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

Ph.D. defence of

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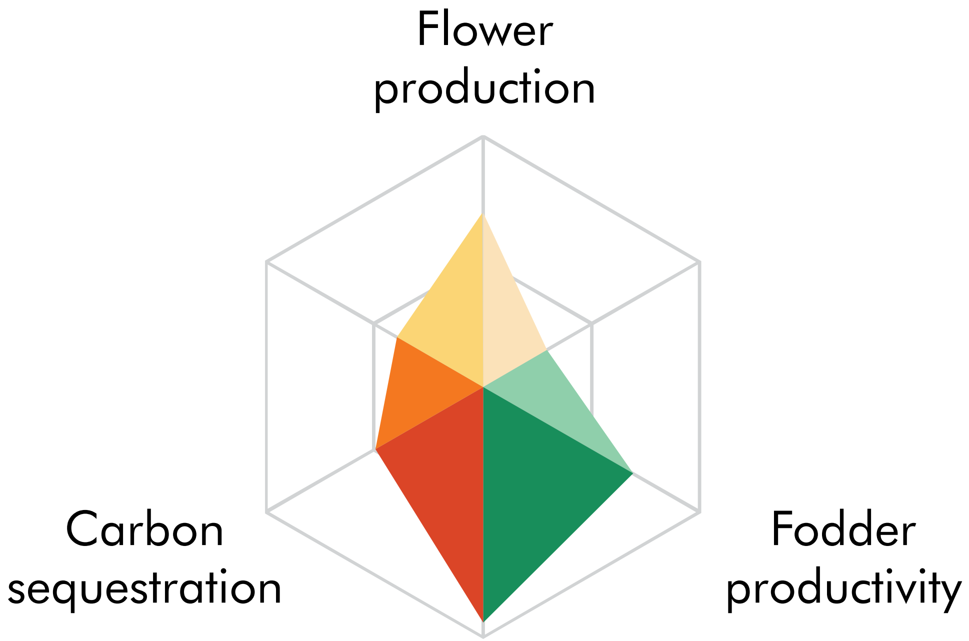
Introduction

From context to questions

Mountain grasslands provide services

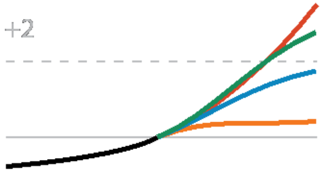


Various and depends on the properties of the community

Assessing grassland ecosystem services

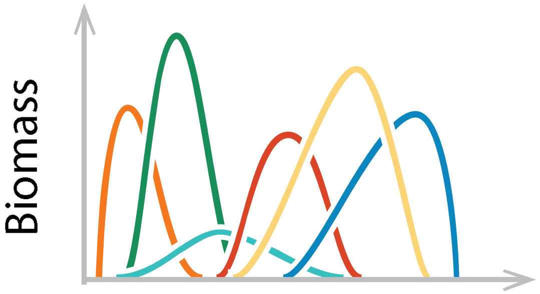
Drivers → Community structure → Summary statistics → Services

Climate

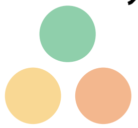


Land-use

Soil



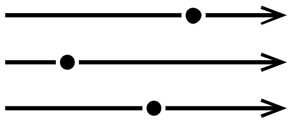
Diversity



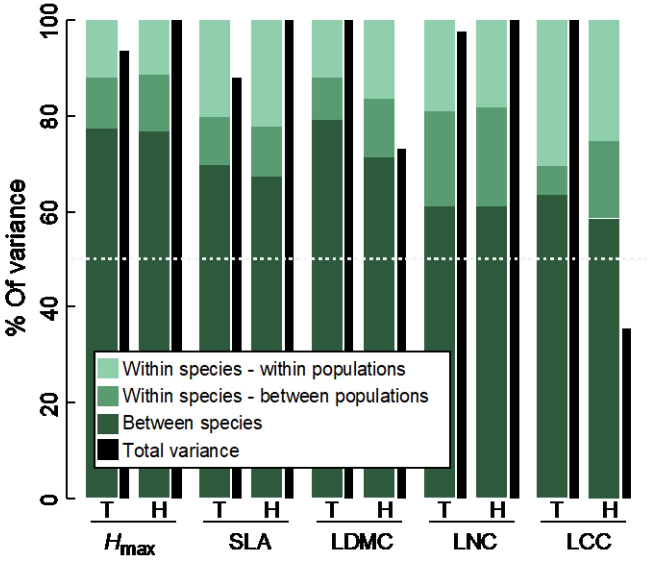
Productivity Identity

Trait CWMs

trait 1
trait 2
trait 3

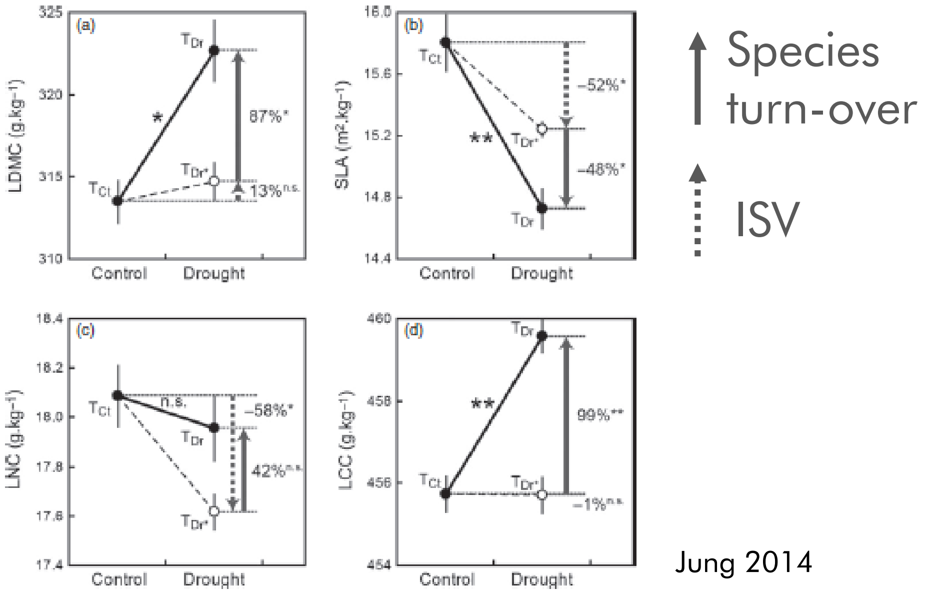


Intra-specific variability matters and impacts the community responses



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

Should be considered in:

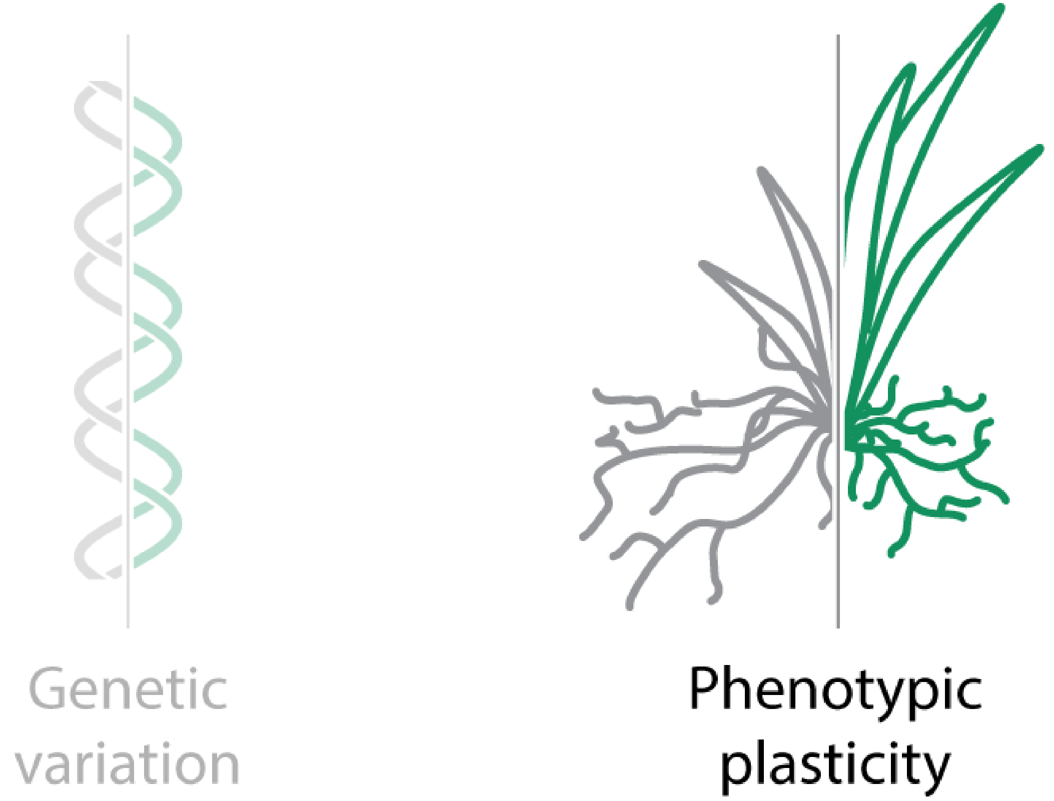
- ES assessments
- Dynamic models

The phenotypic plasticity: one source of variation

Genetic variation

Phenotypic plasticity

The phenotypic plasticity: one source of variation



Rapid response to driver variations

Often overlooked because hard to study in empirical experiments

Mechanistic models to understand

Explicit link with drivers

Understanding by explaining

Emerging behaviour

Experiment at low cost

How does phenotypic plasticity impact grassland community properties?

Species diversity and dominant strategies

How model diverse plant communities integrating phenotypic plasticity?

How does phenotypic plasticity impact grassland community properties?

2 Concepts

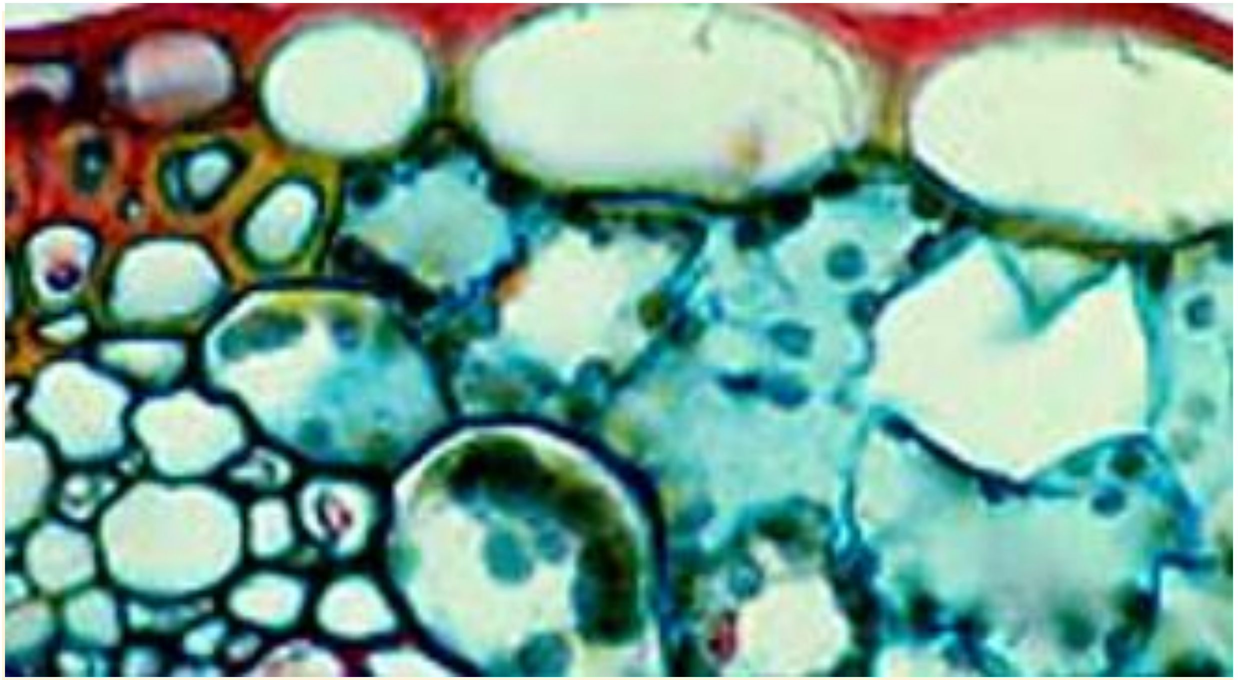
From ecological concepts
to the model *MountGrass*

Keys concepts

Niche and variability

Competition for resources

Strategy trade-ffs

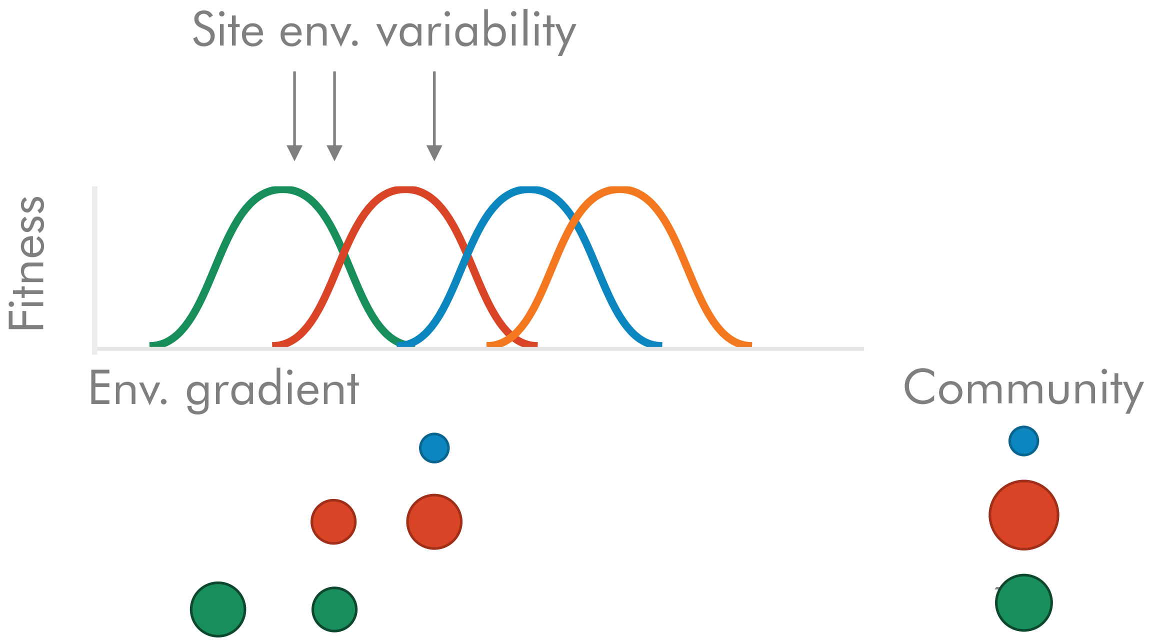


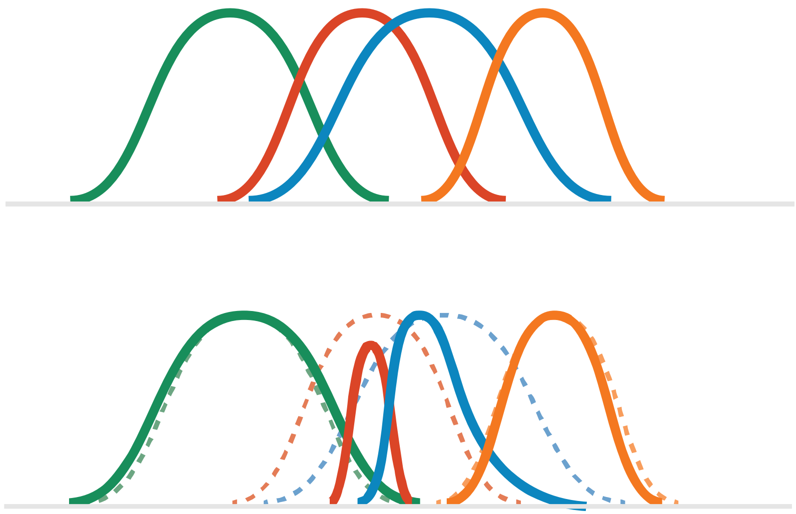
Niche & variability

Fit of a species under specific environmental conditions

Variability promotes coexistence

True for spatial and temporal variability



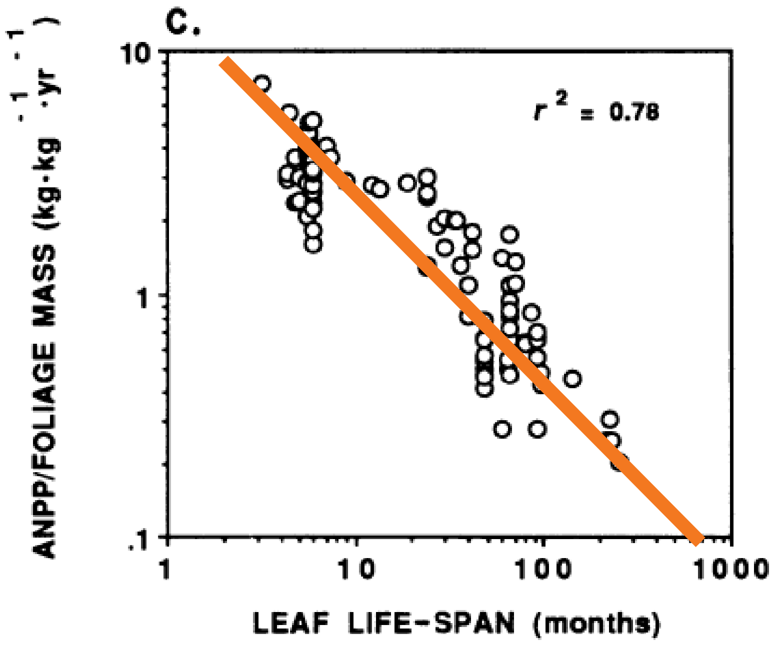


Competition for resources

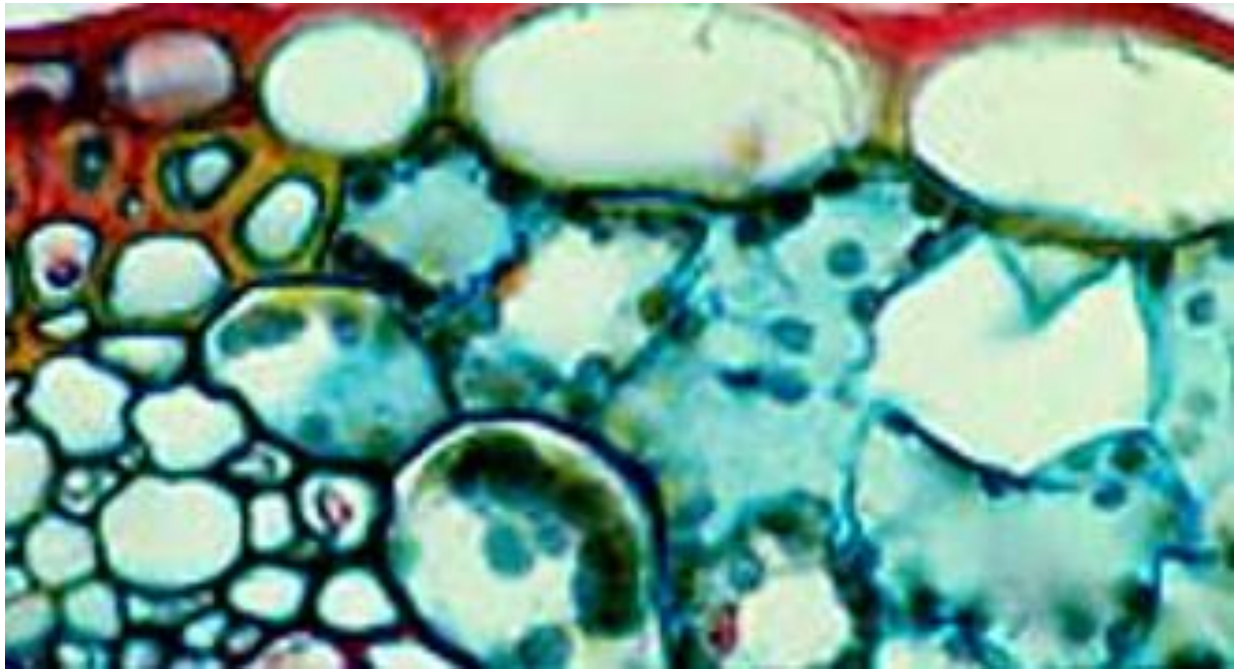
- Main plant interaction mechanism
- Shapes communities by affecting the realised niches
- Depends on plant strategies

Strategy trade-offs

Plant strategies are constrained
→ Dimension reduction
Continuum of plant strategies
Build a strategy space



P. Reich (1992)



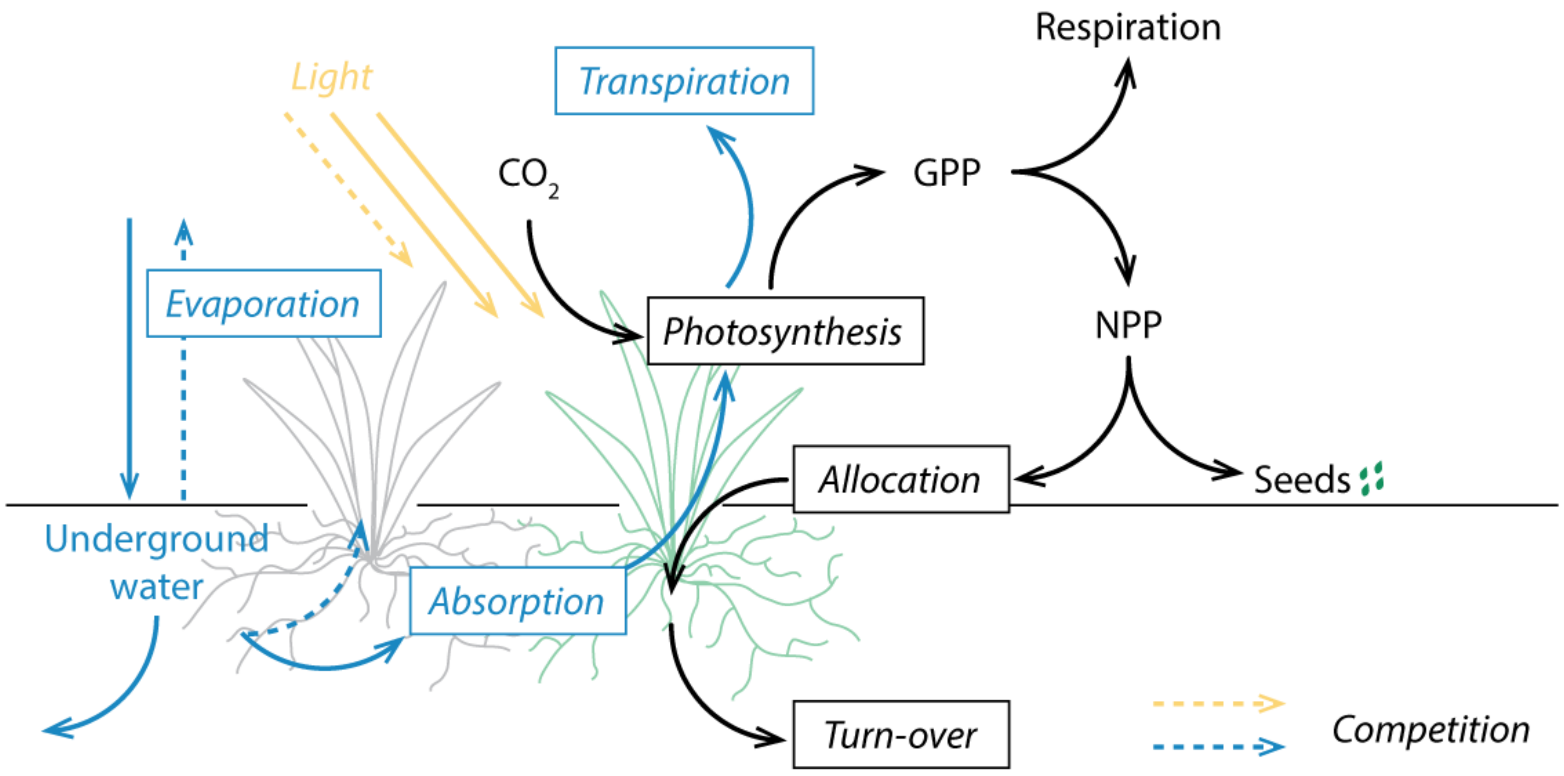
The model *MountGrass*

MountGrass' processes

Response to drivers: physiological processes.

Above and belowground competition: light and water cycles.

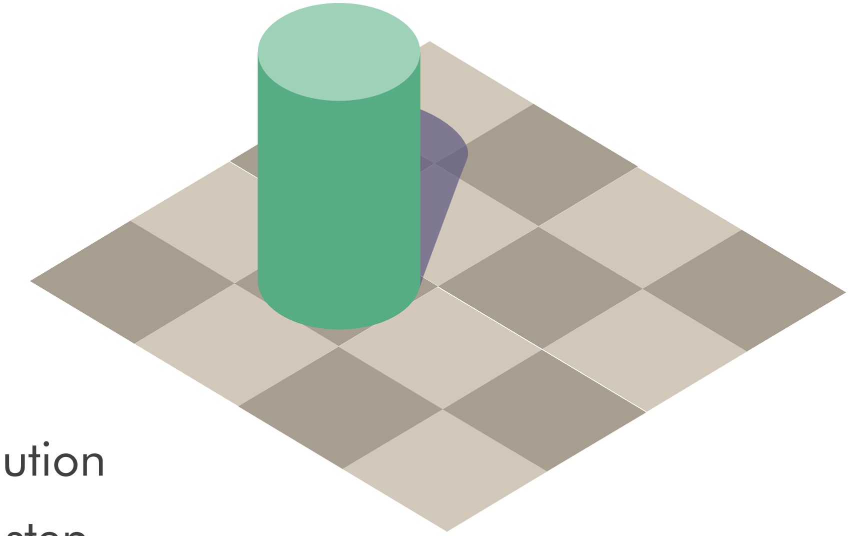
Strategies: carbon allocation trade-offs.



Space & time: the individual plant scale

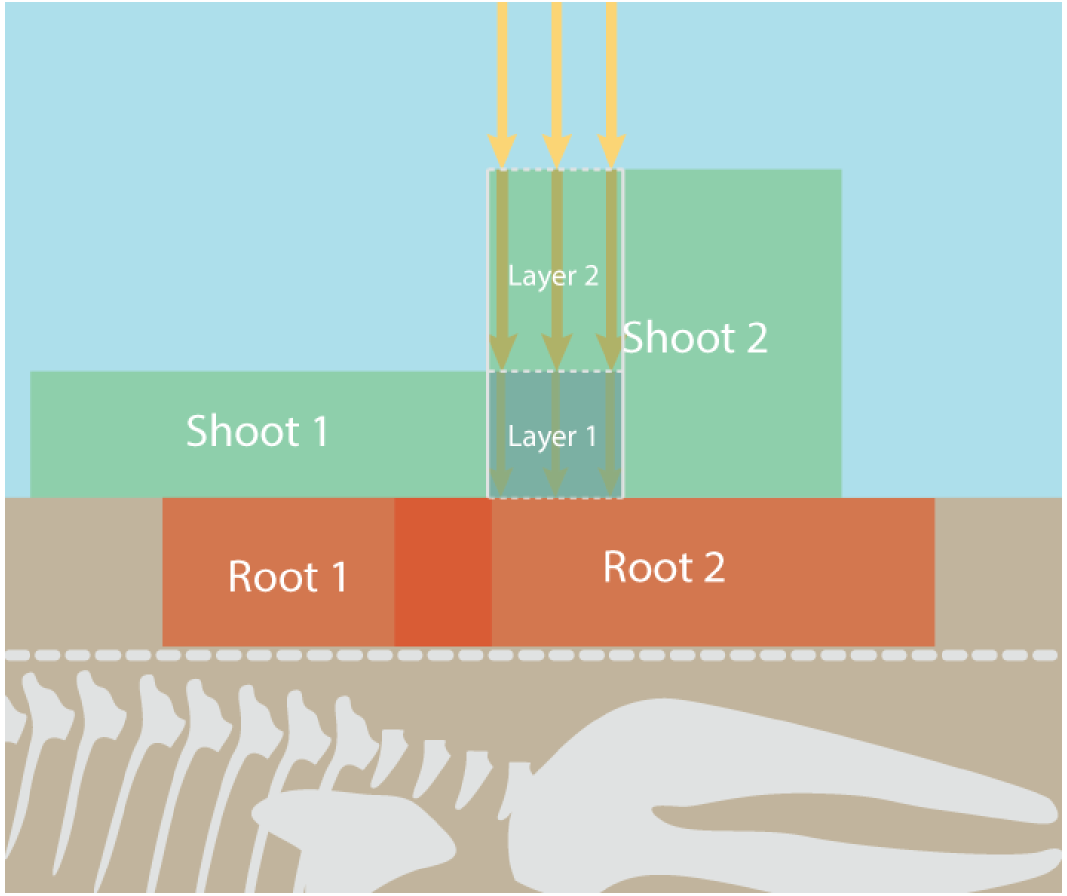
Individual-based model

spatialy explicit: explicit competittion



1 cm resolution

daily time-step

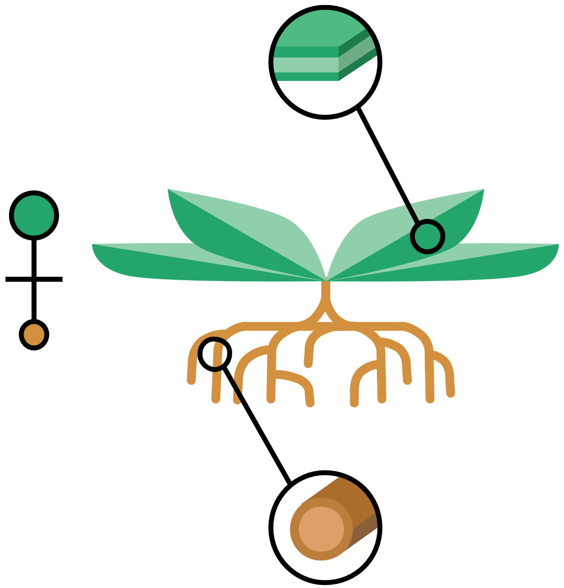


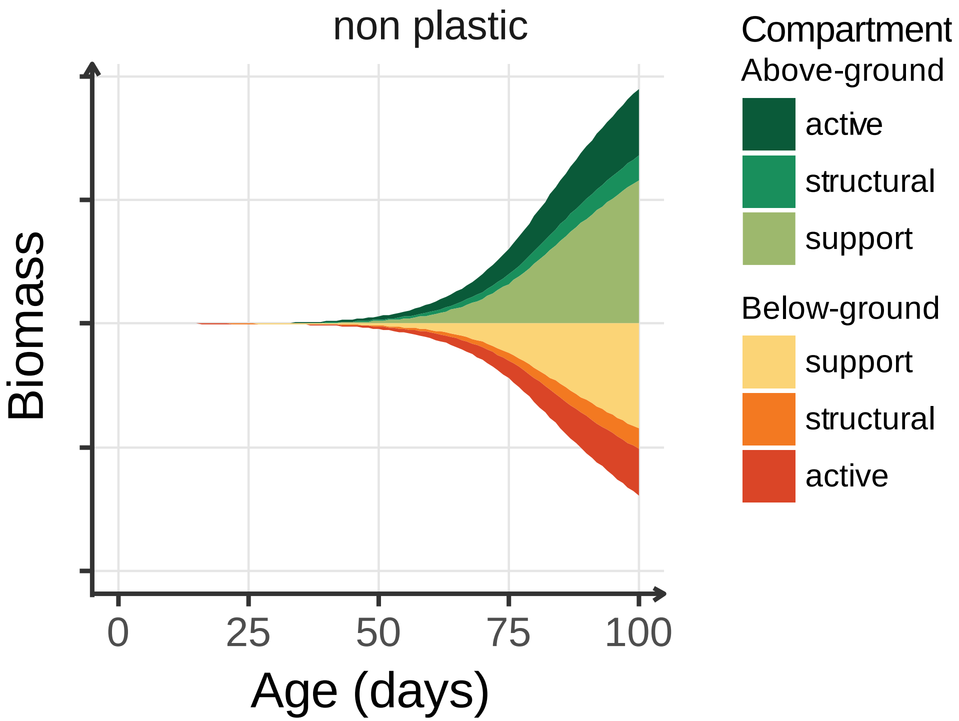
Plant carbon pools and allocation trade-offs

6 vegetative pools

3 dimensions:
- Root:shoot ratio
- Prop. active in shoot
- Prop. active in root

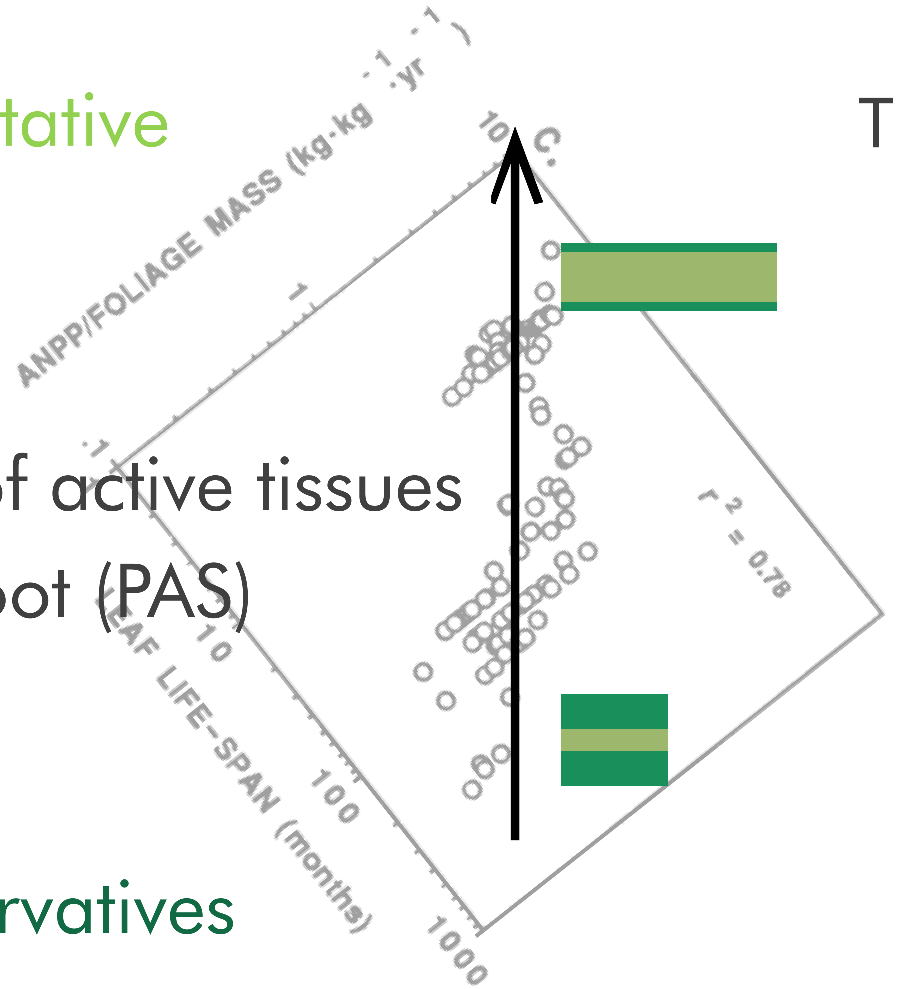
Allocation trade-offs
→ strategic trade-offs





Allocation trade-off into strategic trade-off

Exploitative



Proportion of active tissues in shoot (PAS)

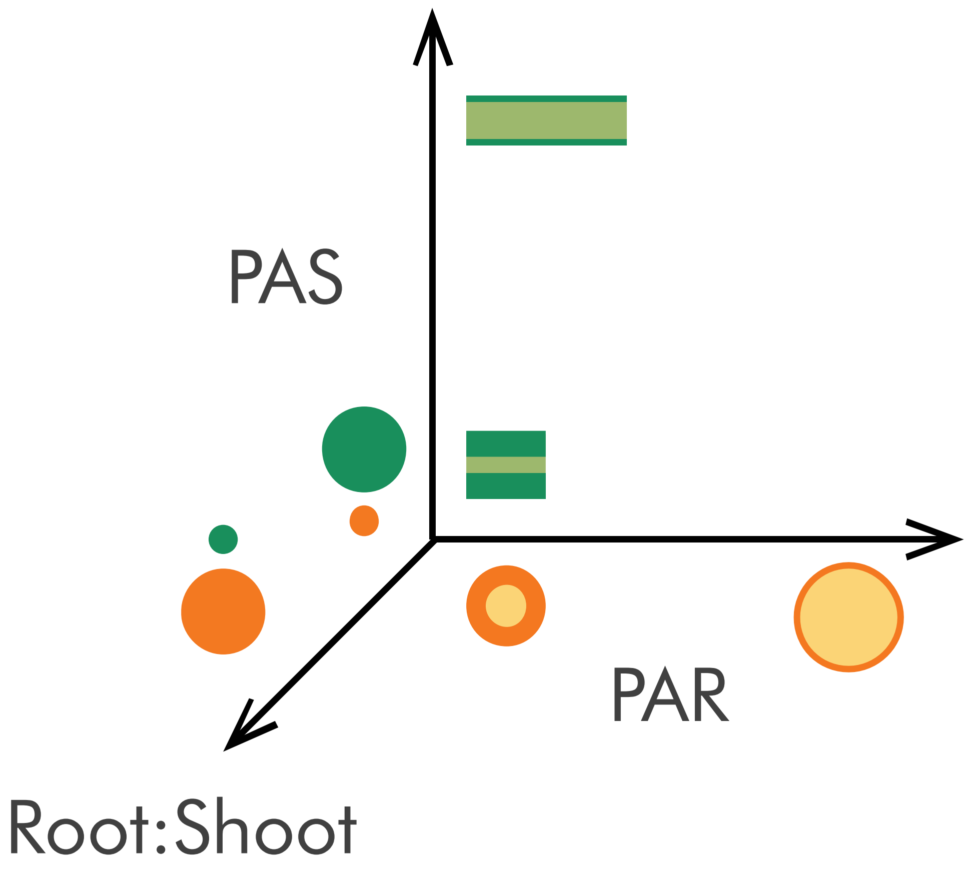
Conservatives

Tissue density

Tissue lifespan

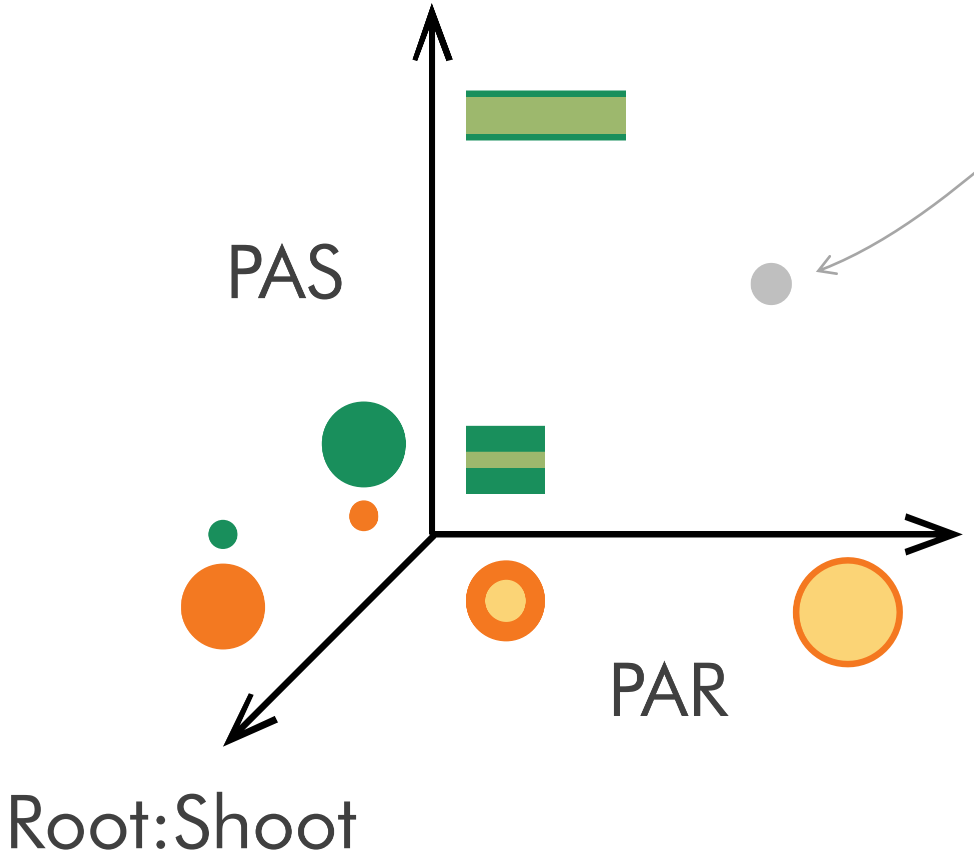
Area/biomass

Phenotypes and strategies

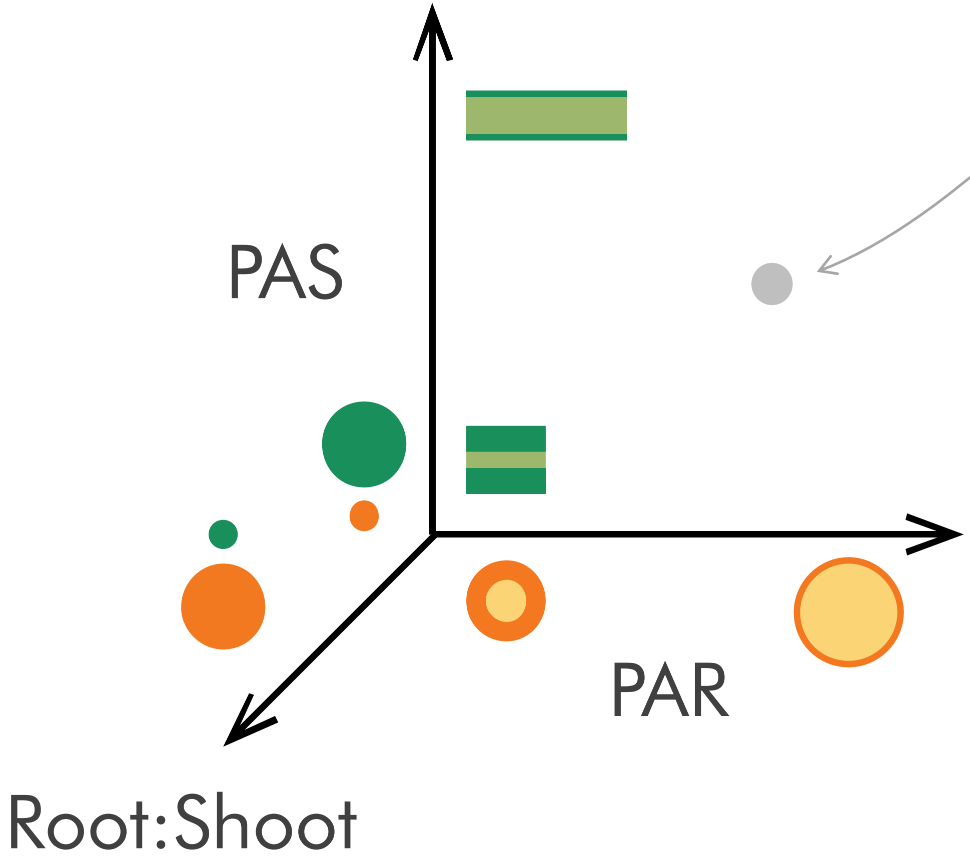


Phenotypes and strategies

Each point is a valid strategy



Phenotypes and strategies



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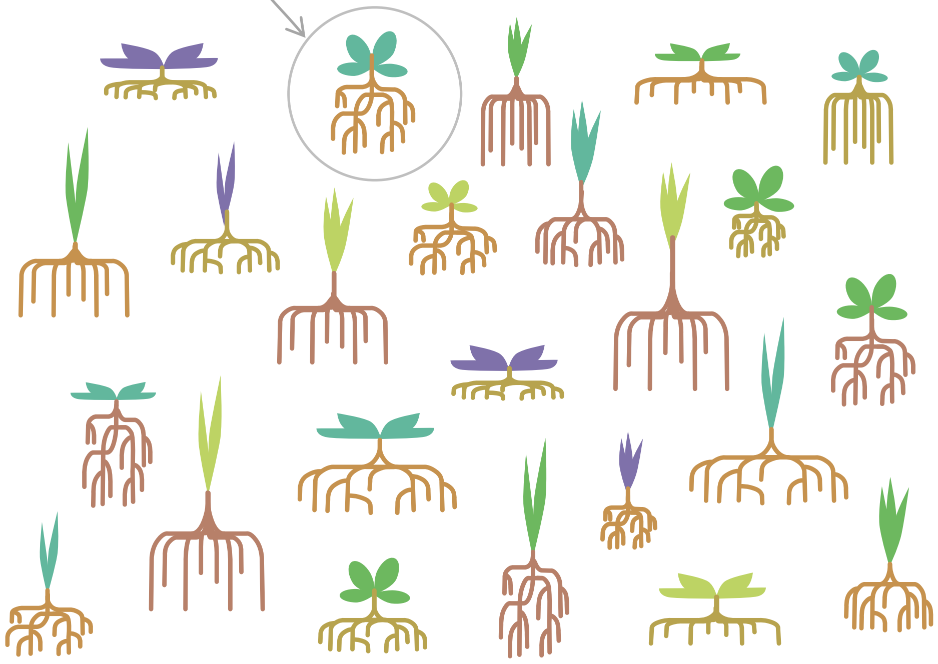
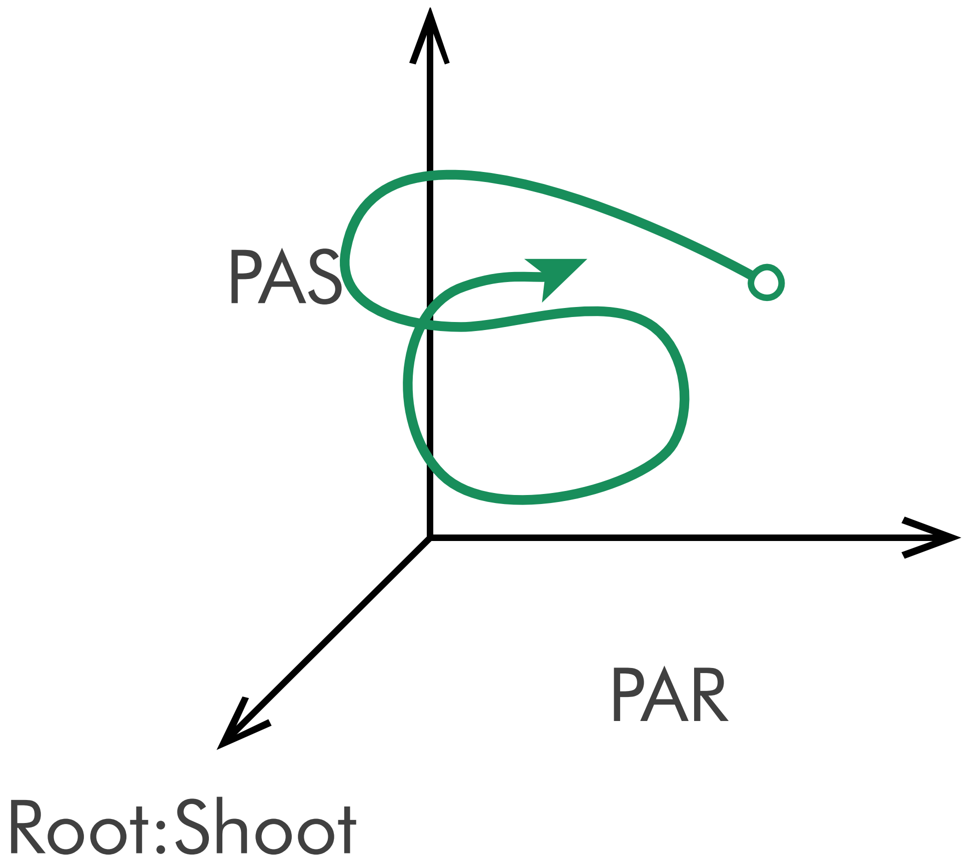


→ sample diverse strategies in a continuous space

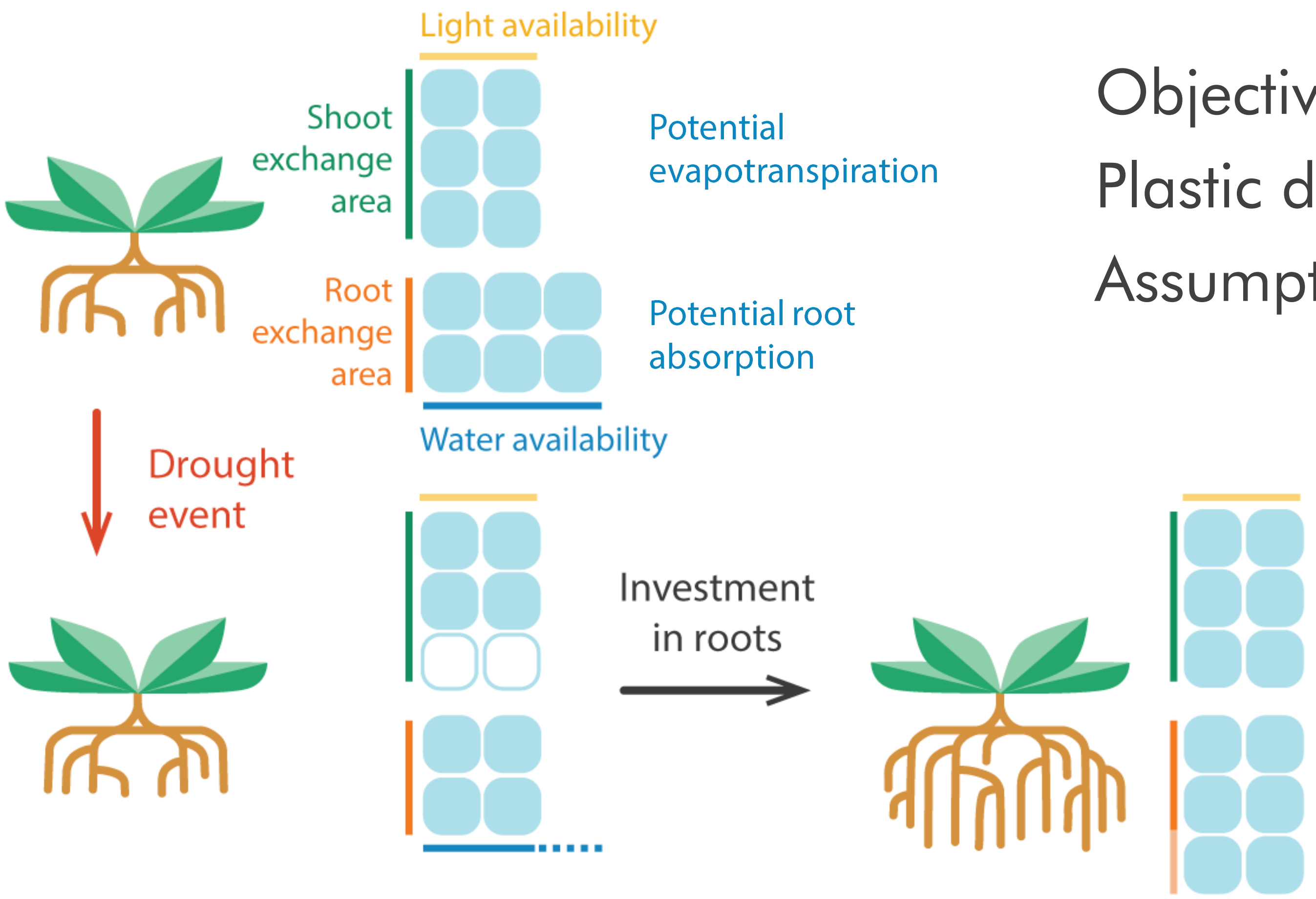
Phenotypes and strategies



Plasticity allows plant to move within this closed space,

but it needs rules.

Plasticity: the functional equilibrium



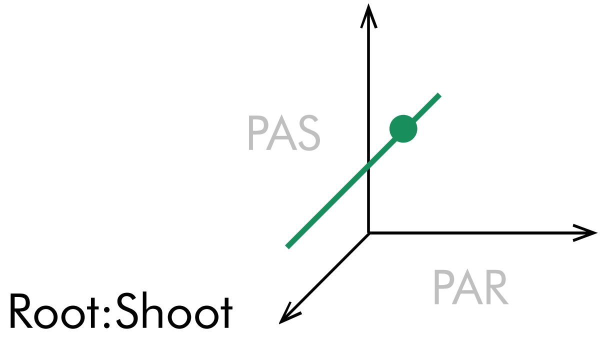
Objective function: root activity = shoot activity

Plastic dimension: Root:Shoot ratio

Assumption: tomorrow same as today

« fixed-equilibrium »

= changes in Root:Shoot only



Results

Individual- and community-level effects of plasticity

111 days

fixed T° & irradiance

12*12*90 cm pots

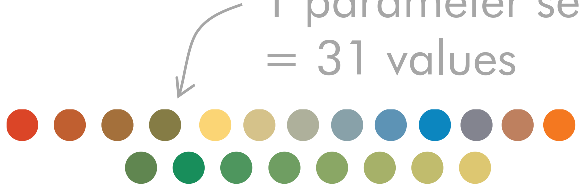
Parameter filtering

31 parameters

Pot growth patterns in 2 treatments of watering

→ Selection of a subset of parameter sets for simulations

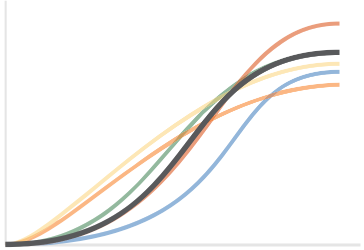
1 parameter set = 31 values



Accepted sets

Simulation sets

Trend from multiple simulations



fixed T° & irradiance

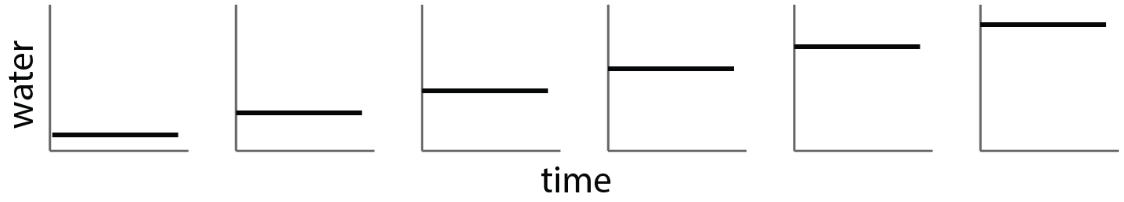
12*12*90 cm pots

100 days

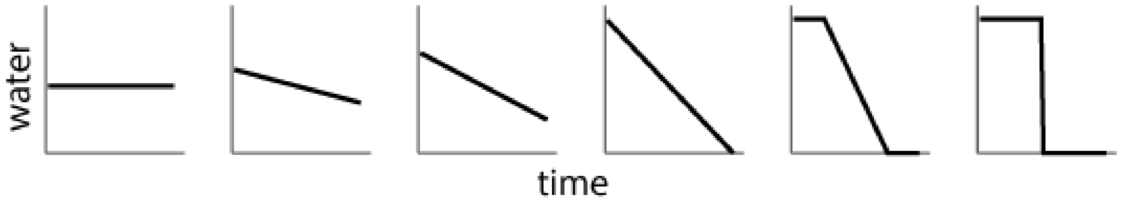
Individual-level simulations

How does plasticity affect community response to spatial and temporal variability?

Individual growth along an availability gradient (spatial)



Individual growth along an variability gradient (temporal)

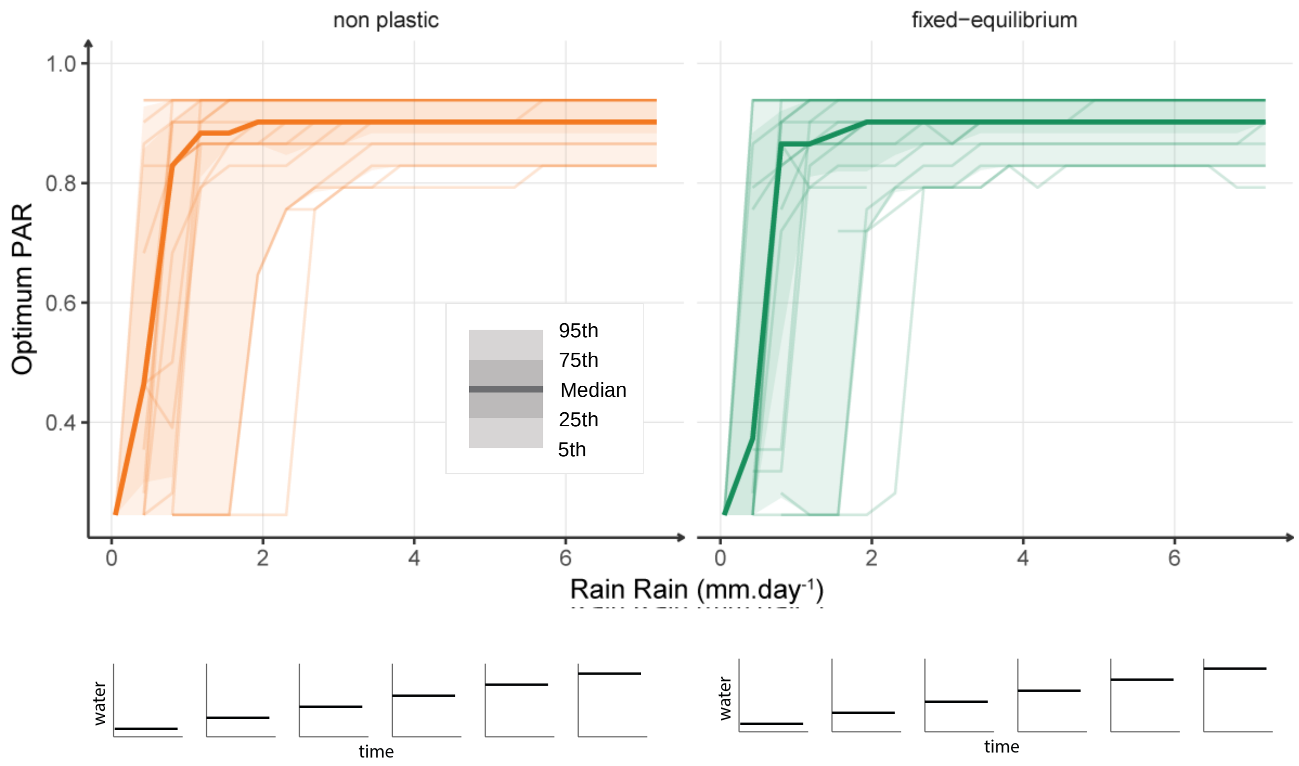


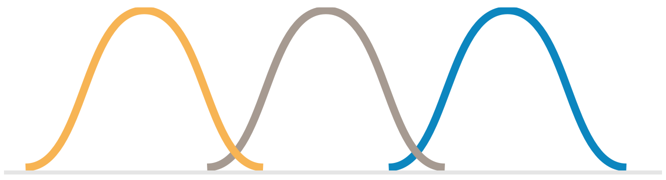
1 resource: water → observe the effect of plasticity on biomass and optimum root strategy (PAR)

Plasticity effect in homogeneous conditions

- No shift in best strategy
- No change in maximum biomass

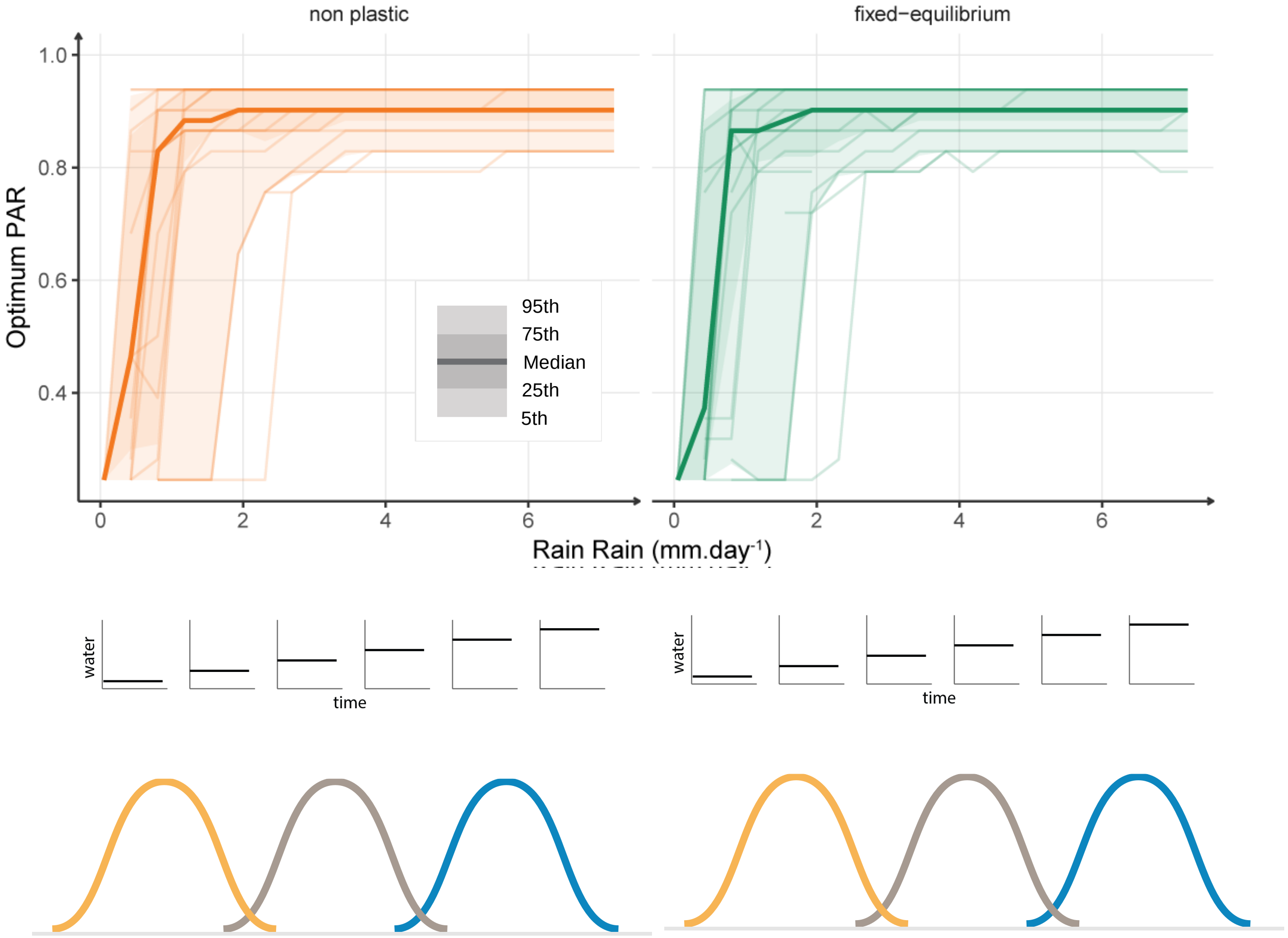
Optimum strategy along a water availability gradient





Plasticity effect in homogeneous conditions

Optimum strategy along a water availability gradient



- No shift in best strategy
- No change in maximum biomass

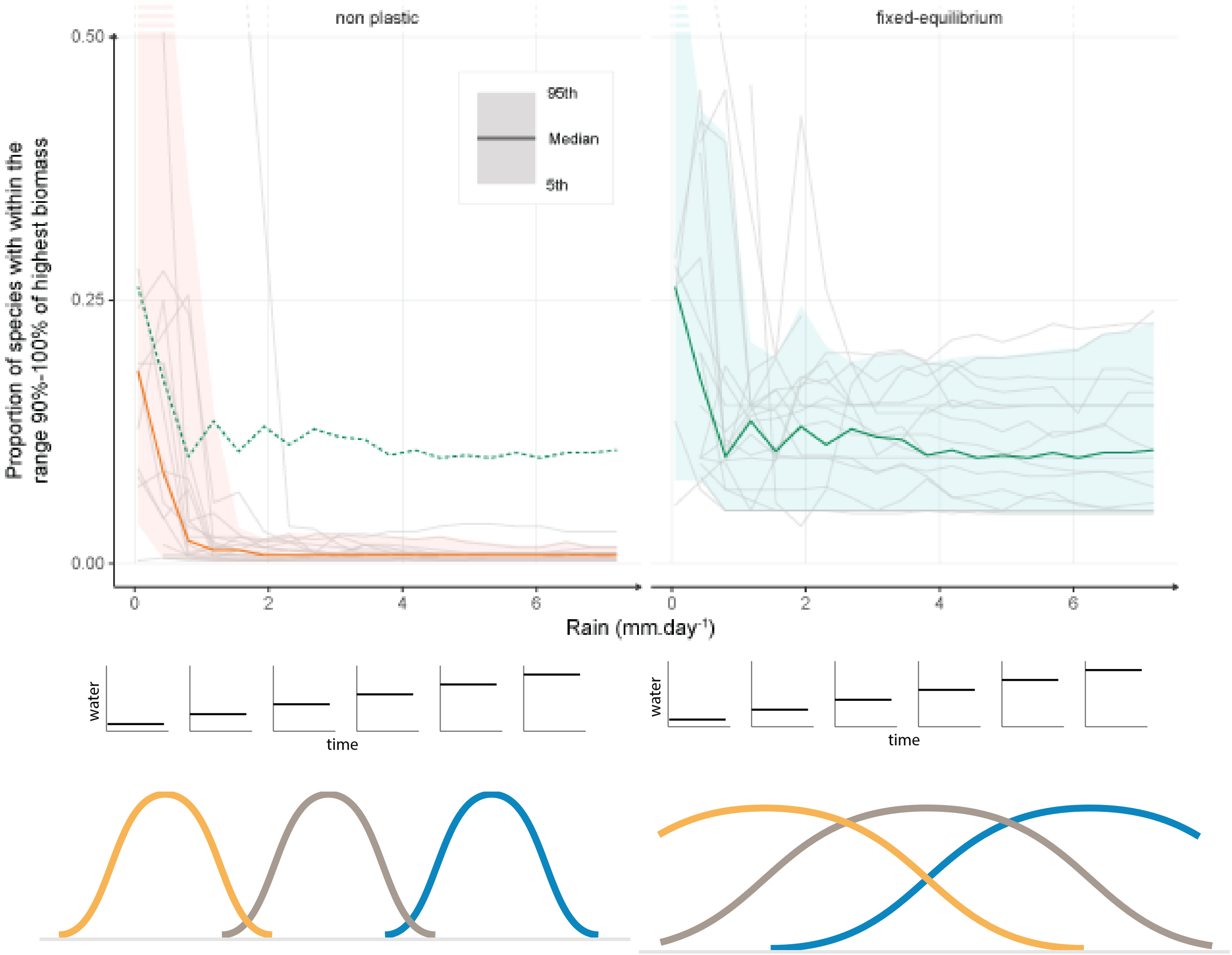
→No shift in the dominant species

Plasticity effect in homogeneous conditions

- Reduction of growth differences

→Niche widening

Proportion of species with high performances along a water availability gradient

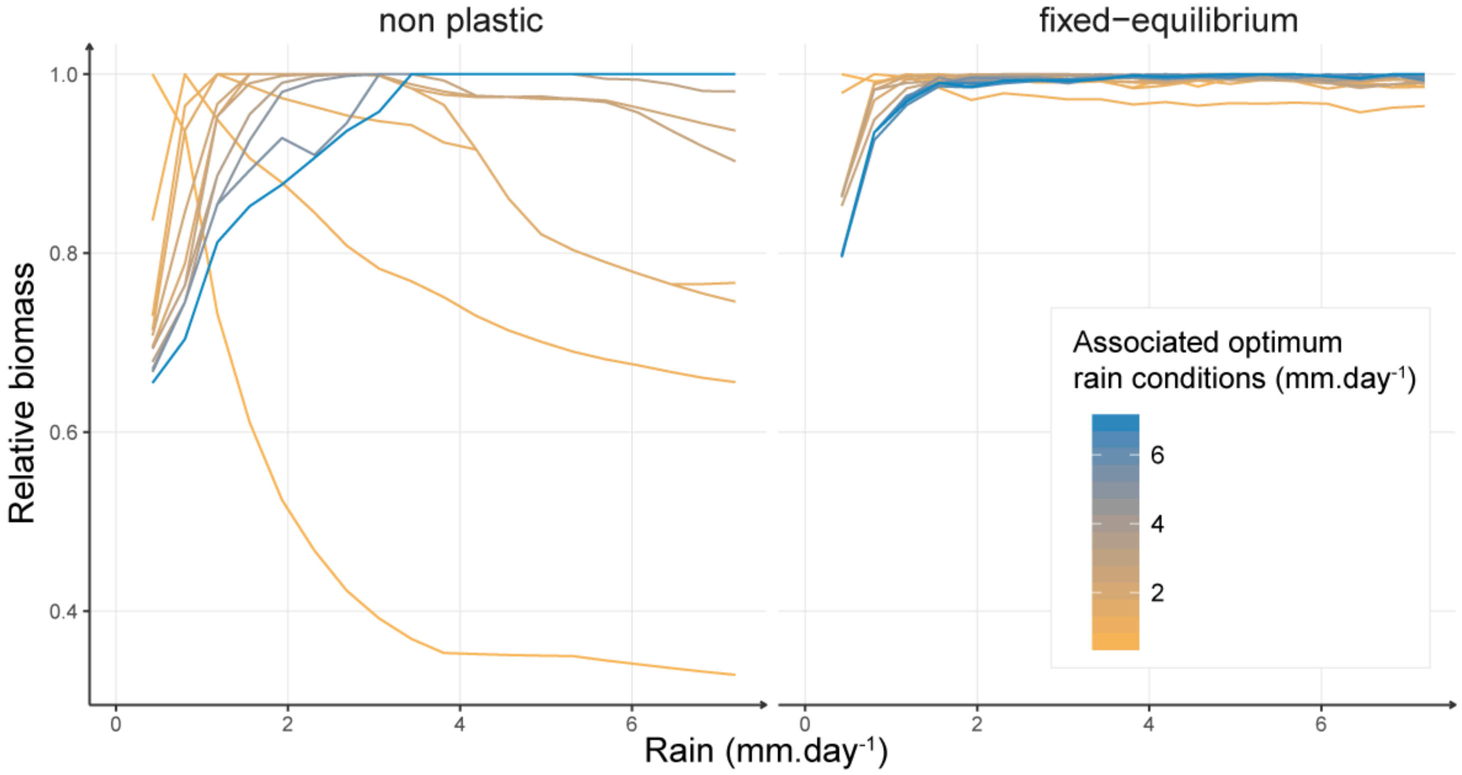


Niche widening in homogeneous conditions

Plasticity

→ increases relative biomass in non optimum conditions

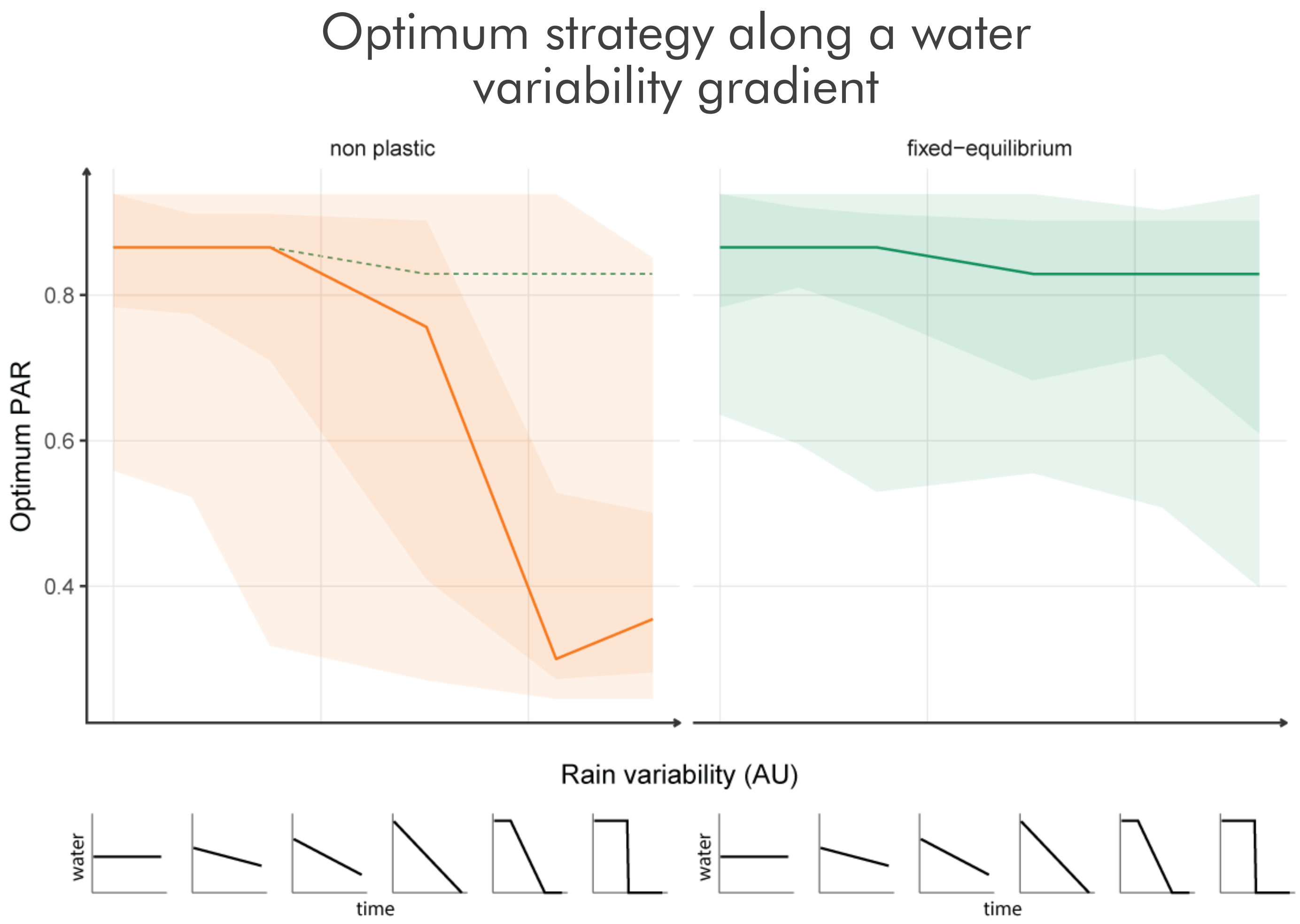
Potential niche of best species



for 1 parameter set

Plasticity effect in heterogeneous conditions

- Changes in dominant strategy in favour of exploitative species
- Reduction of growth differences
- Increase of relative BM



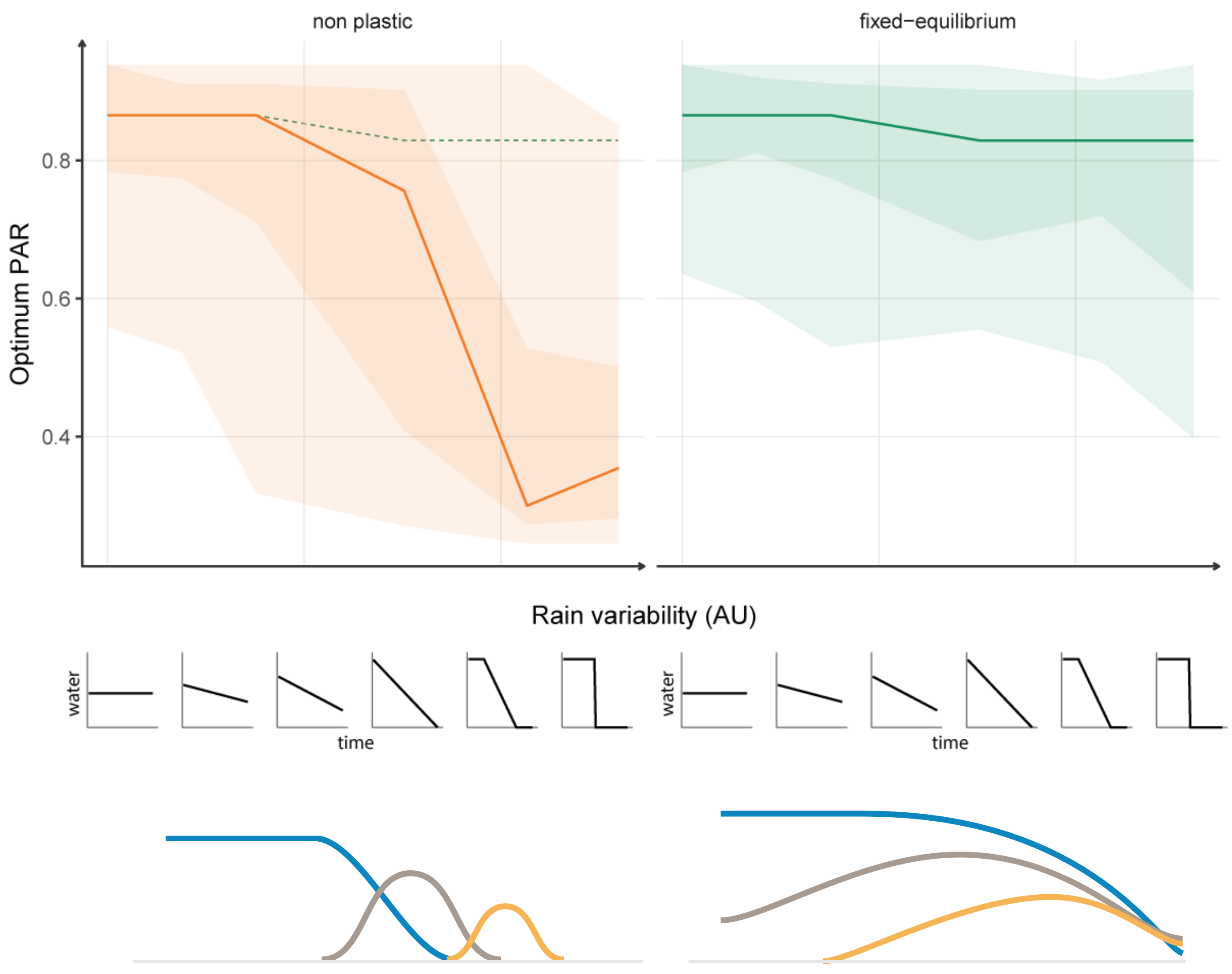
Plasticity effect in heterogeneous conditions

- Changes in dominant strategy in favour of exploitative species
- Reduction of growth differences
- Increase of relative BM

→ Asymmetric gain (+exploitative strategies)

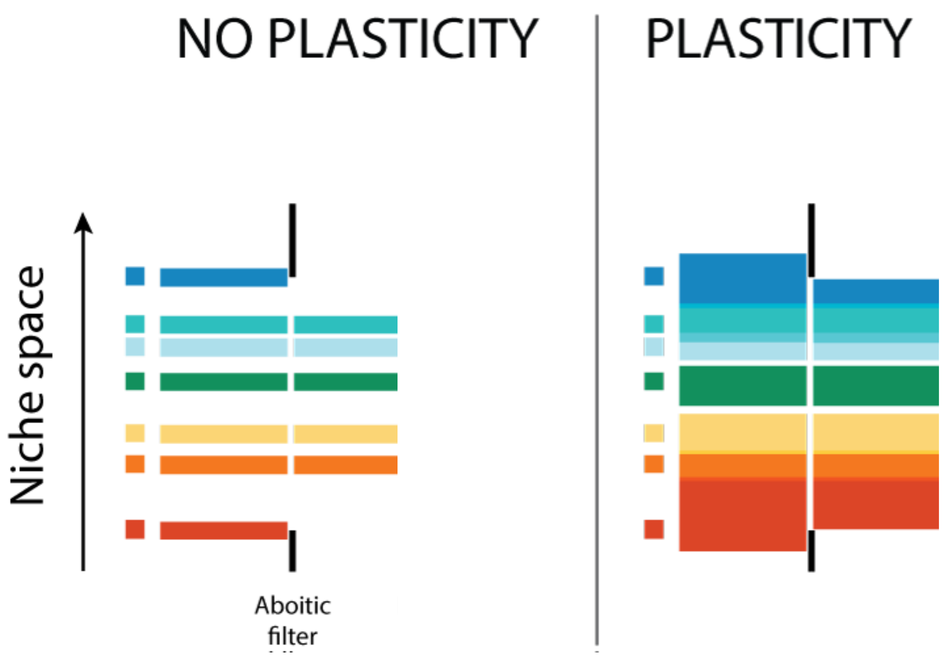
→Niche widening

Optimum strategy along a water variability gradient



Consequences at the community level ?

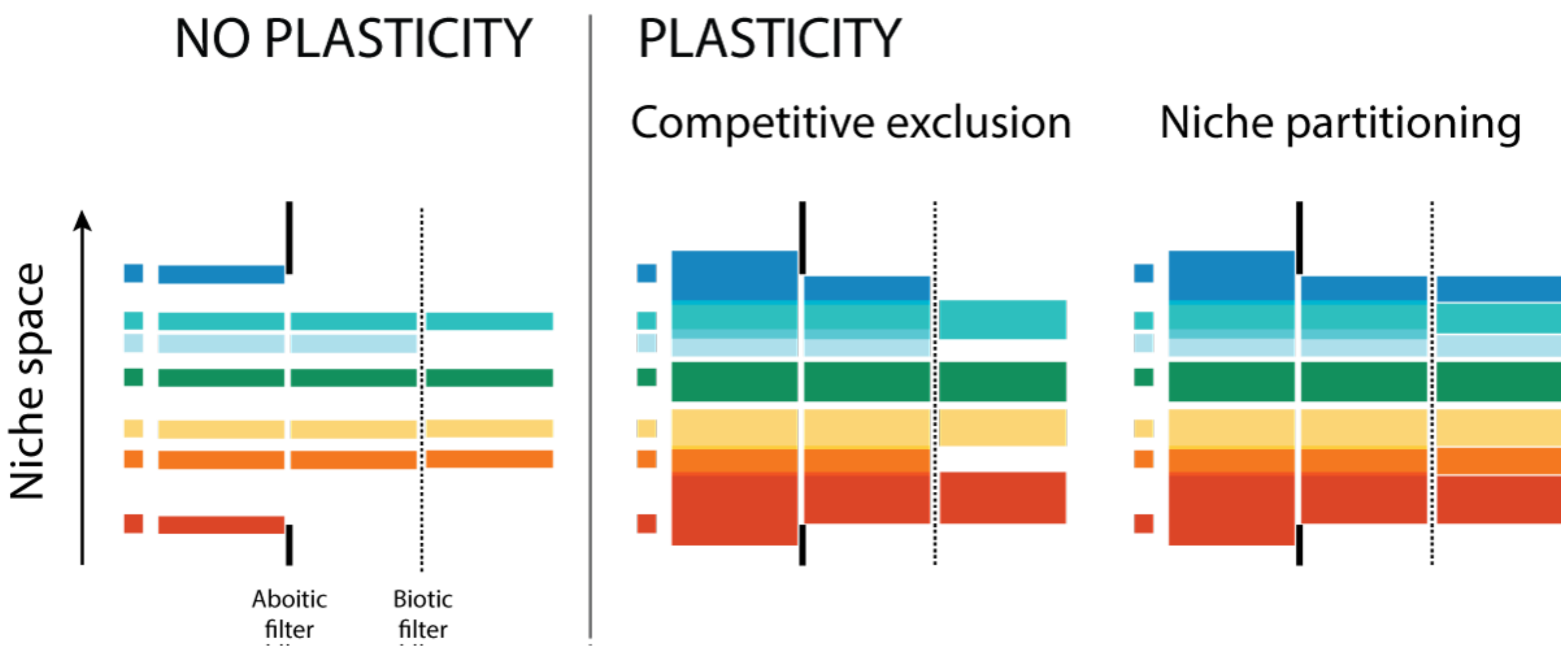
Niche widening = reduction of abiotic filtering + reduction of fitness differences



Consequences at the community level ?

Niche widening = reduction of abiotic filtering

- higher potential species diversity



Asymmetric gain

- Competitive exclusion by exploitative species?

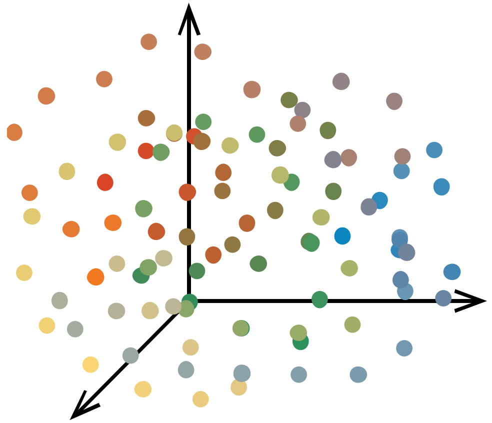
100*100cm plots

6 sites: variable T°, prec. & irradiance

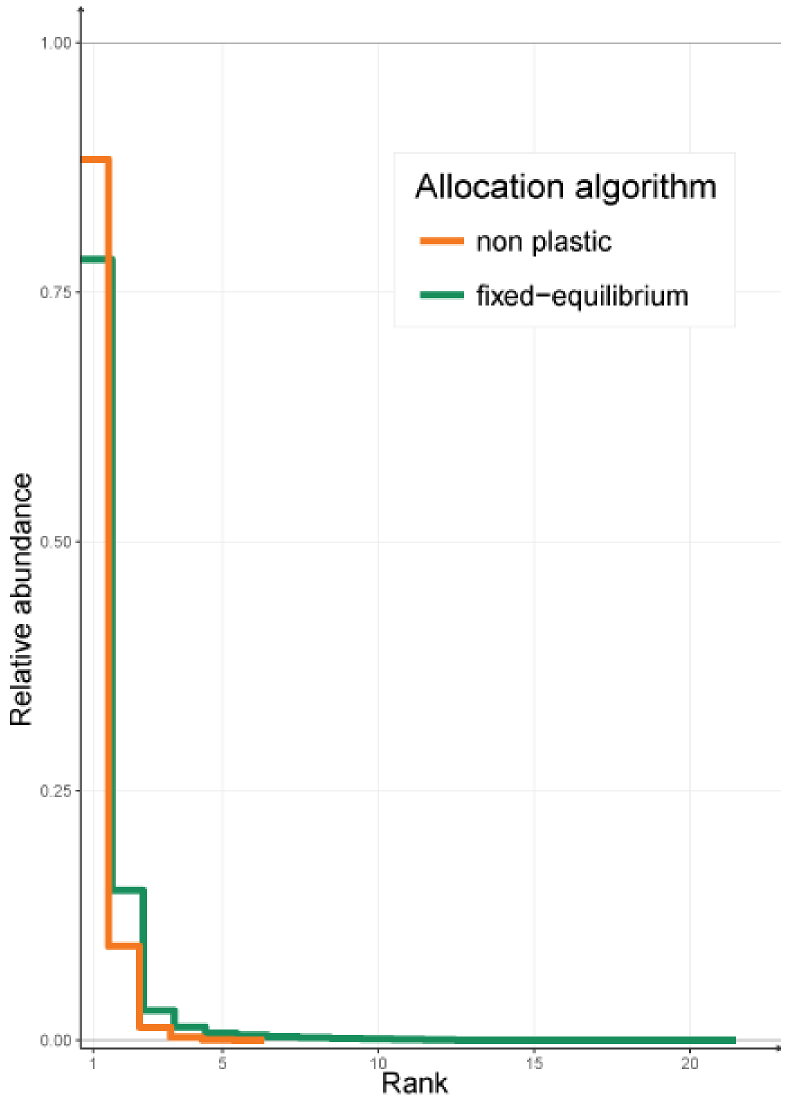
Community-level simulations

Real conditions of variability (weather data for 6 sites) + explicit competitive interactions

- Long term simulations (300 years)
- 12 stable parameter sets (reproducing individual after 50 years in non plastic conditions)
- 400 different phenotypes
- 6 sites: meta-community



Median species abundance per rank

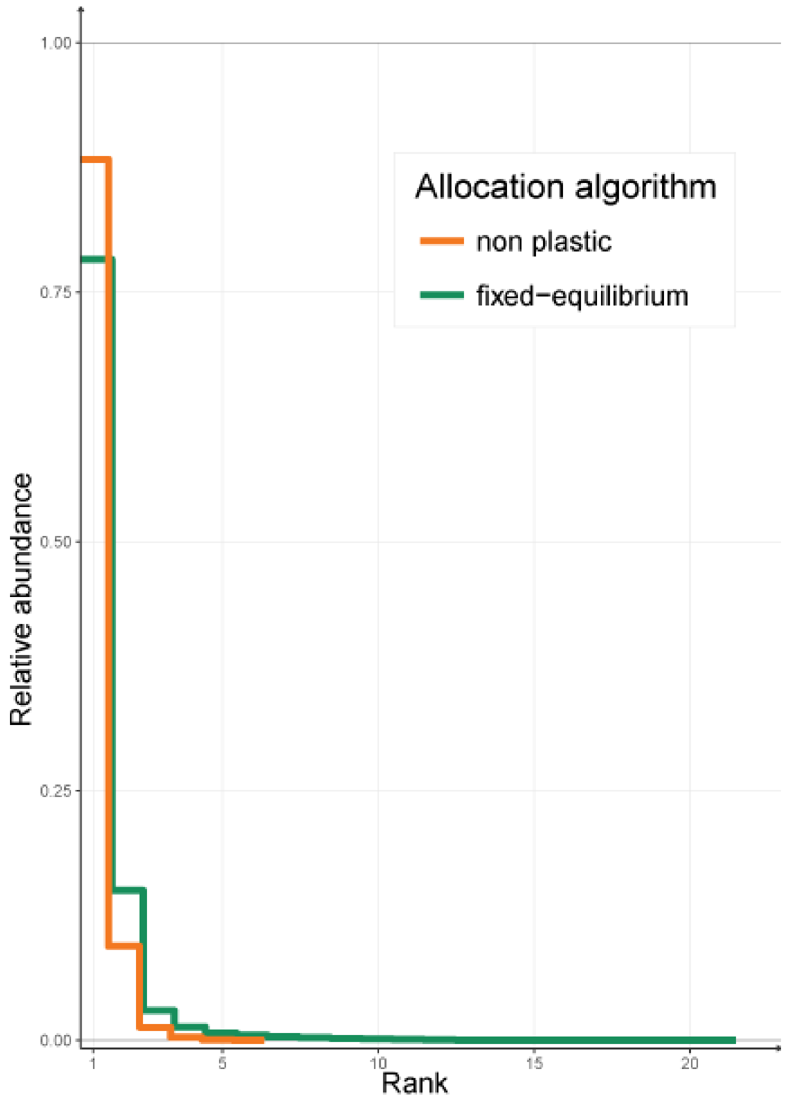


Effects of plasticity on species diversity

Lower abundance of the dominant species

Higher species diversity

Median species abundance per rank



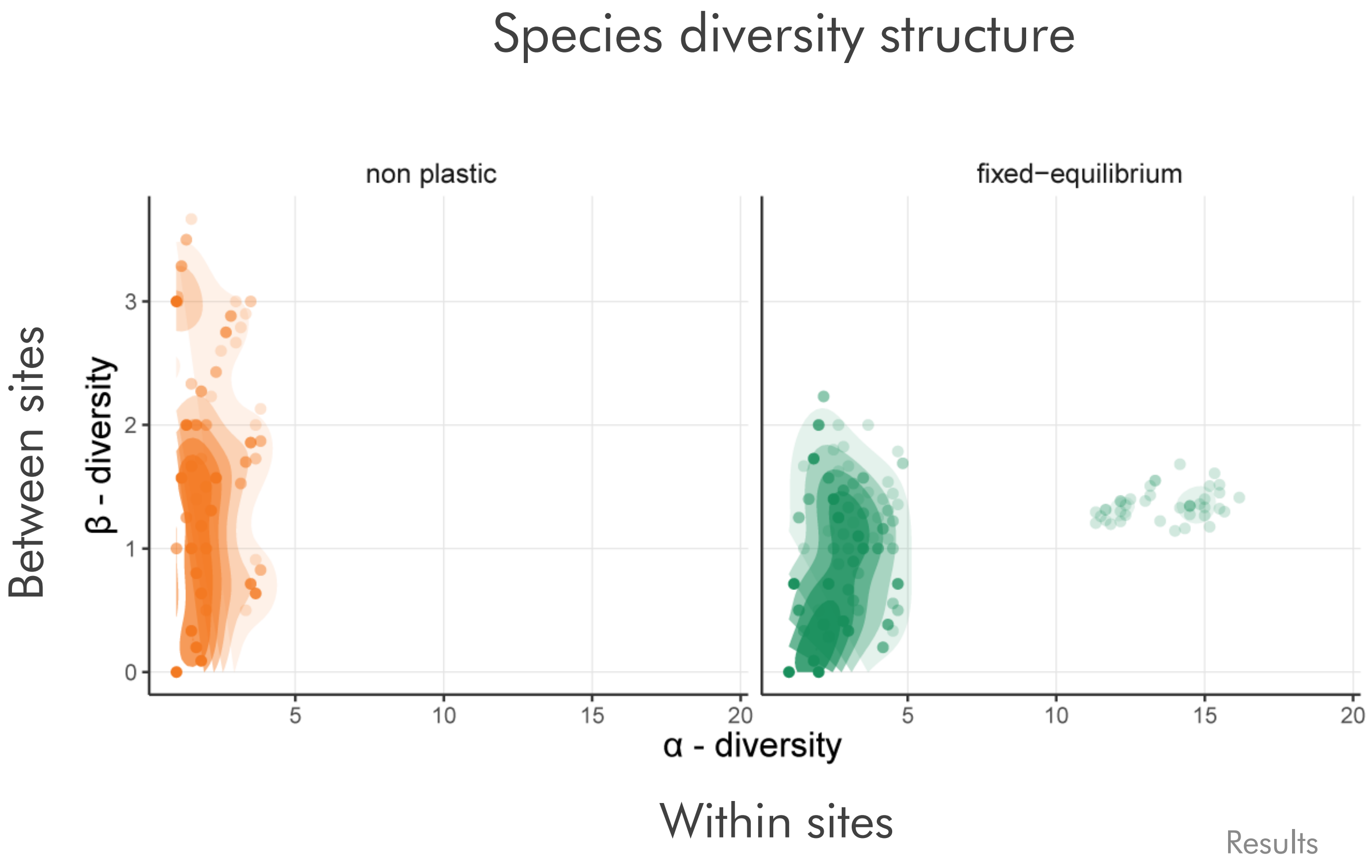
Effects of plasticity on species diversity

Lower abundance of the dominant species

Higher species diversity

Niche widening > asymmetric gain

A shift in community structure?

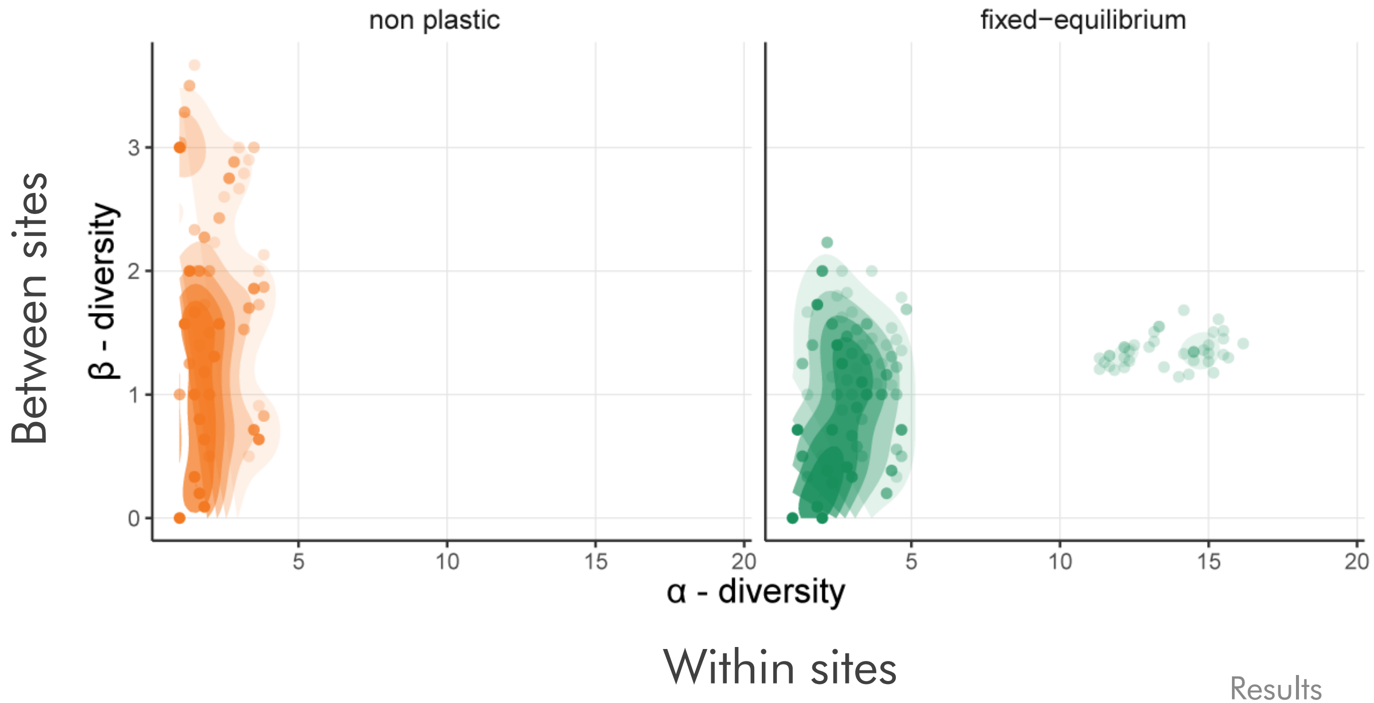


Shift in diversity structure:
- Less distinct site communities
- Richer site communities

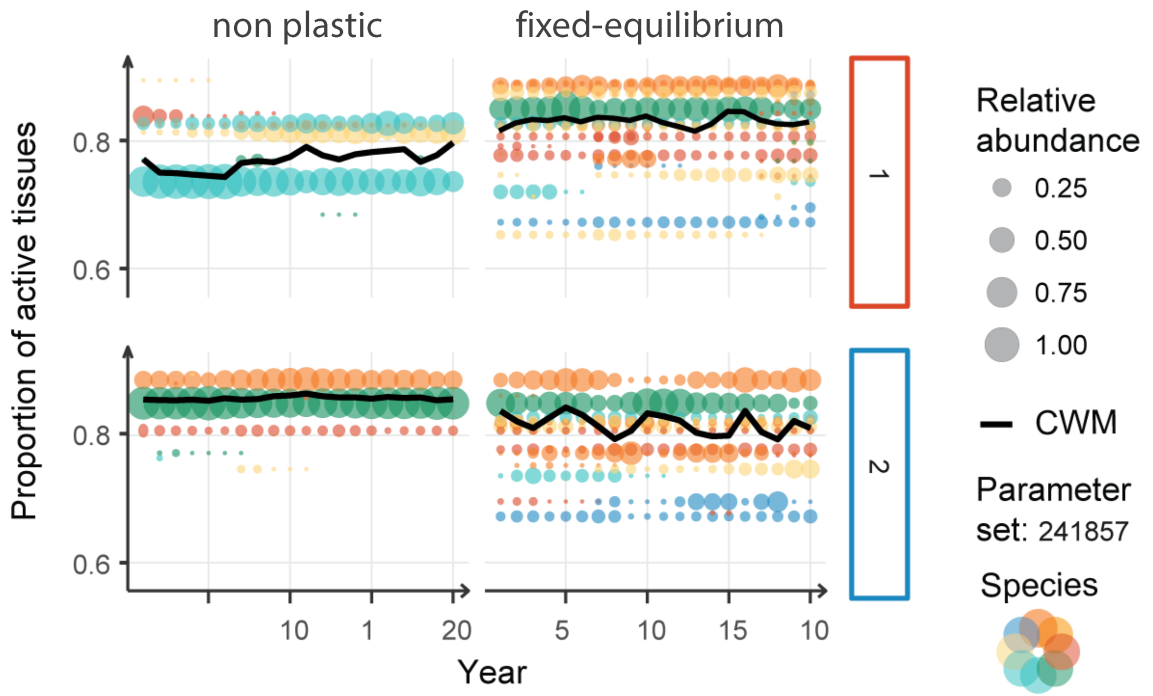
A shift in community structure

More species → abundance variations but no composition shifts

Species diversity structure



Community composition for 2 sites



A shift in community structure

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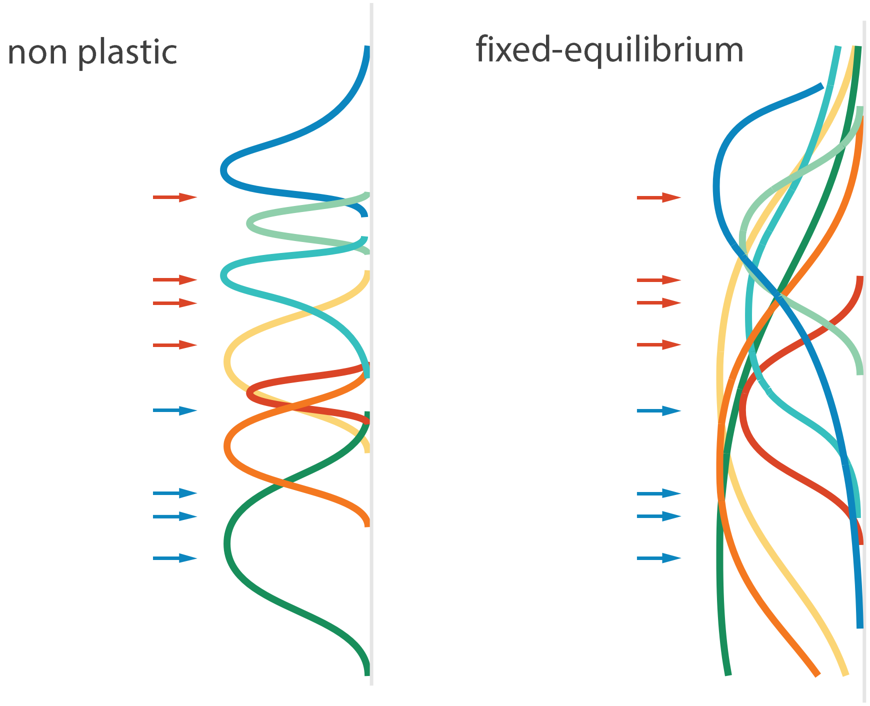
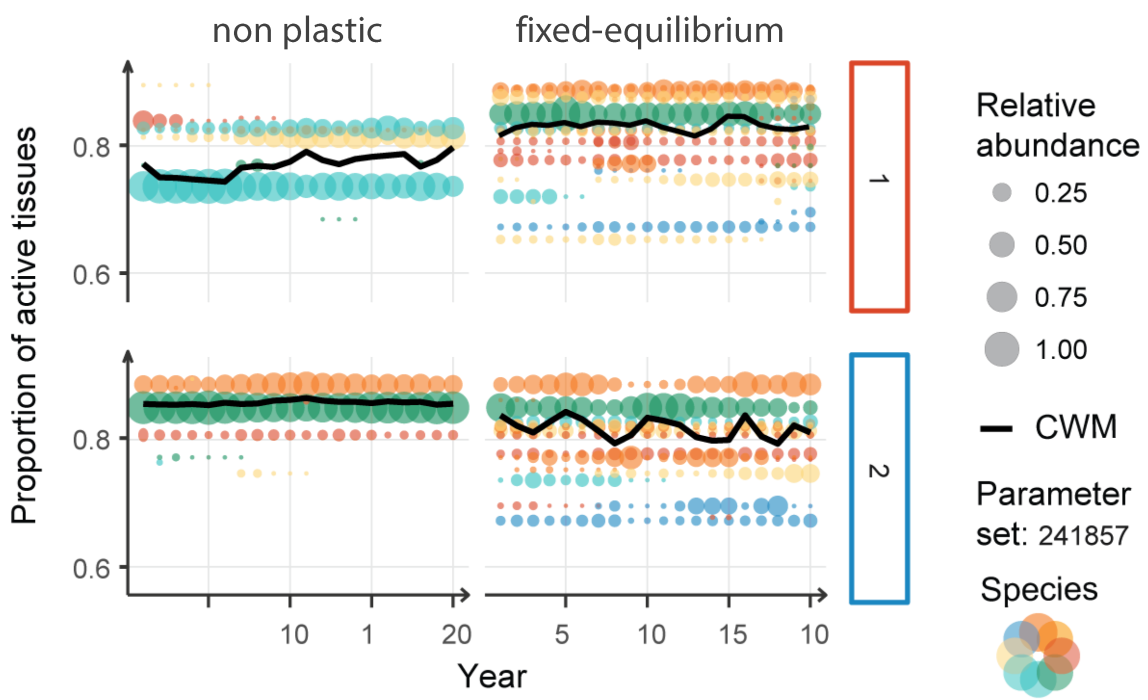
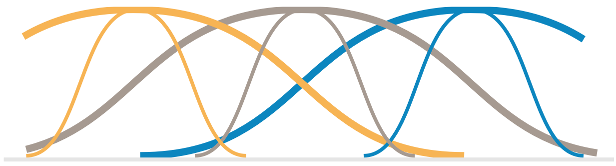


Community composition for 2 sites

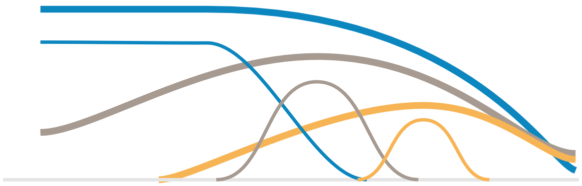


Results summary

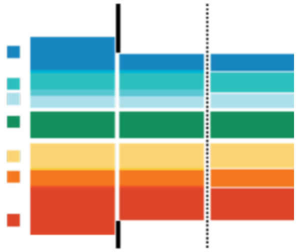
Niche widening



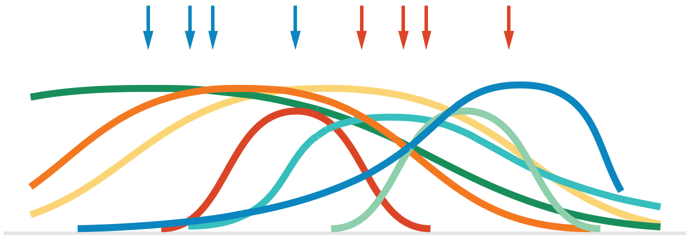
Assymetric gain in favour of exploitative species = loose of sensitivity to resource variability



Niche widening > asymmetric gain



Plasticity alters meta-community structure

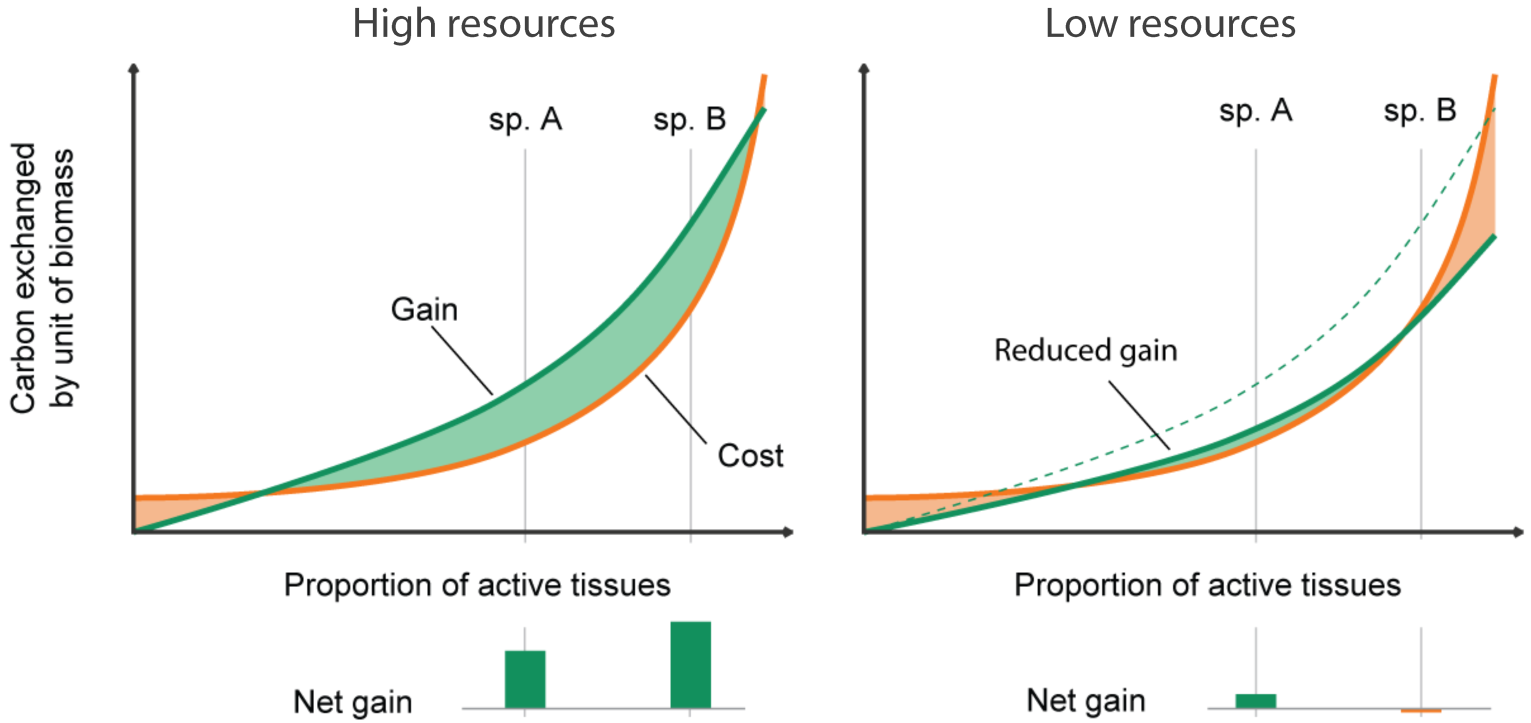


Discussion

Impact on community dynamics and community modelling

How plasticity favours exploitative species?

Gain & costs as a function of the proportion of active tissues



Exploitive= lower efficiency, but higher exchagne rate

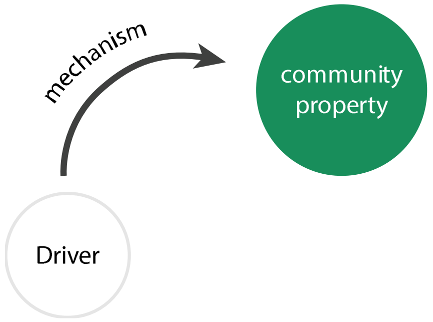
→ Sensitivity to unbalance functioning

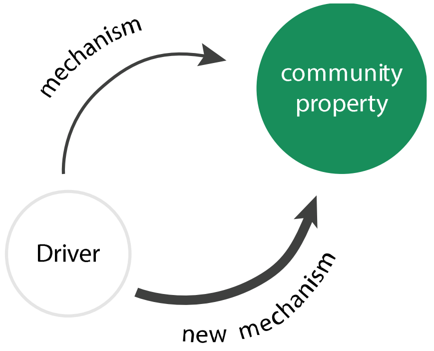
Plasticity ensures balance and negates the sensitivity

Plasticity is a process integrated at the scale of the whole individual

Transfer to real systems?

There is not switch in reality





Is plasticity as important as it seems for diversity?

→ Cost of plasticity

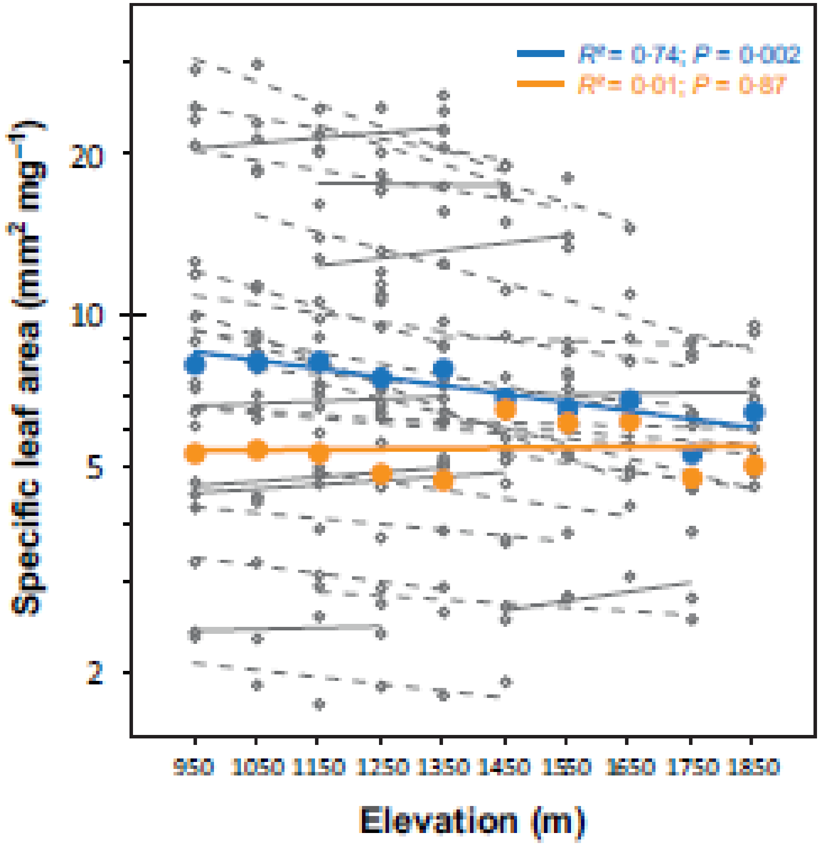
→ Sampling effect

Response to specific disturbances:

Dialogue between models & empirical experiments

MODEL	EMPIRICAL
Plasticity as a structuring process	Plastic dimensions & responses
Experiment with multiple scenarios	Cost of plasticity
Plasticity as a trait	Phenotypic flexibility

Mean specific trait along an elevation gradient



Conclusions & Outlook

New hypothesis and simulations

Model developments

Ecological conclusions:

A better undertanding of plasticity

Better understanding as an integrated growth process not just a response function

Plasticity impacts diversity via multiple mechanism at multiple scales

Plasticity is rarely symmetric (niche widening promotes subordinates species, assymetric gain favours certain strategies)

Ecological conclusions:

A diverse community framework

Diversity in strategies and species
Plasticity in coherent framework
Plasticity as a strategy (not explored)

but…

A lot of parameters: needs better calibration and sampling
High functional convergence

To go beyond

- Better calibration and strategy sampling to confirm results
- Explore the plasticity as a strategy
- Climat, management and perturbation scenarios

Thank you!

Bonus!


FLOWERS ARE PRETTY STUPID.
SEE, IT'S A BRIGHT, SUNNY DAY OUT, RIGHT?
WELL, WITH THIS WATERING CAN, I CAN MAKE THEM THINK IT'S RAINING.
IT'S FUN TO MESS WITH THEIR MINDS.
WATTERSON