

Mountain grassland dynamics: integrating phenotypic plasticity in a new agent-based model

Ph.D. defence of

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Context

Mountain grasslands in a changing world

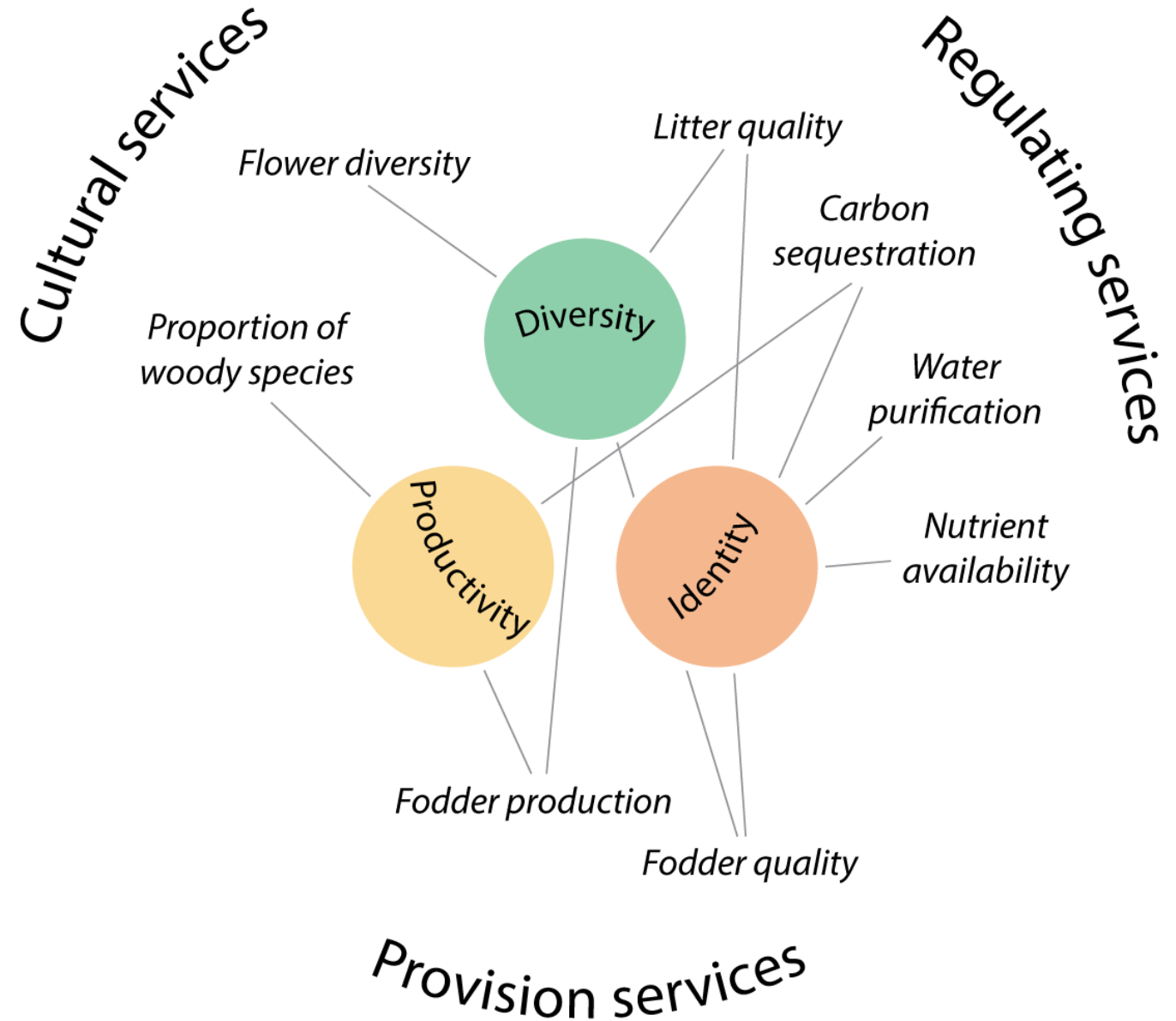
The value of mountain grasslands' diversity.



Ecosystem services

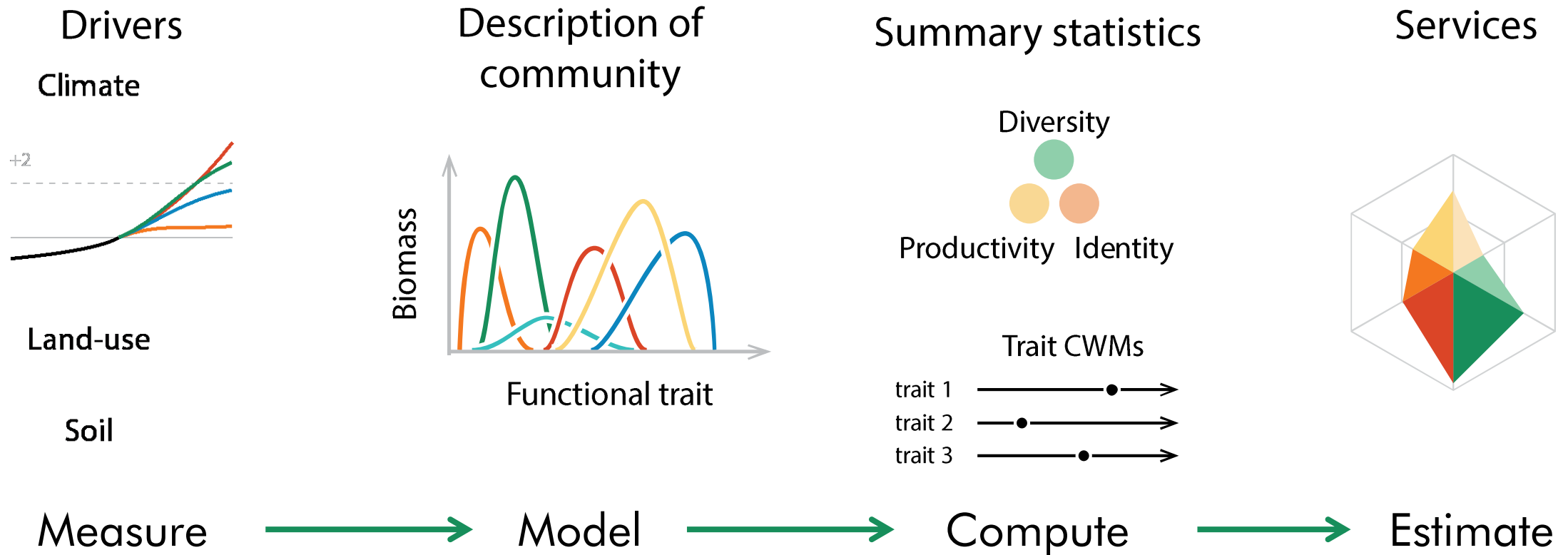
Benefits that humans freely gain from the natural environment

- Argument for nature conservation
- Tool for management

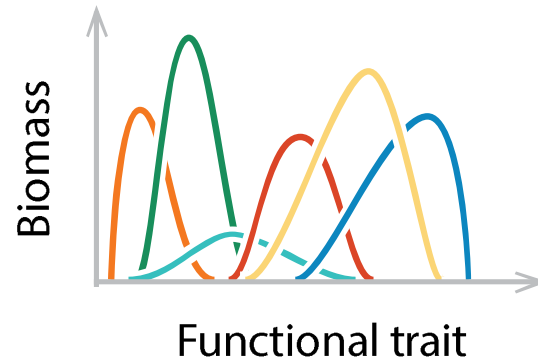
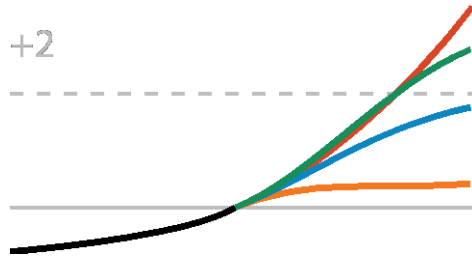


Assessing grassland ecosystem services

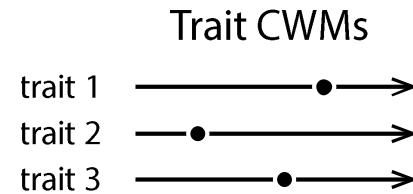
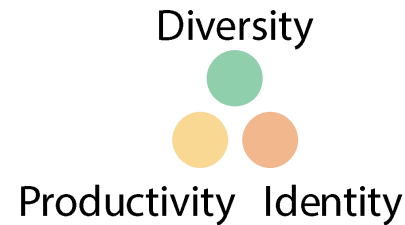
Trait: morphological, anatomical, biochemical, physiological or phenological features of individuals or their component organs or tissues - TRY database



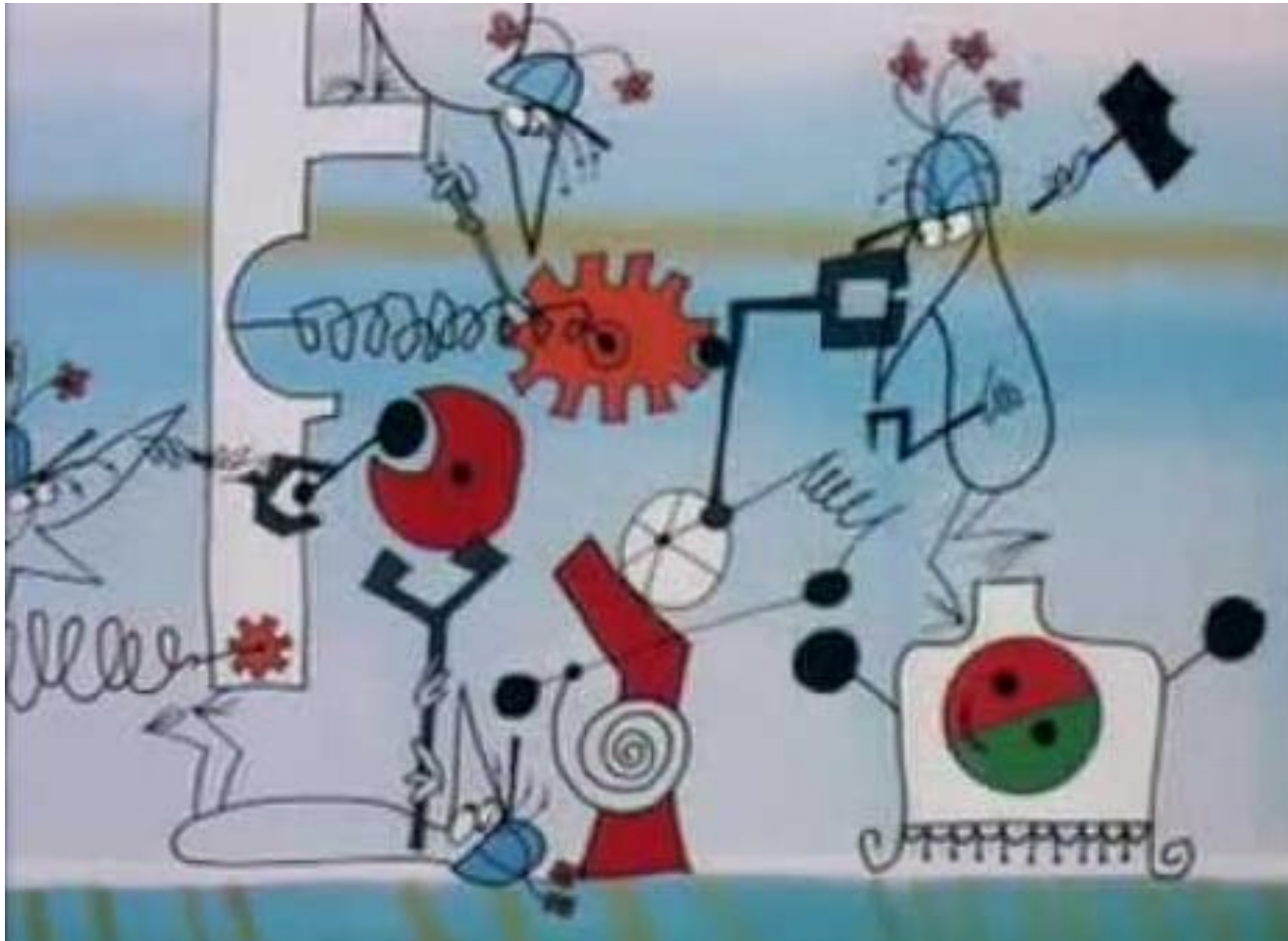
Drivers, global change and services



Summary statistics



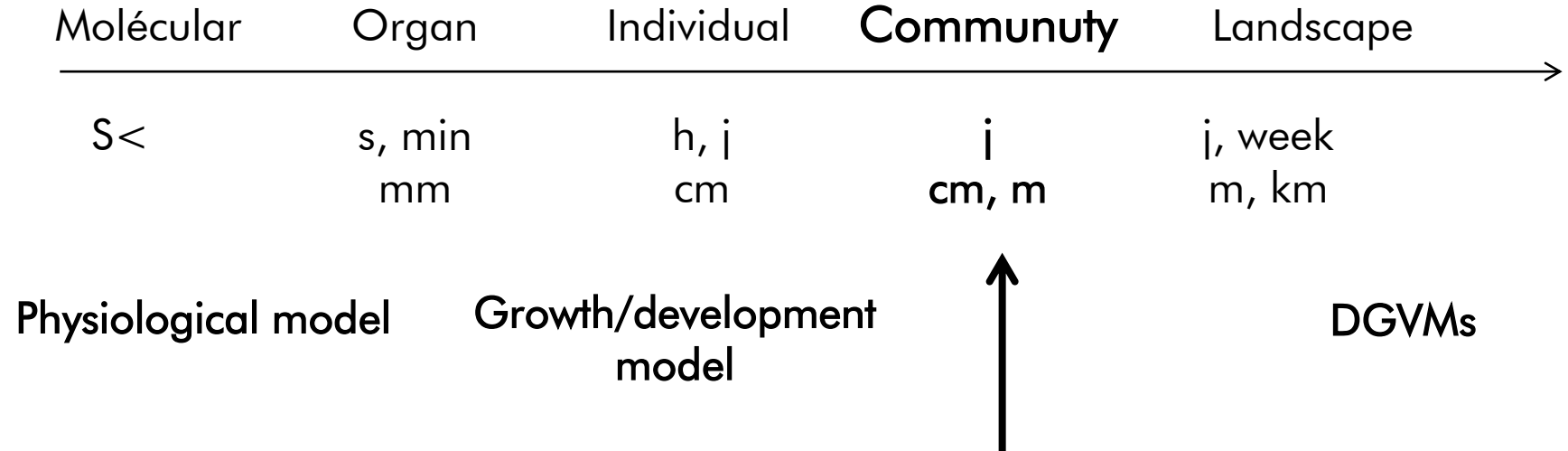
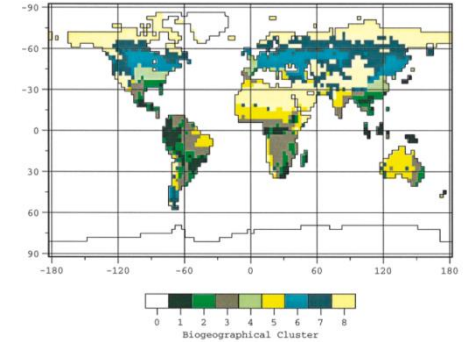
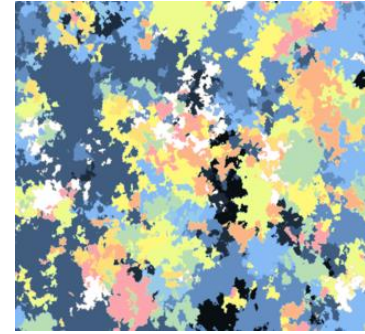
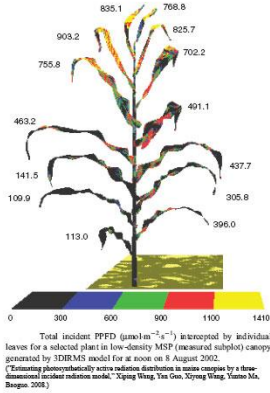
Models to understand and predict



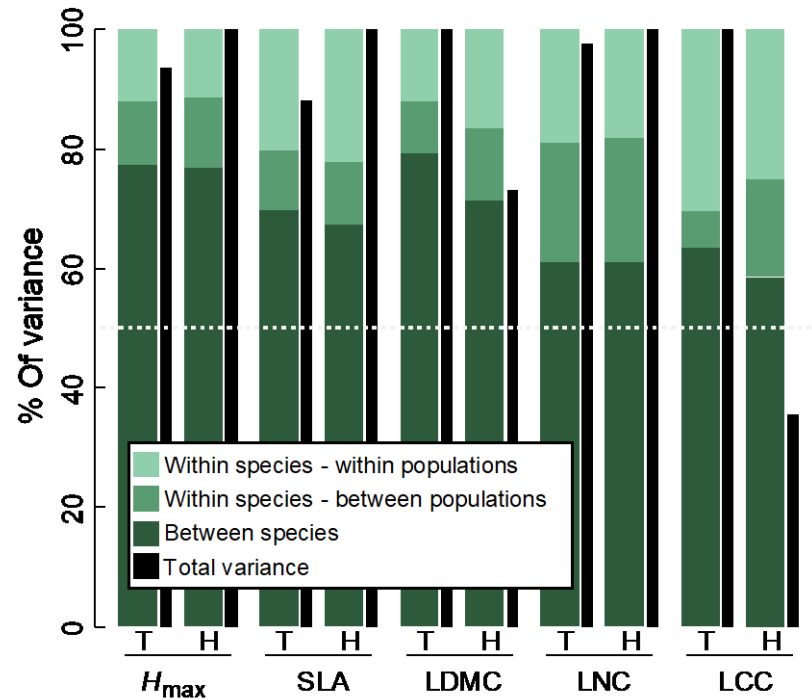
- Understanding by explaining
- Emerging behaviour
- Allow exrtapolations
- Experiment at low cost

A gap to fill

Combine the species diversity and ecological processes of large scale models with the plant level processes of small scale models.

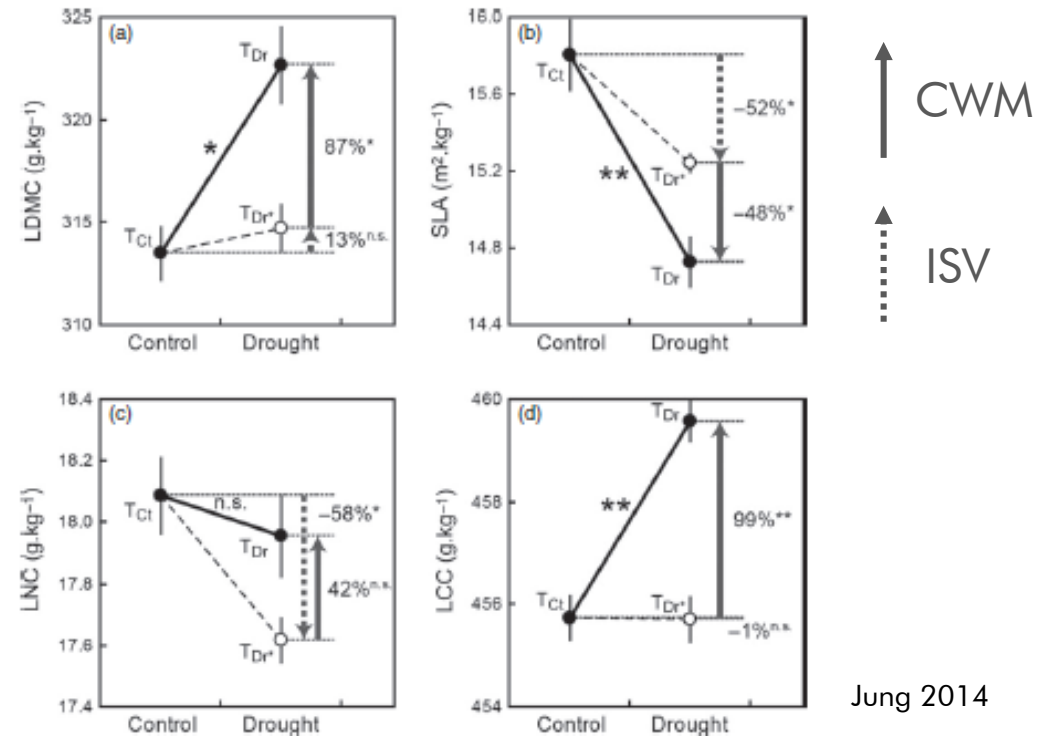


Intra-specific variability matters and impacts the community responses



Variance decomposition into the different levels.
From Albert and al. 2010.

Up to 40% of the total
variability of some traits.



Jung 2014

Strong impact on
community response

Phenotypic plasticity, one source of variation



Genetic
variation



Epigenetic



Phenotypic
plasticity

Plasticity

Often overlooked.

Hard to study in empirical studies.

Potential for rapid adaptation to climate change.

Potential for mitigation of the effects of environmental variability.



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Questions

Technical and scientific interrogations

How does phenotypic plasticity
impact grassland community
properties & dynamics?

How model diverse plant communities
integrating phenotypic plasticity?

How does phenotypic plasticity
impact grassland community
properties?



Introduction

State of the art and concepts

The concept of niche

How a species fit in a set of env. conditions.

Hutchinton: n-dimension volume.

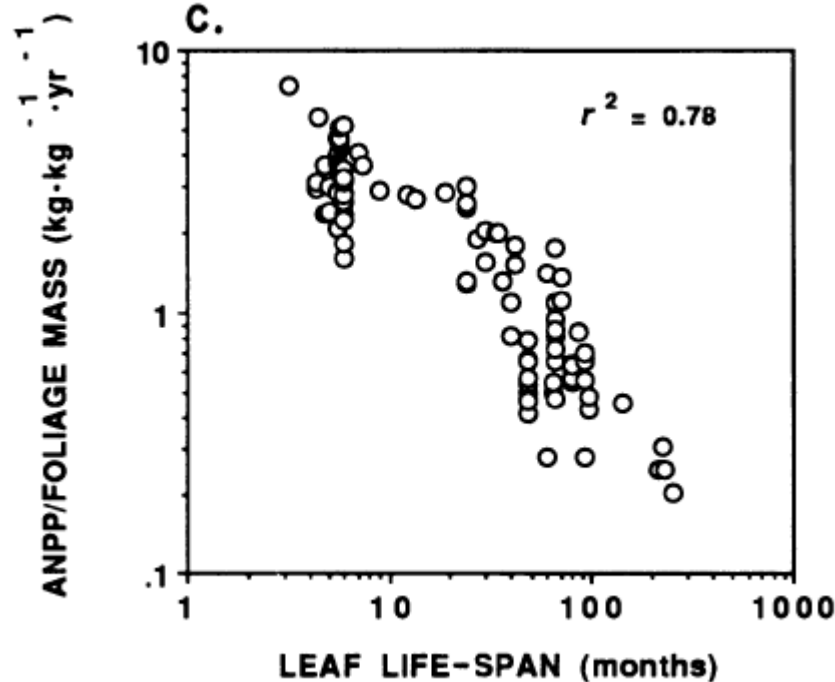
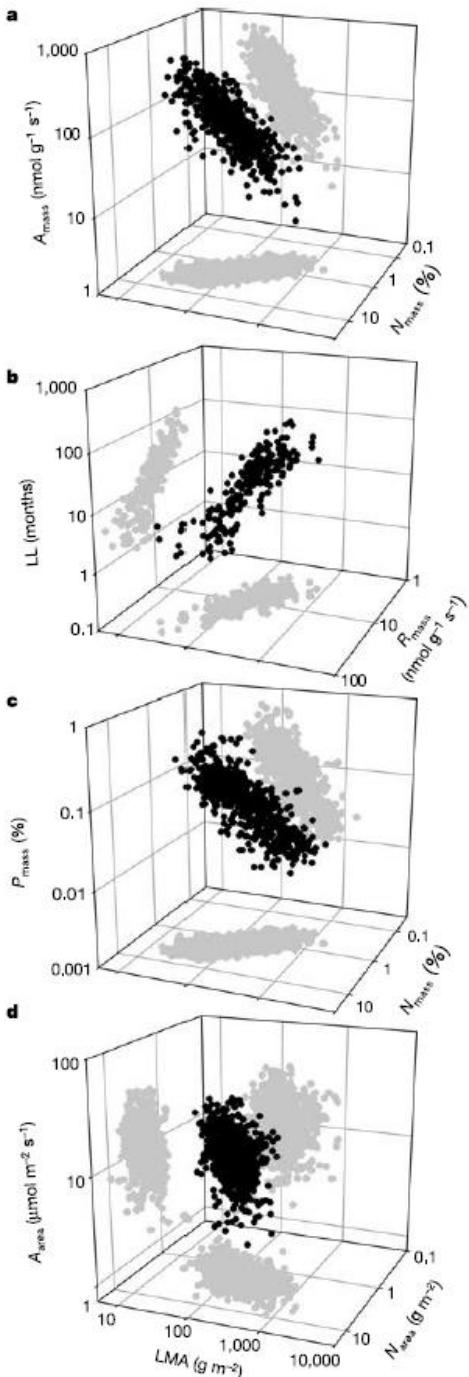
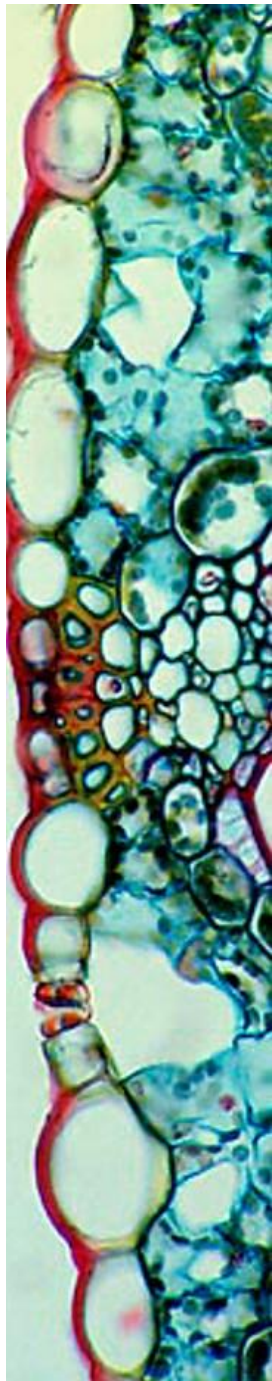
Translate the impact of an environmental factor on the fitness function (growth, survival and reproduction)

Affected by biotic condition fundamental → realised

Despite the similar functioning
Why do not plant share the same niche?

The leaf economic spectrum

- Variation in structure and resource use
- Emerge from ecological and biological constraints
- Allow simplification of plant classification
- Partly explain by the trade-off between active and structural tissues



P. Reich (1992)

Wright et al. (2003)

Trade-offs and strategy space

Strategy space.

Generalise trade-offs to other processes: roots exchanges, reproductions, etc...

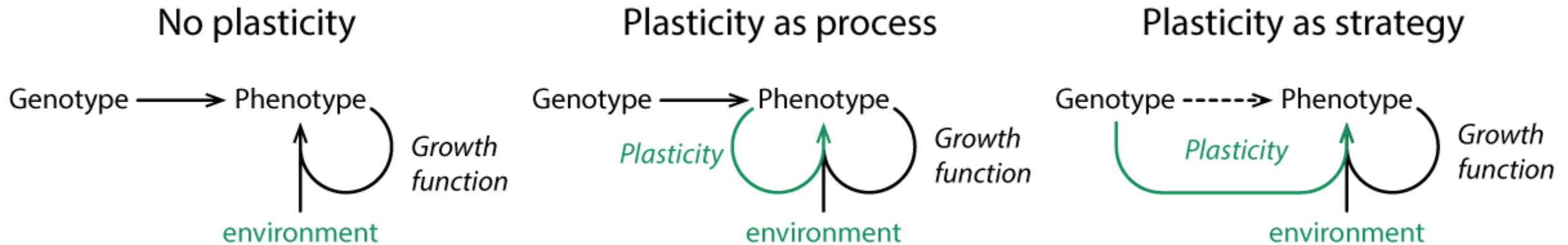
Continuous axis, convenient for modelling

→ Same functioning framework but species differences

- How does plasticity fits in this framework ?

Plasticity as a strategy

Active plasticity: anticipatory, and often highly integrated, phenotypic changes in response to some environmental cue



Modelling plasticity

Finalist perspective

Plasticity in models: dimensions, objectives and assumptions

Dimensions: what traits are plastic,

Objective: what drives the changes,

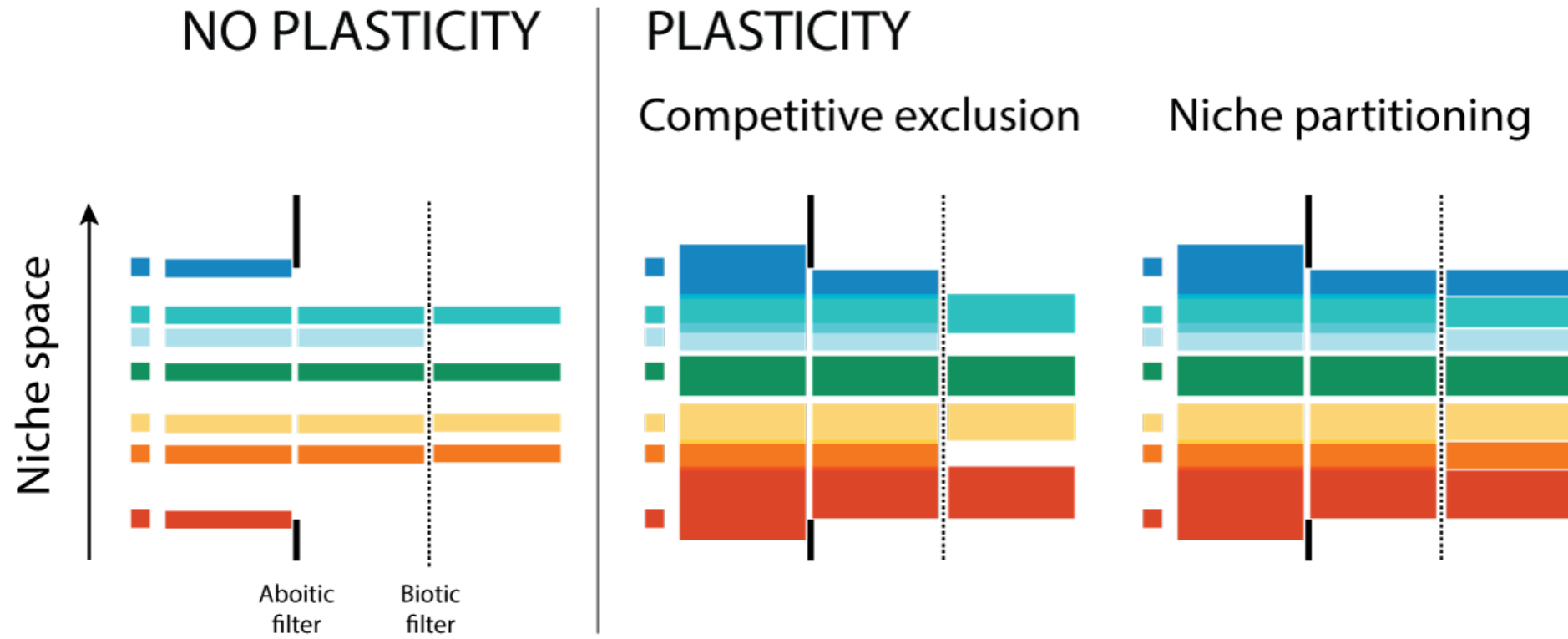
Assumptions: implicit or explicit rules

How does plasticity impact properties and dynamics of plant communities?

Widenning niches

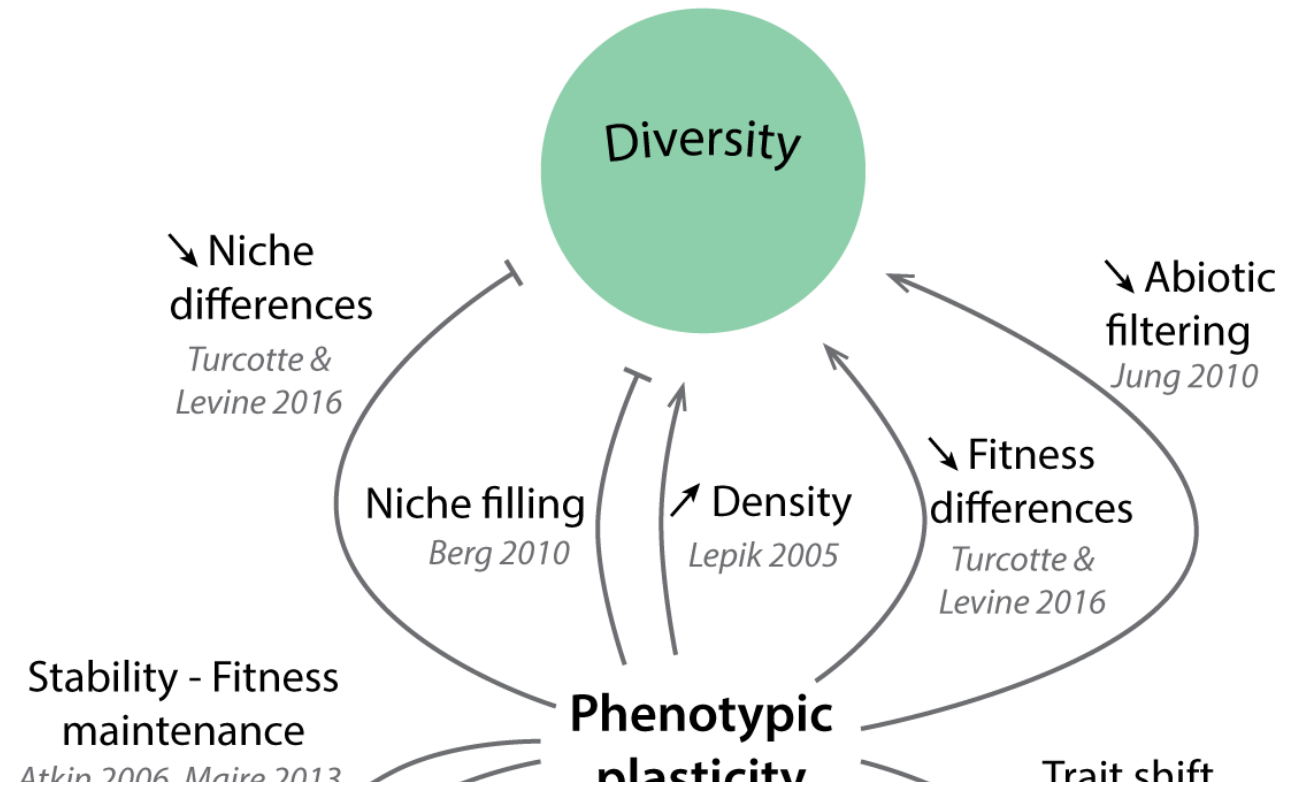
Effect on community's diversity

Niche partitioning vs competitive exclusion



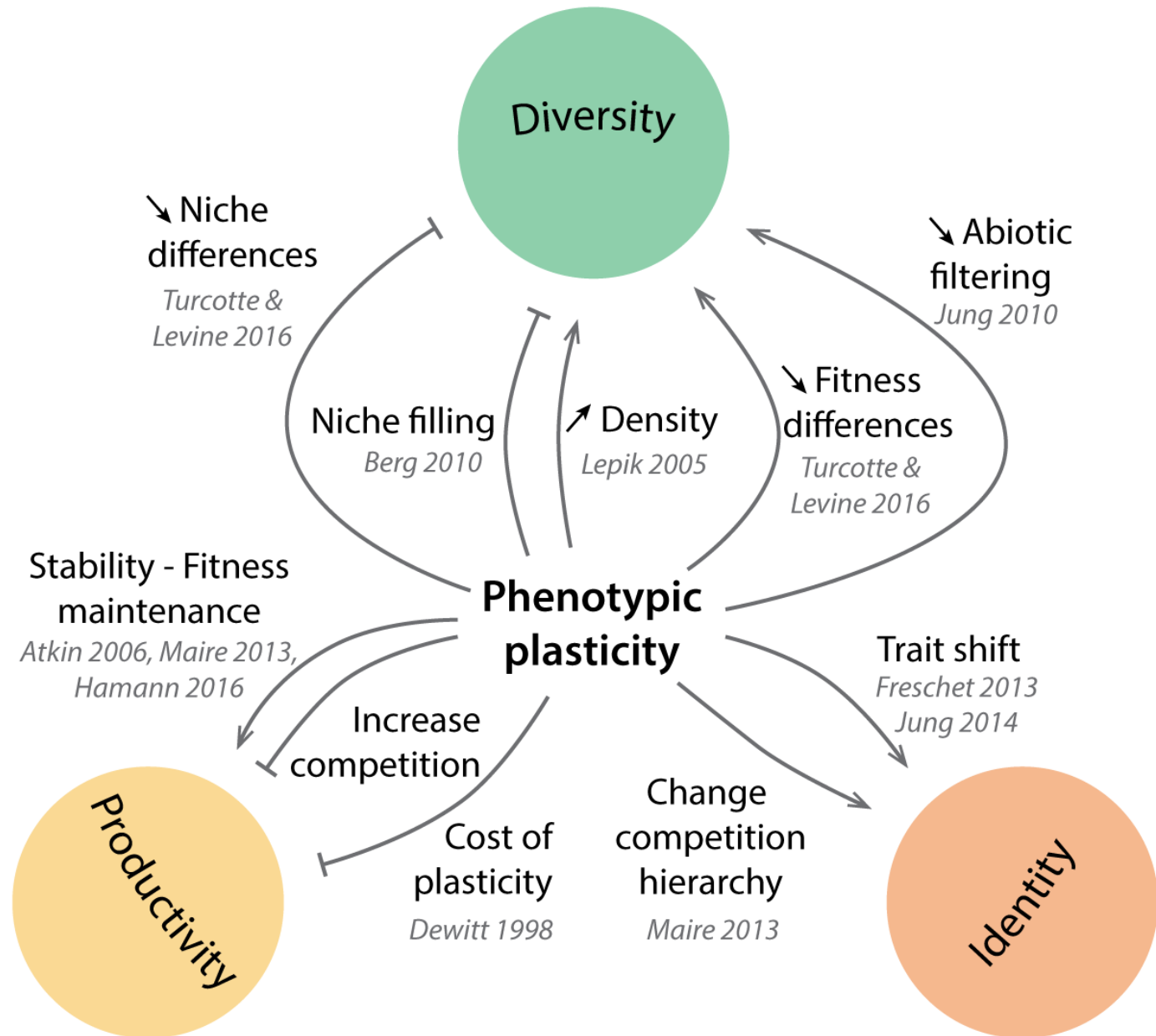
We do not agree, yet

All effects



We do not agree, yet

All effects





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Results

Presentation of *MountGrass*

Individual- and community-level
effects of plasticity

Model overview

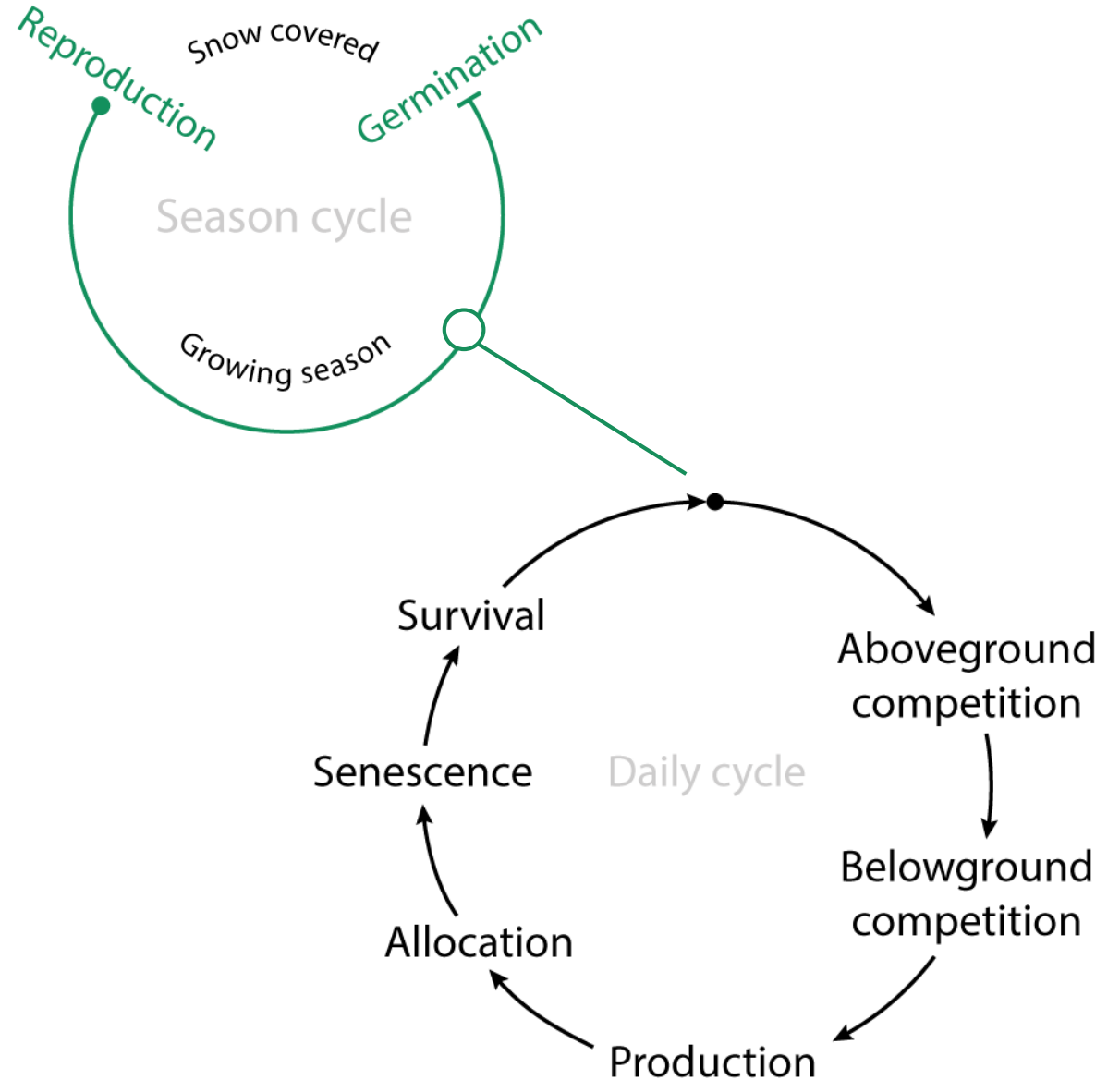


MountGrass' world representation

Obj: community properties and dynamics emerge from plant fcting. → individual

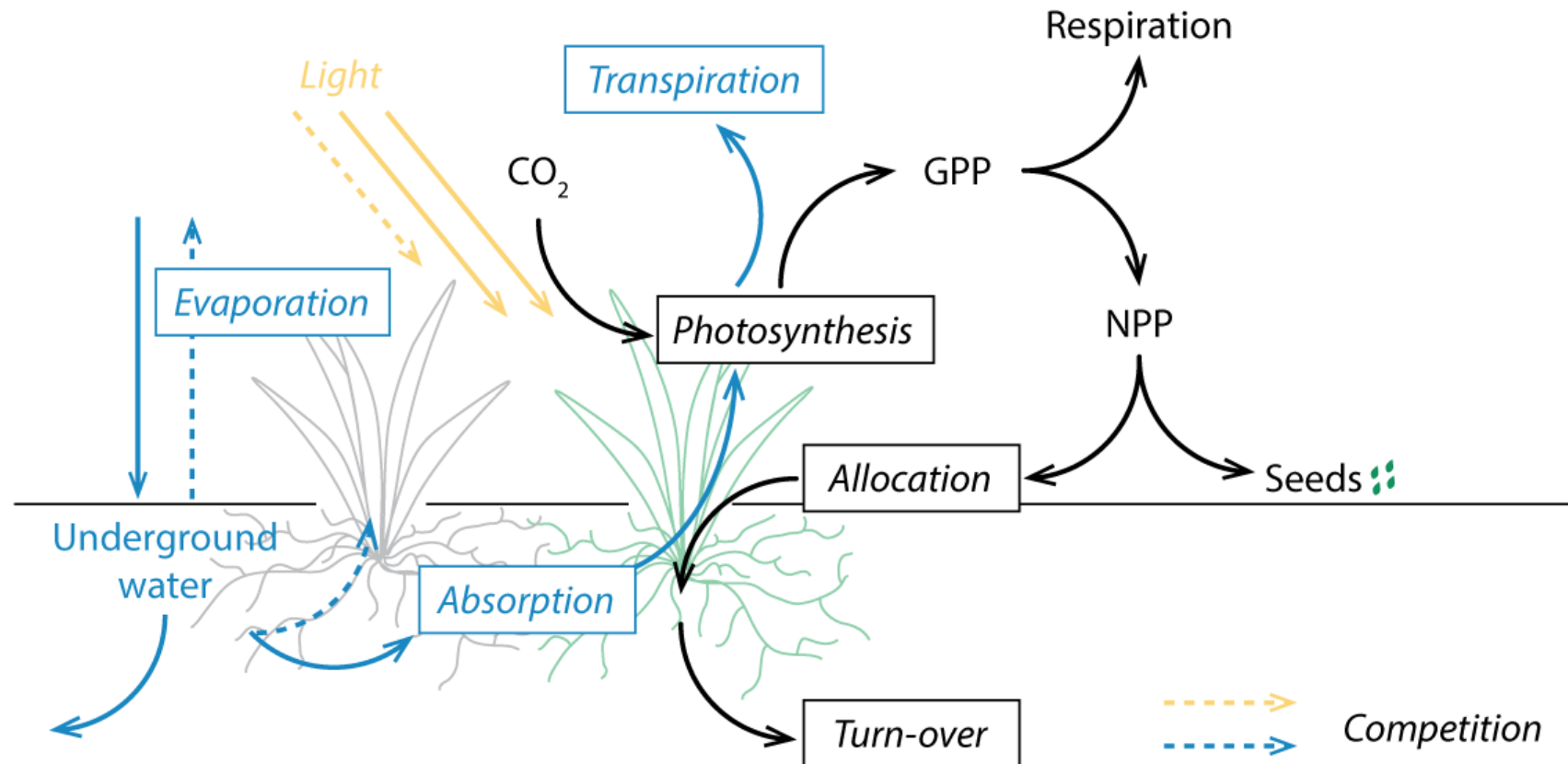
IBM spatially explicit

- Scales and resolutions
- Cm, day
- Seasons
- Grid



MountGrass' processes

- Main processes



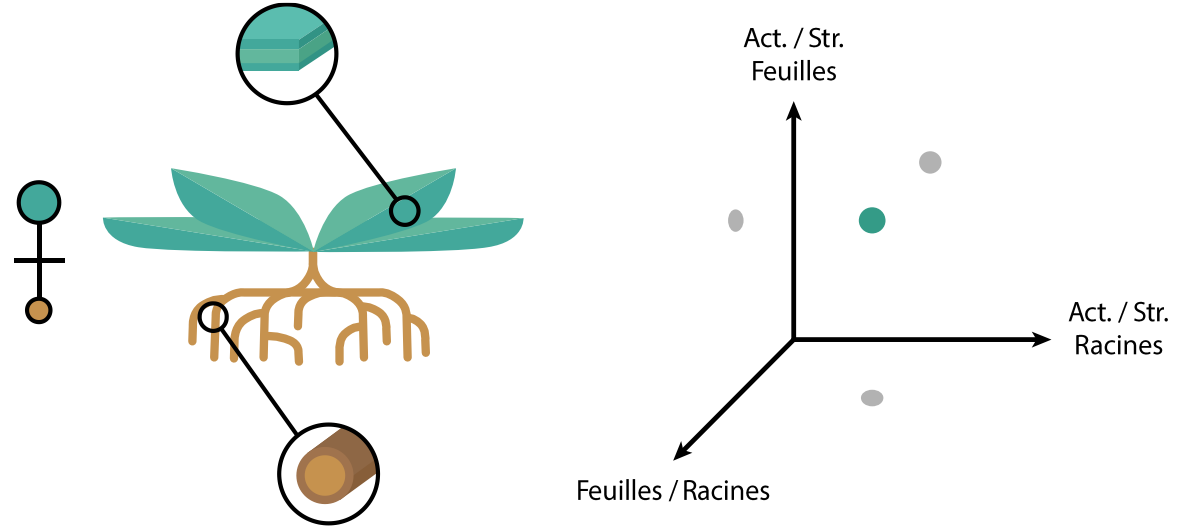
Plant representation



Based on trade-offs
and strategy space

4 vegetative
compartments

Par, pas, r:s



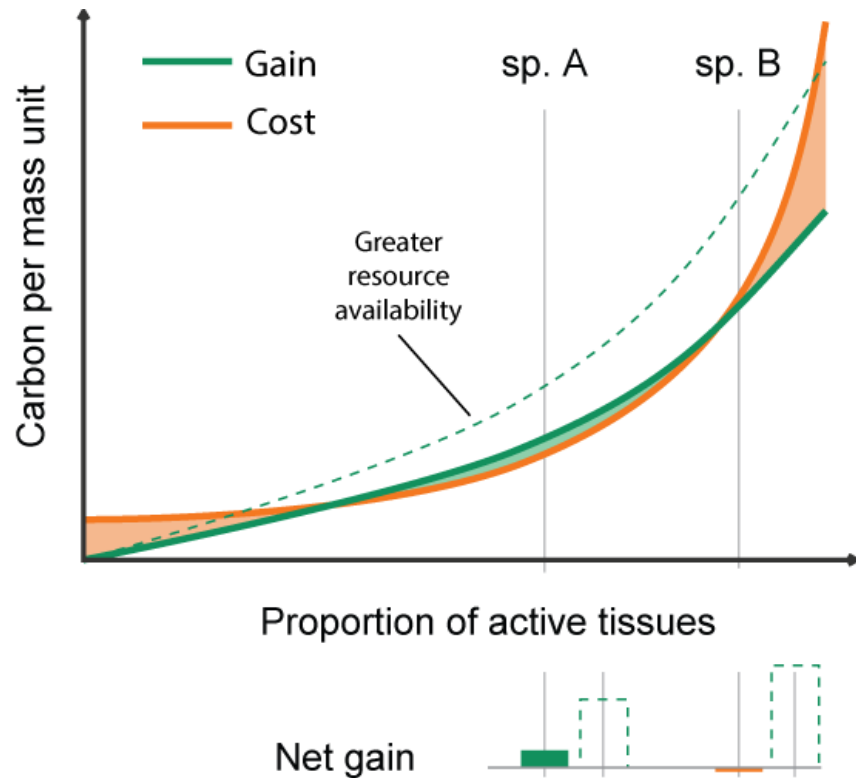
Different dry volumic masses
→ Change the cost of
exchange area

But also alters turn-over and
respiration

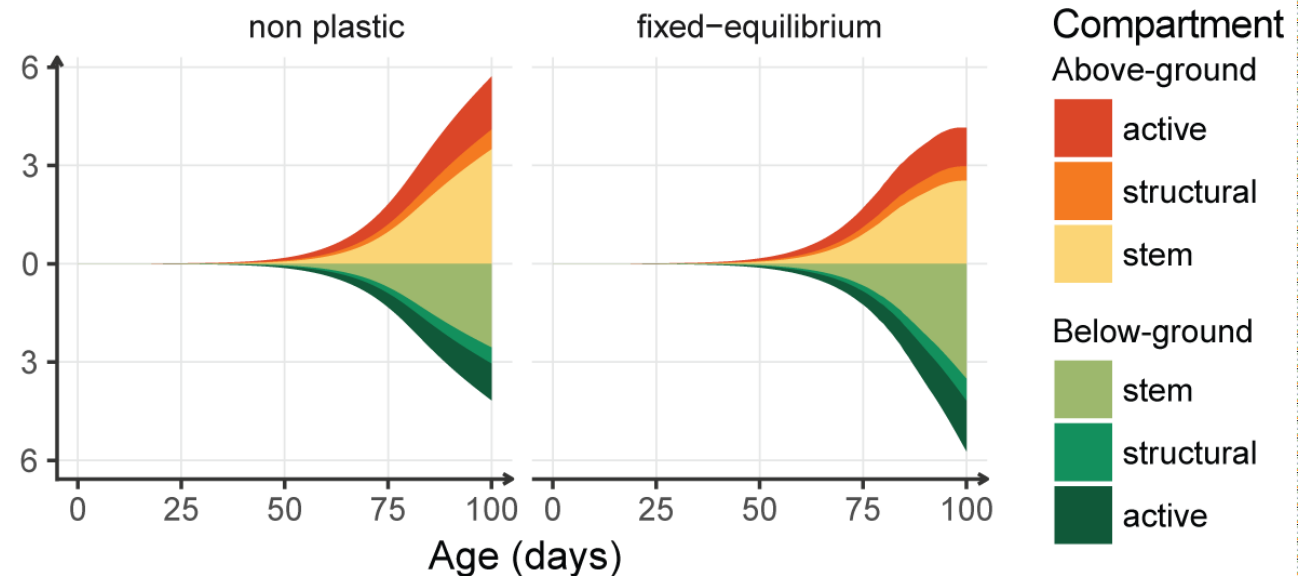
How does the phenotype impact
the plant growth?

The components of plant growth

TISSUE EFFICIENCY



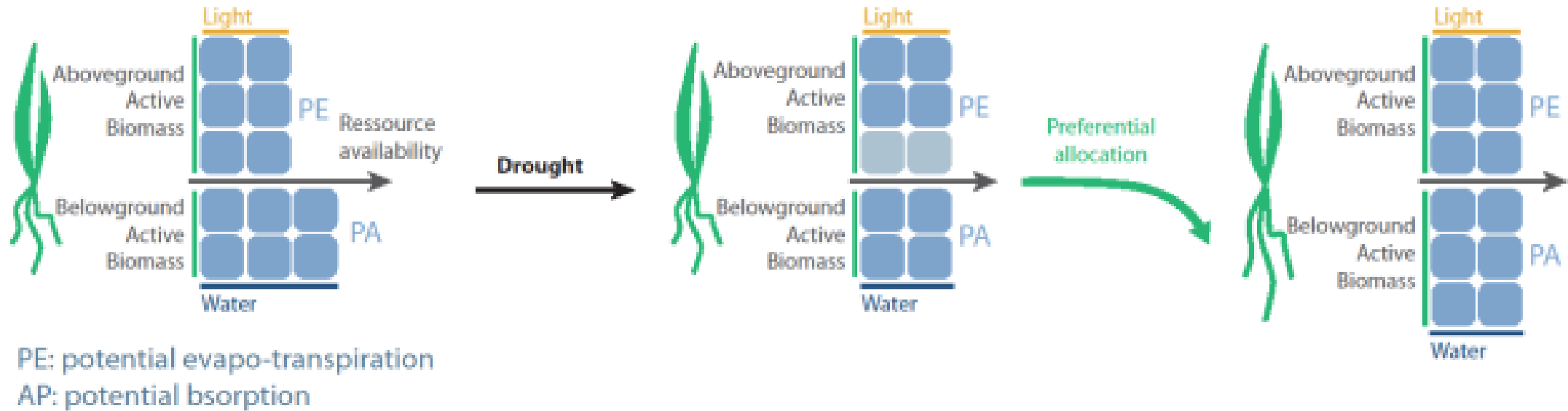
BALANCE



How does plasticity fit this representation and drive the phenotype ?

Algorithms

- Objective functions
- Plastic dimensions
- Assumptions



- Objective function: equilibrium, axis: root:shoot ratio
- One among 3

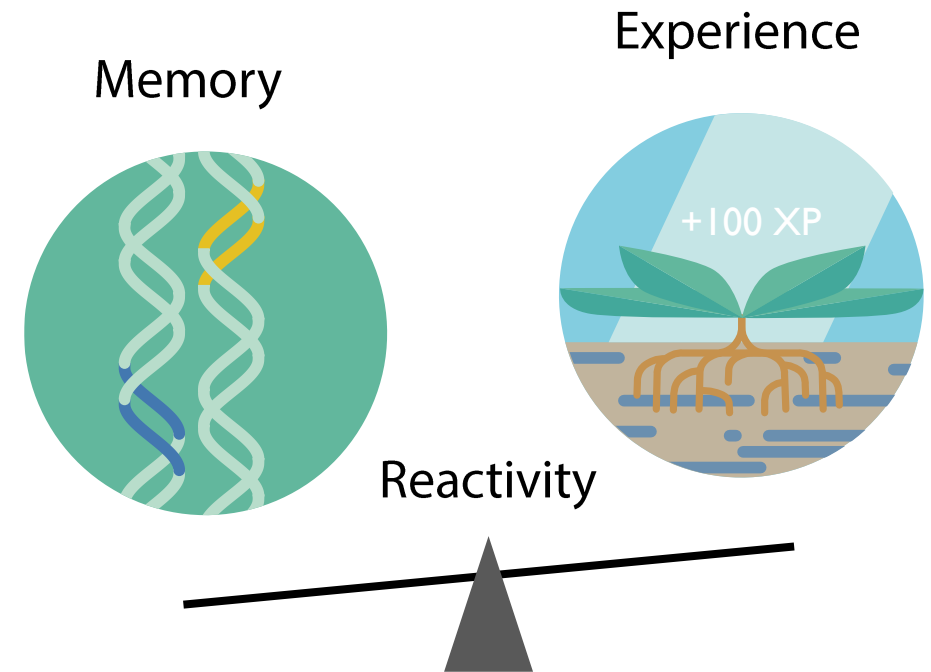
Just rules, not a strategy

The future: between species memory and individual experience

How make it a strategy, and not only a process ? Make the projection definition species specific

Memory: genetic memory of the species

Reactivity: relative weight given to the individual experience





Simulation results



Individual-level simulations

The plasticity and the potential niche

Simulation set-up

Simulations

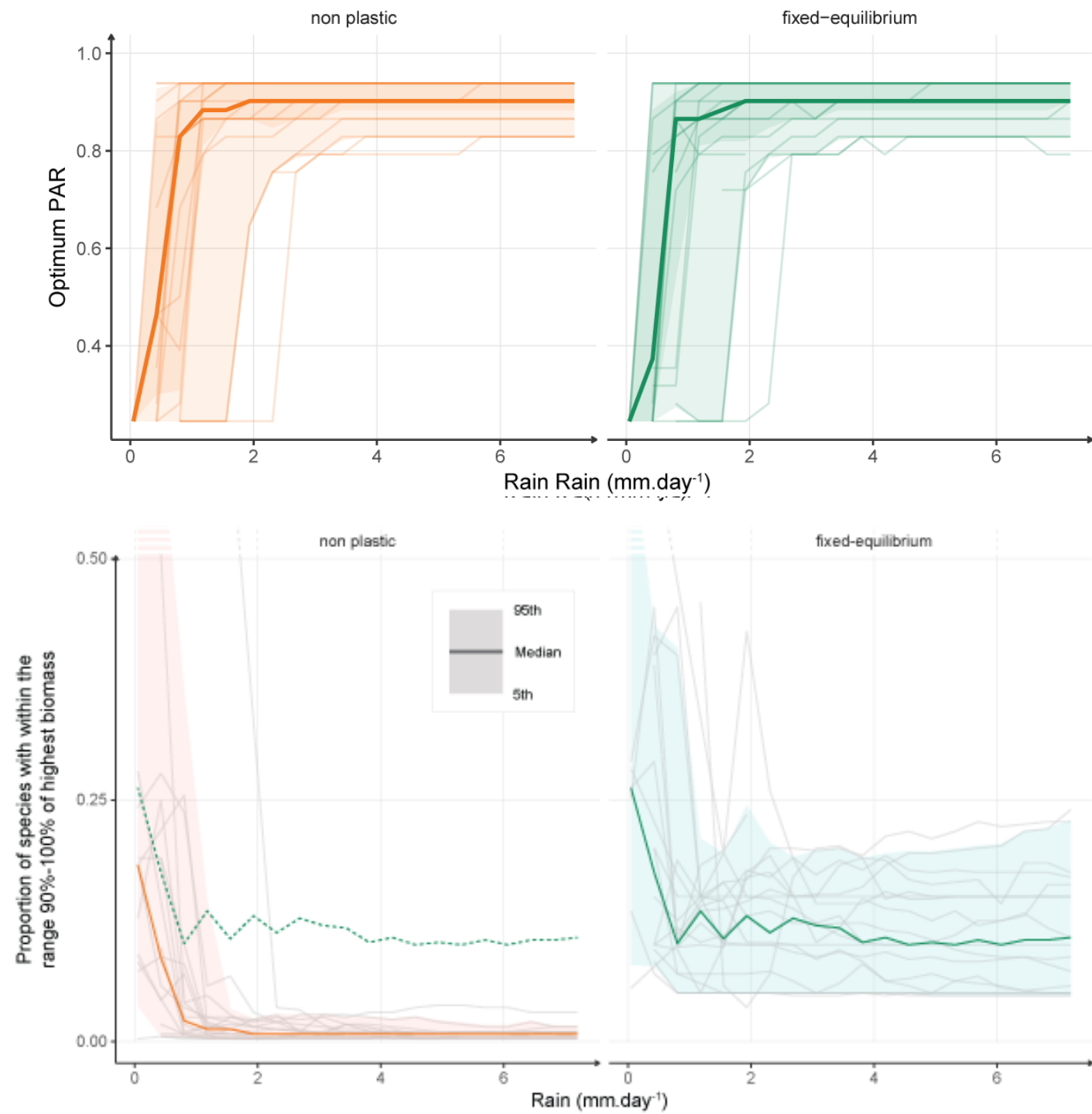
- 20 Parameter sets
- Plastic and non plastic
- Gradient of water availability
- $N * m$ phenotypes

Each simulation

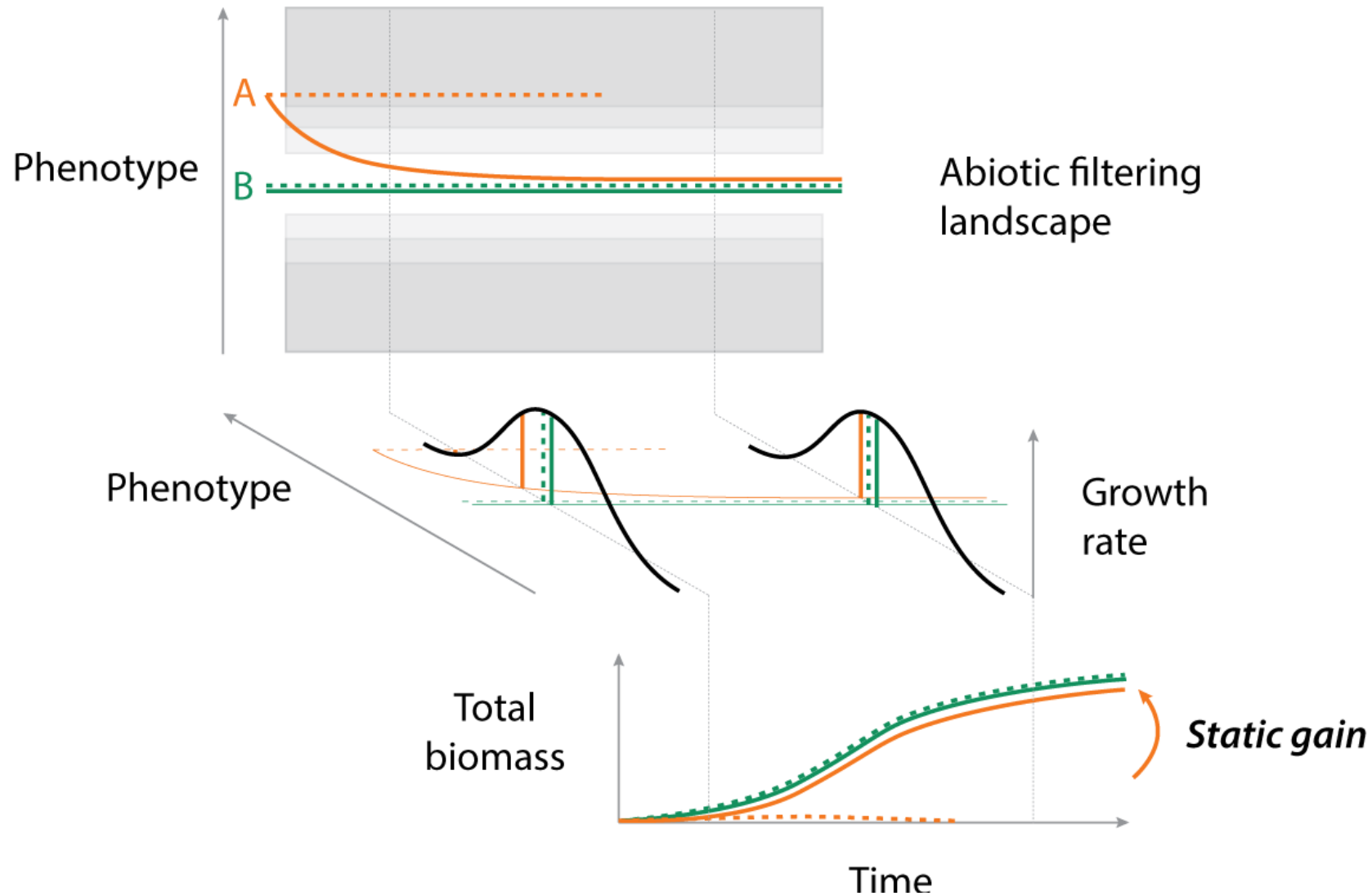
- Size/lenght

Homogeneous conditions & static gain

- No shift in best strategy (proportion of active tissues)
- Reduction of growth differences (not shown)
- Little change in maximum biomass

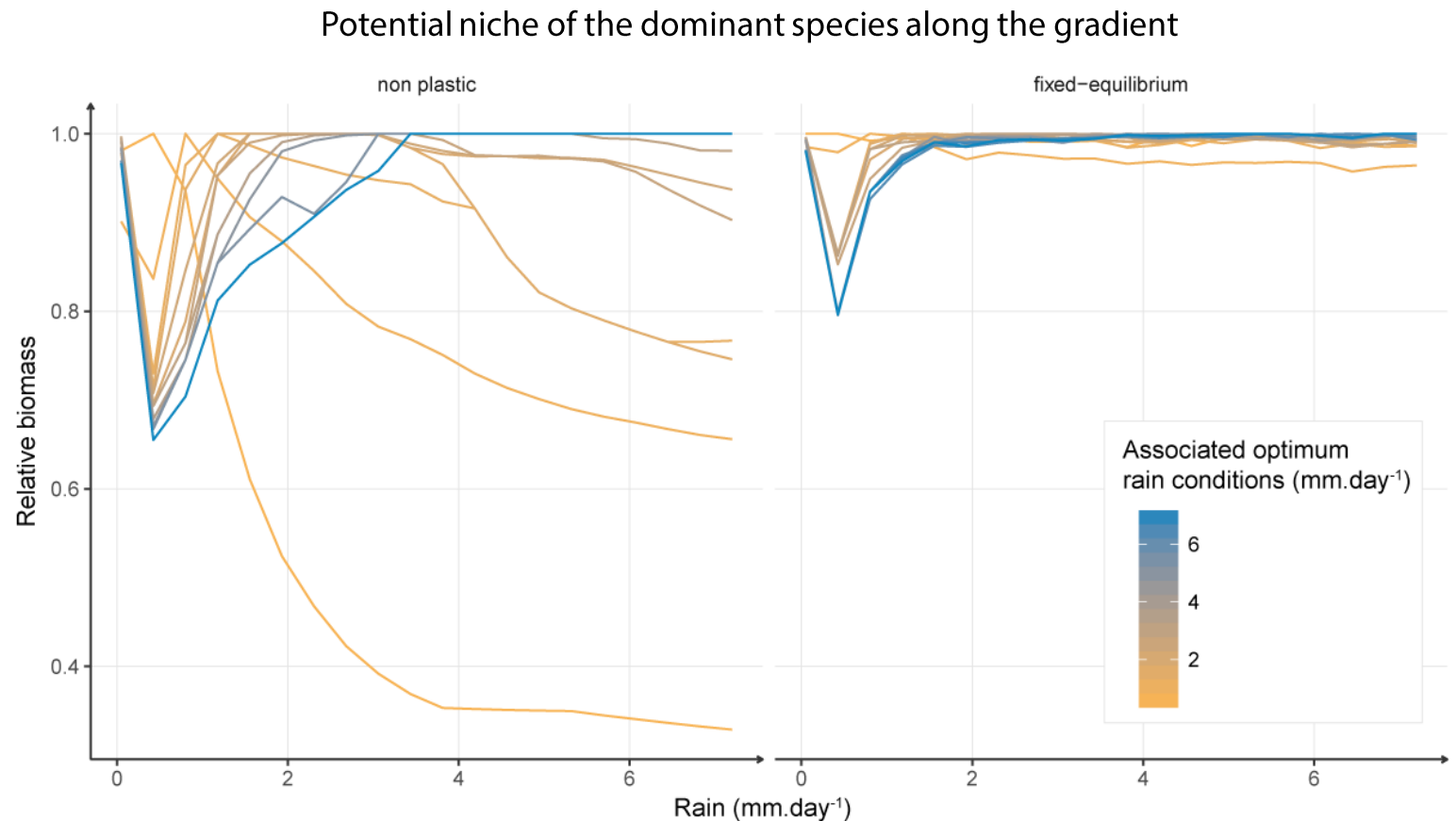


Static gain



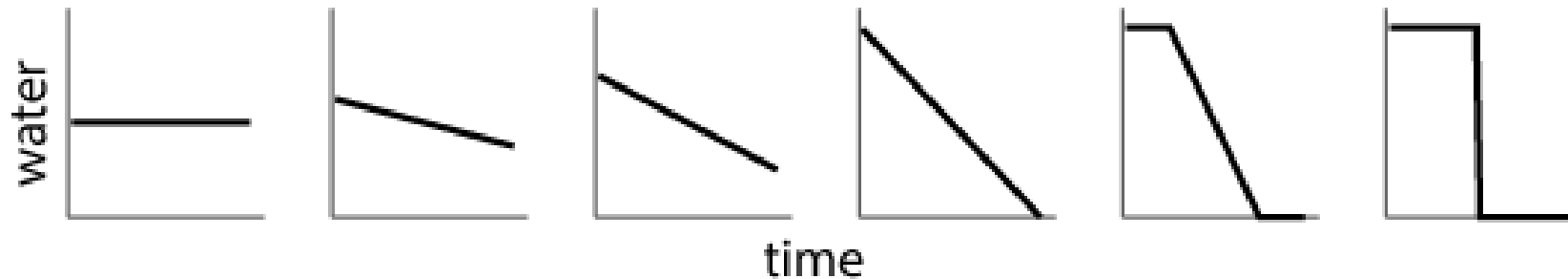
Widenning of the potential niche

- Increase in potential species diversity
- But not functional diversity
- No change in dominant strategies



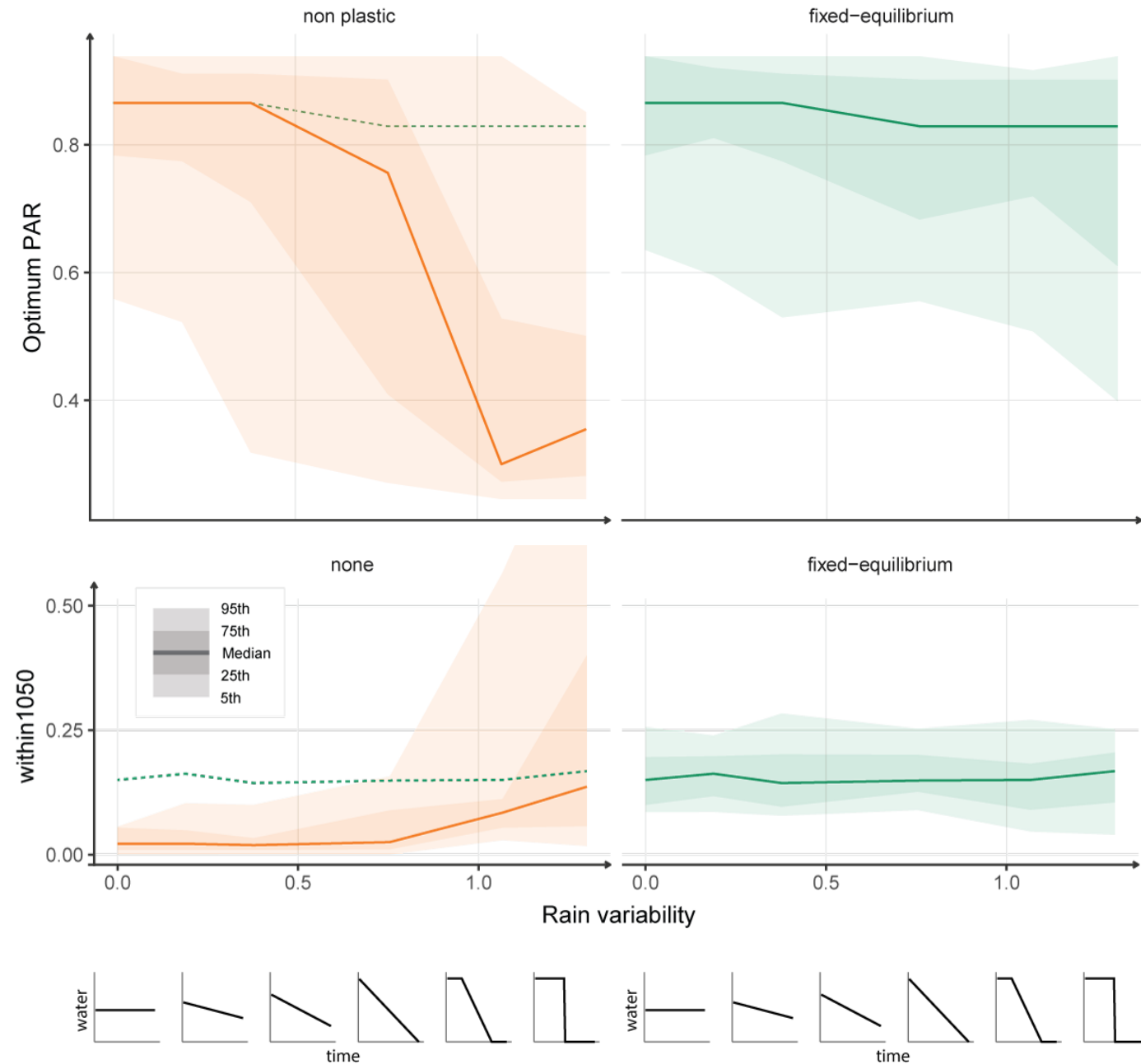
Simulation set-up

- Simulation
 - N Parameter sets
 - M conditions
 - 2 algorithms
- Each simulation
 - Size, length, ...

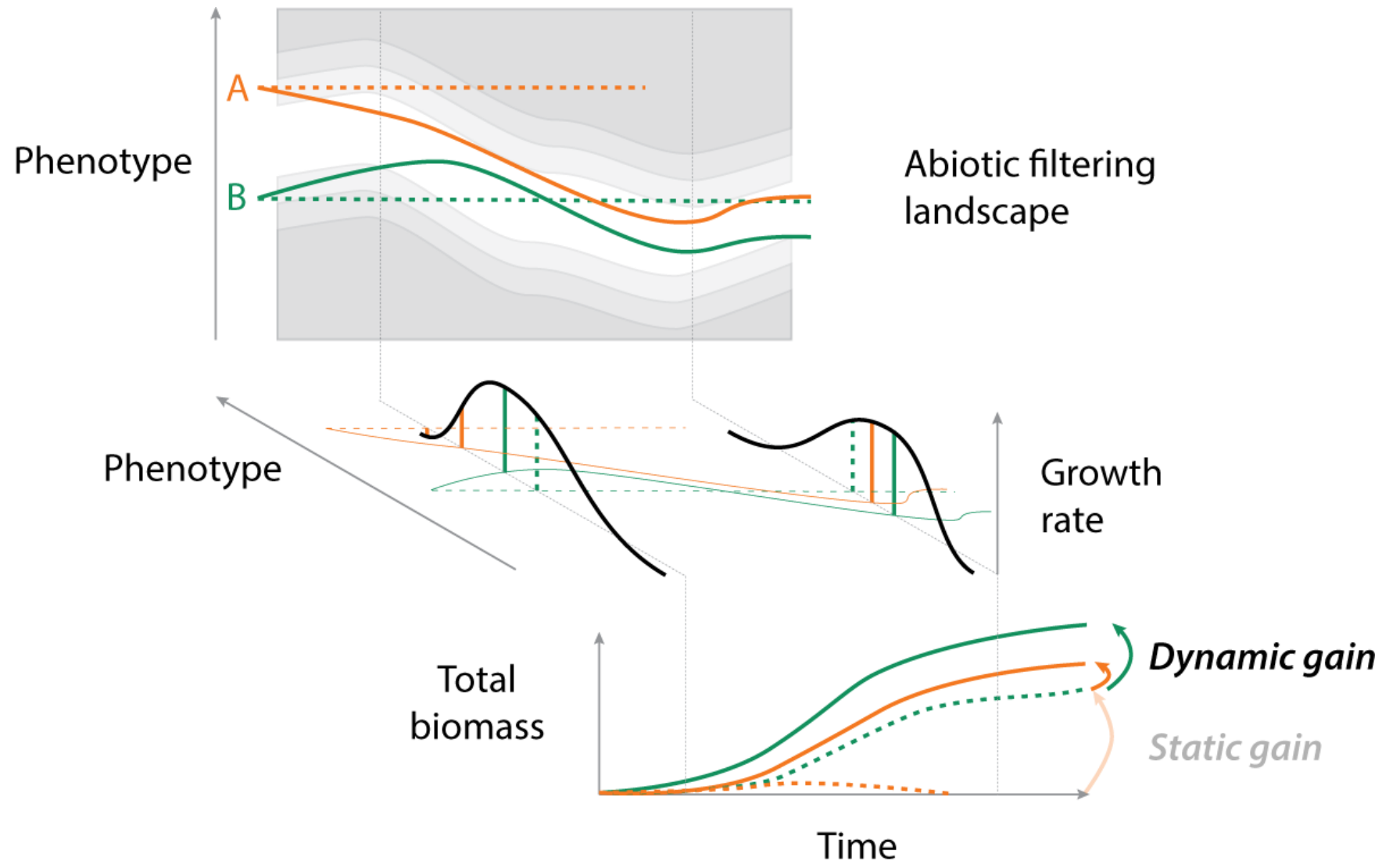


Heterogeneous conditions & dynamic gain

- Increase of relative BM ($\sim n\%$)
- Changes in dominant strategy (asymmetric gain)
- Reduction of growth differences



Dynamic gain



Consequences at the community level ?

- Shift in dominant strategy
- Higher potential species diversity
- Competitive exclusion by exploitative species?



Community-level simulations

Community structure and diversity

The realised balance between mechanisms

Simulation set-up

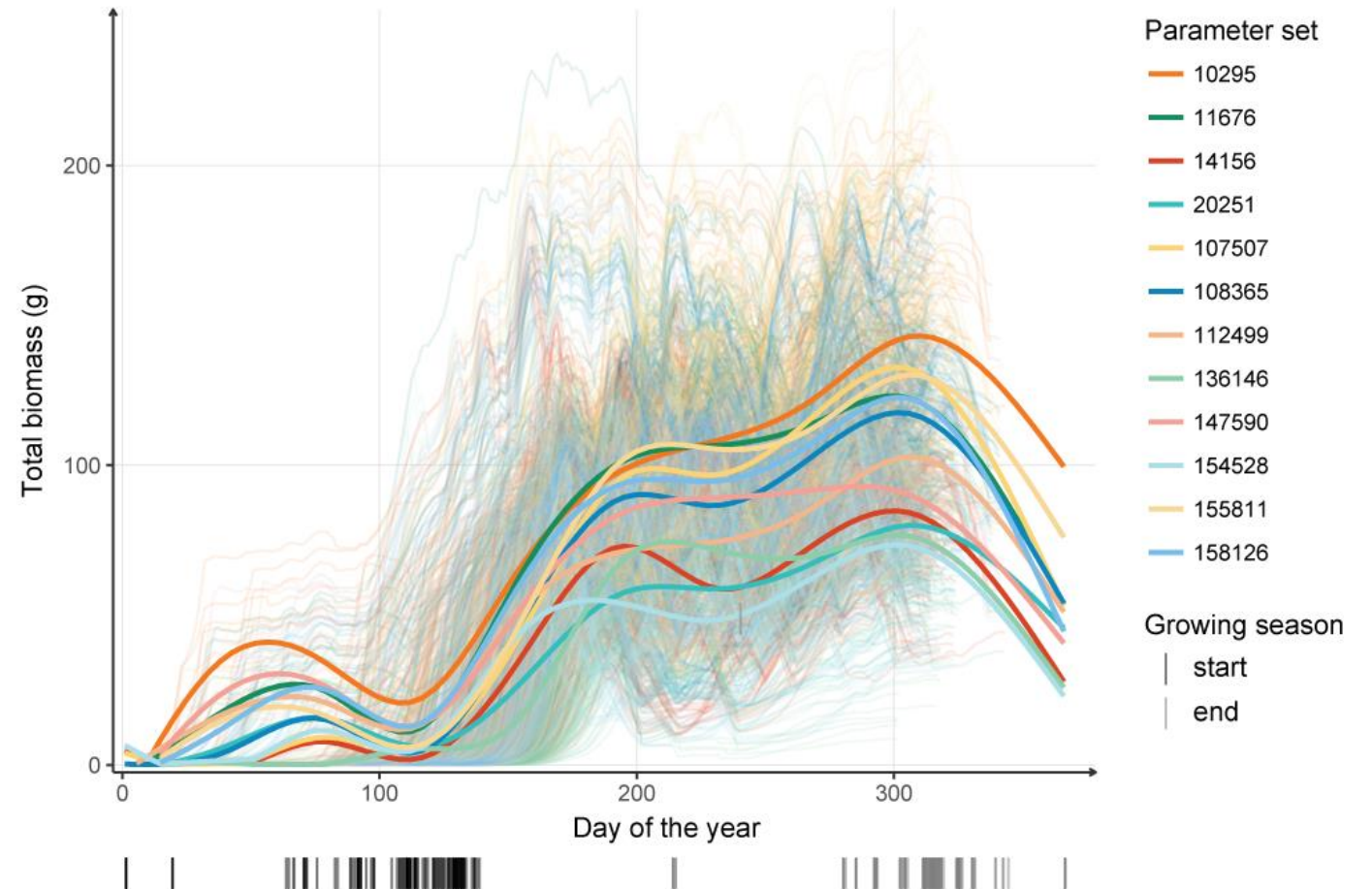
12 parameter sets

300 years

400 phenotypes

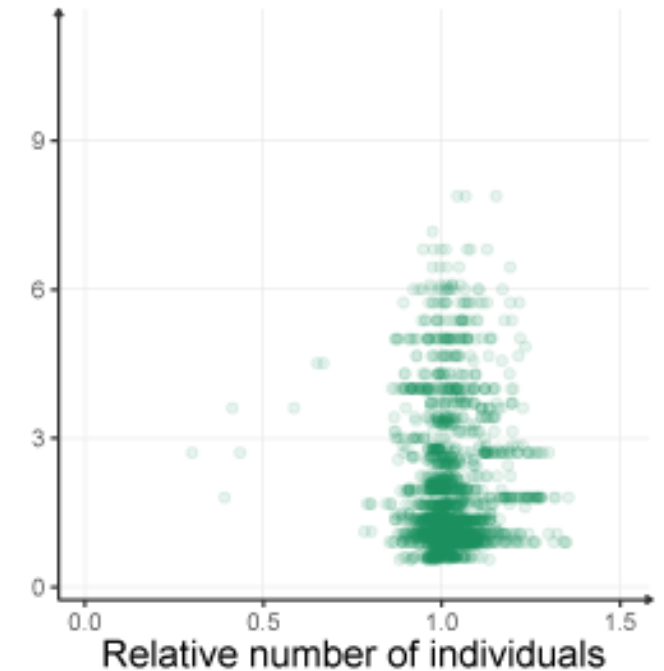
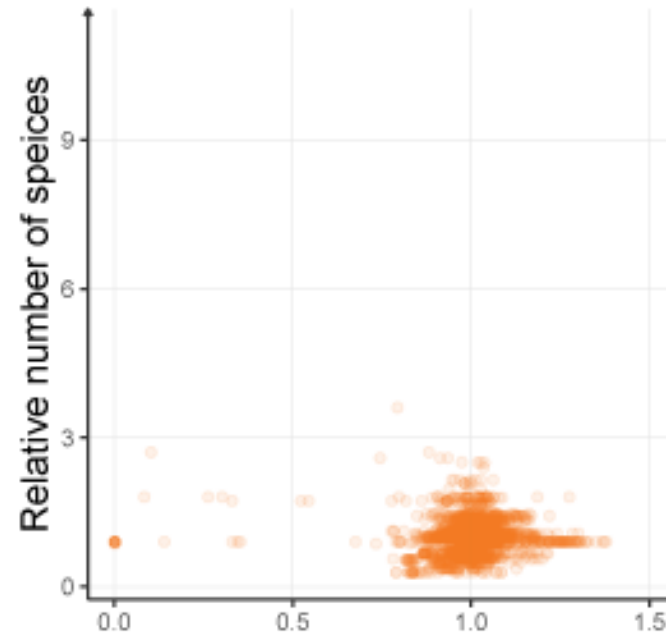
6 sites

Partially shared seedbank



Effect of the niche widening on diversity

- reduction of fitness differences
>> reduction of niche differences
- Toward neutral situation

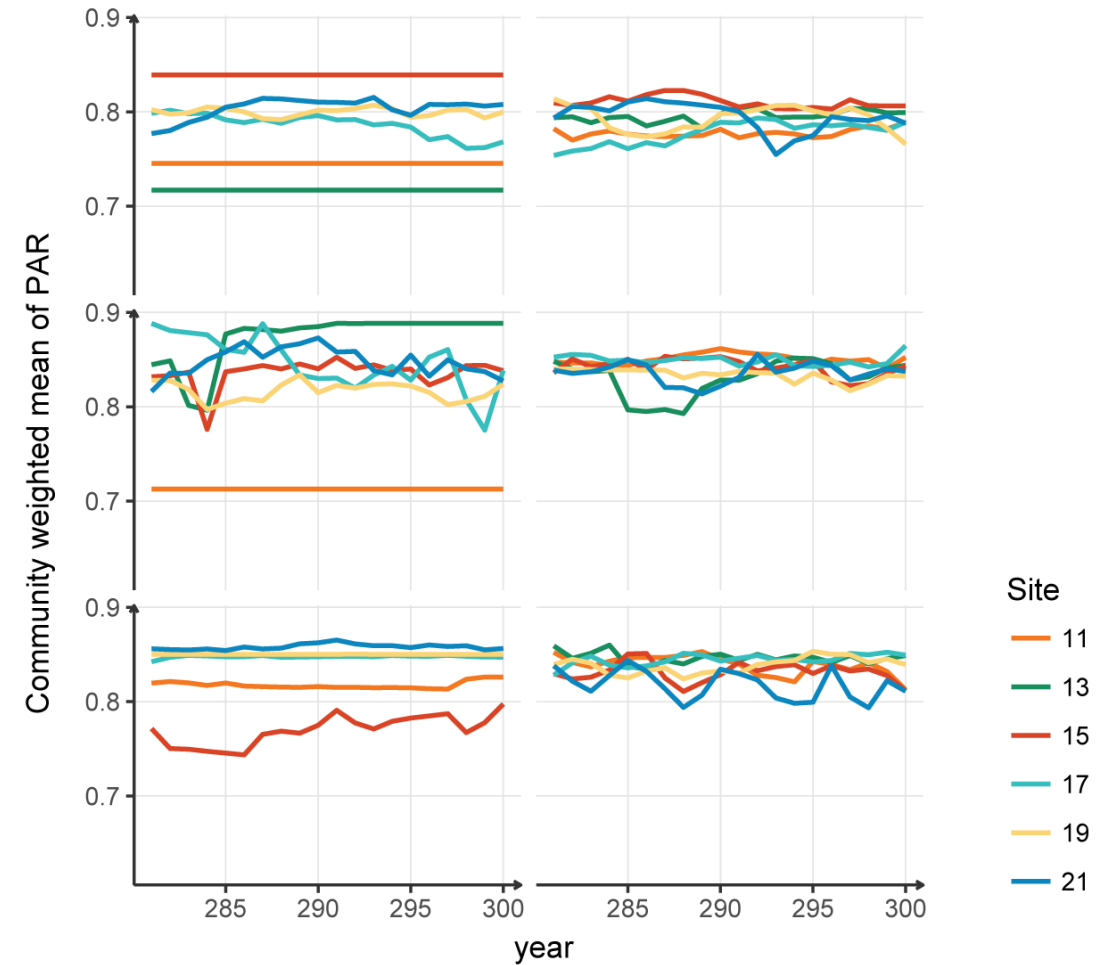


Effect on dominant strategy
(asymmetric gain) ?

Dominant strategies variability

Effects on dominant strategy <<
effects on community structure

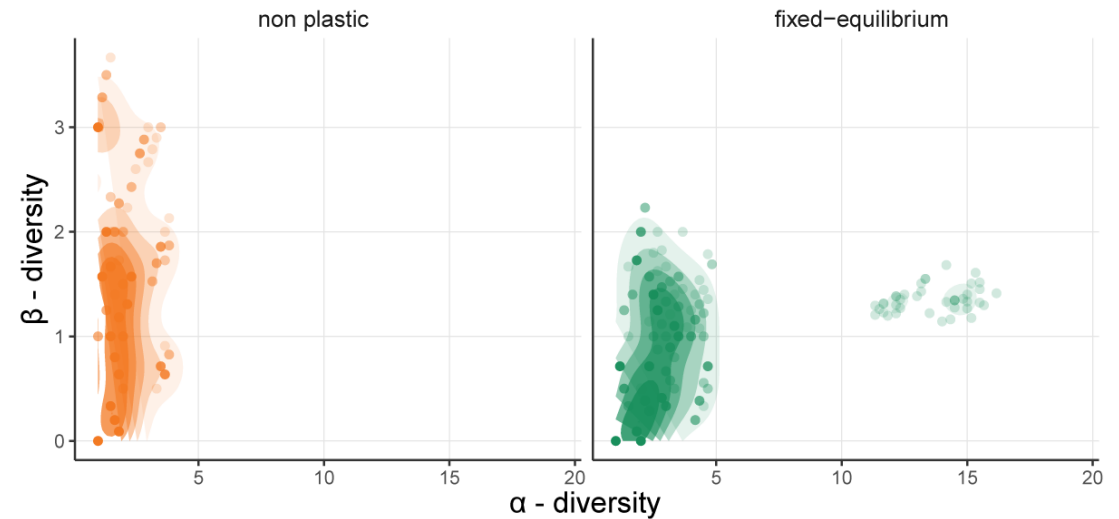
Yet, some differences should
emerge (extended simulations
needed)



Different meta-community
structure

A shift in community structure

- From distinct dominated communities to diverse communities with overlap
- Niche overlap at the meta-community scale. Tissue efficiency more important than memory.
- Reduces the importance of the Root:Shoot ratio axis → better sampling on the other two dimensions (static gain > dynamic gain)





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Discussion

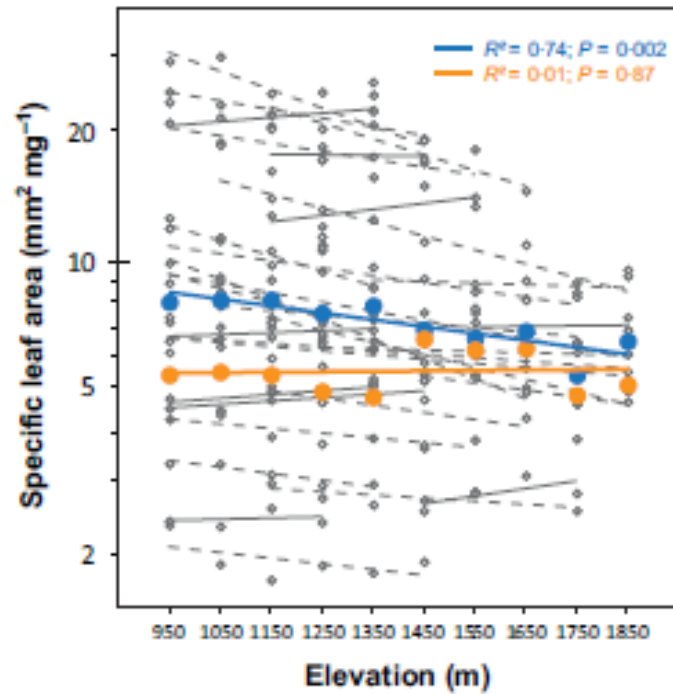
Impact on community dynamics and
community modelling

Community dynamics and stability

Results → hypothesis → simulation plan + limitations

Community variability and overlap → soft abundance changes,
not critical transition → but need to establish stable communities
(better exploration of trait space) to be sure not just sampling

Convergence vs divergence



Solution:

Change assumptions

...but increase model complexity

Niche differentiation

Avoidance vs resistance vs resilience

The frontiers of plasticity

- Traits are measures
- Plasticity is a shift in what is considered constant (allometry, growth rate, growth traits, plasticity traits → genes?)
- Measure of plasticity
- Plasticity of plasticity traits
- Plasticity = question of complexity of models
- How deep should we go in the rabbit hole
- Can we extract some general rule, behaviour that goes with the increasing complexity ?



Conclusion & Perspectives

New hypothesis and simulations

Model developments

Diverse community framework

- Diverse strategies
- Resource dependant optimum
- Integrated plasticity in coherent framework
- Plasticity as a strategy

but...

- Plasticity leads to high convergence, may need to diversify objective functions or assumptions...
- Strategy space must be better sampled for each parameter set

Plasticity is more than ISV

- Need to look at the process (even if not PP)
- Niche widening and competition reduction
- Challenge strong hypotheses

To go beyond

- Better calibration to confirm results
- Explore the plasticity as a strategy
- Climate scenarios
- Management and perturbations
- Stability/invasibility
- New forms of plasticity
- + exploration of other strategy axis (reproduction, frost resistance)
 - Multi-risk plasticity framework
- Epigenetics

Thank you