

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

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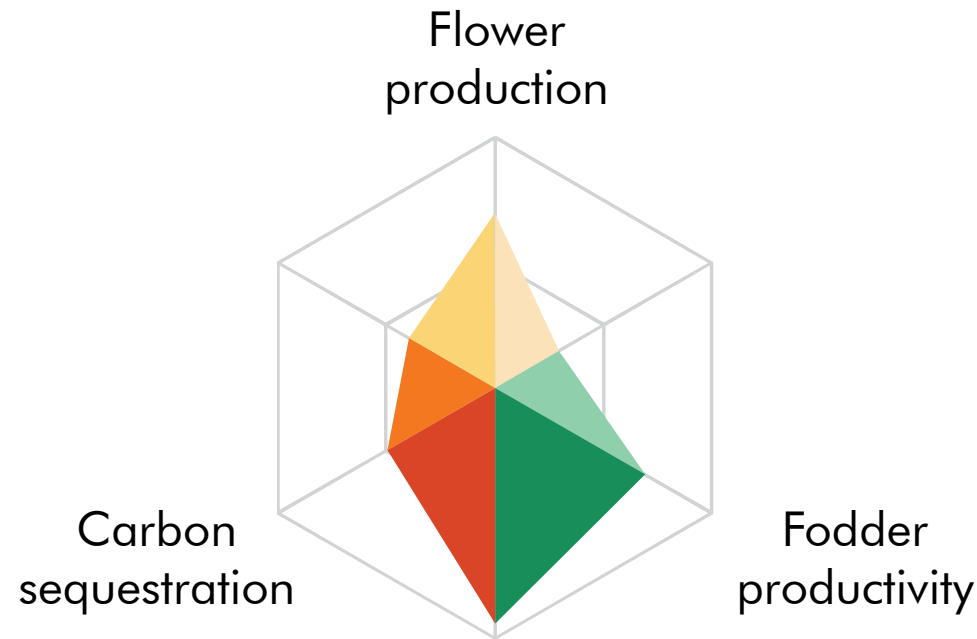
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Introduction

From context to questions

Mountain grasslands provide services

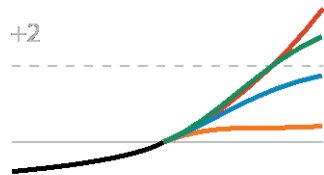


Various and depends on the properties of the community shaped by environmental drivers

Assessing grassland ecosystem services



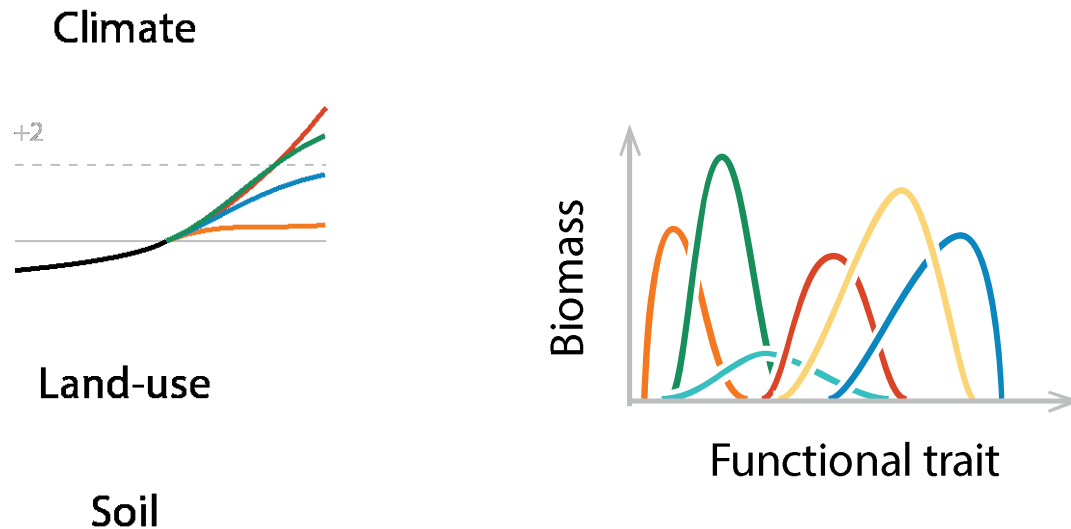
Climate



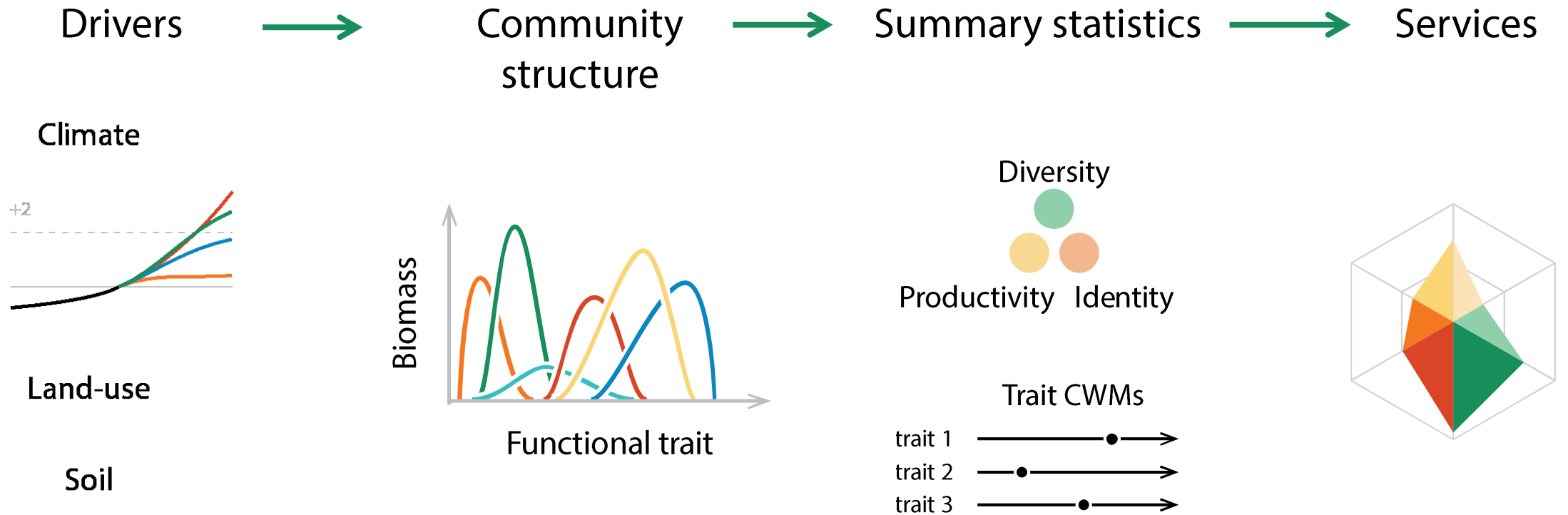
Land-use

Soil

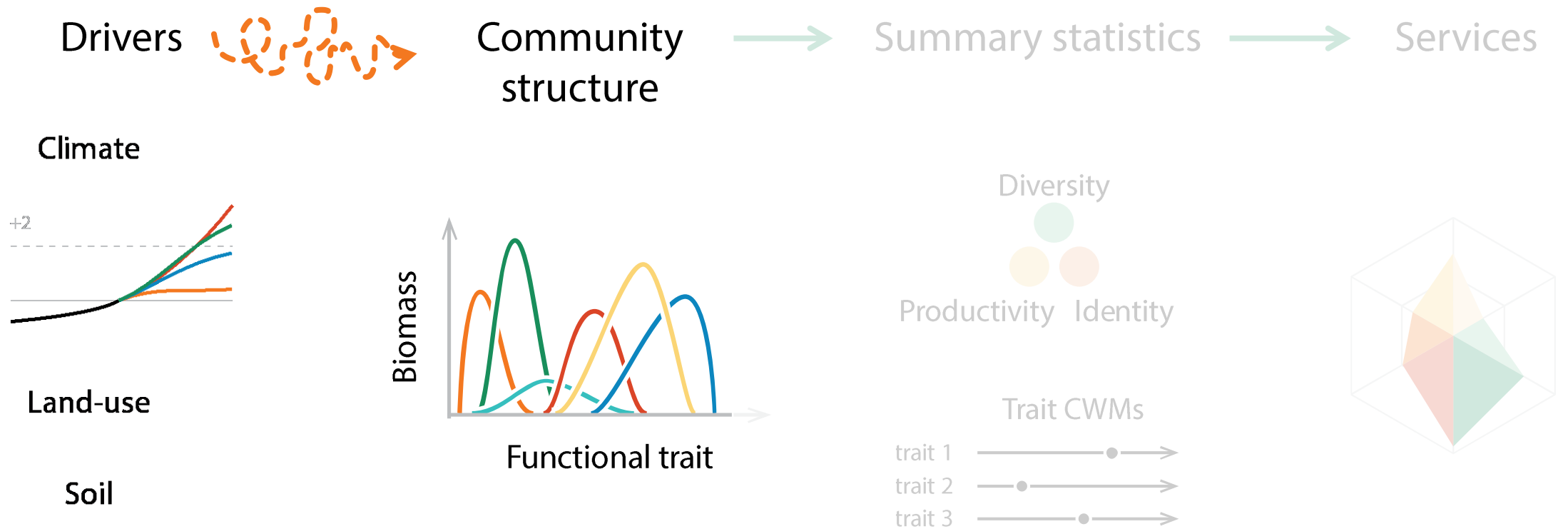
Assessing grassland ecosystem services



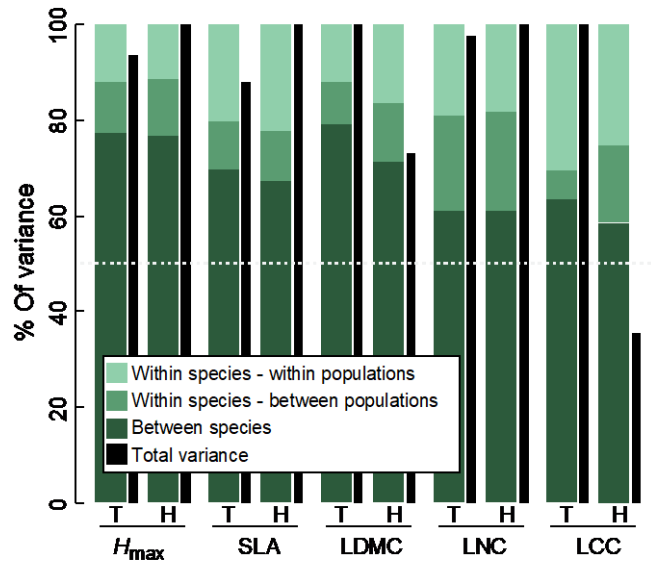
Assessing grassland ecosystem services



Assessing grassland ecosystem services

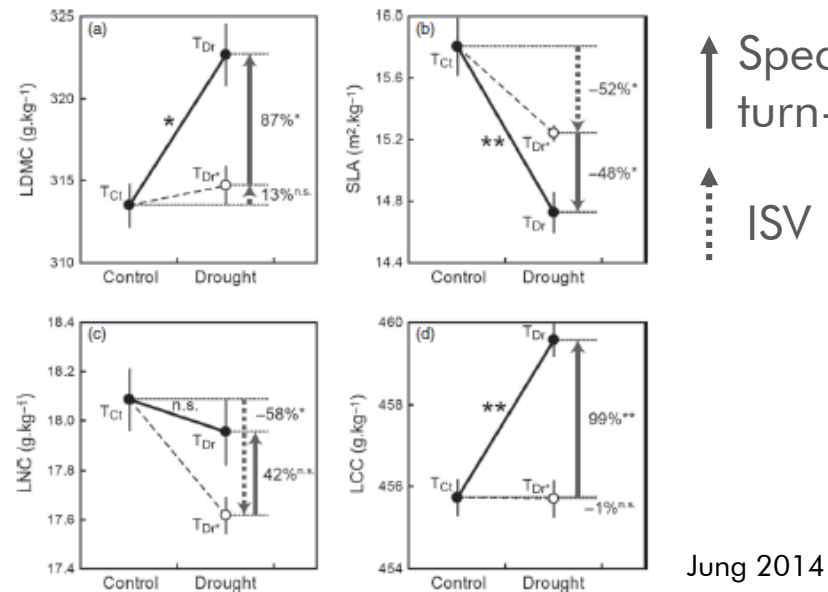


Intra-specific variability matters and impacts the community responses



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

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



Jung 2014

Should be
considered in:

- ES assessments
- Dynamic models

Strong impact on
community response

The phenotypic plasticity: one source of variation



Genetic
variation



Phenotypic
plasticity

The phenotypic plasticity: one source of variation



Genetic
variation

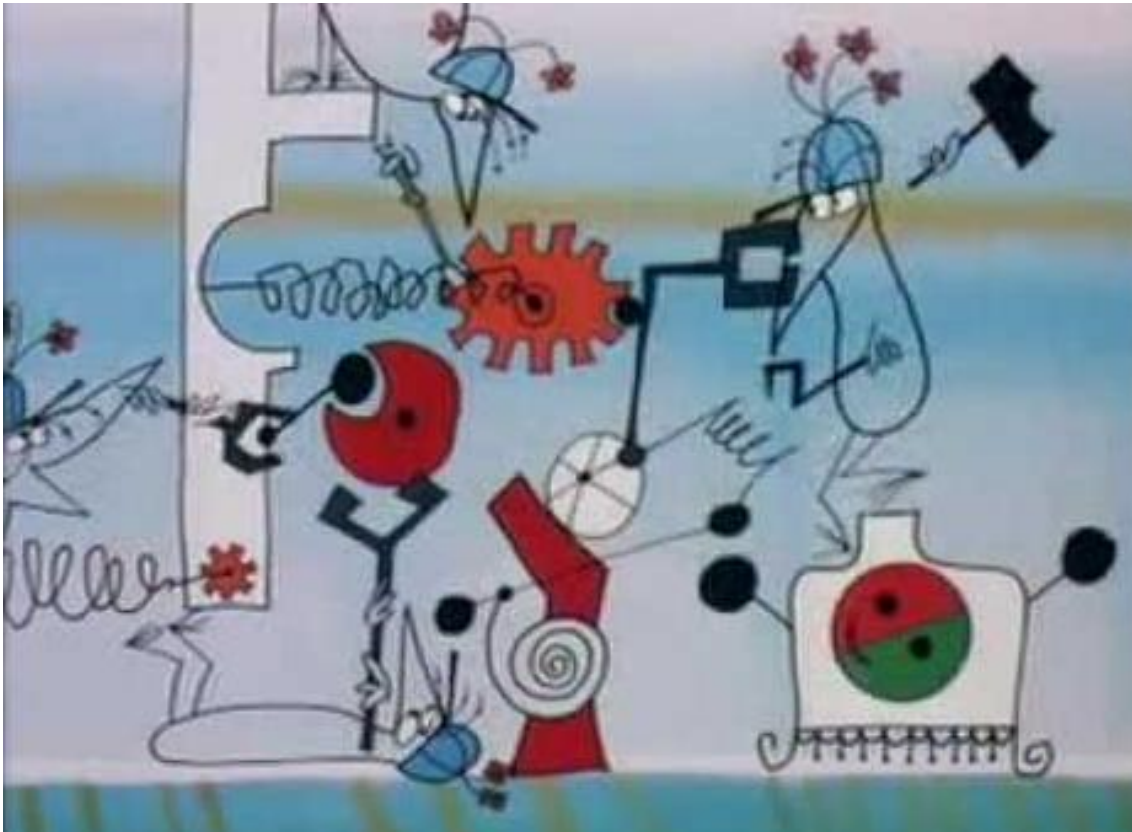


Phenotypic
plasticity

Rapid response to driver
variations

Often overlooked because
hard to study in empirical
experiments

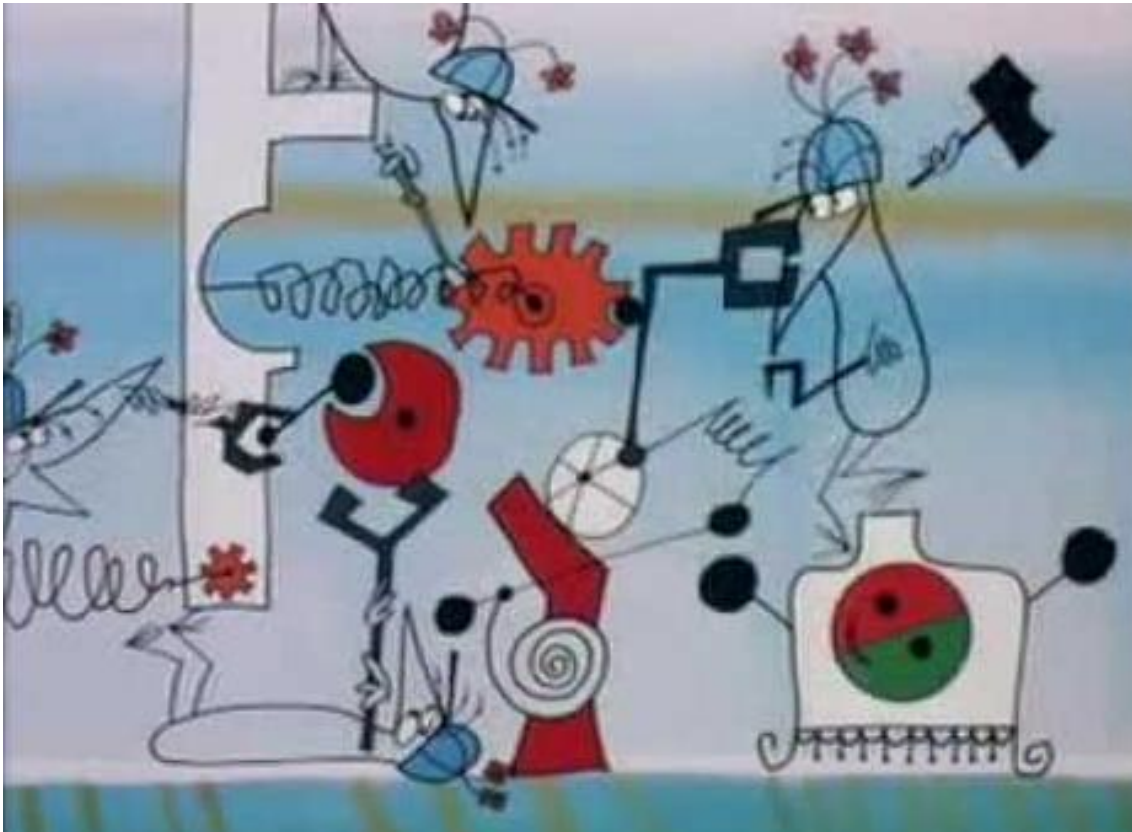
Mechanistic models to understand



Explicit link with drivers

Experiment at low cost

Mechanistic models to understand



Explicit link with drivers

Experiment at low cost

But often **limited to a few species** or functional types in a discrete manner

How does phenotypic plasticity
impact grassland community
properties?

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?



Concepts

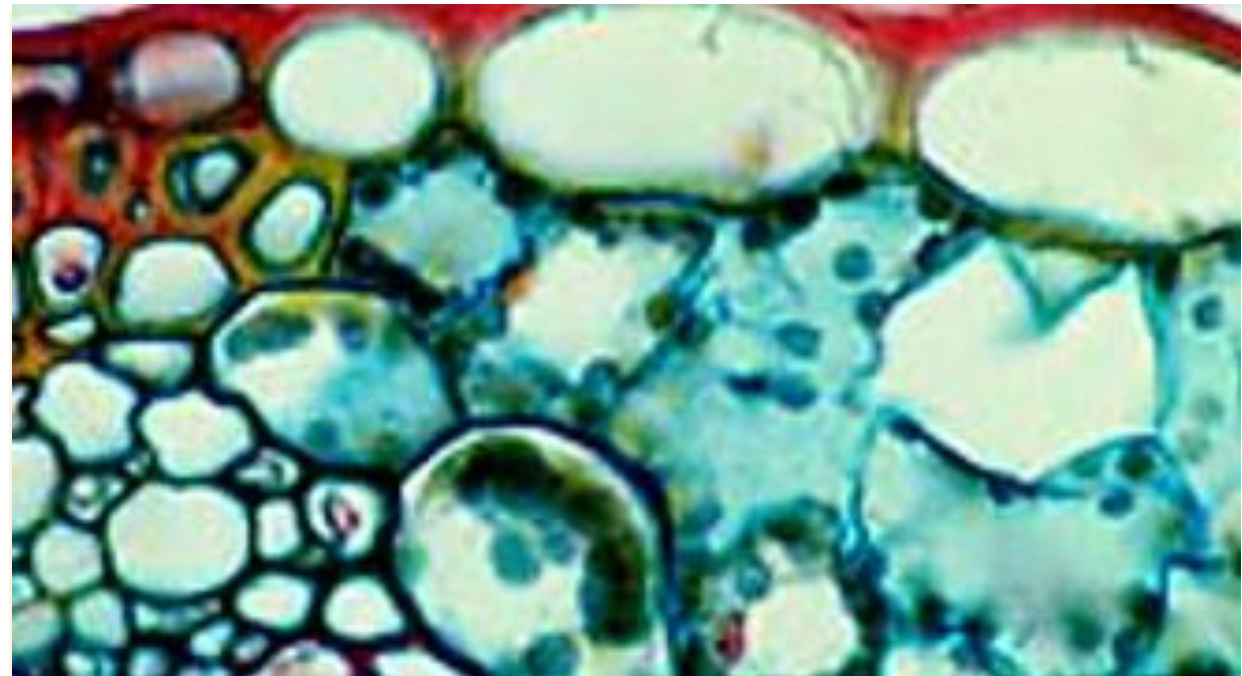
From ecological concepts
to the model *MountGrass*



Niche and variability

Competition for resources

Strategy trade-offs



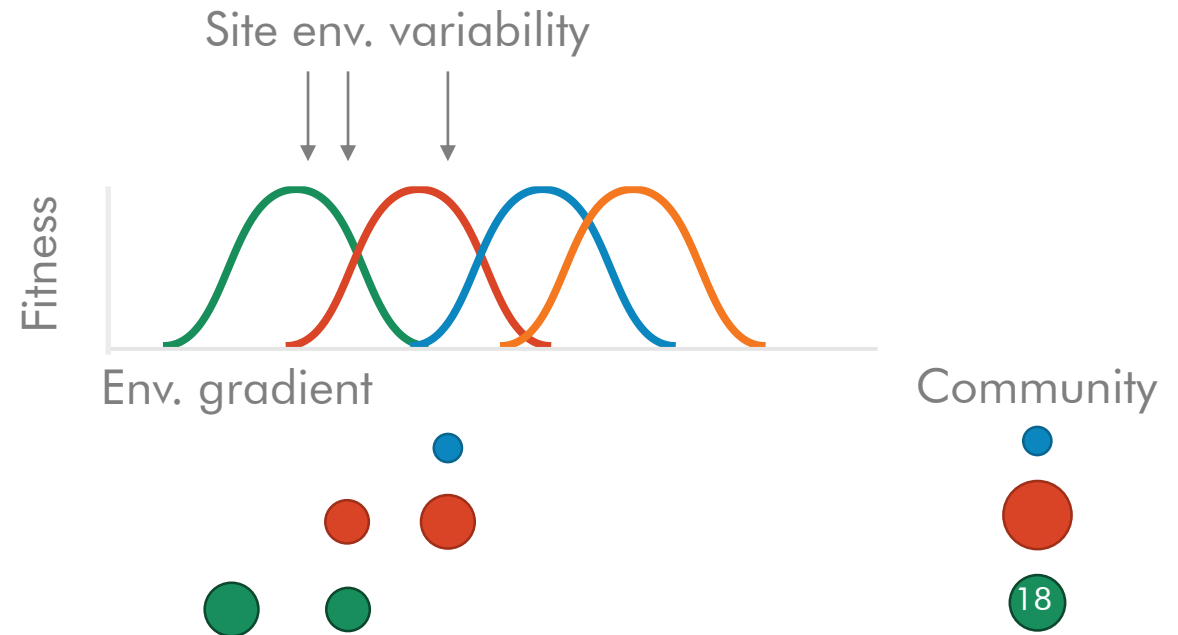


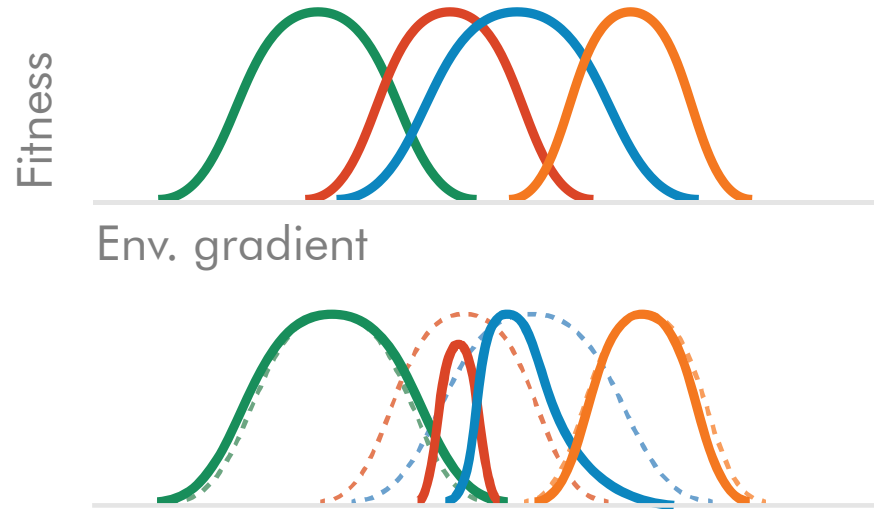
Niche & variability

Fit of a species under specific environmental conditions

Variability promotes coexistence

True for spatial and temporal variability



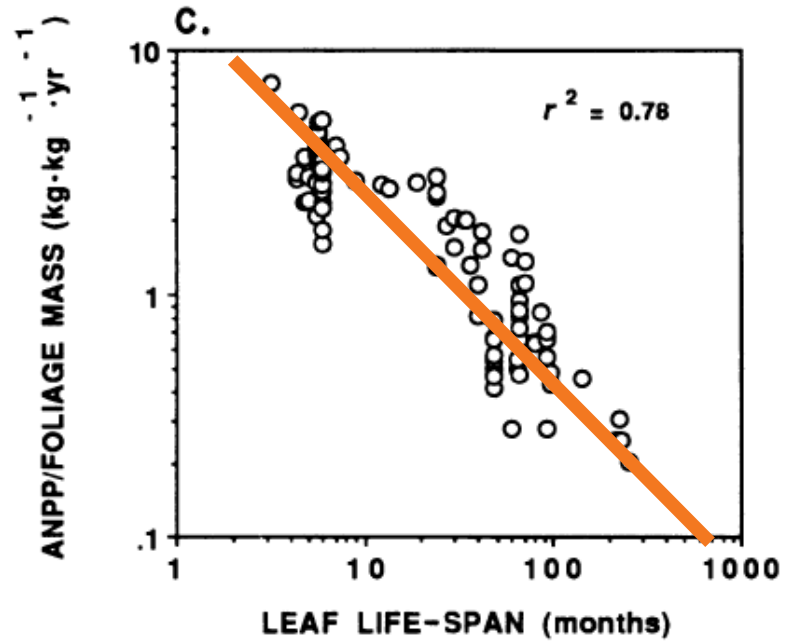


Competition for resources



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

Leaf Economic Spectrum



Strategy trade-offs

Plant strategies are constrained

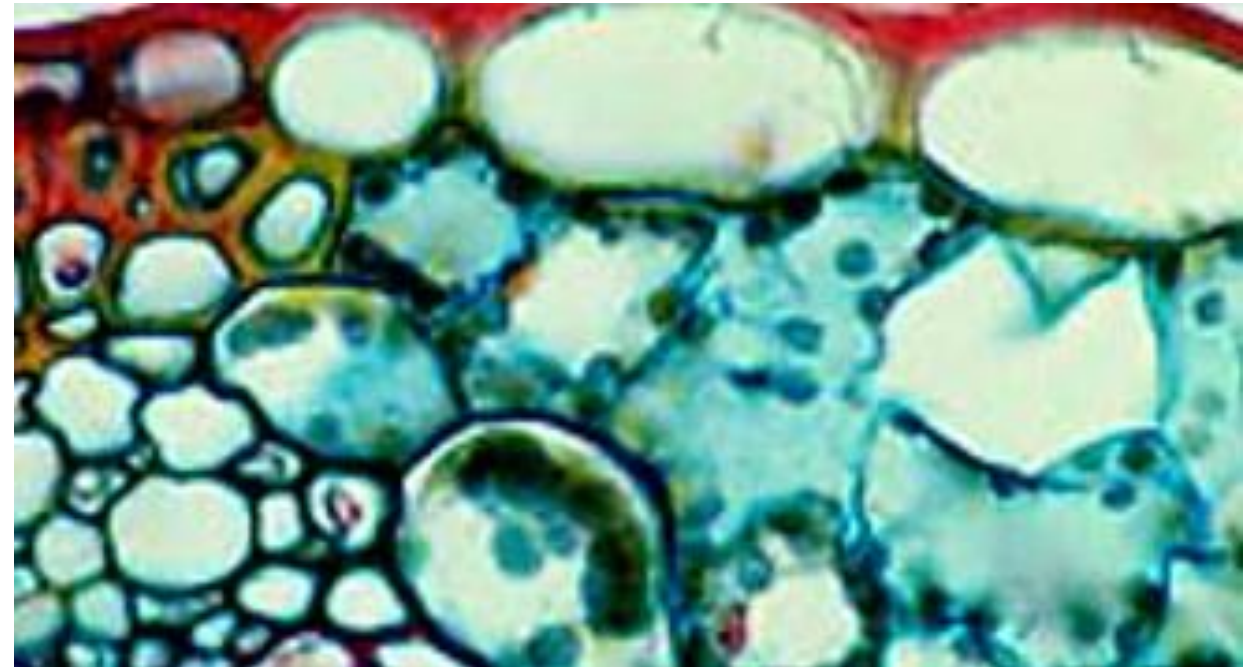
→ Dimension reduction

Continuum of plant strategies

Build a strategy space

Depends on allocation

P. Reich (1992)



The model *MountGrass*

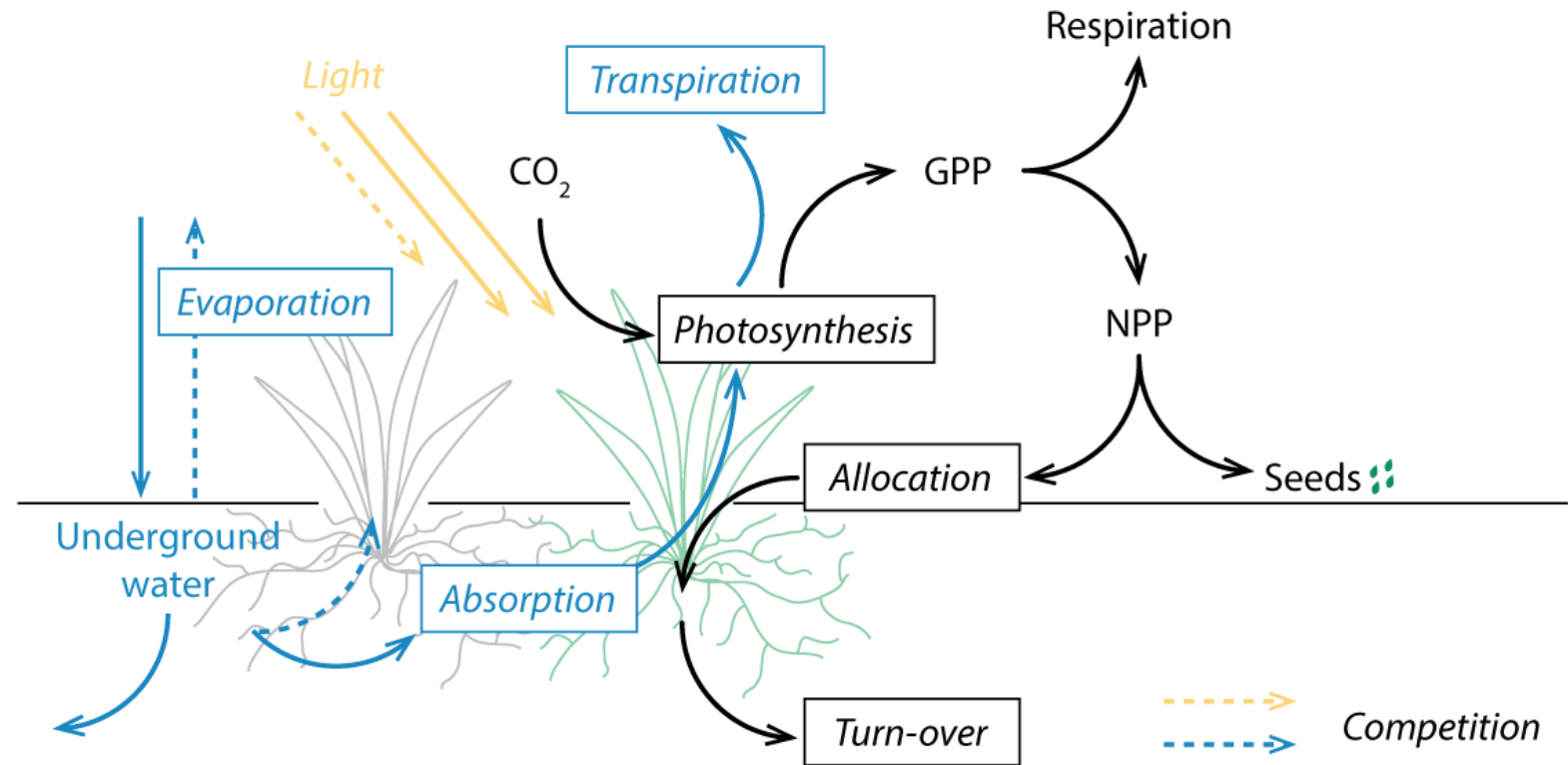


MountGrass' processes

Response to drivers:
physiological processes.

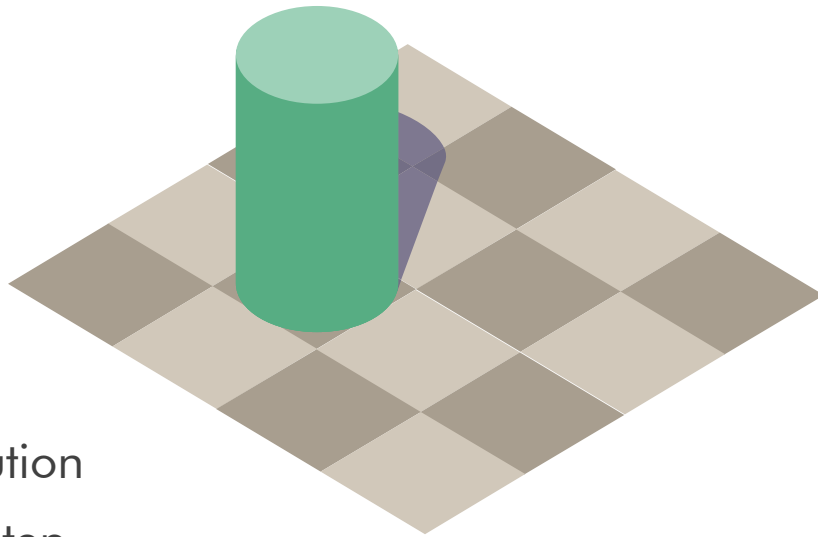
Above and belowground
competition: light and
water cycles.

Strategies: carbon
allocation trade-offs.

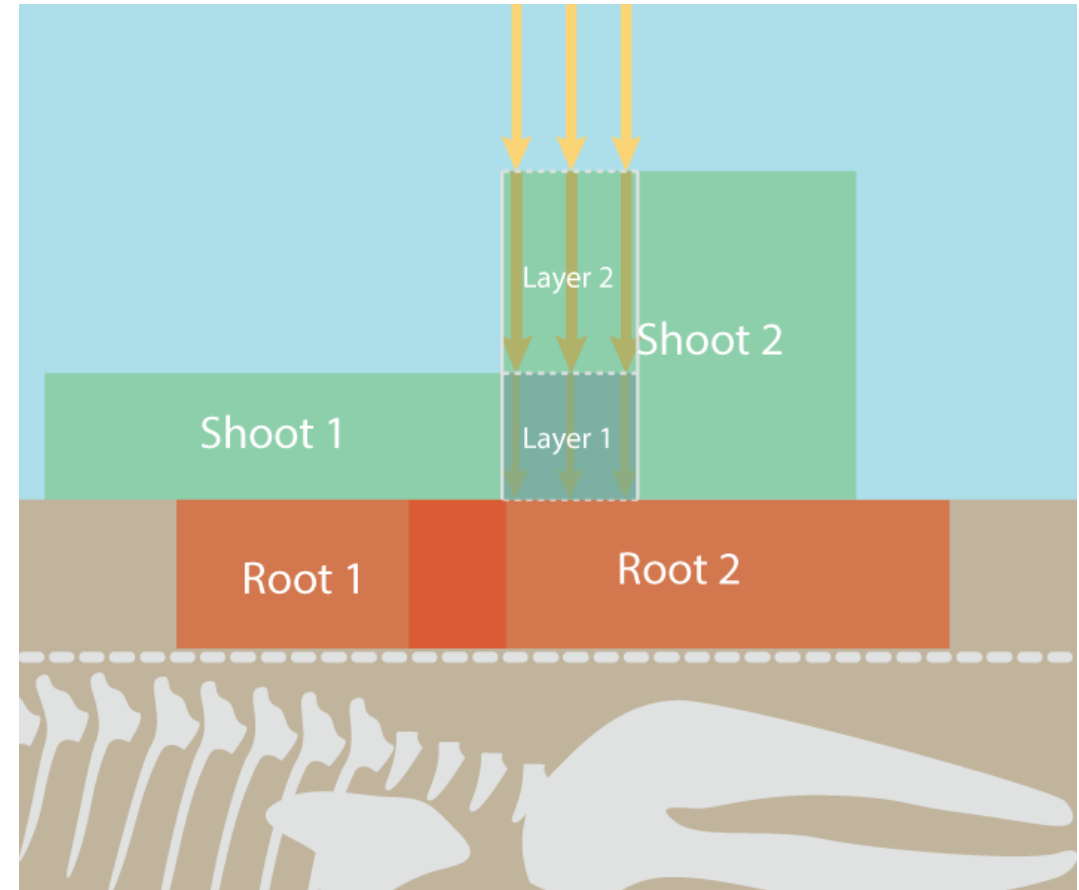


Space & time: the individual plant scale

Individual-based model
spatially explicit: explicit competition



1 cm resolution
daily time-step



Plant carbon pools and allocation trade-offs

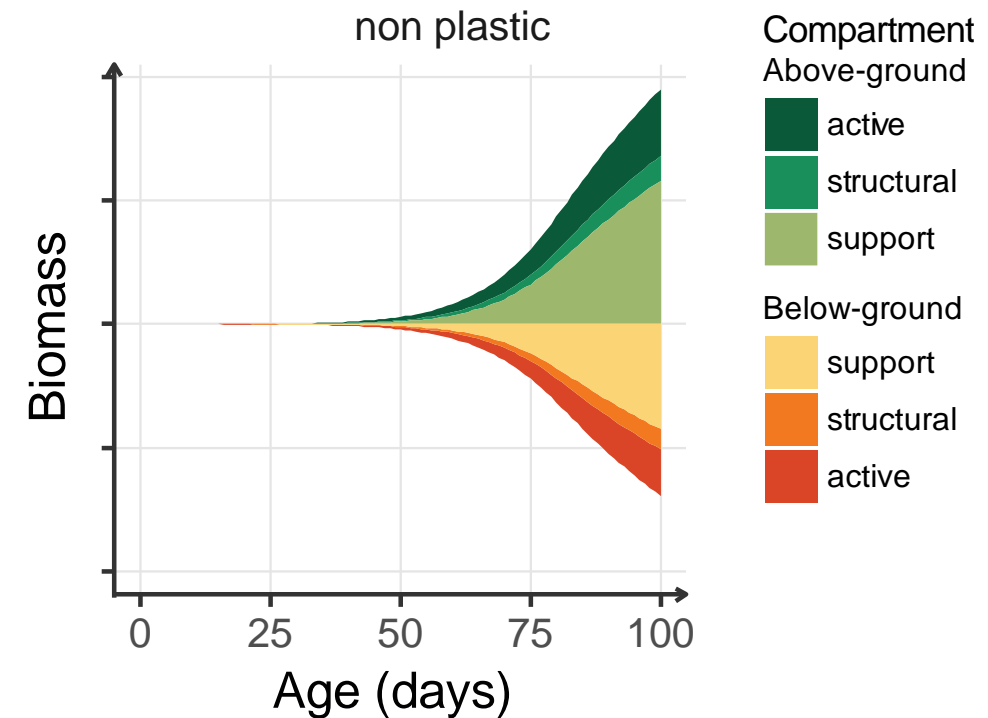
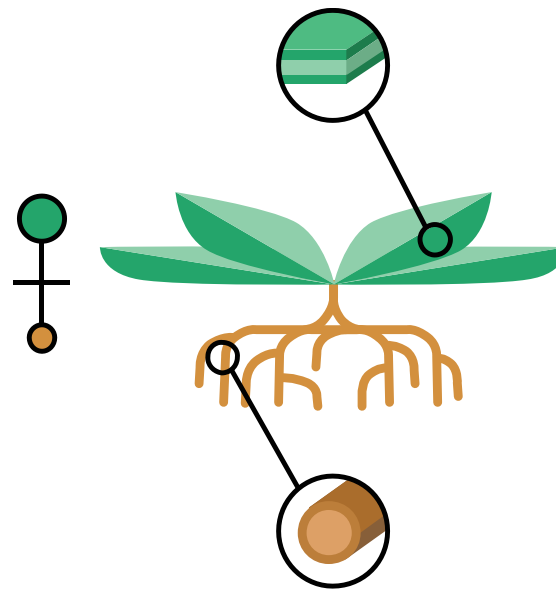
6 vegetative pools

3 dimensions:

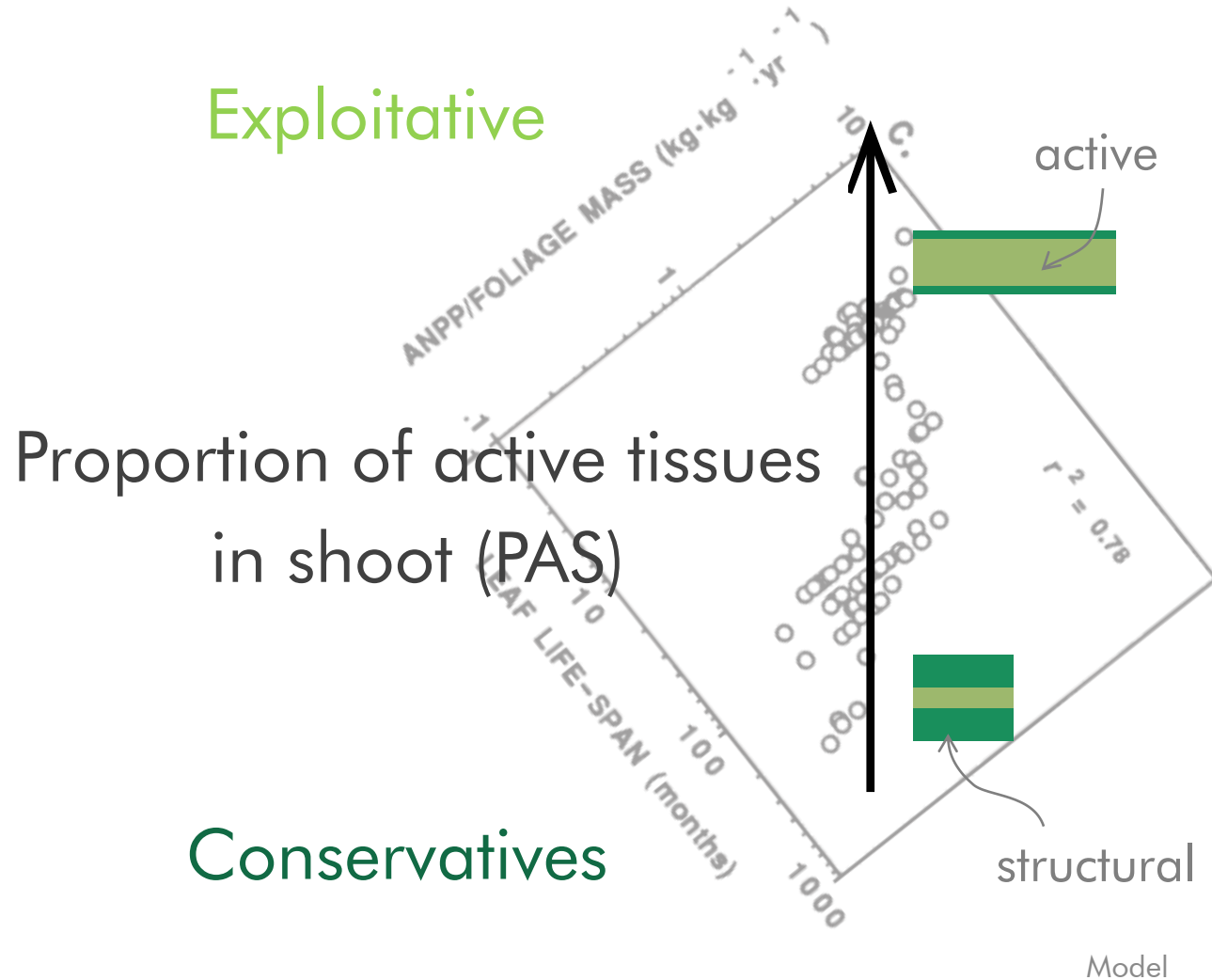
- Root:shoot ratio
- Prop. active in shoot
- Prop. active in root

Allocation trade-offs

→ strategic trade-offs

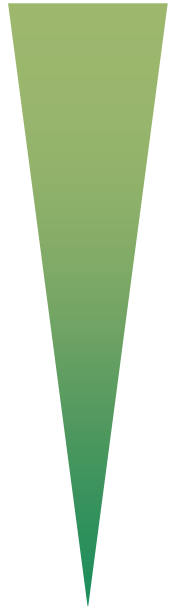
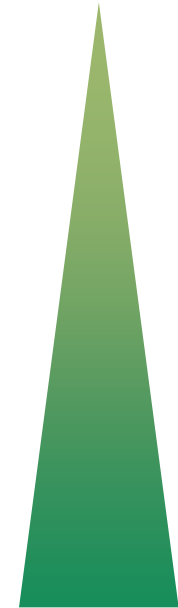
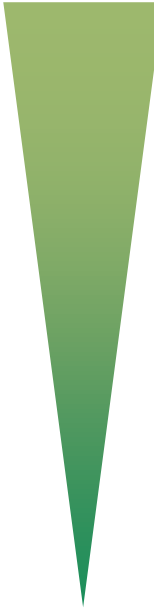


Allocation trade-off into strategic trade-off



density

lifespan

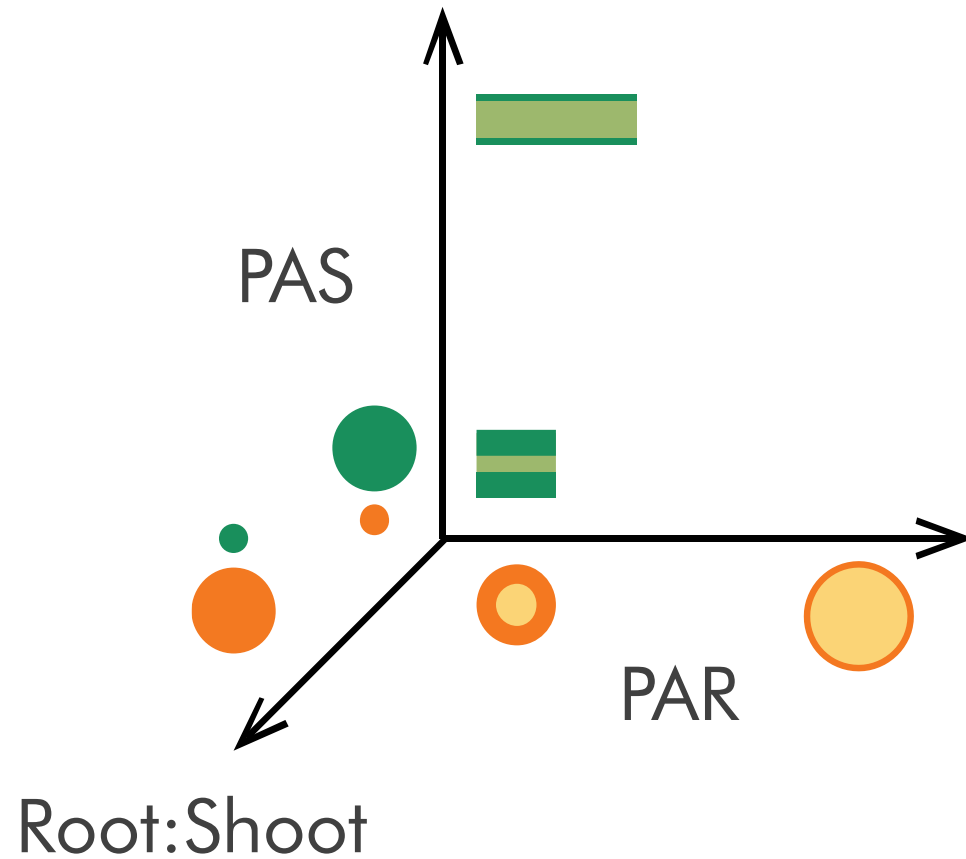


area

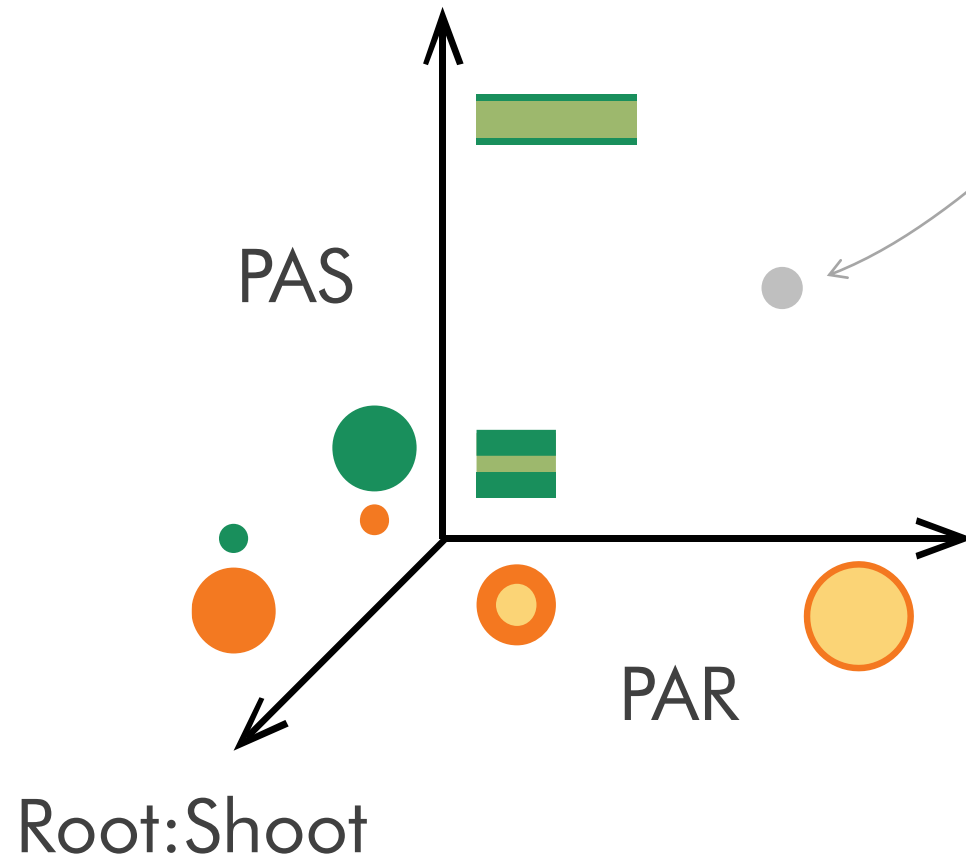
biomass

respiration

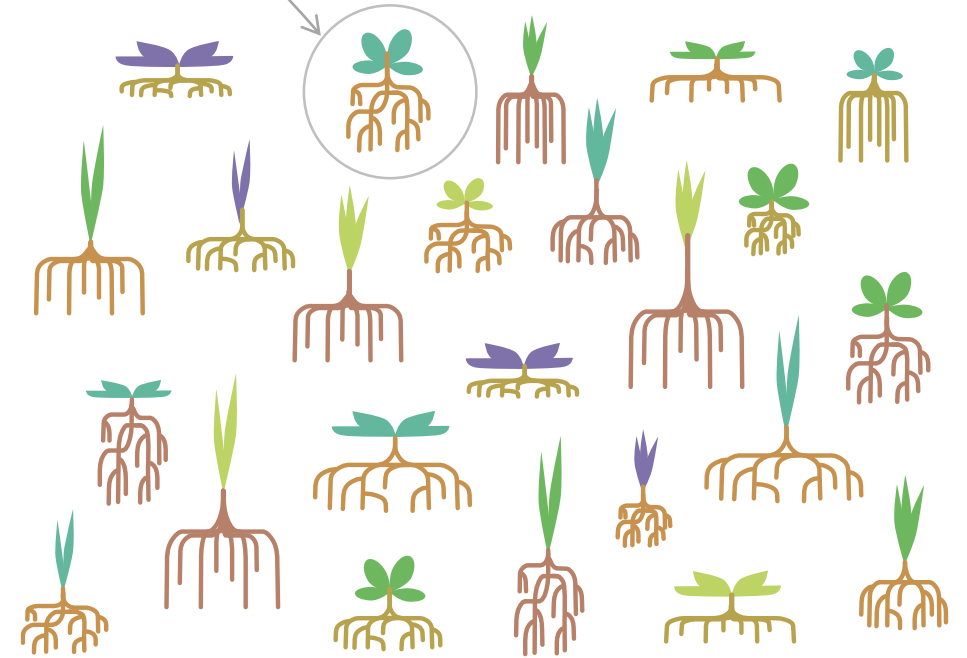
Phenotypes and strategies



Phenotypes and strategies

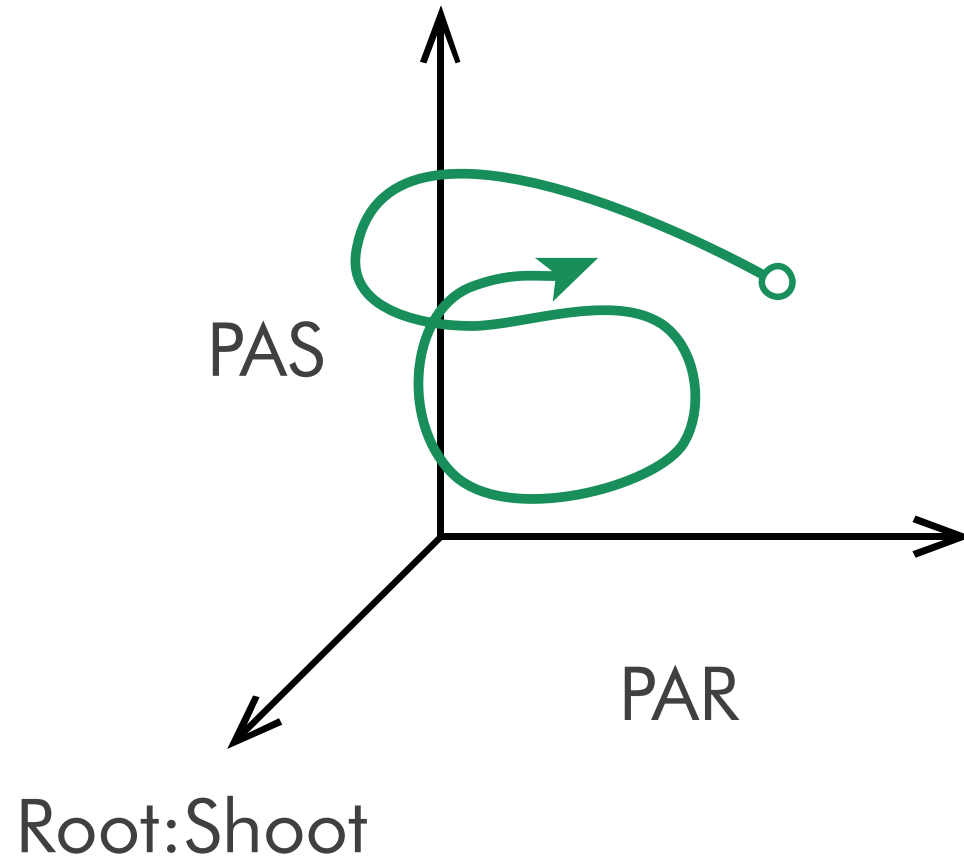


Each point is a valid strategy



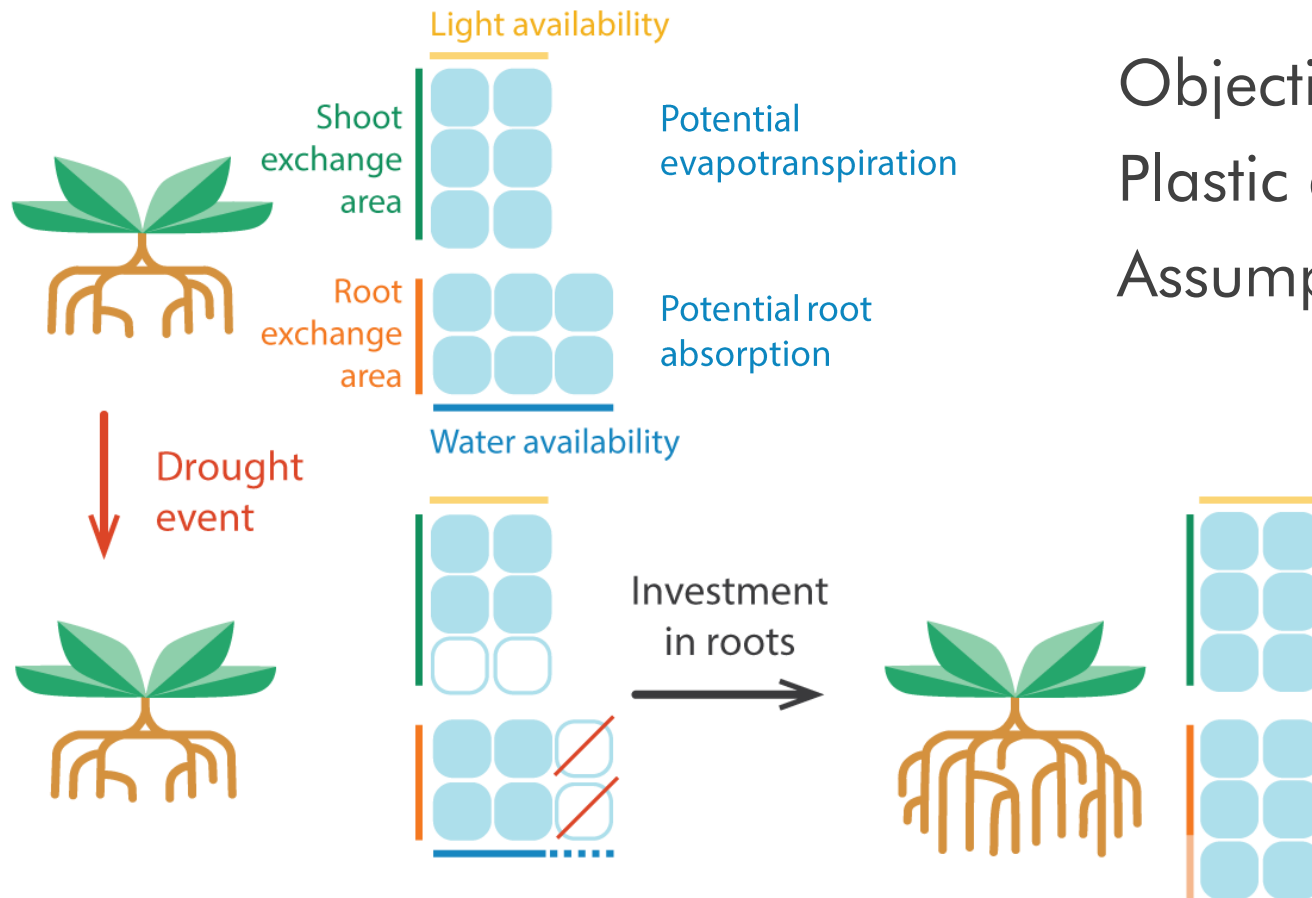
→ sample diverse strategies in a continuous space

Phenotypes and strategies



Plasticity allows plant to move within this closed space, but it needs **rules**.

Plasticity: the functional equilibrium

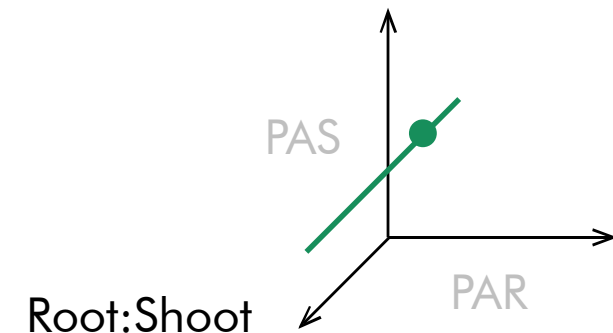


Objective function: **root activity** = **shoot activity**

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

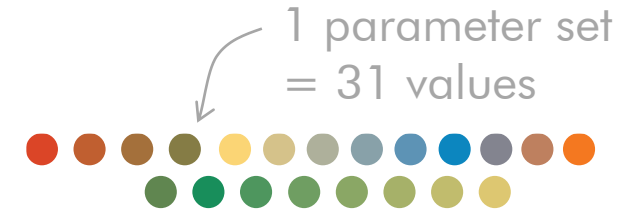
12*12*90 cm pots

Parameter filtering

31 parameters

Pot growth patterns in 2 treatments of watering

→ Selection of a subset of parameter sets for simulations



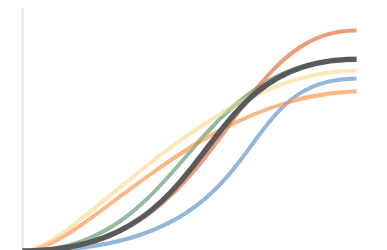
Accepted sets



Simulation sets



Trend from multiple simulations



fixed T° & irradiance

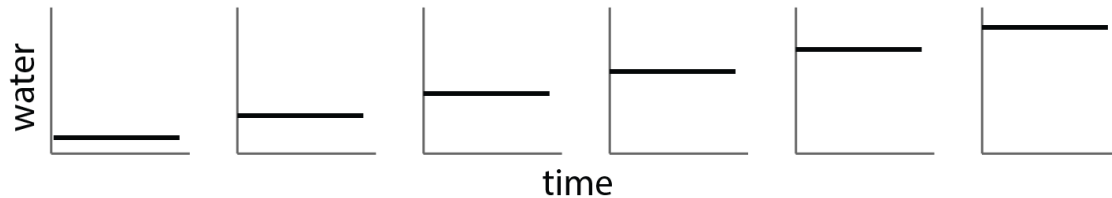
12*12*90 cm pots

100 days

Individual-level simulations

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

Individual growth along an
availability gradient (spatial)



fixed T° & irradiance

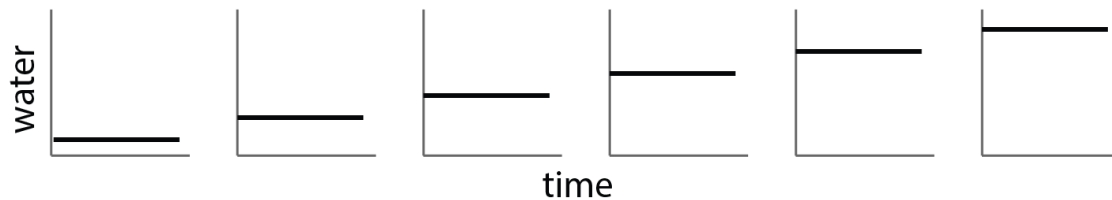
12*12*90 cm pots

100 days

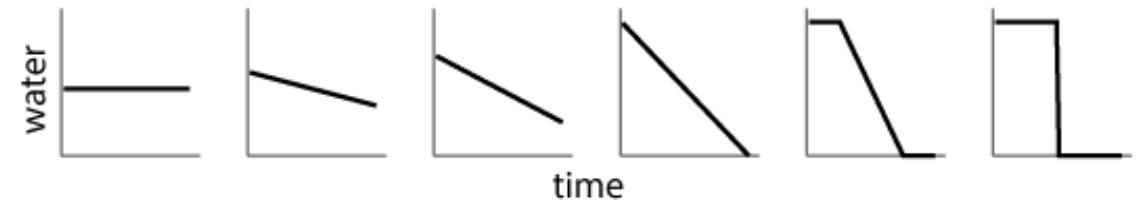
Individual-level simulations

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)



fixed T° & irradiance

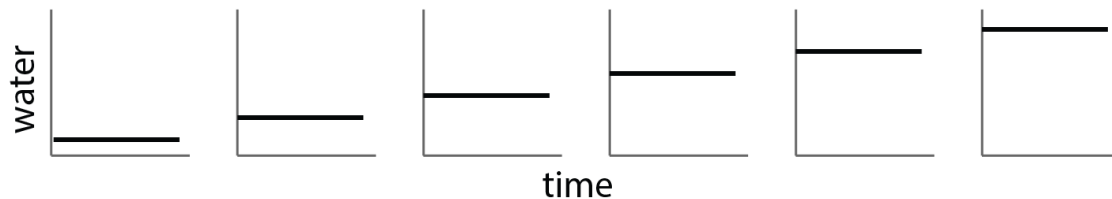
12*12*90 cm pots

100 days

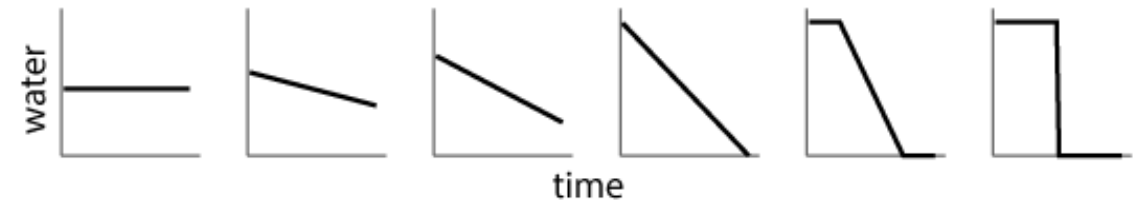
Individual-level simulations

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

Individual growth along an **availability** gradient (spatial)



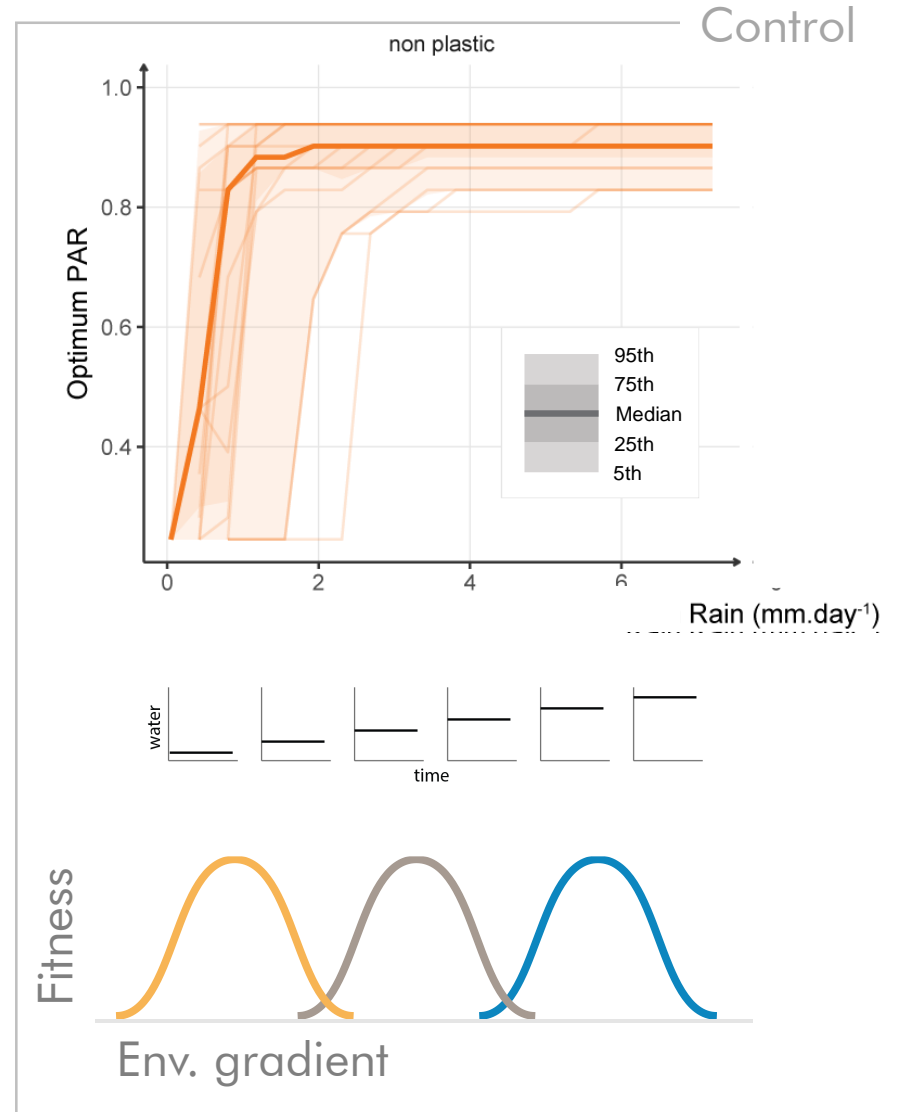
Individual growth along an **variability** gradient (temporal)



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

Plasticity effect in homogeneous conditions

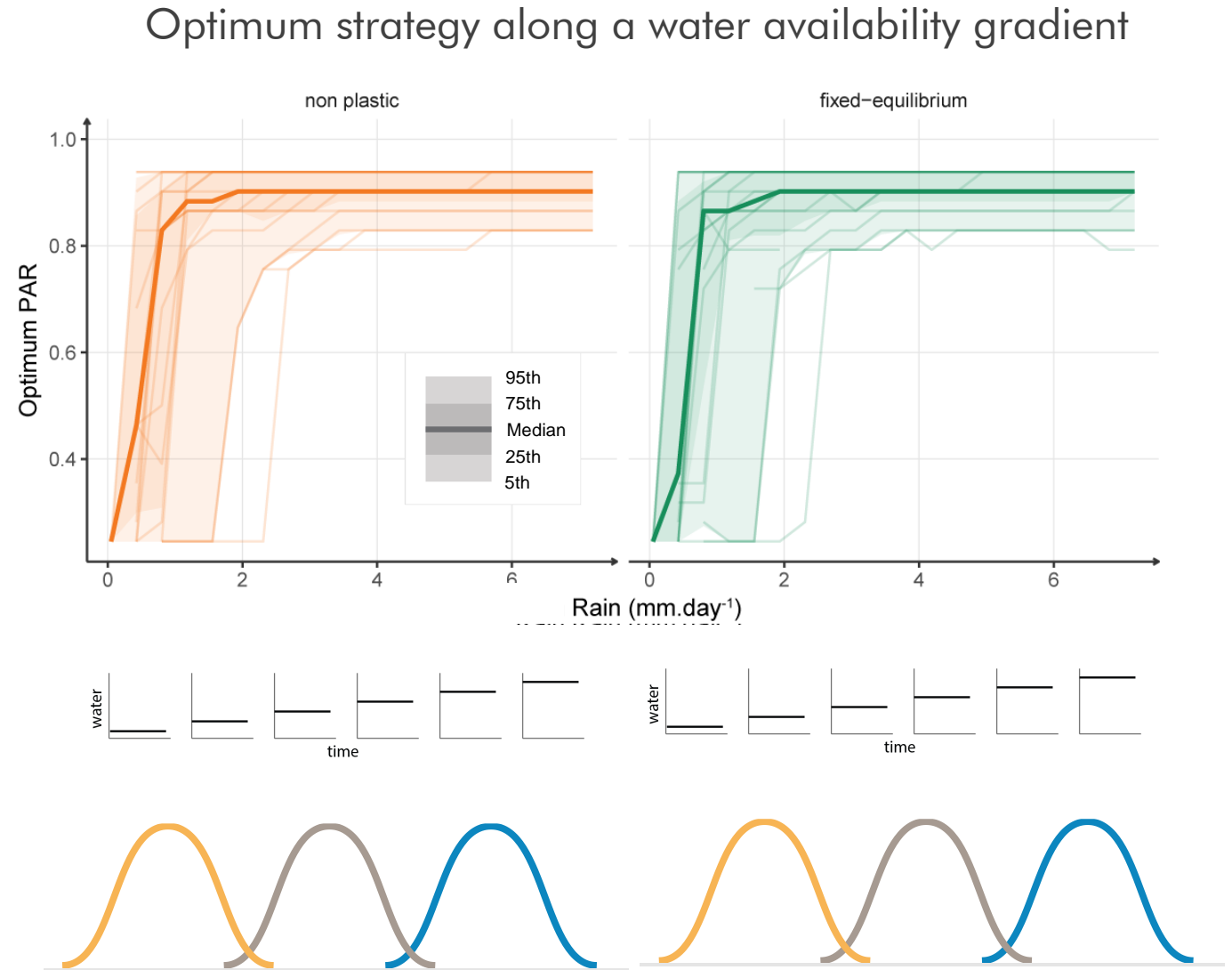
Optimum strategy along a water availability gradient



Plasticity effect in homogeneous conditions

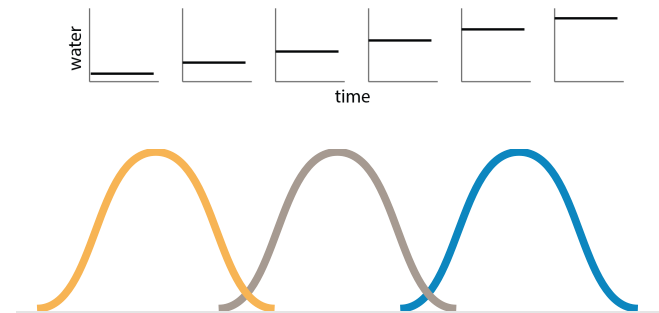
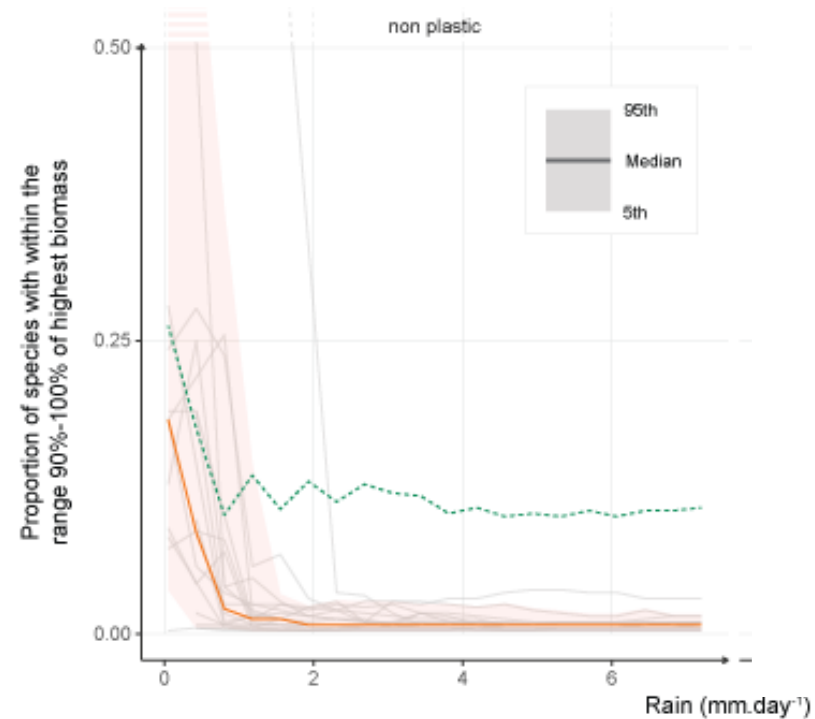
- No shift in best strategy
- No change in maximum biomass

→ No shift in the dominant species



Plasticity effect in homogeneous conditions

Proportion of species with high performances along a water availability gradient

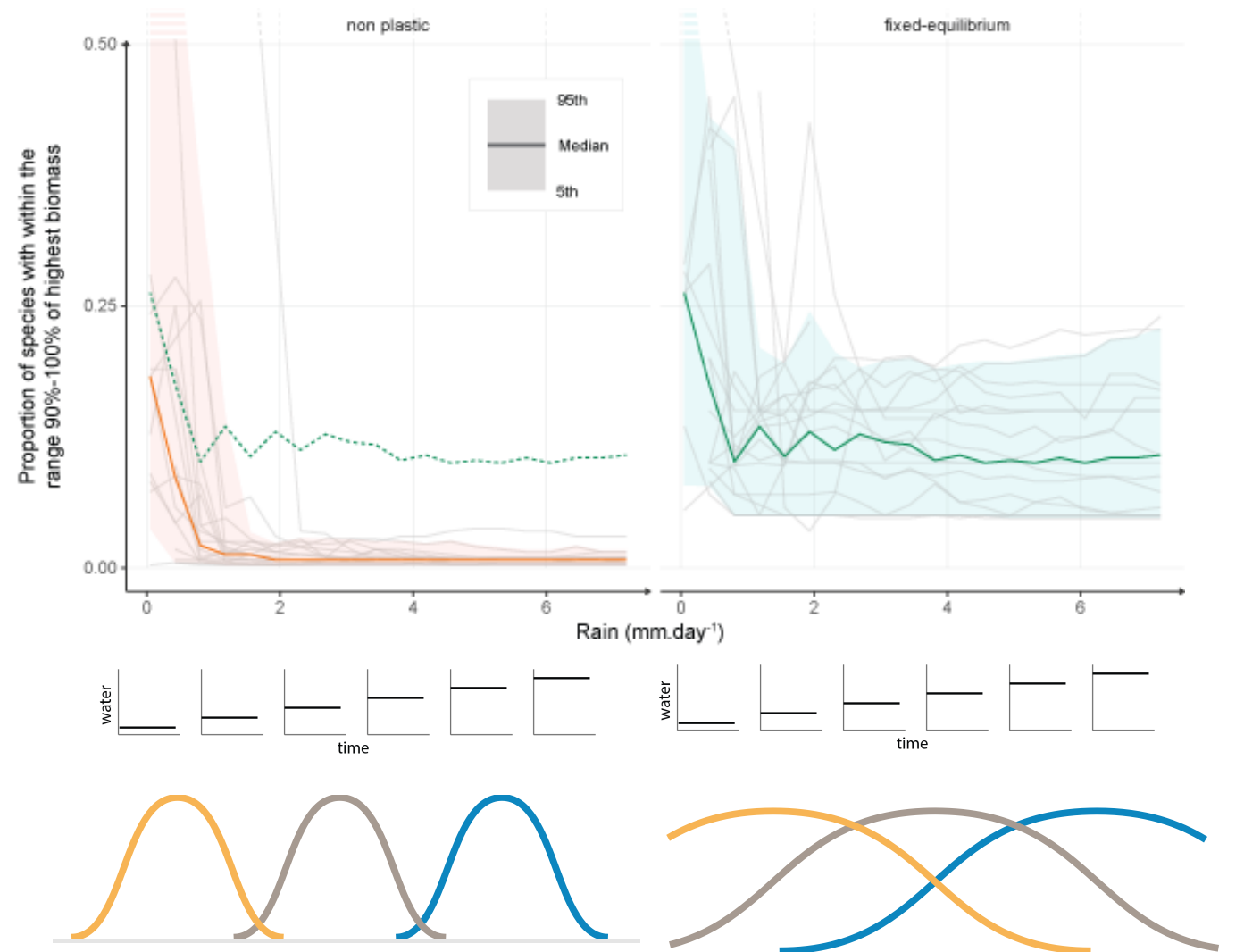


Plasticity effect in homogeneous conditions

- Reduction of growth differences

→ Niche widening

Proportion of species with high performances along a water availability gradient

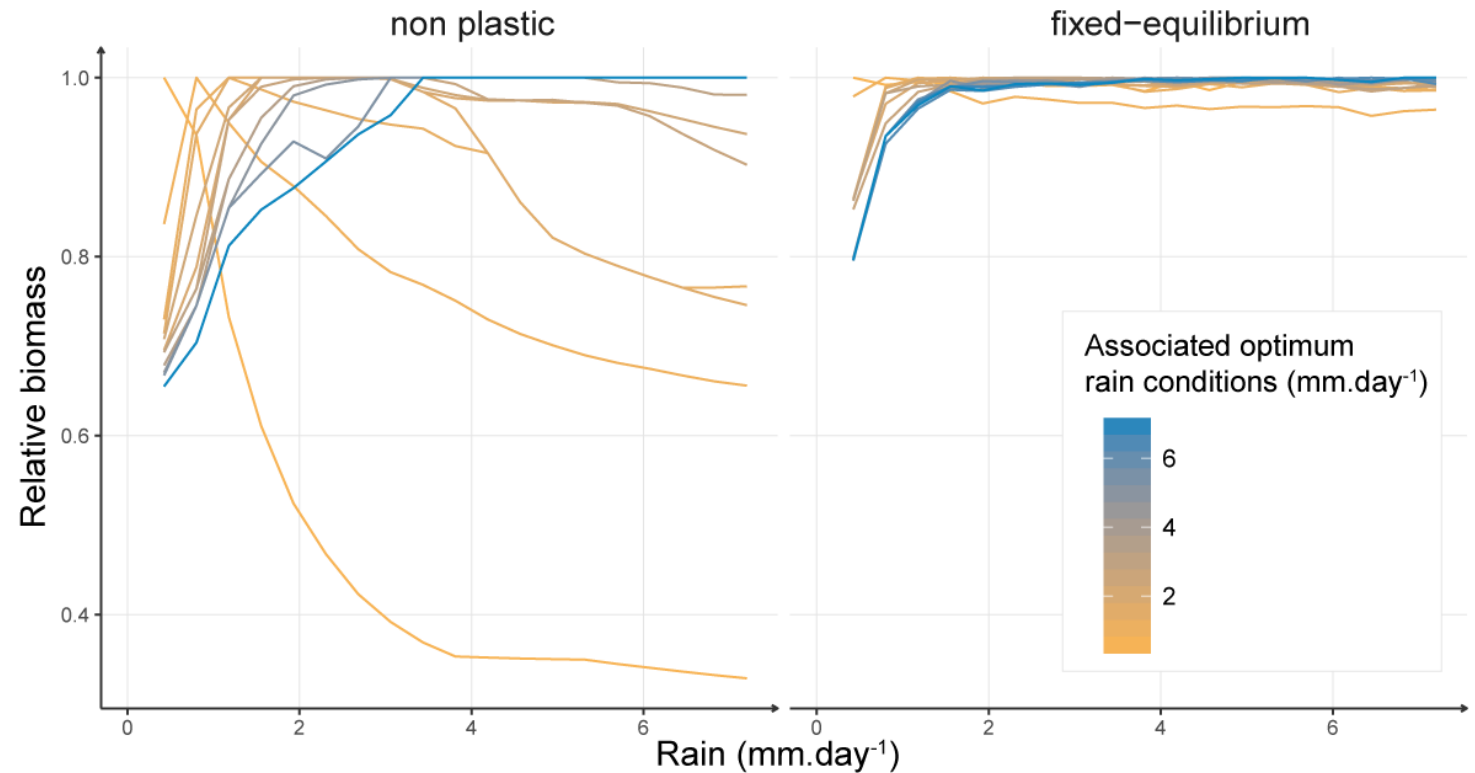


Niche widening in homogeneous conditions

Plasticity

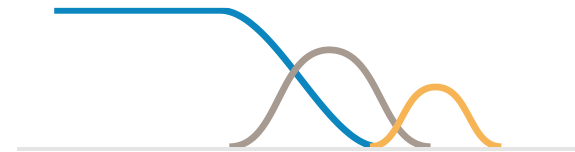
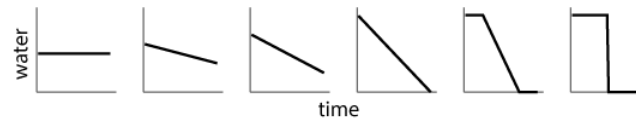
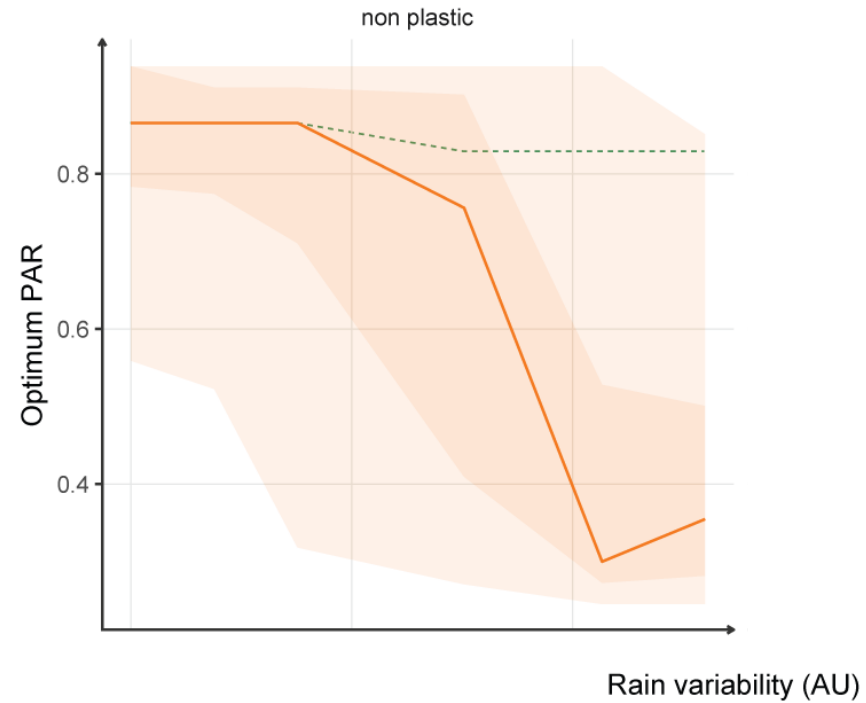
→ increases relative biomass in **non optimum** conditions

Potential niche of best species



Plasticity effect in heterogeneous conditions

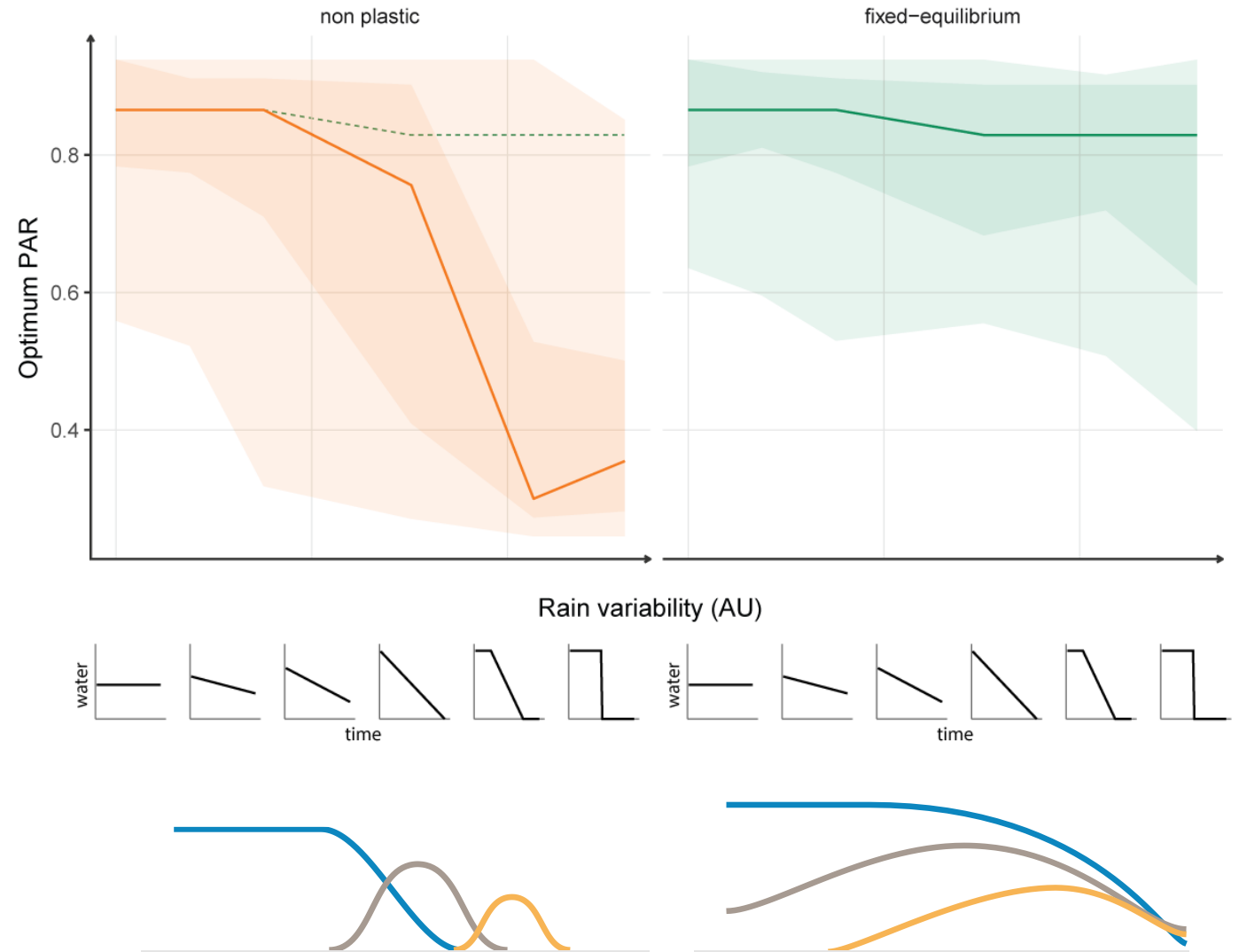
Optimum strategy along a water variability gradient



Plasticity effect in heterogeneous conditions

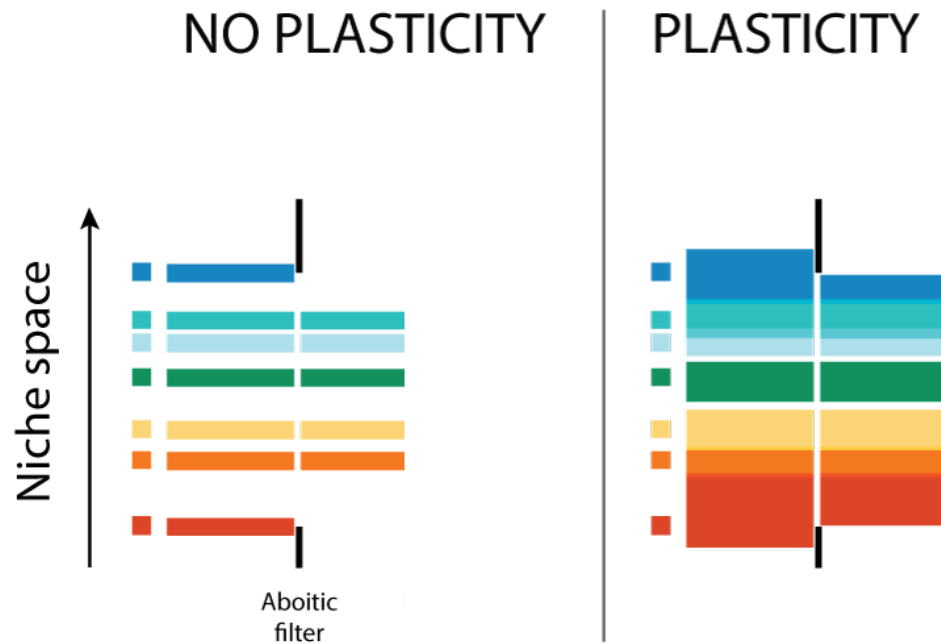
- Changes in dominant strategy in favour of exploitative species
 - Reduction of growth differences
 - Increase of relative BM
- Asymmetric gain
(+ exploitative strategies)
- Niche widening

Optimum strategy along a water variability gradient



Consequences at the community level ?

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



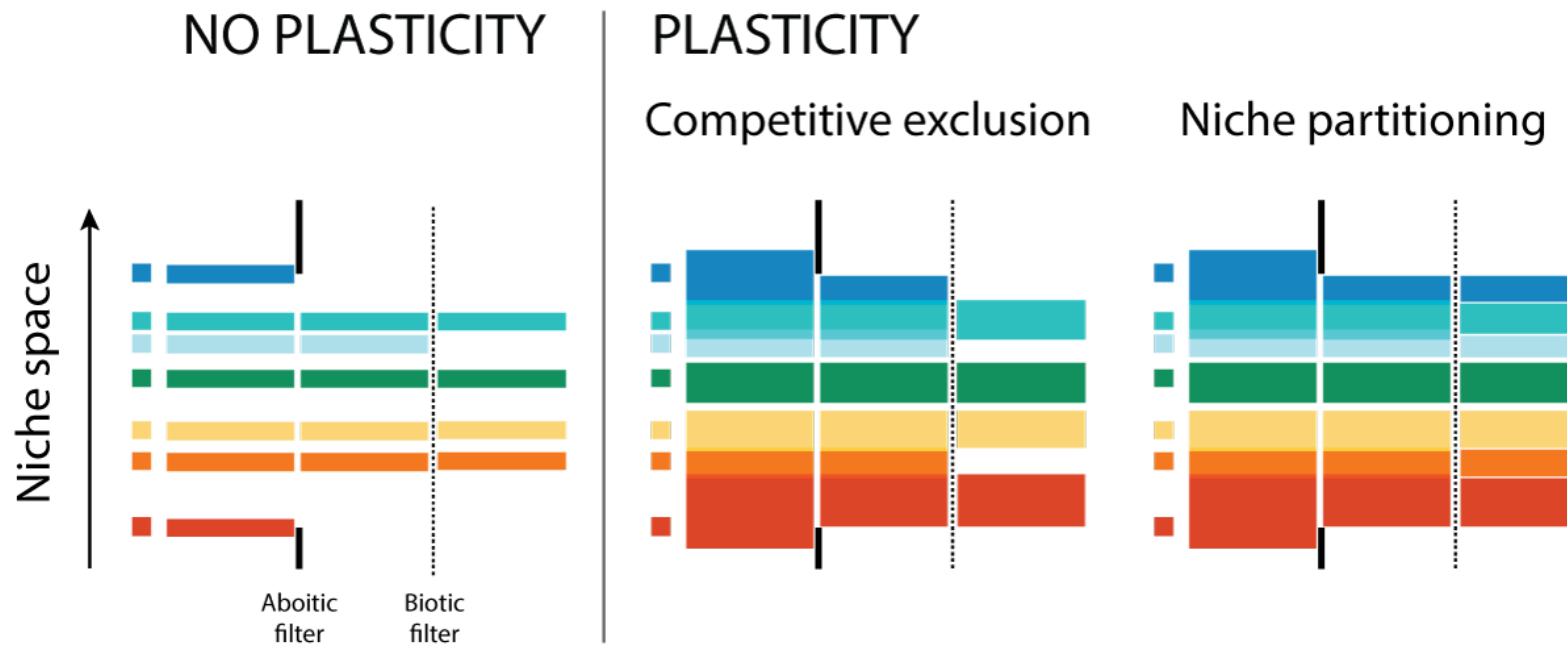
Consequences at the community level ?

Niche widening = reduction of abiotic filtering

- higher potential species diversity

Asymmetric gain

- Competitive exclusion by exploitative species?





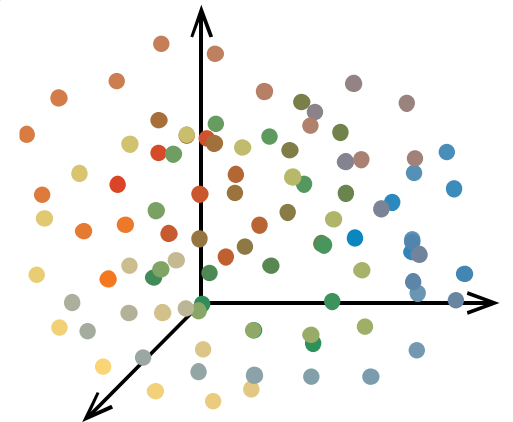
100*100cm plots

6 sites: variable T° , prec. & irradiance

Community-level simulations

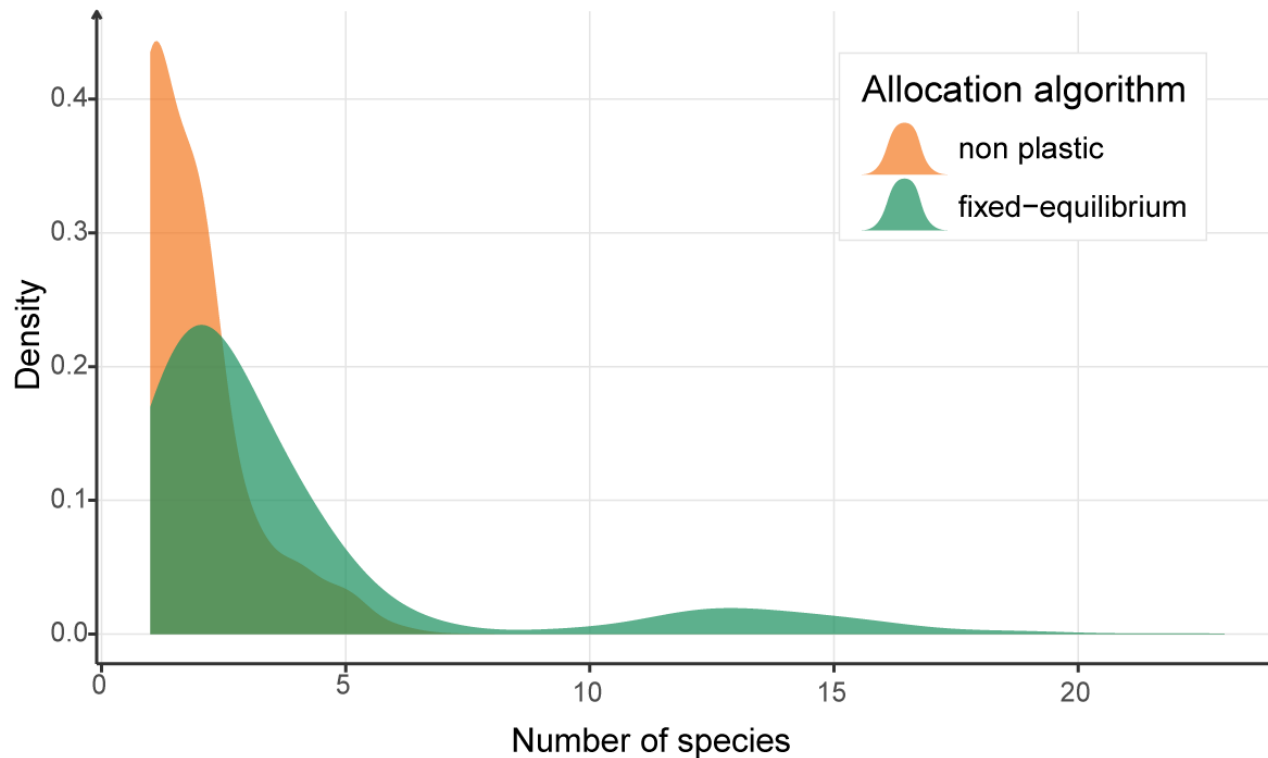
Real conditions of **variability** (weather data for 6 sites) + **explicit competitive interactions**

- 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



Effects of plasticity on species diversity

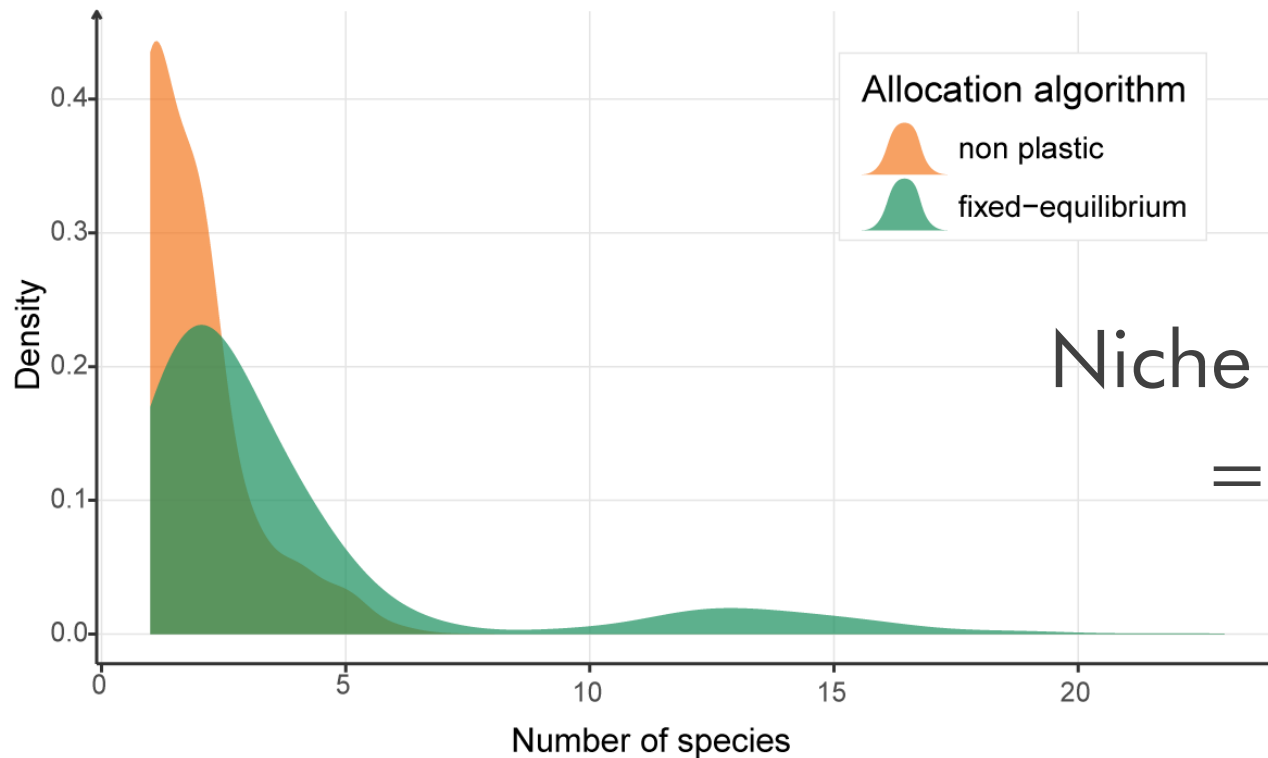
Distribution of species diversities of simulated communities



Higher species diversity

Effects of plasticity on species diversity

Distribution of species diversities of simulated communities

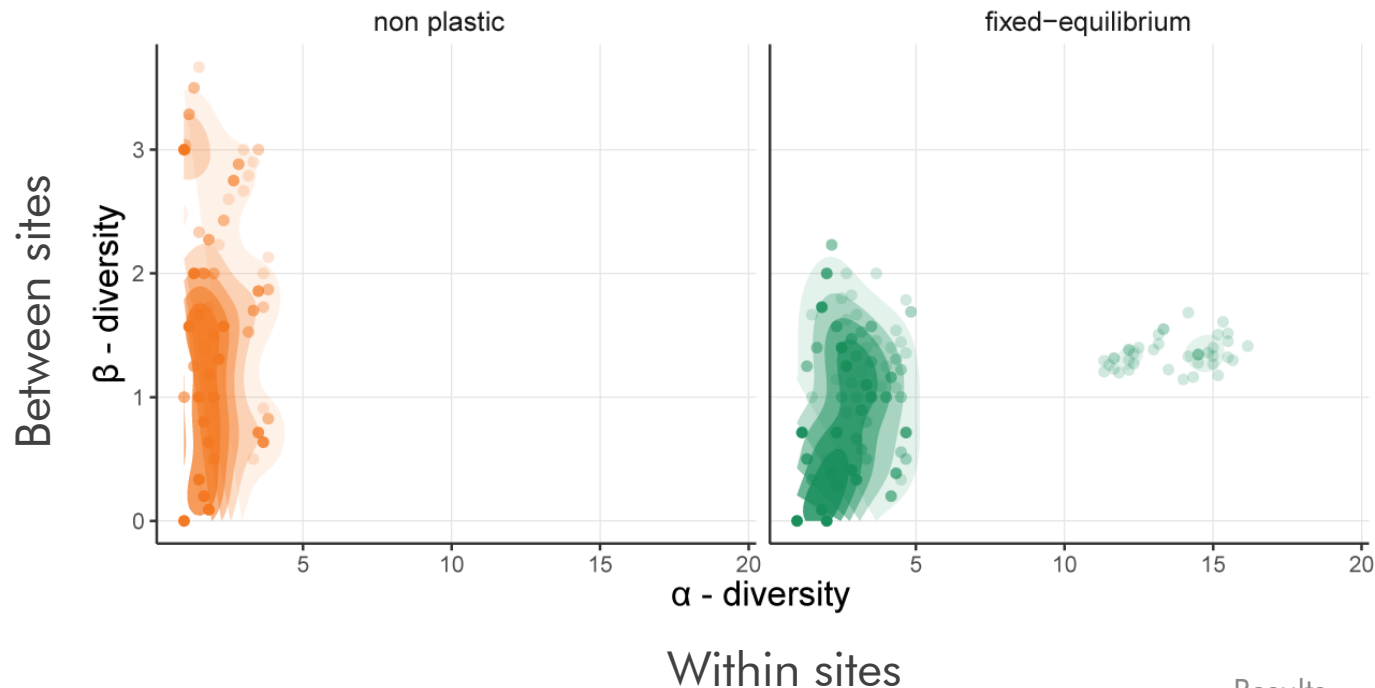


Higher species diversity

Niche widening $>$ asymmetric gain
= better niche partitioning

A shift in meta-community structure?

Species diversity structure

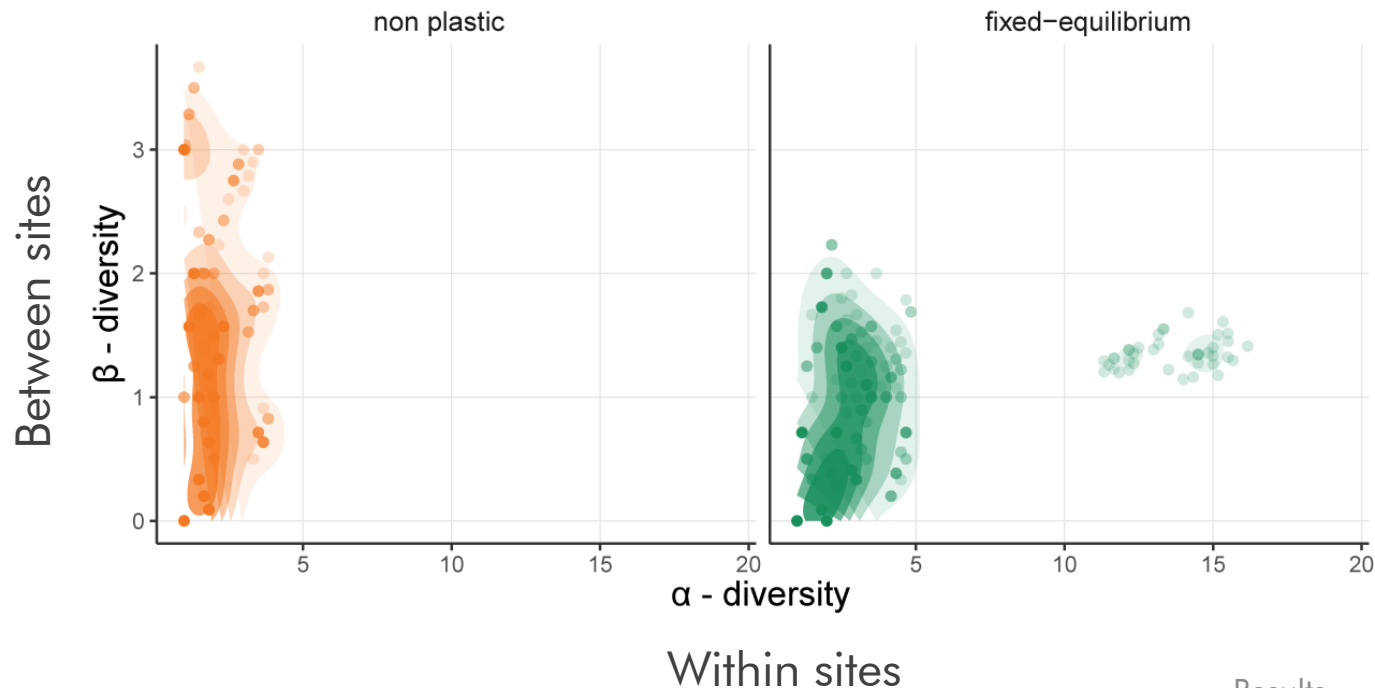


- Shift in diversity structure:
- Less distinct site communities
 - Richer site communities

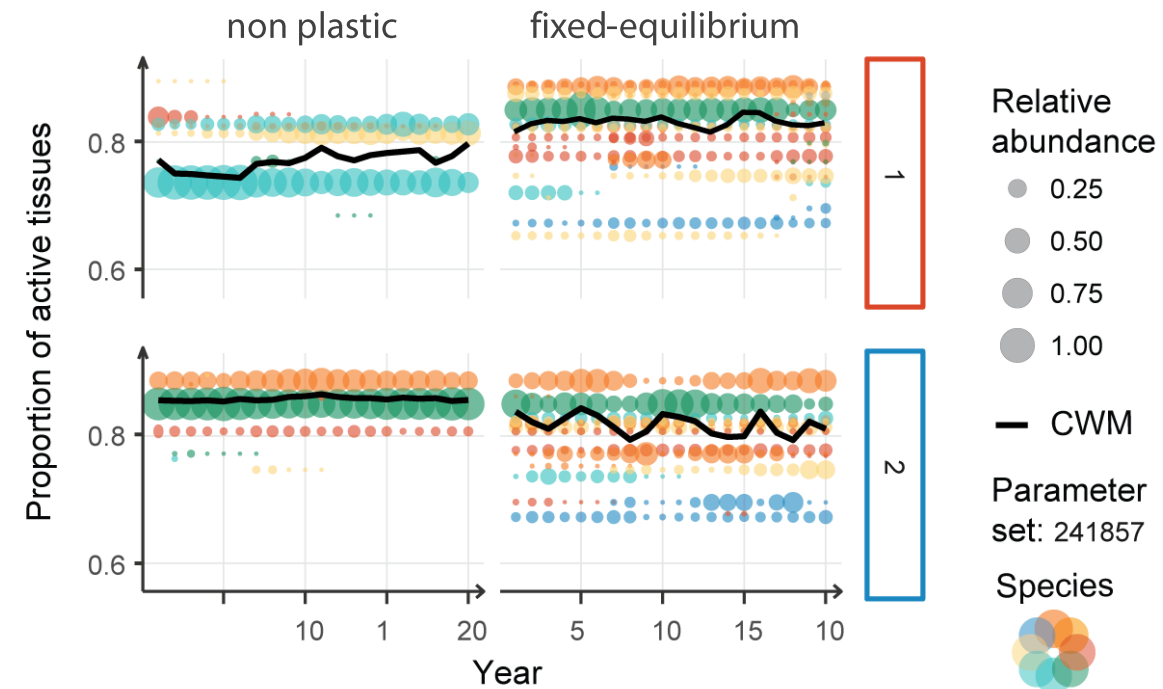
A shift in meta-community structure

More species → abundance variations but no composition shifts

Species diversity structure

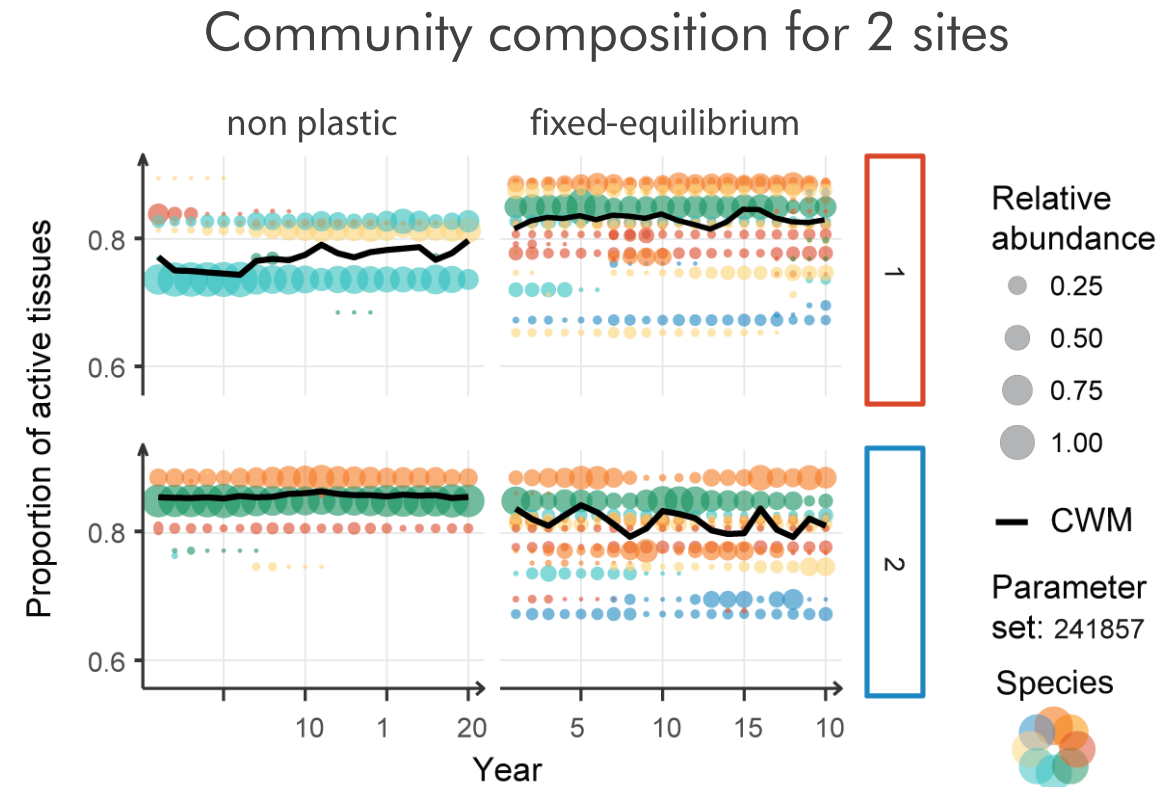
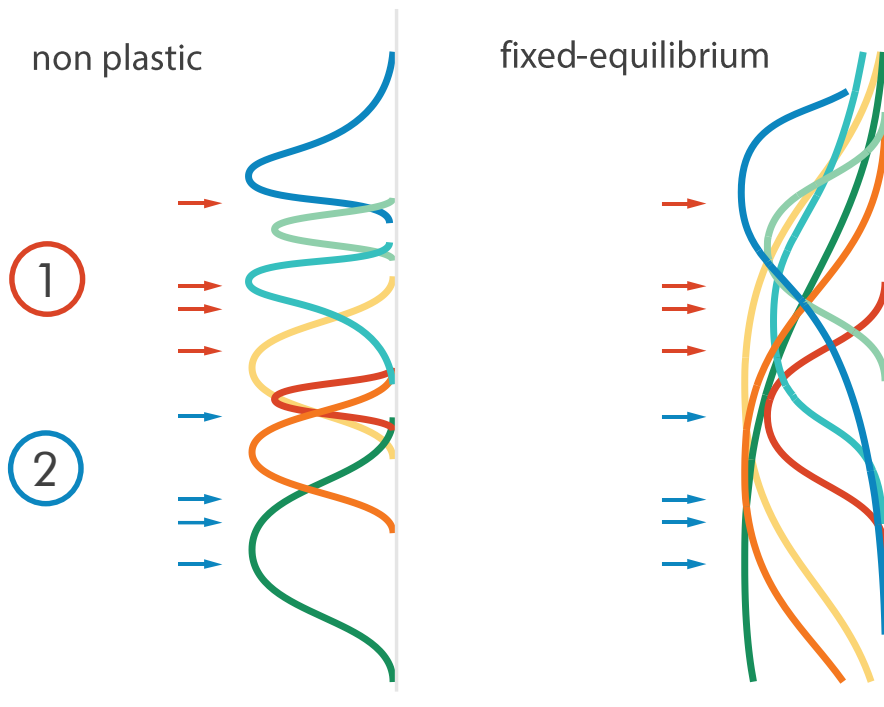


Community composition for 2 sites



A shift in meta-community structure

More species → abundance variations but no composition shifts



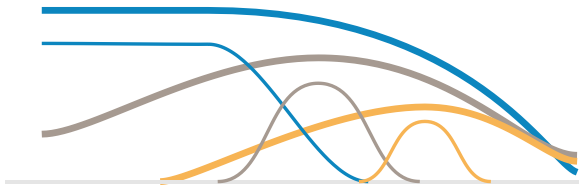
Results summary

Niche widening



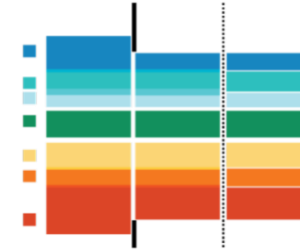
Availability gradient

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

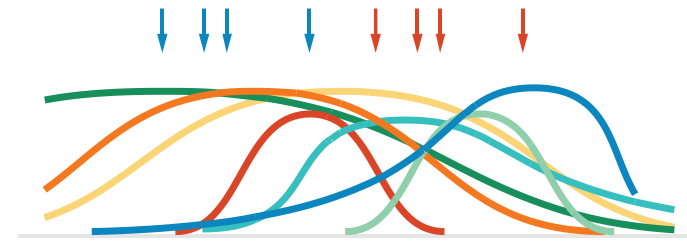


Variability gradient

Niche widening $>$ asymmetric gain



Plasticity alters meta-community
structure





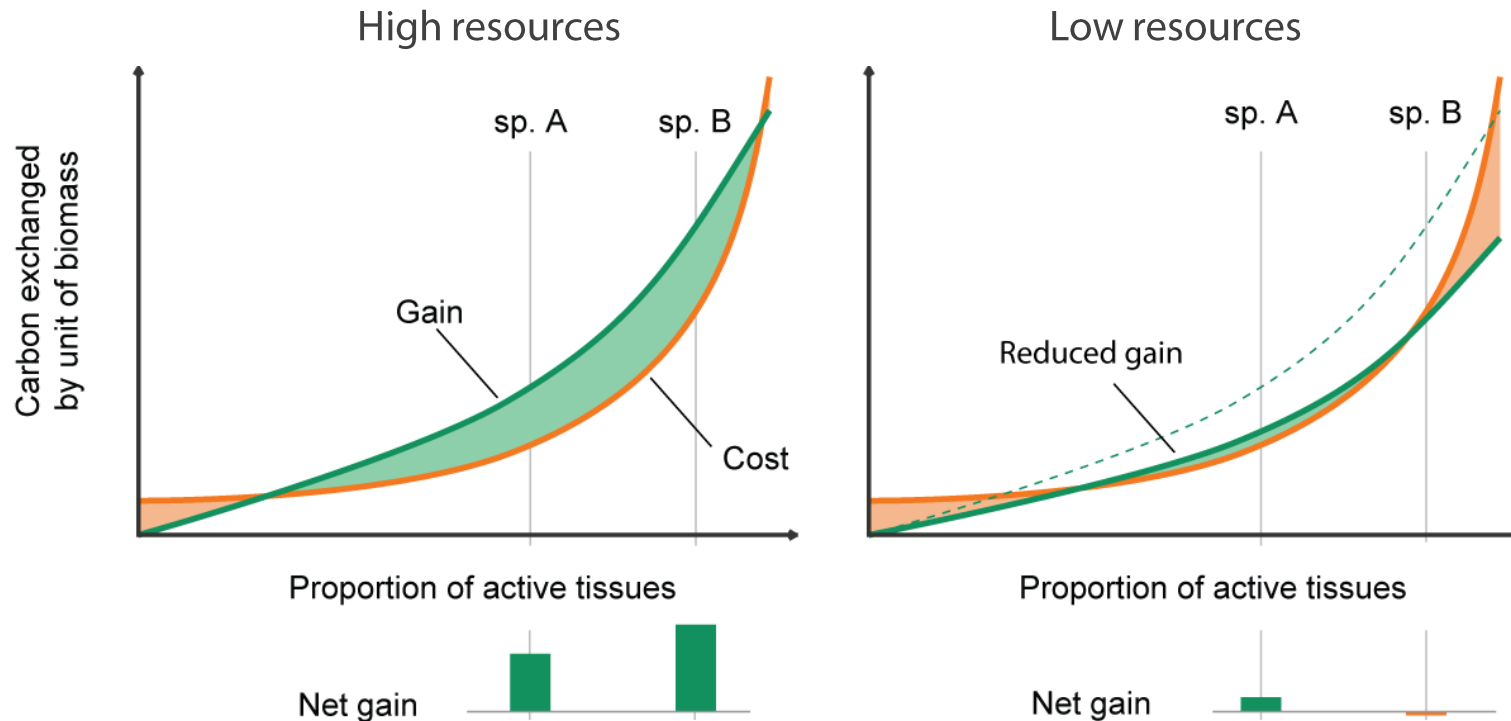
4

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 exchange 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:

- new niche axis;
- asymmetric;

Frost & grazing



Dialogue between models & empirical experiments

MODEL

Plasticity as a structuring process

Experiment with multiple scenarios

Plasticity as a trait

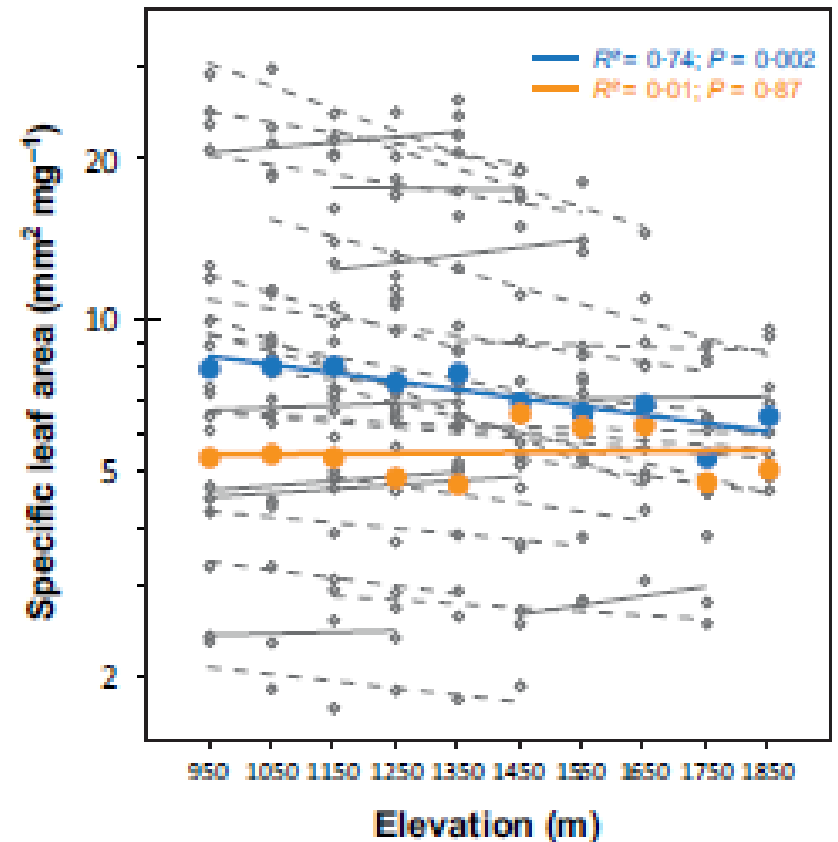
EMPIRICAL

Plastic dimensions & responses

Cost of plasticity

Phenotypic flexibility

Mean specific trait along an elevation gradient





Conclusions & Outlook

A consistent framework for a better understanding of plasticity

Modelling conclusions:

A diverse community framework

Diversity in strategies & species

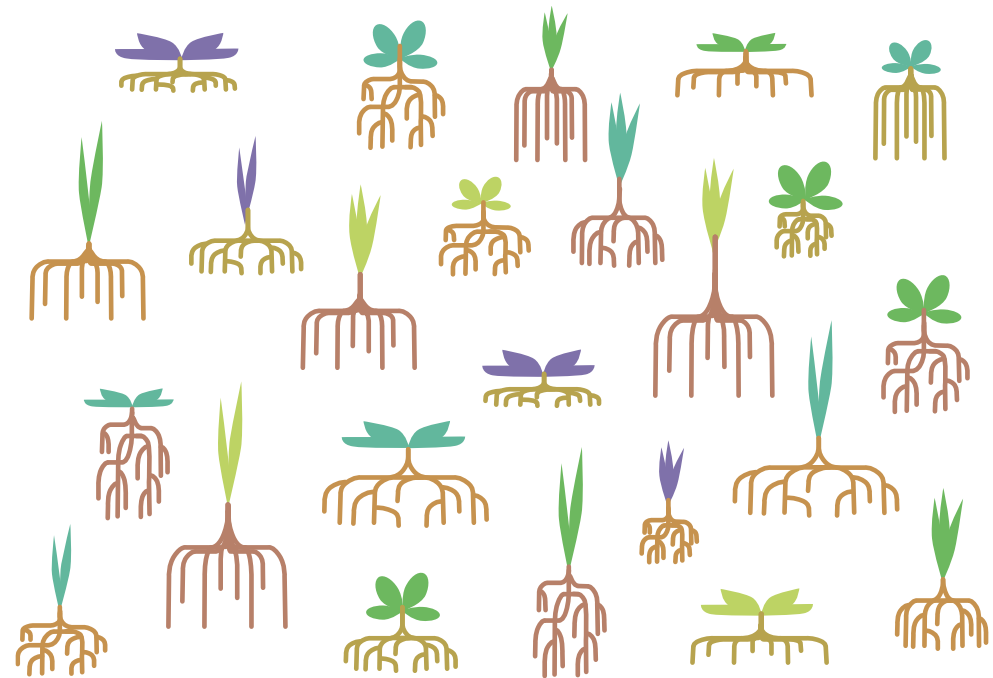
Plasticity in coherent framework

Plasticity as a strategy (not explored)

but...

Reduce the number of parameter sets & stabilise the species

High functional convergence



Ecological conclusions:

A better understanding 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, asymmetric gain favours certain strategies)

To go beyond

Better calibration and strategy sampling to confirm results

Climat, management and perturbation scenarios

Explore the plasticity as a strategy



Thank you!



Merci pour votre attention.

Et merci pour l'accueil, l'aide, les rires, les discussions, les explications, les encouragements, les sorties terrains, les relectures, les photos, les pauses, les blagues, la motivation, le soutien, les distractions, les présentations, les pots, les mots gentils...

Merci !

Bonus!



