# MITIGATION OF CLIMATE CHANGE VIA GENETIC RESOURCES AND PROCESSES IN FOREST TREES

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*Workshop « Climate change and biodiversity for food and agriculture »*

*FAO, Rome, February 13-14 2008*

*Ecology Letters*, (2005) **8**: 1010–1020 doi: 10.1111/j.1461-0248.2005.00796.x

**REVIEWS AND SYNTHESES**

## Running to stand still: adaptation and the response of plants to rapid climate change

alter their genetic composition. The consequences are likely to include unpredictable changes in the presence and abundance of species within communities and a reduction in their ability to resist and recover from further environmental perturbations, such as pest and disease outbreaks and extreme climatic events. Overall, a range-wide increase in extinction risk is likely to result. We call for further research into understanding the

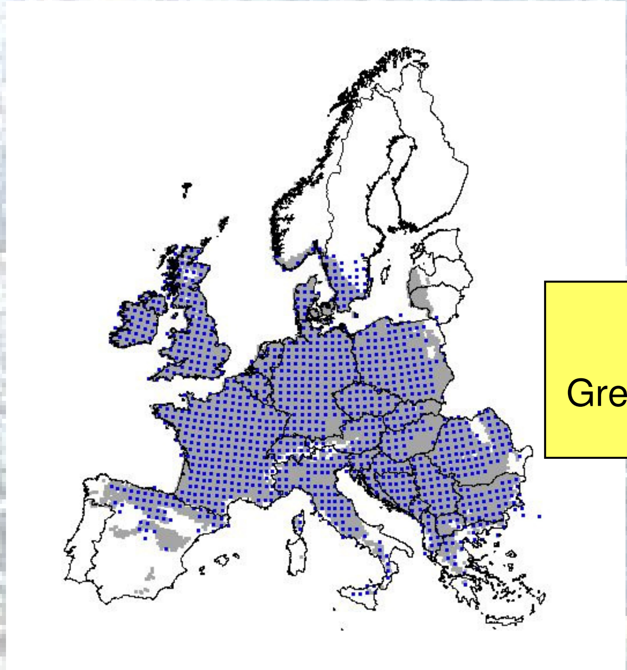
PNAS

## Climate change threats to plant diversity in Europe

Wilfried Thuiller[*,†,‡,§], Sandra Lavorel[*,¶], Miguel B. Araújo[*,‡,‖], Martin T. Sykes[**], and I. Colin Prentice[††]

could become severely threatened. More than half of the species we studied could be vulnerable or threatened by 2080. Expected species loss and turnover per pixel proved to be highly variable across scenarios (27–42% and 45–63% respectively, averaged over Europe) and across regions (2.5–86% and 17–86%, averaged over scenarios). Modeled species loss and turnover were found to

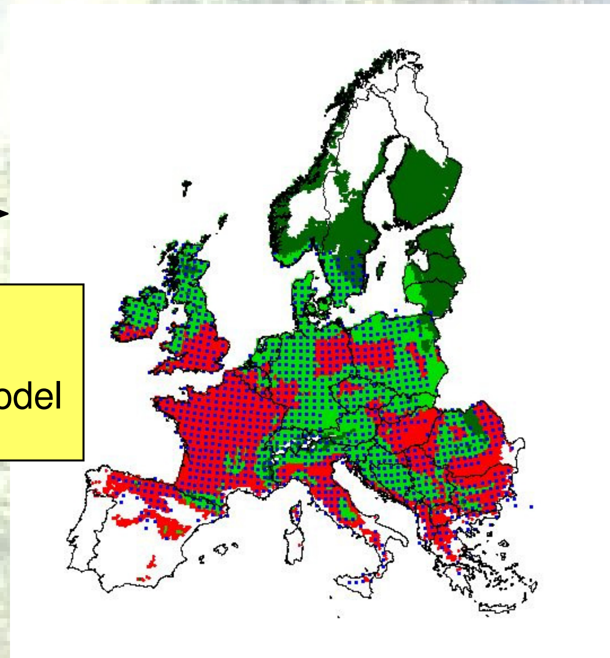
## *SHIFT OF Quercus petraea CLIMATIC ENVELOPE AS A RESULT OF CLIMATE CHANGE*



**Current Distribution**
simulated using BIOMOD

- **Observation**
- **Simulation**

**Project future climate**
Climate model - HadCM3
Greenhouse gas emissions model - A1FI

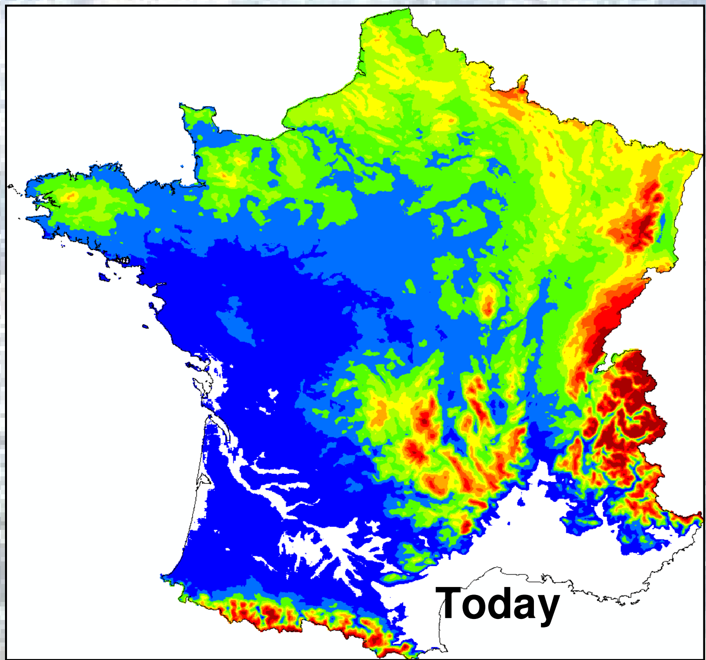


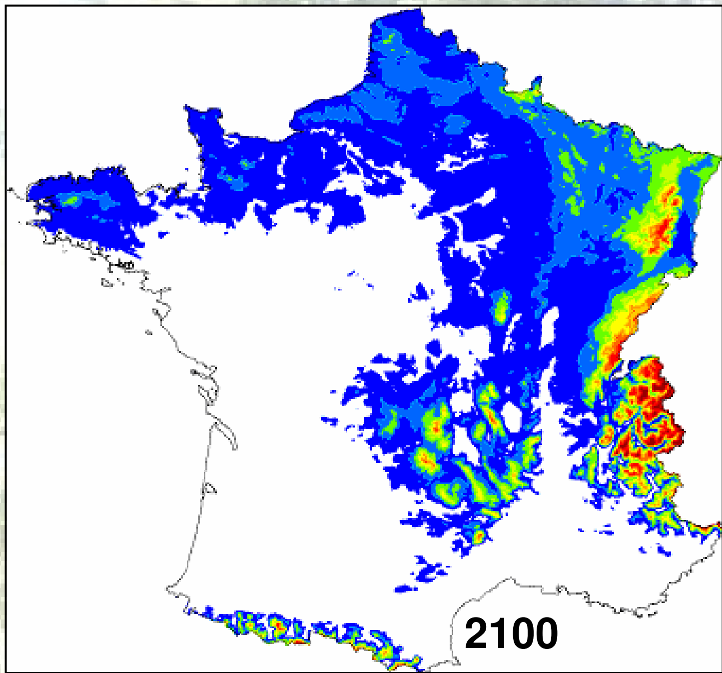
**Future Distribution: 2080**
simulated using BIOMOD

**Loss of habitat**
**Stable habitat**
**Gain of habitat**

Thuiller 2003 *Global Change Biology* 9:1353-1362
Thuiller et al. 2005, *PNAS* 102:8245-8250

## *SHIFT OF CLIMATIC ENVELOPPES OF BEECH IN FRANCE*

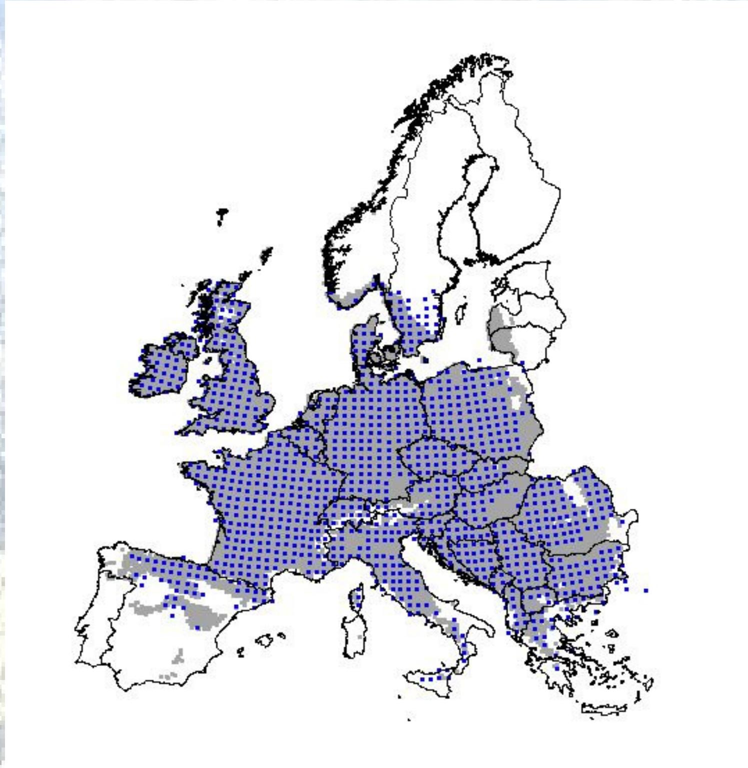


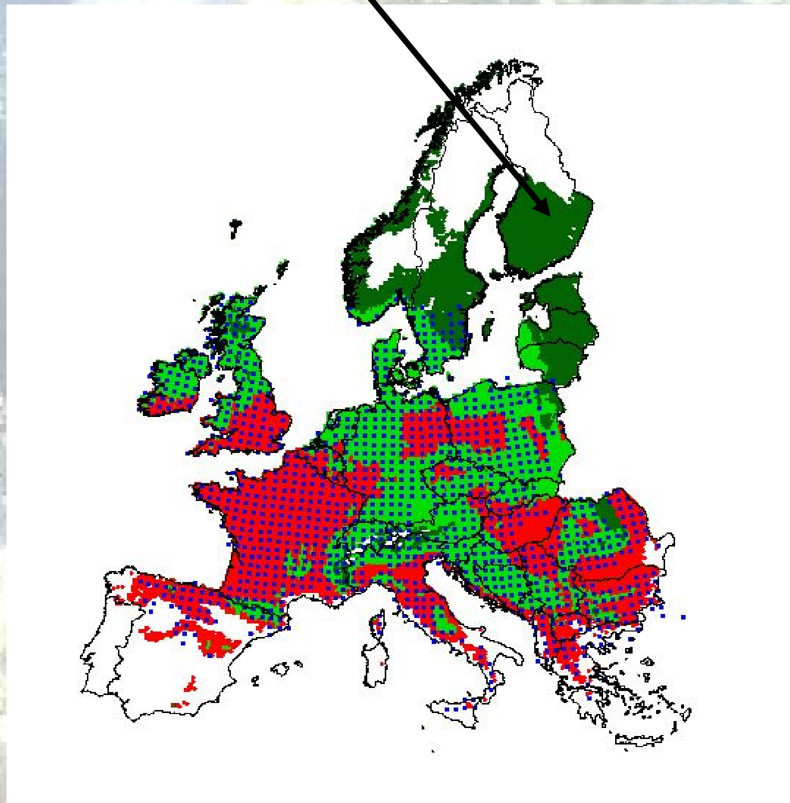




***Fagus sylvatica***

Badeau et al (2005)

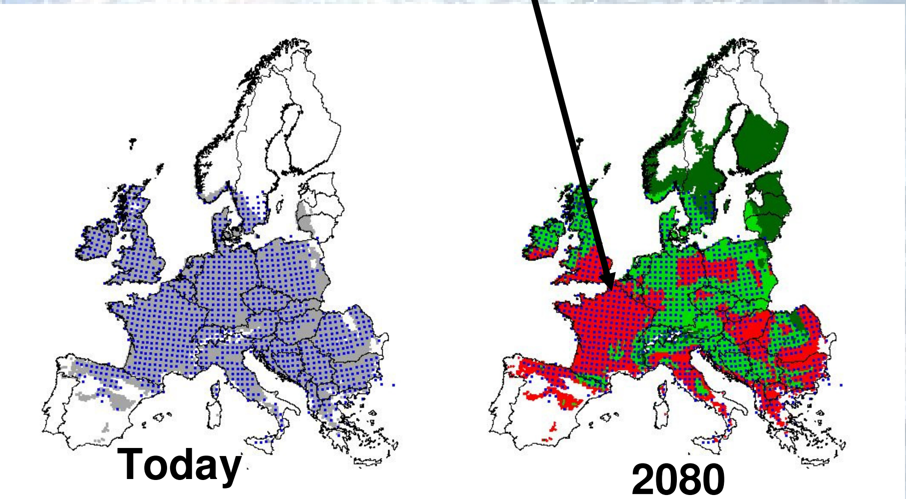
*What is likely to happen in the northern part ?*





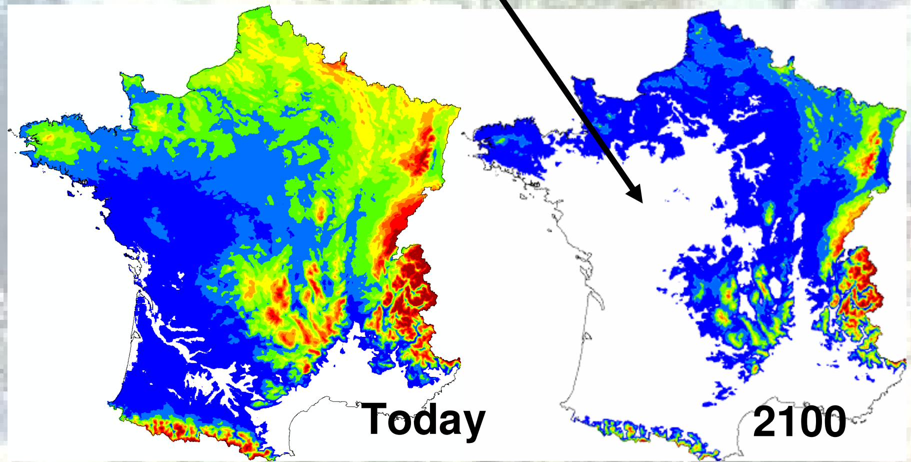
*MIGRATION ? COMPETITION WITH EXISTING SPECIES?*

## *What will happen in the central part of the range ?*




***Quercus petraea*** **- BIOMOD**

**Thuiller (2003)**

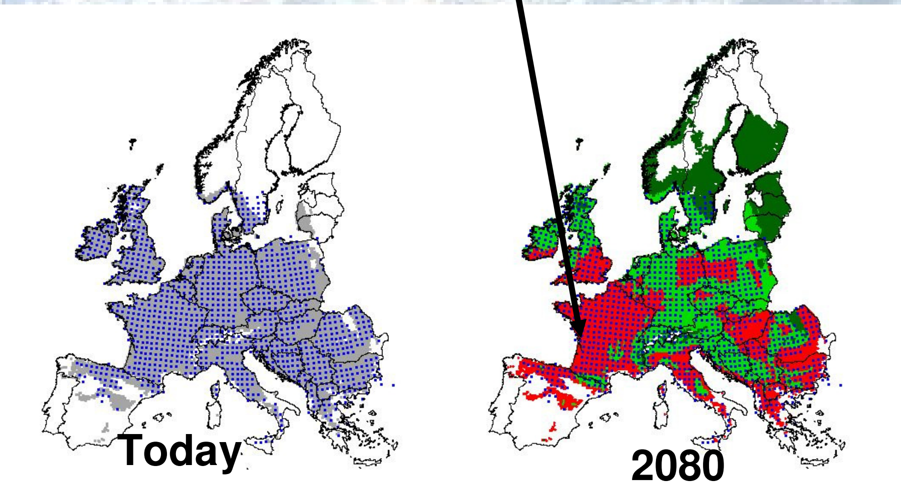


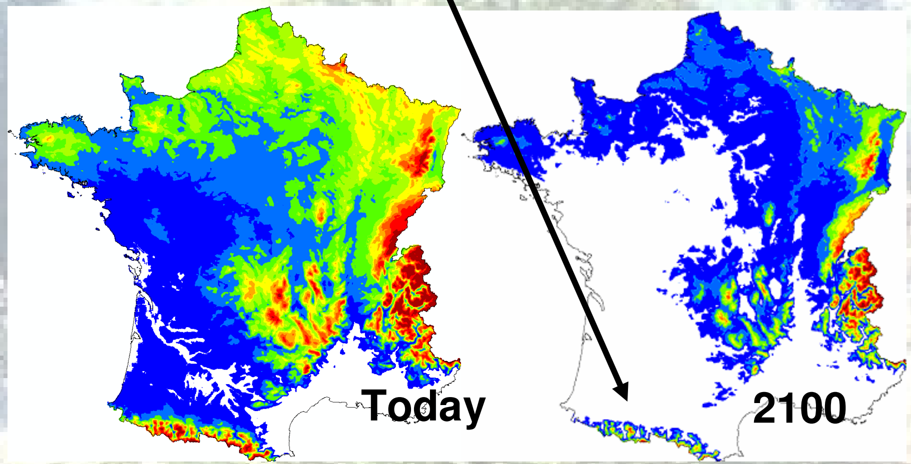

***Fagus sylvatica*** **- Nancy NBM**

**Badeau et al (2005)**

## *DECLINE? ADAPTATION ?*

## *What will happen in the southern part of the range ?*




***Quercus petraea*** **- BIOMOD**

**Thuiller (2003)**

***Fagus sylvatica*** **- Nancy NBM**

**Badeau et al (2005)**

## *DECLINE ?  EXTINCTION ?*

1 NORTHERN LIMIT

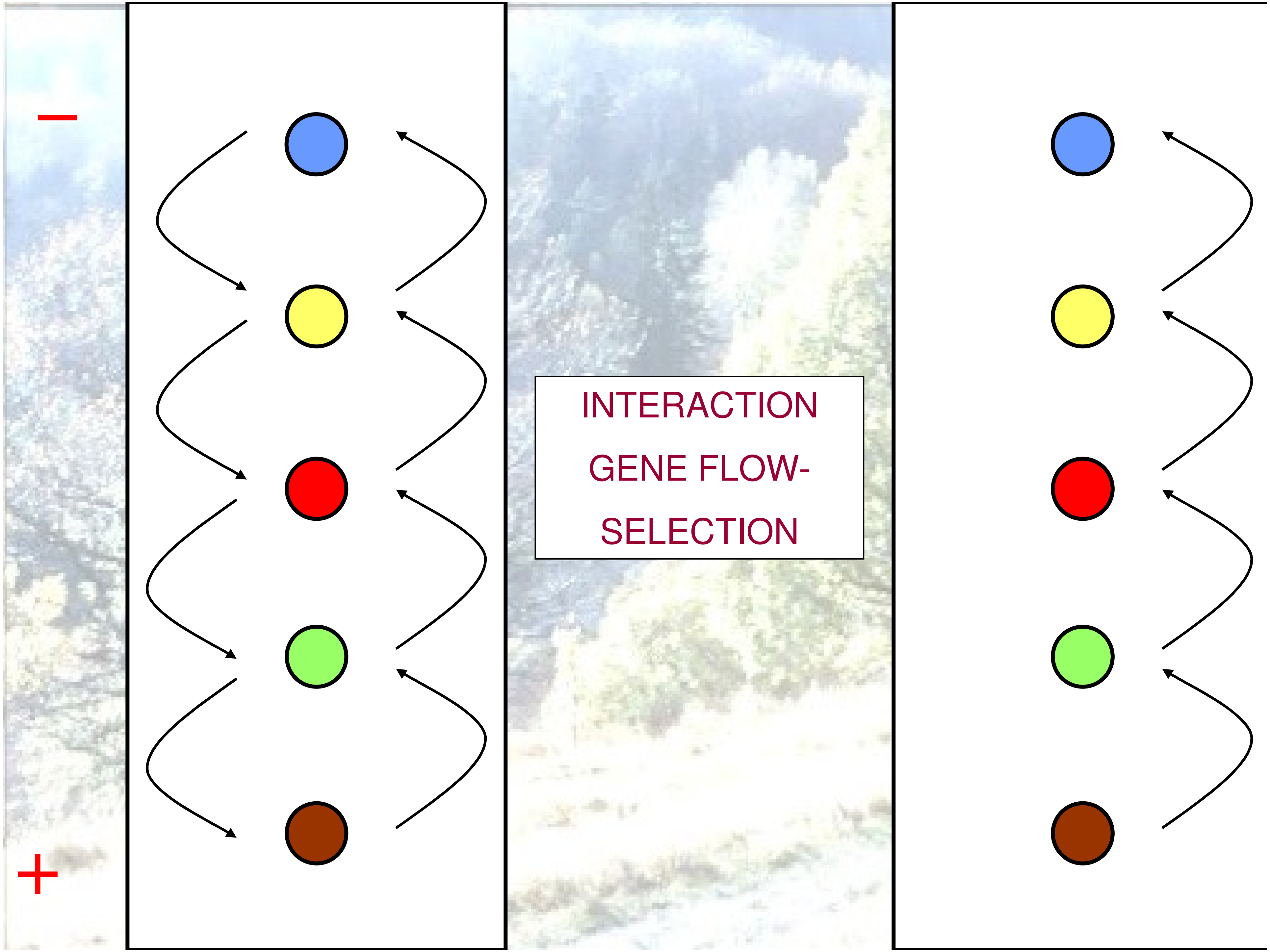
2 CENTRAL PART

3 SOUTHERN LIMIT

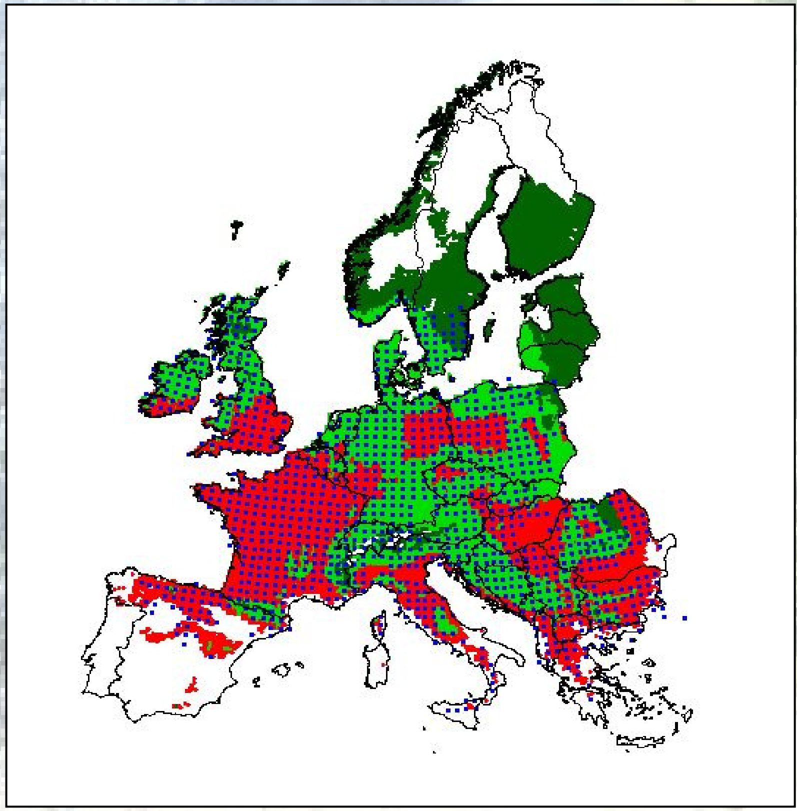
Evolutionary history of trees

Artificial transfer of species mimicking climate change

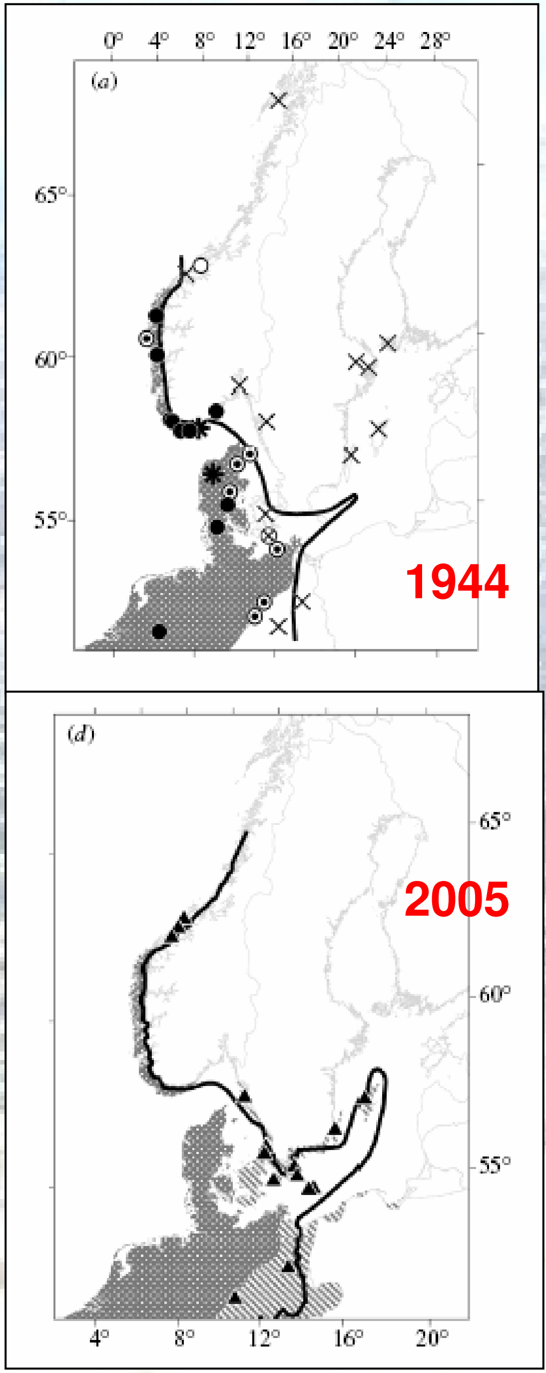
Provenance research


–
+
INTERACTION
GENE FLOW-
SELECTION

# 1 NORTHERN LIMIT



PREDICTED SHIFT OF **100 TO 500 KM** OF THE CLIMATIC ENVELOPPE




Présence mais stérile

Présence

X Absence

Isotherme 0 ° Janvier

## *CHANGES OF THE NORTHERN LIMIT OF HOLLY (Ilex aquifolium)*

Nouvelles occurences

**An ecological 'footprint' of climate change**

Gian-Reto Walther[1,*], Silje Berger[1] and Martin T. Sykes[2]

*Proc. R. Soc. B* (2005) 272, 1427–1432

# POSTGLACIAL MIGRATION VELOCITY IN THE BRITISH ISLES

20 to 50 Km in 100 years

100 to 500 Km in 100 years

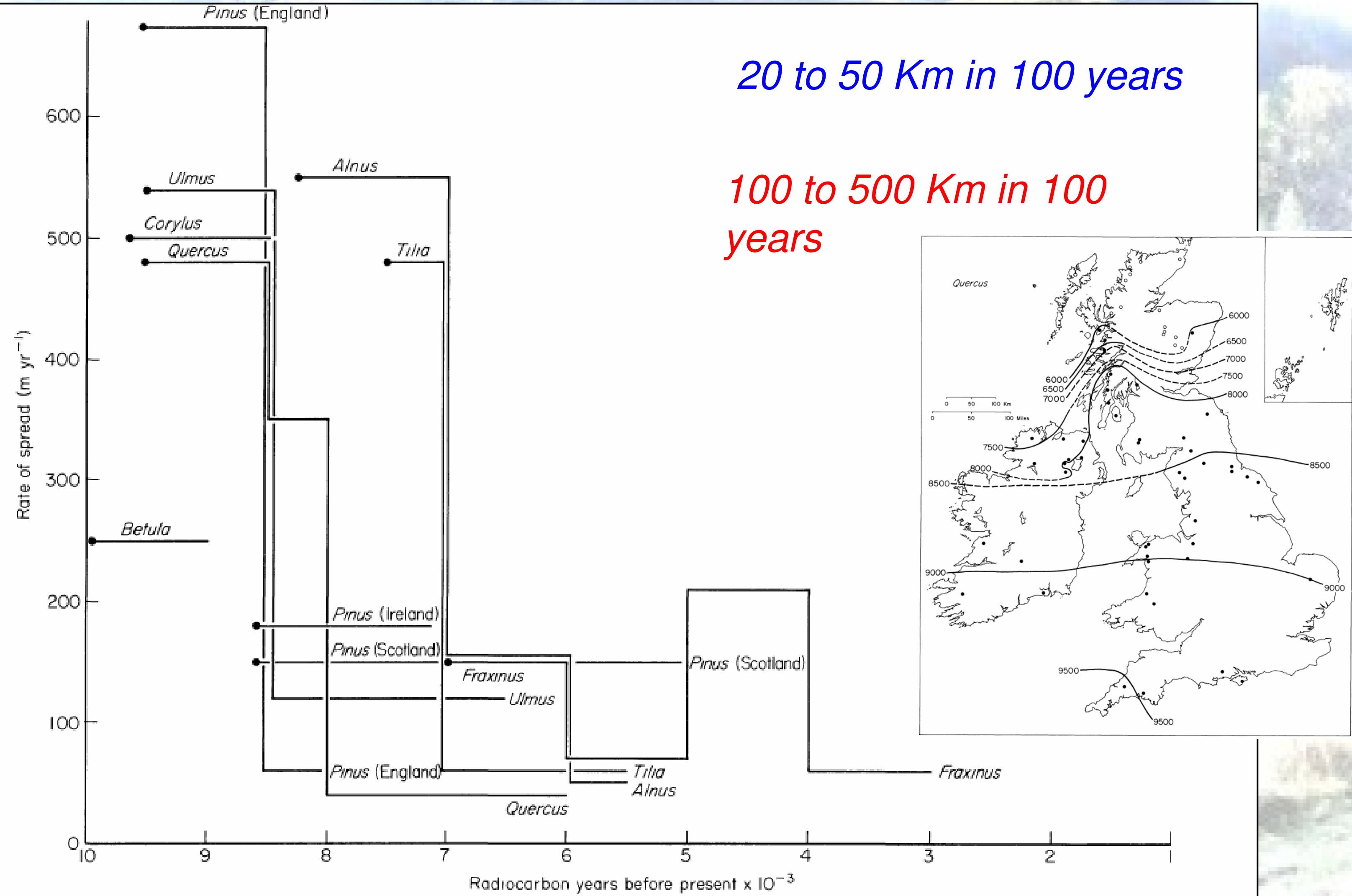
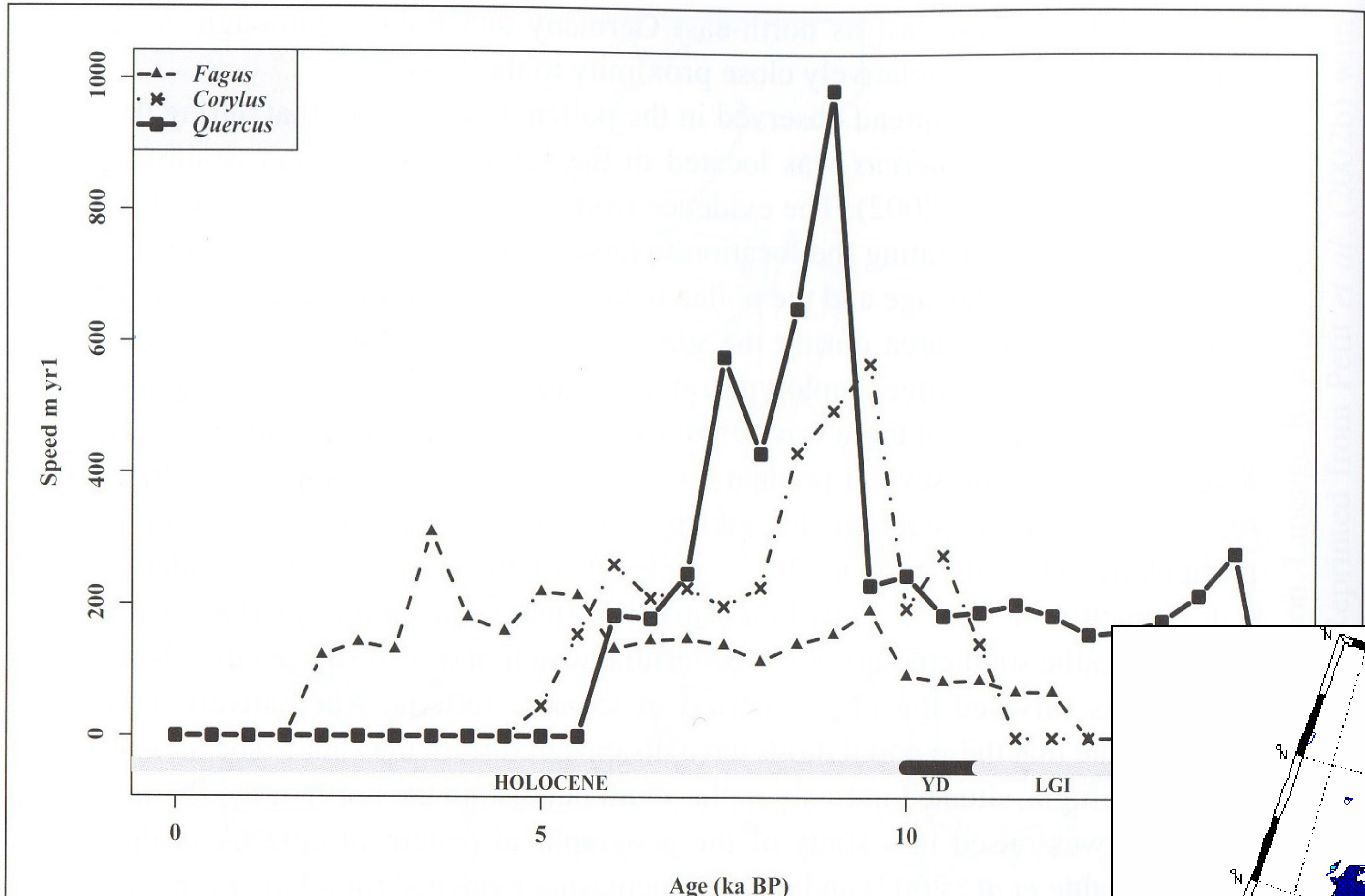



FIG. 12. Approximate rates of spread (m yr$^{-1}$) of forest trees in the British Isles at different times in the Holocene estimated from the isochrone contours in Figs. 2–10.

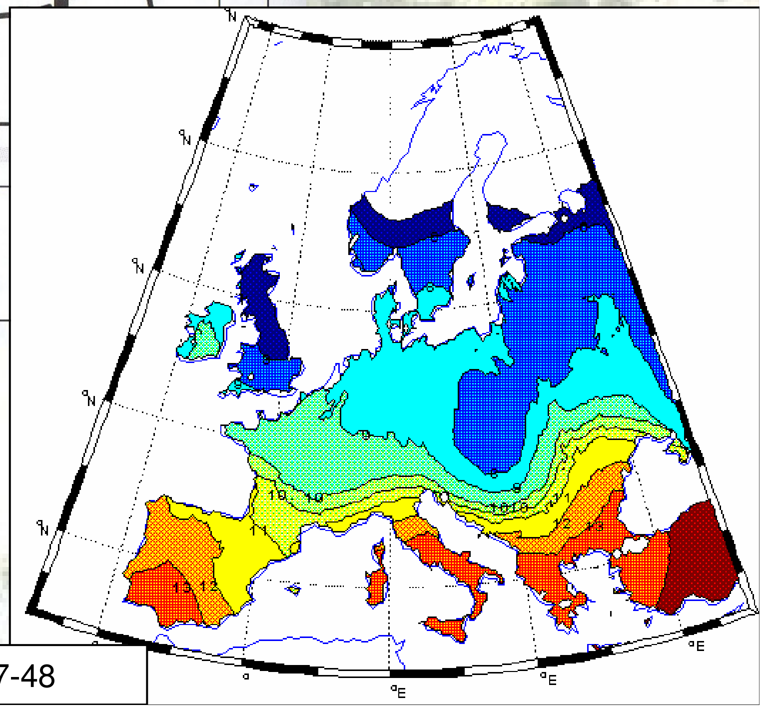
Birks, *Journal of Biogeography* 1989,16:503-540

## POSTGLACIAL MIGRATION VELOCITY OF TREES




Brewer et al., 2005 *Botanical Journal of Scotland* 57: 41-57

*20 to 50 Km in 100 years*



*100 to 500 Km in 100 years*

Brewer et al., 2002 *Forest Ecology & Management* 156: 27-48

# 2 CENTRAL PART OF DISTRIBUTION

## *LOCAL ADAPTATION*

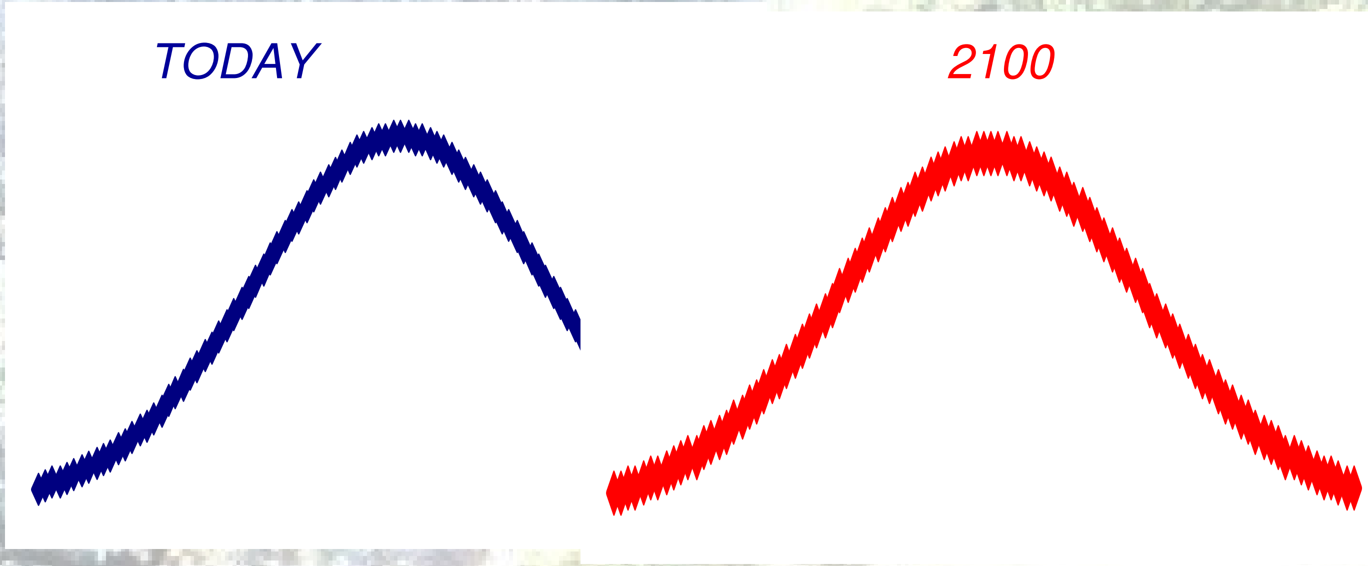
*Ex situ* translocation plantation (Provenance tests)

## *PLASTICITY*

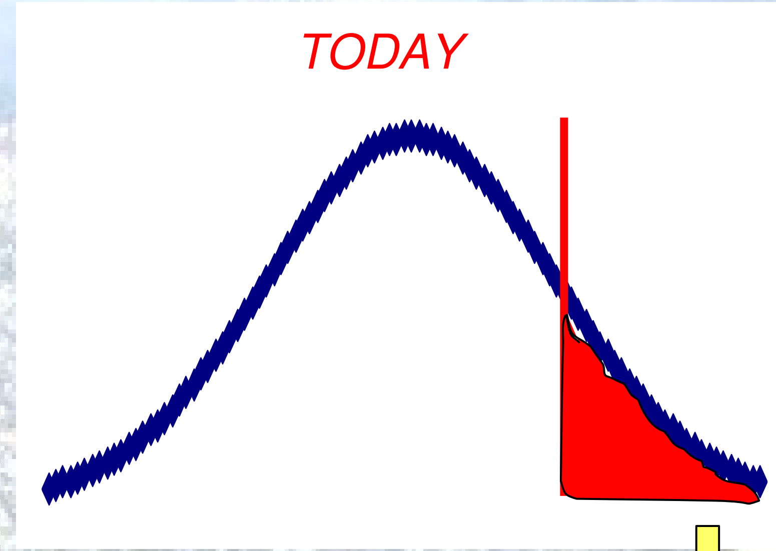
## *INPUT FROM « FOREIGN » GENES*

Gene flow via pollen

# « ADAPTIVE MITIGATION »



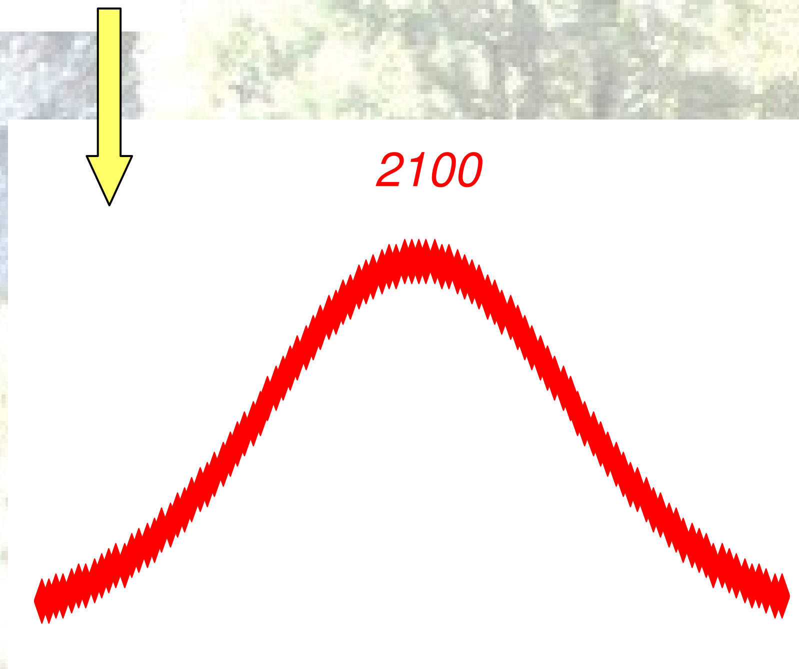
# « ADAPTIVE MITIGATION »



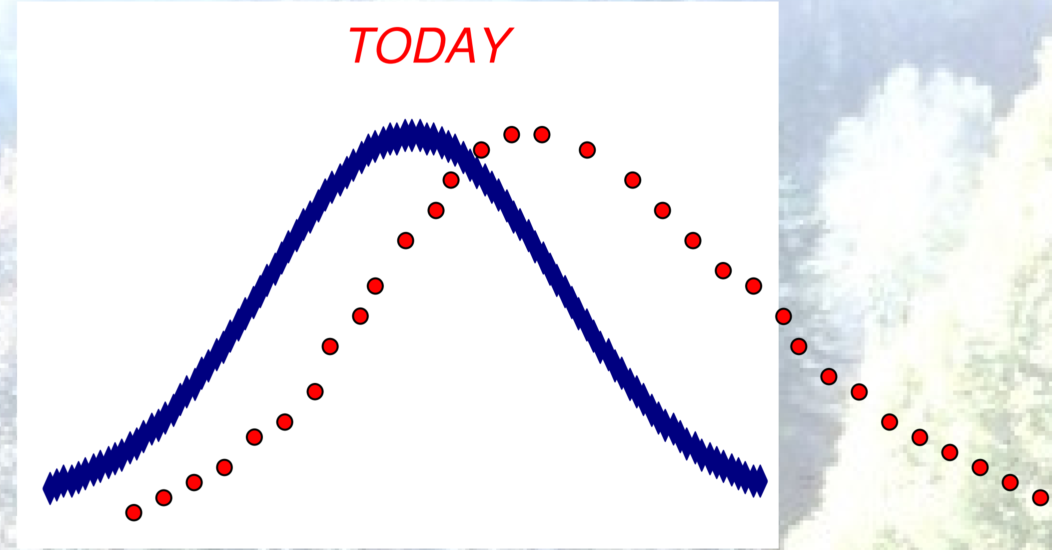

**Darwinian Selection depends on**

Genetic diversity

Strenth of selection (population size)



# « ADAPTIVE MITIGATION »



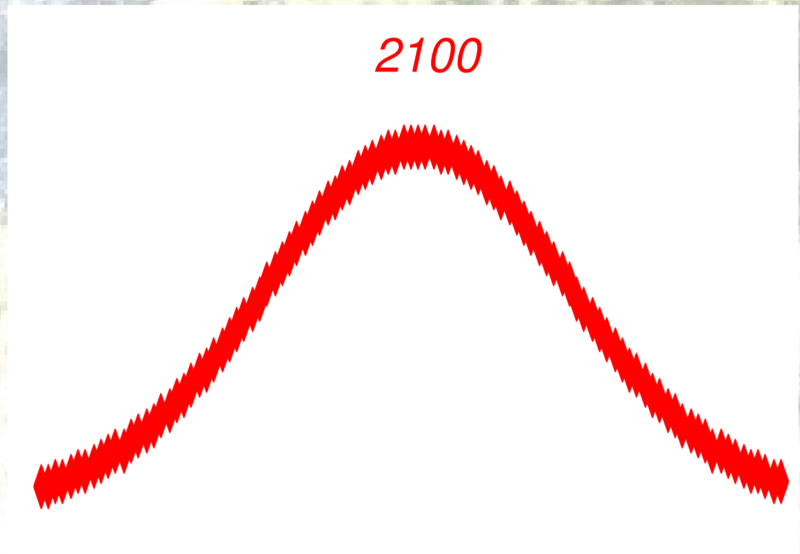

**PLASTICITY**

**depends on**

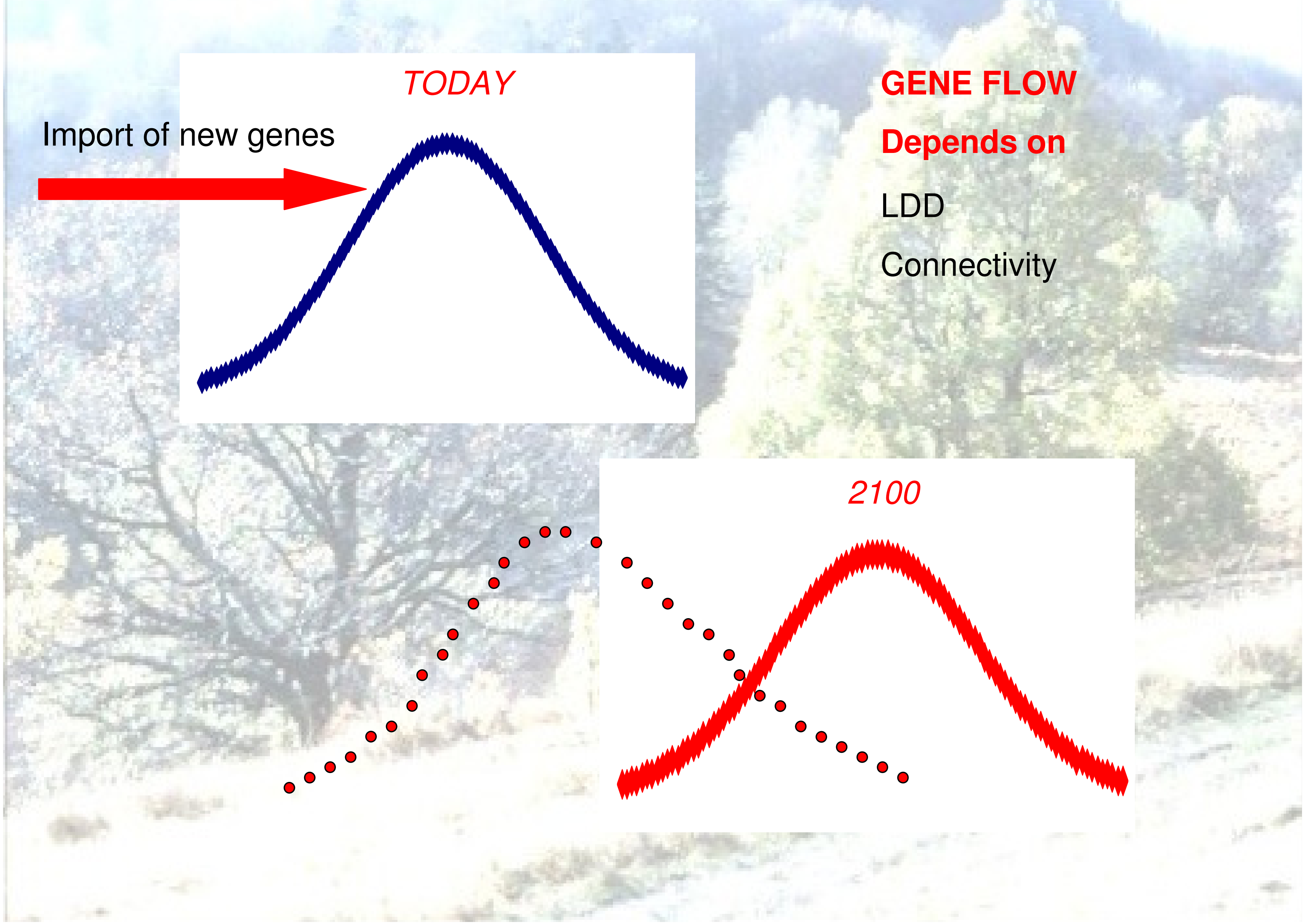
Phenotypic traits

Phenology

Stomatal density



# *« ADAPTIVE MITIGATION »*



# LOCAL ADAPTATION

## Intraspecific responses to climate in *Pinus sylvestris*

GERALD E. REHFELDT†, NADEJDA M. TCHEBAKOVA‡, YELENA I. PARFENOVA‡, WILLIAM R. WYKOFF†, NINA A. KUZMINA‡ and LEONID I. MILYUTIN‡
*†US Department of Agriculture, Forest Service, Rocky Mountain Research Station, 1221 S. Main, Moscow, Idaho 83843 USA,*
*‡Sukachev Institute of Forest, Siberian Branch, Russian Academy of Sciences, Akademgorodok, Krasnoyarsk, 660036 Russia*

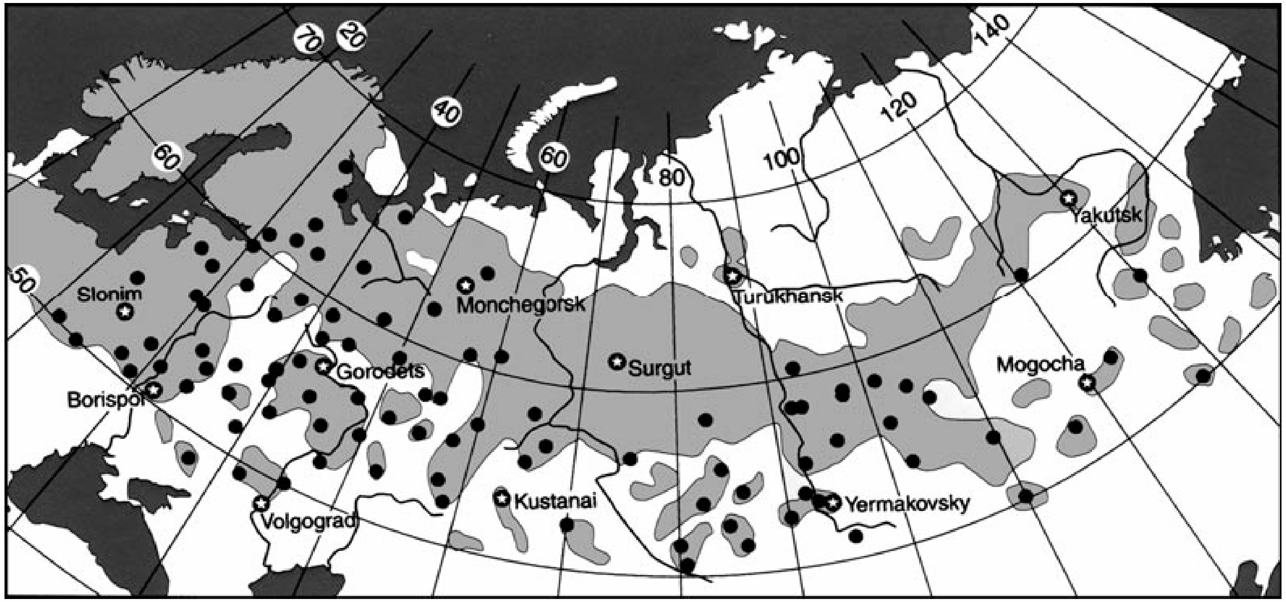



**Fig. 1** Distribution (shading) of *P. sylvestris* (after Critchfield & Little, 1966) and location of populations (dots) sampled. Locations that are named are used throughout the paper to illustrate geographical effects.

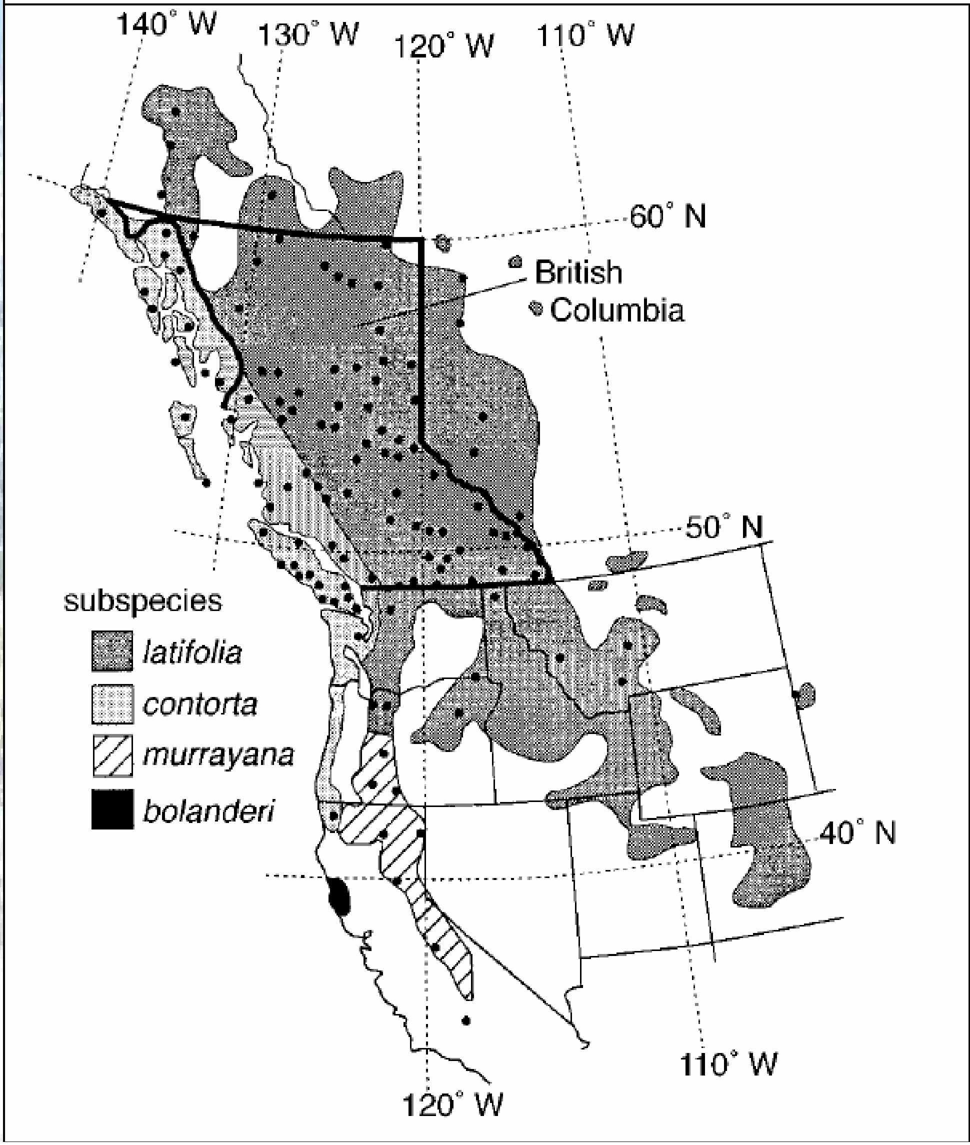
47 provenances tests (39 in Europe + 8 in North America)

110 provenances in at least 6 tests

Rehfeldt et al.,2002 *Global Change Biology* 50: 355 - 376

# GENETIC RESPONSES TO CLIMATE IN *PINUS CONTORTA*: NICHE BREADTH, CLIMATE CHANGE, AND REFORESTATION

GERALD E. REHFELDT,[1,3] CHENG C. YING,[2] DAVID L. SPITTLEHOUSE,[2] AND DAVID A. HAMILTON, JR.[1]




63 provenance tests

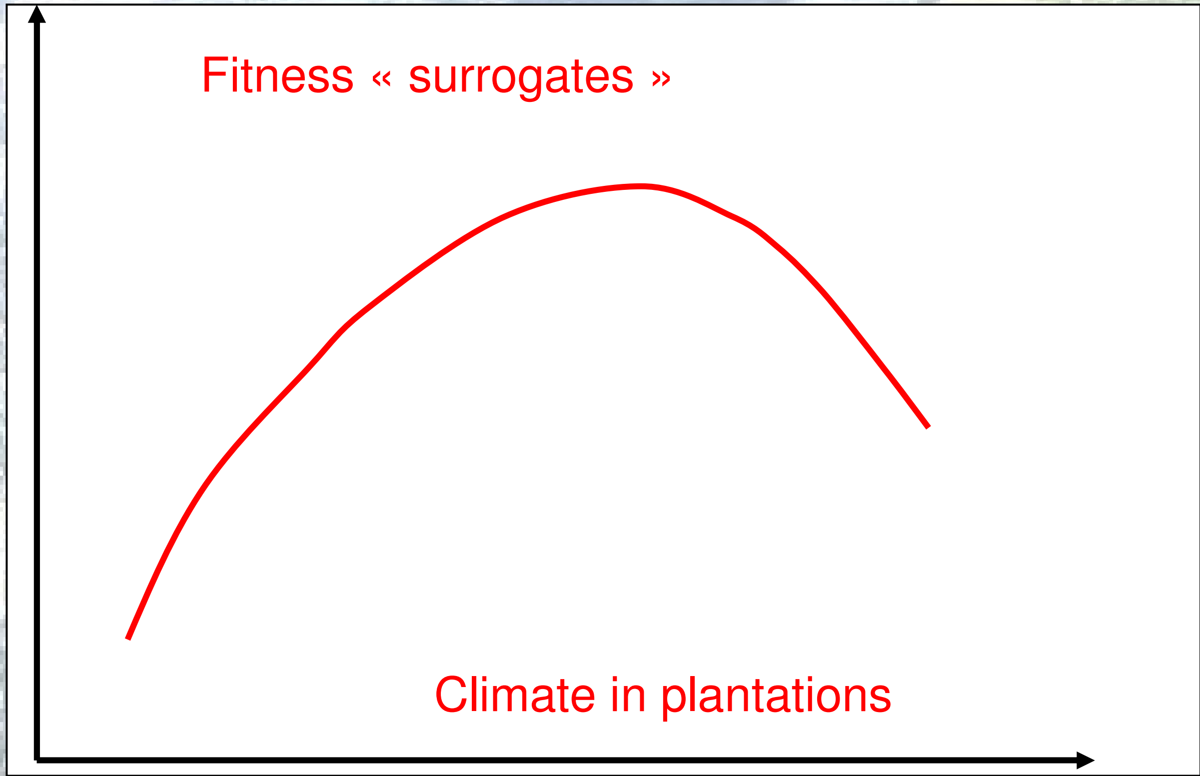
126 populations in at least 5 tests

Rehfeldt et al.,2001 Climatic change 50: 355 - 376

Rehfeldt et al.,1999 Ecology Monographs, 69: 175-407

# CONSTRUCTION OF RESPONSE CURVES

SURVIVAL
HEIGHT




Pinus contorta
Mean annual temperature
Θ of the hottest month
Θ of the coolest month
Nb of days without frost
Period without frost
Annual rainfall
Summer rainfall

Pinus sylvestris
Mean annual temperature
Degree days > 5°C
Θ of the coolest month
Différence Θ summer-winter
Annual rainfall

# *PLASTICITY OF PROVENANCES*

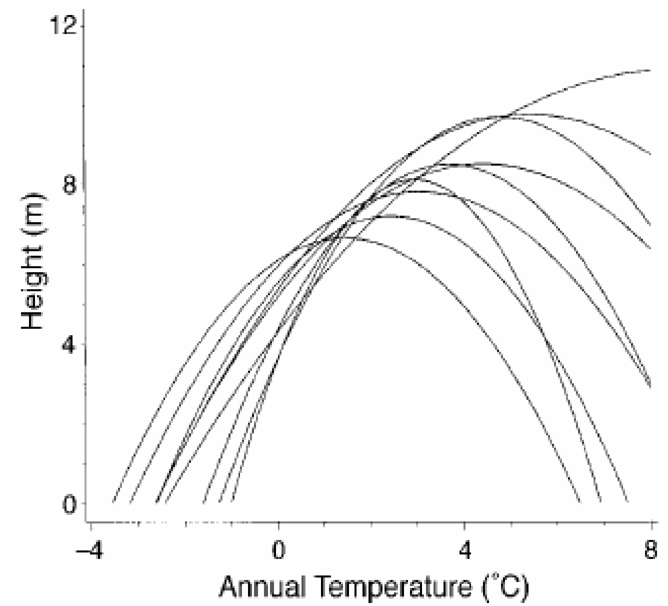
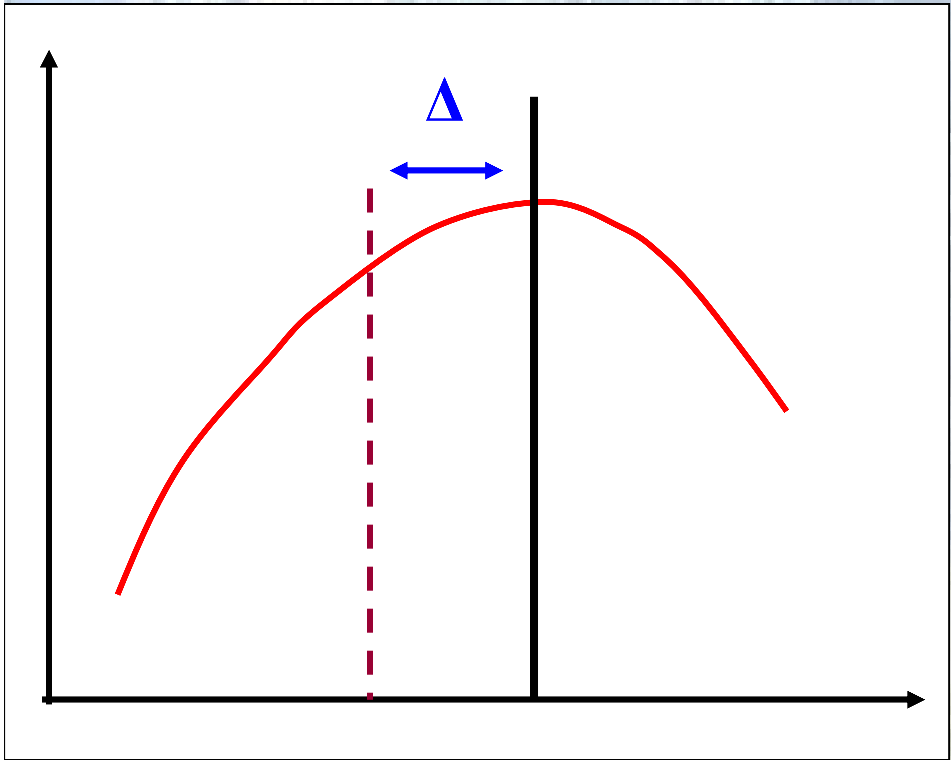




FIG. 8. Response functions using mean annual temperature as a predictor of height for nine populations that represent a variety of responses for ssp. *latifolia*.

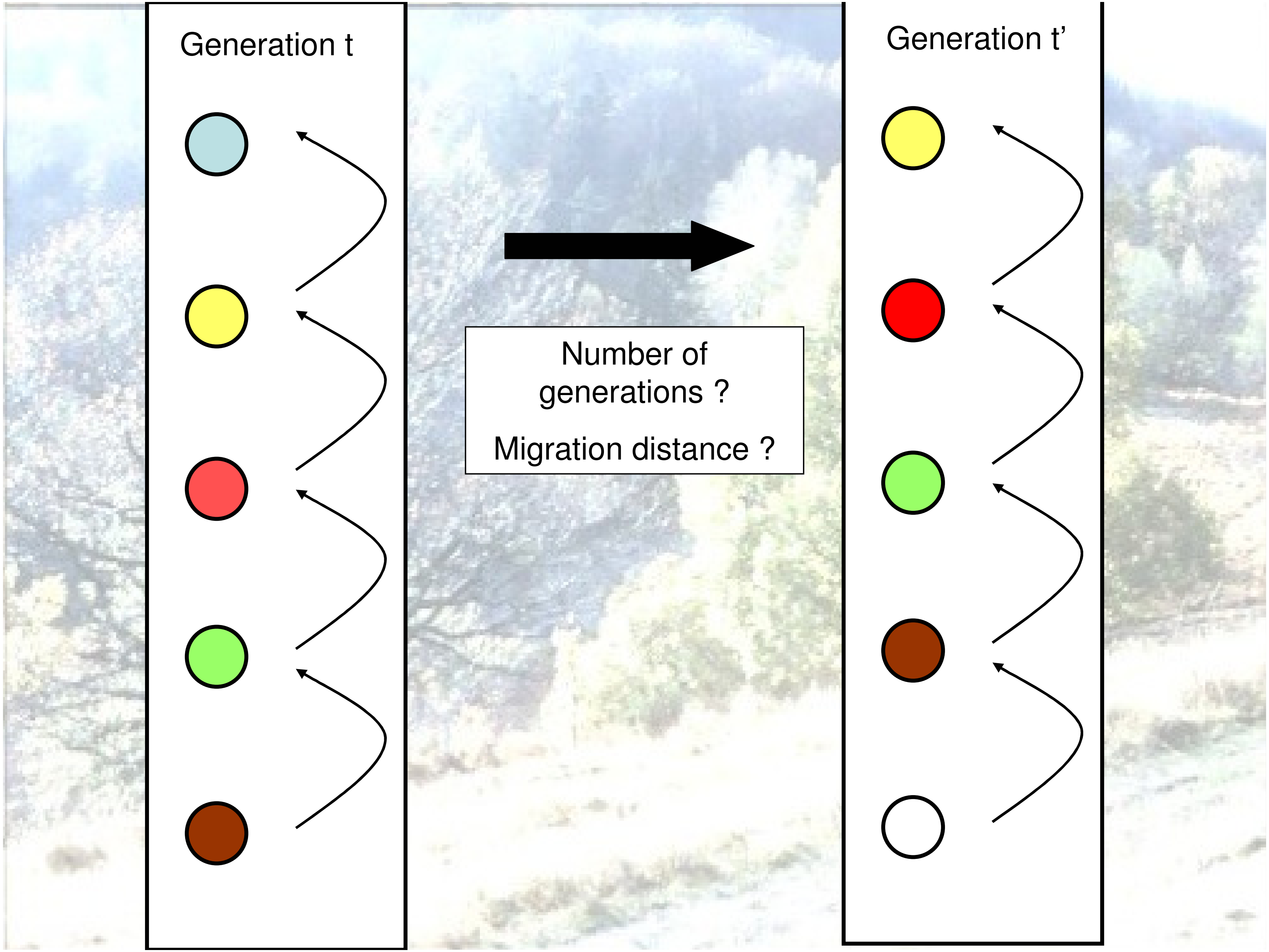
Rehfeldt et al.,1999 Ecology Monographs, 69: 175-407

## ADAPTIVE CAPACITY OF PROVENANCES

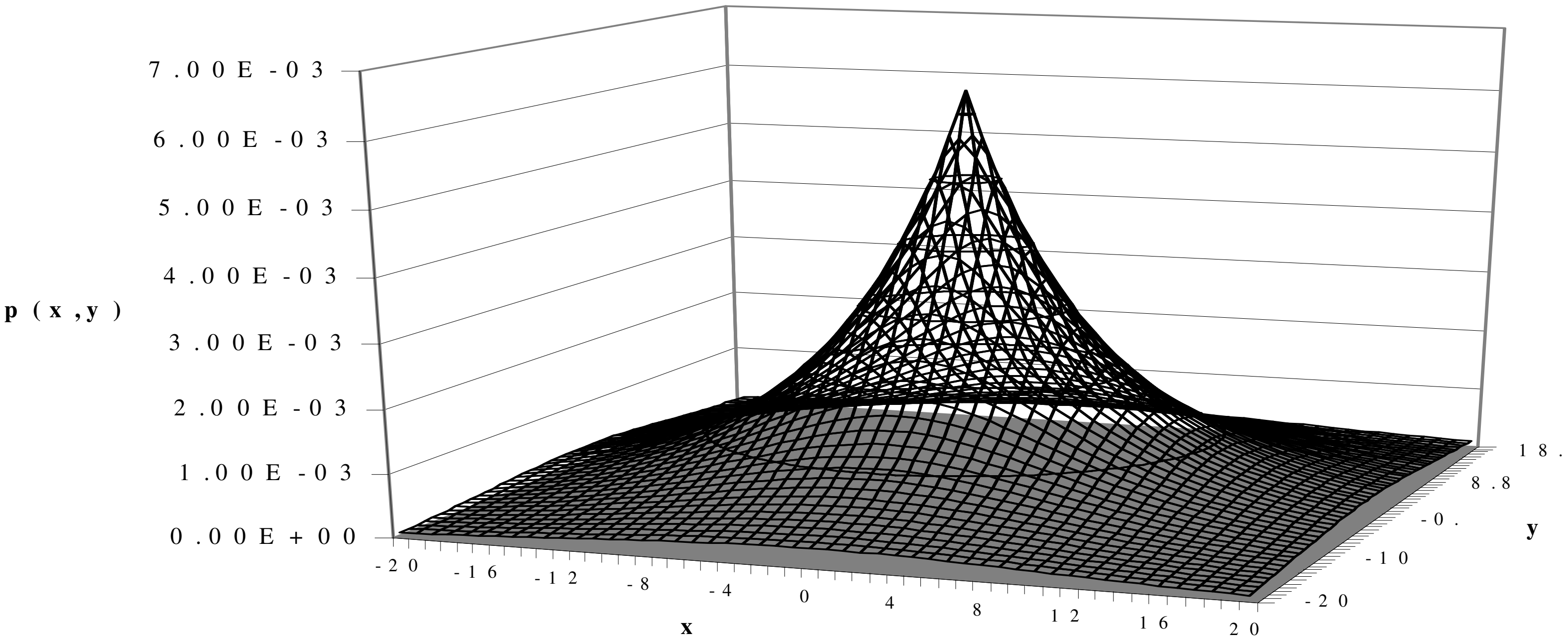



| | Mean Δ |
|---|---|
| *Pinus sylvestris* | 2,7°C |
| *Pinus contorta Ssp latifolia* | 2,8°C |

Rehfeldt et al.,2002 *Global Change Biology* 50: 355 - 376
Rehfeldt et al.,1999 *Ecology Monographs* 69: 175-407


Generation t
Generation t'
Number of generations ?
Migration distance ?

# VIABLE POLLEN DISPERSAL IN TREES



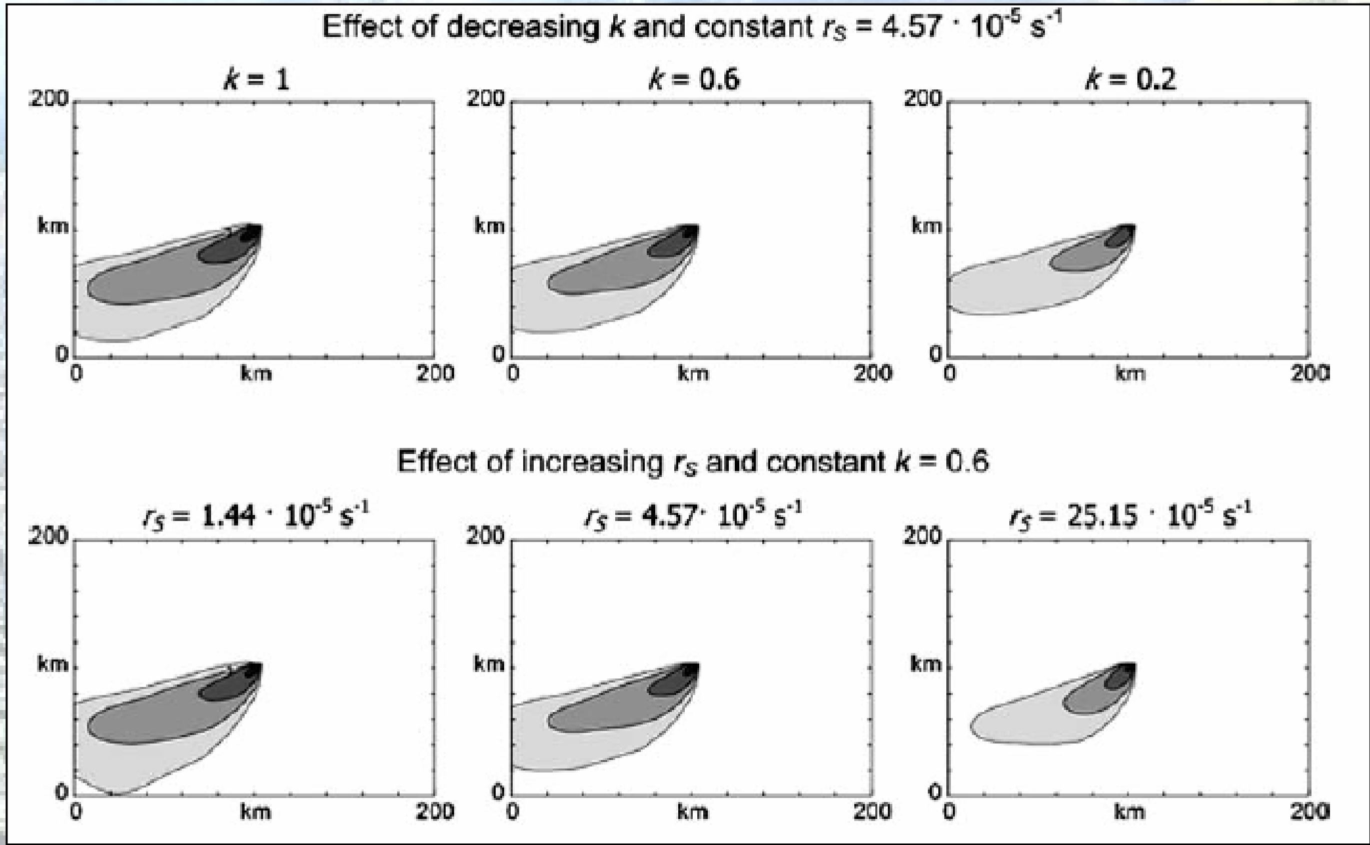

**SDD≈ 1km**

LDD

Measurable by parentage analysis

Estimation ?

# *LDD OF VIABLE POLLEN*




Silvio Schueler · Katharina Heinke Schlünzen · Florian Scholz

Trees (2005) 19: 154–161

**Viability and sunlight sensitivity of oak pollen and its implications for pollen-mediated gene flow**

Distance between « ecological equivalent » zones from today to 2100 : 100 à 500 km

LDD of viable pollen: 20 à 100 km in 1 generation..

# 3 SOUTHERN LIMIT OF THE DISTRIBUTION

*LOCAL ADAPTATION ??*

*PLASTICITY*

*NO IMPORT OF « FAVORABLE » GENES FROM THE SOUTH*

*MIGRATION IN ALTITUDE ??*

## *SHIFT OF SPECIES' DISTRIBUTION OR EXPANSION DURING HISTORICAL WARMING PERIODS ??*

SHIFT EXPANSION

Prediction of bioclimatic enveloppes Extant distribution

## *CONCLUSIONS* *RESEARCH NEEDS*

LOCAL ADAPTATION THROUGH DARWINIAN SELECTION

CONSTRUCTION OF RESPONSE CURVES OF GENETIC RESOURCES

REANALYSIS OF PROVENANCE TESTS (Rehfedt's approach)

EMPHASIS ON REPRODUCTION

## CONCLUSIONS RESEARCH NEEDS

LONG DISTANCE DISPERSION OF GENES

ESTIMATION OF LDD AT THE LANDSCAPE LEVEL

MODELLING OF LDD

VIABILITY OF POLLEN UNDER UV RADIATION

CONNECTIVITY

## CONCLUSIONS

## RESEARCH NEEDS

PLASTICITY

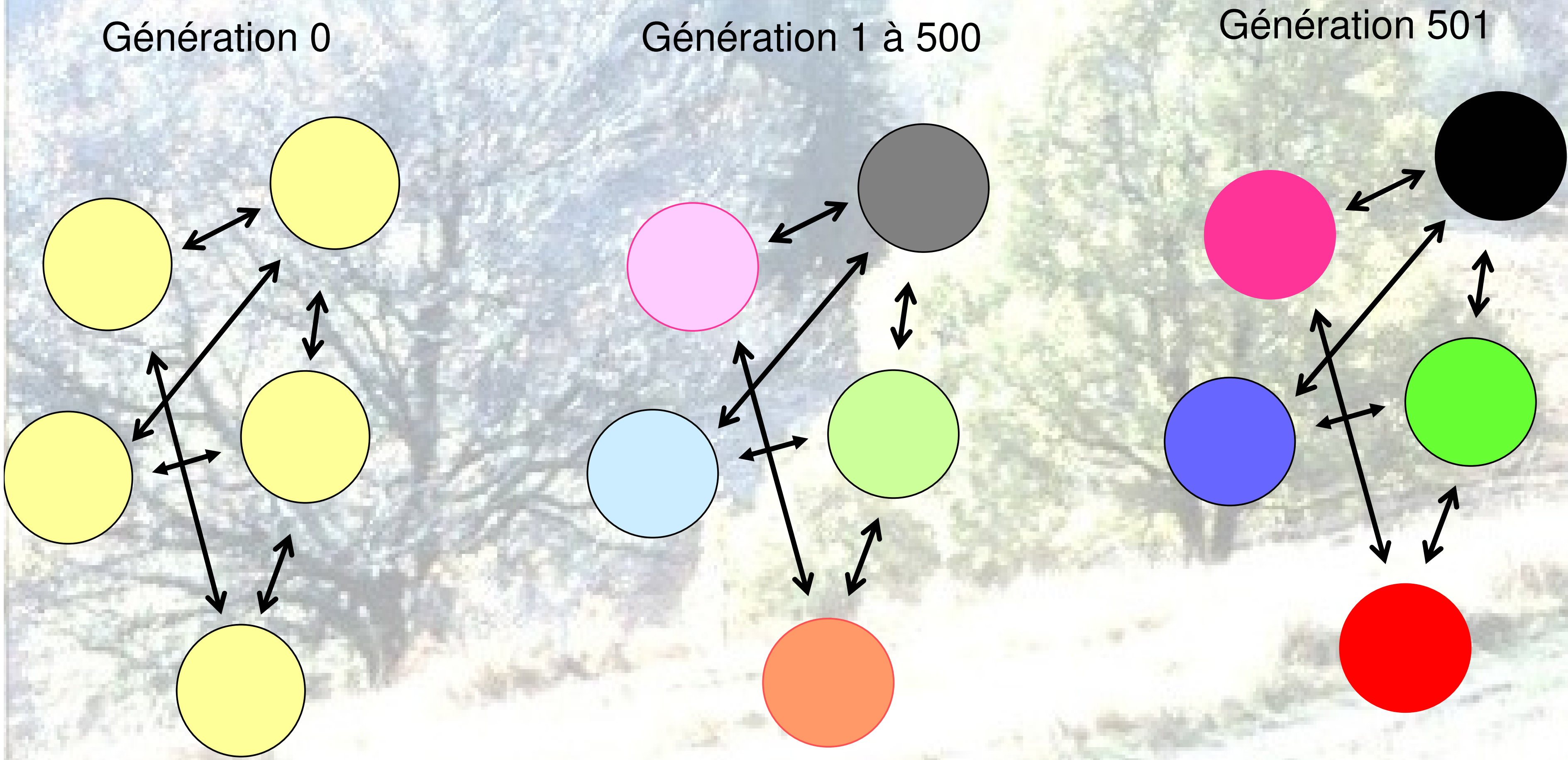
MONITORING GENE EXPRESSION AND PHENOTYPIC CHANGES UNDER CONTROLLED CONDITIONS ....

## *CONCLUSIONS* *RESEARCH NEEDS*

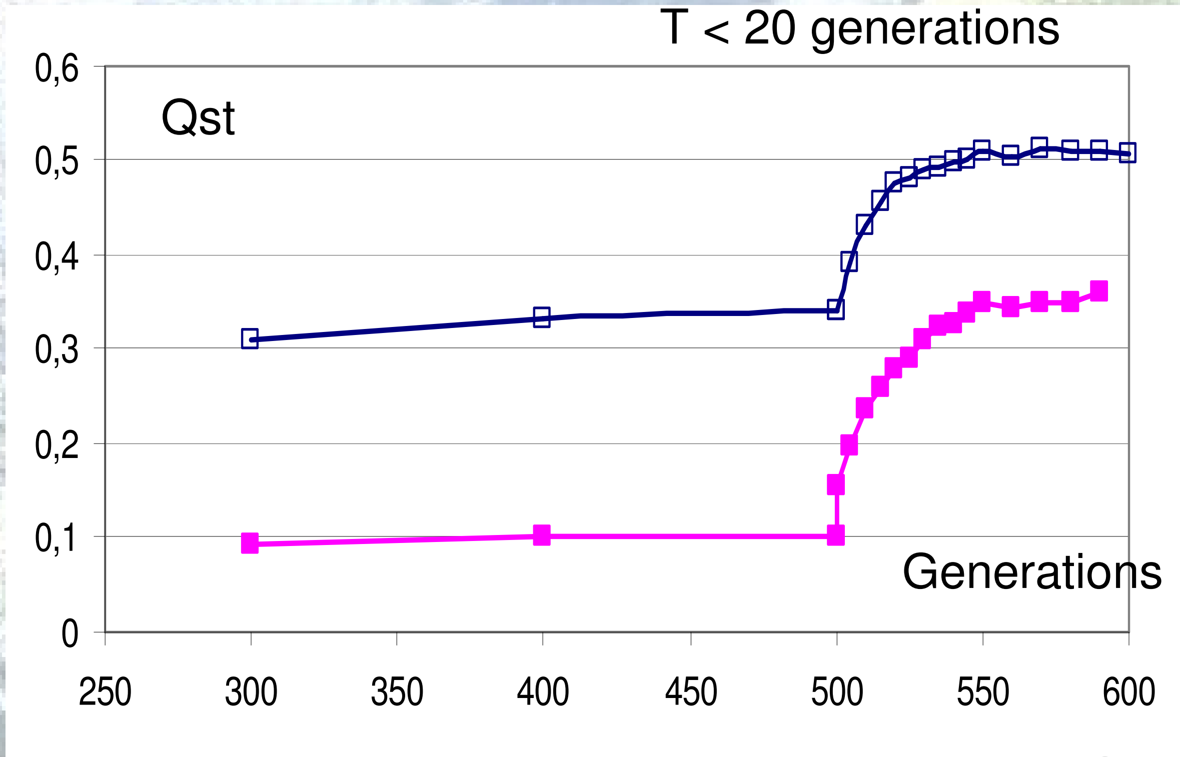
THEORETICAL EXPLORATIONS: SIMULATIONS

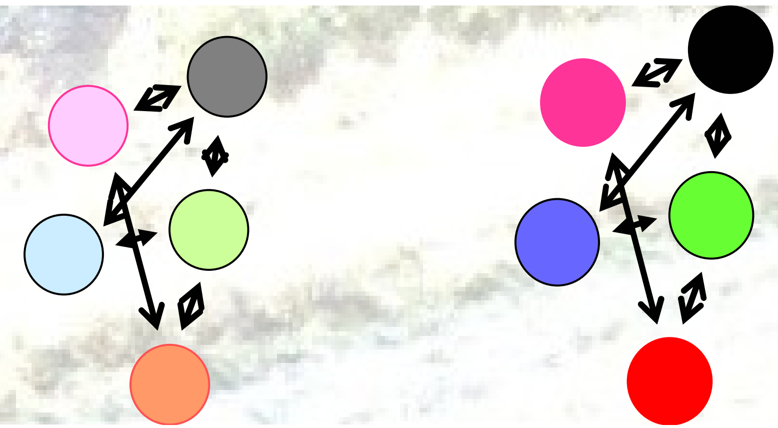
INTERACTION BETWEEN DARWINIAN SELECTION AND GENE FLOW (LDD)

## *THEORICAL PREDICTIONS*



## *EVOLUTION OF POPULATION DIFFERENTIATION*



Kremer & Lecorre, données non publiées

## *CONCLUSIONS* *RESEARCH NEEDS*

ESTIMATION OF EVOLUTIONNARY RATES OF FOREST TREES

LESSONS FROM DOCUMENTED INTRODUCED SPECIES AND THEIR ADAPTATION TO EUROPEAN CONDITIONS

EXOTIC SPECIES or NATIVE SPECIES