Interreg North-West Europe — Co-funded by the European Union

MigFoRest

Assisted Migration of Forest Trees: Aligning Genetic Research and Practice

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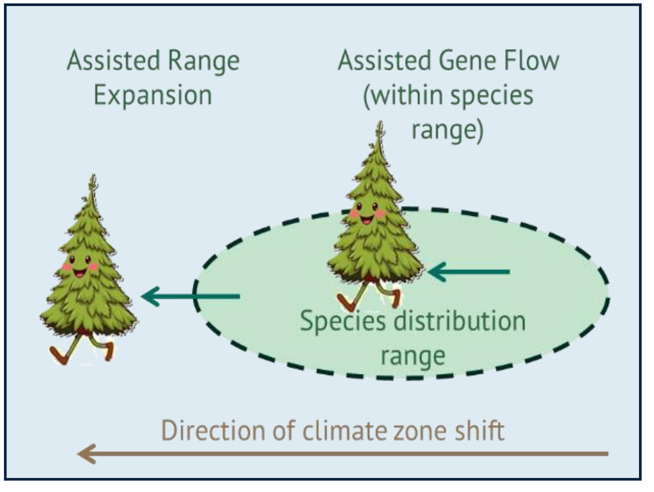
Increasing forest resilience in North-West Europe through assisted migration: risks and opportunities.

International conference, April 14th 2026, Brussels



- [1]FVA Baden-Württemberg, Freiburg, Germany

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Outline

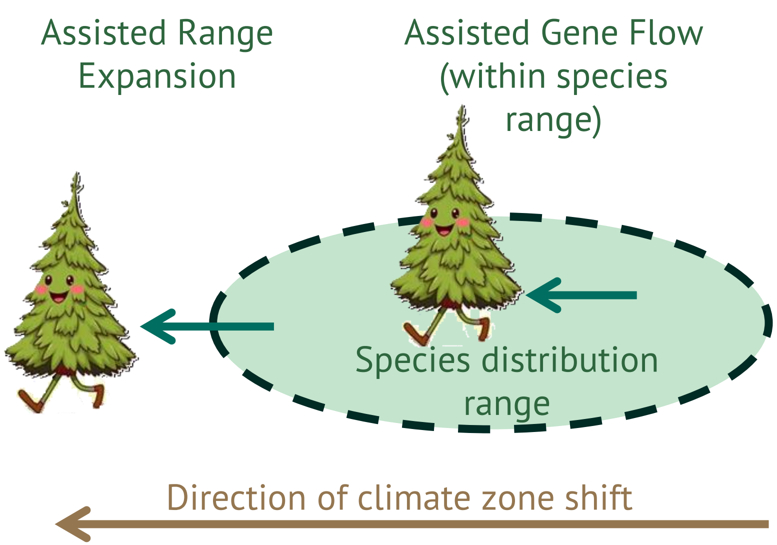
01. Introduction: Assisted Migration and seed sourcing in climate change, forest genetic research tools.

02. How can genetic research inform assisted migration decisions? Case studies.

03. Seed sourcing and Assisted Migration. Current status. Assisted Migration options vs. “local is best” paradigm

04. Is forest practice lagging behind the pace of climate change? Need for more AM? Role of forest genetic research.

Assisted migration as a means to enhance the adaptive capacity of forest trees (focus on Europe)



Tree images created with use of AI (https://redpandaai.com/)

- Forest trees adapted to the local conditions over centuries (evidence from genetic research). Pace of climate change → Future adaptation at risk
- Assisted Migration (AM; Assisted Gene Flow vs. Assisted Range Expansion) → A climate change adaptation strategy
- Do current seed sourcing strategies allow for AM? Are adjustments needed? If yes, which ones? How can forest genetic research inform AM?

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Seed sourcing (FRM transfer guidelines) in Europe

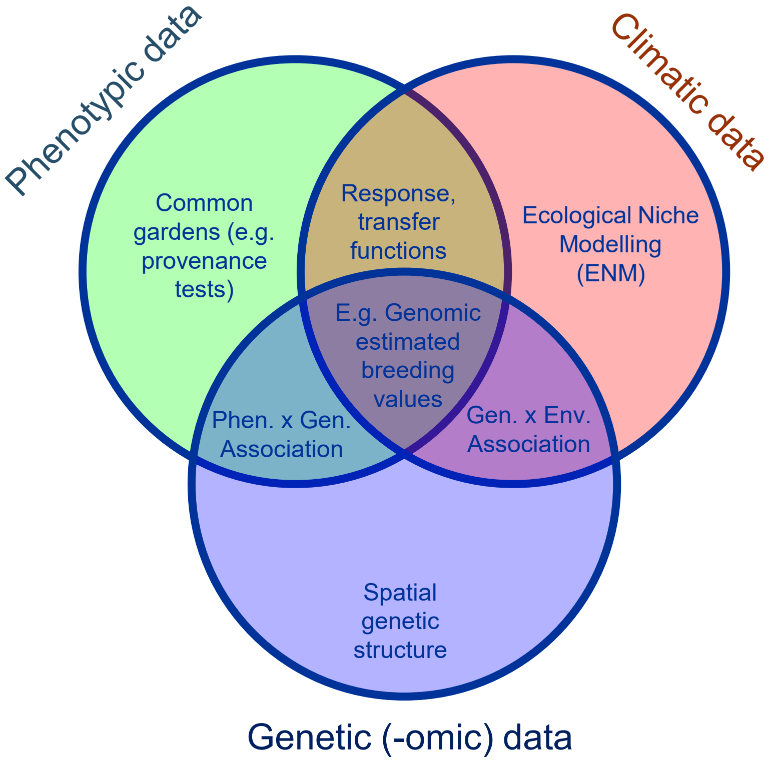
Regions of provenance for a species in a country[1]

Region of provenance	Recommended	Further options
1	1	2, 4, 5
2	2	1, 3, 4
3	3	2, 4
4	4	1-3, 5, 6
5	5	1, 4, 6
6	6	4, 5

[1]Imaginary country and example of guidelines. Map produced using AI (ChatGBT).

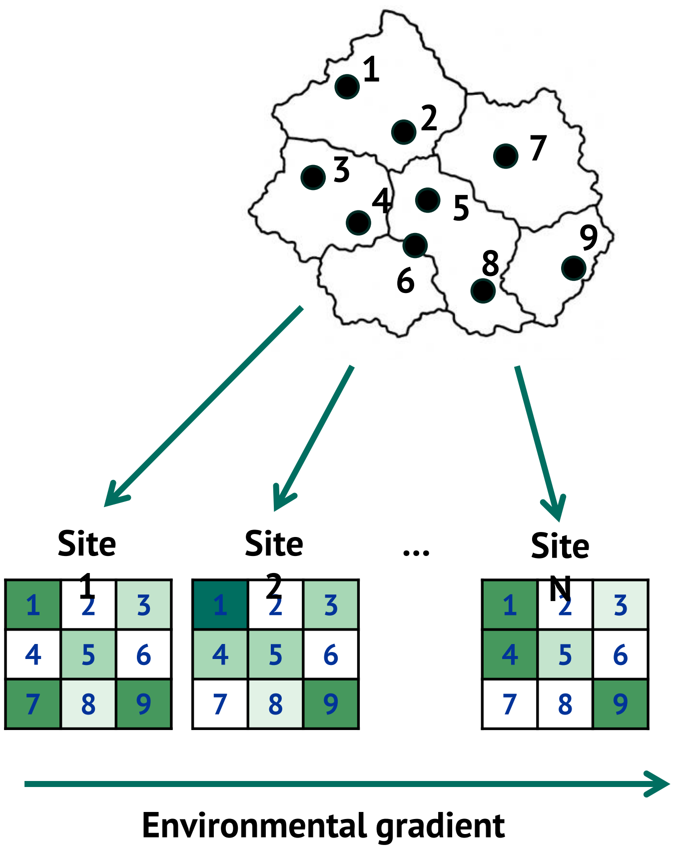
- Forest Reproductive Material (FRM) legislation and regulatory framework: largely harmonized in Europe (EU directive, OECD Scheme for FRM certification)
- Within this context, countries usually issue recommendations (FRM transfer guidelines):
  - Aim: to ensure optimal adaptation
  - Often the basis in order to receive funding for plantations in a forest
  - An imaginary example with a typical format in Fig. But format may vary
- FRM guidelines: a very important tool to implement AM in forest practice

Studying adaptive capacity of species: research approaches



- Climate-based: Ecological niche modelling, comparison to the predicted climate data → identification of source areas for AM, implies that species/provenance are locally adapted
- Phenotype-based: Common gardens with different provenances, repeated on different sites → evidence of adaptation
- Genotype-based: Signatures of adaptation in the trees' genomes → genetic basis of adaptation
- Combination between different approaches increases their efficiency

Phenotype-based studies: the concept of common gardens



- Plants from different provenances are planted in the same field. Same environment → growth differences among provenances = genetic
- Sets of provenances planted across several sites (different climates, soils) → exploration of ecological amplitude of the provenances
- Comparison with climate of origin → understanding of adaptation, e.g. late leaf unfolding as an adaption to cold climates

Phenotype-based studies combined with climate data: variation along climatic gradients (clinal variation)

Adapted from: Vitasse et al. (2009)[1]

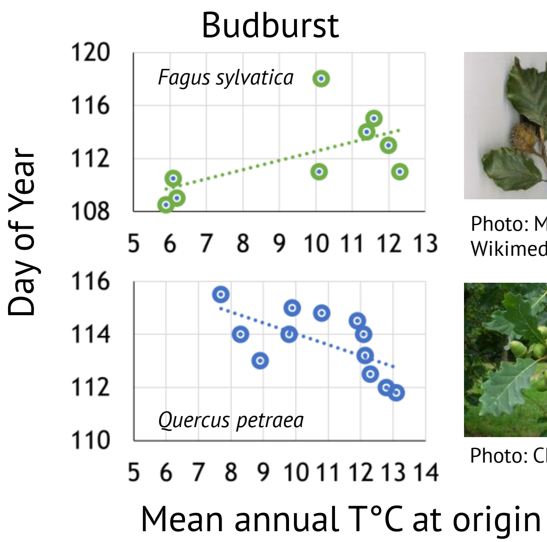


Photo: MPF, Wikimedia commons

Photo: Ch. Neophytou

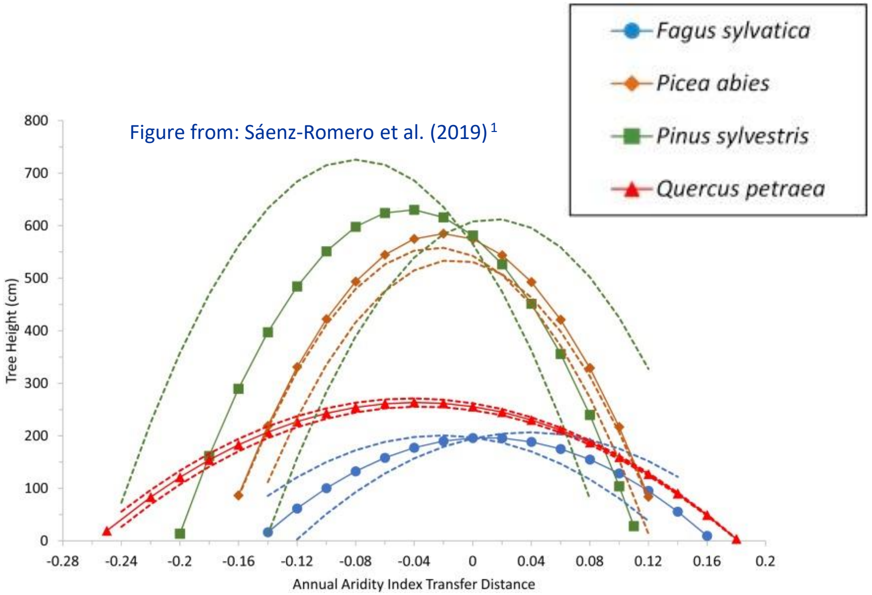
- Clinal variation differs among species. E.g., some species exhibit opposite patterns along altitudinal gradients[1]
- Recommended AM direction based on such results sometimes (rather rarely) deviates from a south-to-north direction:
  - Southward (short-med distance) AM for *Pinus sylvestris* in Sweden and Finland[2]
  - "Optimal" source for AM in French *Abies alba* located in the Northwest of the species' range[3]

[1]Vitasse et al. (2009). Altitudinal differentiation in growth and phenology among populations of temperate-zone tree species growing in a common garden. Canadian Journal of Forest Research, 39(7), 1259-1269

[2]Berlin et al. (2016). Scots pine transfer effect models for growth and survival in Sweden and Finland, Silva Fennica 50, 1562

[3]Benito-Garzón et al. (2018). Trees on the move: using decision theory to compensate for climate change at the regional scale in forest social-ecological systems. Regional Environmental Change, 18(5), 1427-1437.

Phenotype-based studies combined with climate data: drought adaptation of four European species



- Adaptive vs. plastic responses to environmental changes: significant differences among species[1]
- Adaptational lag (optimum towards cooler climate): evident in several cases[1]
- AM more meaningful for species with pronounced local adaptation / clinal and ecotypic variation. E.g. Norway spruce (*Picea abies*) rather than sessile oak (*Quercus petraea*)[1,2]

[1]Sáenz-Romero, C. et al. (2019). Common garden comparisons confirm inherited differences in sensitivity to climate change between forest tree species. PeerJ, 7, e6213

[2]Chakraborty, D. et al. (2019). Disentangling the role of climate and soil on tree growth and its interaction with seed origin. Science of the Total Environment, 654, 393-401

Genotype-based studies combined with climatic data: genetic vulnerability of provenances

- Identification of populations with high genetic vulnerability:
  - High "genomic offset", slow pace of adaptation at the tree line for stone pine (*Pinus cembra*) near the tree line in the Alps[1]
  - High "genomic offset" for cork oak (*Quercus suber*) in SW Iberia and Morocco[2]
- Complex adaptive patterns for *Abies alba* in southern French Alps (seed source mixing as an option in climate change)[3]
- Identification of areas (with high genetic vulnerability) to prioritize AM, but no golden standard how to apply AM[2,3]

[1]Dauphin et al. (2021). Genomic vulnerability to rapid climate warming in a tree species with a long generation time. Global Change Biology, 27(6), 1181-1195

[2]Vanhofe et al. (2021). Using gradient Forest to predict climate response and adaptation in Cork oak. Journal of Evolutionary Biology, 34(6), 910-923.

[3]Roschanski et al. (2016). Evidence of divergent selection for drought and cold tolerance at landscape and local scales in *Abies alba* Mill. in the French Mediterranean Alps. Molecular Ecology, 25(3), 776-794

Seed sourcing in climate change: AM options in European provenance recommendations

GERMANY (BAVARIA)

- Local/alternatives based on past experience
- "Climate-resilient provenances" (AM/AGF)
- Provenances for experimental plantations (long-range AM/AGF)

FRANCE

- Guidelines vary per species. E.g.:
  - Silver fir: mix local with other listed options
  - Sessile oak: use sources from drier and hotter areas combined with local material

Sessile oak (*Quercus petraea*)

LUXEMBOURG

HERKUNFTSEMPFEHLUNGEN (keine quellengesichert ausser L, keine Pa, keine montane Stufe)

Baumart orange: nicht FoVG -- grün: 2x empfohlen + HKG L -- blau: Sonderherkünfte -- rot: nur 1 HKG in RhPf -- bei **Höhenangaben** handelt es sich um HKG mit Höhenstufen
☼ speziell Klimawandel -- ☺ weiträumig / Klimawandel -- kursiv: Saatgutbestände oder Samenplantagen

Baumart	Liste	HK-Gebiet-Nr	Land	BundL	quellg.	ausg.	SHK	qual.	gepr.	Klimaw.	Herkunftsgebiet / Ausgangsmaterial	Gutland	Ardenne
Bu	L	AR	L			x					*601 (Laschet)*		x
Bu	W, F	FSY201	F			x				☺	France Nord-Est		
Bu	L1997, W,	810 07	D	RhPf		x					Rheinisches und Saarpfälzer Bergland,		
Bu	L1997, W	810 09	D			x					Harz, Weser- und Hessisches Bergland,		
Bu	W	810 17	D			x				☼	Württembergisch-Fränkisches Hügelland		
Bu	W	7	B	W		x					Bas-plateaux Mosans		

☺ = generalists (wide ecological amplitude / adaptive capacity)
☼ = provenances adaptable to drier/hotter conditions
} AM (AGF) options

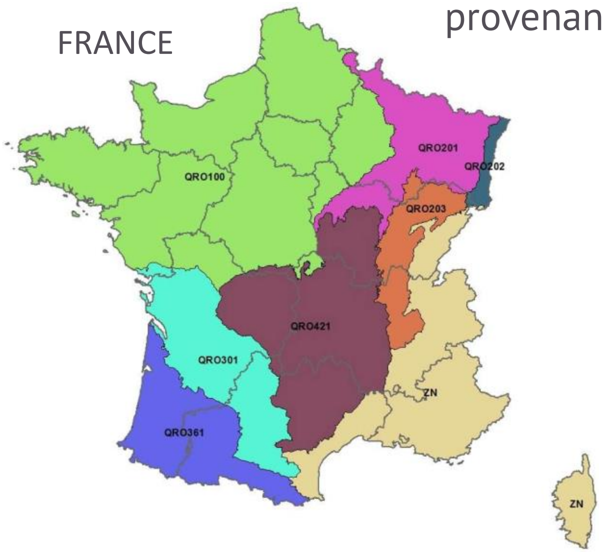
Common beech (*Fagus sylvatica*)

Photo: MPF, Wikimedia commons

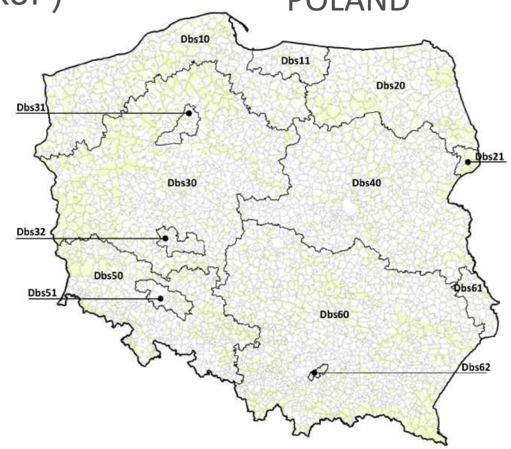
Seed sourcing in climate change: “Local is best” often the main option currently

Regions of provenance (RoP)

FRANCE



POLAND

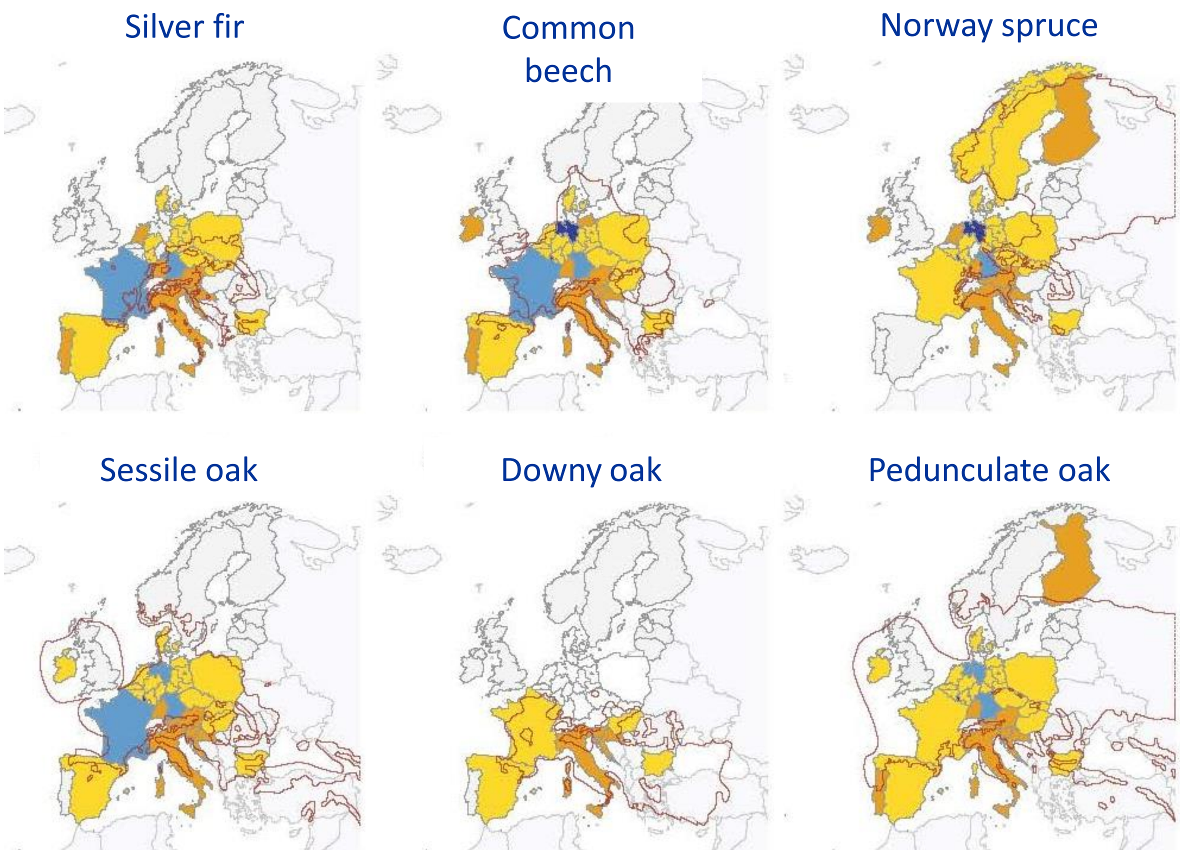


Pedunculate oak (*Quercus robur*)

- First priority: the local RoP. Neighbouring RoP can substitute the local one (e.g. if local reproductive material is not available)
- France: “AM/AGF premature based on the current research status”

Seed sourcing in climate change: status quo in Europe

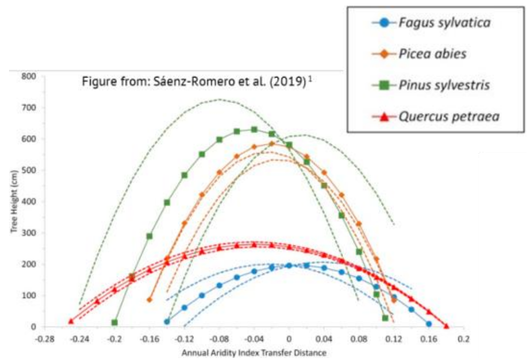
Map: F. Rentschler

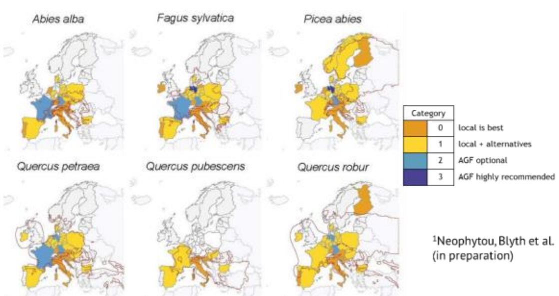


Category		
	0	local is best
	1	local + alternatives
	2	AGF optional
	3	AGF highly recommended

[1]Neophytou, Blyth et al. (in preparation)

Are seed sourcing practices lagging behind? How can forest genetic research guide recommendations?

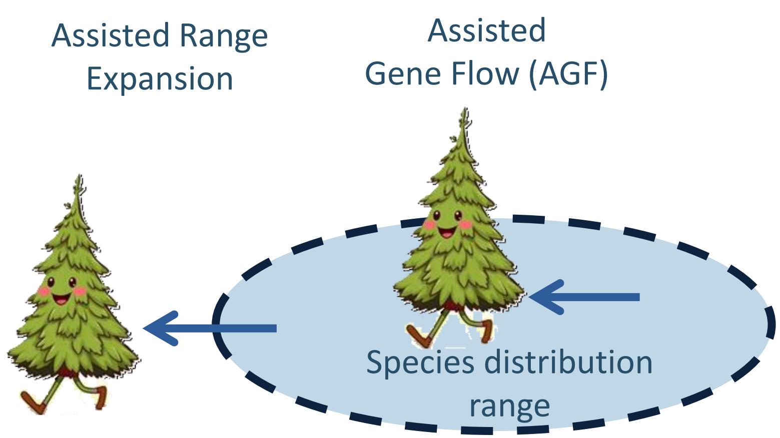




[1]Neophytou, Blyth et al. (in preparation)

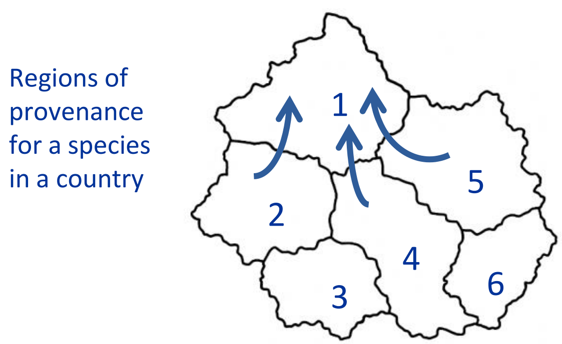
- Forest tree adaptation is lagging behind the pace of climate change (evidence from forest genetic research)
- Provenance recommendations largely follow the paradigm that 'local is best'
- Research results can help identifying vulnerable areas and source populations
- However, there is no golden standard how to apply AM
- Also risks have to be taken into account

Assisted Migration in practice: assessing and reducing risks and uncertainties



- Risks if a new species is introduced:
  - Invasive behaviour
  - Introduction of harmful associated organisms
  - Hybridization with native relatives (this can be also an opportunity)
  - Maladaptation
- AGF with non-local provenance of a native tree species is a low-risk option.
- Native species under pressure → Assisted Range Expansion a further important option (but risks should be assessed)

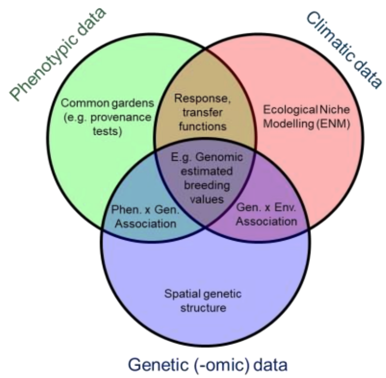
Assisted Migration in practice: which seed sources?

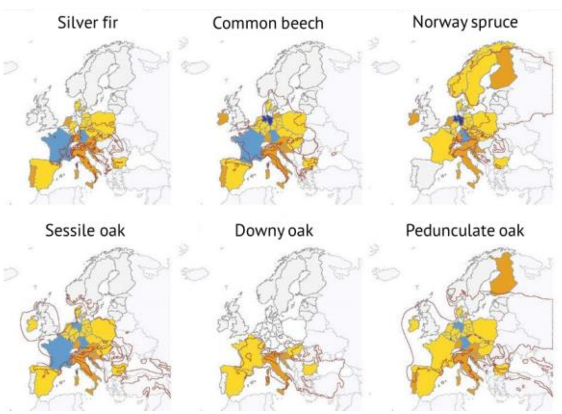


Acorn image created with use of AI (https://redpandaai.com/) and edited

- No golden standard how to perform AM. Uncertainties in forest genetic research and climate change models!
- Models do not consider all factors. Light regime, local soil conditions often not accounted for:
  - Poleward transfer over many degrees of latitude → risk of maladaptation to light conditions, day-night length, frost
  - Local adaptations beyond climate (soil, geology) → imported provenances may be less capable to adapt to these conditions
- Avoid transfer over too long distances (too many degrees of latitude), mixture with local material → in most cases a prudent strategy

Conclusions: transferring research results into the forest practice





- AM has risks and uncertainties, <u>but non acting may be coupled with more significant risks</u>
- No golden standards, but research can inform species-specific decisions.
- Need to move away from the ‘local is best’ paradigm.
- Practical aspects to be taken into account: is there available forest reproductive material for AM? Quality? Accessibility?
- High risk (e.g. remote provenances / species)? Limit the extent of AM.

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Thank you very much for your attention!

Thanks to: all people of the ACORN consortium who contributed to the seed sourcing / research review