

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

Ph.D. defence of

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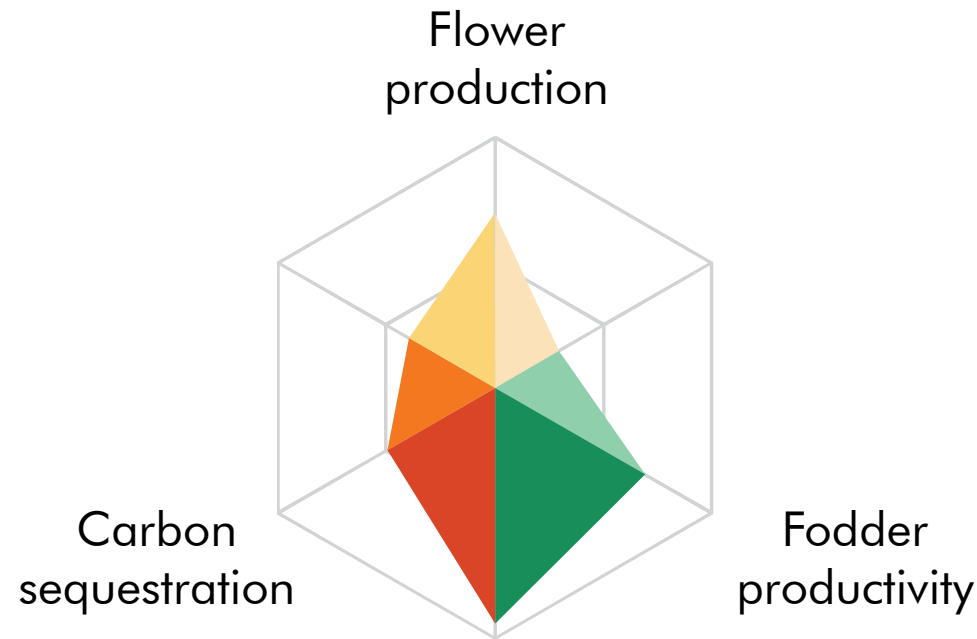
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# Introduction

From context to questions

# Mountain grasslands provide services

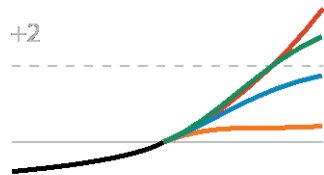


Various and depends on the properties of the community shape by environmental drivers

# Assessing grassland ecosystem services



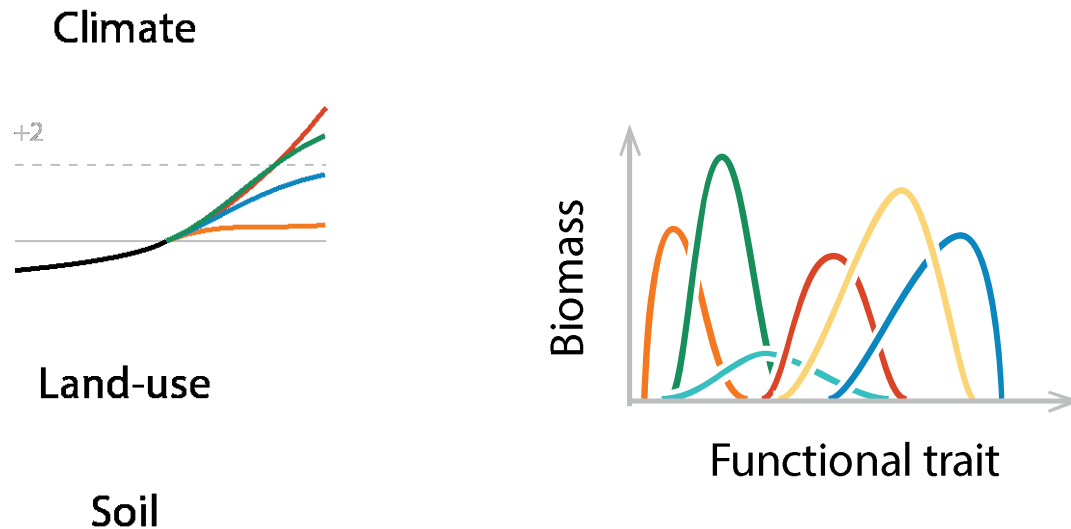
Climate



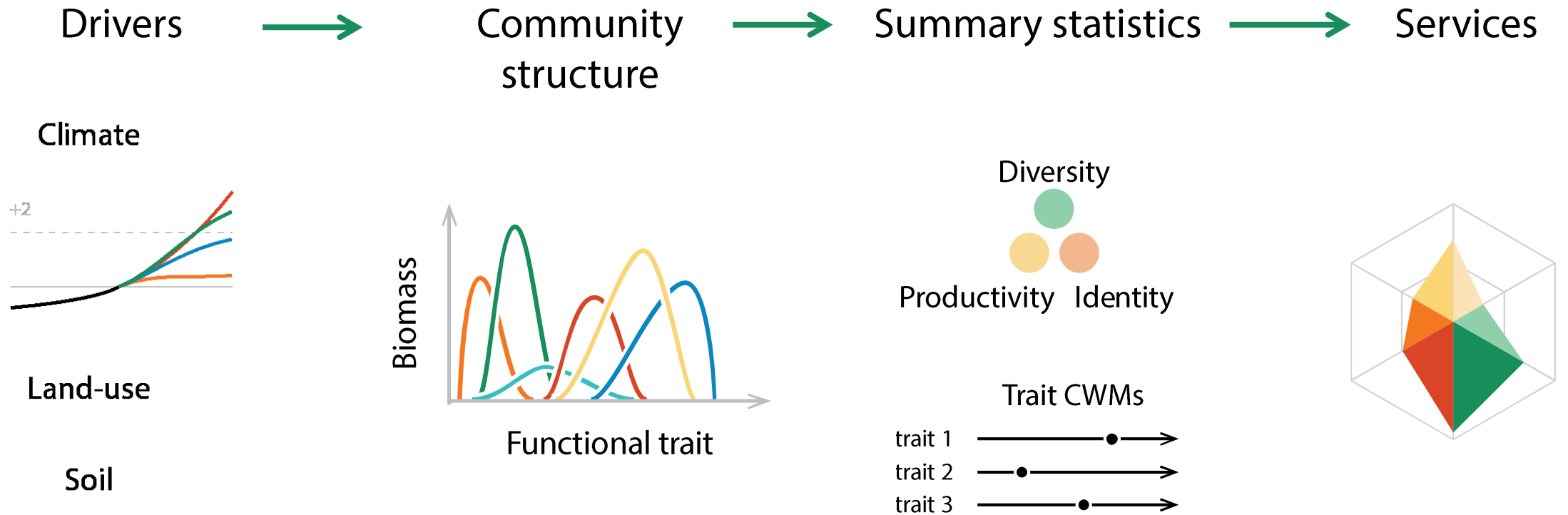
Land-use

Soil

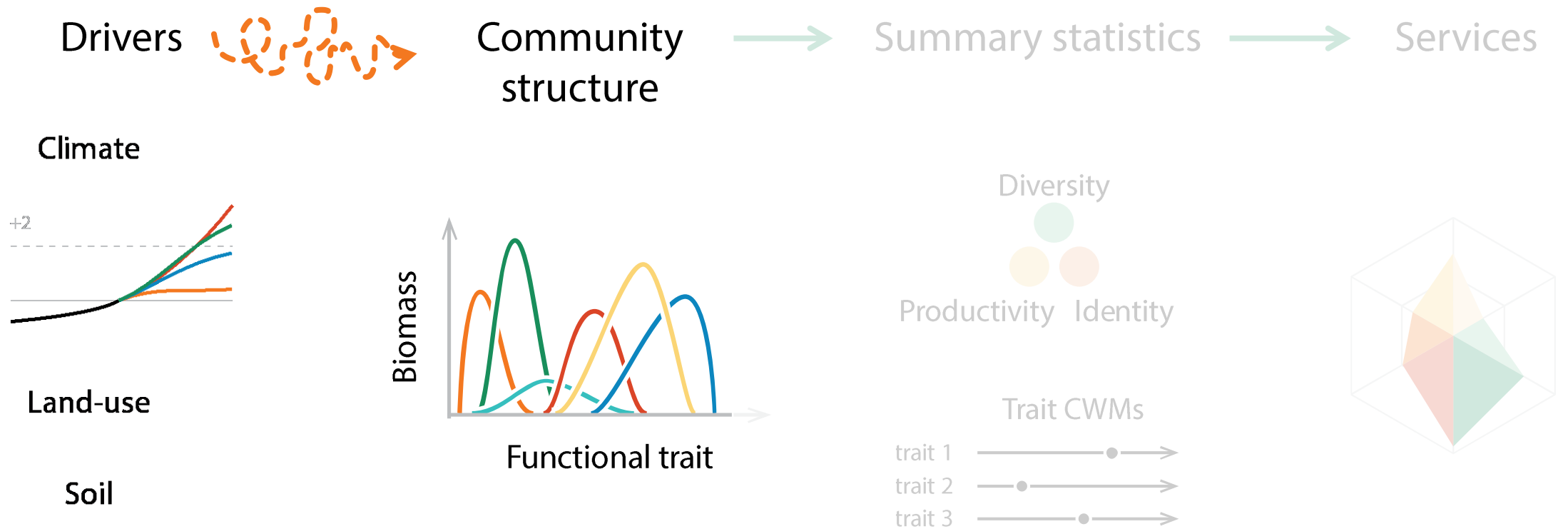
# Assessing grassland ecosystem services



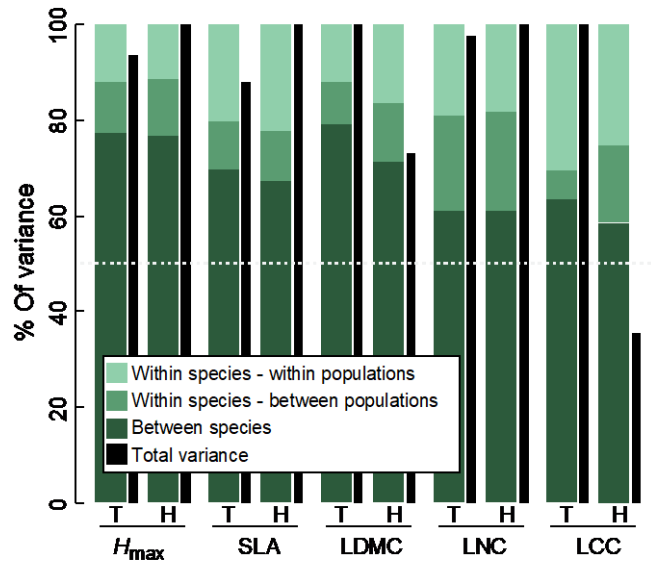
# Assessing grassland ecosystem services



# Assessing grassland ecosystem services

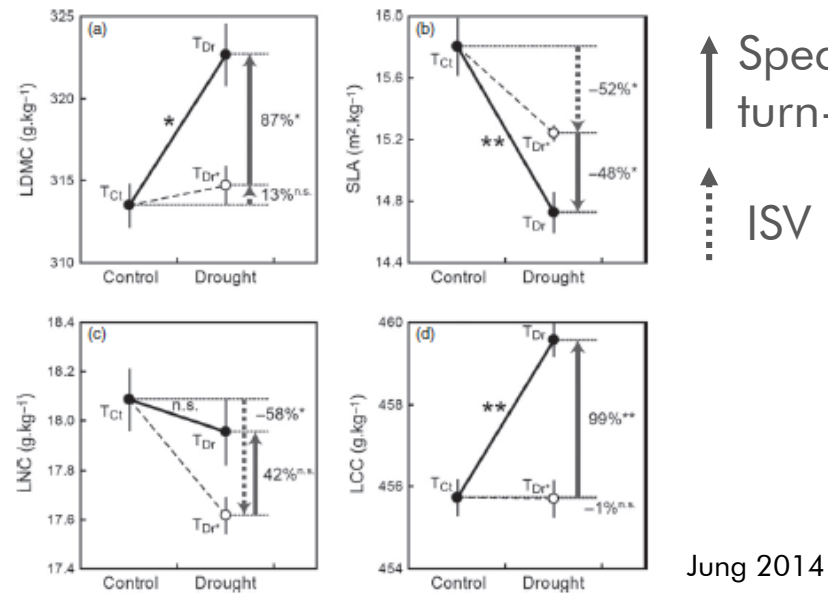


# Intra-specific variability matters and impacts the community responses



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

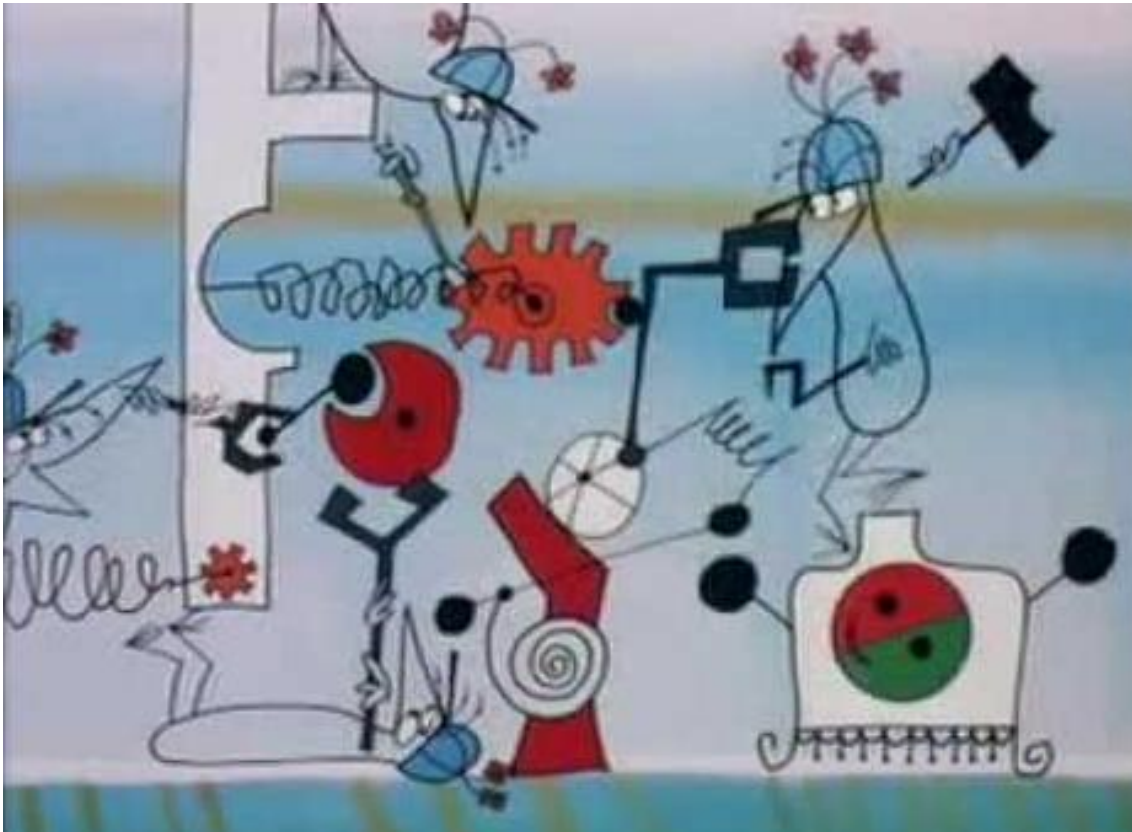


Phenotypic  
plasticity

Rapid response to driver  
variations

Often overlooked because  
hard to study in empirical  
experiments

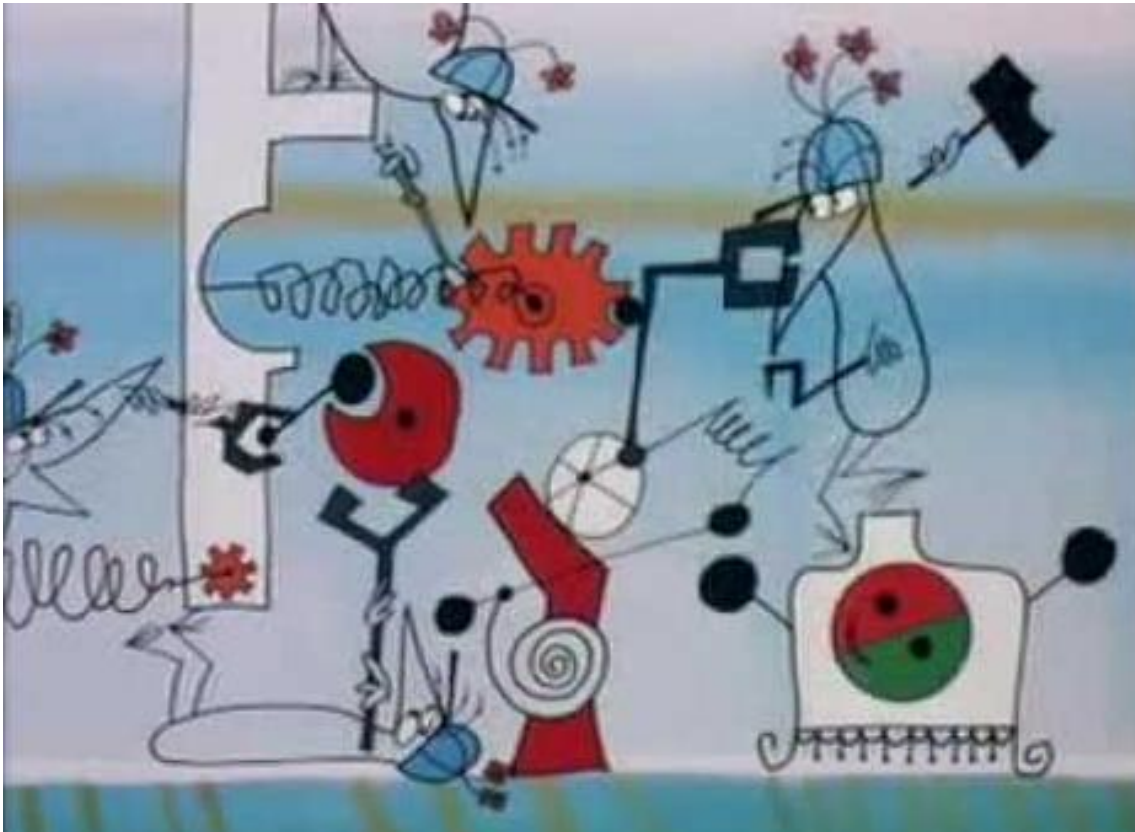
# Mechanistic models to understand



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?



# 2

# Concepts

From ecological concepts  
to the model *MountGrass*

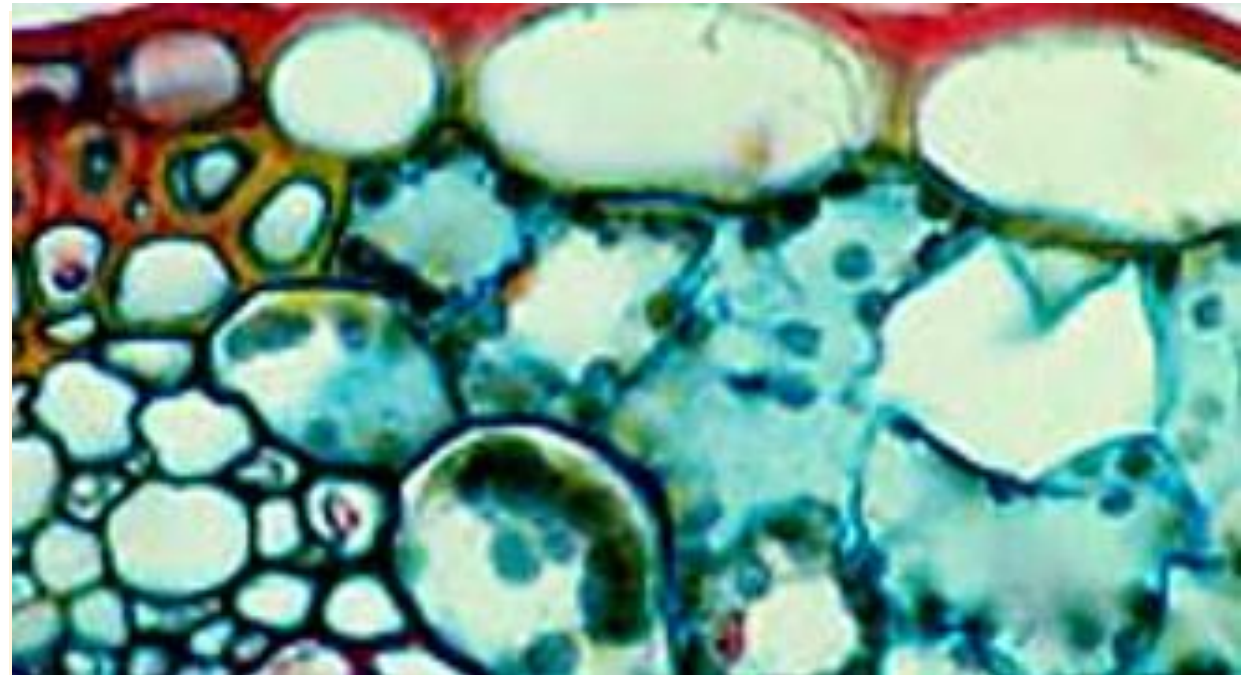




Niche and variability

Competition for resources

Strategy trade-offs





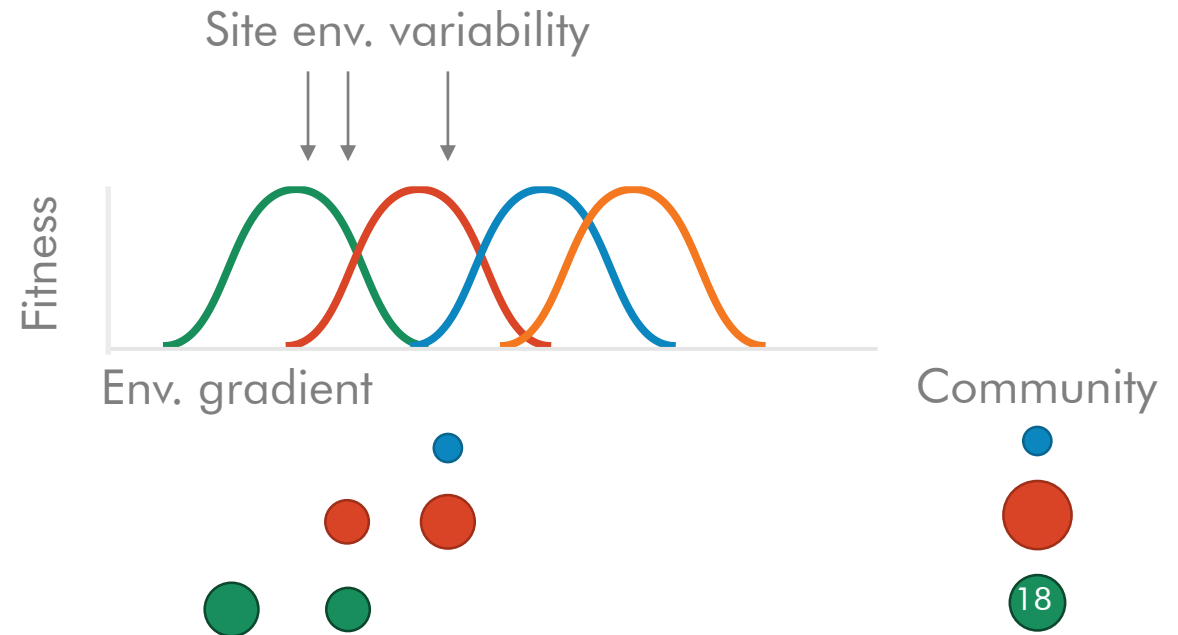


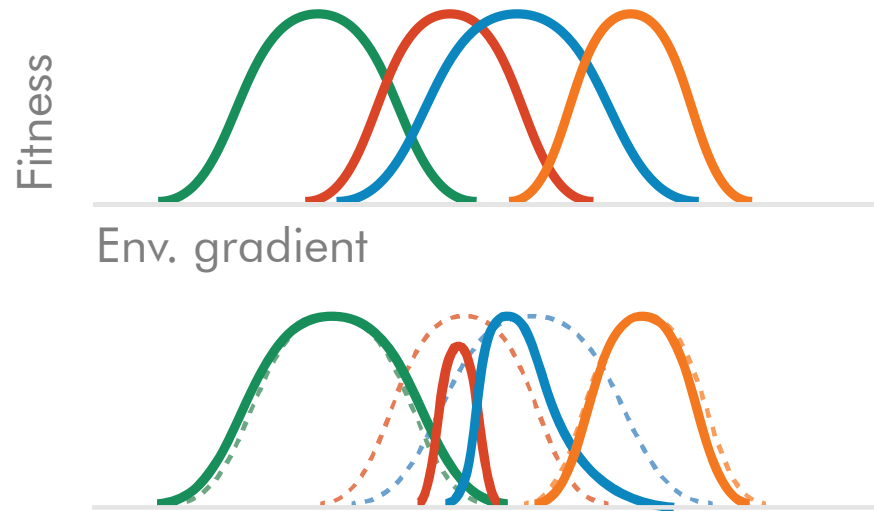
# Niche & variability

Fit of a species under specific  
environmental conditions

Variability promotes coexistence

True for spatial and temporal variability



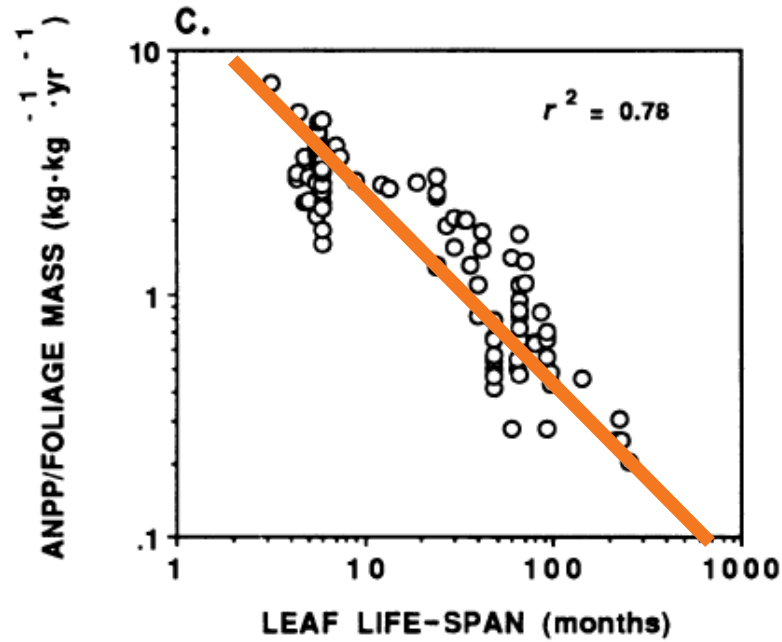


# Competition for resources



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

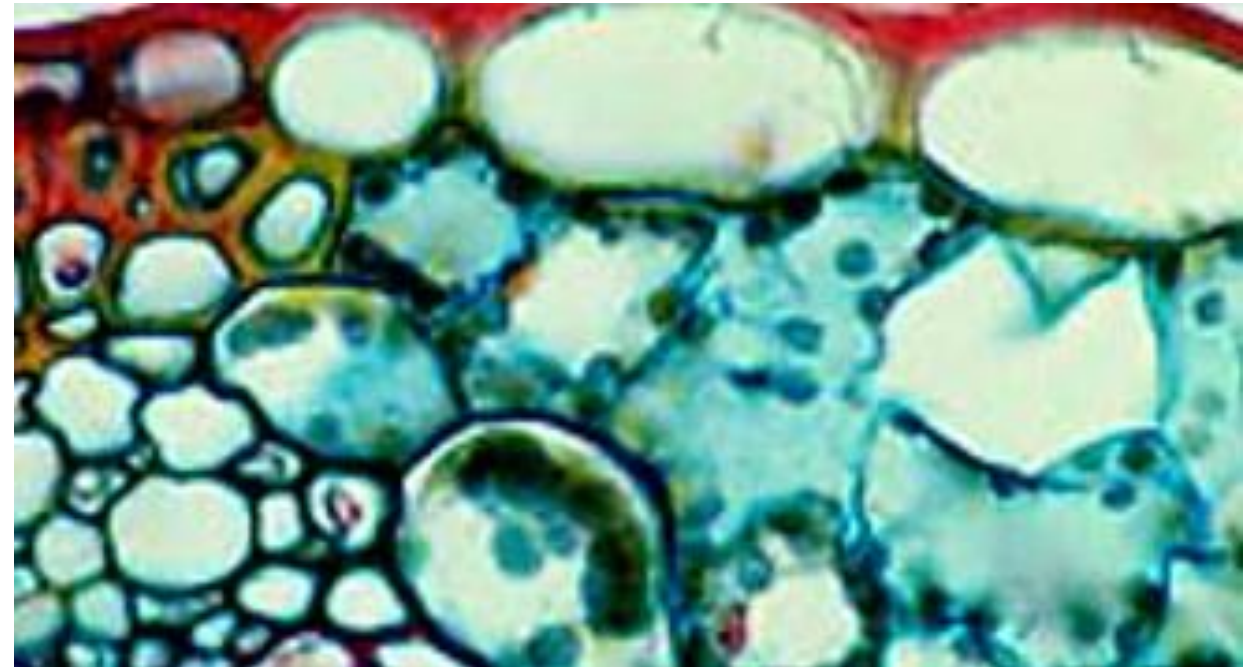
→ Dimension reduction

Continuum of plant strategies

Build a strategy space

Depends on allocation

P. Reich (1992)





# The model *MountGrass*

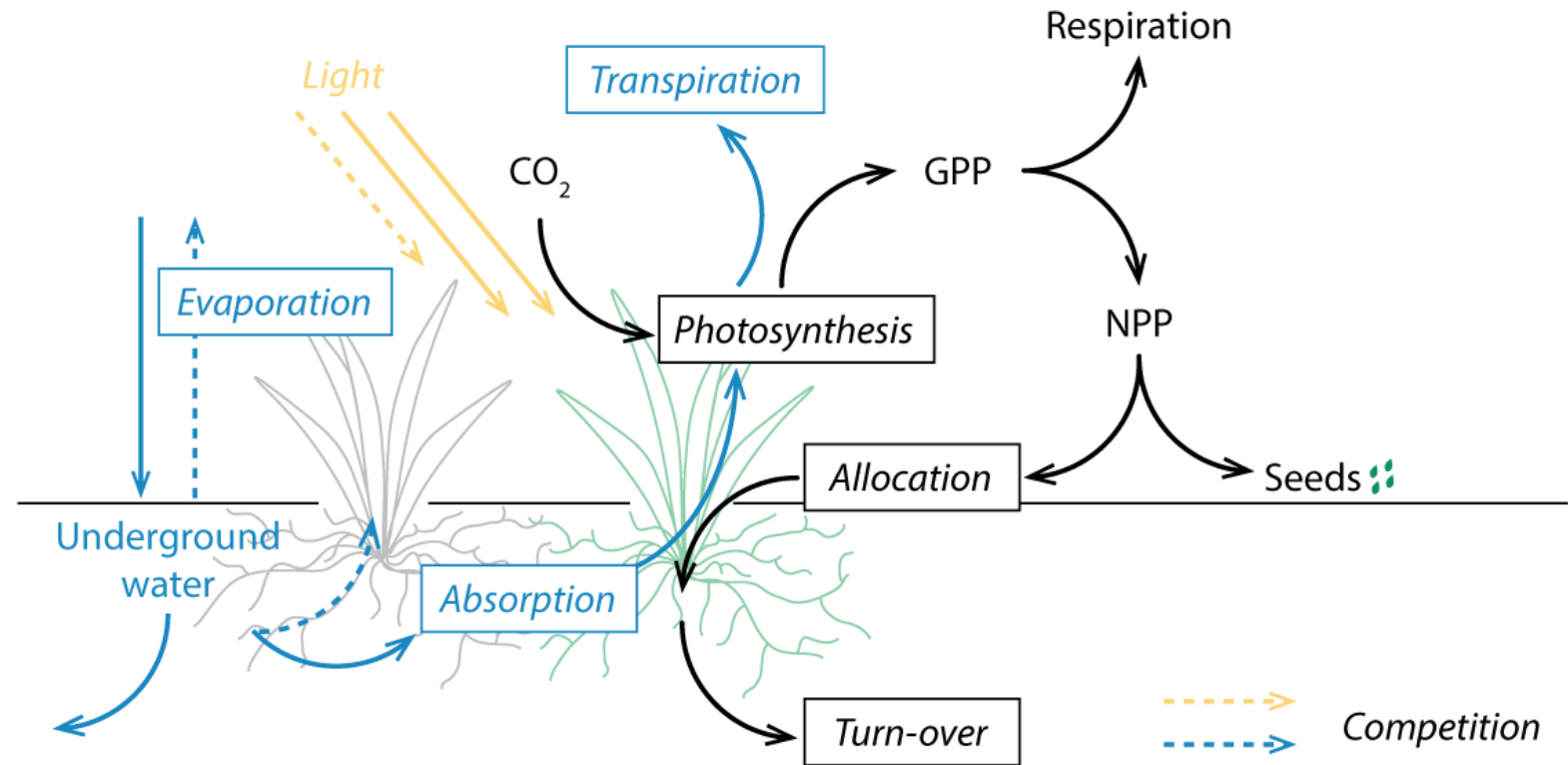


# MountGrass' processes

Response to drivers:  
physiological processes.

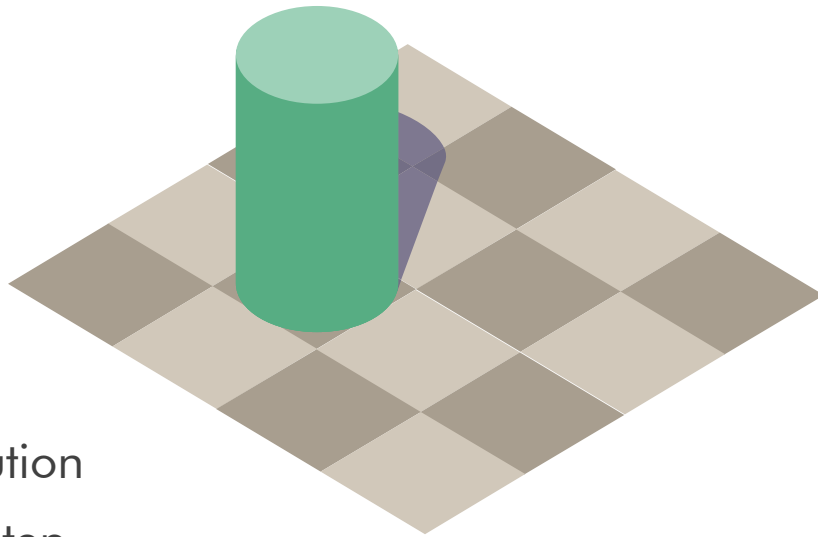
Above and belowground  
competition: light and  
water cycles.

Strategies: carbon  
allocation trade-offs.

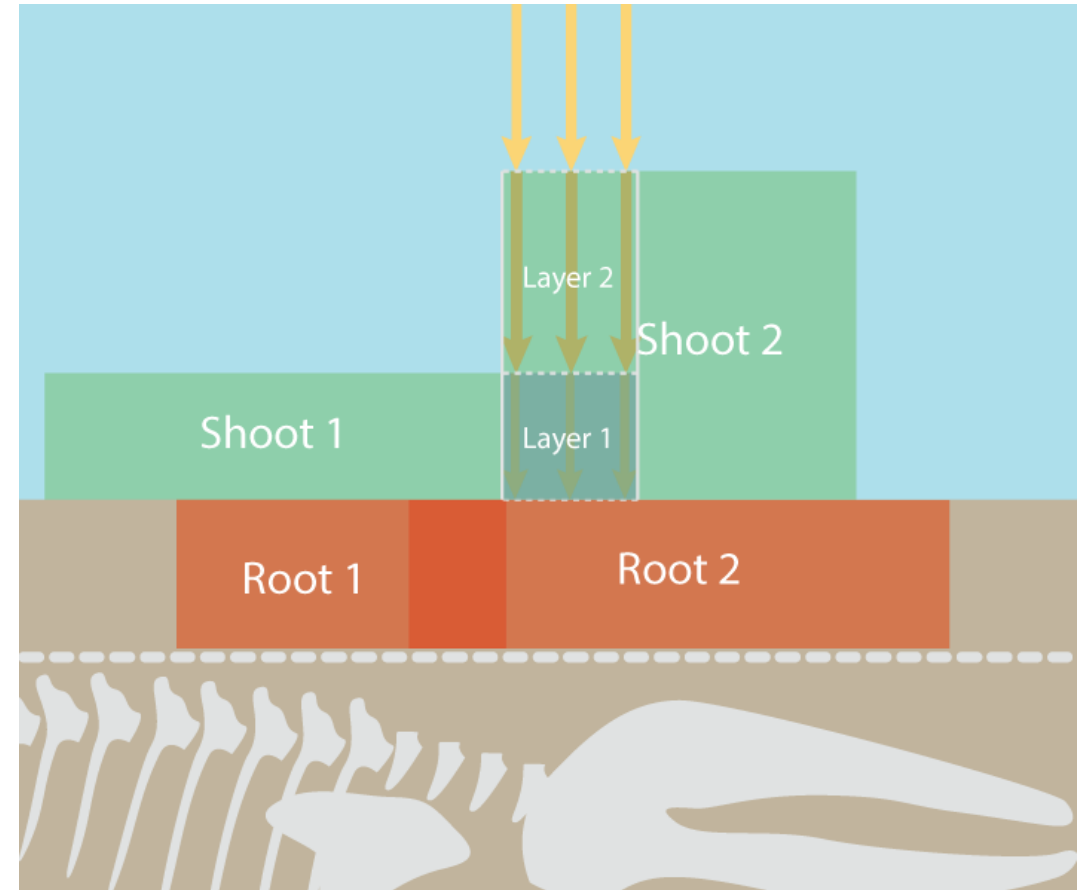


# Space & time: the individual plant scale

Individual-based model  
spatially explicit: explicit competition



1 cm resolution  
daily time-step



# Plant carbon pools and allocation trade-offs

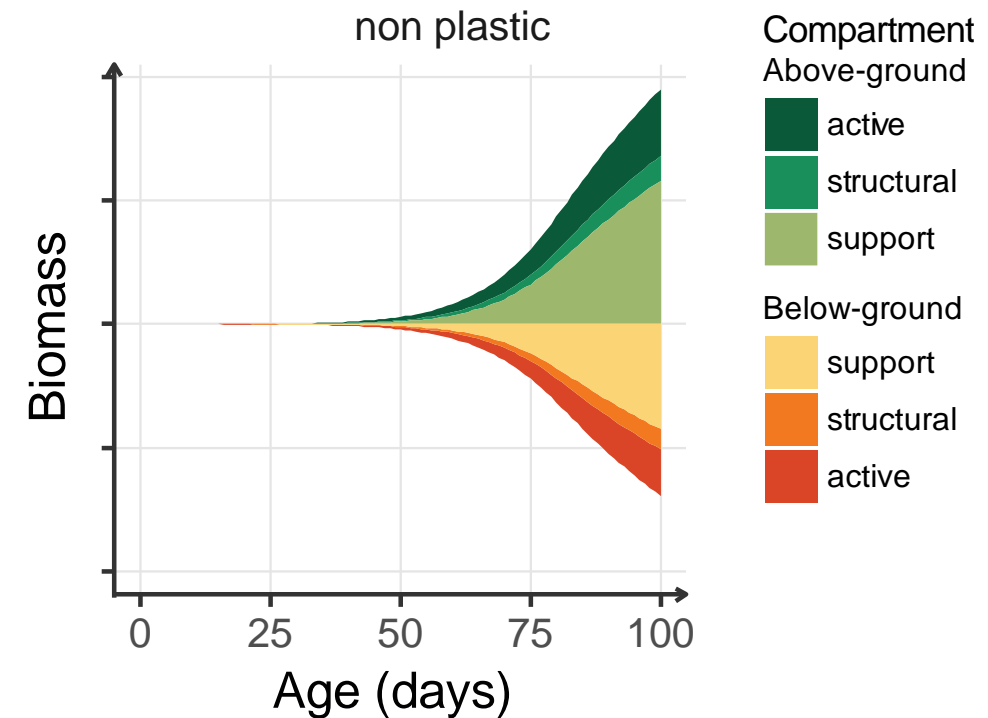
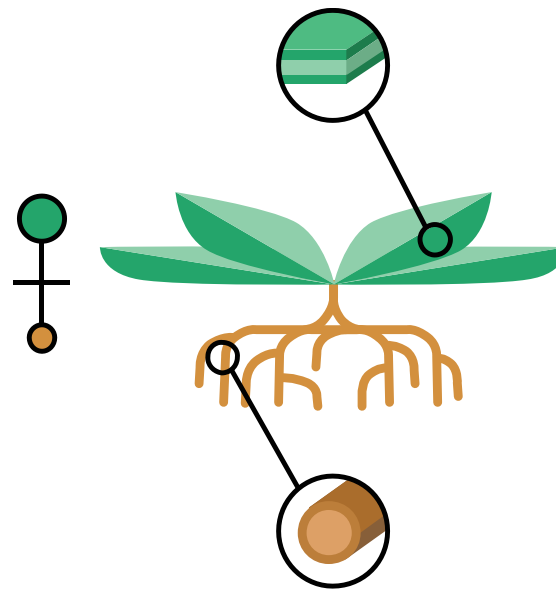
6 vegetative pools

3 dimensions:

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

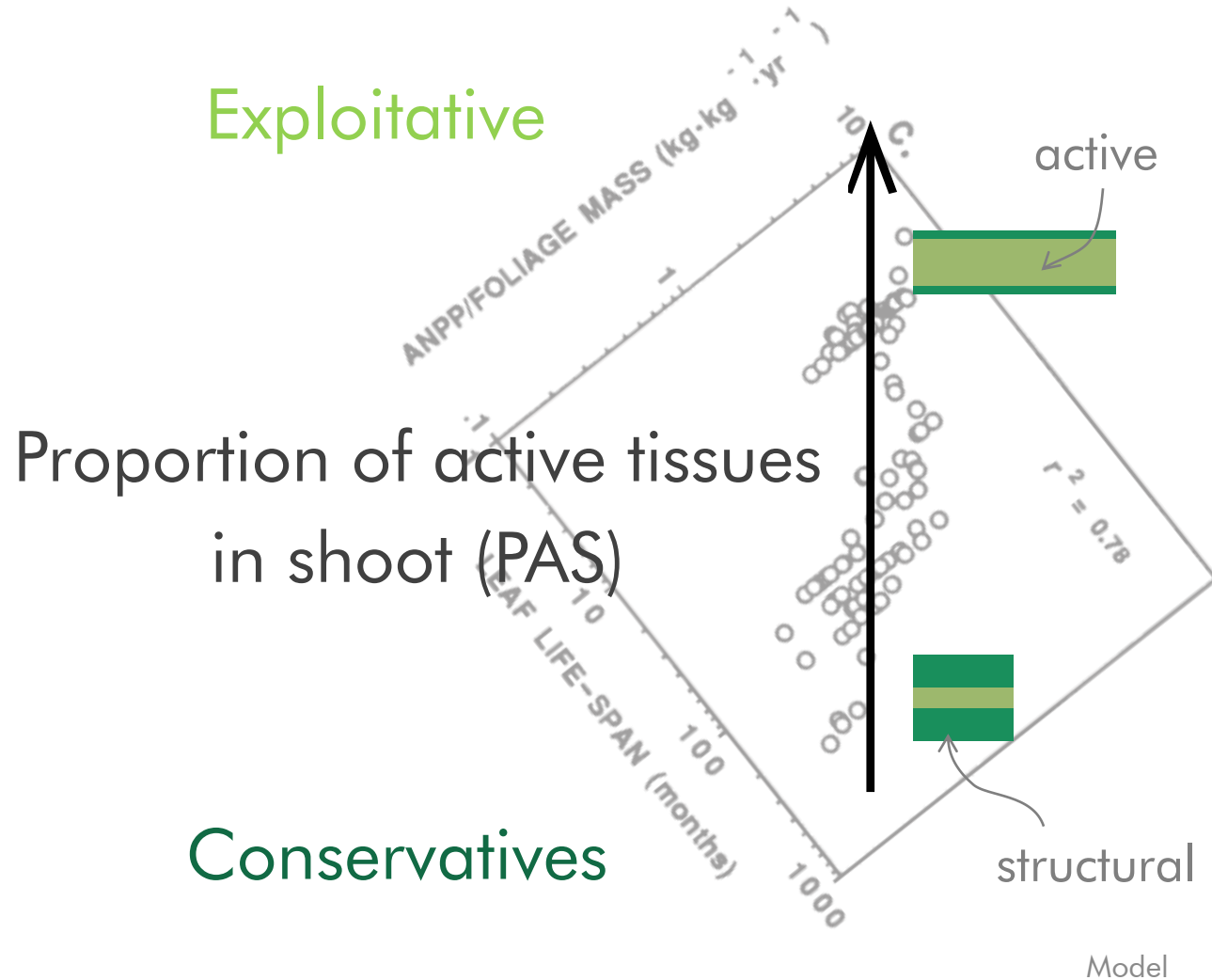
Allocation trade-offs

→ strategic trade-offs





# Allocation trade-off into strategic trade-off



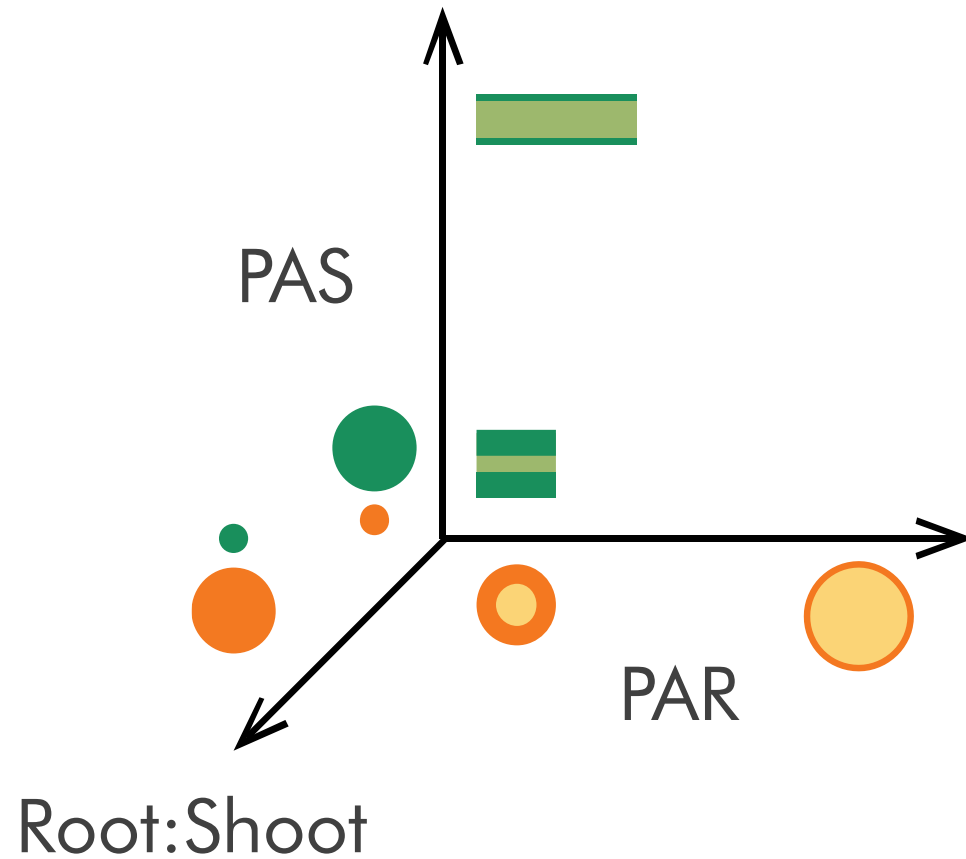
density

lifespan

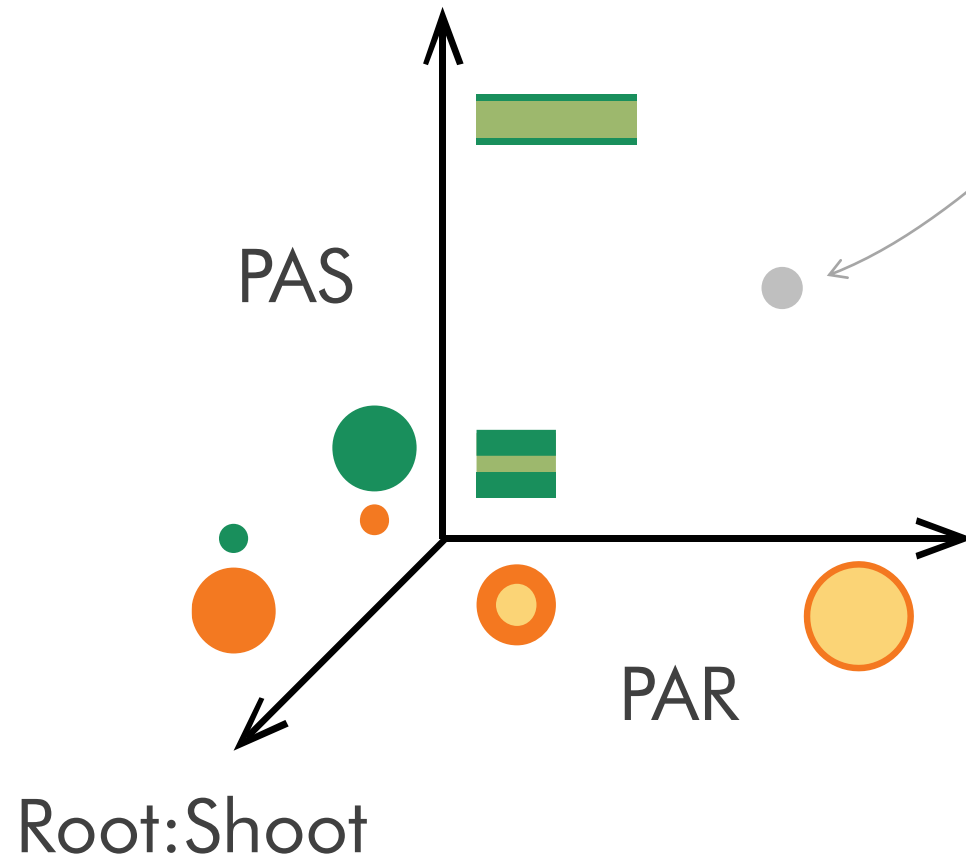
area  
biomass

respiration

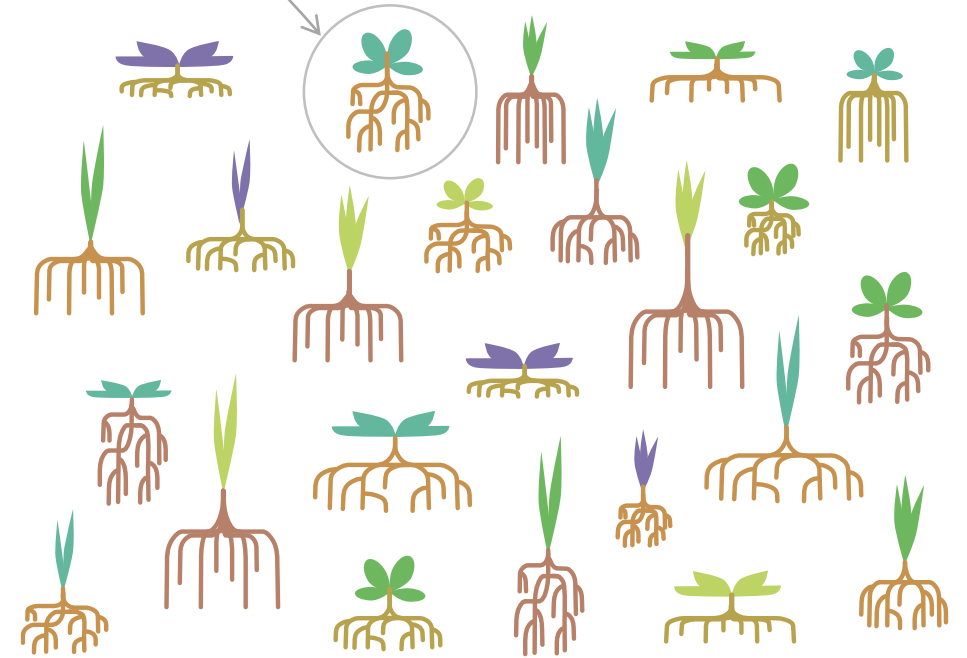
# Phenotypes and strategies



# Phenotypes and strategies

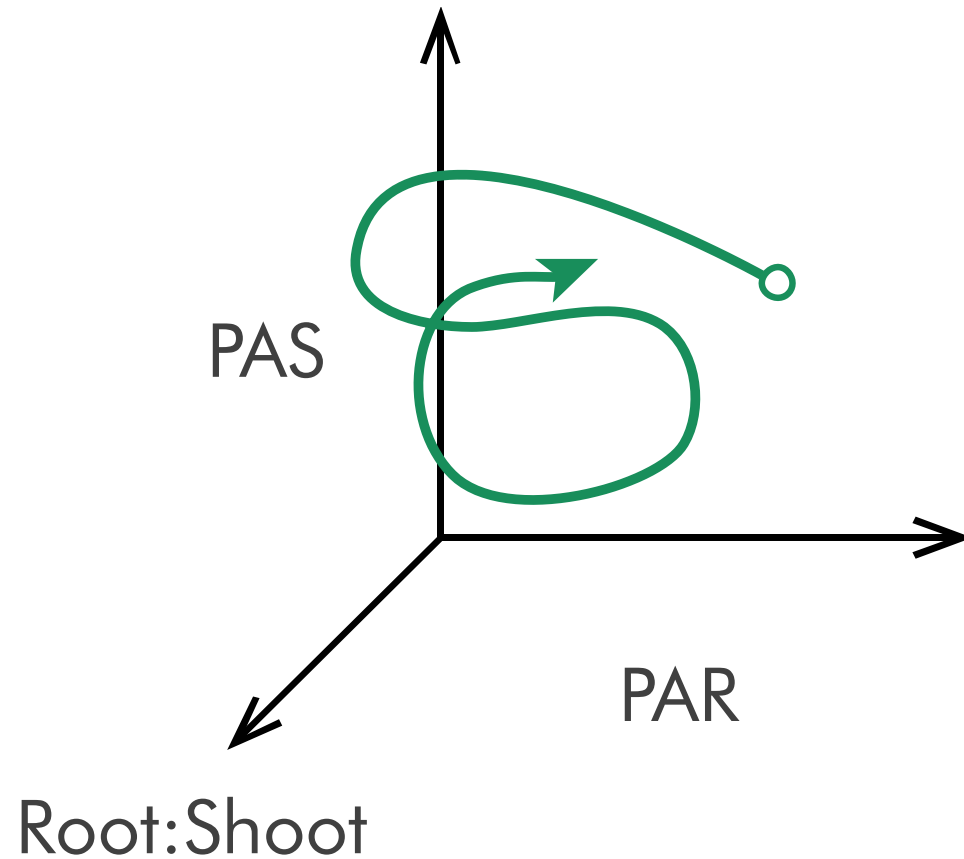


Each point is a valid strategy



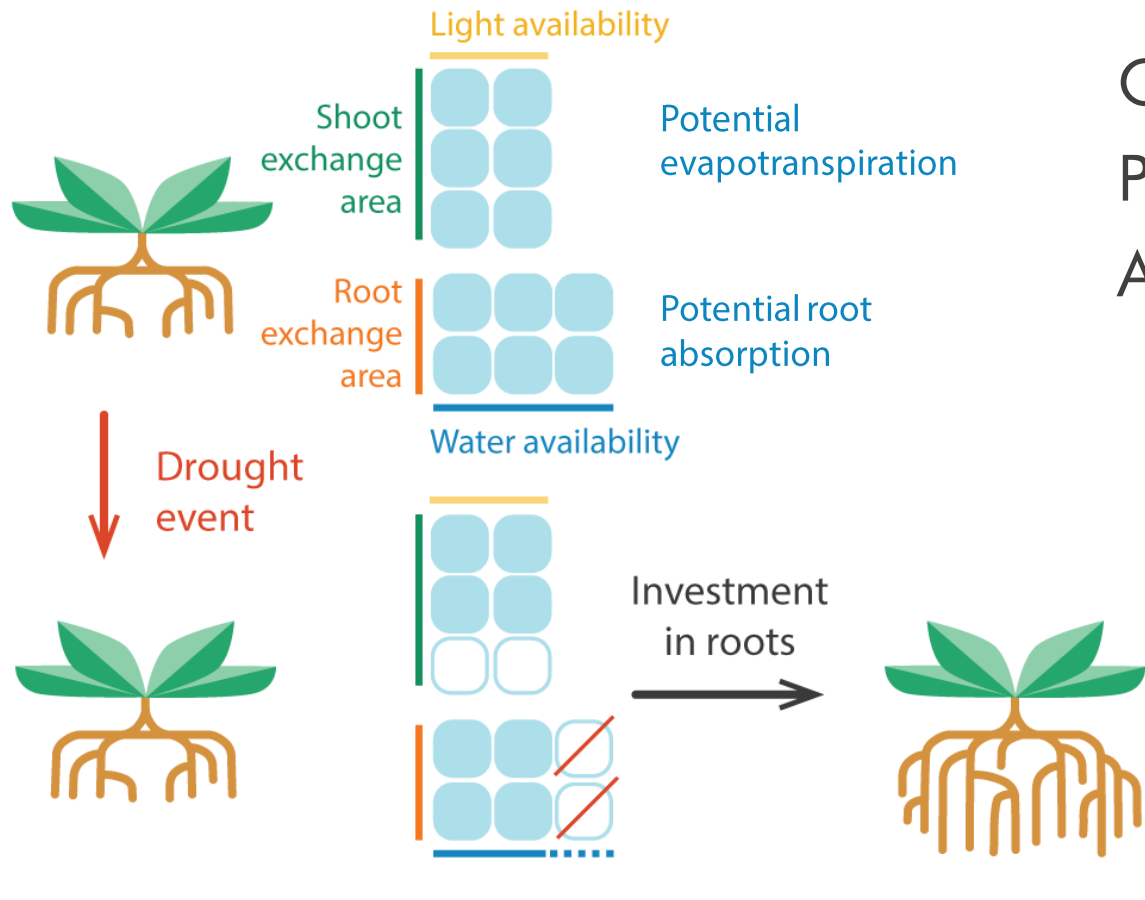
→ sample diverse strategies in a continuous space

# Phenotypes and strategies



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

# Plasticity: the functional equilibrium



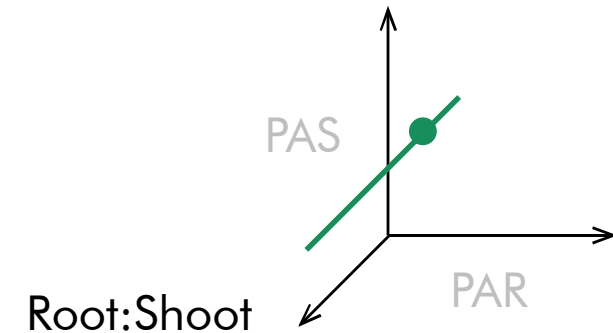
Objective function: **root activity** = **shoot activity**

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  $T^\circ$  & irradiance

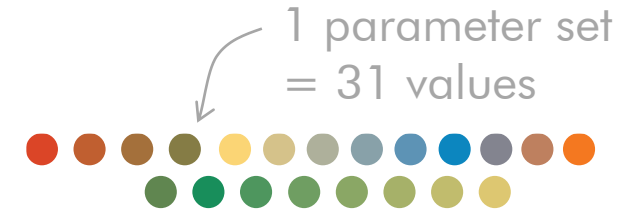
12\*12\*90 cm pots

# Parameter filtering

31 parameters

Pot growth patterns in 2 treatments of watering

→ Selection of a subset of parameter sets for simulations



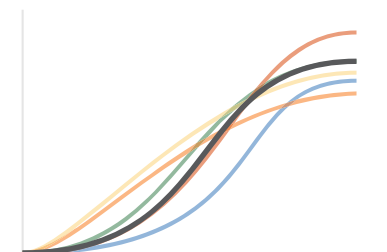
Accepted sets



Simulation sets



Trend from multiple simulations



fixed T° & irradiance

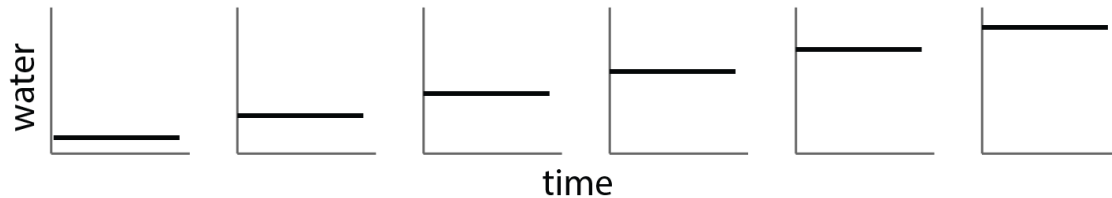
12\*12\*90 cm pots

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

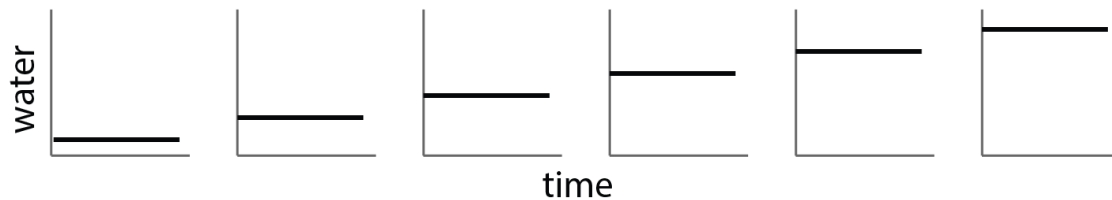
12\*12\*90 cm pots

100 days

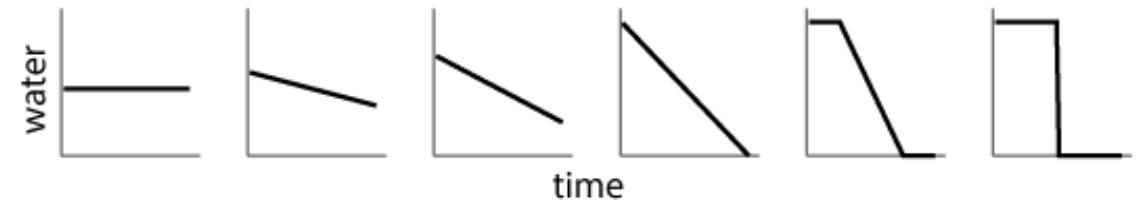
# Individual-level simulations

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

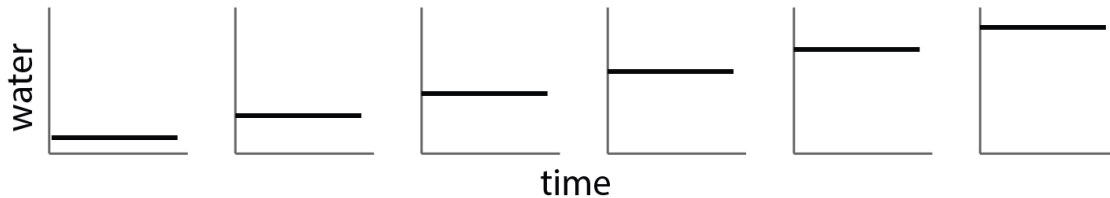
12\*12\*90 cm pots

100 days

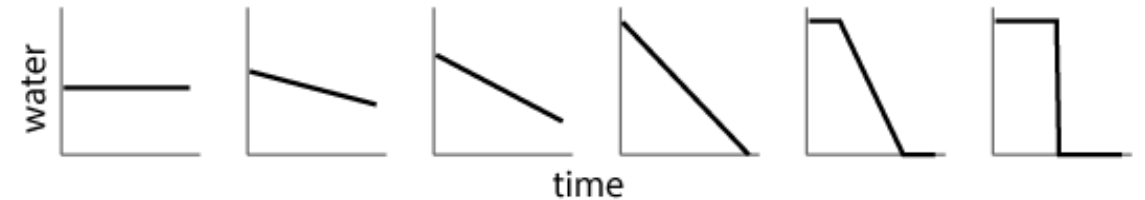
# Individual-level simulations

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

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



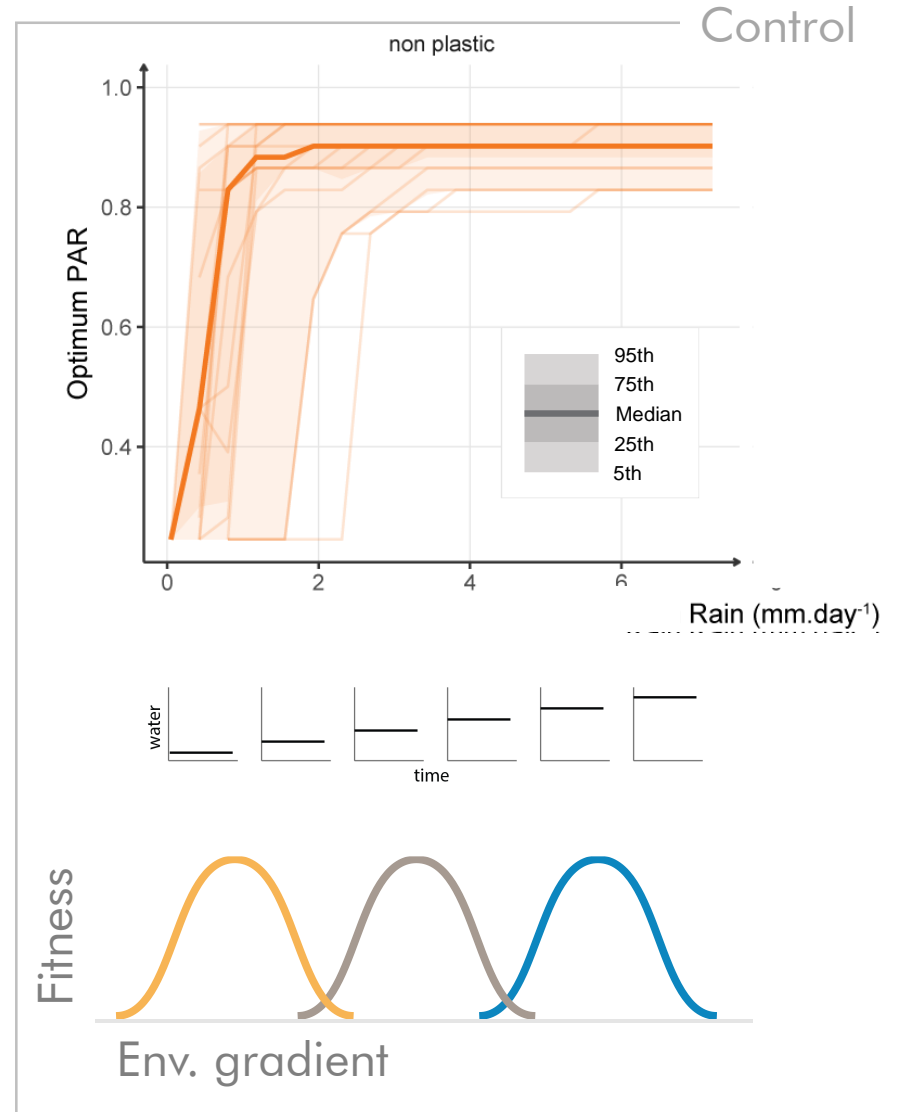
Individual growth along an **variability** gradient (temporal)



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

# Plasticity effect in homogeneous conditions

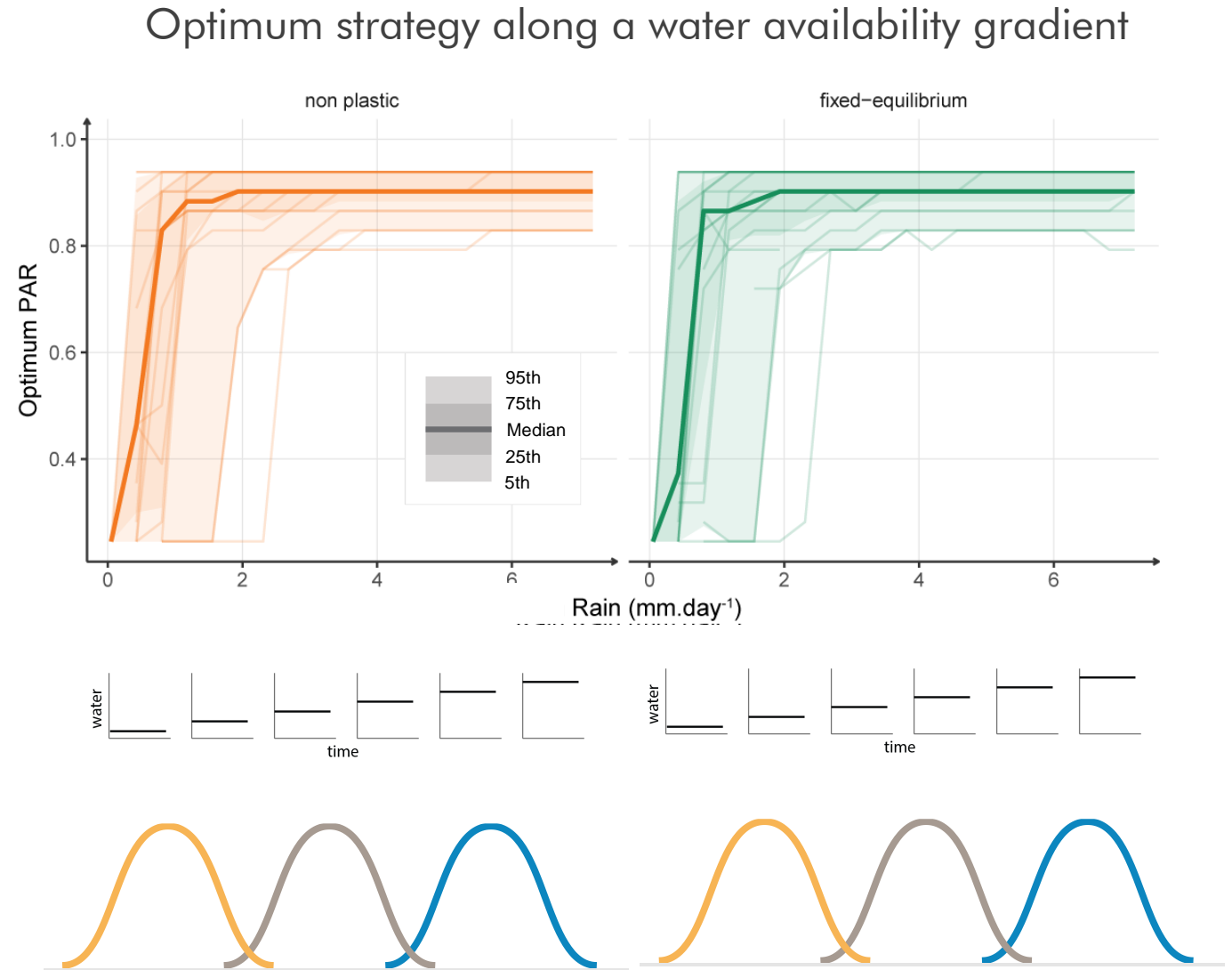
Optimum strategy along a water availability gradient



# Plasticity effect in homogeneous conditions

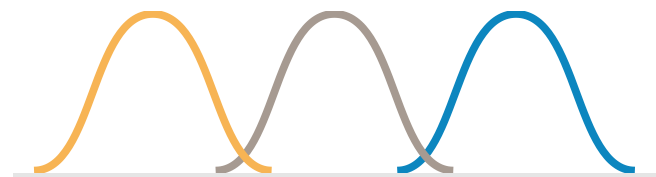
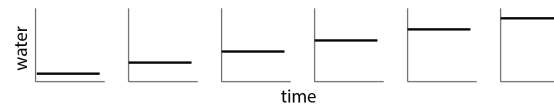
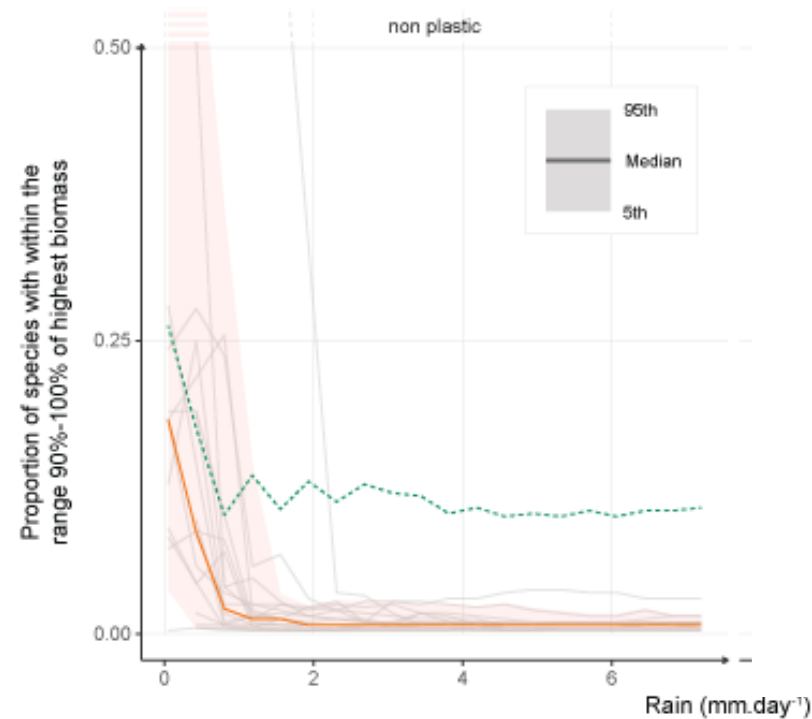
- No shift in best strategy
- No change in maximum biomass

→ No shift in the dominant species



# Plasticity effect in homogeneous conditions

Proportion of species with high performances along a water availability gradient

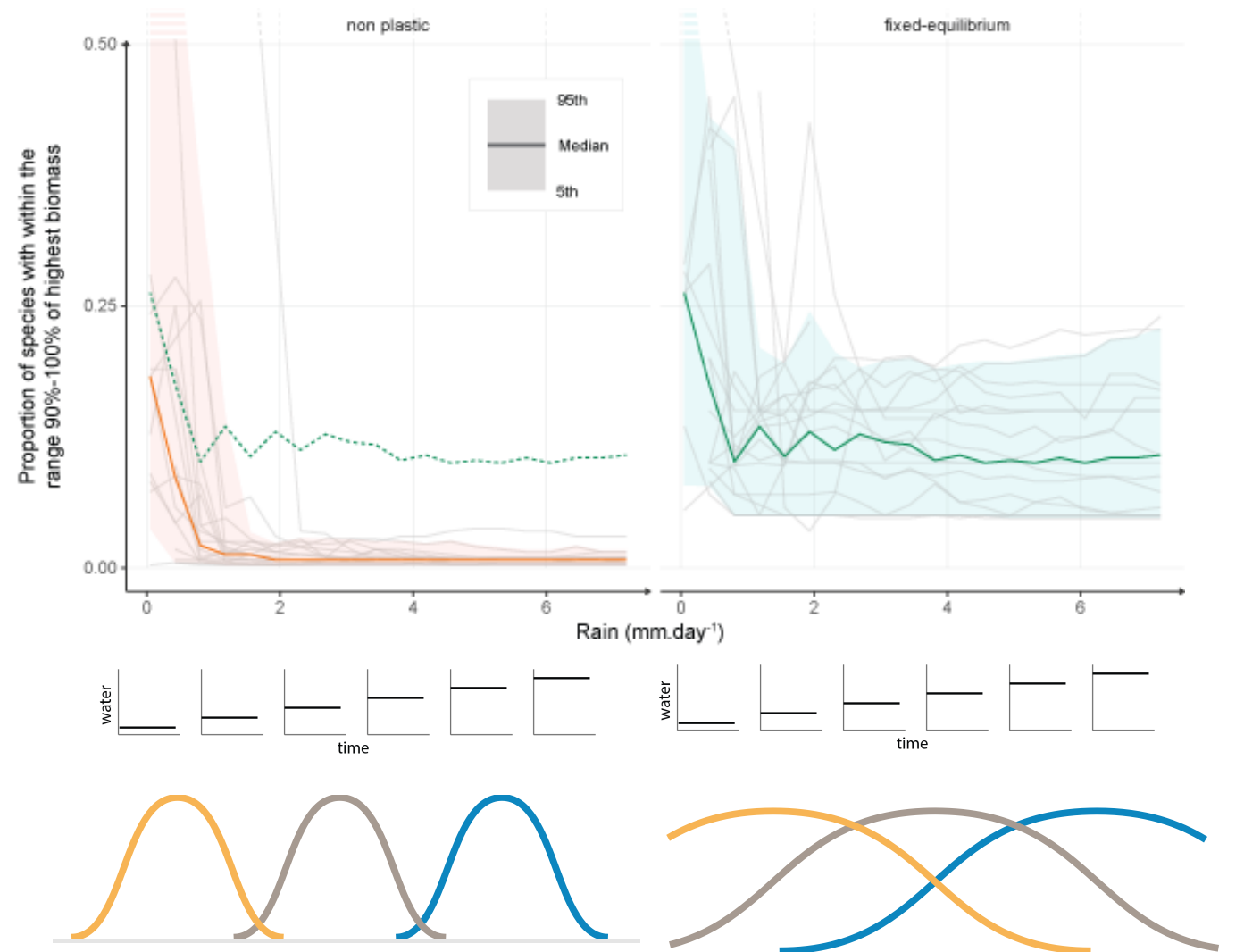


# Plasticity effect in homogeneous conditions

- Reduction of growth differences

→ Niche widening

Proportion of species with high performances along a water availability gradient

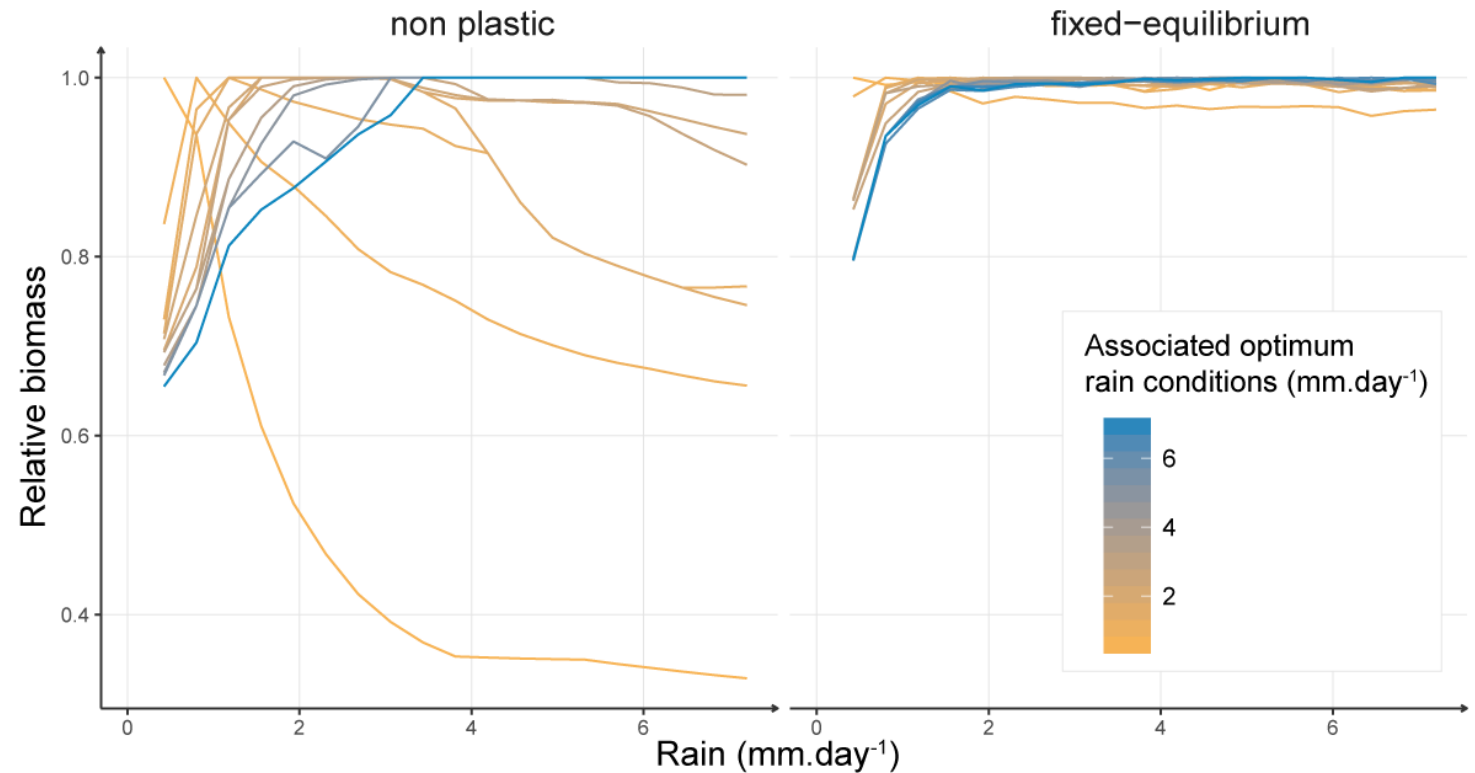


# Niche widening in homogeneous conditions

## Plasticity

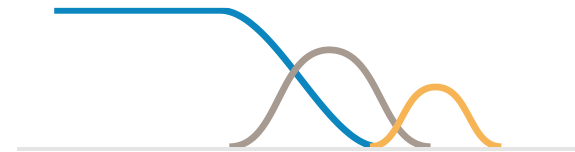
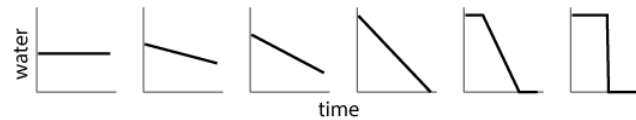
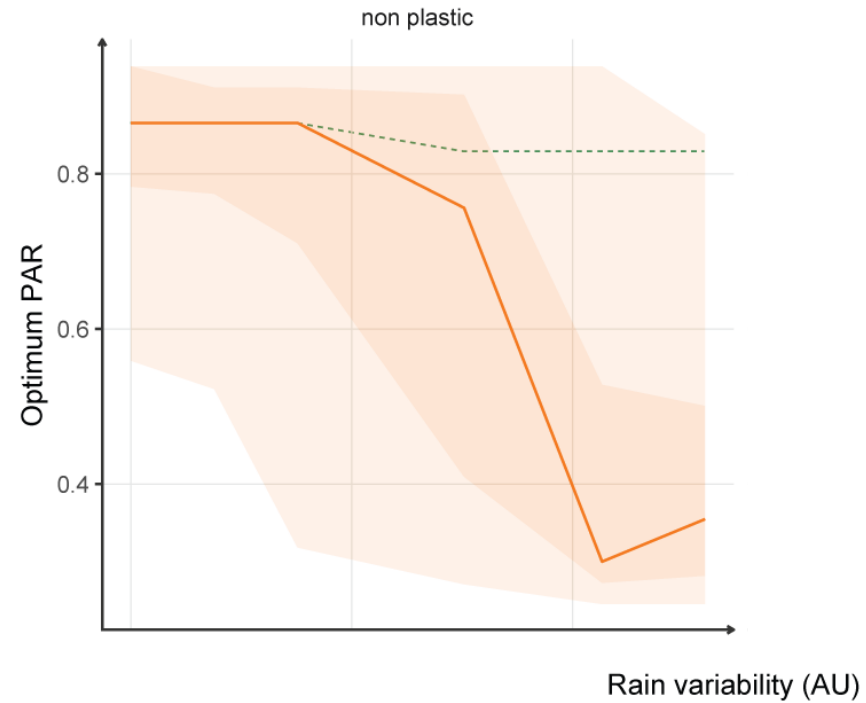
→ increases relative biomass in **non optimum** conditions

## Potential niche of best species



# Plasticity effect in heterogeneous conditions

Optimum strategy along a water variability gradient



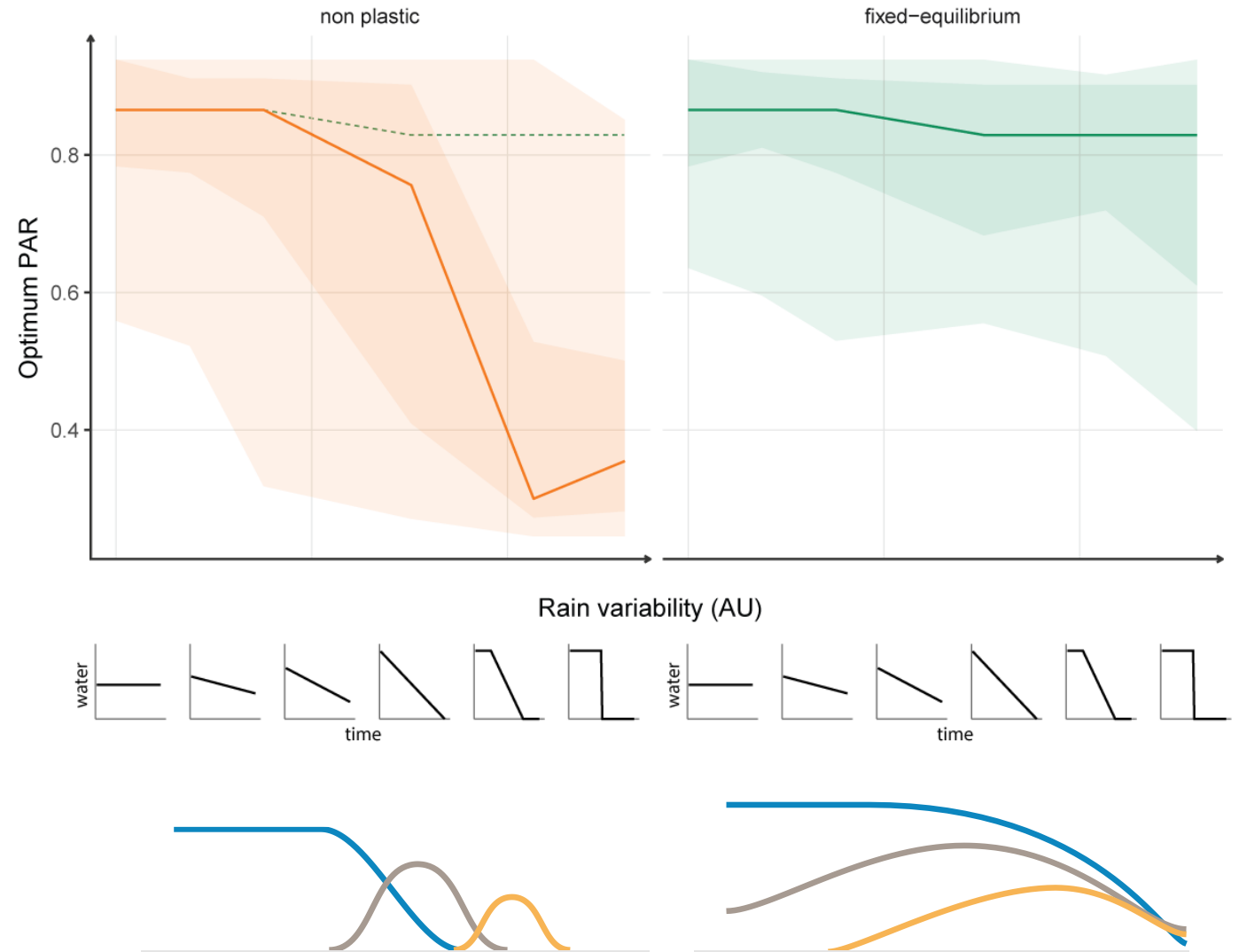
Results



# Plasticity effect in heterogeneous conditions

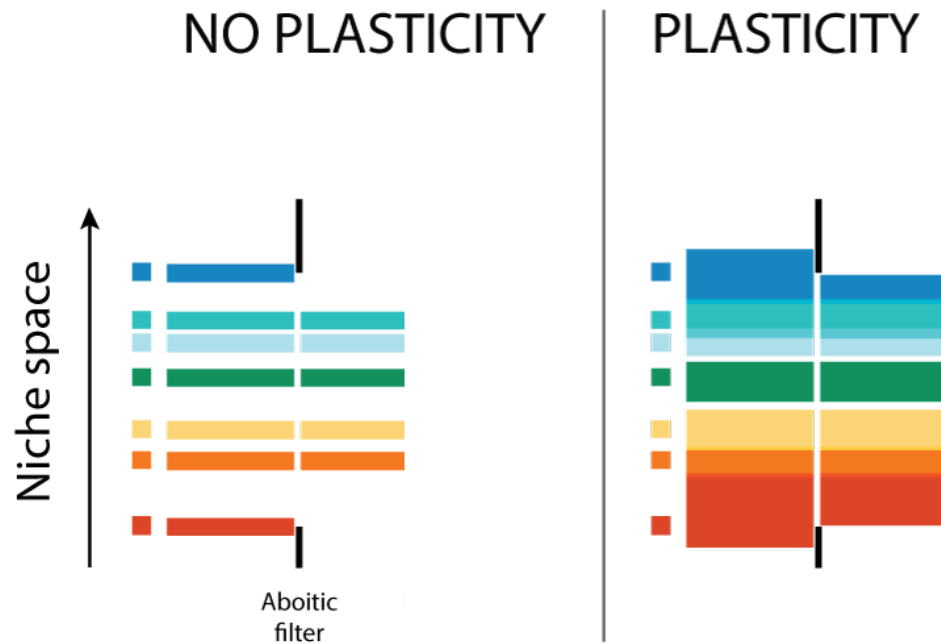
- Changes in dominant strategy in favour of exploitative species
  - Reduction of growth differences
  - Increase of relative BM
- Asymmetric gain  
(+ exploitative strategies)
- Niche widening

## Optimum strategy along a water variability gradient



# Consequences at the community level ?

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



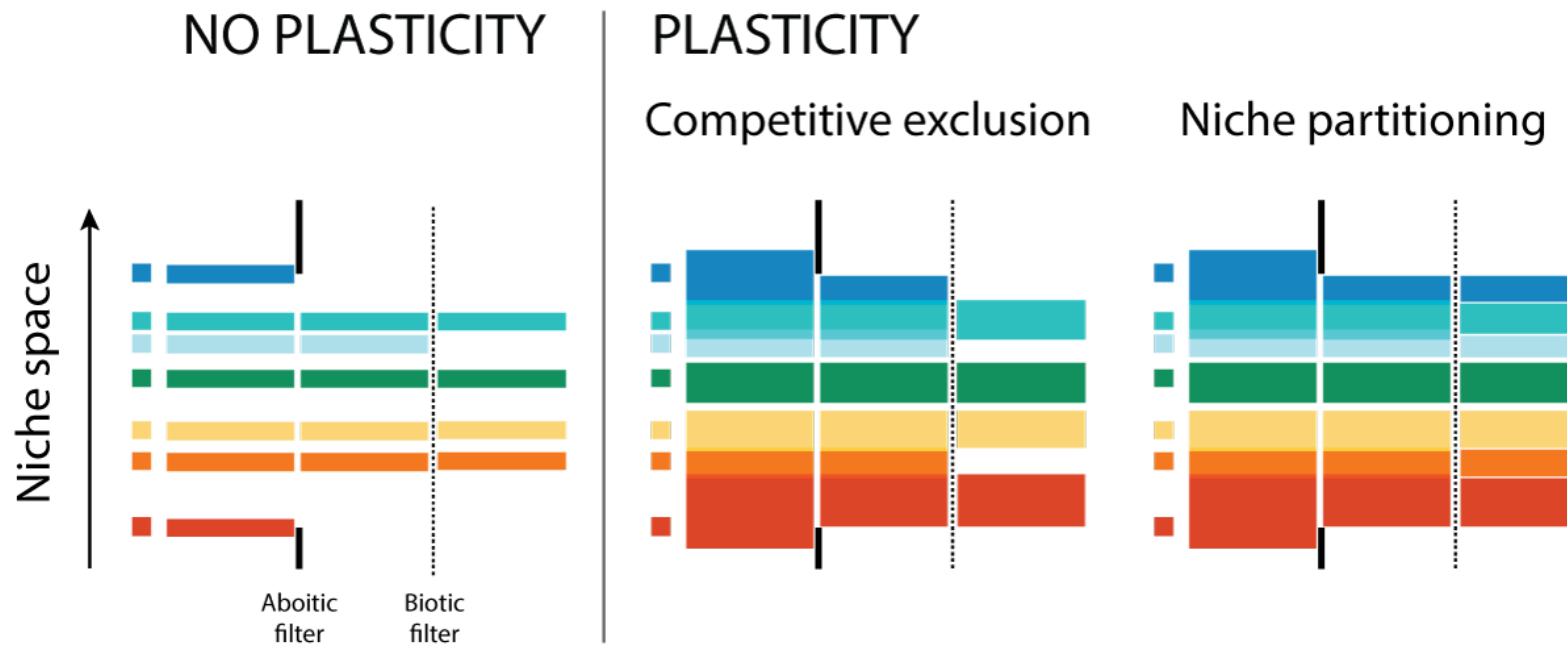
# Consequences at the community level ?

Niche widening = reduction of abiotic filtering

- higher potential species diversity

Asymmetric gain

- Competitive exclusion by exploitative species?





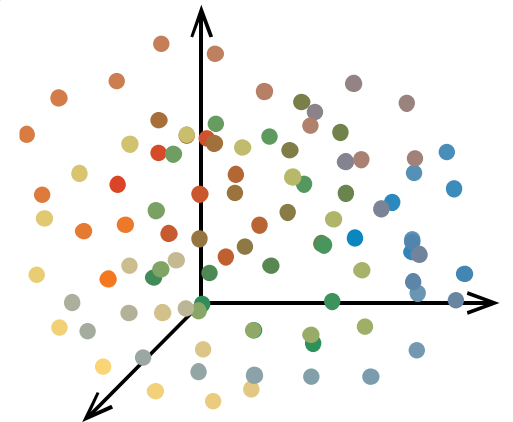
100\*100cm plots

6 sites: variable  $T^{\circ}$ , prec. & irradiance

# Community-level simulations

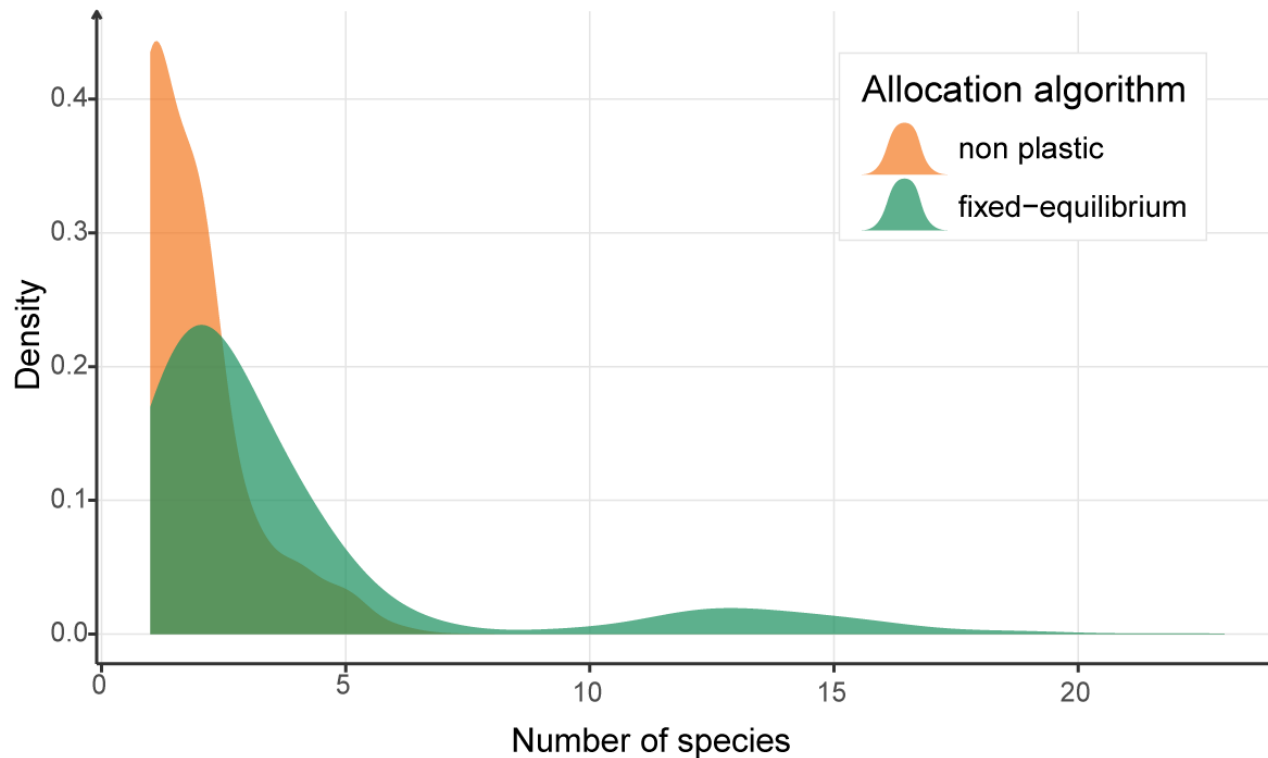
Real conditions of **variability** (weather data for 6 sites) + **explicit competitive interactions**

- 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

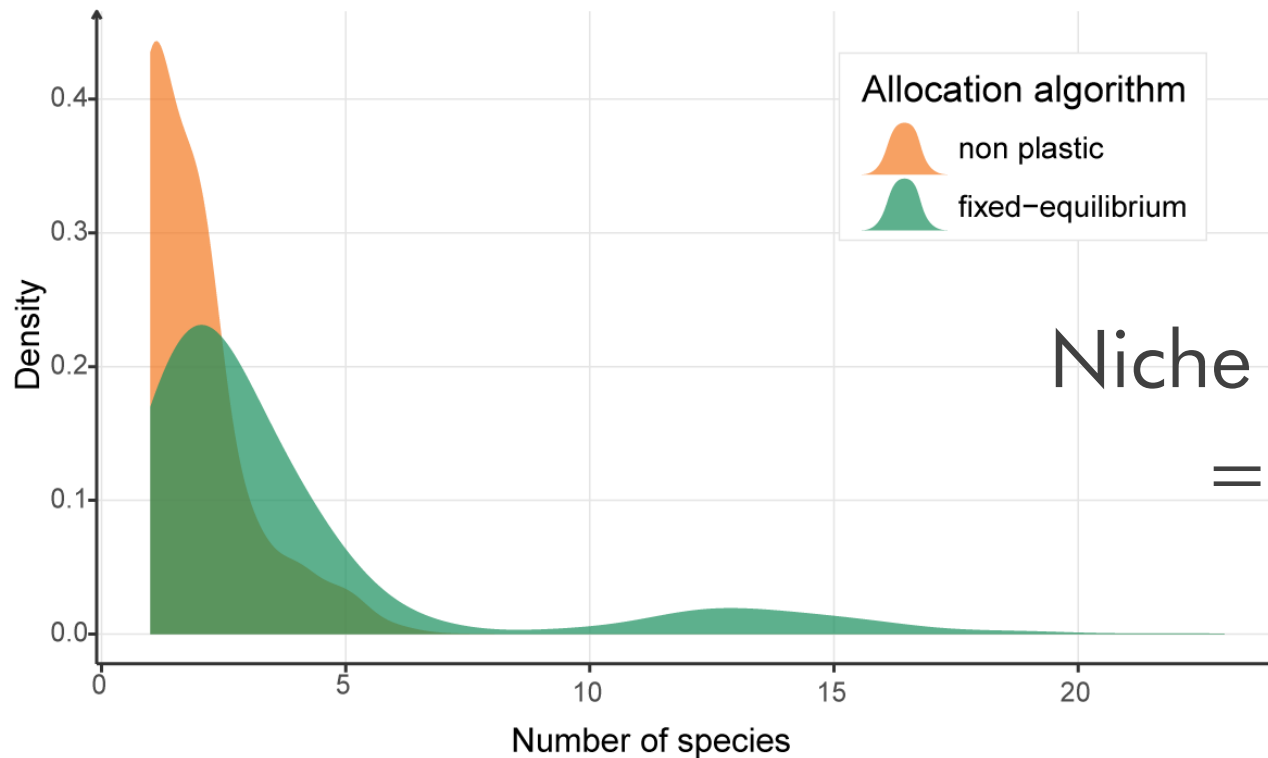
Distribution of species diversities of simulated communities



Higher species diversity

# Effects of plasticity on species diversity

Distribution of species diversities of simulated communities

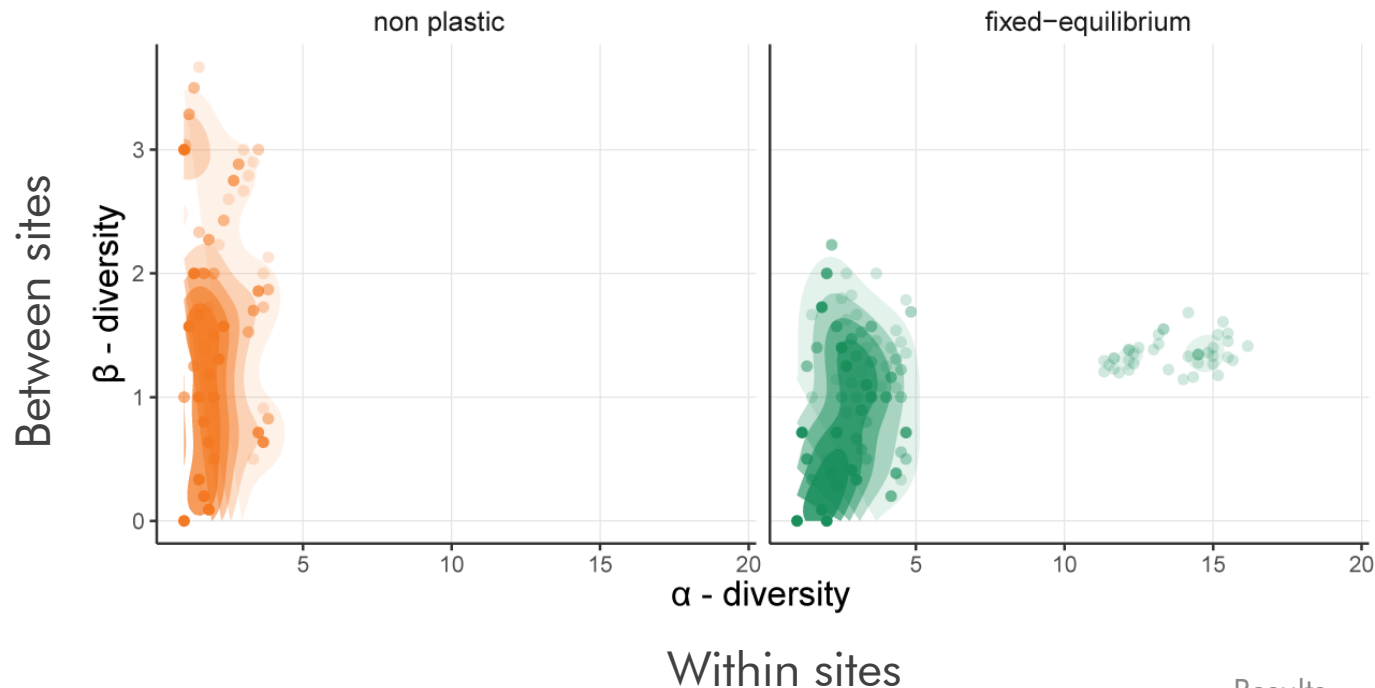


Higher species diversity

Niche widening  $>$  asymmetric gain  
= better niche partitioning

# A shift in meta-community structure?

Species diversity structure

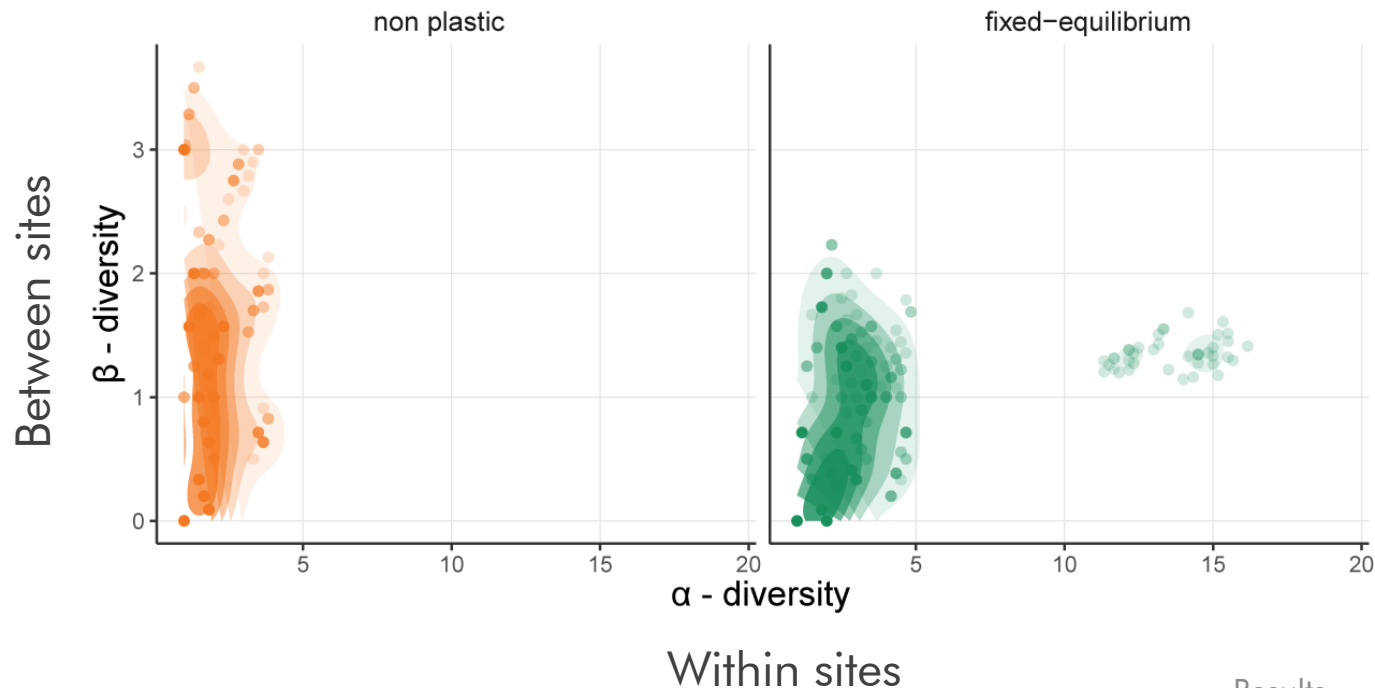


- Shift in diversity structure:
- Less distinct site communities
  - Richer site communities

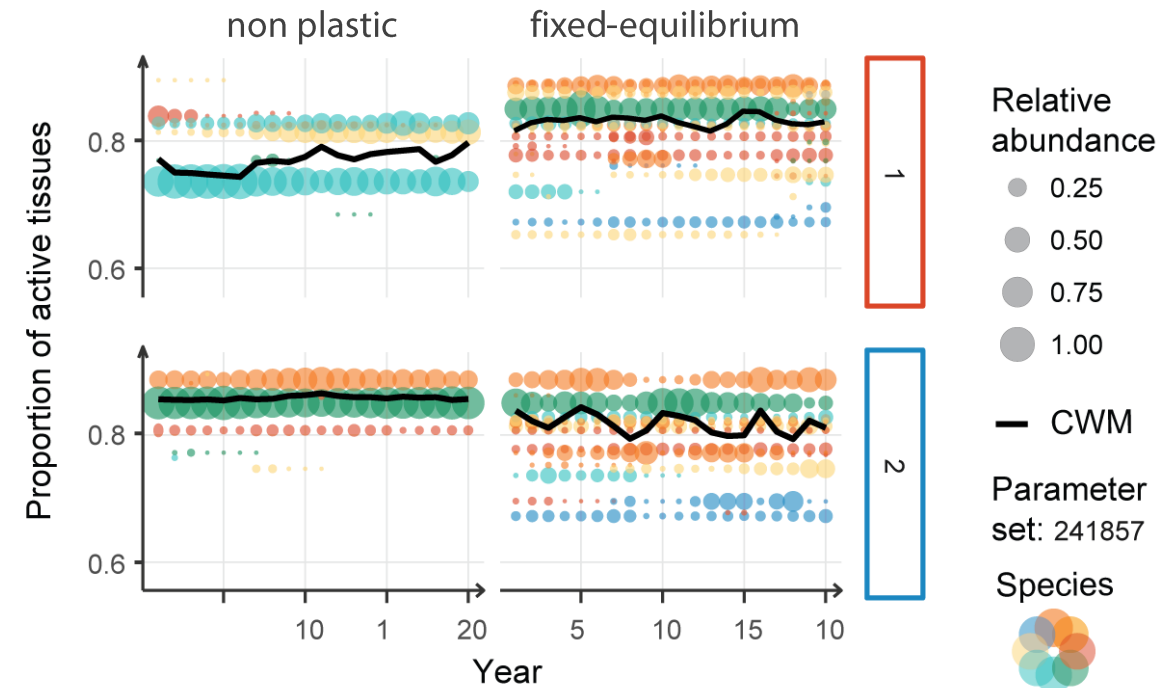
# A shift in meta-community structure

More species → abundance variations but no composition shifts

Species diversity structure



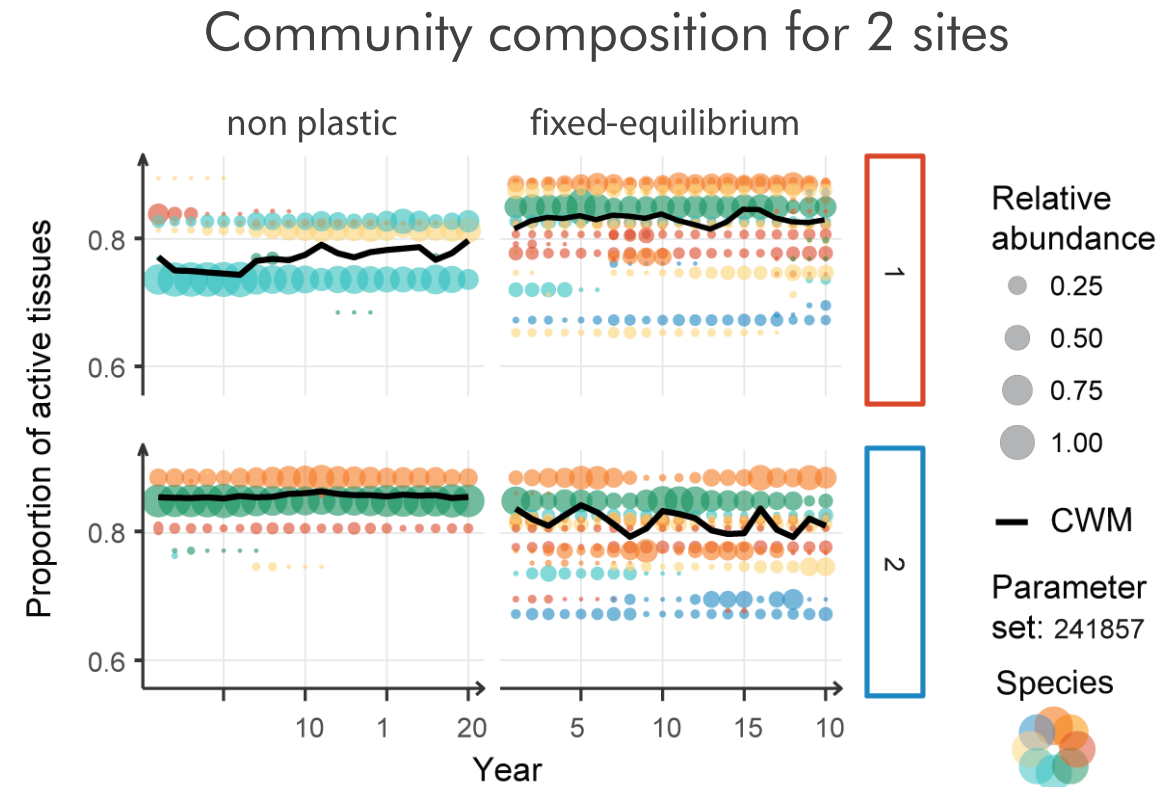
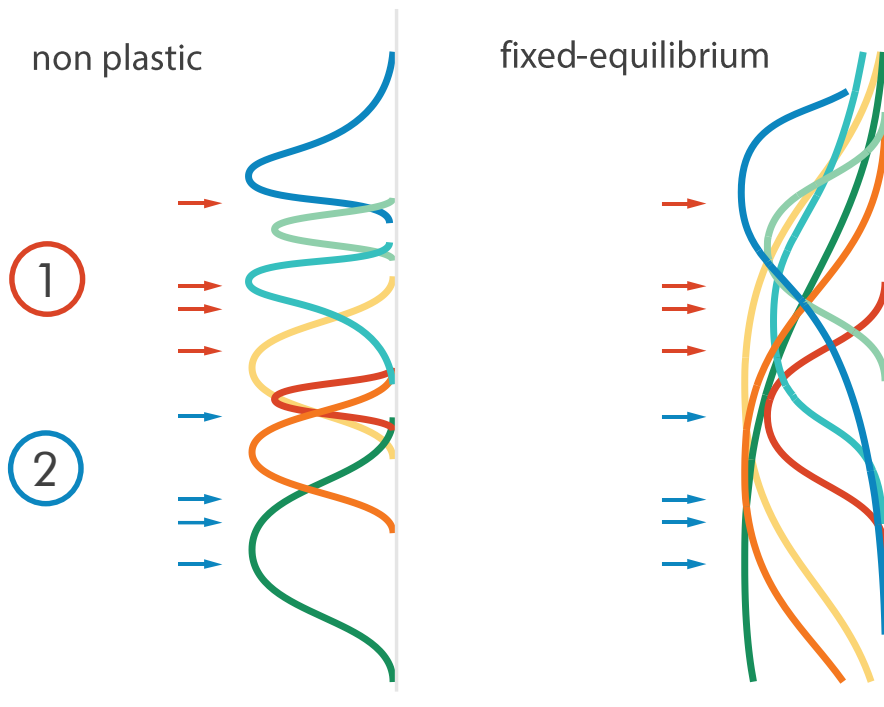
Community composition for 2 sites





# A shift in meta-community structure

More species → abundance variations but no composition shifts



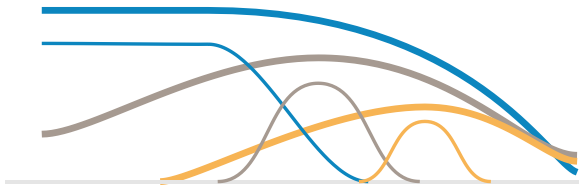
# Results summary

Niche widening



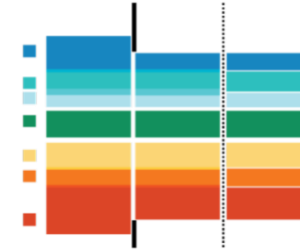
Availability gradient

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

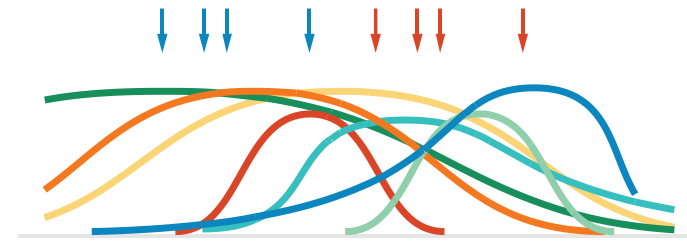


Variability gradient

Niche widening  $>$  asymmetric gain



Plasticity alters meta-community  
structure





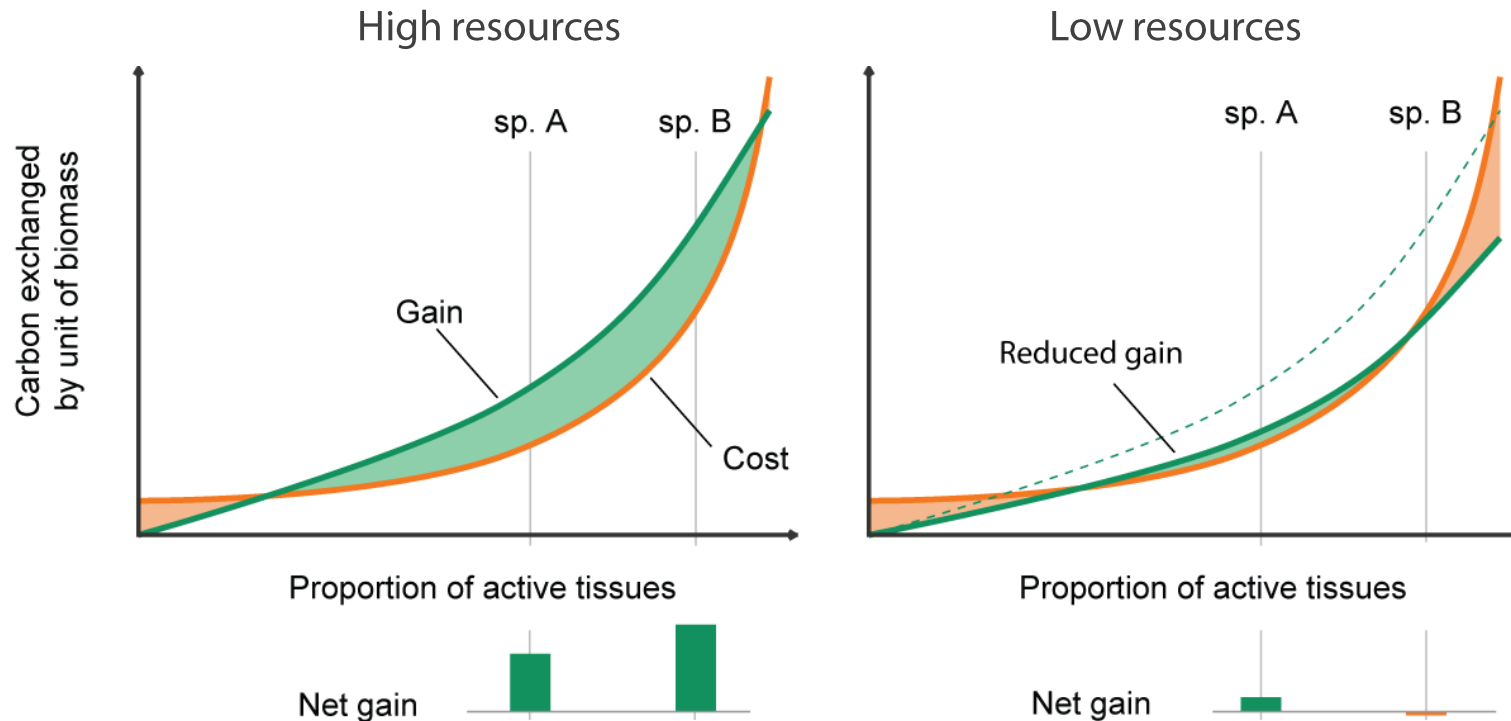
# 4

# 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

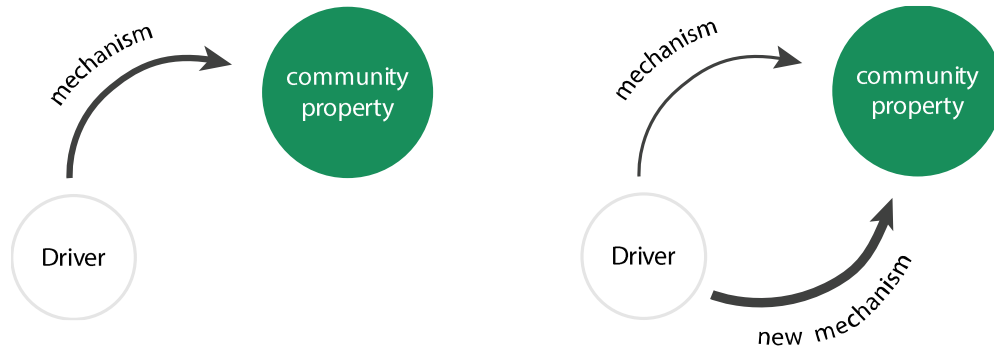
→ **Sensitivity** to **unbalance** functioning

**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

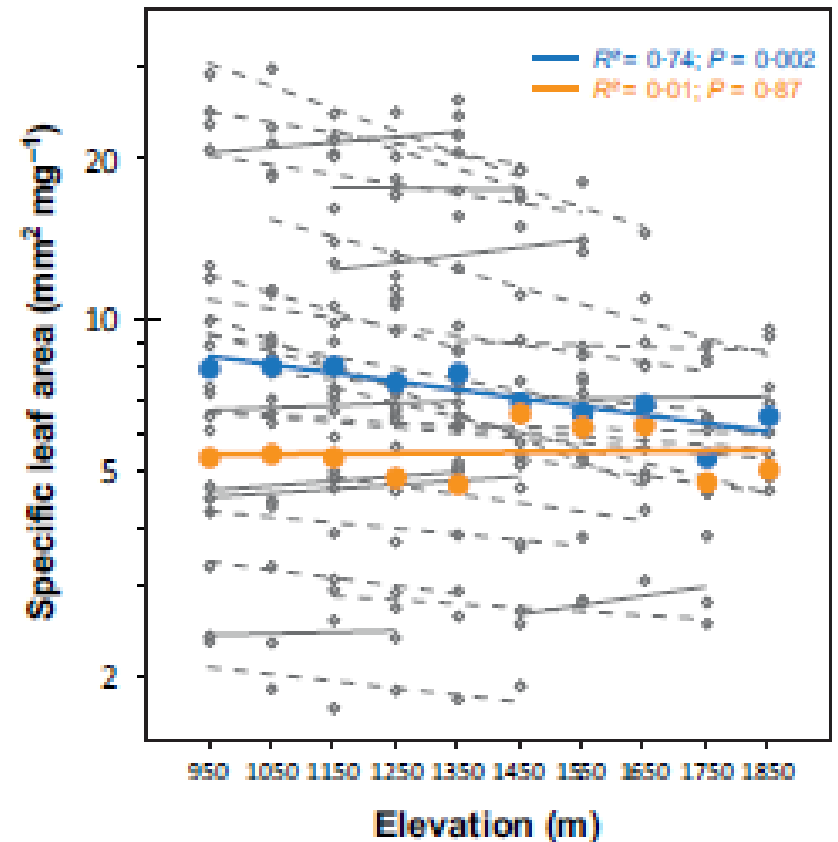
## EMPIRICAL

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

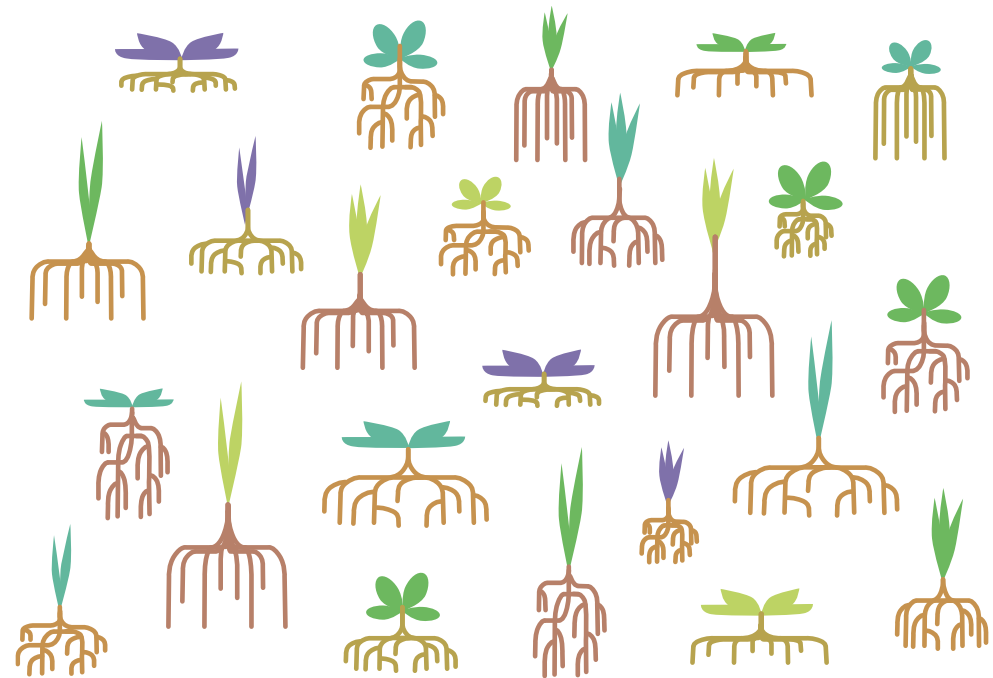
Plasticity in coherent framework

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!









