What do genetic field trials tell about the future use of forest reproductive material?

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West Hungarian University, Sopron

Sękocin Stary 2010

Waldzukunft Report (Freiburg 2008)

Delphi interview, over 1000 forest experts

Out of 12 forecasts for 2050:

- Forests hit by climate change
- Genetic diversity declining
- GMOs unwanted but progressing

out of 5 unclear problems:

- Adaptation strategies?
- Risk management?

FRM use review → Climate change!

Problems, conventional forecasting of climate change effects

- limits assumed exclusively climatic
- vegetation supposed to move in community
- spontaneity of vegetation adjustment assumed
- human impact on European landscapes unconsidered: NO EMPTY SPACES!

→**no forestry imput?**

- Intraspecific adaptability differentiation of forest trees left unnoticed: “monolithic species?”

→**no genetic input?**

– ***role of forestry & genetics in internat’l climate mitigation: formal to nonexistent!***

Adaptability and tolerance are genetically set

Quantitative genetic knowledge is needed for:

- forecasting adaptive response
- formulating strategy of mitigation
- ***actively supporting adaptation***

(reprod. material trade, resource use & conservation)

Quantitative (growth , yield) forecasting needs <u>field</u> observations and tests!

Why are answers not ready?- 1

- Basic paradigm appropriate? (equilibrium and optimation as attainable goals?)
- Evolutionary change potential unclear
- Unsatisfactory coupling of quant. genetics with ecology, genomics
- Skewed approach to genetic processes: random vs directed →

Why are answers not ready?- 2

	Effect on response	Ease of investigation
(neutral) variation of the genome	?	xxxx
Past migration and drift	x	xxxx
Current selection, adaptation	xxxx	xx
Plasticity, epigenetics	xxxx	x

„The existence of climatic races within species is probable but it is not worth to follow further"

(Dengler 1935)

Can we offer anything beyond this?

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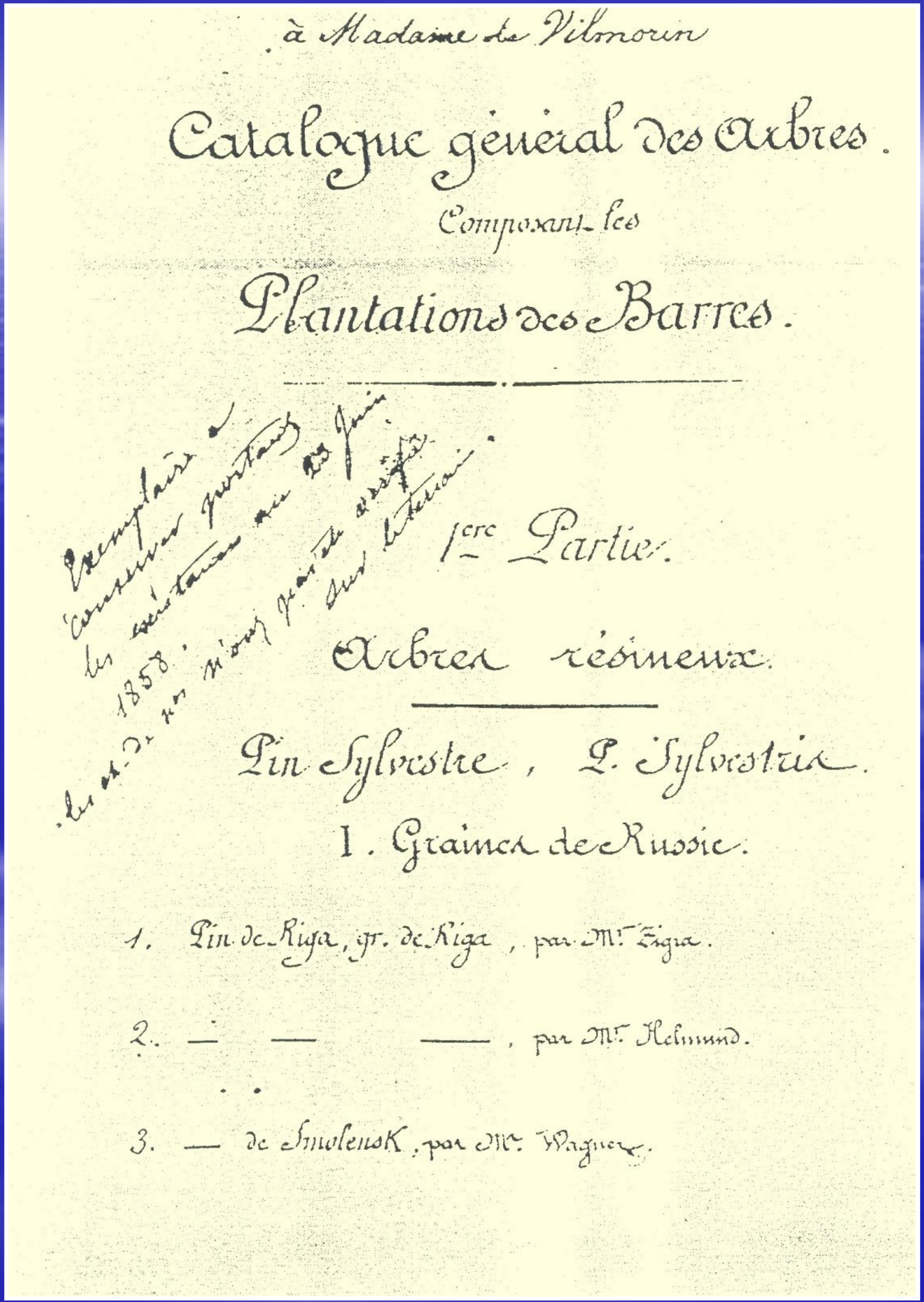
Can we offer anything beyond this?

There are answers in common gardens since Ph. Vilmorin, 1840



à Madame de Vilmorin

Catalogue général des Arbres.

Composant les

Plantations des Barres.

Exemplaire à
conserver portant
les mentions au 25 Juin
1858.
Les 1er et 2e nos n'ont pas été vérifiés
sur le terrain.

1ère Partie.

Arbres résineux.

Pin Sylvestre, P. Sylvestris.

I. Graines de Russie.

1. Pin de Riga, gr. de Riga, par Mr Zigra.

2. — — ——, par Mr Helmund.

3. — de Smolensk, par Mr Wagner.

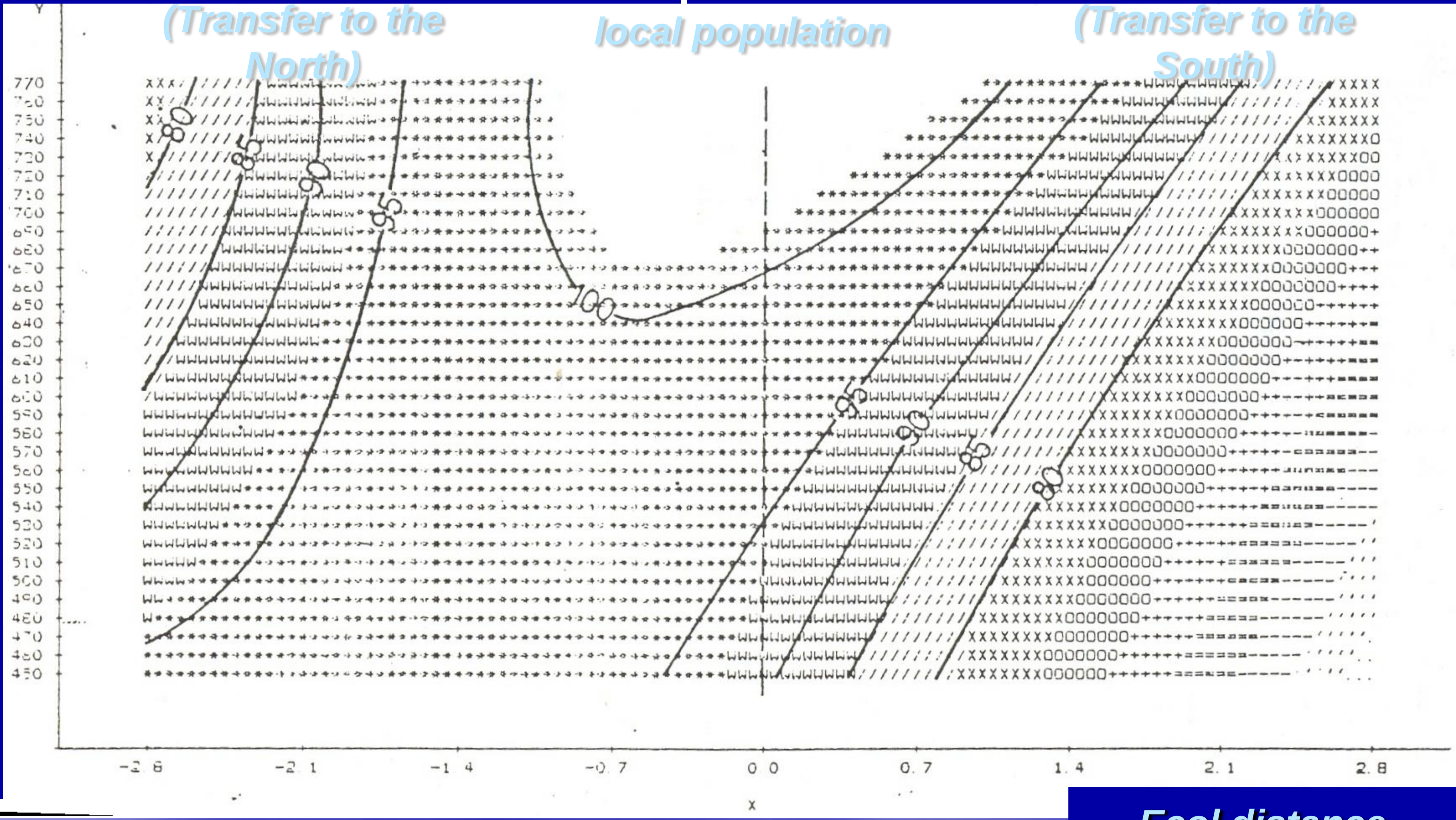
Common gardens

Provenance tests*:* probably the most important contribution of forestry to biology

- the only true simulation possibility for estimating adaptive response
- ***New use of tests****:* assessment of response to changed conditions
- ***Transfer analysis*** (Matyas 1987): growth and health across test sites interpreted as response to changed climate

cooling

warming



(Transfer to the North)

local population

(Transfer to the South)

Height of local provenance (cm)

Ecol.distance

Transfer analysis *P. banksiana in: Mátyás – Yeatman 1992*

What are the genetic options to cope with climate change ?

- **Present generation:**

Plasticity/ acclimation: response tailored to environment

Selection (differentiation, mortality): survival of the fittest

- **Succeeding generations** :

Migration to friendlier places: dispersal

Inheritance of traits of the fittest: adaptation

Random replenishment of genet. resources: gene flow

Superscript over genetic codes: epigenetics

Climate selection, plasticity
and their interaction, consequences

This process is genetic-driven!

Photo: K. Kovács

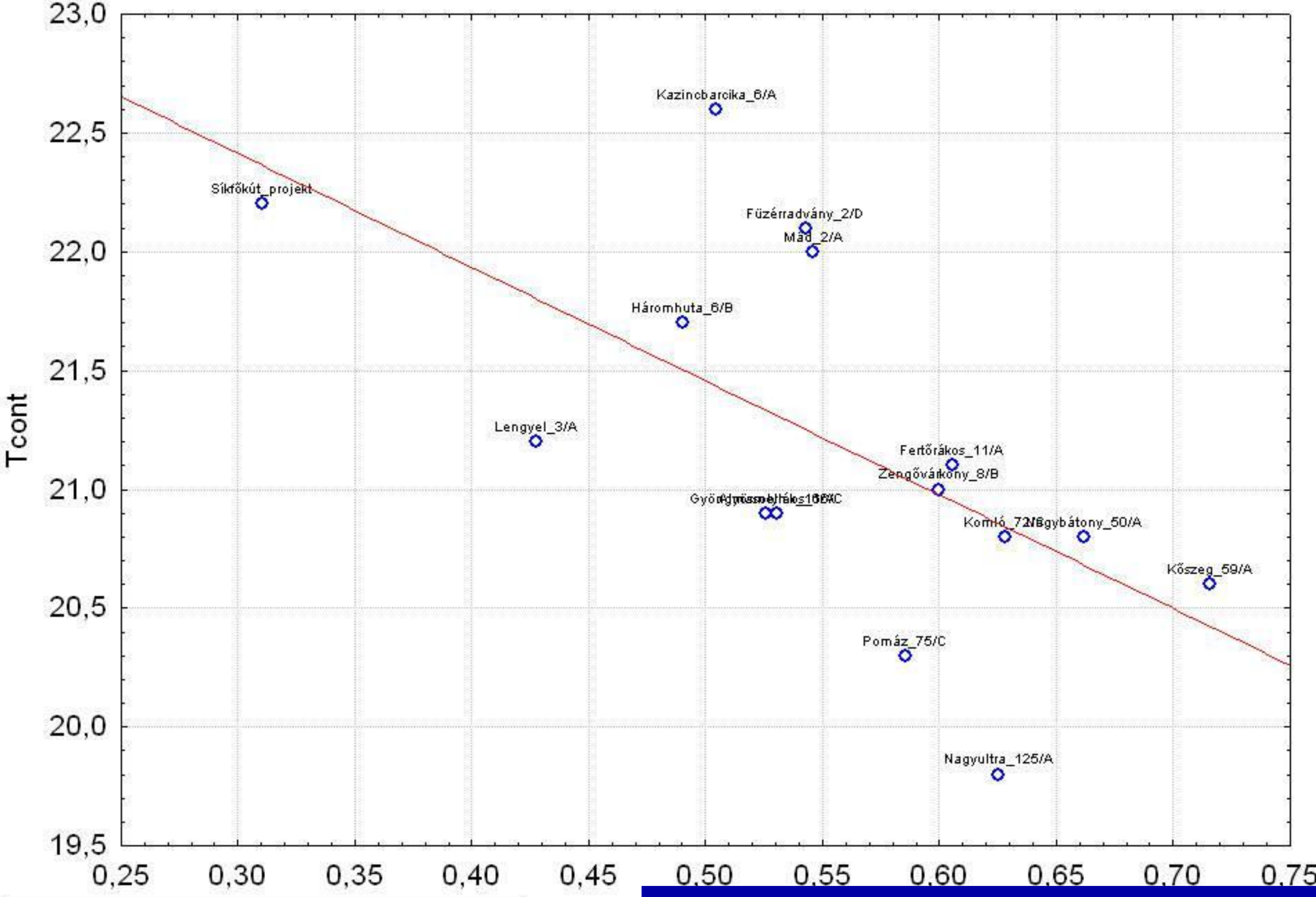
Effect of climate selection on allelic diversity:

Spring precipitation vs allelic frequency of ADH alleles:

(data for sessile oak by A. Borovics)

Allele type	Correlation with P_{spring}
ADH-3	+ 0,67 *
ADH-4	non sign.
ADH-5	- 0,73 * *
ADH-6	- 0,65 *

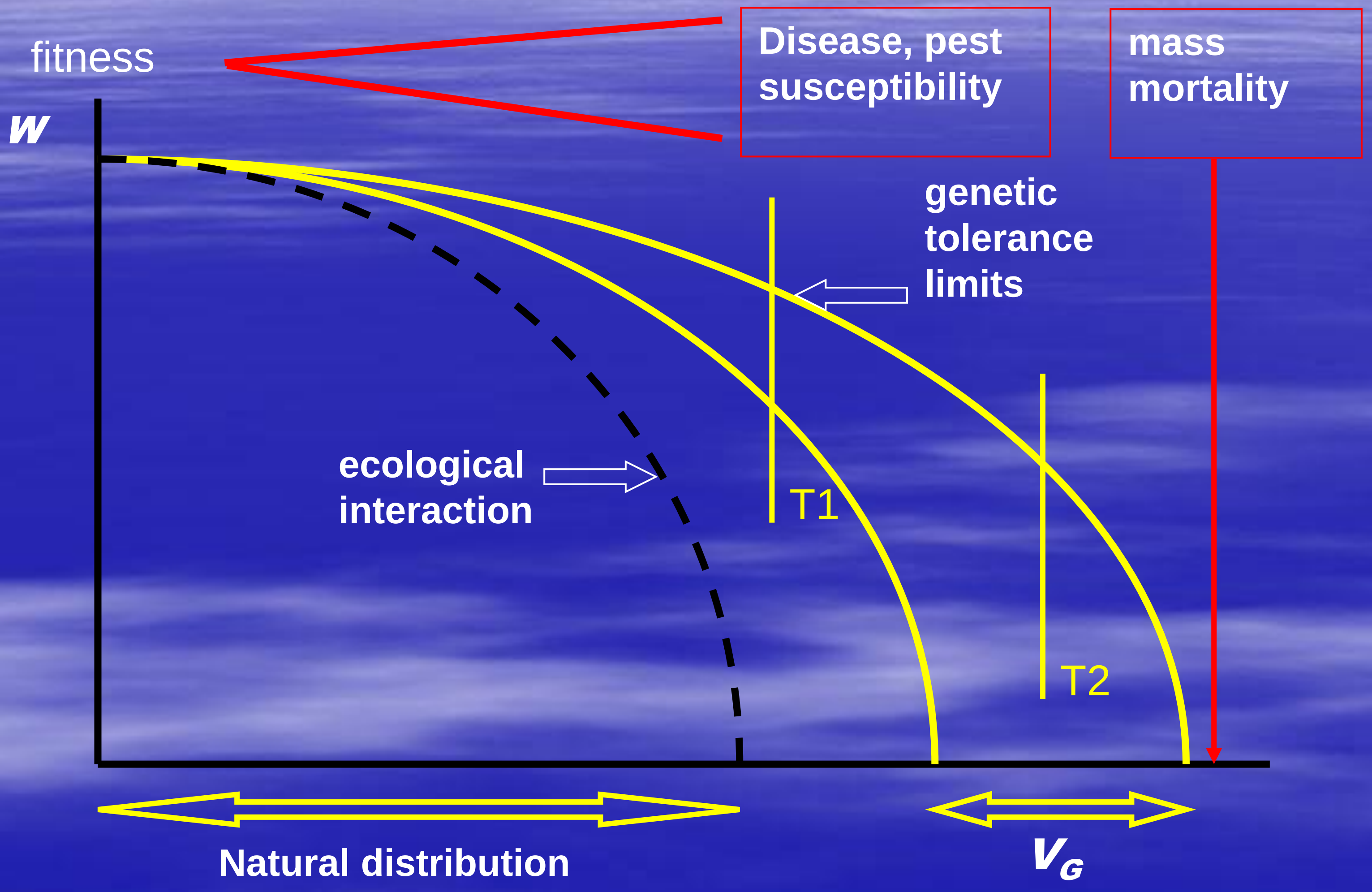
Continentality of temp. vs. exp. heterozygosity at EST-A



EST-A:Tcont: r = -0,6143, p = 0,0148

Data for sessile oak by A. Borovics

Ecological-genetic concept of population response to climatic changes



Worsening climate factors >>>>

Scots pine provenances, age 6, Kámon Arboretum


Cherkassk UA


P.apáti H

Ajan Pacif.RU


Beskarachaisk, Kazakhstan


Murmansk RU

Mass mortality, beyond the limits of tolerance

Test site: Kamon (Hungary) nr. ffd: 180, ann. prec.: 700 mm

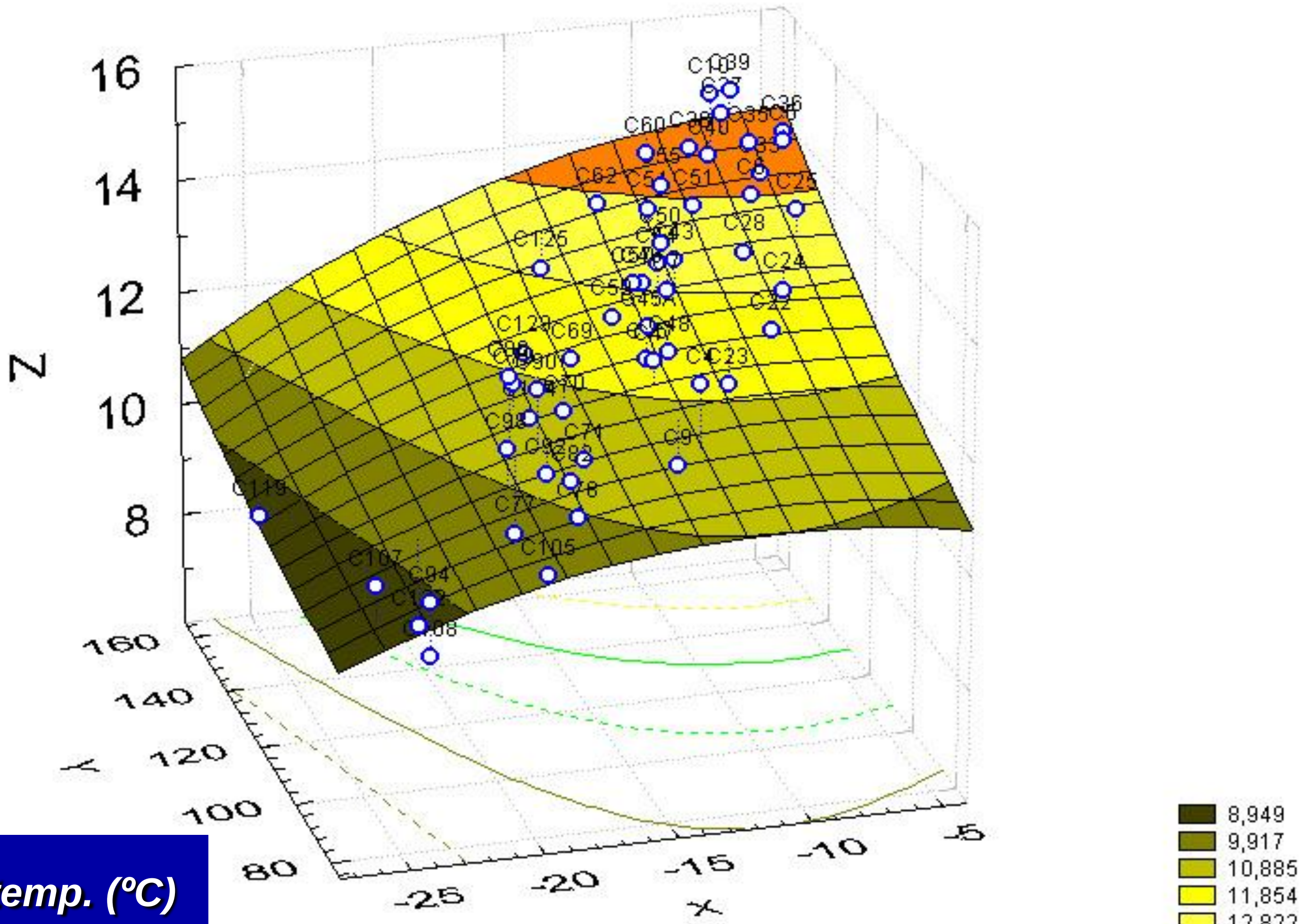
Provenance: Ayan, Yakutia (Russia)

Number of frostfree days: 107, annual precipitation: 890 mm

Height response of provenances in the VNIILM test Recsk, Hungary, age 15

$$Z = 6.753 - 0.267x - 0.007x^2 + 0.019y + 0.0001y^2 + 0.001xy$$

$$R = 0{,}907\ ;\ R^2 = 0{,}824$$

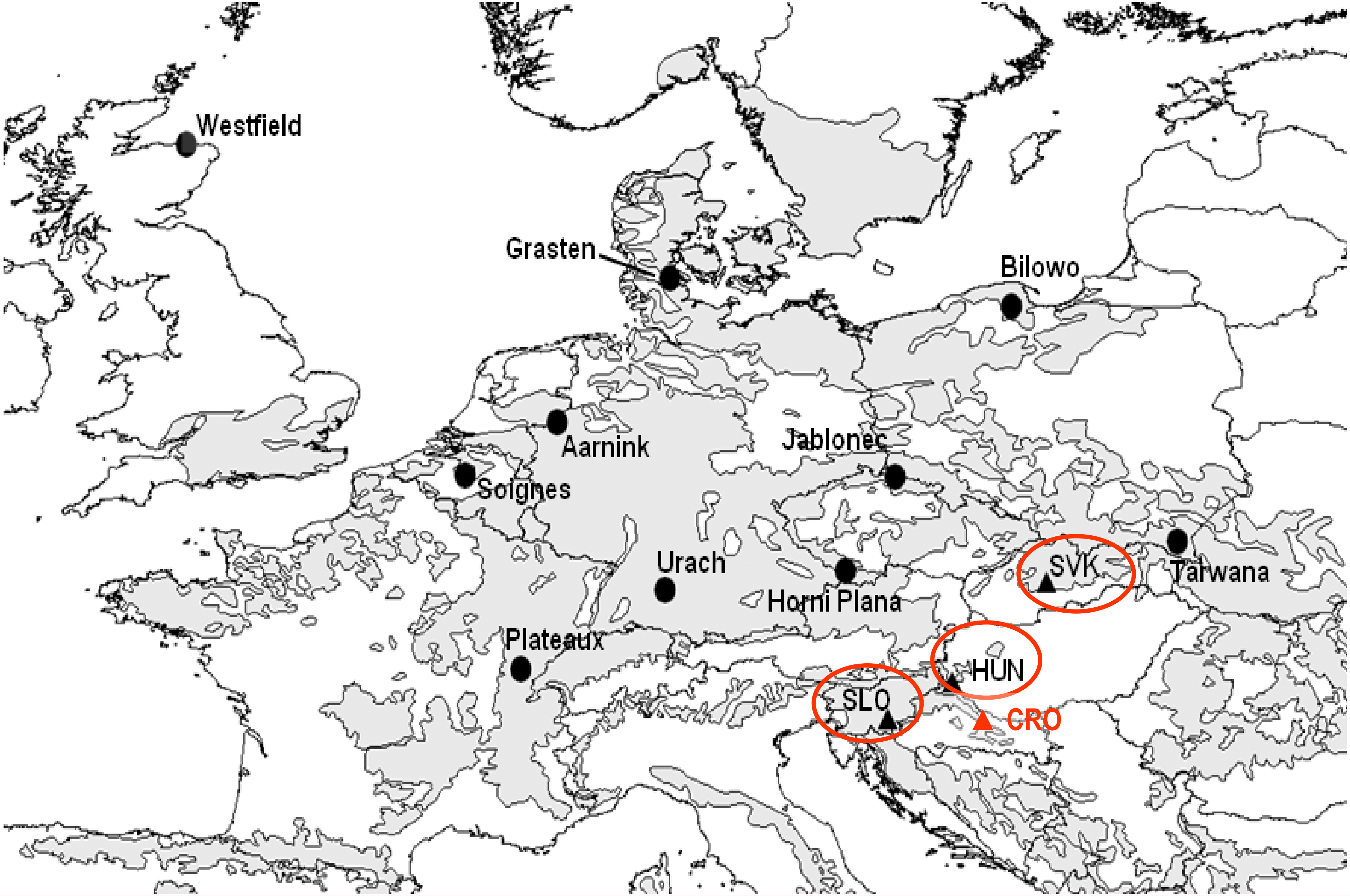


X: Mean January temp. (ºC)
Y: Number of frost days
Z: D $_{1.3}$


52. M.egregy (H) H: 3,13 m


13. Soignes (B) H: 2,62 m

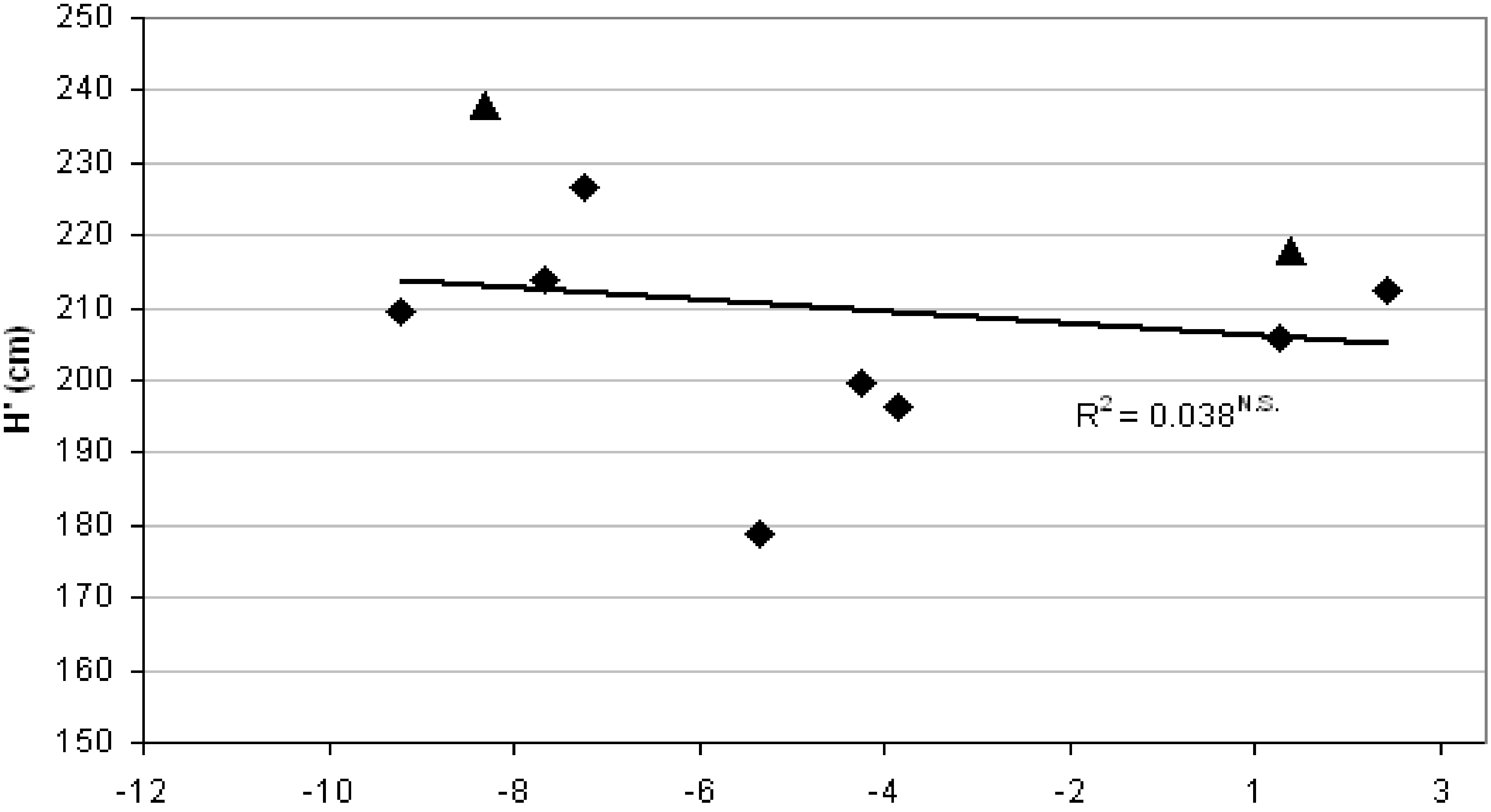
Gramatikovo, BG



Common provenances at SE European test sites

Response of juvenile height growth (*H'*) of beech to changed climate at the humid cool site Straza, SLO (*EQ:* 15.3)

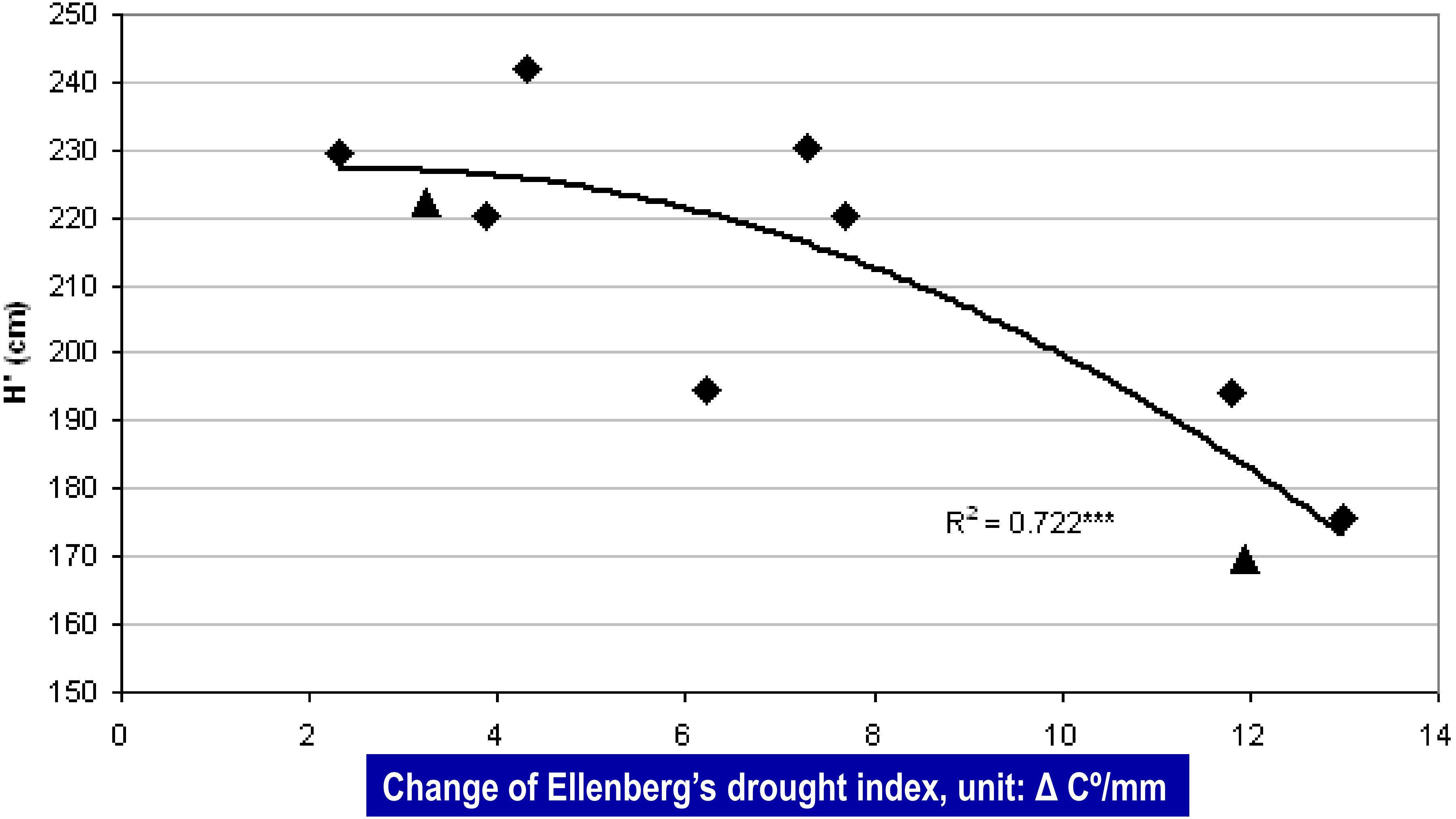
▲ interaction: Tarnawa (POL, left) and Plateaux (FRA, right).

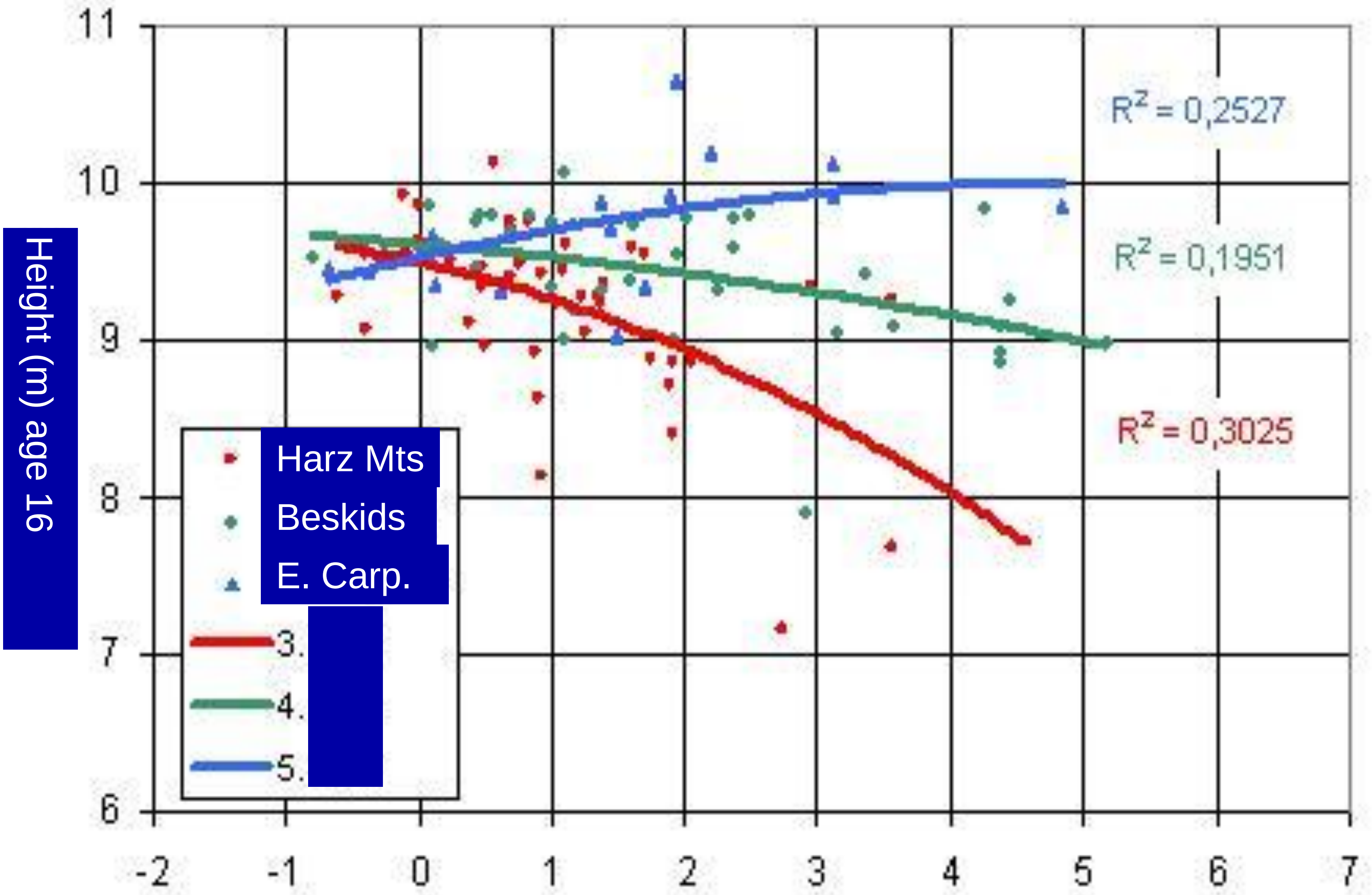


Change of Ellenberg's drought index, unit: Δ Cº/mm

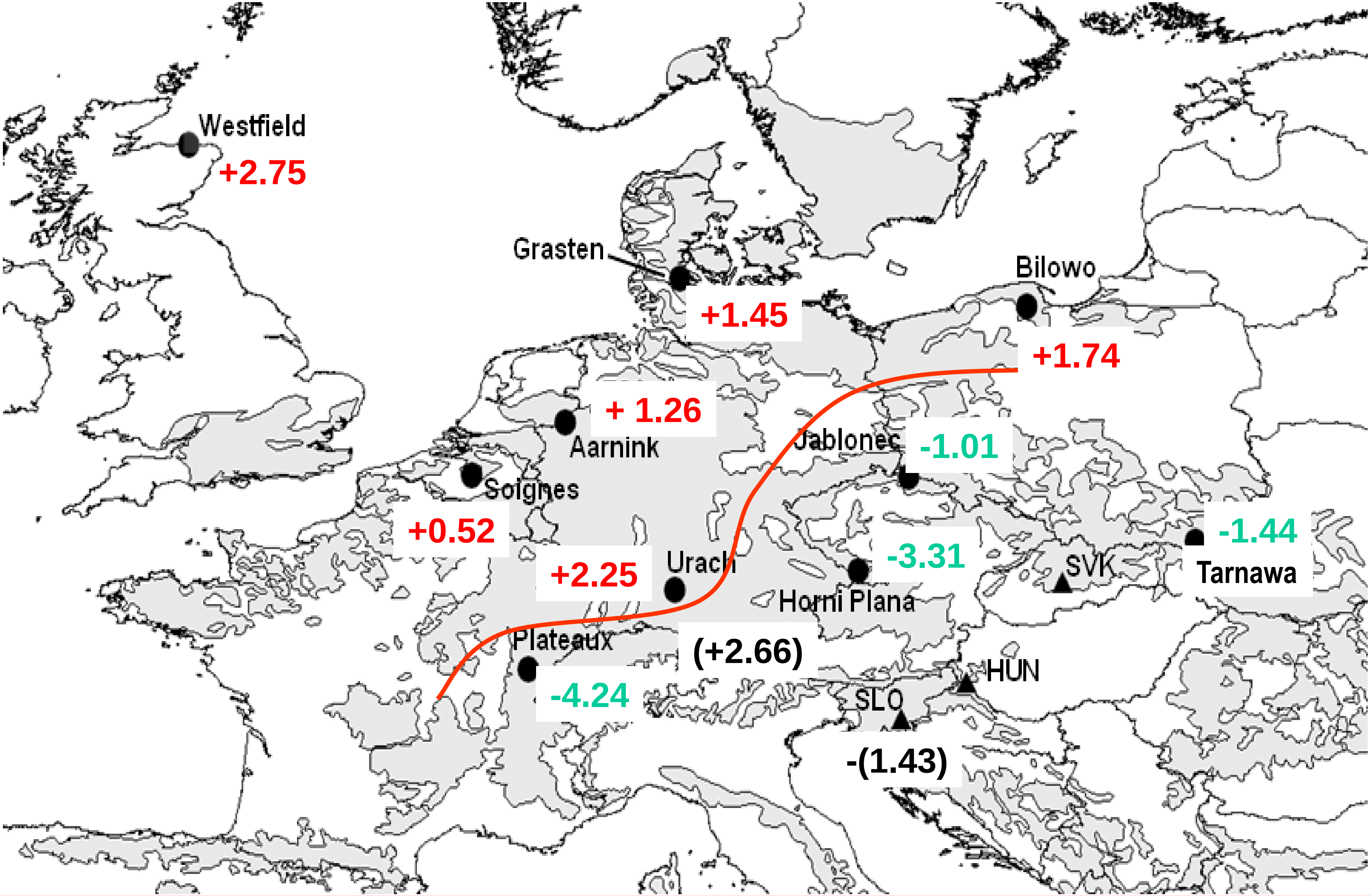
Response of juvenile height growth (*H'*) of beech to changed climate at the warm, xeric limit in Bucsuta, H (*EQ:* 26.3)

▲ interaction: Tarnawa (POL, left) and Plateaux (FRA, right).



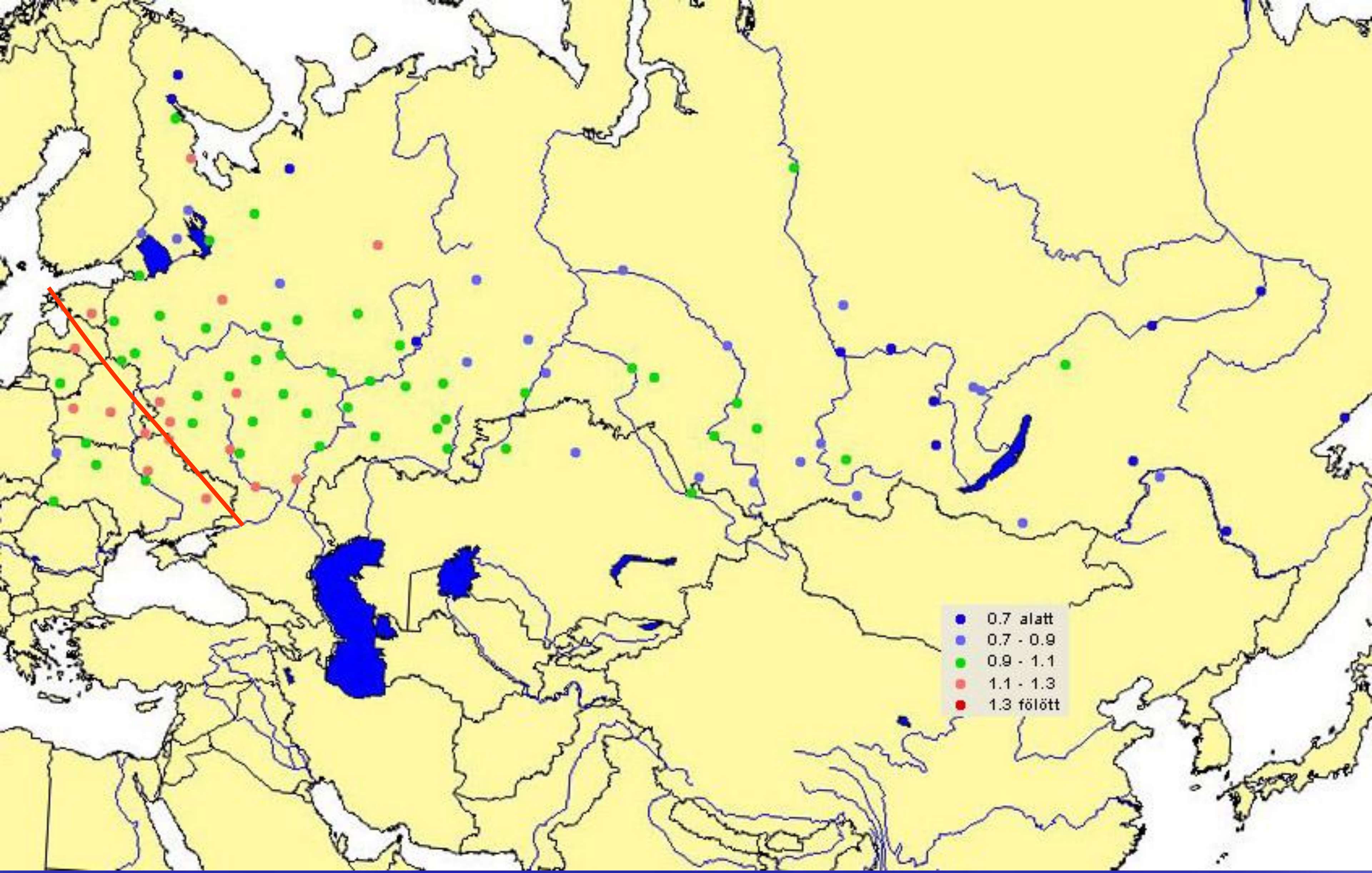


Height age 16 versus change of annual temp. change in plasticity differences in the IUFRO Norwa spuce trial (data É. Ujvari-Jarmai)

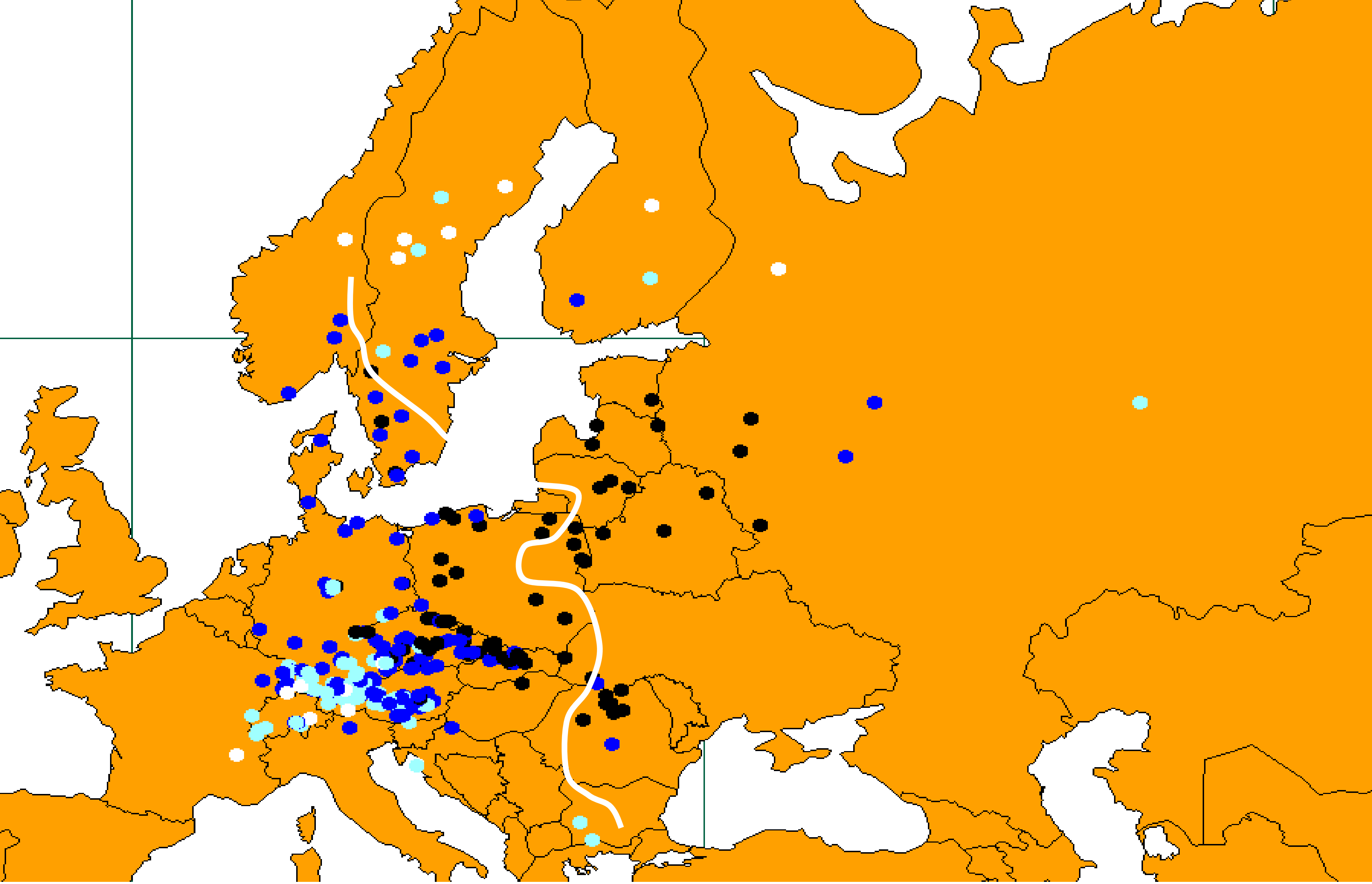


Response regression slopes indicating phenotypic plasticity

Juvenile beech populations tested in SE Europe (SVK, HUN, SLO)



Responsiveness (plasticity) of Scots pine provenances in Russian tests
(trait. juvenile height: L. Nagy unpubl.)



Responsiveness of Norway spruce in 5 IUFRO trials

Relative performance: black 100-120%, blue 90-100%, light blue 80-90%, white: 50-80% (Mátyás, Ujvári unpubl.)

Evolutionary optimisation thru adaptive disequilibrium

Paradigm of non-equilibrium state of ecosystems

valid also at the genetic level of adaptation to the (climatic) environment

- (genetic) selection and phenotypic plasticity are acting jointly,
- plasticity counterbalances the effect of natural selection= adaptation lag,
- “perfectly adapted”: in reality under constant strain = better performance in more favourable environments.

Silviculture: adaptive optimization implicitely assumed:

- **Basic dogma of FRM use**

Consequences of adaptive non-equilibrium

Corollaries

“Decoupling” of local populations? →fitness loss and extinction risk across the whole range following fast changes?

- Reality: depend on location, may lead even to growth acceleration

Prediction models: → assume equilibrium

- models predict responses too pessimistic
- the genetic/physiological possibilities for persistence are not instantly exhausted under changing conditions

Revision of principles of FRM use necessary

Caveats: conclusions based on juvenile test responses!

Conclusions

General (descriptive) result of tests

- Differences between populations in all traits confirmed…
- Although effect of climate traceable, adaptability is broad,
- Between-population differences in phenotypic plasticity,
- Local is not necessarily best,
- Differences between species in adaptation pattern

not particularly exciting …

Predictive results

- **Macroclimatic adaptation + (simulated) climatic change** explains a significant part of response
- Response depends on change direction and limiting factors: **predictable**
- **Plasticity: a key factor in adaptation to fast climate change!**
- Natural populations not in adaptive optimum;
- Plasticity seems to be linked to climate selection: plastic zones?
- Extreme conditions → genetic depletion: special management needed

Prediction of growth response (considering only macroclimate)

Growth response depends on

- **macroclimatic adaptation** (at origin),
- the climatic **environment** where the population is growing/tested
- **climatic distance** of change,
  respectively: by which the population was moved
- **plasticity!**

Plasticity:

Role of plasticity in adaptation and speciation

- selection effects buffered
- acts for stasis of species, against isolation, speciation
- Result: local genetic inequilibrium

Questions directly related to FRM use:

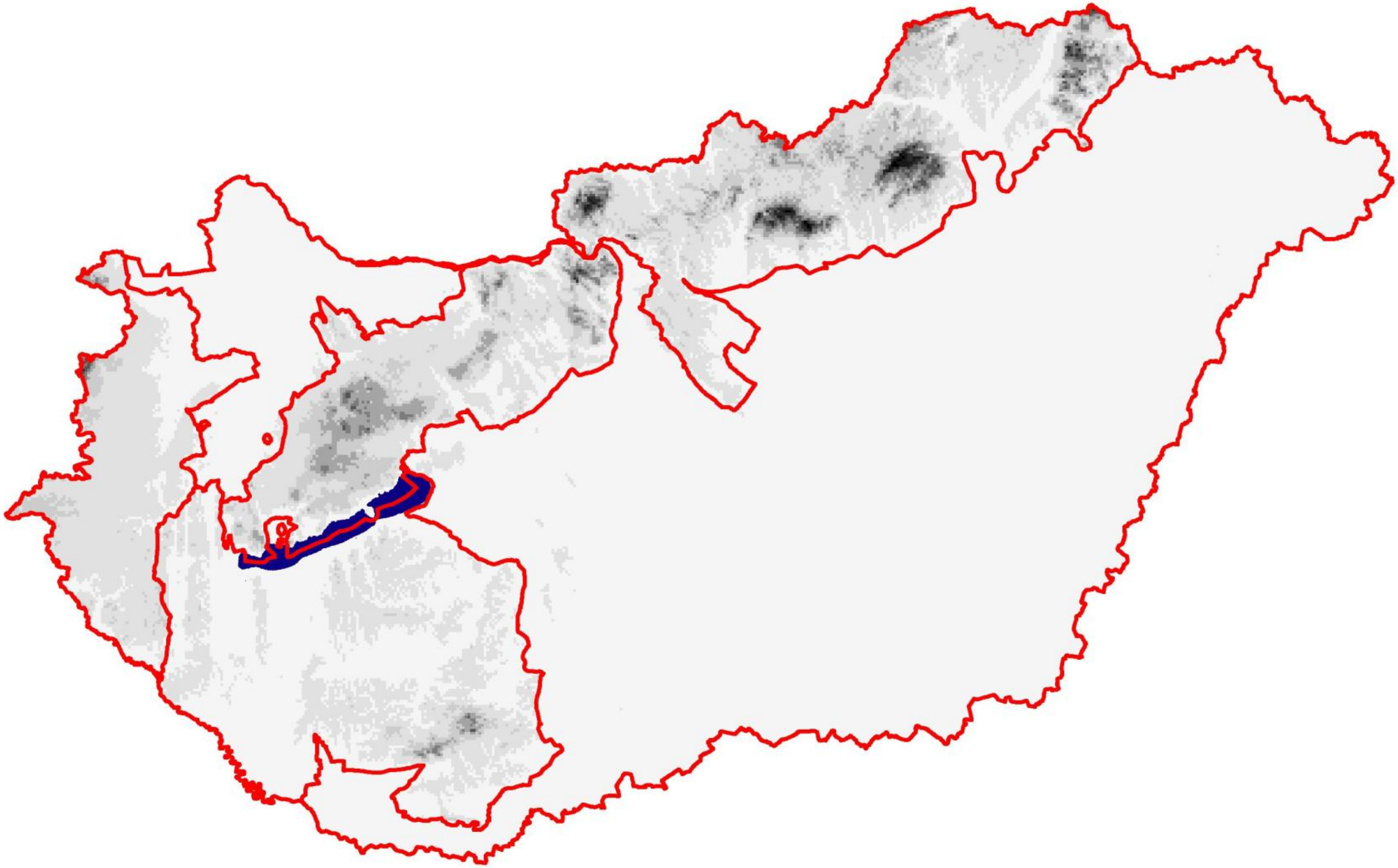
Value of autochthonity?

Width of plasticity?

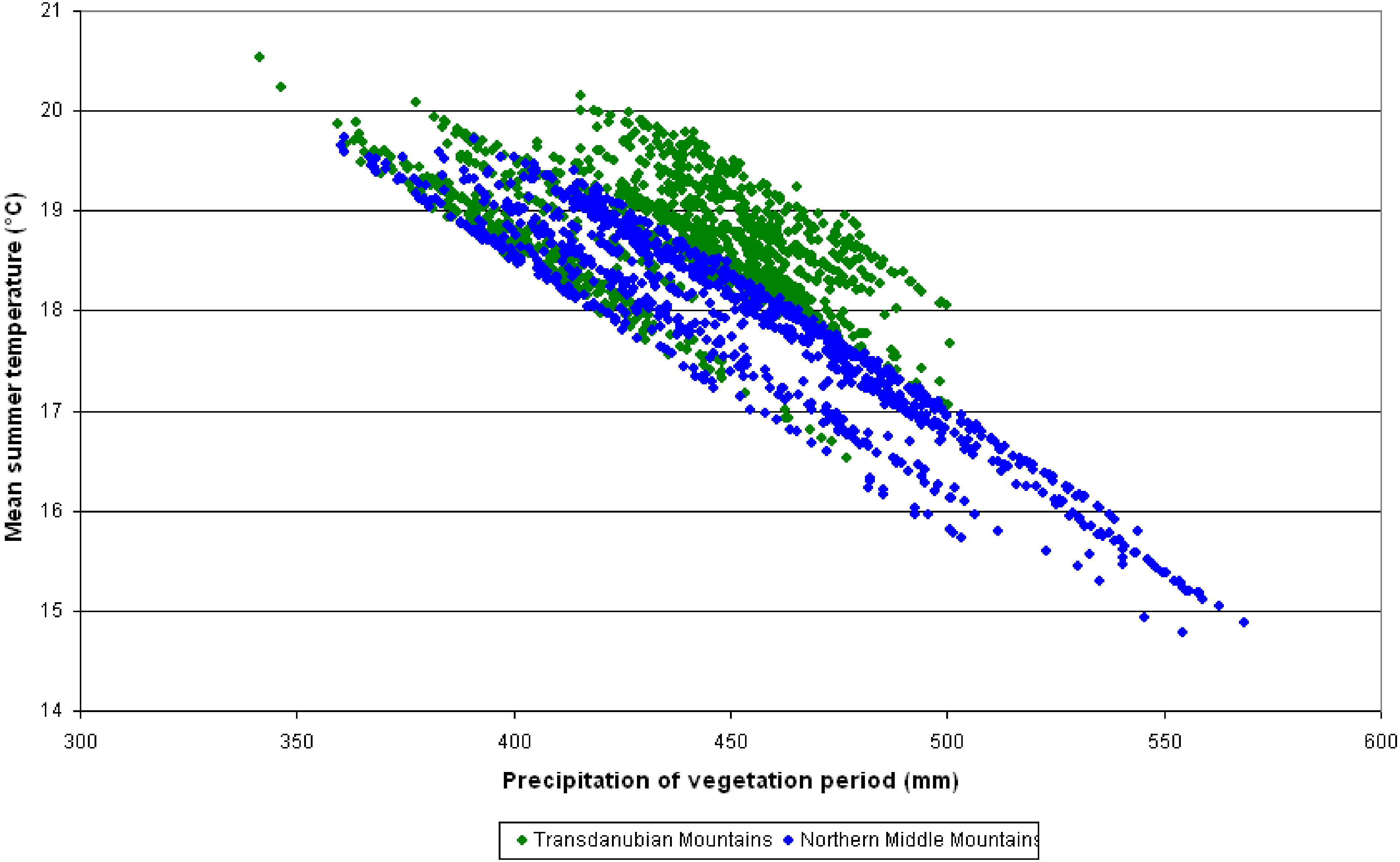
Speed of acclimation?

Unresolved: epigenetics??

Beech seed zones, Hungary



Climatic niche of beech stands in two seed zones in Hungary



Populations at the extremes

1.Effectivity of selection at extremes:

Severe selection depletes→plasticity loss

Effect may be very fast

2. Rethinking of forest management rules

Seed zones: pops at margins resemble each other better than geogr. adjacent ones

Special rules for exposed regions?

3. Conservation / management strategy

Marginal populations less valuable?

Spontaneous processes disrupted: interference unavoidable

Consequences, FRM use

Consequences for deployment of reproductive material

FRM policy: risk minimalization - ecology first

- leave more room for selection: plant higher numbers, prefer seeding, etc.
- reinterpretation of autochthony principle
- Preference for plastic, adaptable populations
- provenance regions to be redrawn – at least for extreme zones? (for optimum, northern: less urgent)
- novel bases for prop. material
- evacuation of threatened gene pools
- FRM serves „human supported migration"

Conclusions, FRM transfers

- apply ecological criteria instead of geographic-based ones to define recommended directions and limits of transfer;
- transfer effects are not similar in different part of the distribution area, in particular:
- in the range of the climatic optimum, in the area centre, and towards the thermal limit (north- upward) transfers are less critical;
- in (macro)climatical sense, local superiority is mostly not valid;

Conclusions: differentiated use of FRM

- individual („ecotypic”) differentiation of pops in growth and plasticity, further support the use of selected sources, (seed) stands;

Reconsidering seed zones

- proposed separate treatment of higher elevation populations is supported by the deviating behaviour of provenances from above 1000m;
- stressful and uncertain conditions at the lower (xeric) limit of the species: more rigorous rules for use and conservation;

Again: seed zones and epigenetics???

General policy recommendations

- Concept of adaptation and appropriate use of FRM to be incorporated in **national forest strategies**
- Flexible pan-European guidelines to be developed
- Orienting research in adaptive response **(further field tests with specified aims)**

Priorities

- threatened extreme limit populations (mostly south-continental, mediterranean)
- phenotypically plastic populations
- rare species at xeric tolerance limit

Common plan of action

- crossborder collaboration
- sharing of responsibilities

References

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- *Mátyás C. 2010. Forecasts needed for retreating forests (Opinion) Nature 464: 1271, April 29, 2010*


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End of (spontaneous) evolution?

Why human interference is indispensable

- Changes too fast!
- Human-dominated landscapes : slow or missing spontaneous adjustment
- Genetic adaptation unreliable
- Natural processes constrained at (lower) ecological limits (flowering, regeneration)
- ***SE continental Europe especially threatened***

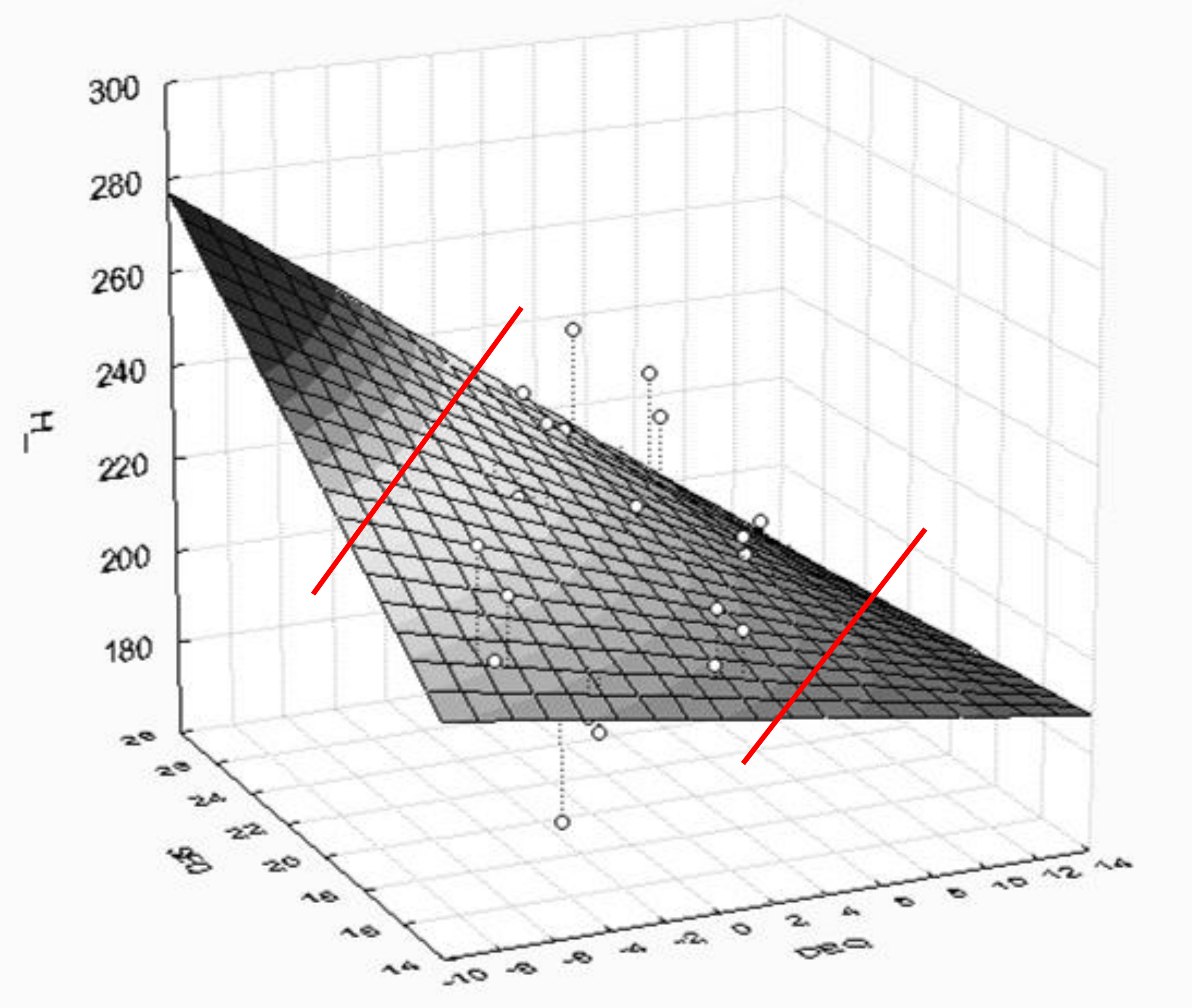
Method

Ecodistance approach:

Phenotypic response to climate depends:

- on the **climatic conditions** where the population is actually grown or tested, and
- on the **ecodistance of transfer**, i.e. on the magnitude and direction of environmental change experienced due to the transplanting to the test site

Selected variable: of ecological (not geographical!) relevance



Height response: thermic vs xeric limit

corrected height (*H'*) vs. climatic shift in EQ (*DEQ*, right) and test site climate in *EQ* (*SEQ, left)*

Width of plasticity / Autochthony:

Importance of autochtony determined by:

- Species level: genetic system and distributional pattern of species
- Within species: local selection pressure, local level of plasticity
- Planting site: severity of selection on site; ecological risks and constraints
- Genetic quality of population (human effects) and surrounding stands
- Policy level: priority of production vs conservation

How will trees respond *within a generation?*

- **How much climatic (site) change is tolerated?**
- Are available genetic resources sufficient?
- Speed of adaptation/evolution?
- Limits to genetic adjustment?
- Acting of natural (spontaneous) evolution?

In forestry/conservation practice:

- **Which populations to plant, where?**
- **How to conserve, what?**