GENTREE

Modelling management effects on forest genetic resources (FGR) under climate change

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INRA SCIENCE & IMPACT

E F I

Optimizing the management and sustainable use of forest genetic resources in Europe

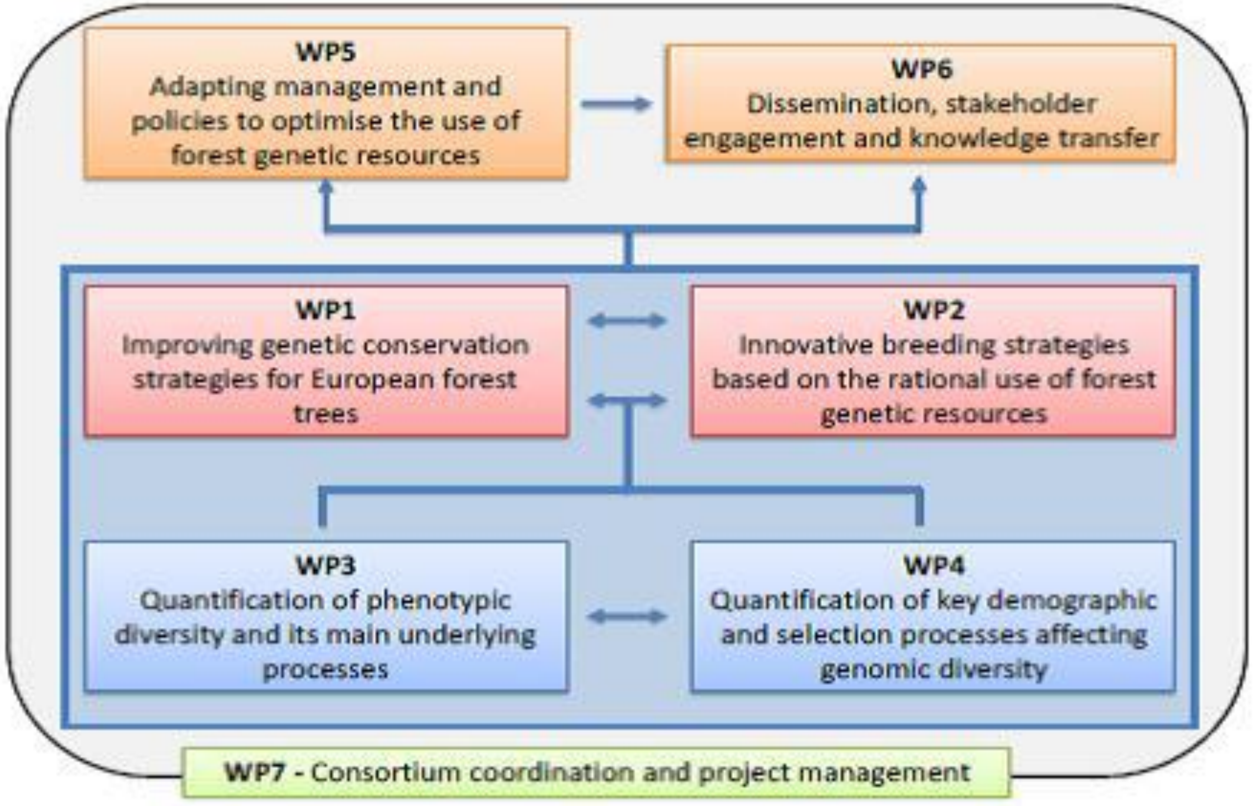
Duration: 1st March 2016 – 28 February 2020

Partners: 22 public and private research organizations and enterprises. Coordination: INRA

Goal: *to provide the European forestry sector with better knowledge, methods and tools for optimising the management and sustainable use of forest genetic resources (FGR) in Europe in the context of climate change and continuously evolving demands for forest products and services.*

FGR= the heritable materials maintained within and among tree and other woody plant populations that are of actual or potential economic, environmental, scientific or societal value (FAO)

Overview of the breakdown of WPs and their relationships.



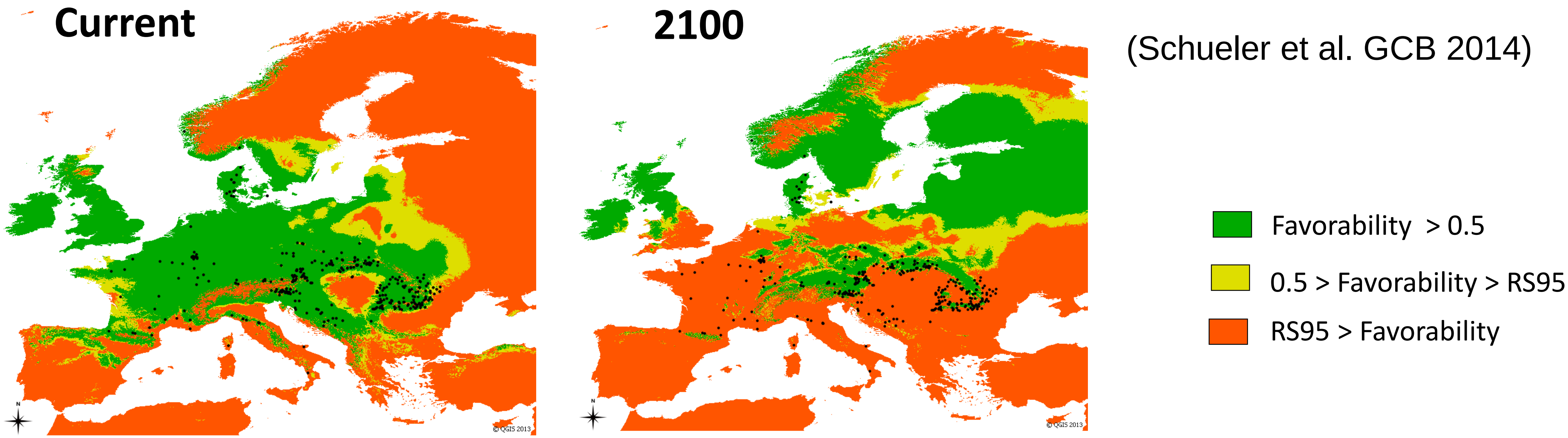
http://www.gentree-h2020.eu/

FGR in the context of climate change (CC)

0,5 million hectares of European forests are specifically managed for in-situ dynamic conservation

"the goal of genetic conservation is the maintenance of a diverse group of mating individuals and populations across different environmental gradients to ensure continued evolutionary processes" (Koskela et al. 2013)

Modelled favorabilities of European beech with the location of Dynamic Conservation Units (•)



(Schueler et al. GCB 2014)

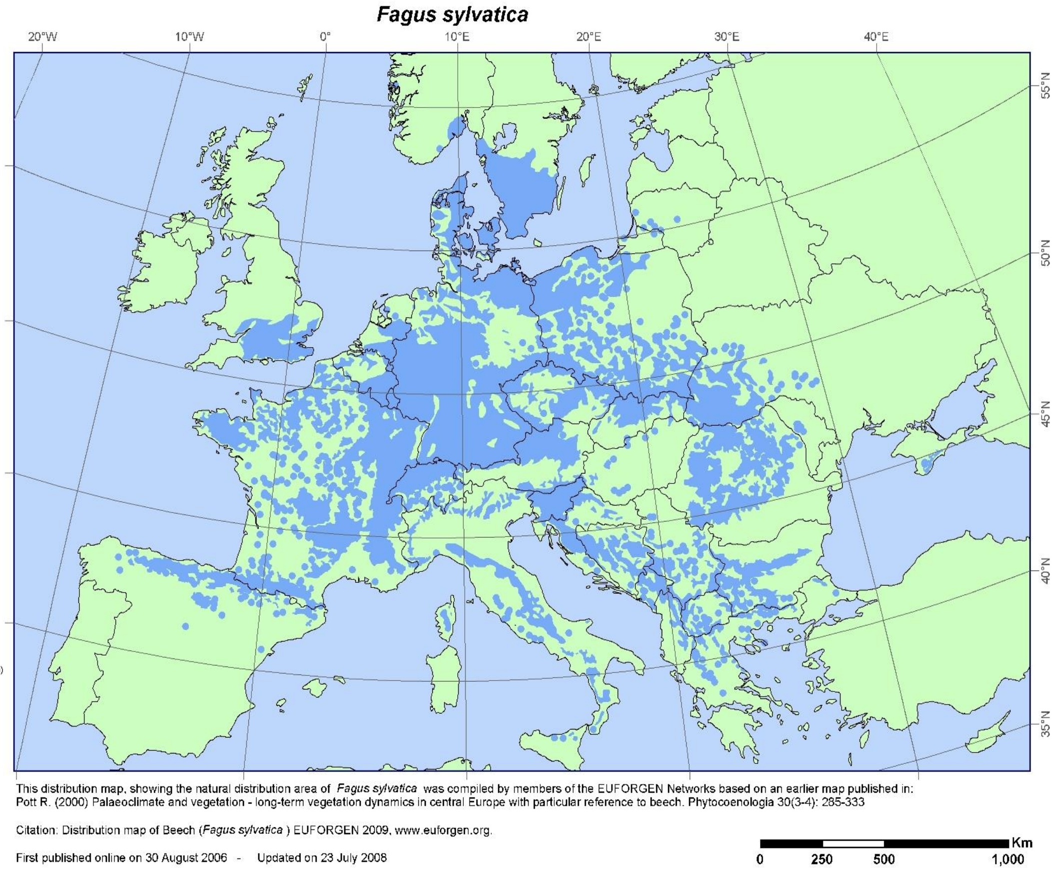
Q1: What is the vulnerability of DCU's/network to ongoing and predicted CC ?

Q2: How can adaptive management strategies integrating intraspecific variability (IV) mitigate harmful effects or exploit beneficial opportunities related to CC?

Overview

1. Process-based modeling of forests dynamics: a review (Oddou-Muratorio, Davi, Lefevre in prep)
2. Combined effects of climate and management on European beech vulnerability across Europe (Petit-Cailleux et al. in prep)
3. Accounting for intra-specific variability to predict the effects of climate (and management) on European beech tree vulnerability and growth across Europe (Petit-Cailleux et al. in prep)

Beech die-off in Switzerland June 2019
https://www.letemps.ch/suisse/jura-situation-catastrophe-forestiere

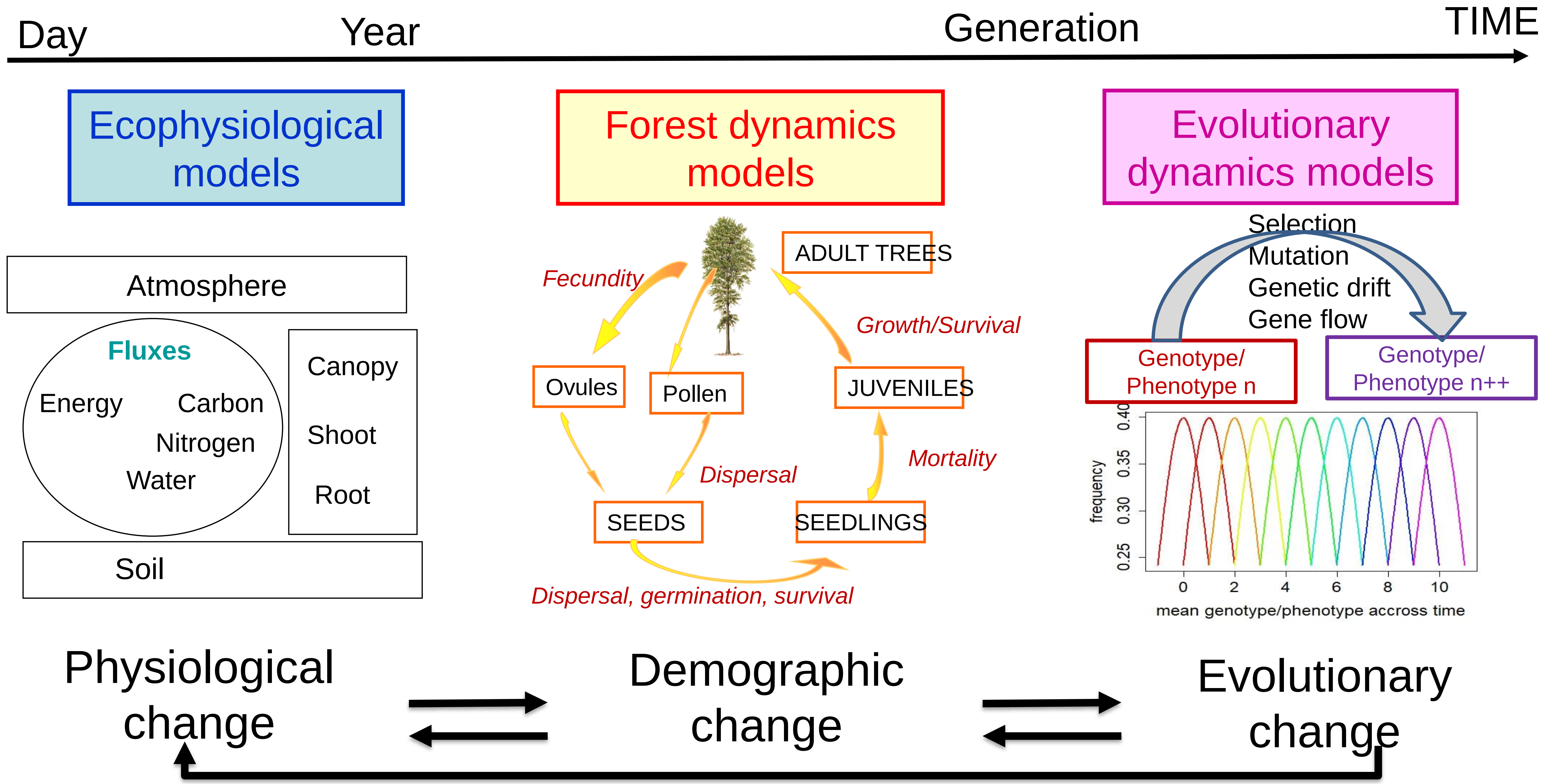


This distribution map, showing the natural distribution area of *Fagus sylvatica* was compiled by members of the EUFORGEN Networks based on an earlier map published in: Pott R. (2000) Palaeoclimate and vegetation - long-term vegetation dynamics in central Europe with particular reference to beech. Phytocoenologia 30(3-4): 285-333

Citation: Distribution map of Beech (*Fagus sylvatica*) EUFORGEN 2009, www.euforgen.org.

First published online on 30 August 2006 - Updated on 23 July 2008

1. Process-based modeling of the dynamics of forests

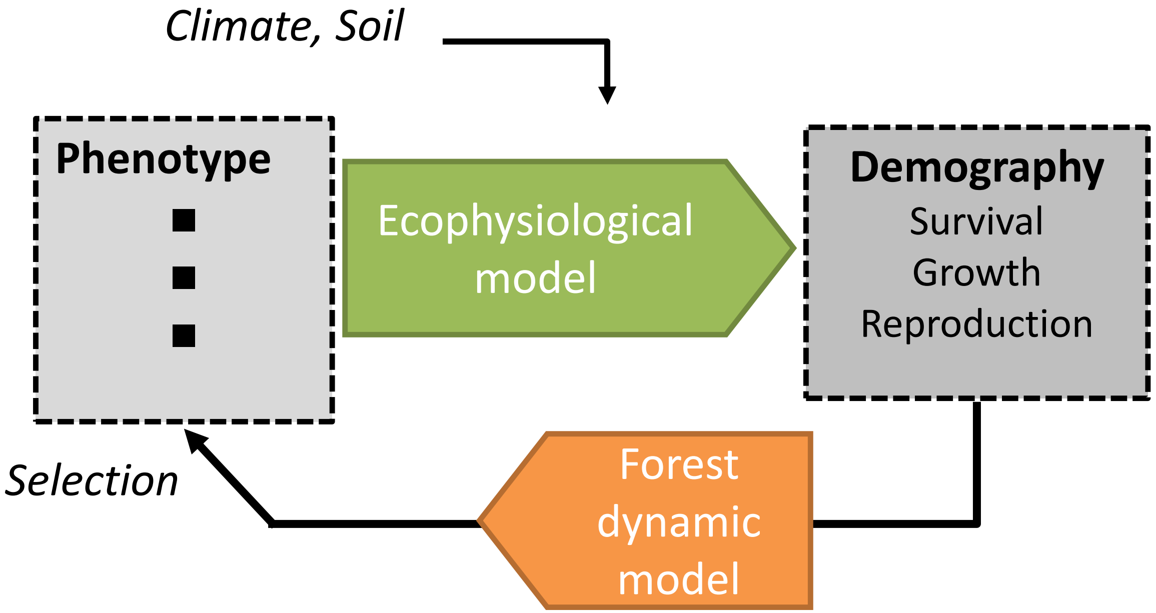


Models coupling physiological and demographic processes

(forest AND tree AND (physiolog OR vegetation) AND (mortality OR survival OR growth OR dynamic*) AND (process-based model* OR DGVM* OR DVM*)*

→ 95 papers presenting new results based on models between 1992 and 2018

- **Forest dynamic** models are increasingly integrating ecophysiology (21 %)
- **Ecophysiological models** are increasingly integrating dynamic processes (89% of the papers) either at global scale (41%) or at the scale of regions (12%) or plots (47%),



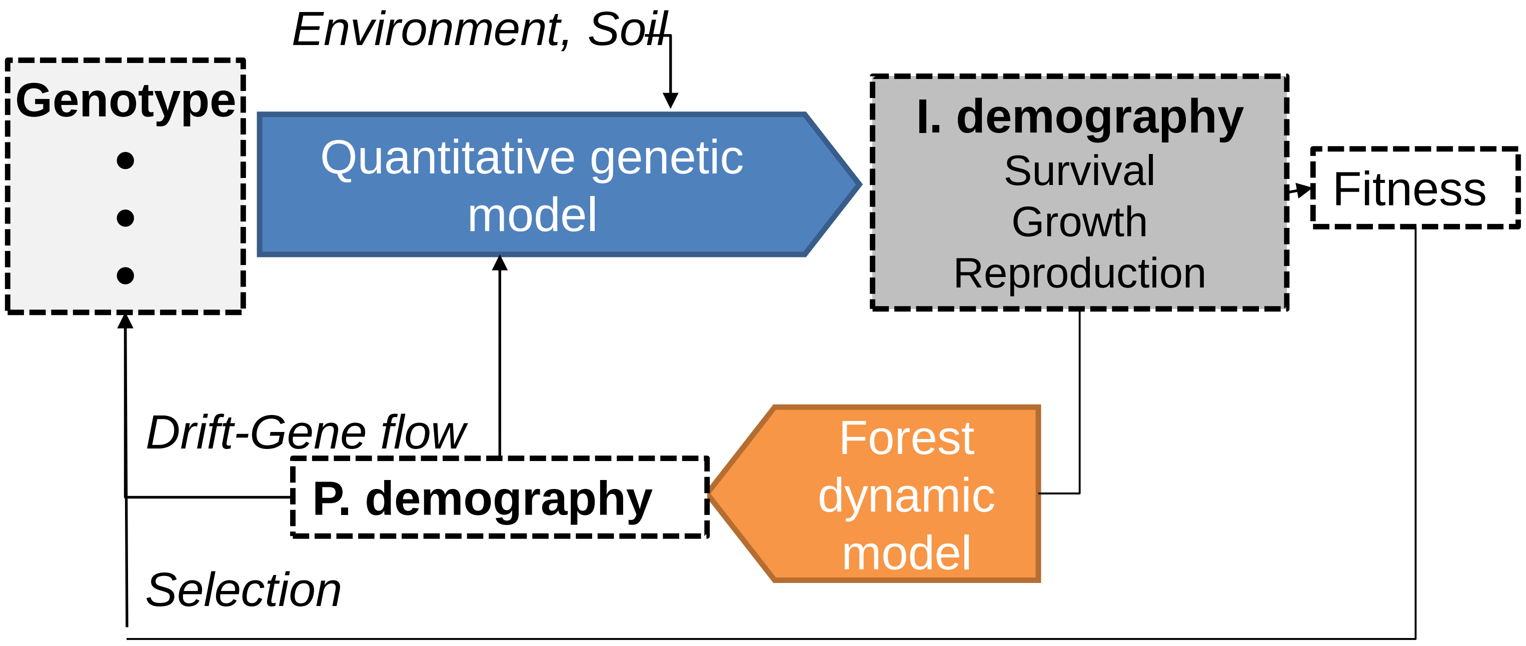
Example of questions/themes which can be addressed :

- How do several functional traits contribute to overall performance/fitness ?
- What are the form and dynamics of phenotype-performance and environment-performance maps ?
- Towards a better definition of the fundamental/realized niche
- Impact of traits IV on demographic dynamics ? Yes, but not for trait evolution. Berzaghi et al. submitted

Models coupling demographic and genetic processes

Forest dynamic AND (metapop OR demogr*) AND (model*) AND (adapt* OR evolut* OR genet*)*

34 papers (1992 and 2018)

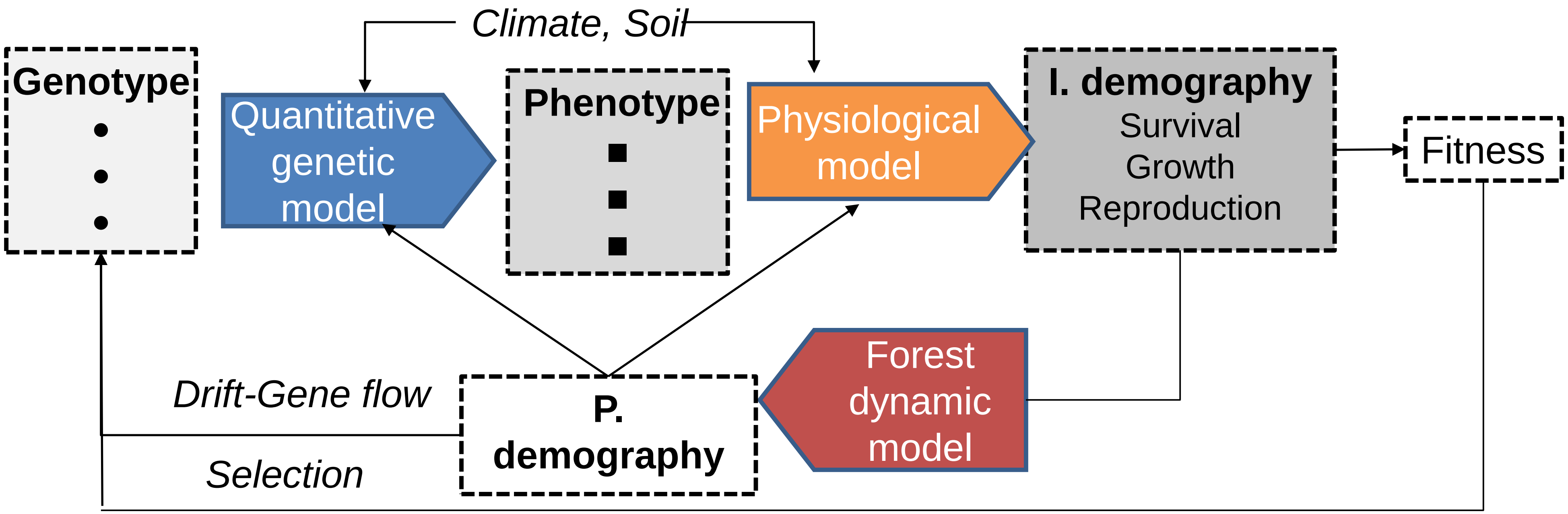


- **Models with demographic impact on genetic composition**, without feedbacks
- **Multi-species forest community models:** include some level of genetic diversity and feedback effect on dynamic processes, but without genetic processes (inheritance)
- Truly **demo-genetic models** are rare (Hoebee et al 2008, Kuparinen & Schurr 2007, Kuparinen et al. 2010, Moran & Ormond 2015)

Example of questions/themes which can be addressed :

- How can fitness evolve at contemporary, ecological timescale ? How management affect this evolutionary dynamics ?
- How does fitness build up in natural populations ? But bypass functional traits

Models coupling physiological, demographic and genetic processes



(ALL KEY WORDS)
→ 8 papers

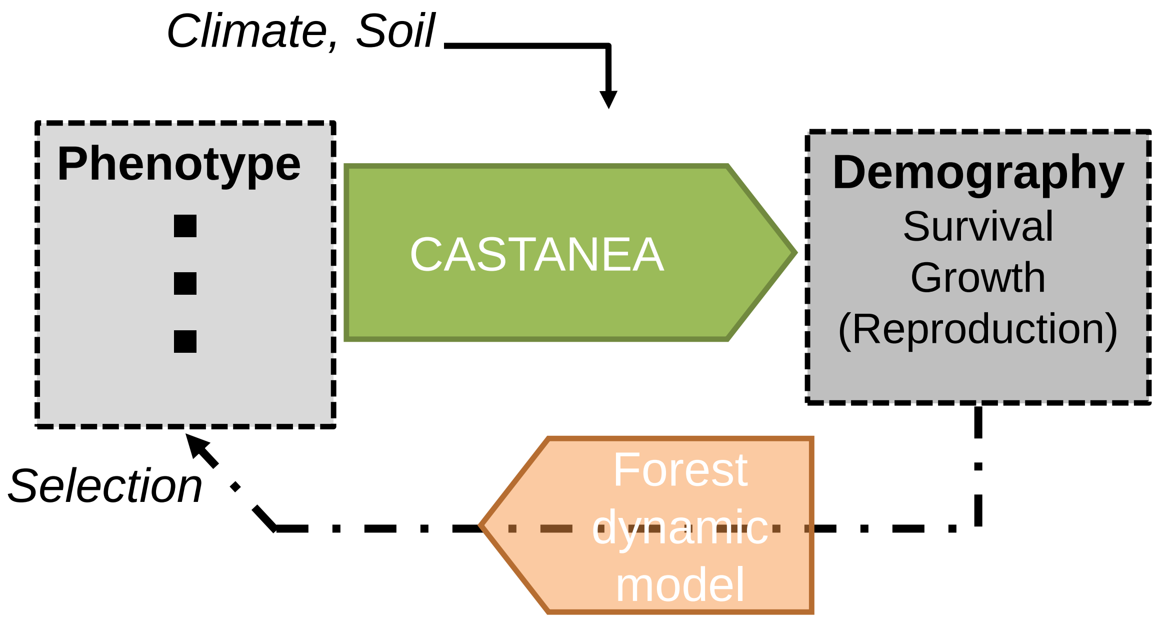
- Potential of adaptive response of a Beech stand for different traits (Kramer et al. 2008)
- Adaptive response of Beech along an altitudinal (Oddou-Muratorio & Davi 2014) or latitudinal gradient (Kramer et al. 2015)

Example of questions/themes which can be addressed :

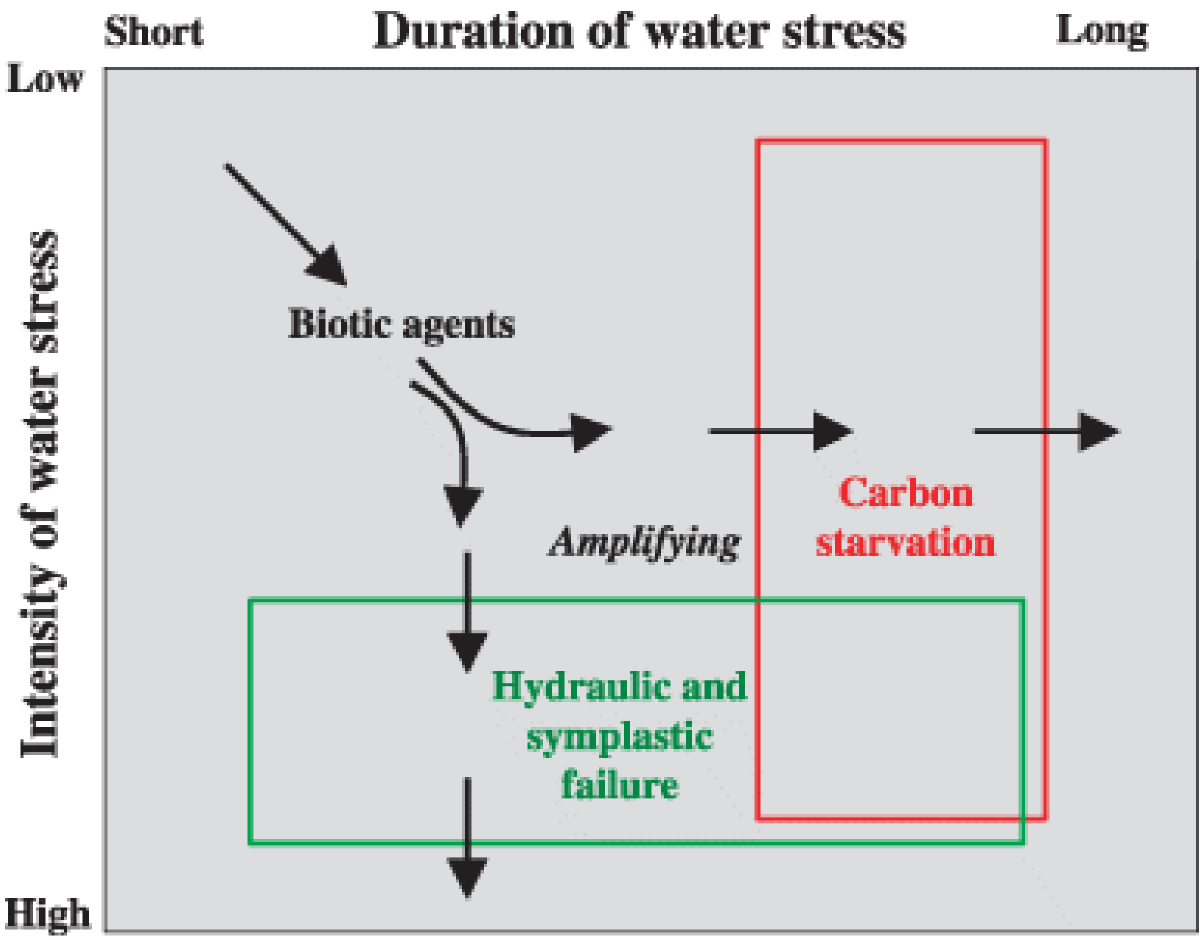
- What are the limits of adaptation in CC/GC context?
- How genetic diversity and evolution of functional traits can mitigate the vulnerability to CC/GC?

Combined effects of climate and management on beech tree vulnerability across Europe.

Cathleen Petit-Cailleux, *Hendrik Davi, François Lefevre, Hans Verkerk, Marcus Lindner & Sylvie Oddou-Muratorio*



Mechanisms driving decline in response to drought



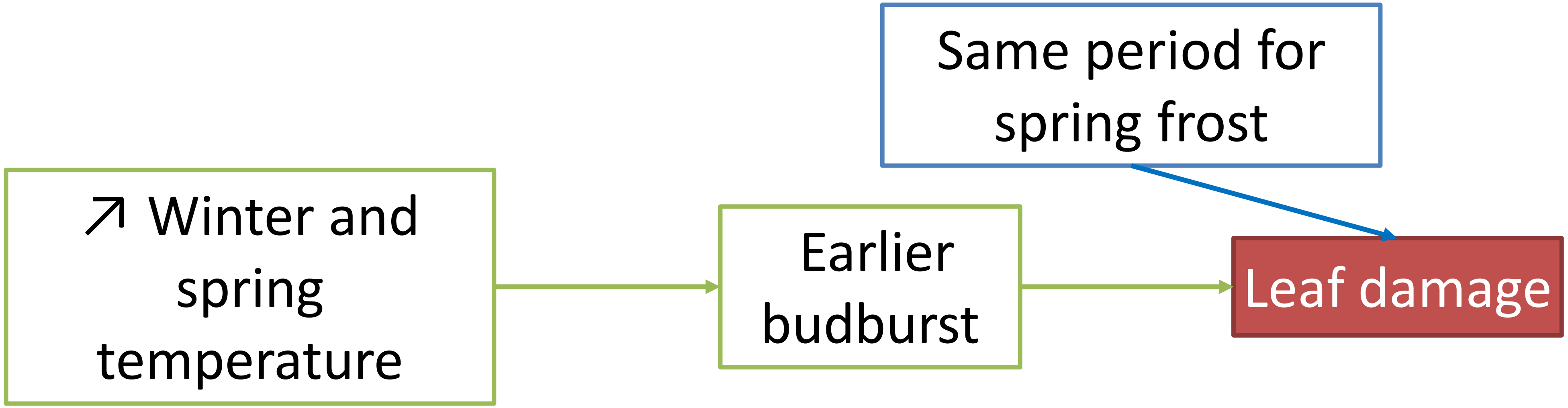
McDowell et al. 2008

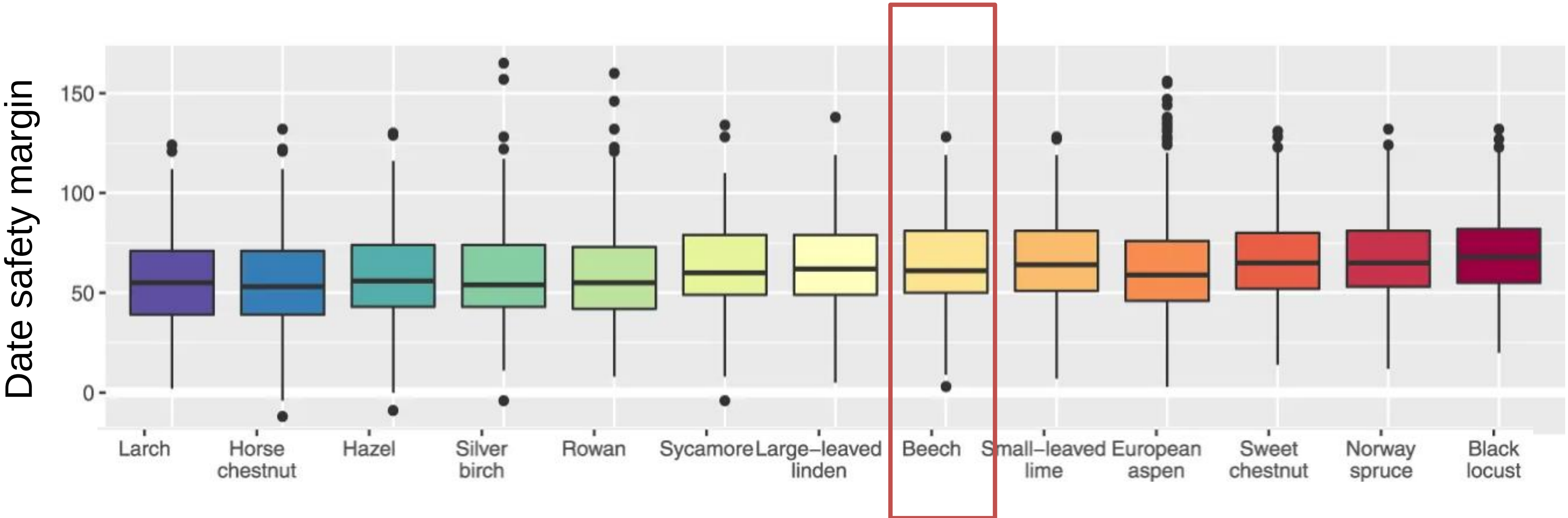
Key physiological variables indicators of these stresses :

- % of loss of conductance (PLC) for hydraulic failure
- The level of carbon storage for carbon starvation

They are mediated by several functional traits

Mechanisms driving decline in response to frost





Bigler and Burgman 2018

The process-based model CASTANEA

INPUT

Climate parameters

Daily temperature, precipitation…

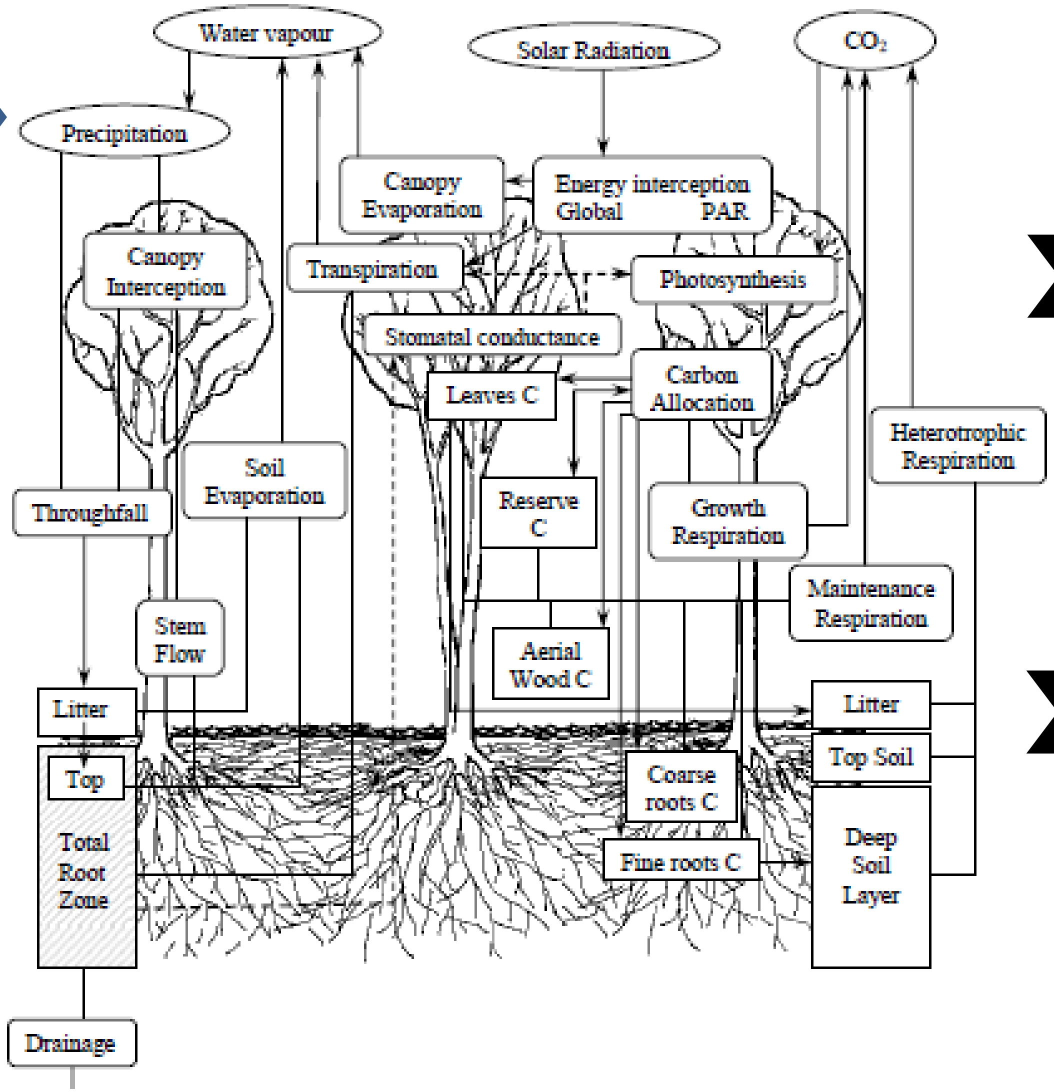
Stand parameters

Soil property, stage age, size

Species parameters

Parameters of the physiological model

Water Balance **Carbon Balance**



OUTPUT

Dynamic variables related to vulnerability :

- *Date of budburst*
- *Carbon storage*
- *Percentage of Loss of conductance*
- *…*

Dynamic variables related other ecosystem services:

- *Stand volume*
- *Carbon sequestration*
- *…*

Simulations

Climate (daily) data:

- Current climate (1979-2008): WATCH
- RCP 4.5 and 8.5 scenario (2006-2100): Hadgem model corrected using WATCH

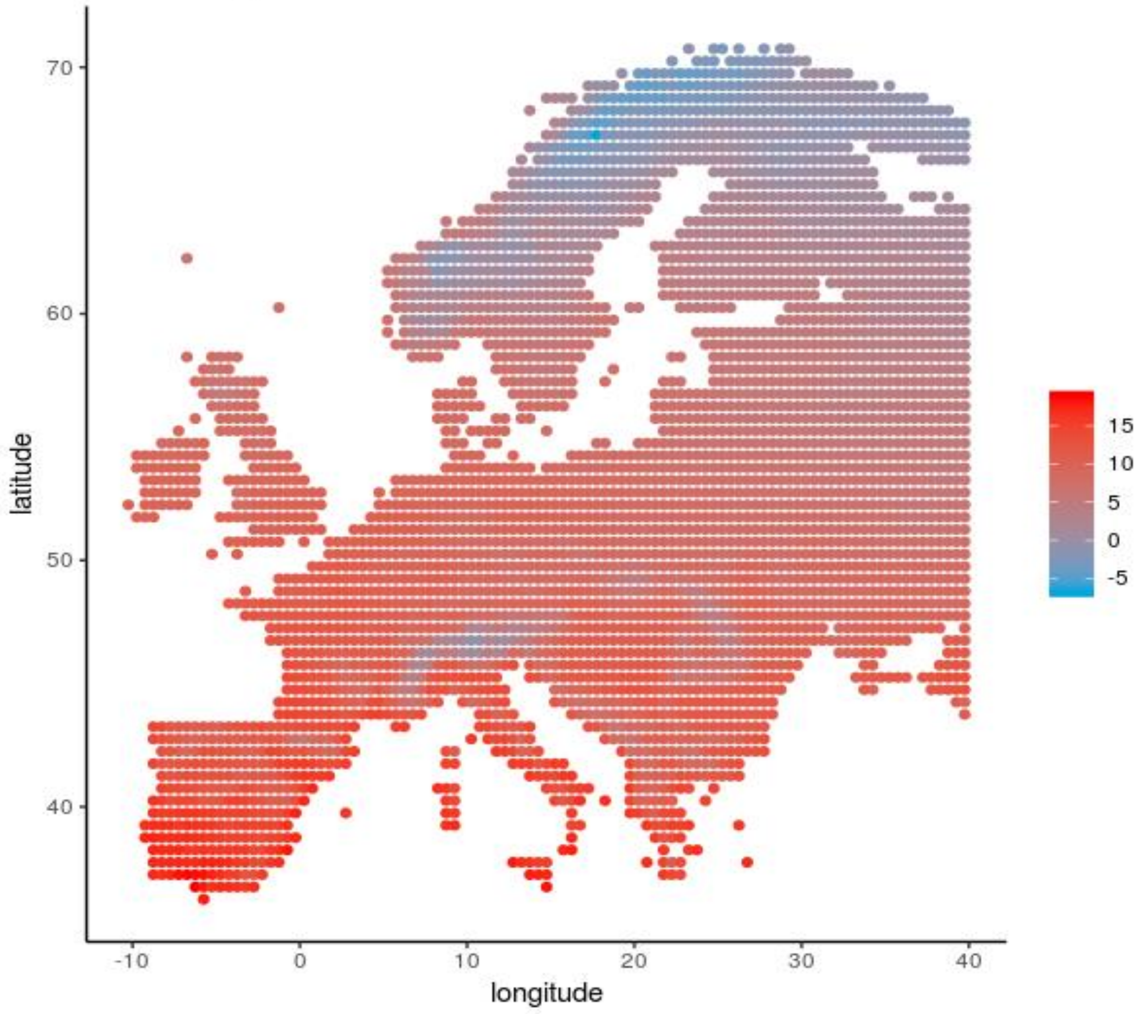
Soil data:

- Soil grid dataset
- 3D Soil Hydraulic (ESDAC)

1 average tree/cell

- Stand parameters (DBH, density...)
- Species parameters

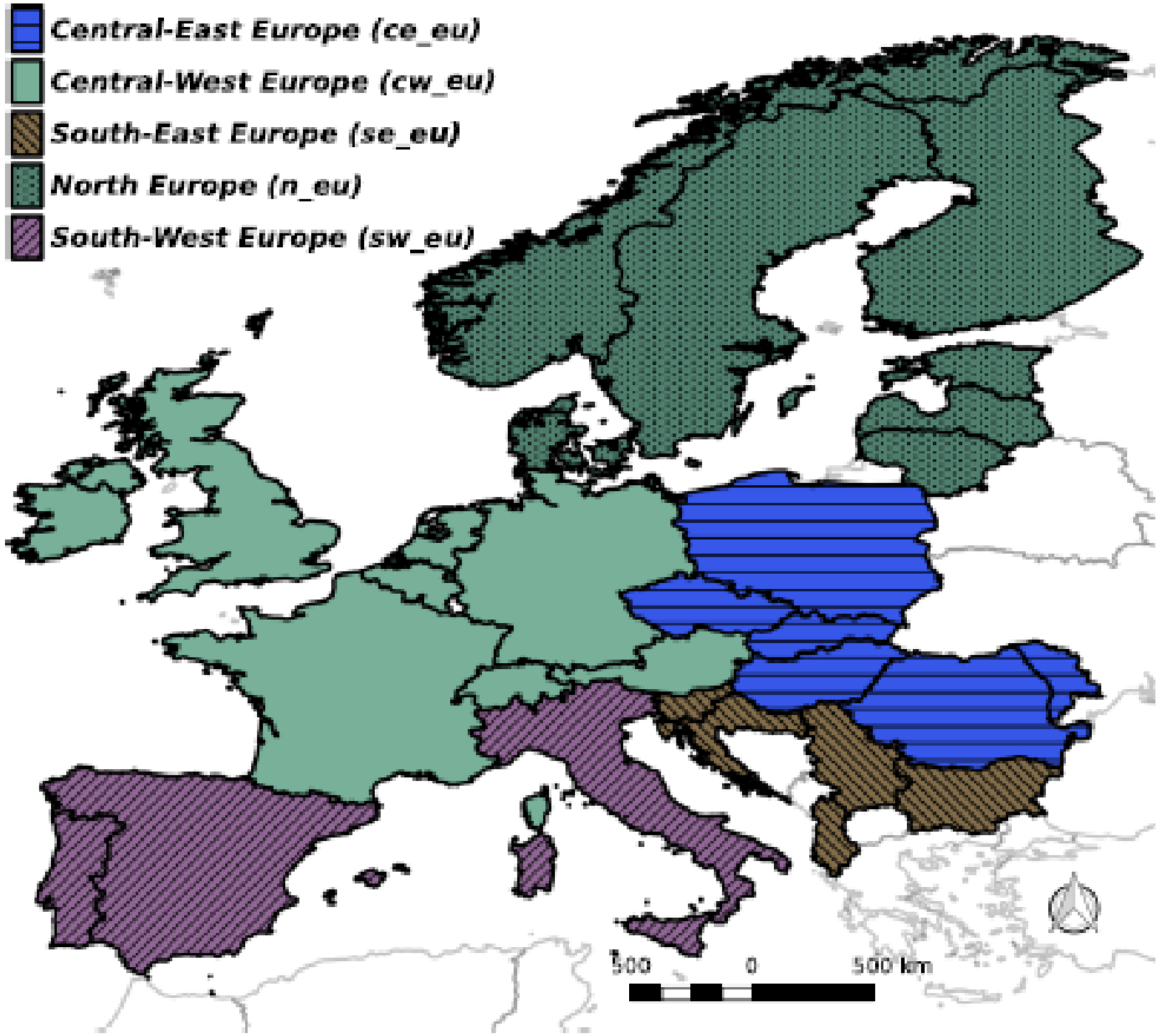
Mean T° (1979-2008)



Grid of 3174 cells, 0.5° by 0.5°

Management scenarios

Eco-Region (Cardellini et al. 2017, Härkönen et al 2019)



Reference management scenarios according to 7 sylvicultural systems

- Even-aged forest management with shelterwood
- Even-aged forest with clear-cut
- Unmanaged forests

Varying age and % felling as describe din Harkonnen et al. (2019)

% of share of each sylviculture : EFISCEN database

Simulations design

Climate model
Hadgem
CM5

×

Climate scenario
Current
Future RCP 4.5
Future RCP 4.5

×

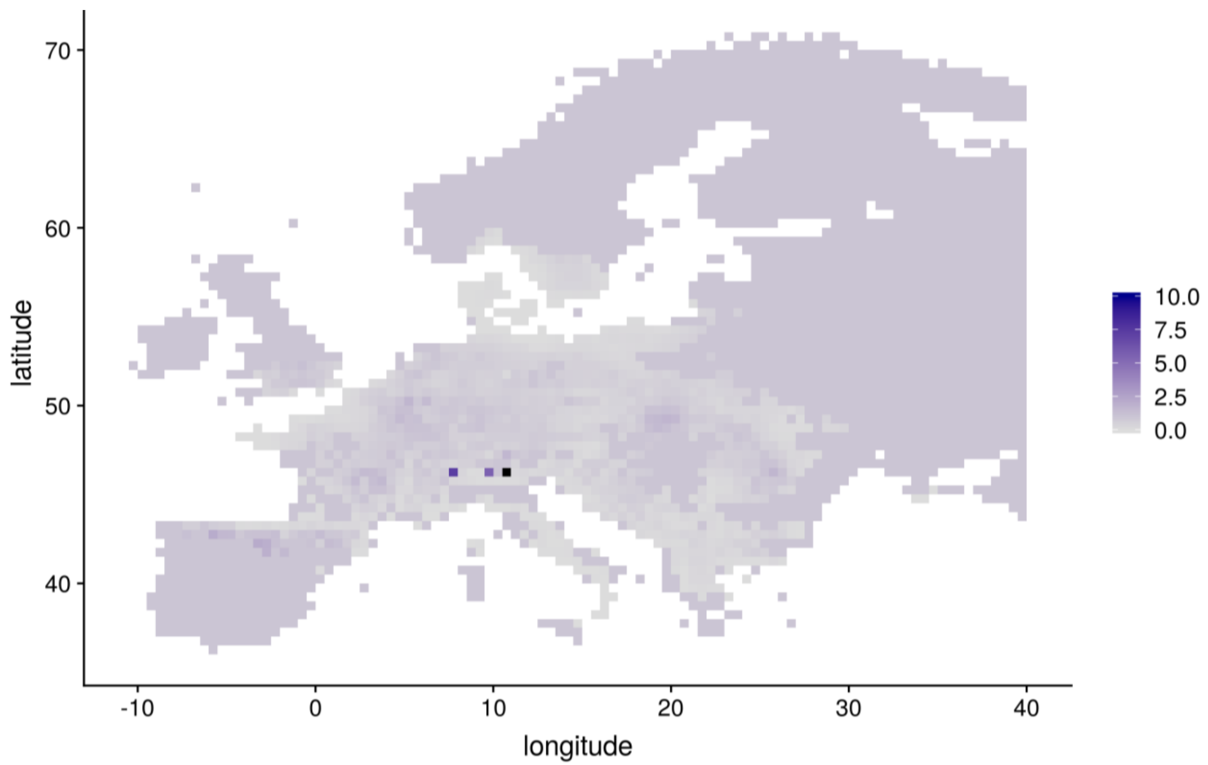
Management scenario
Even-aged forest management with shelterwood
Even-aged forest with clear-cut
(Continuous cover forest management)
Unmanaged forests

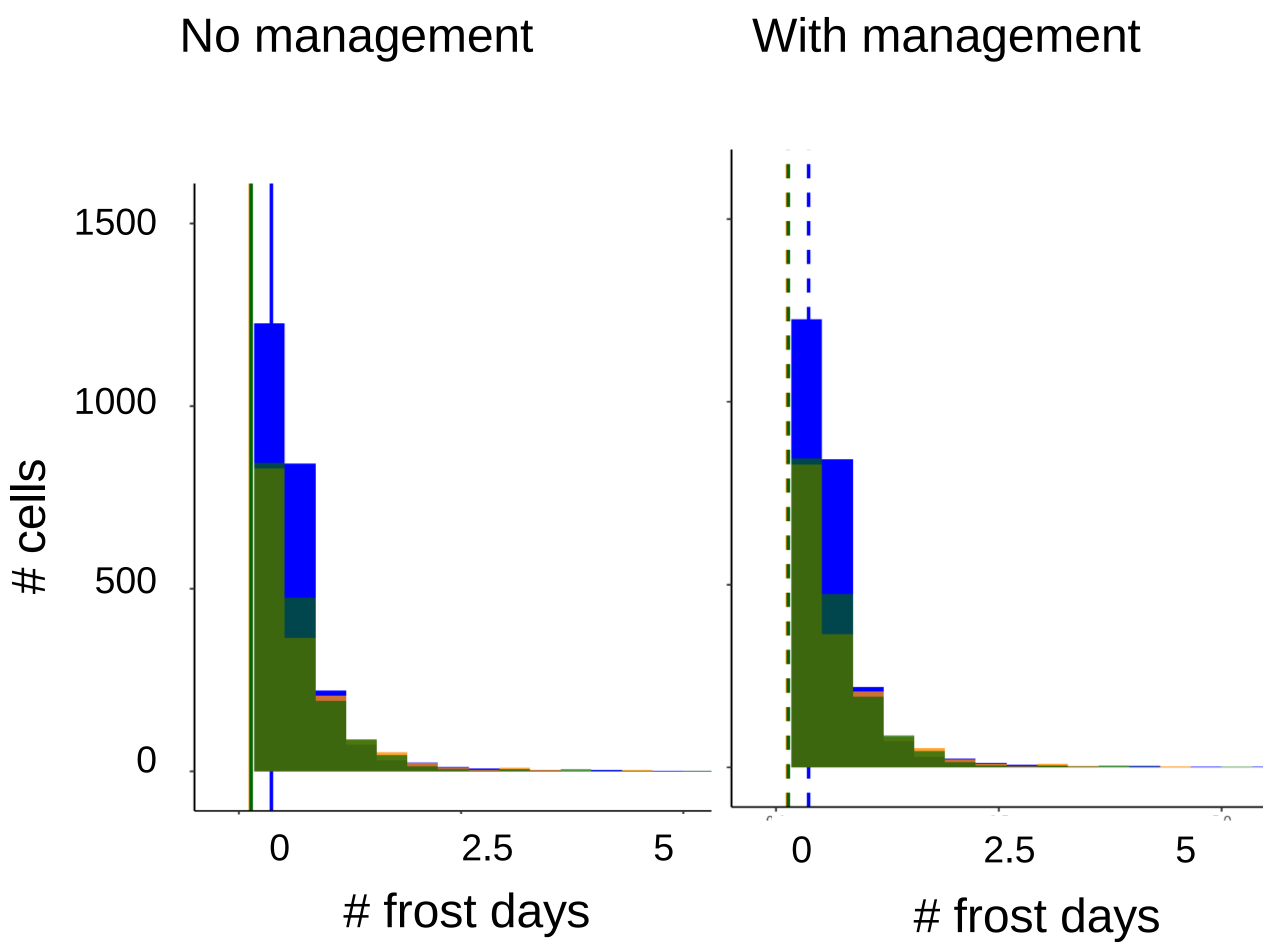
=> 18 × 3174 = 57,132 simulations

Vulnerability of beech to frost

Current | RCP4.5 | RCP8.5

Mean number of spring frost days after budburst (current)

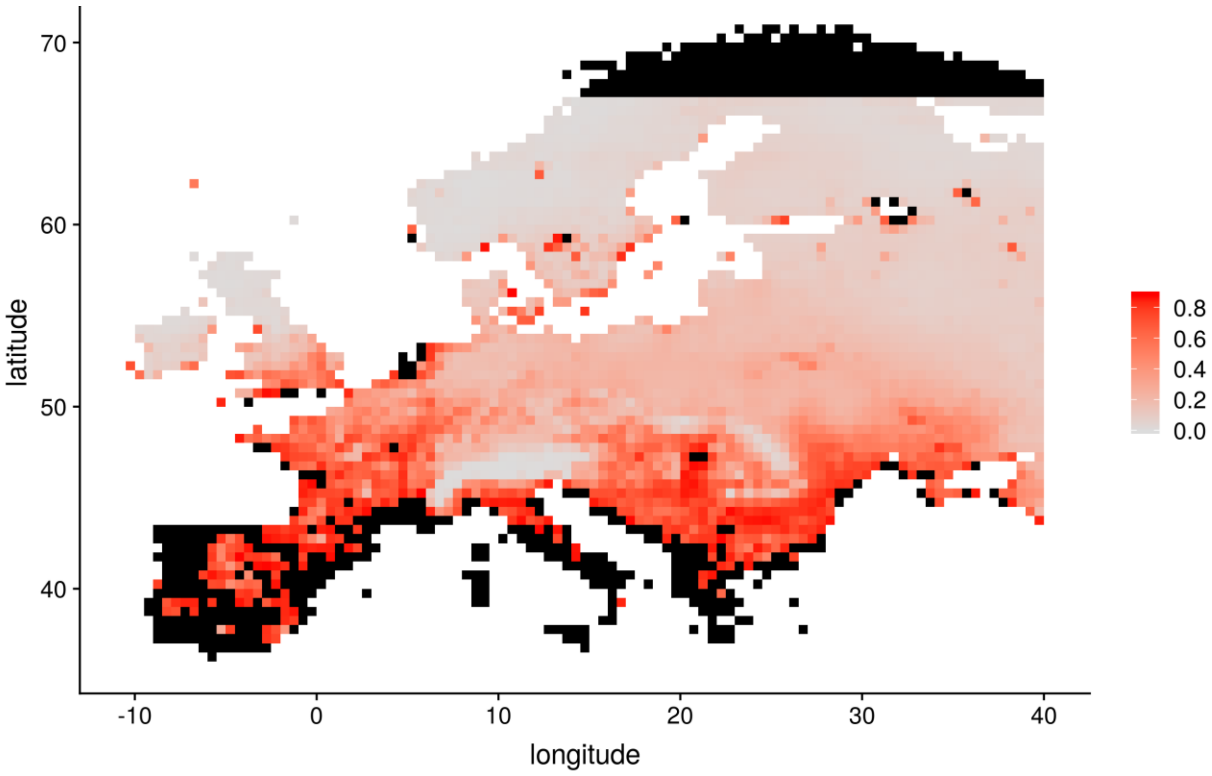




- Damaging late frosts occur/will in the coldest parts of Europe and northern Spain.
- Less spring frost events are expected under future climate than observed under current climate.
- No impact of the investigated management practices

Vulnerability of beech to hydraulic failure

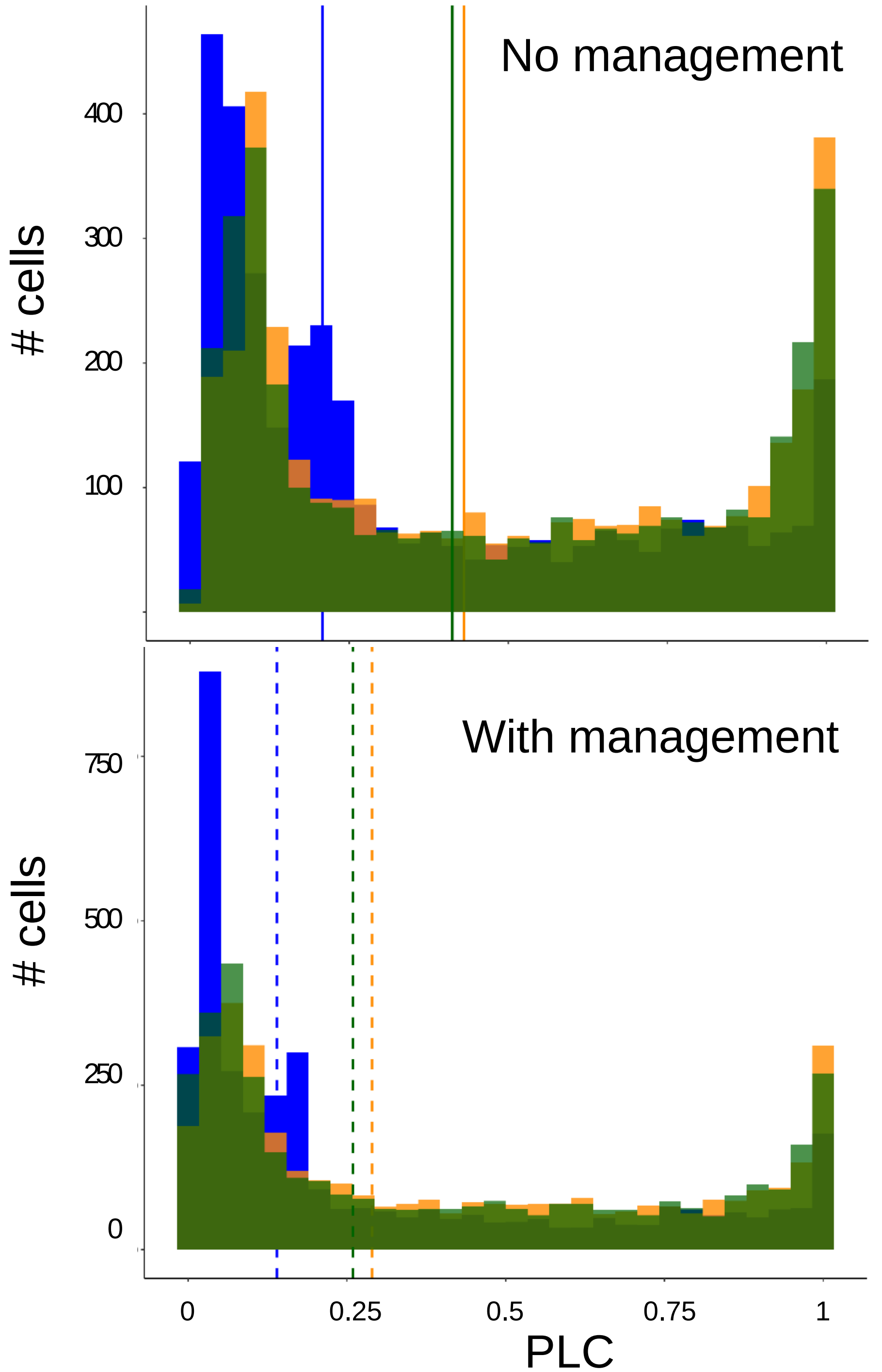
Maximum of percentage of loss conductance= PLC (current)



Current

RCP4.5

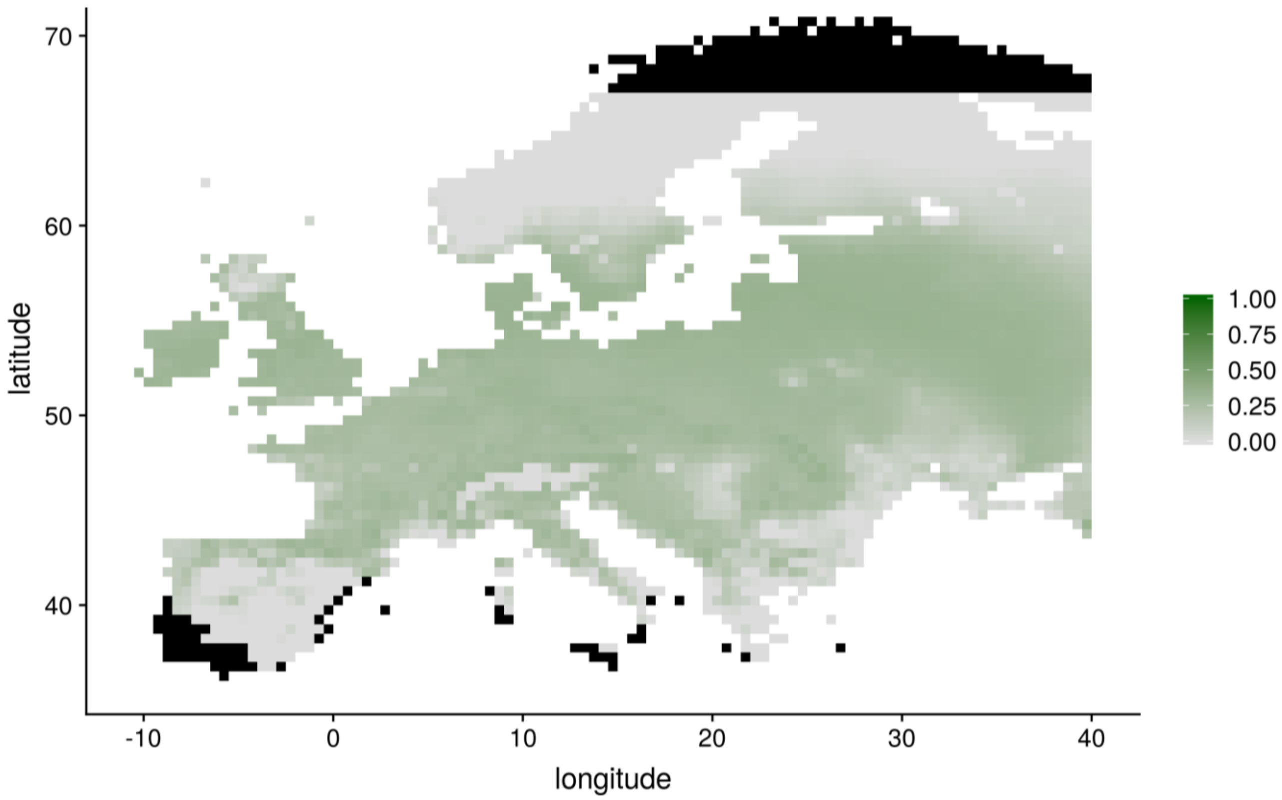
RCP8.5

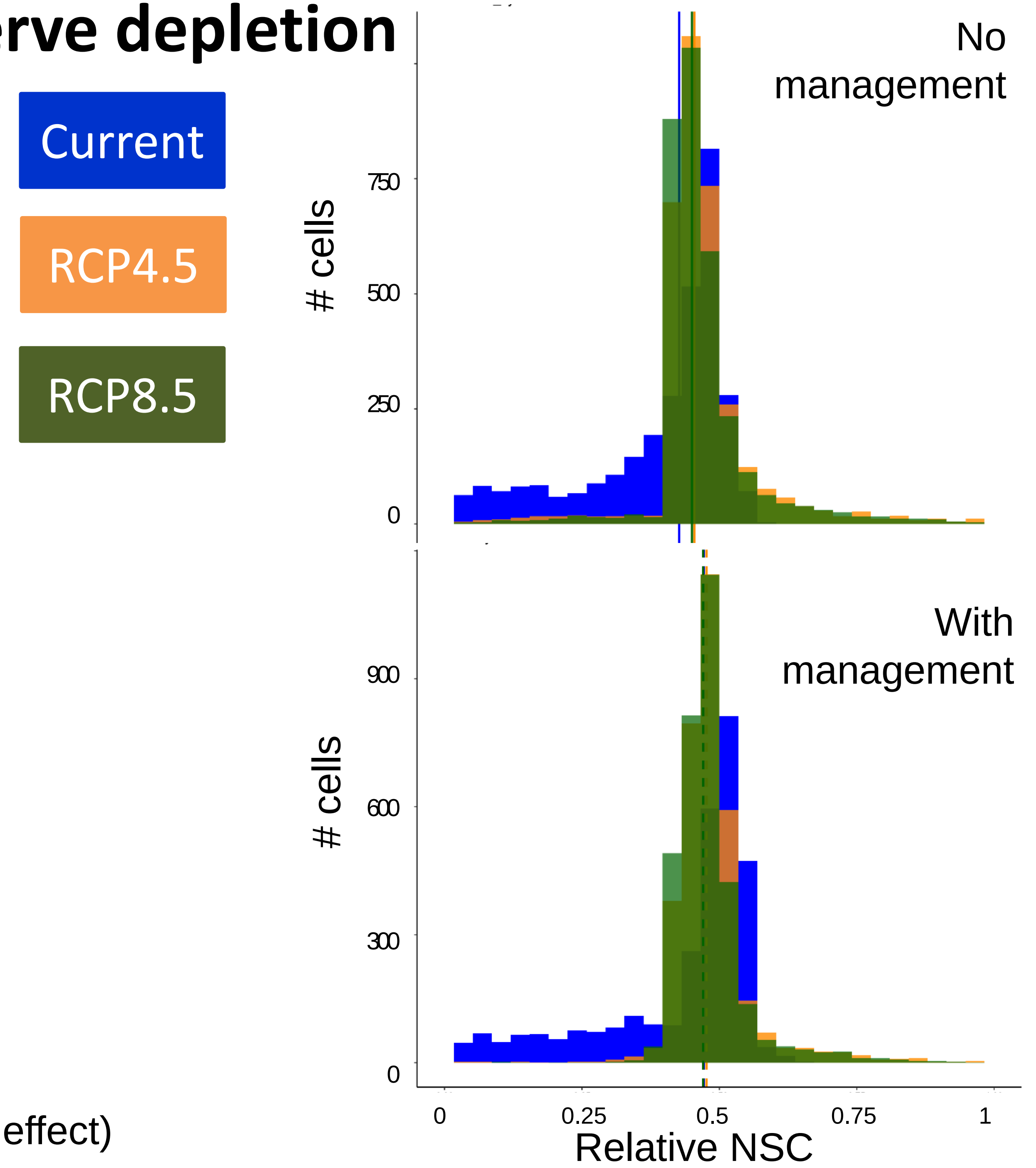


- Stronger PLC occur in southern parts of Europe
- Increased vulnerability to hydraulic failure under future scenarios
- Forests under management are less vulnerable to hydraulic failure

Vulnerability of beech to carbon reserve depletion

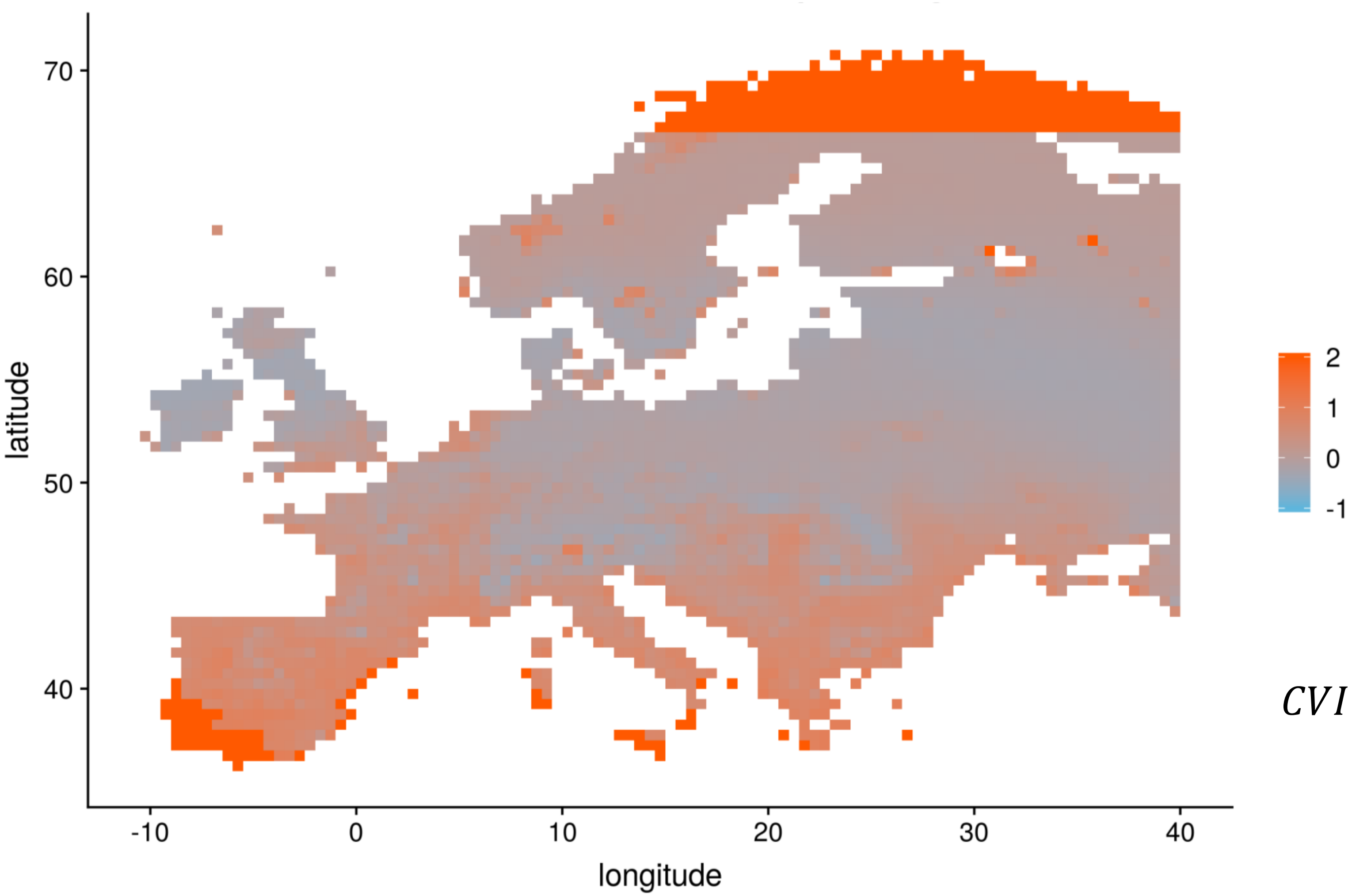
Mean NSC (current)

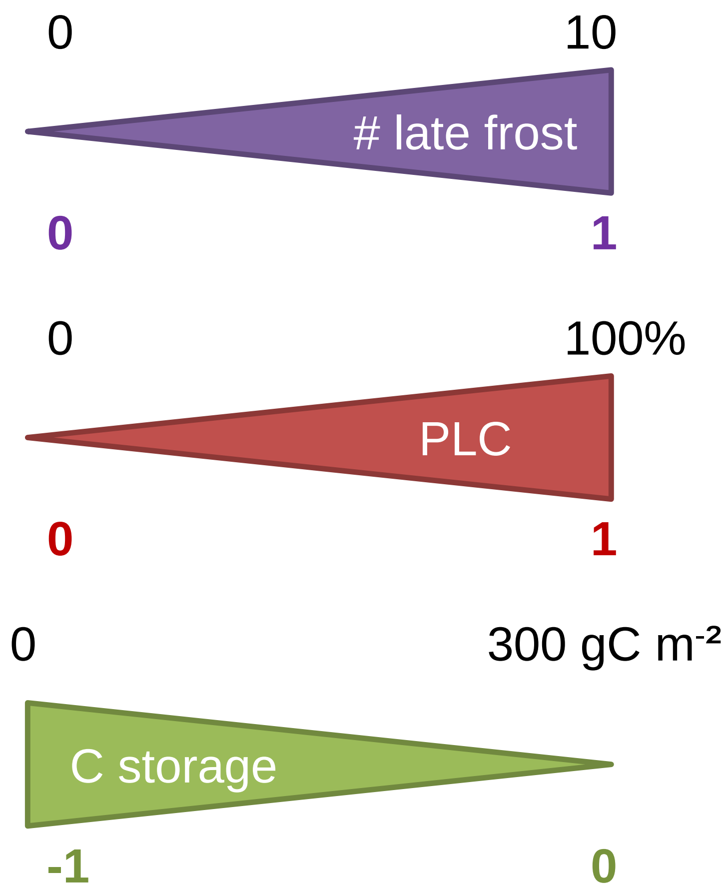




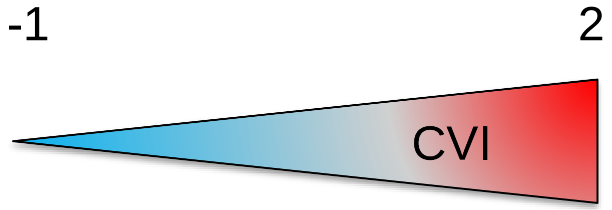
- Beech distribution is well simulated
- Relative C storage decreases under future climate
- Relative C storage decreases with management (size effect)

A new combined vulnerability index = CVI

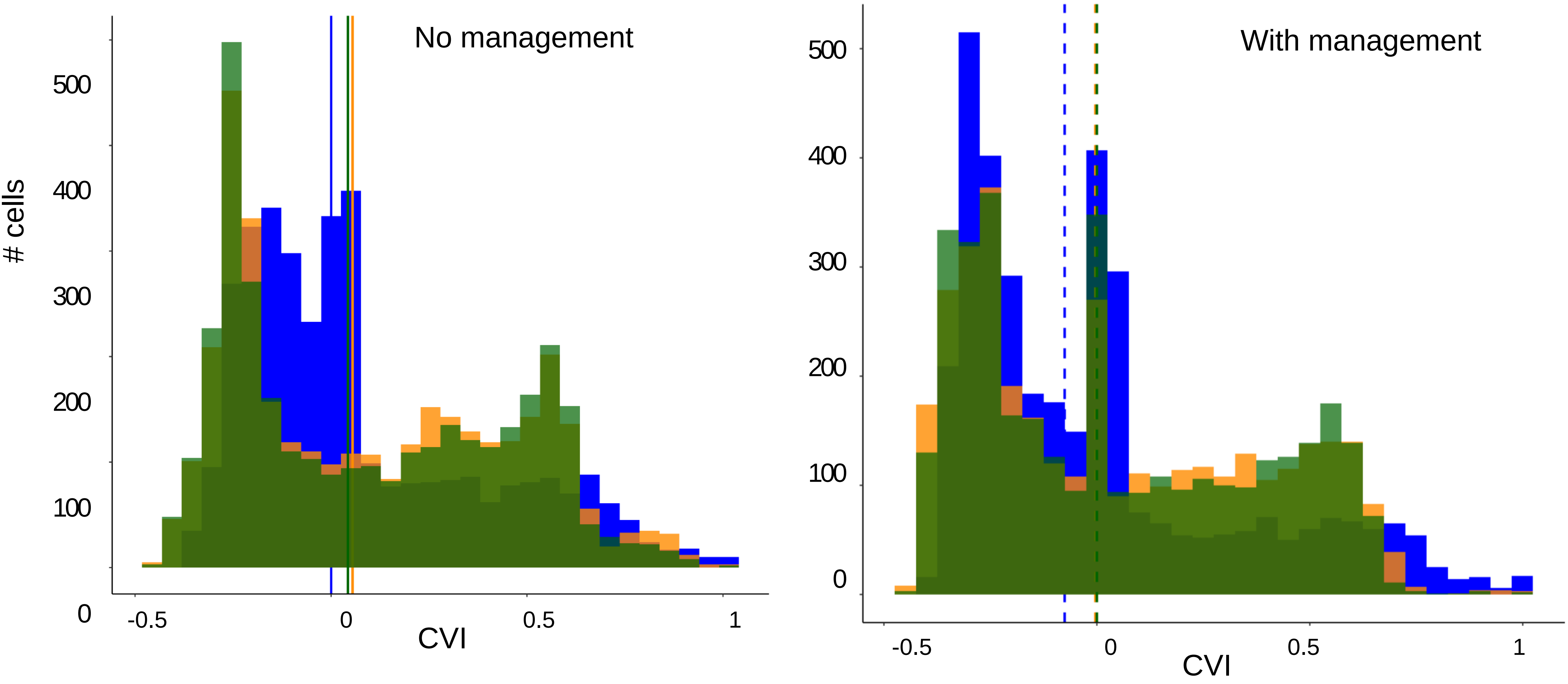




$$CVI = \frac{\#late\ frost}{max(\#late\ Frost)} + \frac{PLC}{\max(PLC)} - \frac{Cstorage}{\max(Cstorage)}$$



Comparison of beech vulnerability among climate and management scenarios



- **Beech vulnerability overall increases under future climate**
- **Beech vulnerability overall decreases under management**

Accounting for intra-specific variability to predict the effects of climate (and management) on beech tree vulnerability and growth across Europe.

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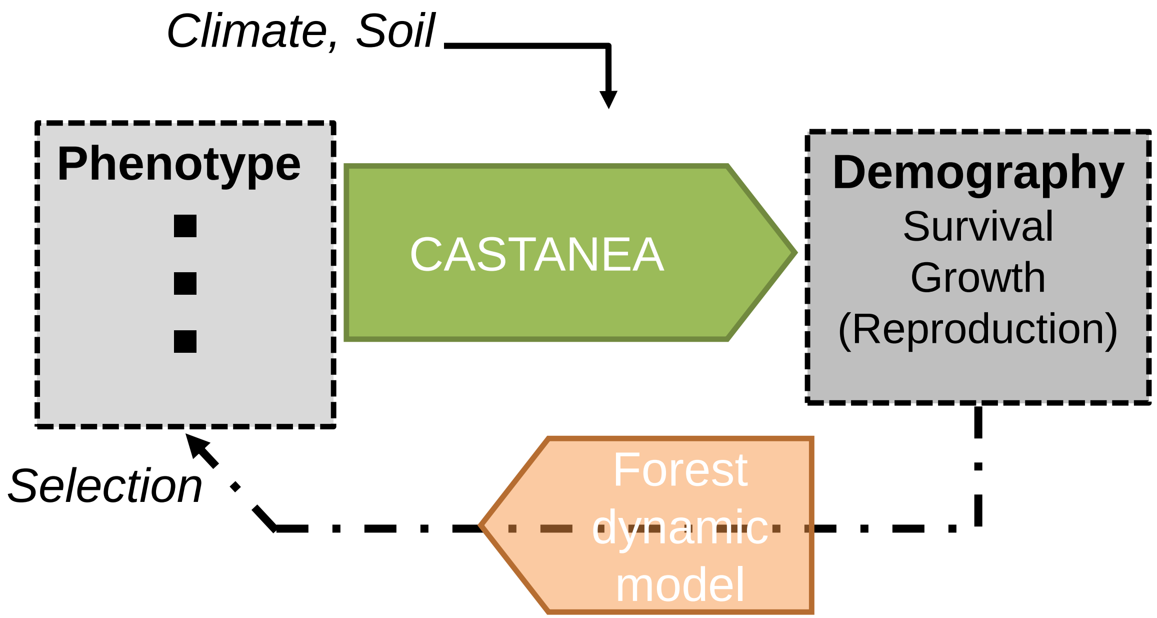
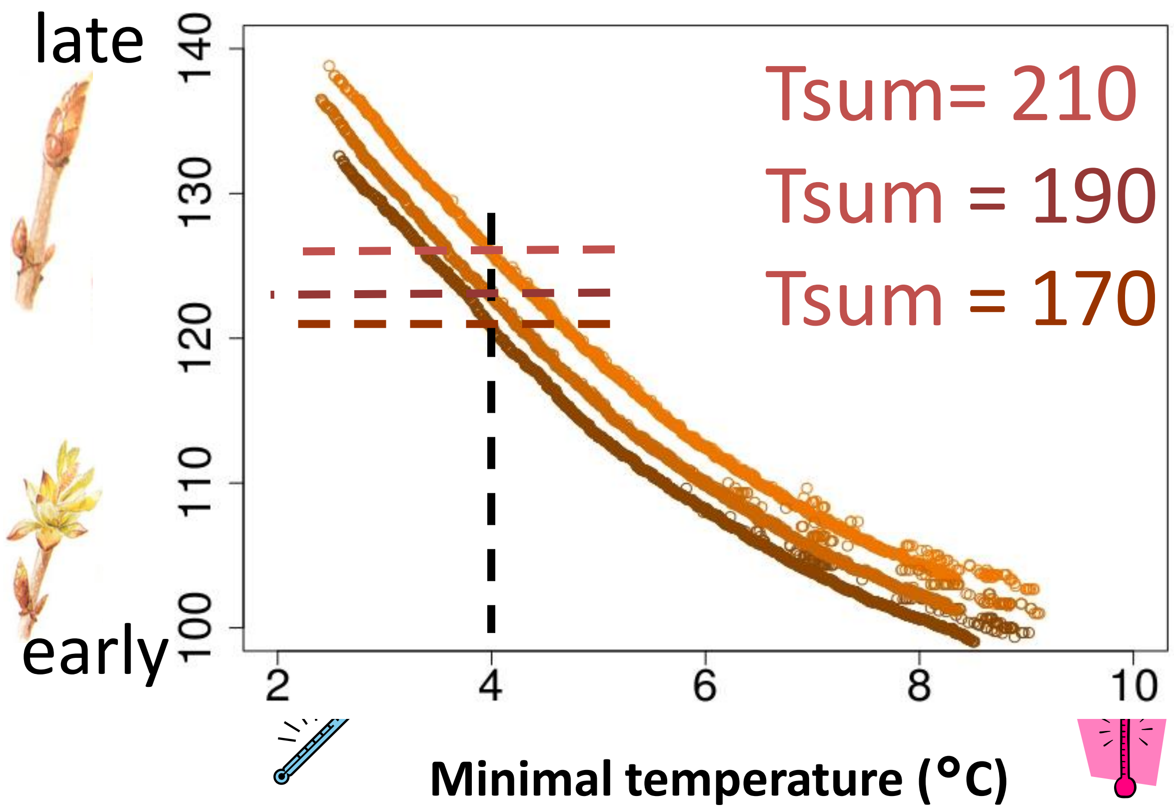


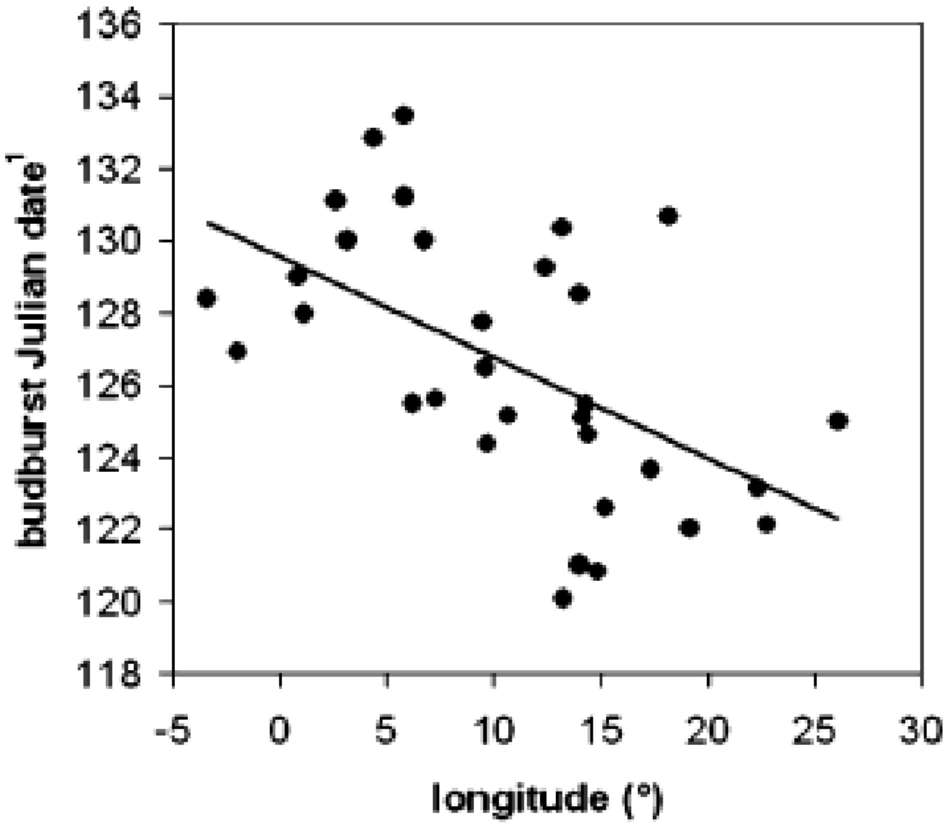
Intraspecific variation in functional traits occurs both from plasticity and genetics : the case of TBB

TBB(day of the year)



High Tsum = Later tree

Between population variation

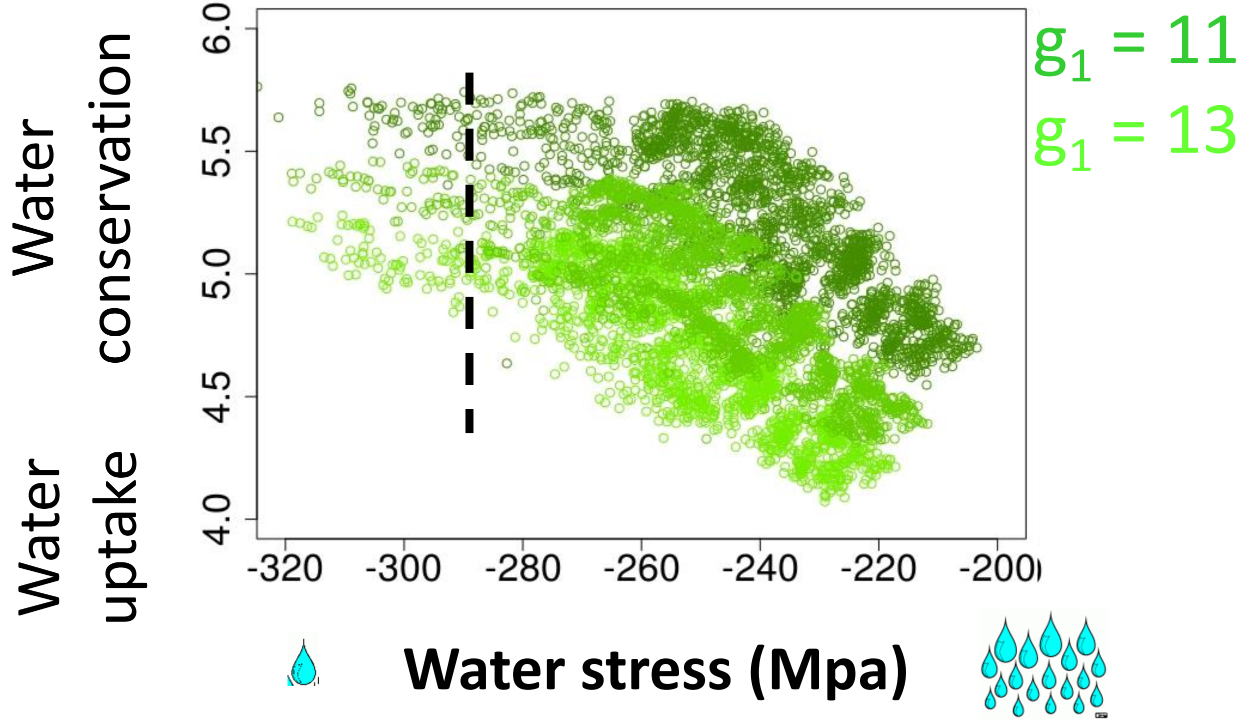


Gomory & Paule 2011

High Tsum for populations of Western Europe, low altitude

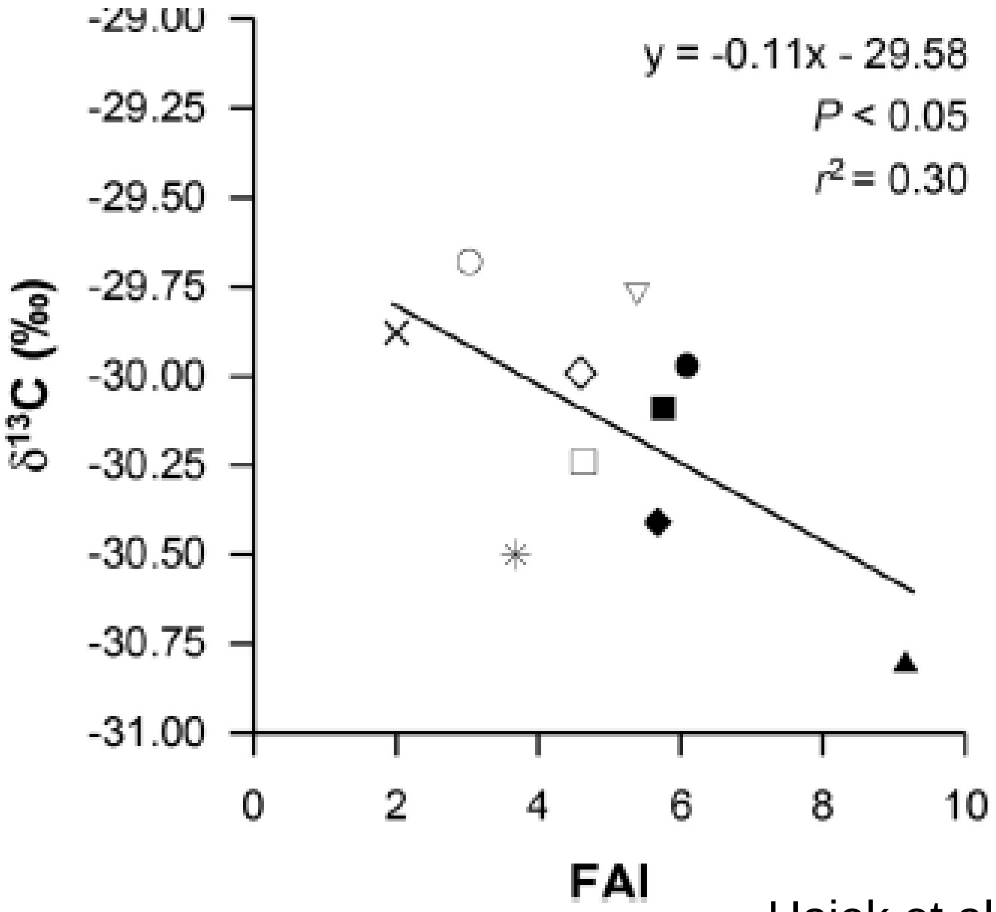
Intraspecific variation in functional traits occurs both from plasticity and genetics : the case of Water-Use efficiency

Water Use Efficiency (g_C.mm^1)



Low g1 = less evapotranspiration, higher WUE

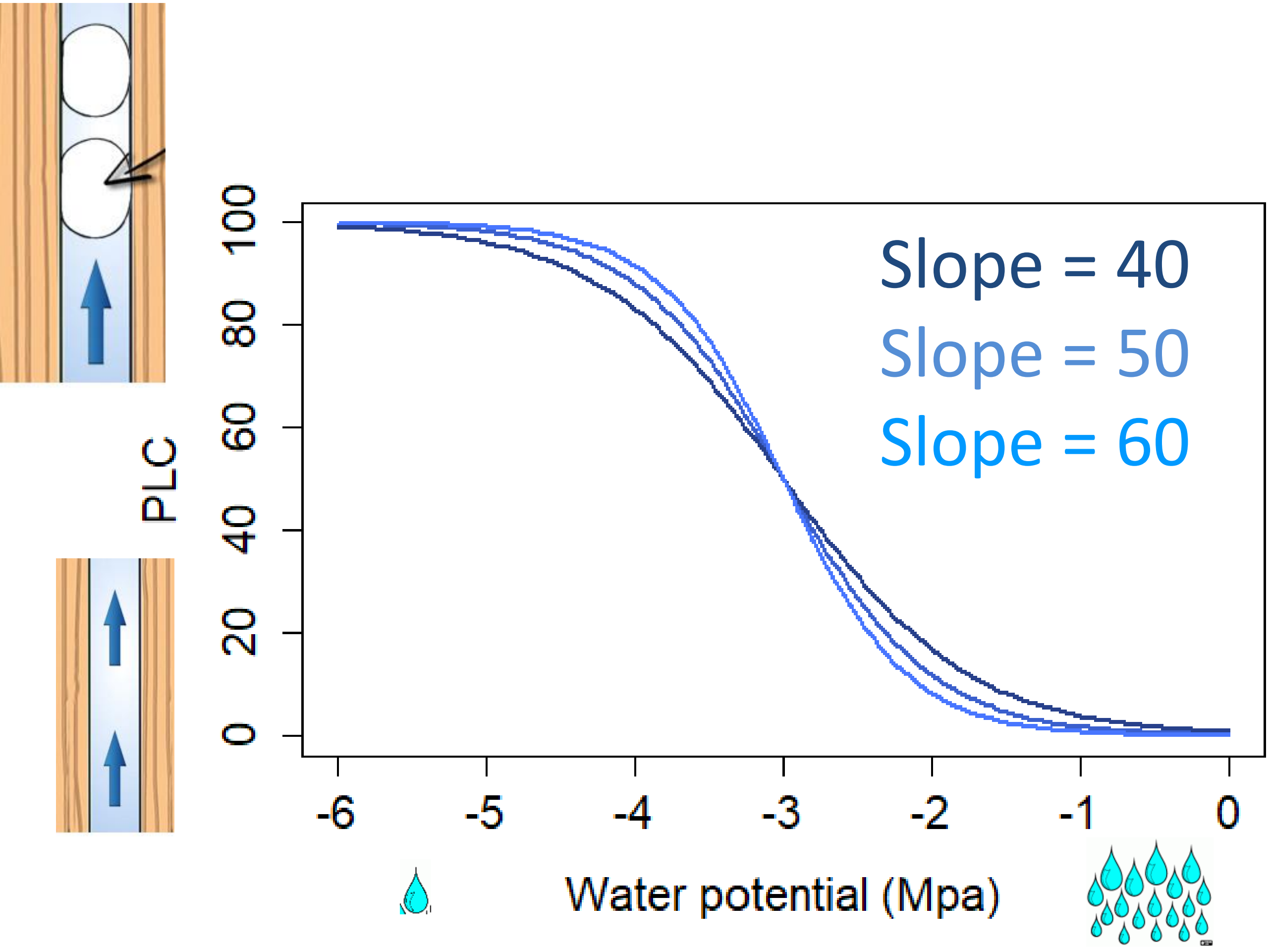
Between population variation



Hajek et al. 2016

Lower WUE for populations originating from arid climate

Intraspecific variation in functional traits occurs both from plasticity and genetics : the case of xylem embolism



No significant genetic variation between populations

Low slope: cavitation occurs later

Simulations

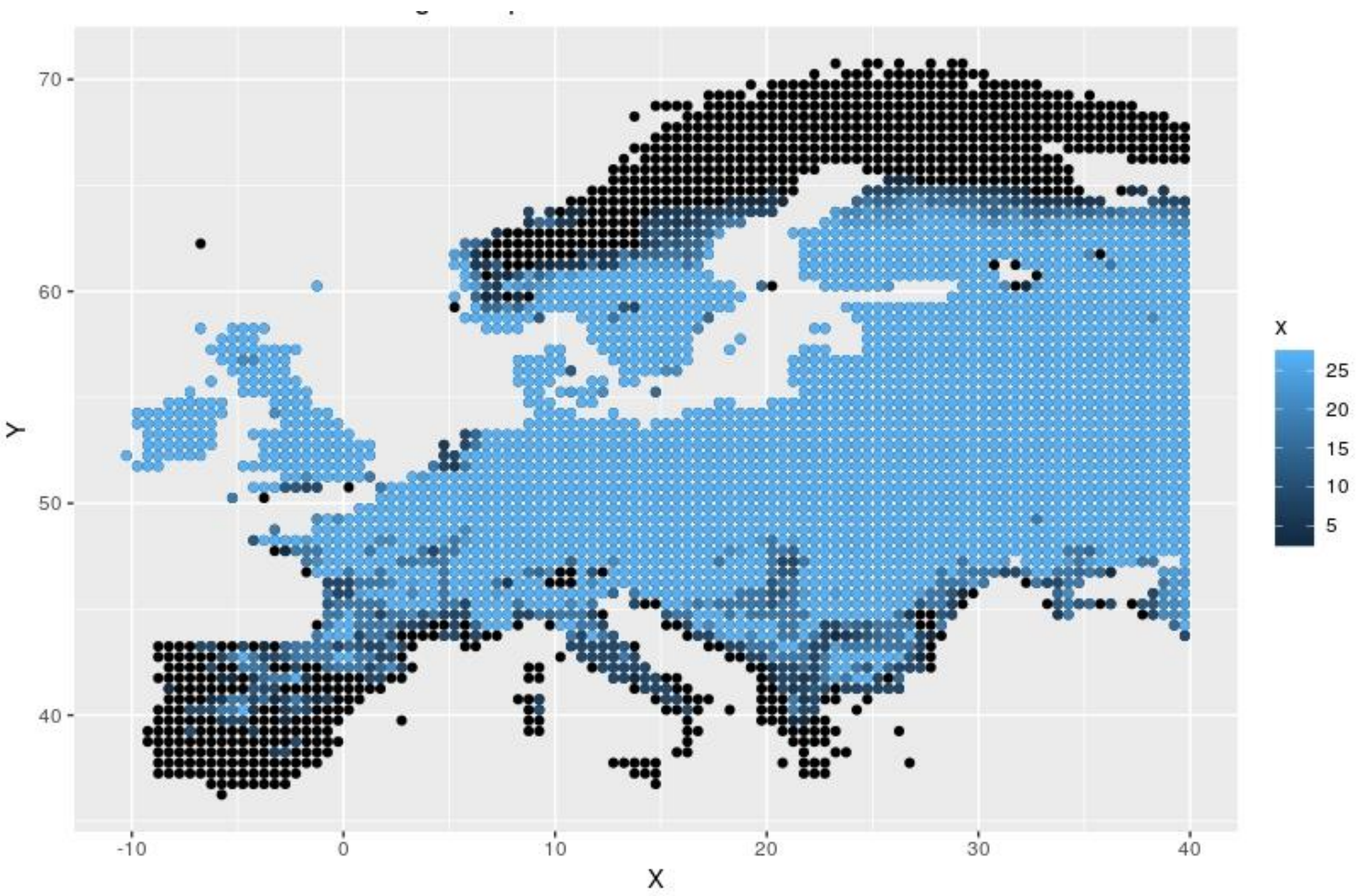
Climate scenario
Current
Future RCP 4.5
Future RCP 4.5

×

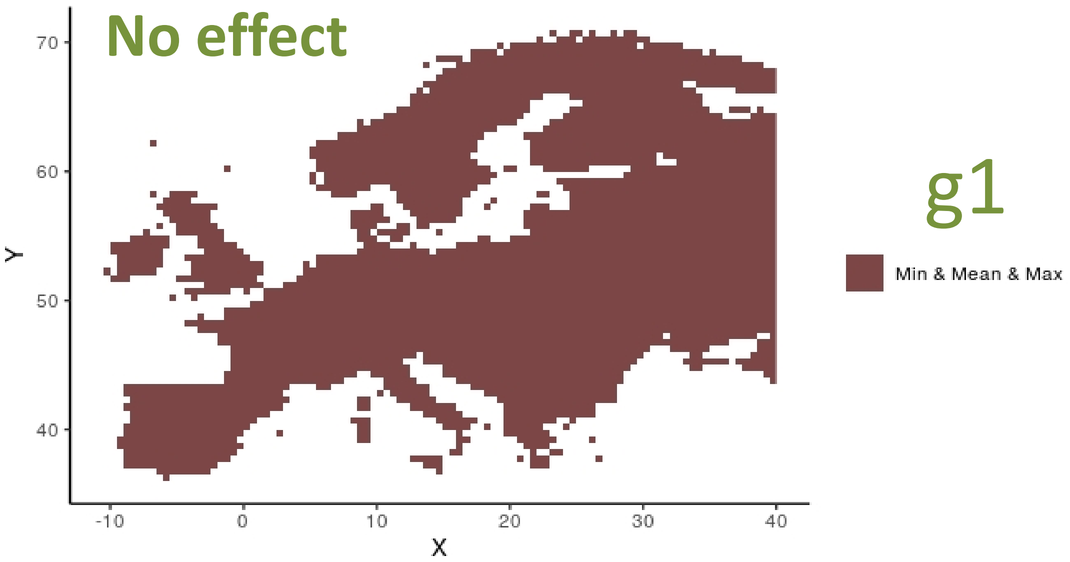
Min, mean, max values
Tsum
g1
$slope_{PLC}$

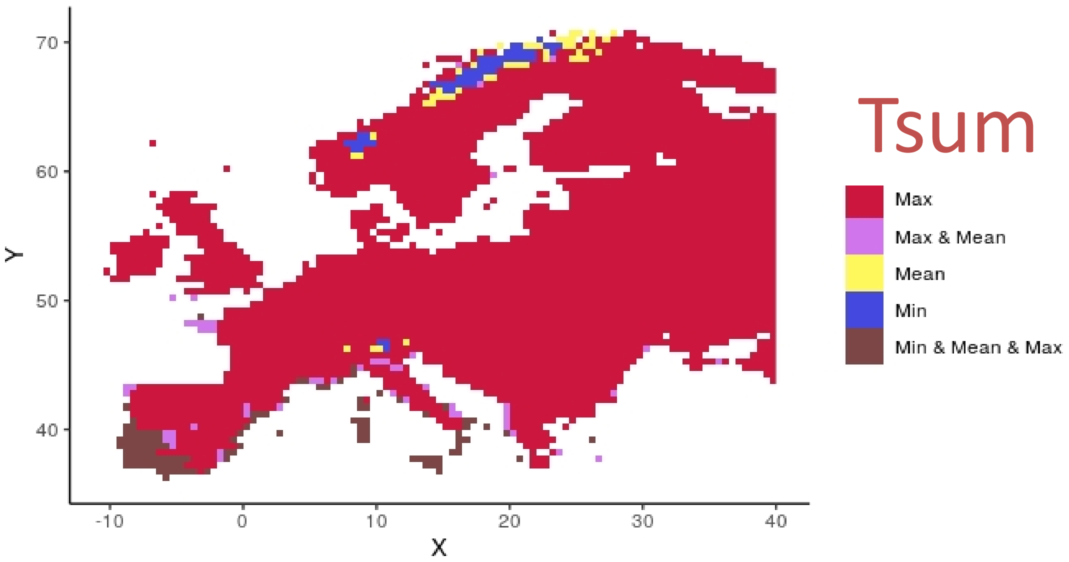
= 3 × 27 × 3174 = 257,074 simulations

Number of viable genetic combinations

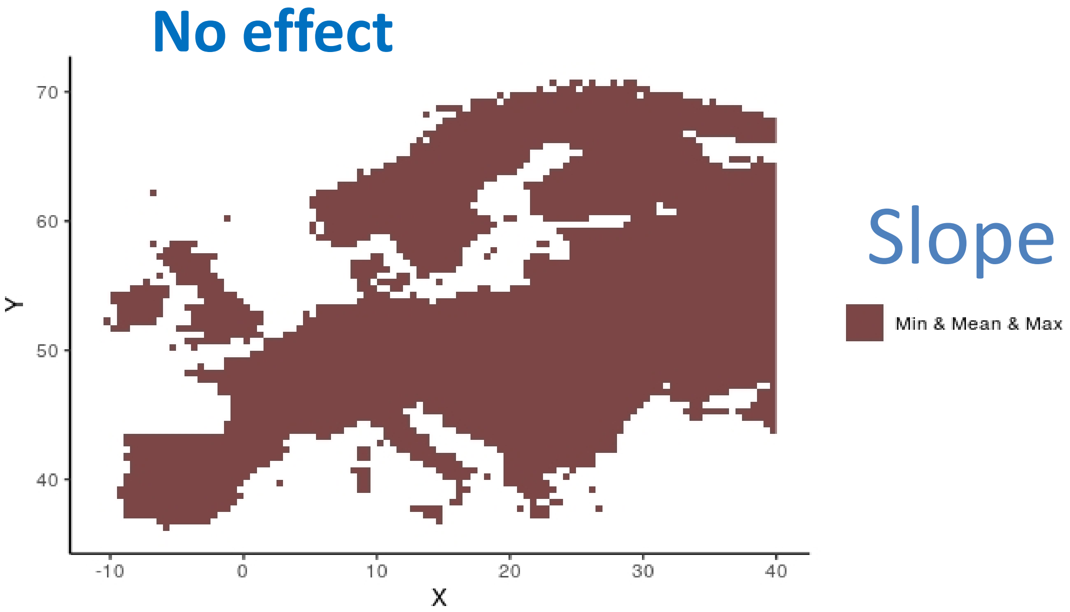


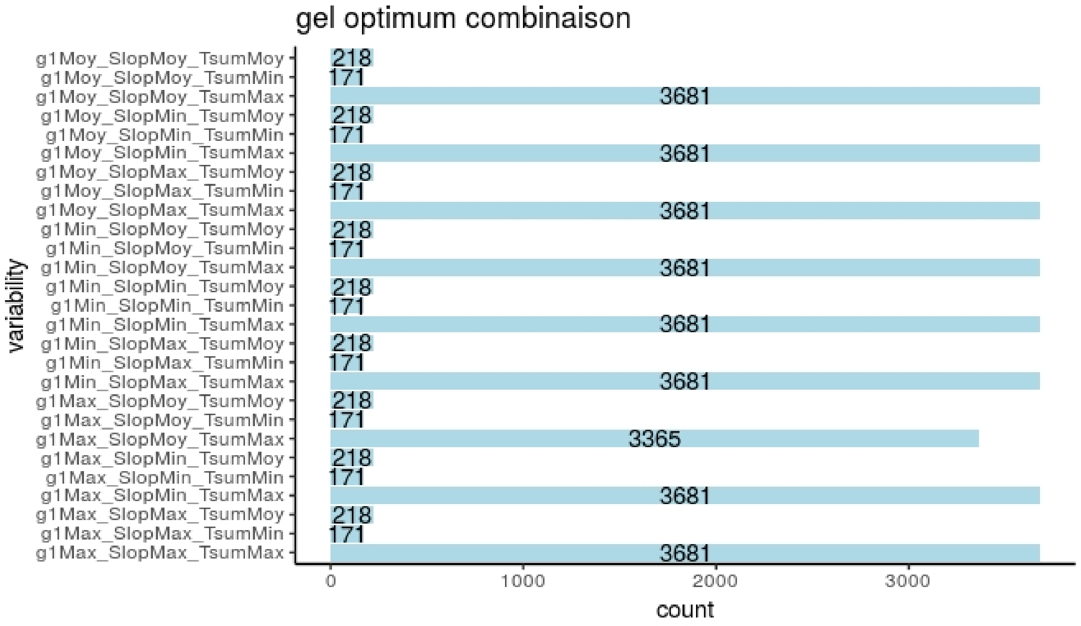
Genetic combination minimizing the vulnerability to frost





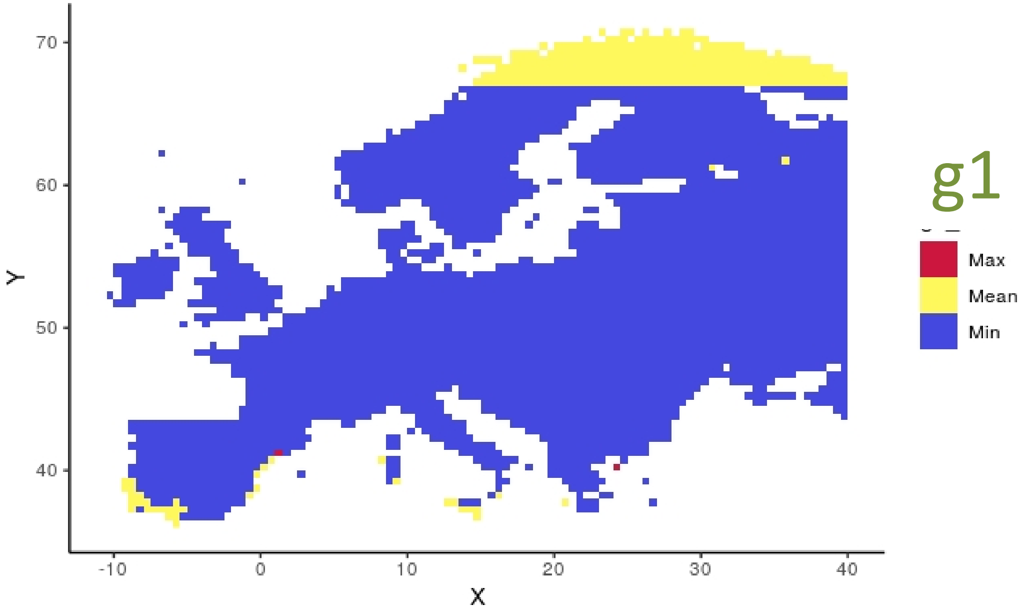
Higher Tsum +- everywhere



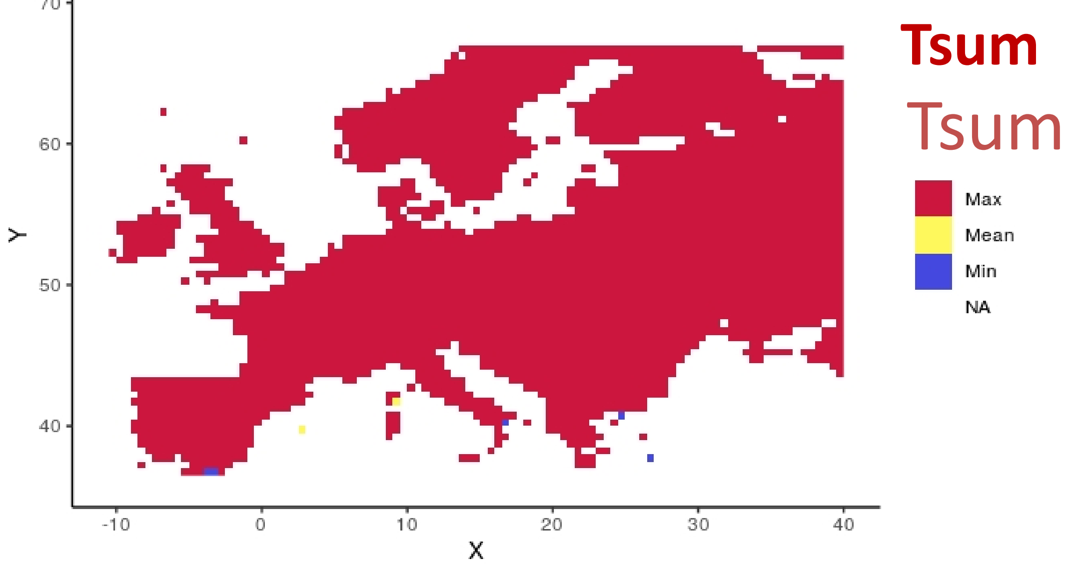


Genetic combination minimizing the vulnerability to hydraulic failure

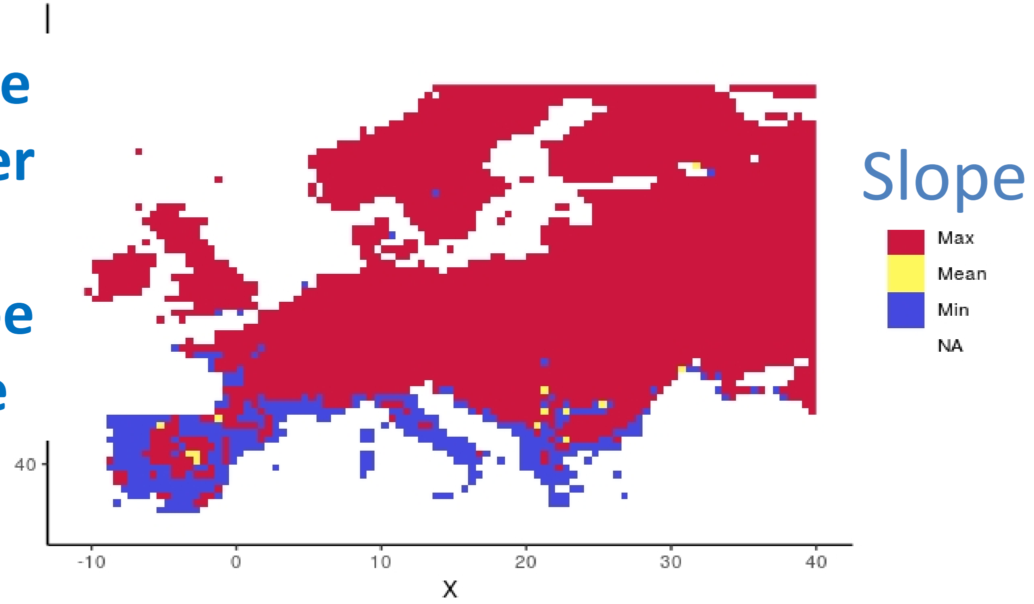
Lower g1

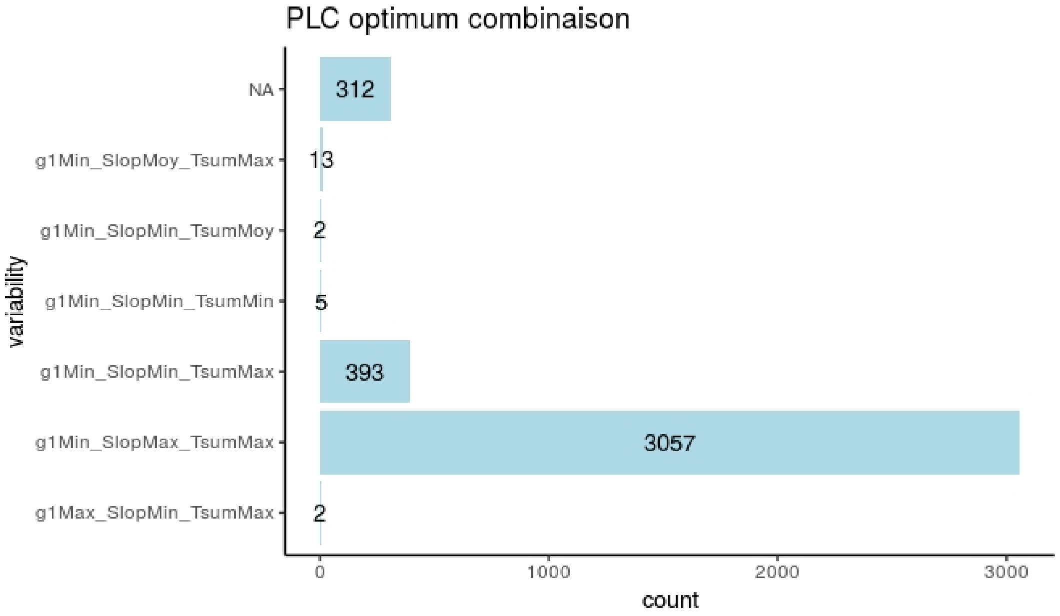


Higher Tsum



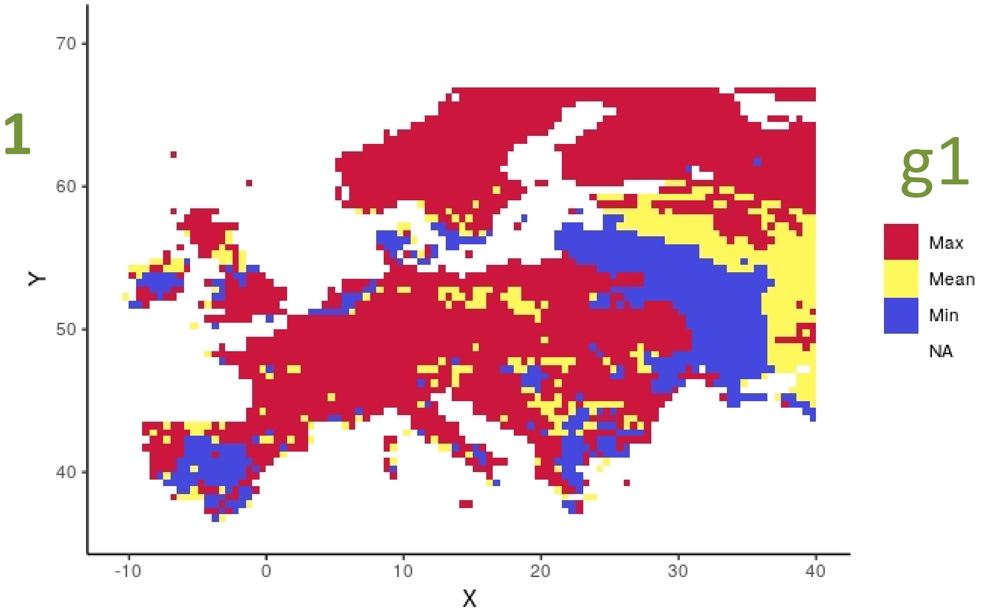
Lower slope under water stress; higher slope elsewhere



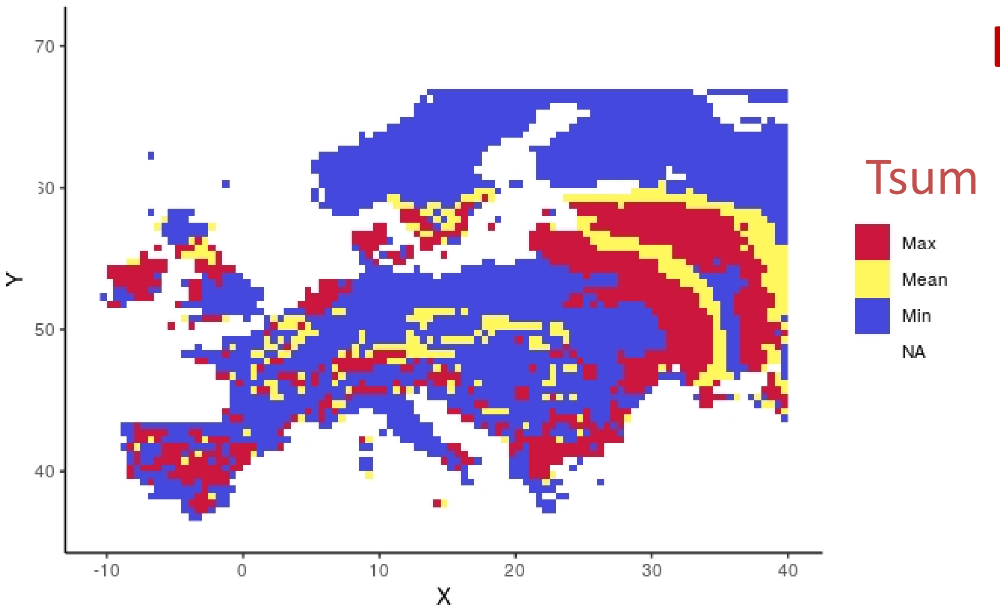


Genetic combination minimizing the vulnerability to carbon starvation

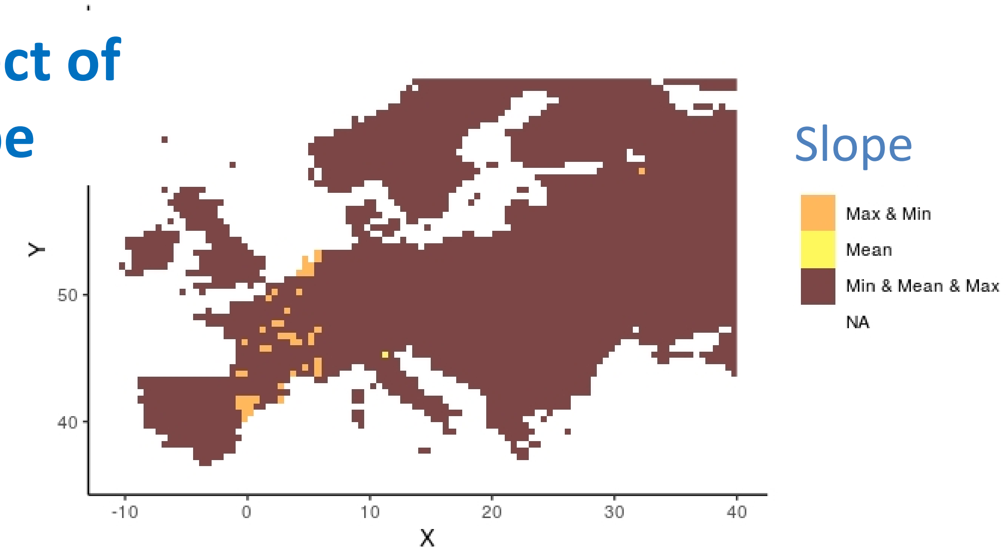
Higher g1

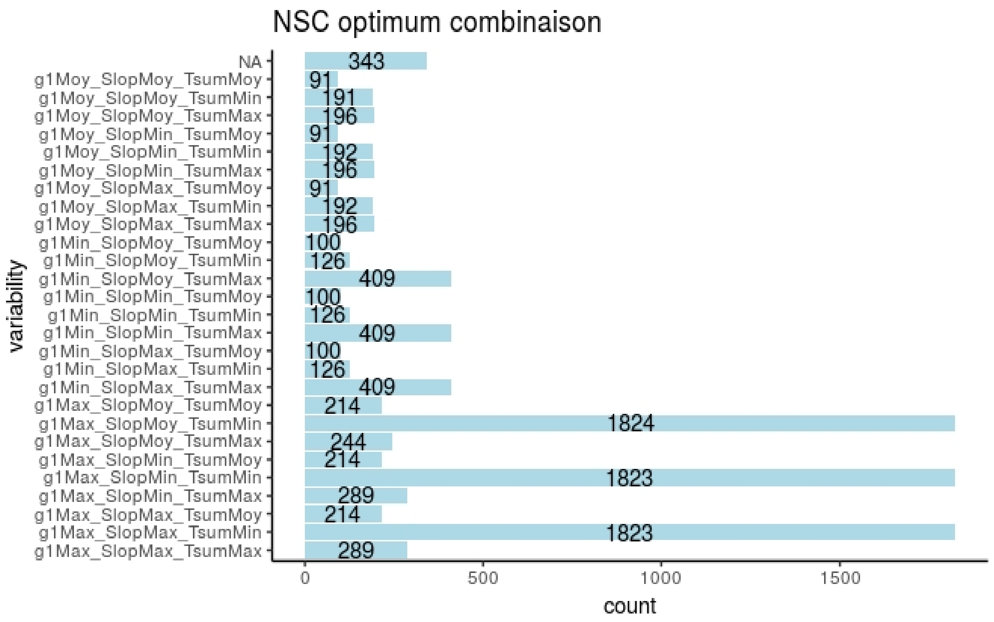


Lower Tsum



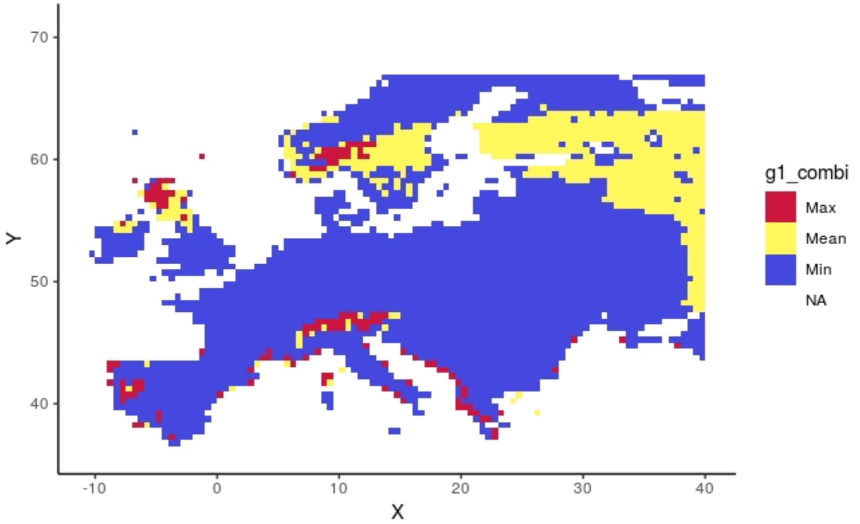
No effect of slope



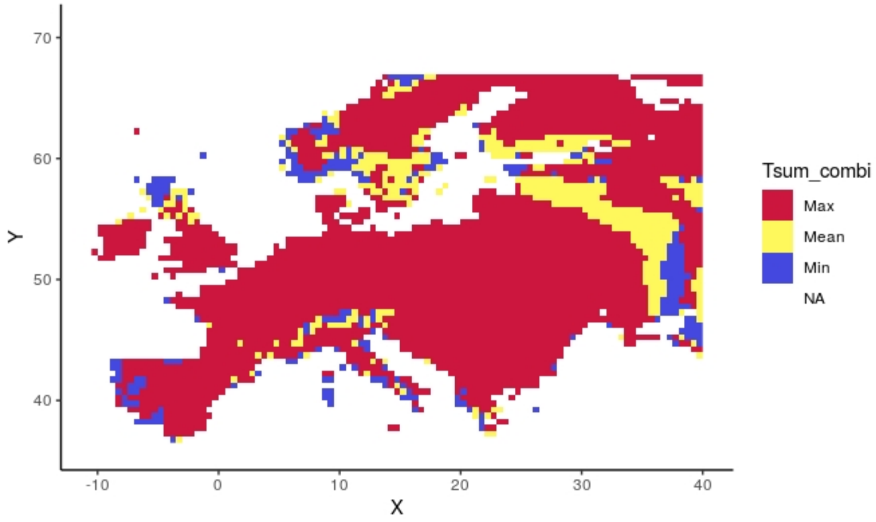


Genetic combination minimizing the overall vulnerability as measured by CVI

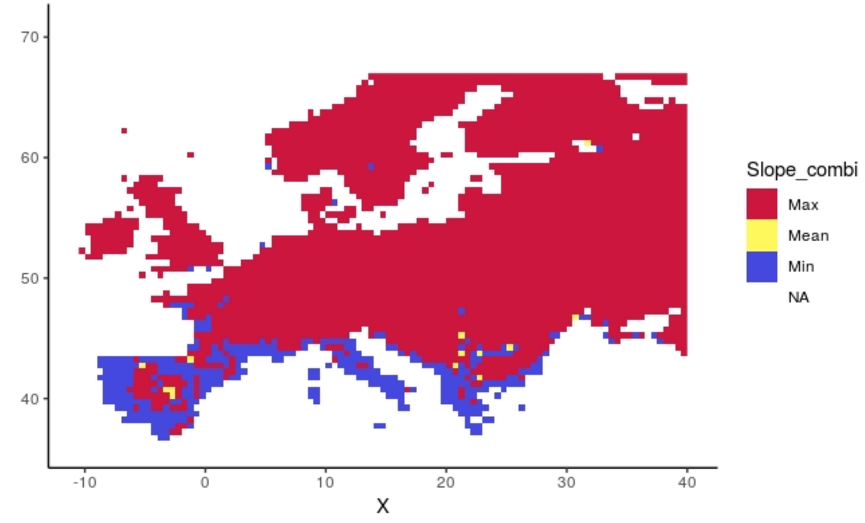
Lower g1

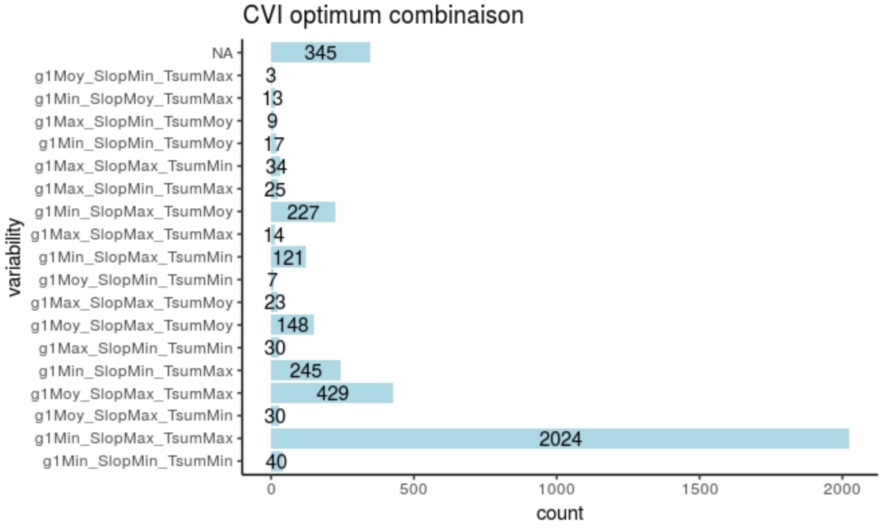


Higher Tsum



Lower slope under water stress; higher slope elsewhere

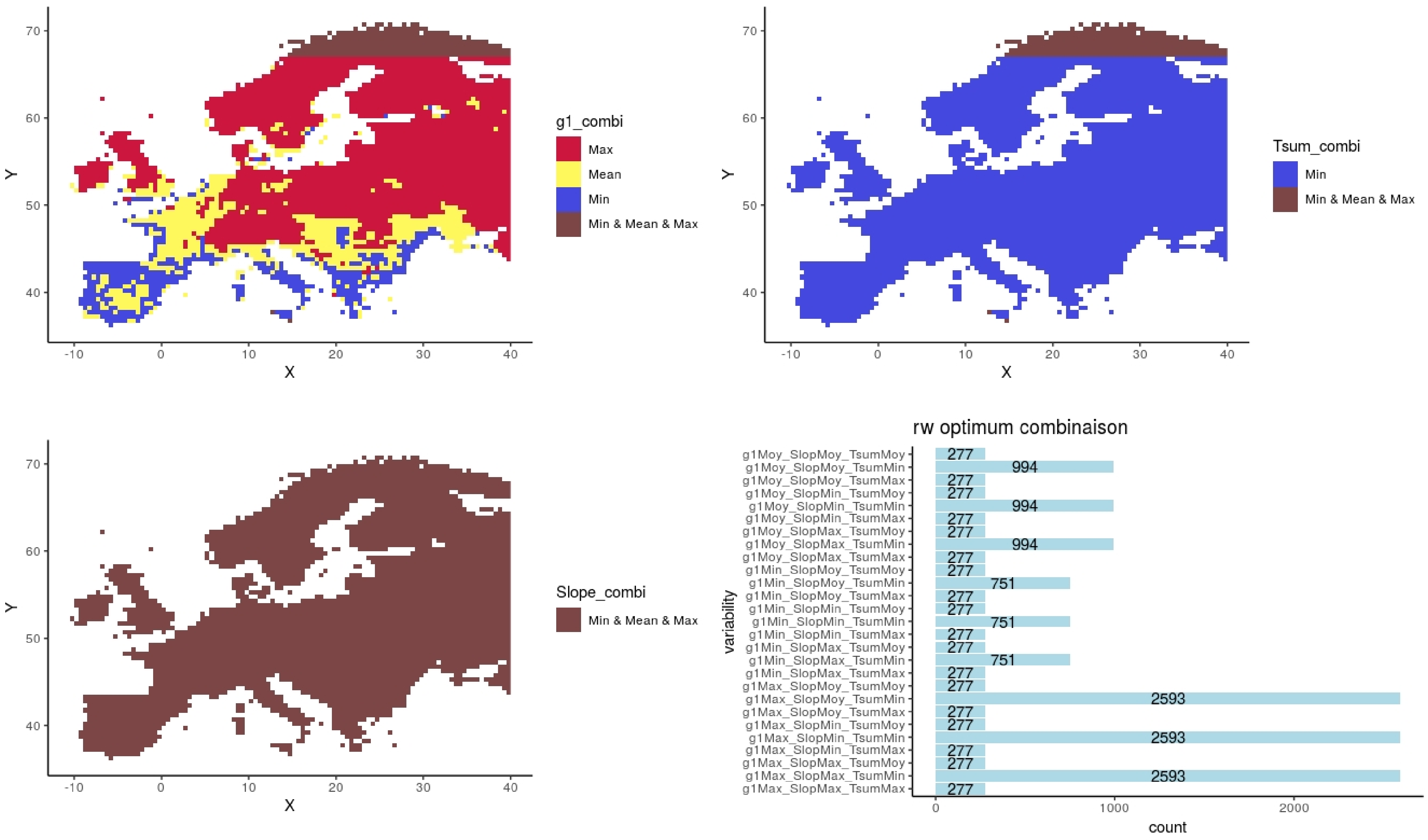




Two “winning” genotypes to avoid climatic stress, depending on the intensity of water stress

Genetic combination maximizing growth performance

Lower g1 under water stress, higher without



Lower Tsum

Trade-off between growth and stress resistance

Take home messages

- Later budburst decreases vulnerability to late frost
- Trees which reduce evapotranspiration sooner and cavitate later are less vulnerable to hydraulic failure
- Trees which reduce evapotranspiration later and budburst earlier later are less vulnerable to carbon starvation

- Budburst optimum indicates a tradeoff between survival and growth
- There is not a single genotype maximizing survival and productivity

- Management strategies including BAU + assisted migration need to be simulated

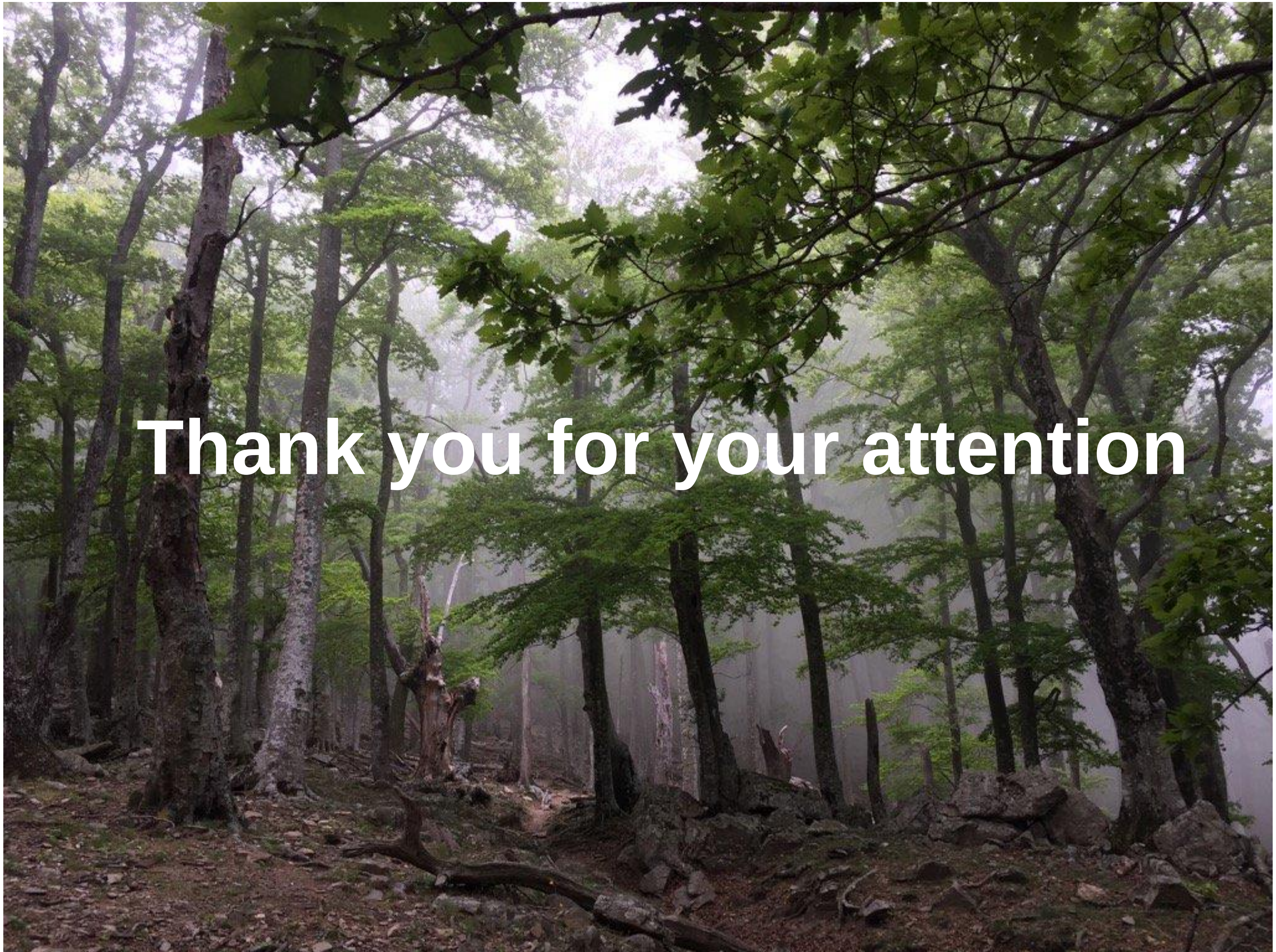
Climate scenario
Current
Future RCP 4.5
Future RCP 4.5

×

Min, mean, max values
Tsum
g1
$slope_{PLC}$

×

Management scenario
Even-aged forest management with shelterwood
Even-aged forest with clear-cut
(Continuous cover forest management)
Unmanaged forests


Thank you for your attention