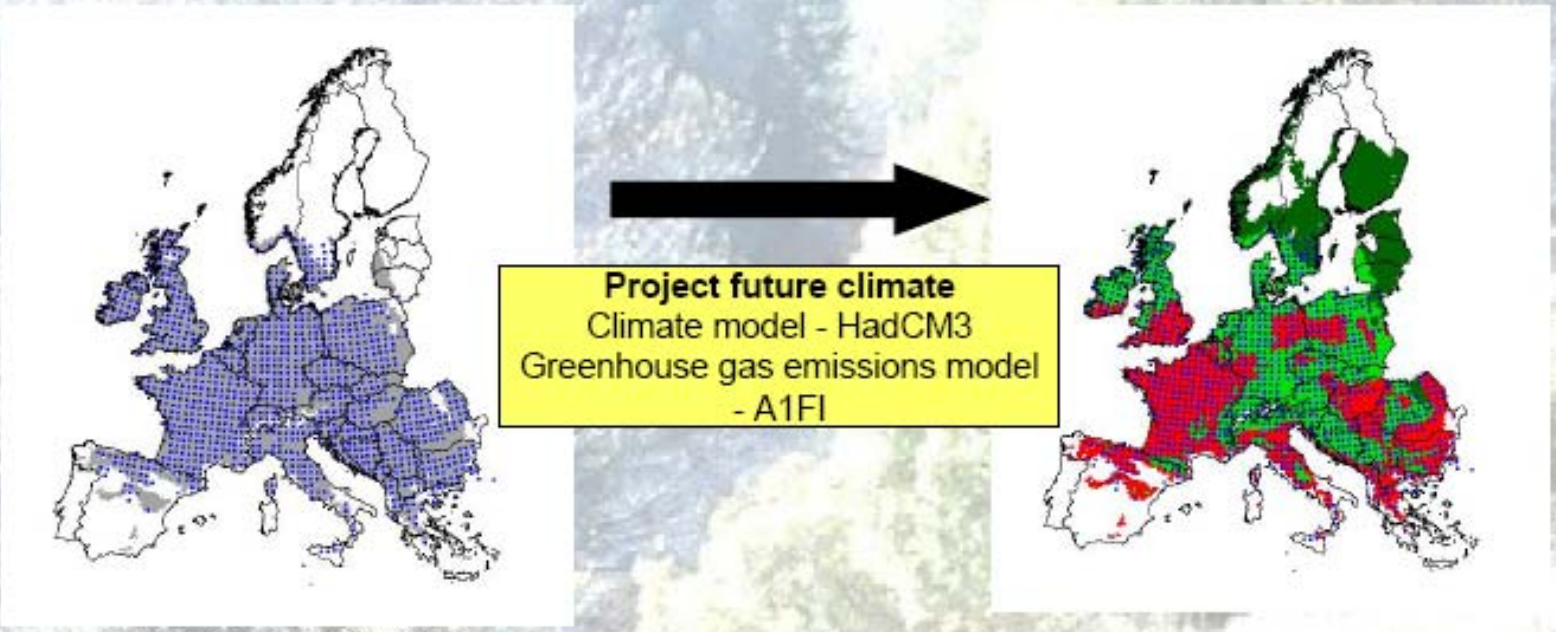
What will happen to trees that are present in the areas where ecological conditions are no longer optimal?

(some limitations to) *Plasticity*

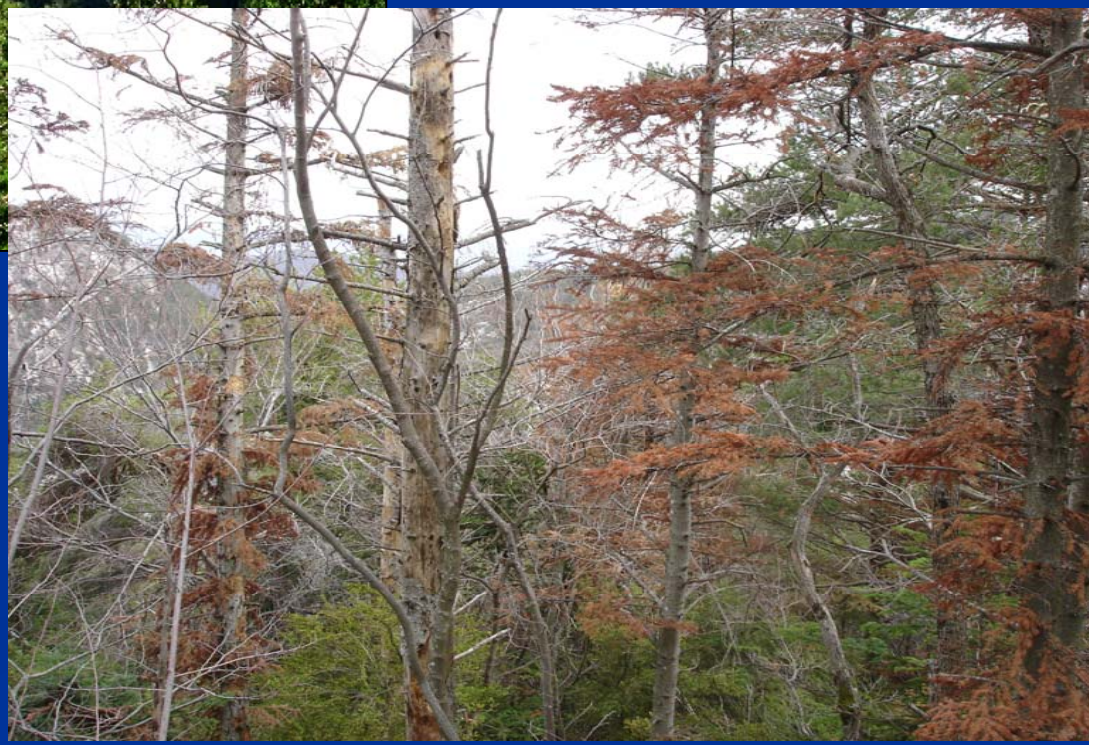


Quercus petraea, Thuiller GCB 2003, Thuiller et al. PNAS 2005

What will happen to trees that are present in the areas where ecological conditions are no longer optimal?

(some limitations to) *Plasticity*

Marginal stands: autochthony is not always best



Abies alba dieback after the 2003 summer heat wave, southern France (Mont Ventoux, elevation 1200 m).

What will happen to trees that are present in the areas where ecological conditions are no longer optimal?

Adaptation

Forest trees:

- are very variable in their genetic diversity despite known bottlenecks in their history (*Hamrick et al., NEFO 1992; Fady, Taxon 2005*)
- show altitudinal and latitudinal clines of adaptation for many traits (*e.g.* bud break and flower phenology) (*Mimura & Aitken, Heredity 2007*)

i.e. there is potential for adaptation when the environment changes

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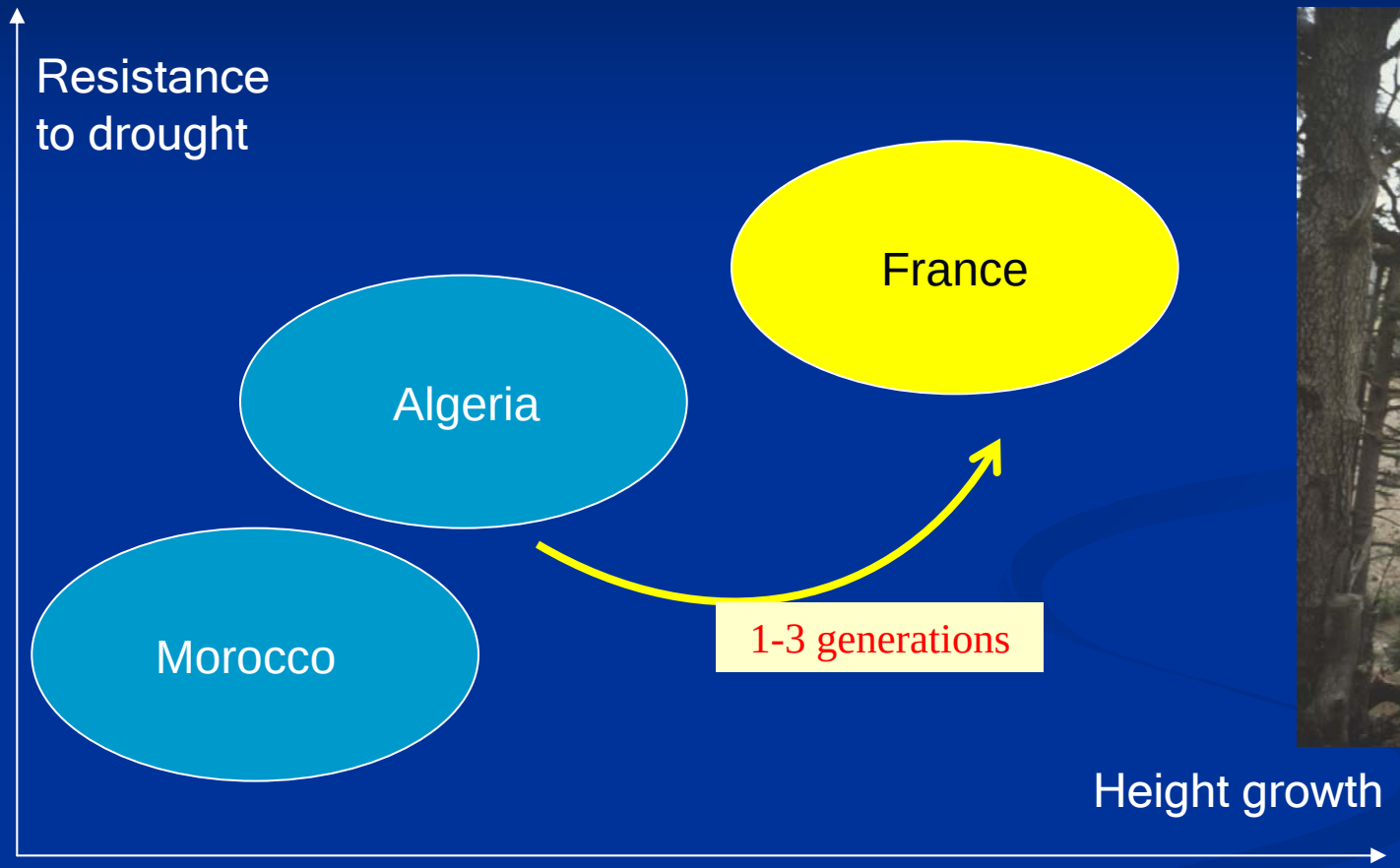
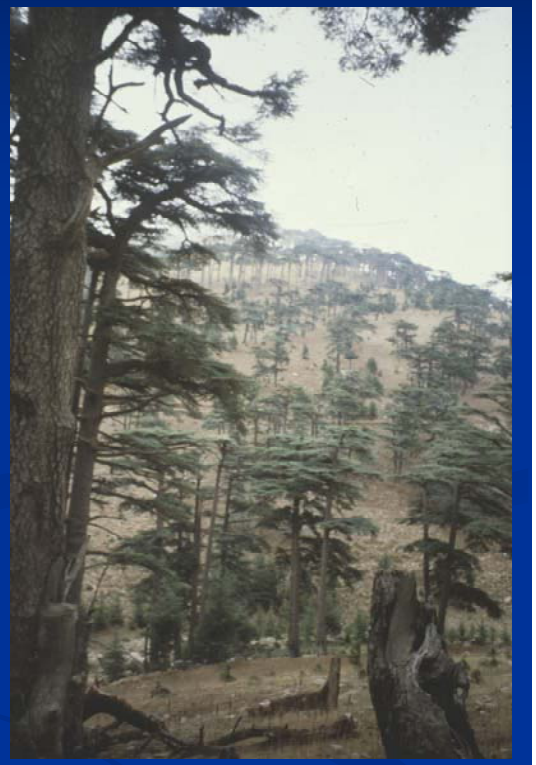
What will happen to trees that are present in the areas where ecological conditions are no longer optimal?

Adaptation





An ecological crisis can rapidly trigger adaptation through selection and strong bottlenecks. ==> **material for breeding!!** *Lefèvre et al. unpublished*

An example with two fitness related traits in French *Cedrus atlantica* common gardens

What will happen to trees that are present in the areas where ecological conditions are no longer optimal?

***Adaptation** is possible, but at which costs?*

• Although very genetically diverse, several tree genera went extinct in Europe because of climate change during the Pleistocene (glacial / interglacial cycles): *Taxodium*, *Sequoia*, *Cedrus*, ...

• Genetic variability of different traits may be inversely correlated. Fitness related traits may involve many low effect genes.

• A need for 1 to 12 generations to accommodate for climate change (*Rehfeld et al., Global Ch Biol 2002*) in *Pinus sylvestris* depending on location ==> 50 to 1000 years!

• Marginal populations (the "founder" populations under climate change) are genetically different and under more severe threats than core populations (*Mimura & Aitken, Am J Bot 2007; Restoux et al., Web Ecol 2008*).

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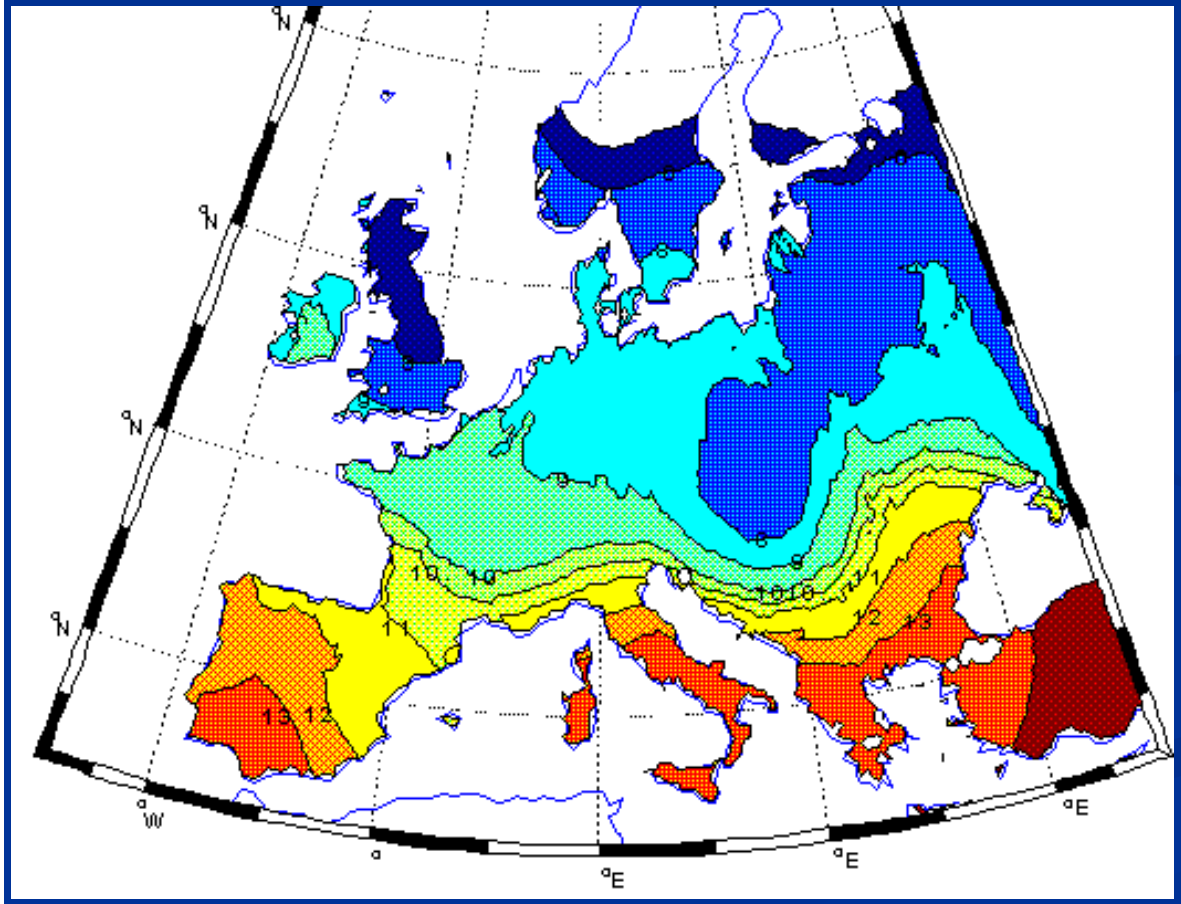
What will happen to trees that are present in the areas where ecological conditions are no longer optimal?

Long distance dispersal



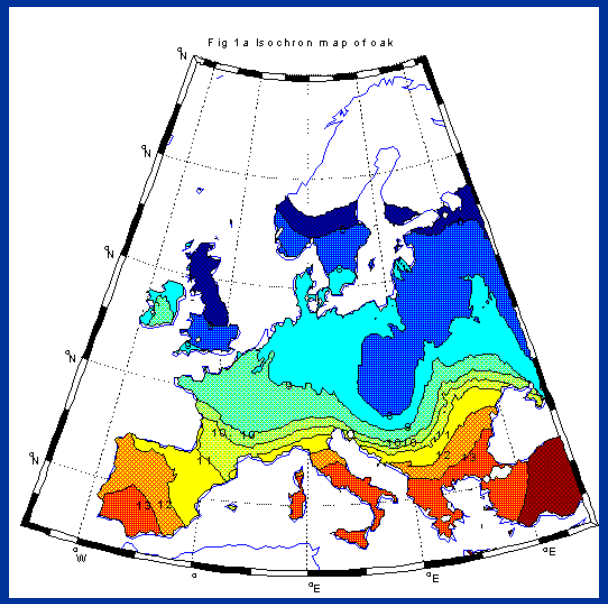
European oak isochronal pollen map (www.pierroton.inra.fr/Fairoak/)

Fossil pollen data show a rapid habitat recolonization of tree species across Europe after the last Ice Age (up to 500 m per year on average during the last 12 000 years) (*Hewitt, Nature 2000; Petit et al., Science 2003*)

… is this enough?

Is long distance dispersal (estimated from paleo-records) enough to track climate change?

"… the (*Pinus sylvestris*) genotypes best suited to the climate of 2090 currently exist at large distances (>1000 km) from the site of their future optima" (*Rehfeld et al., GBC 2002*)



==> 2000 years needed to reach 2090 conditions!!

and …

current landscape structure prohibits long distance dispersal!

What will happen to trees and forest ecosystems?

Clearly, trees can

- acclimatize,
- adapt,
- move …

… but only up to a certain limit!

And this is where scientific and policy making and management challenges remain.

What can be done to protect our forest ecosystems and resources against climate change?
- Research and development -

✓ Research has to better understand the effects of climate (and global) change on tree diversity, physiology, ecosystem functioning, in interaction with social sciences, etc. ==> Multi-scale projects, multidisciplinary projects, but also long term monitoring projects. Prospects in ecological genomics.

✓Breeding must take into consideration the fact that the environment is not stable any longer ==> include some long term plasticity component

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What can be done to protect our forest ecosystems and resources against climate change?
- Policy making and management -

✓ Public awareness needs to be better raised on climate change and its effects on forest ecosystems and resources:

==> strengthen collaborative networks (such as Euforgen) that aim at raising public awareness.

==> better integrate conservation (genes, species, habitat) networks and conservation networks with management. Too often is conservation limited in scope and management devoid of conservation considerations.

What can be done to protect our forest ecosystems and resources against climate change?
- Policy making and management -

✓ The “forest community” needs to ask itself the question: “what can I do with already existing knowledge and uncertainties ?”

==> managing to increase evolutionary potential as an everyday practice!

What can be done to protect our forest ecosystems and resources against climate change?
- Managing to increase evolutionary potential -

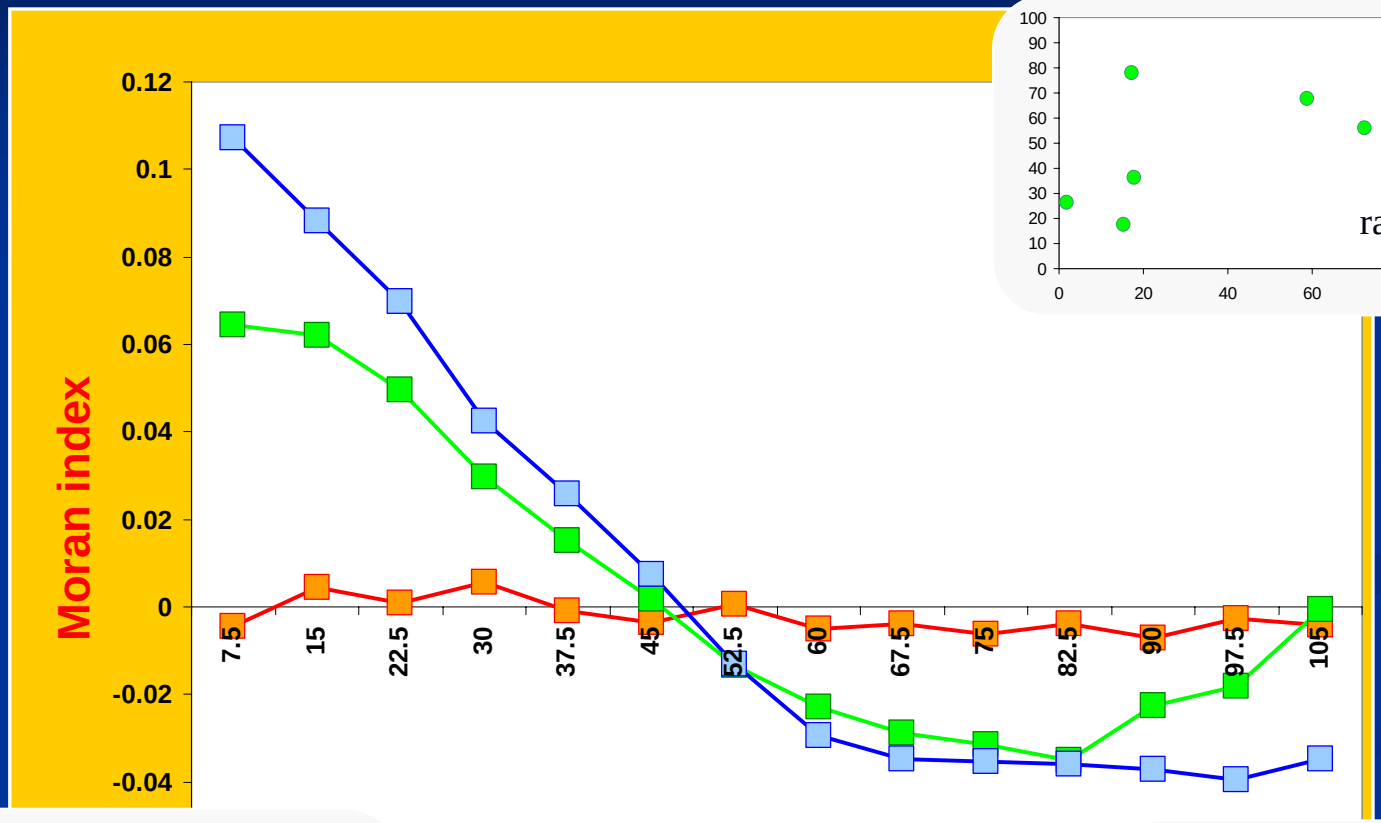
1- Make sure marginal and disjunct areas (where ecological conditions are already severe and selection already at work) are included within conservation networks and research strategies. Extirpate / transfer populations most at risk.

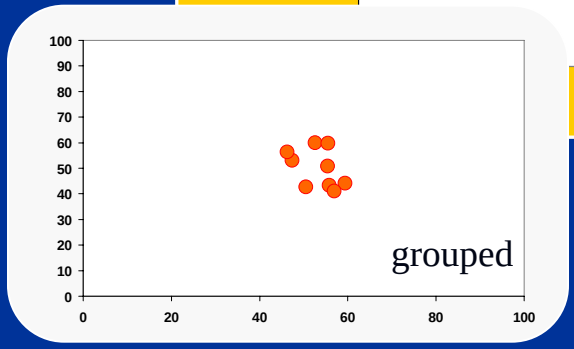
What can be done to protect our forest ecosystems and resources against climate change?
- Managing to increase evolutionary potential -

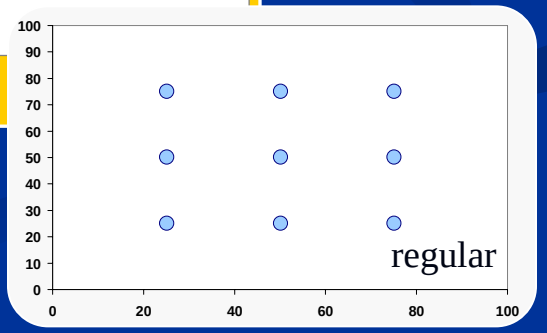
2- Diversify management systems within the same climatic zone / forest area to facilitate and promote evolutionary mechanisms:

- *e.g.* increase plantation density,
- *e.g.* avoid fragmentation, too small populations,
- *e.g.* multi species management (mixed forests),
- *e.g.* variable densities (mosaic type structures) …

Distribution of adult trees and spatial genetic structure of their seedlings: a computer simulated example using a biallelic locus (*Sagnard et al., unpublished*)







What can be done to protect our forest ecosystems and resources against climate change? - Managing to increase evolutionary potential -

3- Use proper Forest Reproductive Material (FRM).

- the cheapest FRM is not necessarily the best. Do not plant in marginal areas.

- change seed collection practice. Seed lots should be made of at least 20 trees per populations or a mix of trees from several populations within one region of provenance. Enough genetic diversity for selection to work on is crucial!

- Breeding program must include plasticity

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What can be done to protect our forest ecosystems and resources against climate change?
- Managing to increase evolutionary potential -

4- Follow plantation guidelines and seed transfer rules, but:

- Include southern / heat resistant / high phenotypic plasticity FRM in a-forestation / reforestation projects?

- Plant outside current distribution area (*e.g.* beyond current northern limits)?

- Promote hybridization (within and among natural and exotic species)?

- Ask the question “should I plant anything at all or should I promote natural regeneration?”

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What can be done to protect our forest ecosystems and resources against climate change?
- Managing to increase evolutionary potential -

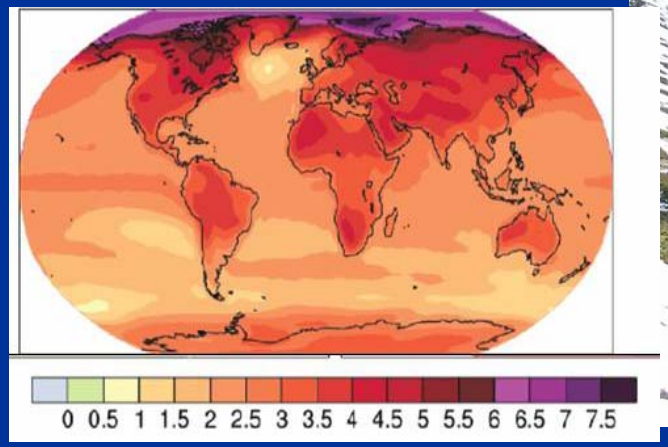
We have some tools …

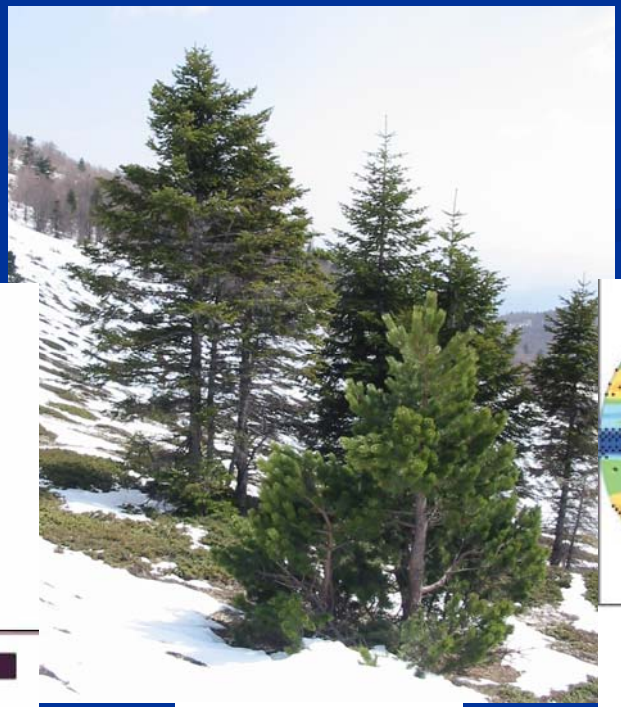
… and we should use them !

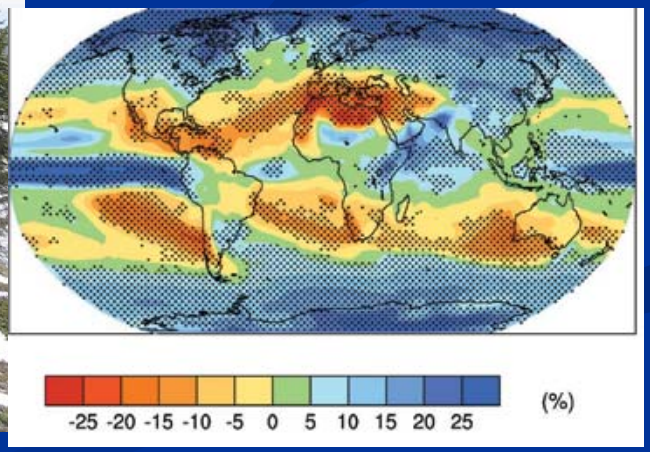
European Forest Week, *FAO headquarters, Rome, Italy, 21 October 2008*

Adaptation of European forest trees to climate change

Thank you for your attention !







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