The role of breeding in contemporary forestry: Forest tree breeding in Europe

Luc Pâques

The role of breeding in contemporary forestry

Forest tree breeding in Europe

Luc E.Pâques

INRA-AGPF-Orléans (France)

Over 60 years of forest tree breeding:
where do we stand?

Most breeding programmes have been started in the 50's

Mostly conifers vs broadleaves
(*planted*) (*naturally regenerated*)

- 1st step: 'Pre-breeding' = genetic diversity studies
  = seed stands &
  provenance recommendations

- 2nd step: 'Breeding': launching of recurrent
  selection schemes

  = breeding populations
  = recombination
  = evaluation
  = mass-propagation
  = deployment

  Optimisation

Over 60 years of forest tree breeding:
where do we stand?

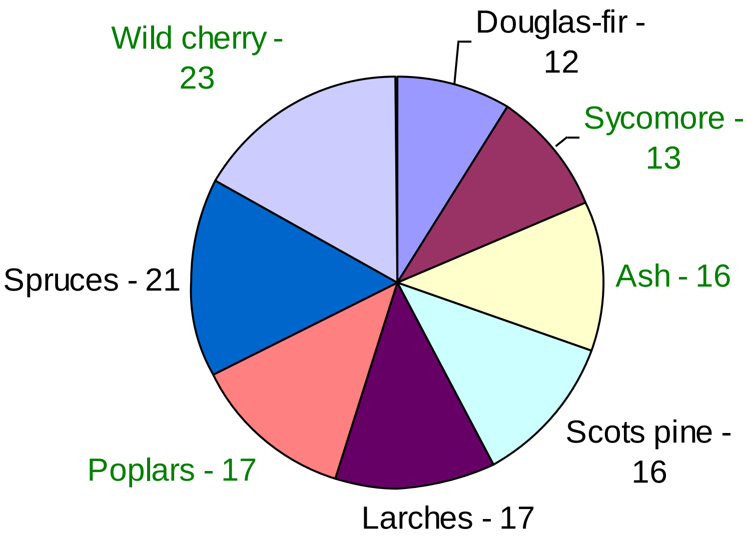
> 135 'breeding programmes'

for 8 species

across 18 countries

+/- 1 programme/species/country !!

> 54 others for 11 species



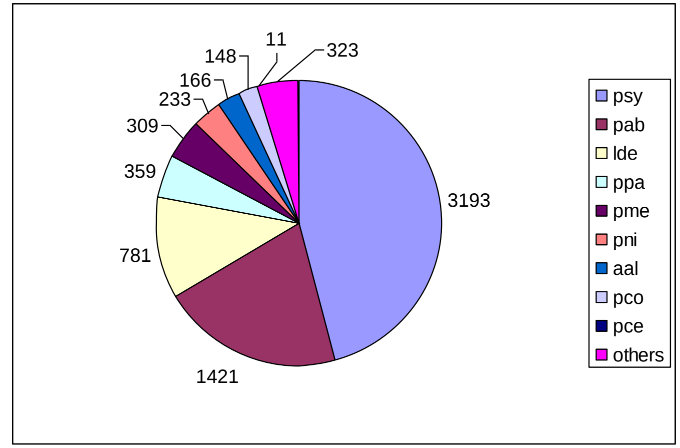
Source: Treebreedex: Mertens et al.2008

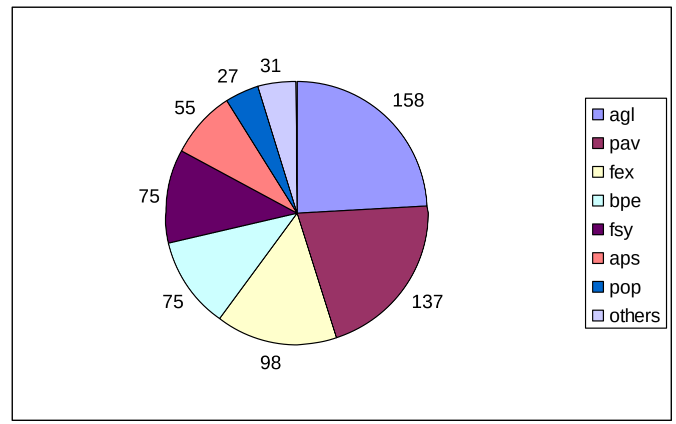
Over 60 years of forest tree breeding:
where do we stand?

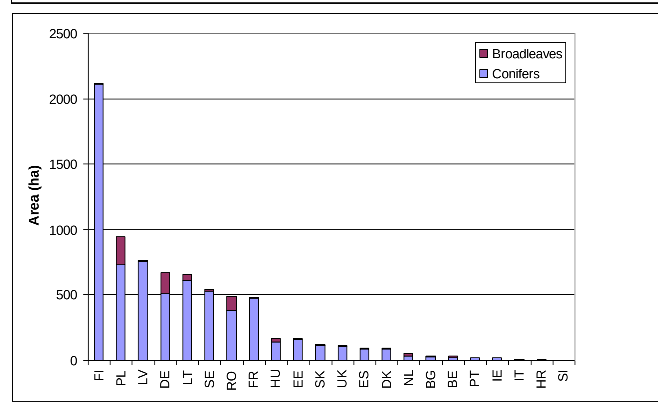
RESULTS

Over **65 500** selected seed stands
(57% conifers/ 43% broadleaves)

> **1 200** Seed Orchards over
7 600 ha for around 40 species







Source: 'Community List of Approved Basic Material for the Production of Forest Reproductive Material, based on the national lists as supplied by the Member States according to Article 10(2) of Council Directive 1999/105/EC

RESULTS

FRM – seed orchards and use

In many countries, most planted material is from improved material (SO)
Questions about SO dimensioning?

Ratio of planted area vs seed orchard area

	Norway spruce	Scots pine	European larch	Douglas-fir
A				454
B	19310			1146
CZ			1081	889
DK	5100	2570		927
FI				
F	5190	17330	5087	4371
D	21330	10725	4121	5325
GB			11207	44800
IRL		2330	8808	1889
I				
LI	390	745	166	
NL		6760		1067
NO				
PL	14052		229	65
RO	3681		105	253
SK			304	
S				
SP		48380		7538

Over-sized?

Under-sized?

RESULTS

Expected genetic gains

Examples of predicted genetic gains from different breeding programmes across Europe: Sitka spruce

				Material from:			
Country	Year	Trait	Age	Seed orchard	Vegetative propa-gation (half-sib family mixes)	Vege-tative propa-gation (full sib families)	Reference
Great Britain	2010	Diameter	15	15 - 20%	20%	20 - 30%	Queen Charlotte Import
		Stem straightness	15	10% - 15%	20%	15 - 30%	
		Branching Score	15			10 - 15%	
		Wood density	15	-10% to 0%	0%	0% - 10%	
		Rotation sawlog volume	Rotation age	approx 40%	approx 50%	approx 60%	Queen Charlotte Import # #
		Rotation volume	Rotation age	approx 20%	approx 30%	approx 30%	
Ireland	2010	Height		15% to 20%			Unimproved stock
		Stem form		7%			
Denmark	2010	Diameter	15	7%			Unimproved Danish landrace
		Stem straightness	15	12%			
		Volume	18	30%			Unimproved Danish landrace
		Wood density*	18	0%			
		Leader breaks	18	-7%			
		Stem straightness	18	4%			
		Forks	18	-3%			
		Stem straightness	10	11%			Unimproved Danish landrace
		Diameter	10	5%			
		Wood density*	10	0%			
		Flushing score	5	-12%			Unimproved Danish landrace

Source: *Forest Tree Breeding in Europe, Springer*

RESULTS

‘Little gains’ … ‘great benefits’

Genetic gain: *25 % in volume from 2^{nd} generation SO*

		Hypothesis 1	Hypothesis 2	Hypothesis 3
Reforested area 2002-2020 (ha)	non improved	380000	190000	76000
	improved	0	190000	304000
Total volume (10^6 m^3)		85.5	96.2	102.6
H2-H1	10^6 m^3		**10.7**	
	10^6 euros		**534**	
H3-H1	10^6 m^3			**17**
	10^6 euros			**854**

Maritime pine, Landes (FR)

Lesgourgues, 2002

Over 60 years of forest tree breeding:
where do we stand?

1) Probably (one of) the **most significant** human impact in forest management

- ➢ Quantitative & qualitative increase of timber production
- ➢ Increase of financial resources from forests

2) **But...**

- Cases of *maladaptation*: over-extension: Norway spruce…
- Breeding with a *too narrow genetic basis*: rust and poplars...
- *Under-use* of some FRM: wild cherry clones…
- *Extra-cost* of some FRM: hybrids, clones
- ‘*Invasion*’ by ‘exotics’: hybrid & Japanese larches, douglas-fir, poplars…
- Still some *orphelin species*…
- Top-quality FRM: Incentive for pure stands?, *monoculture*?
- FRM & nurseries: *vector* of diseases: *Sphaeropsis* blight, …
- …

Over 60 years of forest tree breeding:
where do we stand?

3) **In a 'stable' world**

Timber production

'Stable' climate

'Known' biotic threats

'Known' abiotic risks

What has changed? What is changing?

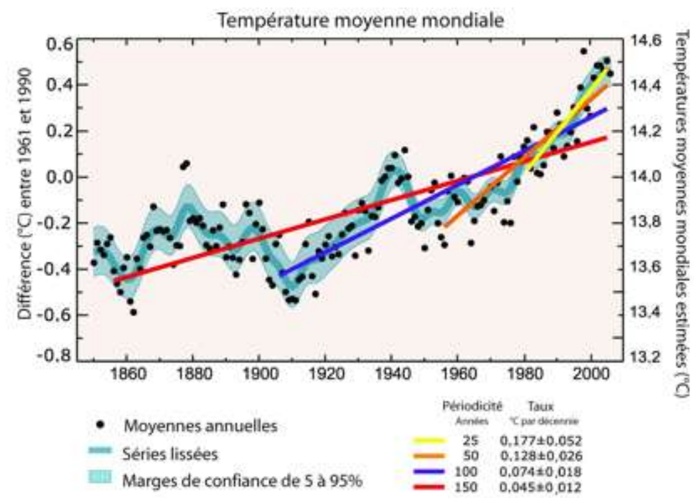
A mostly 'un-stable world'

Budget /staff

'Conflicting' end-products

Species interest

Climate change



Emerging biotic threats

What has changed? What is changing?

Management options have enlarged

- Classical plantations
  - clear-cutting
  - *natural regeneration*
- Intensive plantations
  - low density (timber)
  - *high density (biomass)*
    - *short-rotation coppice*
    - *short-rotation high forest*
- *Mixed plantations*
- *Plantations with emerging species*
- No plantation: natural regeneration

Breeding:

- Species priority
- Long-term / short-term
- Genetic basis
- Traits priority
- Intra/inter-species competition
- Transfer of breeding tools/results to management

What has changed? What is changing?

‘Wood’

Growing regimes

High-standard forest

SR standard forest
SR coppice

Specialisation of products




For breeding:

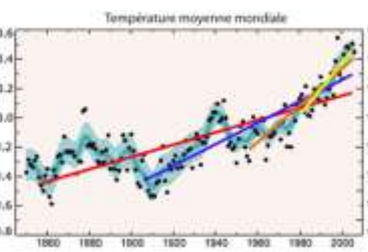
Growth +
Straightness, branching
(Density)
Pulp-link properties

Competition
Age (juvenile wood)

Heartwood proportion
Durability
Colour
Grain angle
Extractives
Lignin <-> cellulose
MOE, MOR
EW-LW density ratio
…

What has changed? What is changing?

'Climate'



Temperature + water + wind

Pests + diseases

For breeding:

'Overall' adaptation
Survival & Frost resistance
→ *Breeding zones*

✚

Heat / drought / wind resistance / tolerance
→ *Deployment zones*

✚

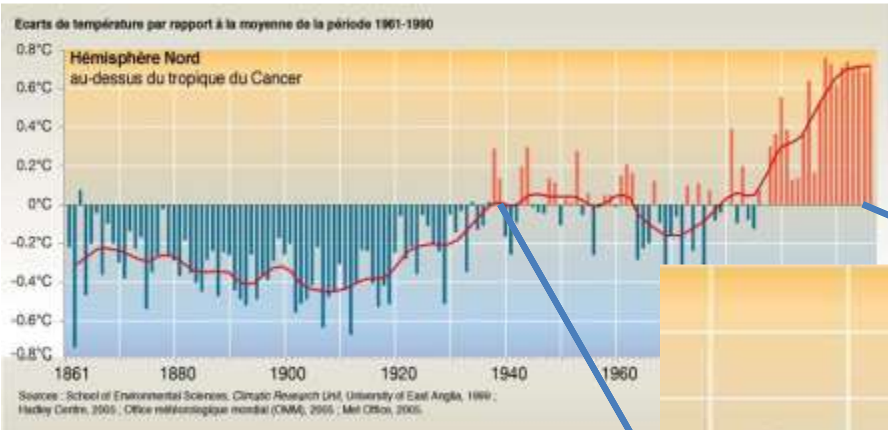
Impact on phenology

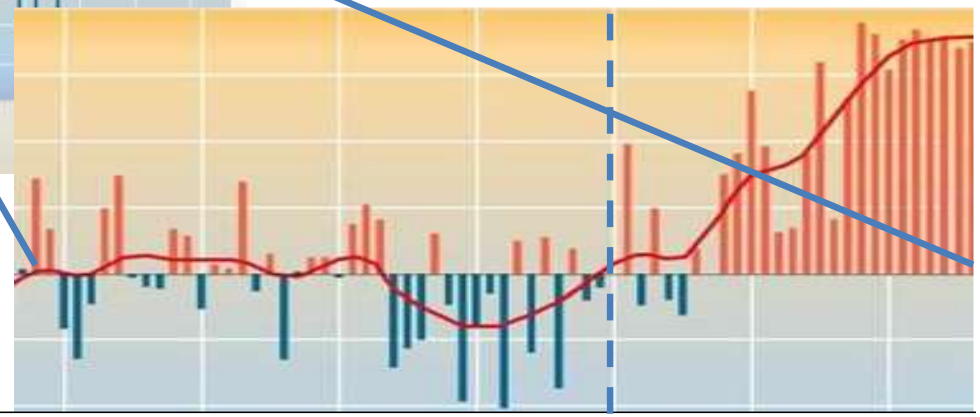
- *frost*
- *growing season*
  - *growth-architecture*
  - *wood formation*

✚

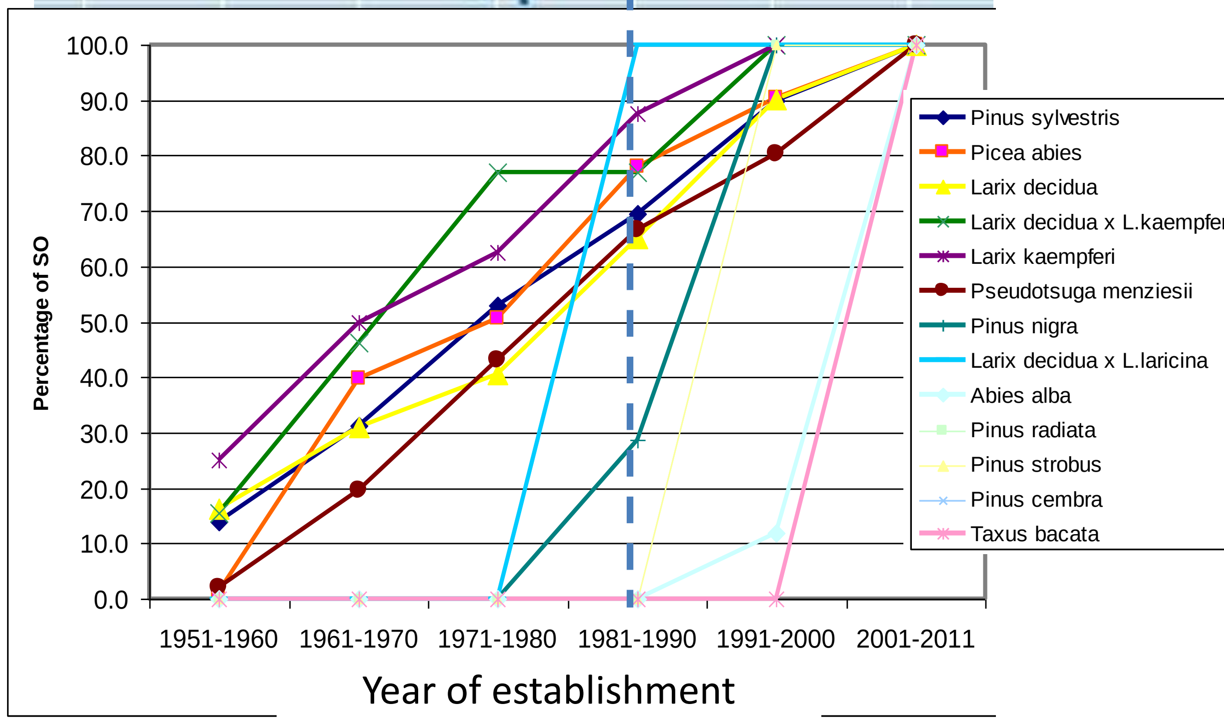
Pest and disease resistance / tolerance

FRM and climate change





Most commercial seed lots are produced in seed orchards planted with selections made in cooler/wetter conditions



Treebreedex

Treebreedex database (sample of 750 SO)

What is needed?

Reactivity and efficiency

Flexibility

- Adapt: shift species / reprofile breeding populations / review deployment zones / target traits
- Shorten / speed up: breeding/ selection/ FRM mass-production

Integration

- Multi-purposes/ multi-traits
- Multi-disciplines
- Research → Development → Management

Up-scaling

- Enlarge environmental conditions
- High-throughput
- Enlarge views: from regional → national → international

Scrutiny

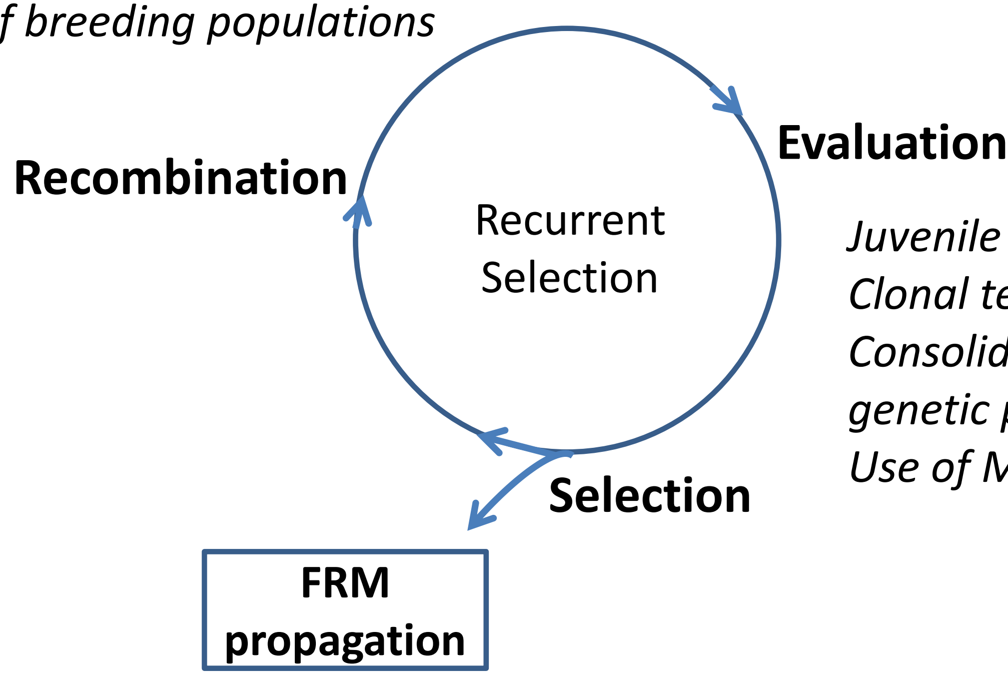
- Dissect traits
- More precision needed
- Inter-relationships

Uncertainty → *Reactivity and efficiency* → ***Joined efforts***

Joined efforts: why?

1) To better circulate information, exchange methodologies, benefit from synergies

Controlled crossing
Flower induction
Management of breeding populations
Fingerprinting



Juvenile evaluation/selection
Clonal testing
Consolidated knowledge on genetic parameters
Use of MAS

SO reproduction engineering
Vegetative propagation (cutting, in vitro)

Joined efforts: why?

2) *To improve efficiency and valorise breeding efforts*

- Critical mass: breeding efforts vs reforestation needs?
- Coherence?

Survey based on 115 breeding programmes, 28 forest tree species from 19 EU-countries

Breeding	Observed fact	Risk
Closed long-term breeding population	Among-family selection (15 out of 20)	Maintenance of genetic diversity
Recombination of genotypes	Open-pollination instead of controlled pollination	Control of relatedness?
One vs two-stage selection	Progeny testing vs clonal testing	Genetic gain per unit time
Breeding vs multiplication populations	49% not separated	Ineffective deployment
Breeding zones	No consideration for 42% ; only 22% have breeding zones based on climate	Risk for reduced adaptedness
MAS / simulation	4% / 6%	

Danusevicius et al. 2010

Treebreedex

Joined efforts: why?

3) To better tackle challenges of common interest

- Priorities for joined breeding

  (Source: Forest Tree Breeding in Europe, Springer)

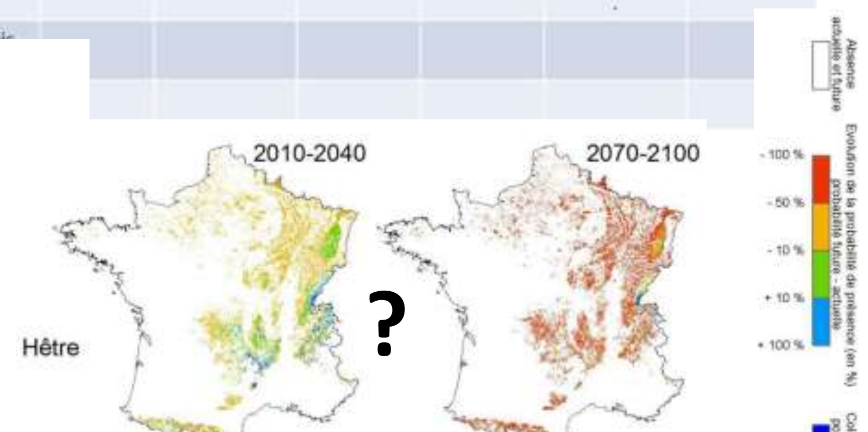
	NS	SS	SP	La	DF	Sycamore	Ash	W.Cherry
Genetic diversity				X at European scale		X	x	X & margin zones
Climate /adaptation	Reaction norms for B/C/ST		Physiology / GxE	Reaction norms	Frost/ drought	Drought/ frost	phenology, frost, drought GxE	Phenology, drought
Pests	Root rot/ spruce decline						Chalara (genetic and environment)	X
Wood	Non-destructive			Mechanical & durability	Mechanical & durability	Grain		X
Early selection		MAS Blup	MAS & Predictors					
Common protocols			X	X	X			X
Common evaluation	X		GxE	SO	SO / EU-trials	Prov. & clones		SO & clones
Sexual reproduction	Acceleration	Accelerat.	Accelerat.	X HL more efficiency	Managt SO	Reprod. SO	Common SO with resist.clones	Control crosses
Veg.prop.	X	Efficiency	X	X HL more efficiency	X	Clones		Promote existing clones
Breeding zones/deployment	BZ Seed transfer	Seed transfer	X	X	X	X	Review recommendat	X
Economic models		Economic						

- ‘omics’-assisted selection

  high-throughput genotyping & phenotyping

- Assisted-migration of species, seed transfer

  plasticity & adaptability



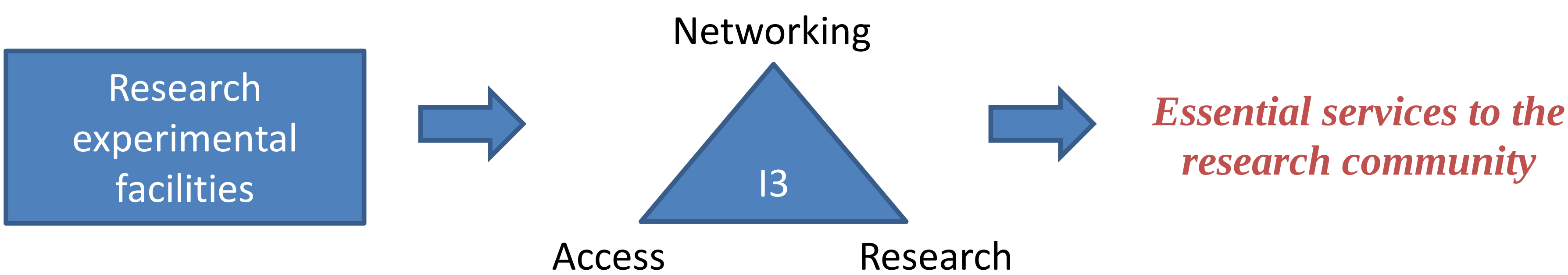
Piedallu et al. 2009

How to join efforts?

An opportunity at European Union level:

"Structuring the European Research Area"
Action: Support for Research Infrastructures

State-of-the-art infrastructures



Long-term integrating effect

Joined research & breeding

European Tree Breeding Centre

Networking
Access
Research

Networking

TREES 4 FUTURE

Designing Trees for the Future

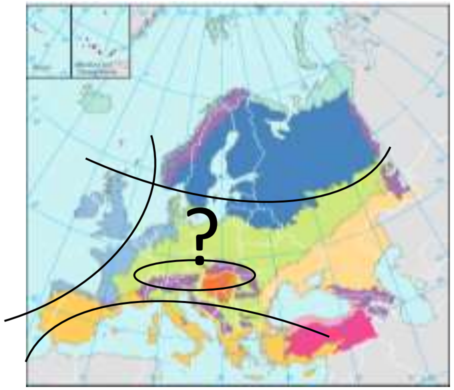
Treebreedex

A working model network of tree improvement for competitive, multifunctional and sustainable European forestry

2006-2011

2012-2015

?



Ac3. Geographical structure of Species genetic variability:

towards delineation of breeding zones across Europe

Treebreedex

Step 1

Ac4. Structure, organisation and long-term management of FTB material:

towards a joined management of breeding populations

Ac5. Optimisation of Breeding methods and strategies:

towards joint development of breeding activities and genetic research

Ac6. Mass-production & deployment of varieties:

share of expertise for a more efficient dissemination of varieties

Networking activities

Surveys: Breeding programmes/strategies across Europe
Genetic resources
National regulations
Seed transfer
Experimental facilities
Methodologies…
Cost/benefit of joined breeding

Seminars/ workshops
Adaptability/plasticity, Genetic variability and adaptive potential
Long-term breeding strategies
Breeding zones delineation
Breeding programmes
Vegetative propagation
Seed orchard
ABS-DUS
Field experimental network
Optimal deployment and use of FRM, Mutualisation of efforts…

State-of-art reports
Interspecific hybridisation
Phenotypic selection
Regions of provenances
Guidelines on Genetic Quality of Forest Reproductive Materials
Roadmap for joined breeding…

Standardisation
Traits assessment protocols

Treebreedex database of genetic resources
http://treebreedex.eu/


TREEBREEDEX
REFERENCE PROTOCOLS FOR ASSESSMENT OF TRAITS
AND
REFERENCE GENOTYPES
TO BE USED AS STANDARDS
IN INTERNATIONAL RESEARCH PROJECT

To provide **support tools** for R&D

Step 2

Forest clearinghouse
(environmental data)

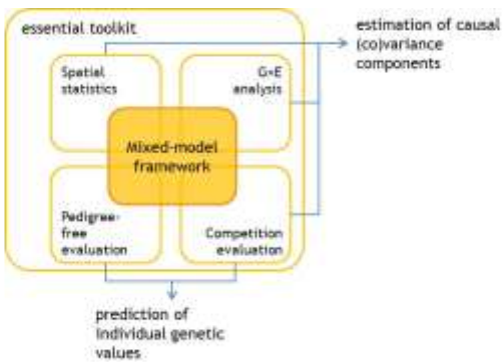
Genetic databases
(Treebreedex, Evoltree, Genfored…)

Trees4Future web-portal

Forest resources models
(Efiscen, Orchidee, Forgem, Tosia…)

Site-climate matching tool
GIS decision-making tool
(species site matching, delineation of breeding, deployment zones)

Statistical platform



To provide **support tools** for R&D

Plasticity
expert group

Phenology
expert group

Methodological and experimental support

Definition of standards
Field assessment and labs
Data management

Phenotyping

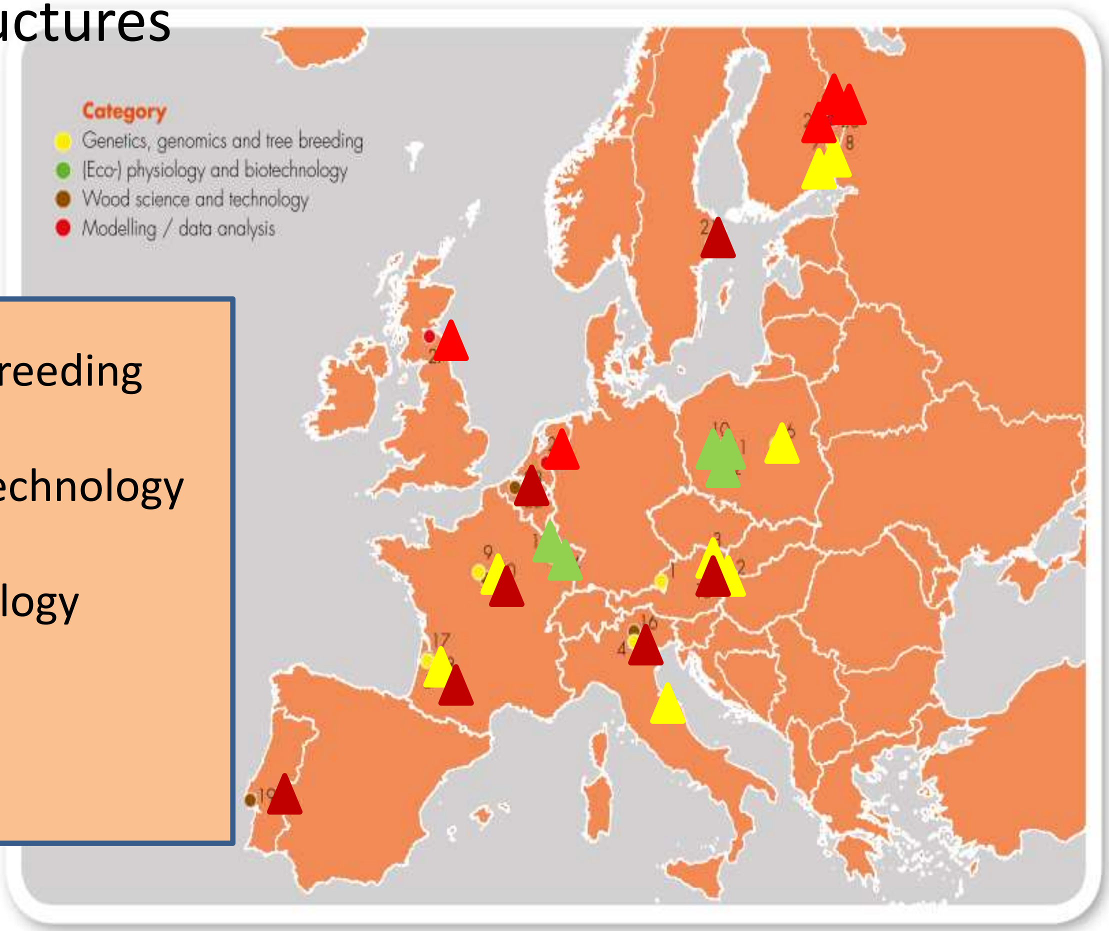
Genotyping

Development of high-throughput phenotyping techniques
Phenology
Tree-water relation
Wood properties

Development of a molecular platform
Fingerprinting
Support to FRM/wood traceability

To give access to **key-research facilities**

28 research infrastructures in access



- Genetics, genomics & breeding
- (Eco) physiology & biotechnology
- Wood science & technology
- Modeling

Physical visits (up to 3 months) – remote services – data access

Apply now!!!
http://www.trees4future.eu/

Towards a European Tree Breeding Centre?

Step 3

R&D INFRASTRUCTURES

Documentation
(state-of-art)

Data
(genetic resources)

Standards
(labs&fields)

Experts
networks

Tools

INFRASTRUCT.?
(Service labs)

Management of
genetic resources

IPR & Regulations

Exchange
of information
(workshops-seminars)

Training
(scientific-technical)

Communication

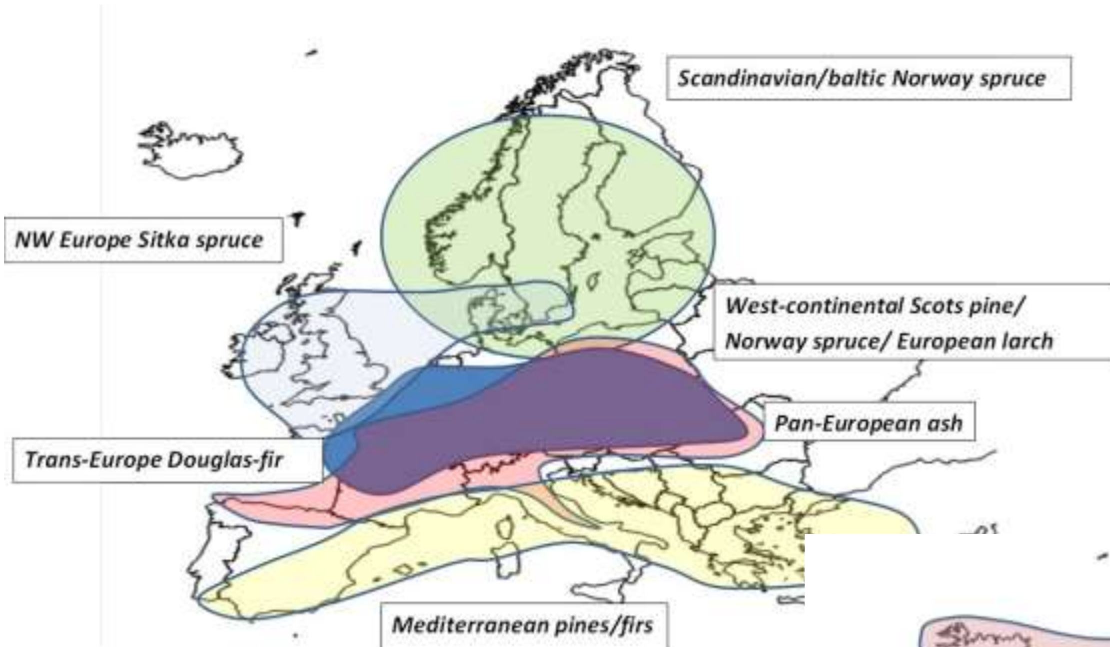
Joined Research projects

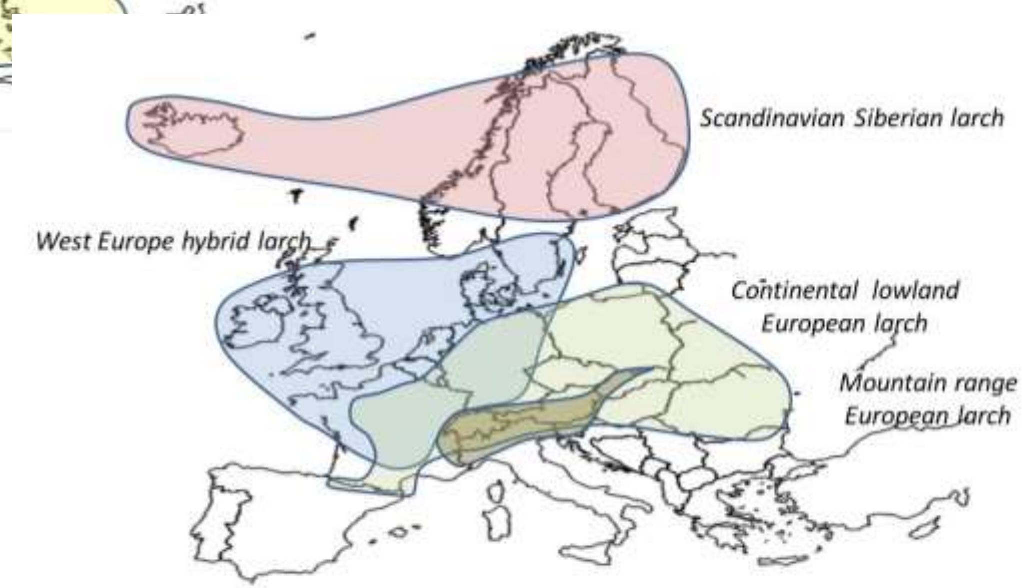
Collaborative breeding programmes

Joined breeding programmes…

Why not in Europe?

Step 4





Thanks for your attention