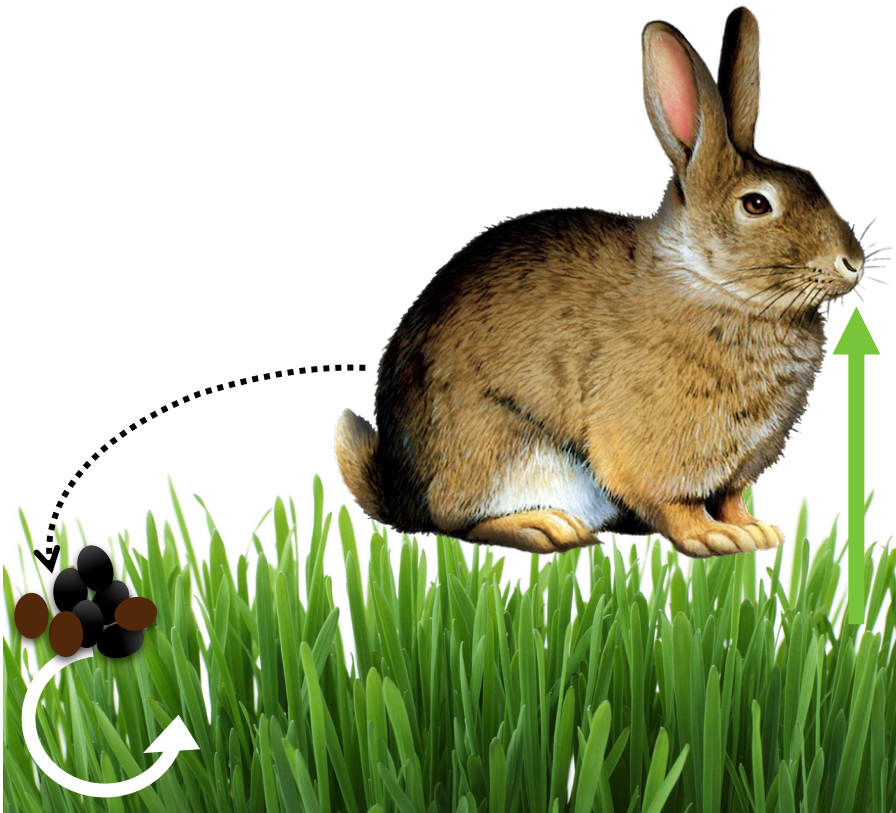




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Interactions between foraging and dispersal scales drive the emergence of spatial heterogeneity in abiotic resources in plant-herbivore systems



Gounand I., Loeuille N., Charberet S., Fronhofer E., Harvey E., Kéfi S., Leroux S.L., Little C.J., McLeod A., Saade C., and Massol F.

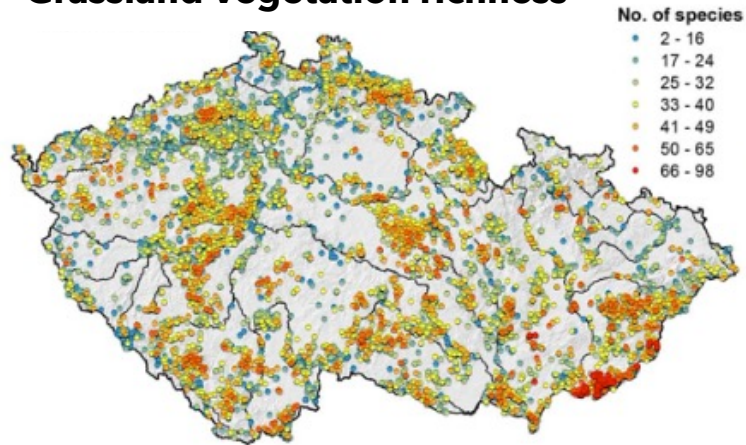
RED-BIO working group supported by CESAB and CIEE

November 22, 2022, Metz

CONTEXT

Community ecology → How spatial heterogeneity of resources drives species coexistence, foraging behaviour, etc.

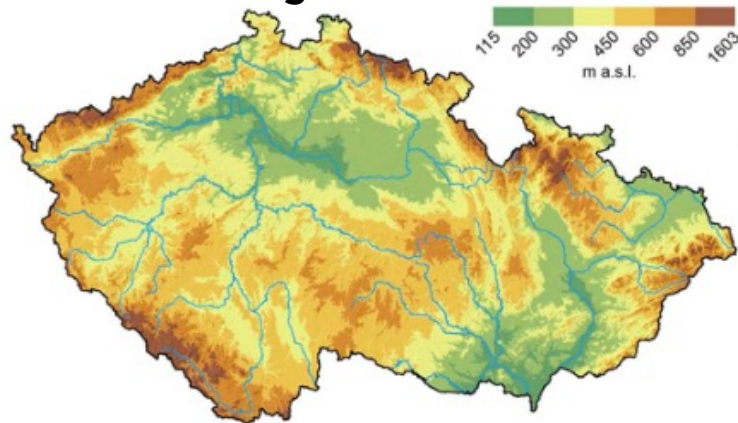
Grassland vegetation richness



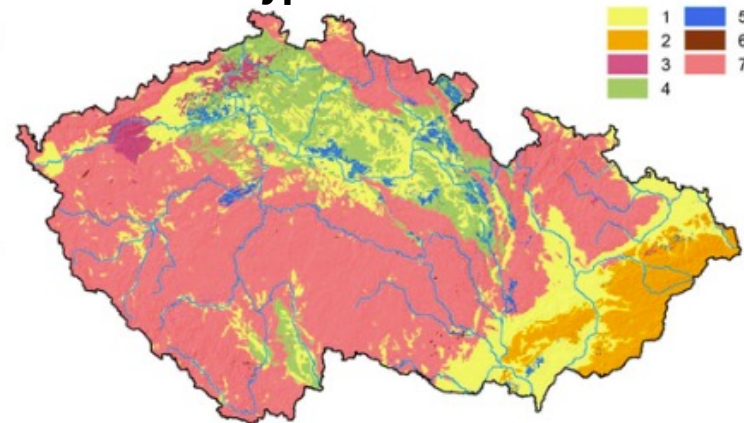
in Czech Republic

Divišek & Chytrý 2018,
Ecological Indicators

Altitudinal range



Bedrock type

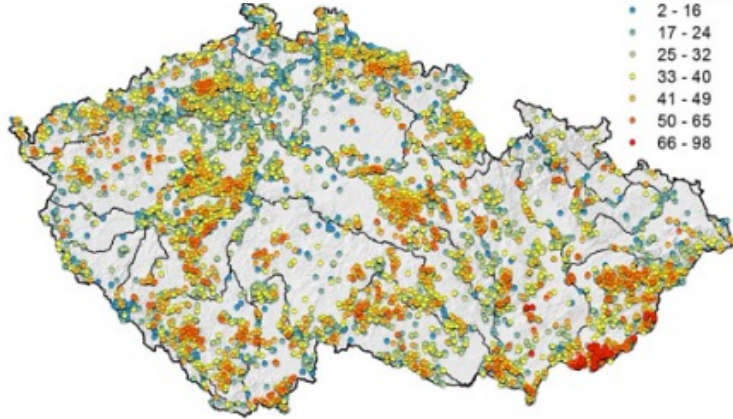
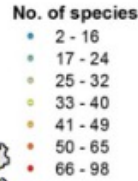


Heterogeneity: geology, topology, climate, driving resource distribution

CONTEXT

Community ecology → How spatial heterogeneity of resources drives species coexistence, foraging behaviour, etc.

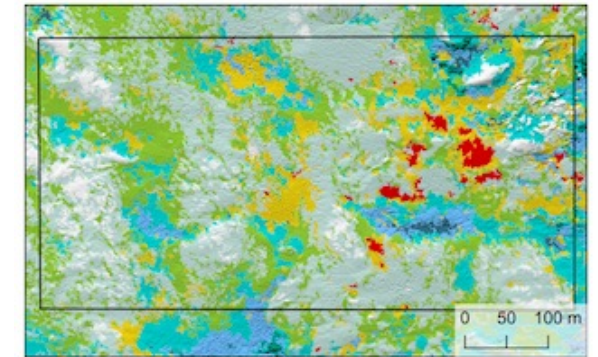
Grassland vegetation richness



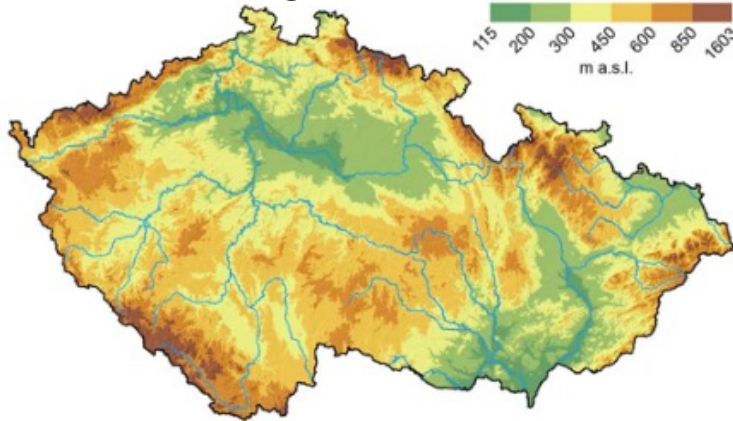
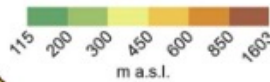
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Divišek & Chytrý 2018,
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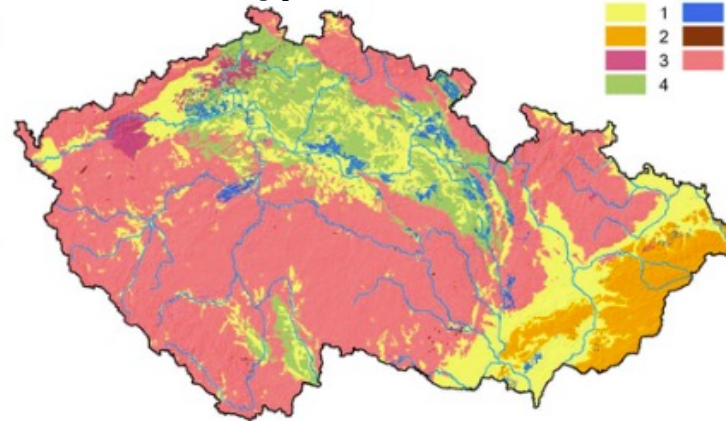
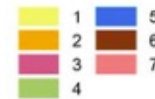
Vegetation types in Norway



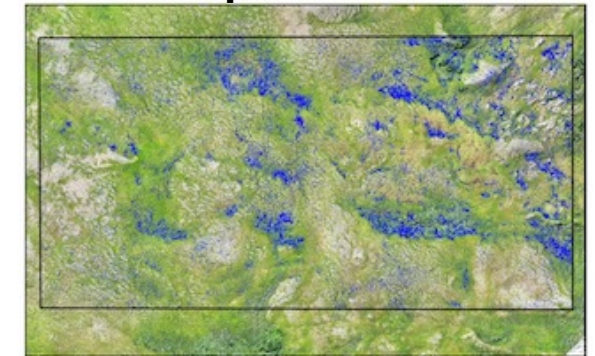
Altitudinal range



Bedrock type



Rodent impact estimate



Siewert & Olofsson 2021,
Scientific Reports

Heterogeneity: geology, topology, climate, driving resource distribution

CONTEXT

Metaecosystems, zoobiochemistry → Animals move resources

Loreau et al. 2003 Ecology Letters, Gounand et al. 2018 TREE, Schmitz et al. 2018 Science



Subalusky et al. 2015, *Freshwater Biology*

There is a feedback between communities and abiotic resources

CONTEXT

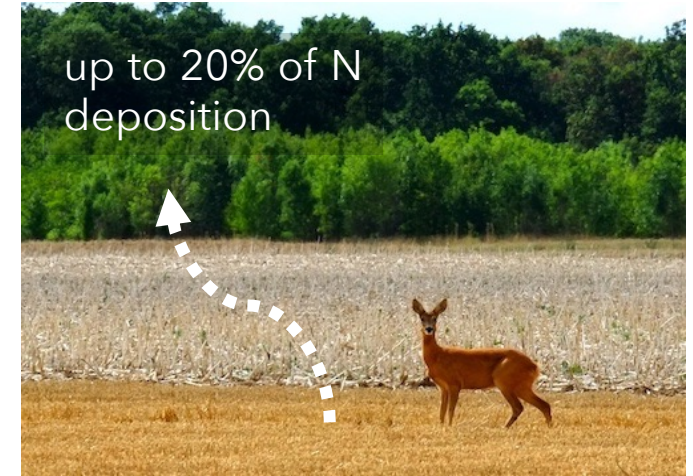
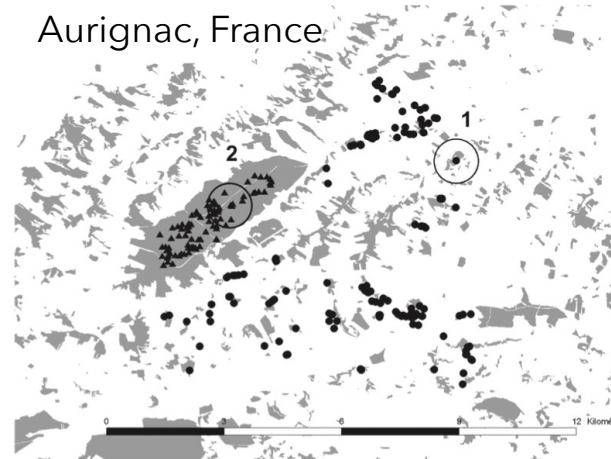
Metaecosystems, zoobiochemistry

→ Animals move resources

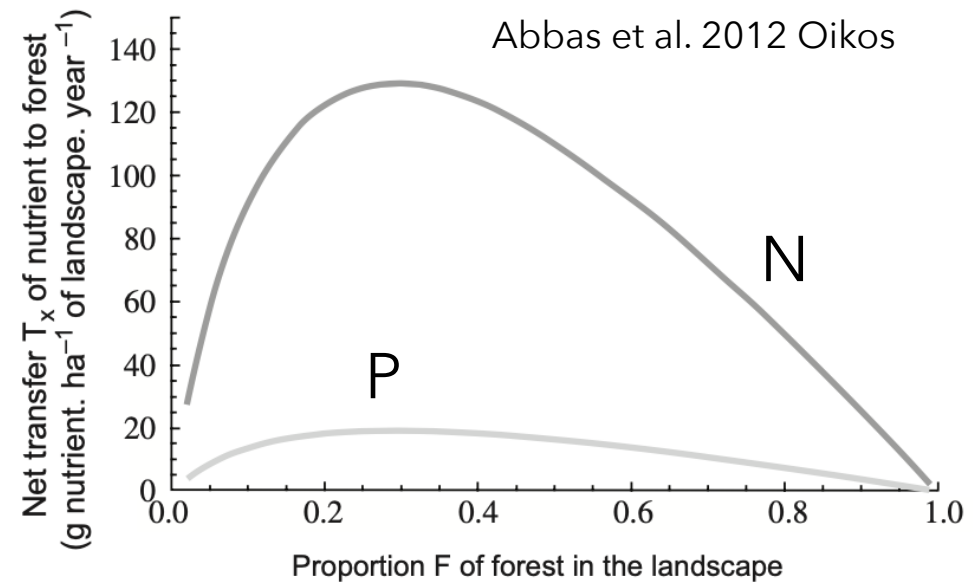
Loreau et al. 2003 Ecology Letters, Gounand et al. 2018 TREE, Schmitz et al. 2018 Science



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Abbas et al. 2012 *Oikos*



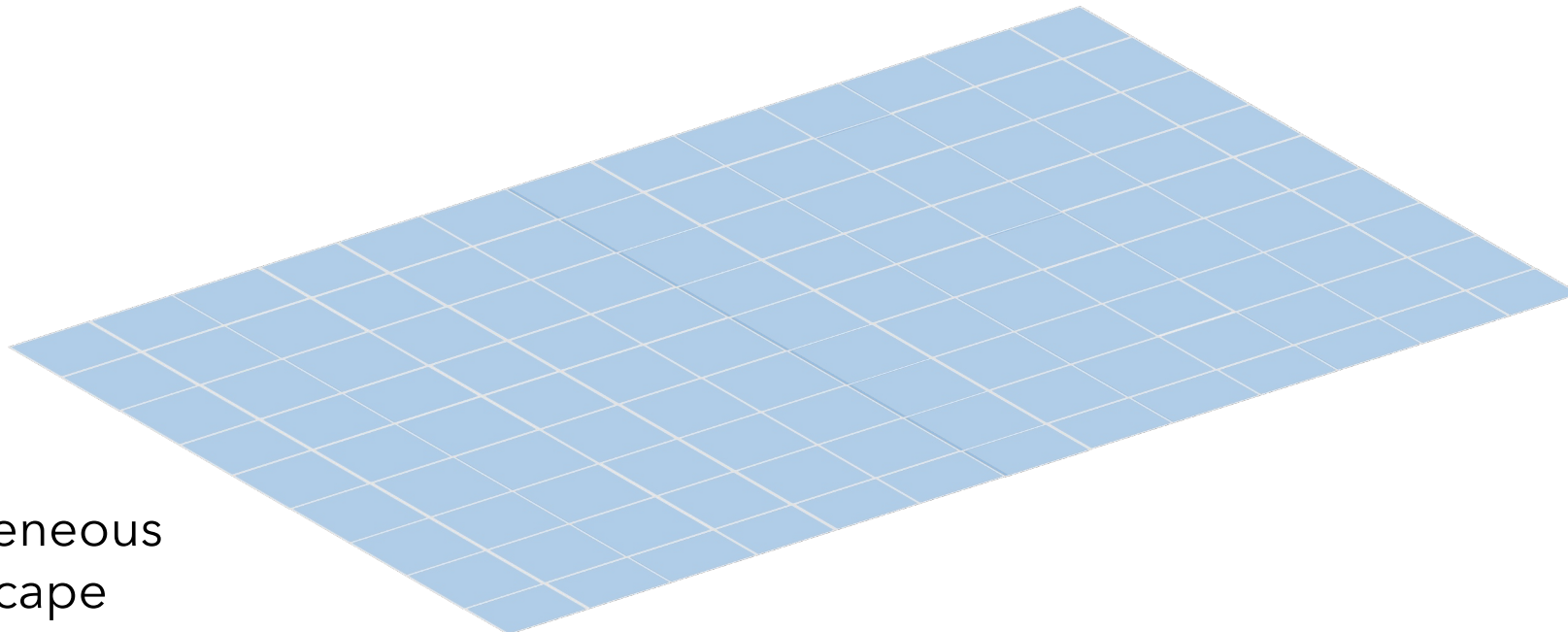
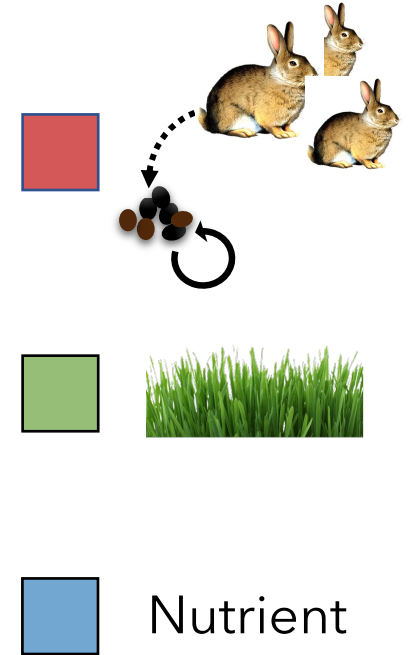
There is a feedback between communities and abiotic resources

CONTEXT

Metaecosystems, zoobiochemistry

- Animals move resources
- recycled within the foraging range

How can biotic interactions generate resource heterogeneity?



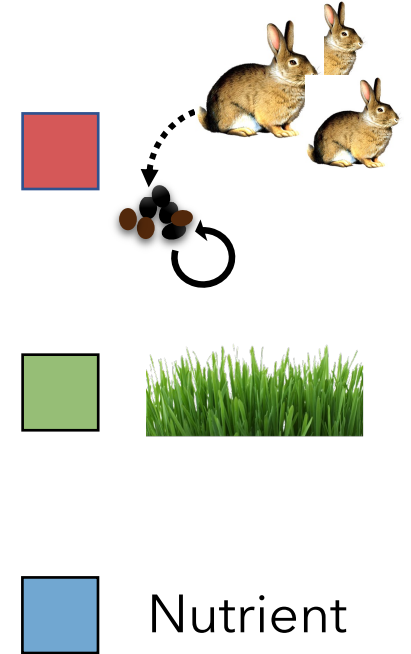
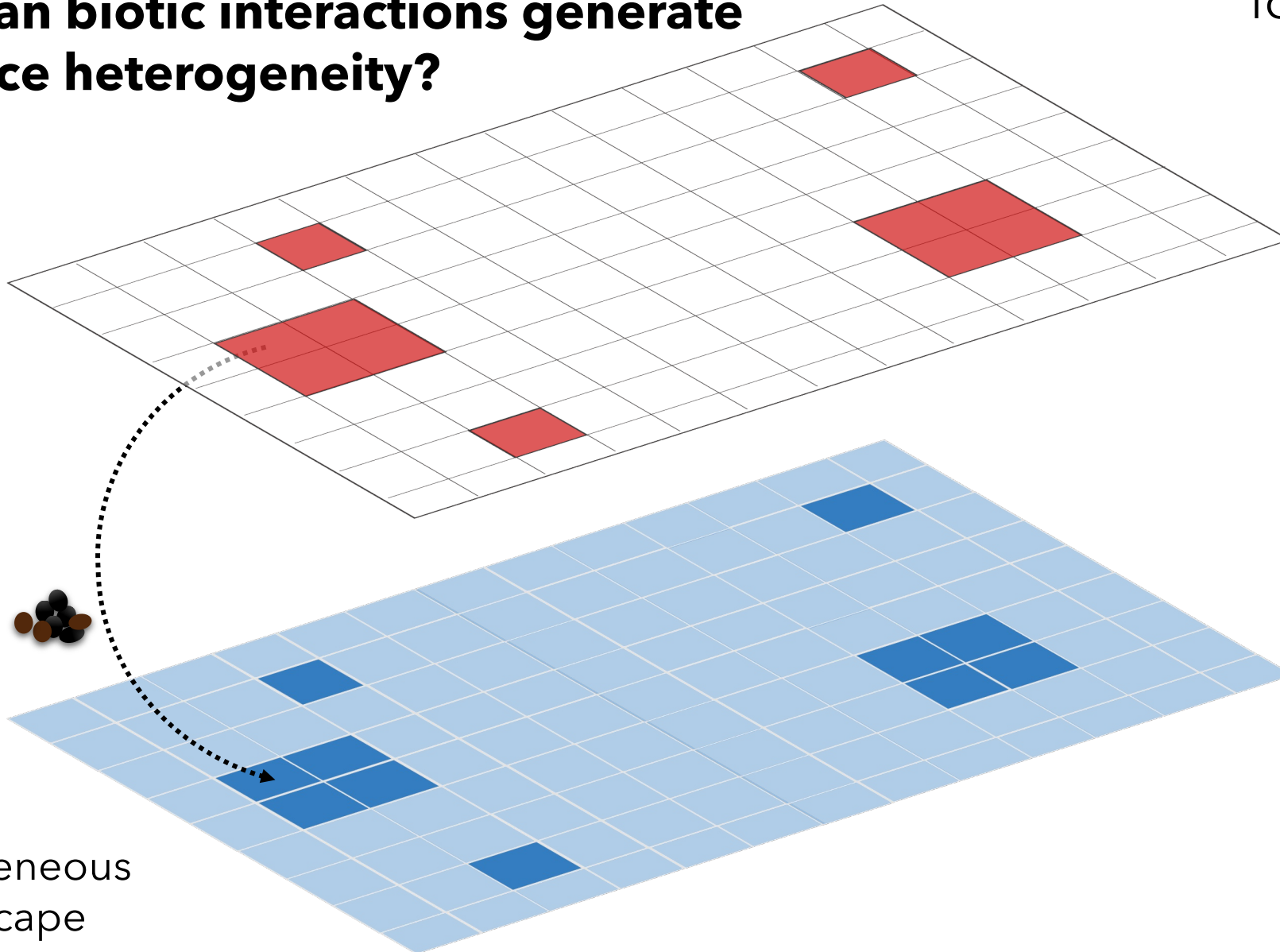
Homogeneous
landscape

CONTEXT

Metaecosystems, zoobiochemistry

→ Animals move resources
→ recycled within the foraging range

How can biotic interactions generate resource heterogeneity?



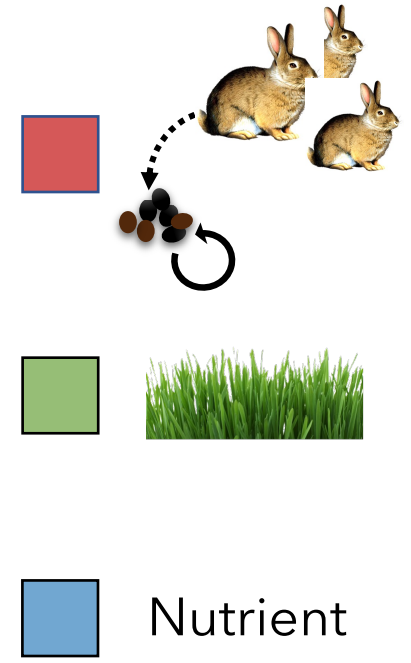
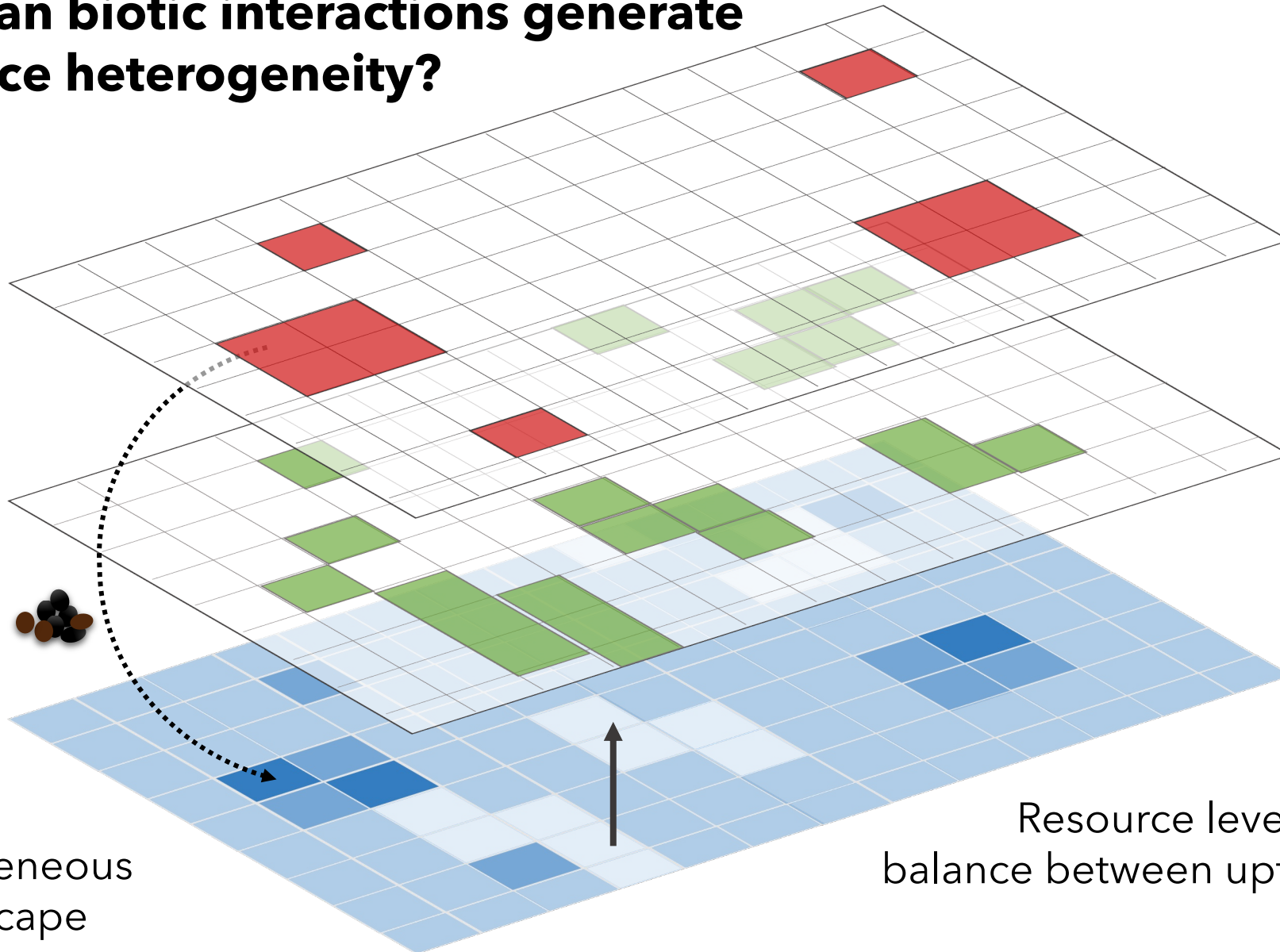
Homogeneous
landscape

CONTEXT

Metaecosystems, zoobiochemistry

→ Plants deplete nutrients

How can biotic interactions generate resource heterogeneity?



Homogeneous landscape

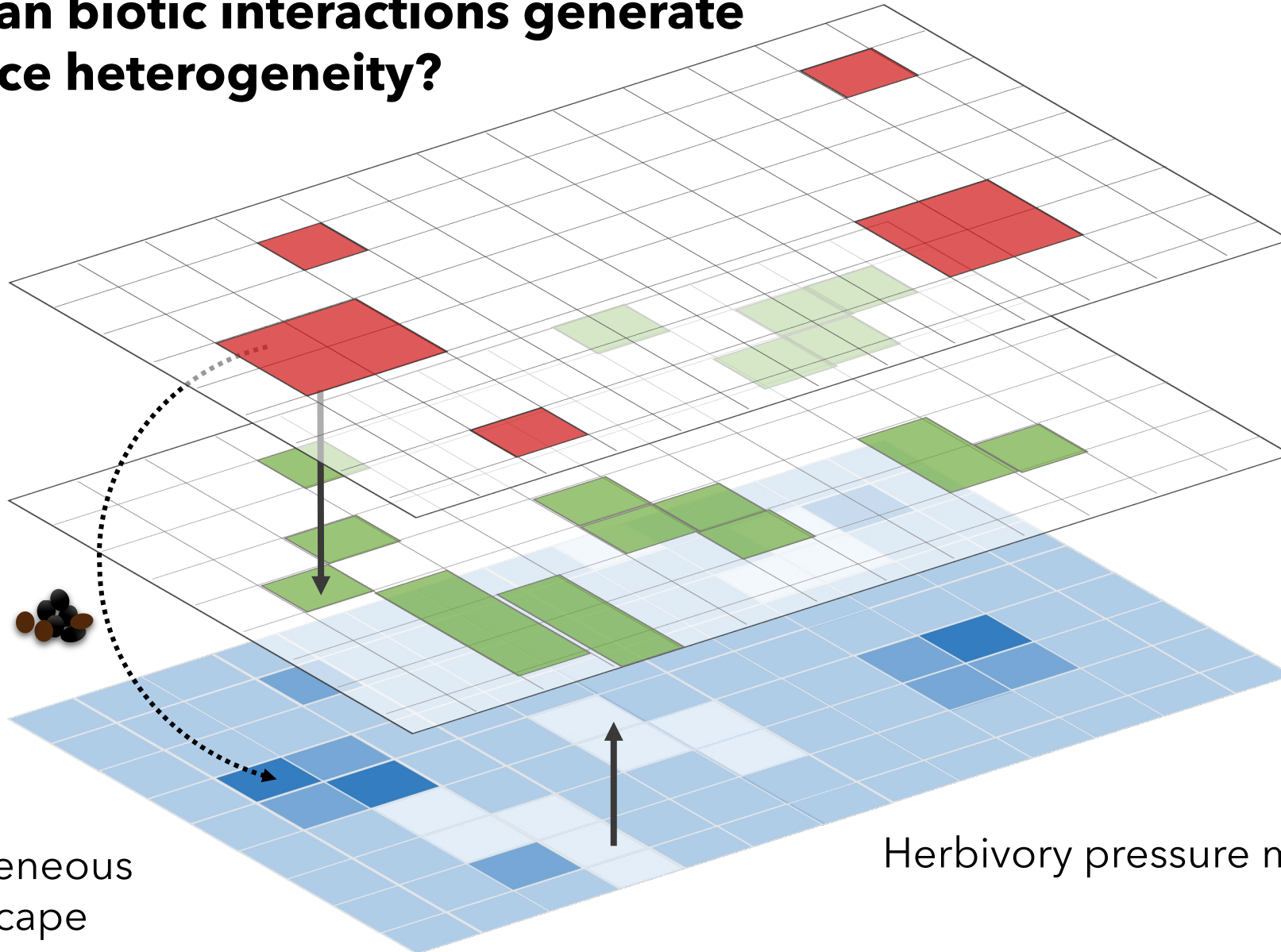
Resource level depends on the balance between uptake and **recycling level**

CONTEXT

Metaecosystems, zoobiochemistry

→ Plants deplete nutrients
→ Herbivory pressure

How can biotic interactions generate resource heterogeneity?



Homogeneous landscape

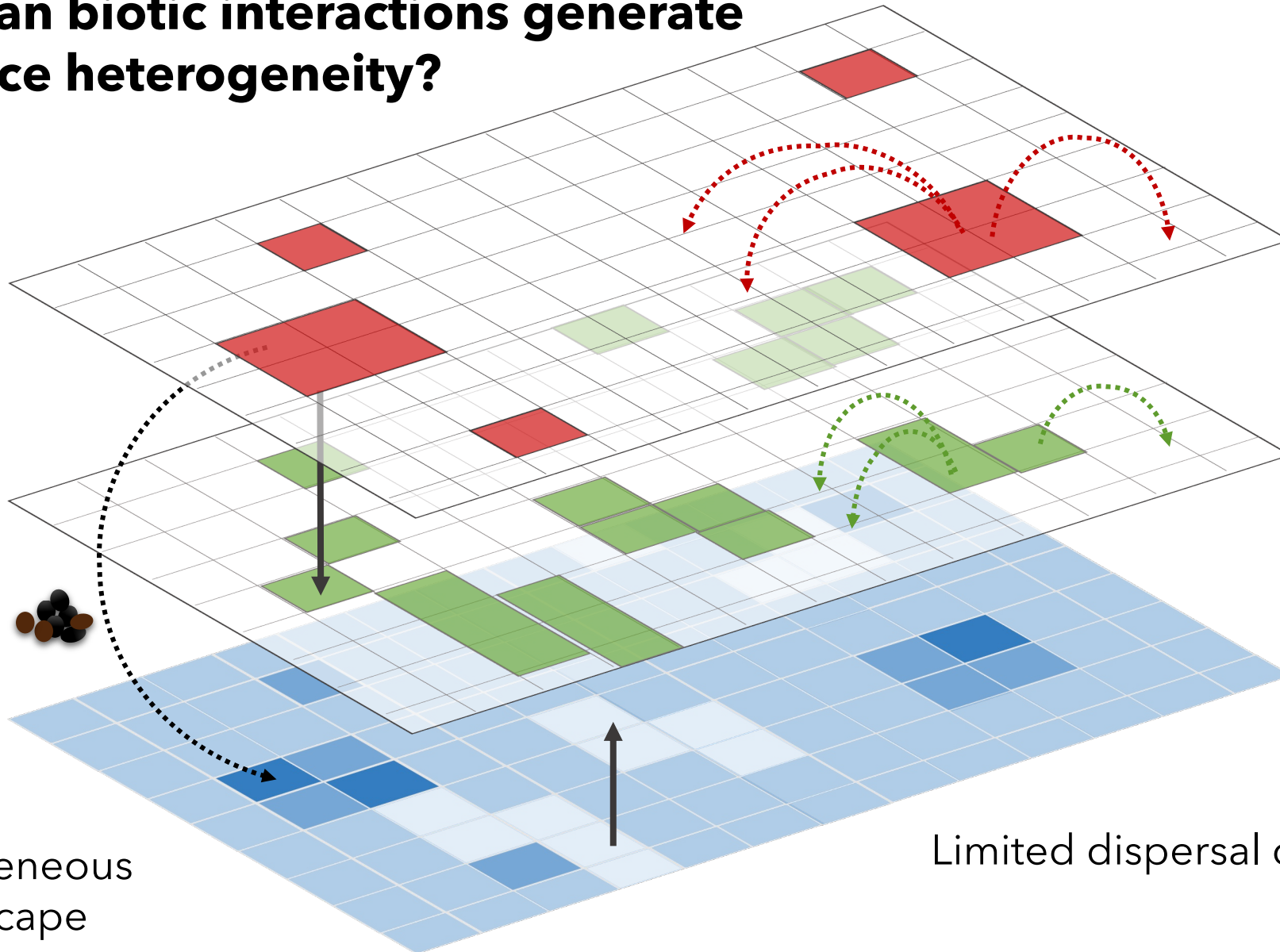
Herbivory pressure modulates plant abundance

CONTEXT

Metaecosystems, zoobiochemistry

→ Organisms disperse

How can biotic interactions generate resource heterogeneity?



Homogeneous landscape

Limited dispersal drives species distribution

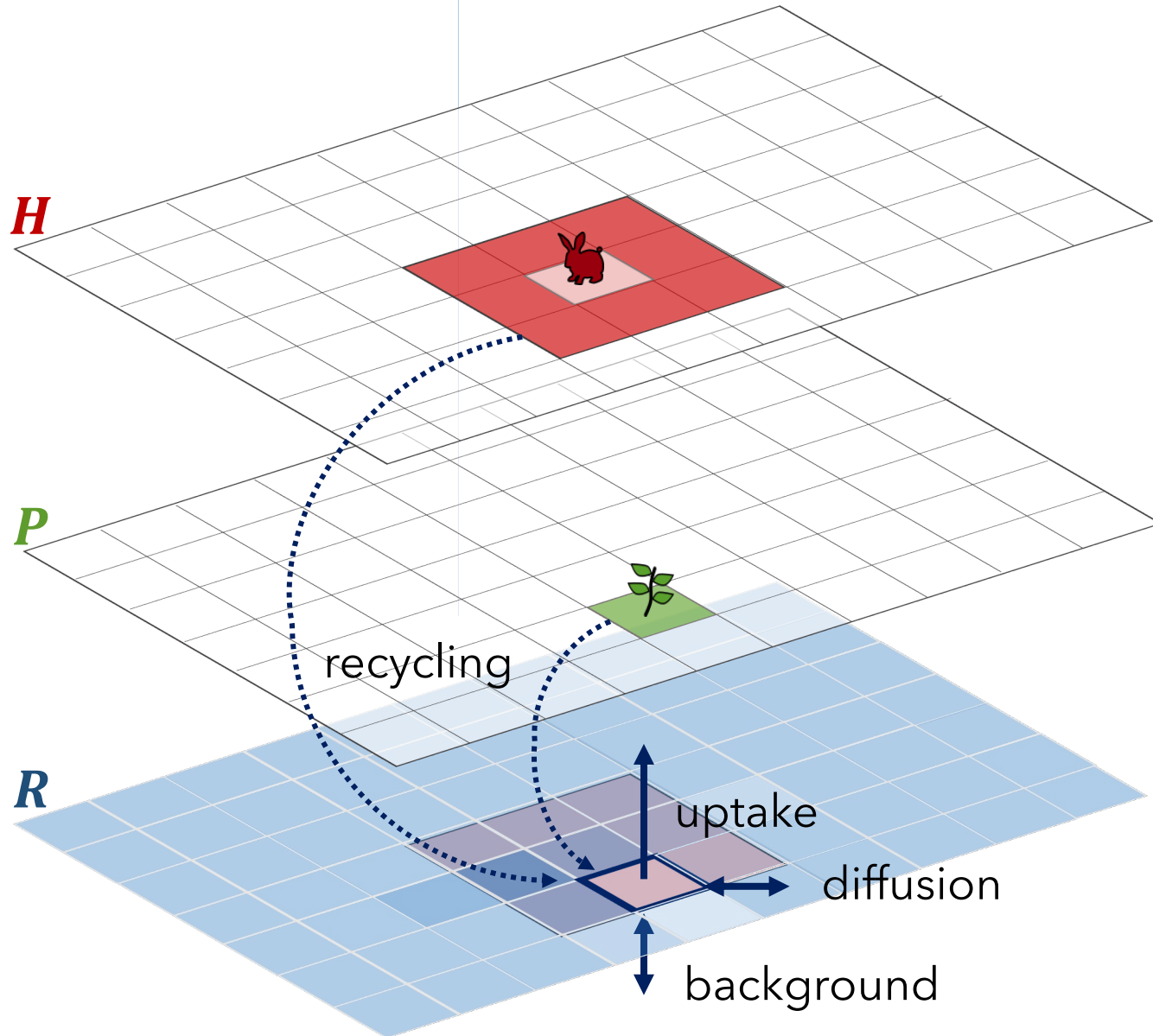
RESEARCH QUESTIONS

Q1 How do **the scales of dispersal and foraging of plants and herbivores affect the spatial heterogeneity of abiotic resources?**

Q2 How does resource patchiness depend on **recycling level?**

THE MODEL

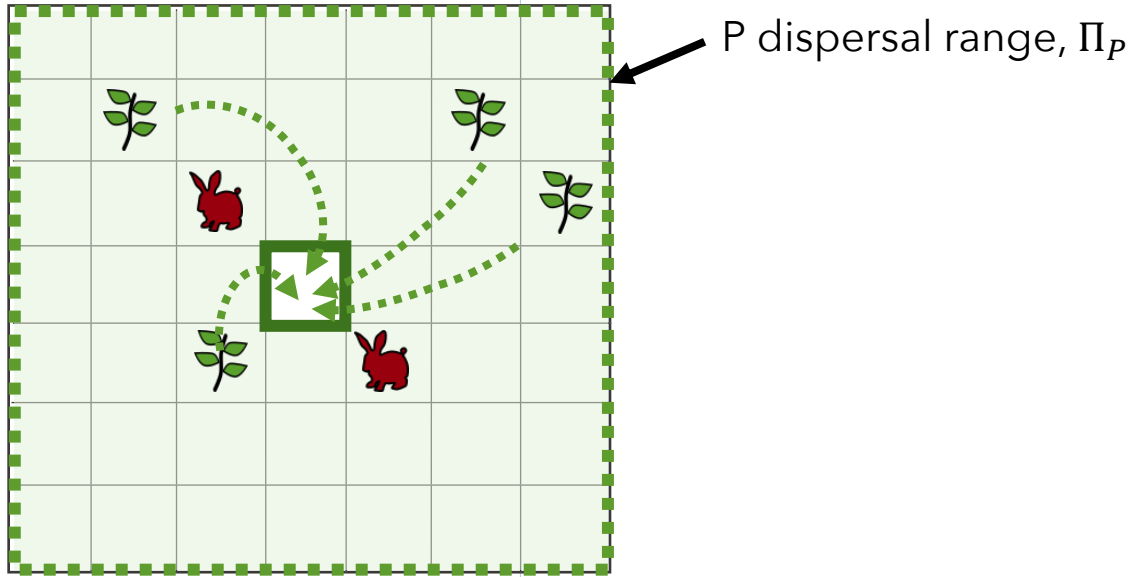
Occupancy model (presence/ absence, no abundance)
100 x 100 lattice, R, P, H layers, 1 cell = plant population foraging range



Resource dynamics at local scale

- Background: tends to come back to R_0
- Diffusion: tends to homogenize (#8 neigh)
- Uptake: tends to decrease to 0
- Recycling: tends to increase

THE MODEL

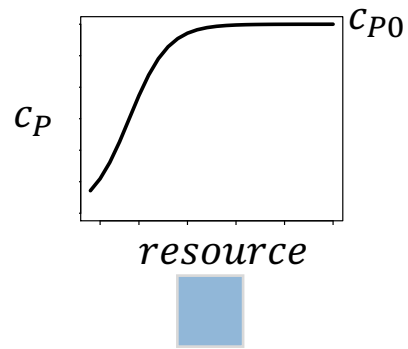
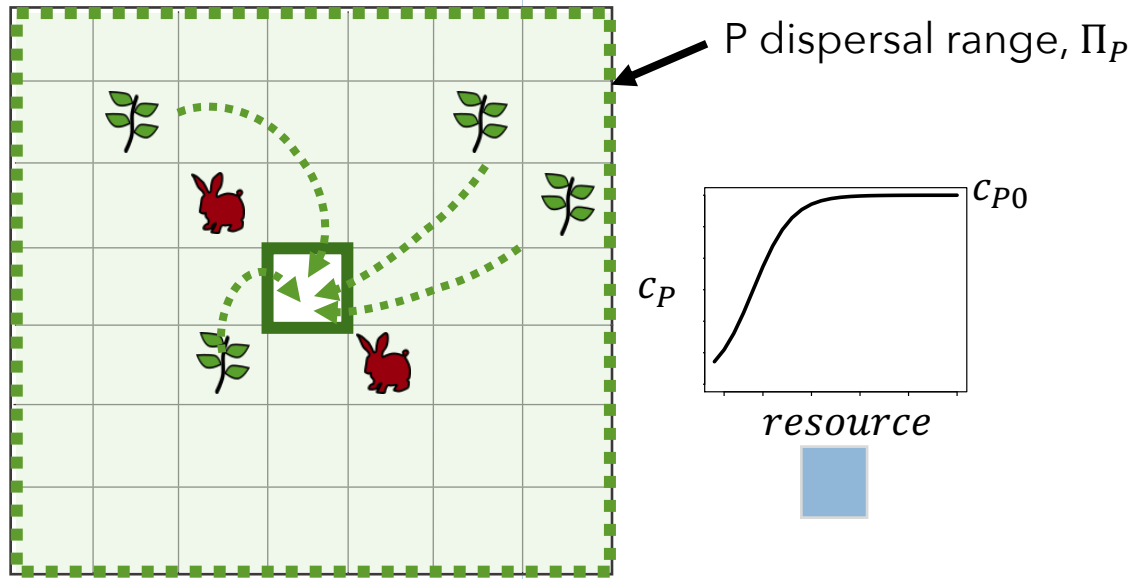


Colonization-extinction dynamics

Colonization, c , of an empty cell depends on

- basal colonisation rate, c_0
- proportion of colonizers in Π

THE MODEL

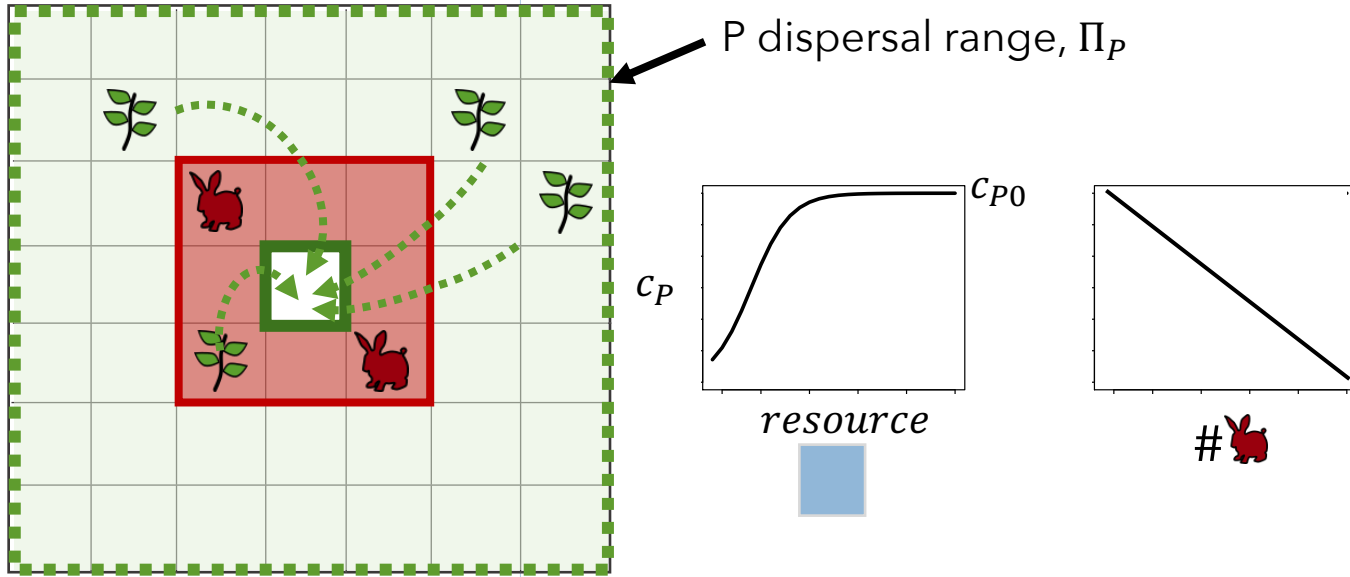


Colonization-extinction dynamics

Colonization, c , of an empty cell depends on

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- resource availability

THE MODEL

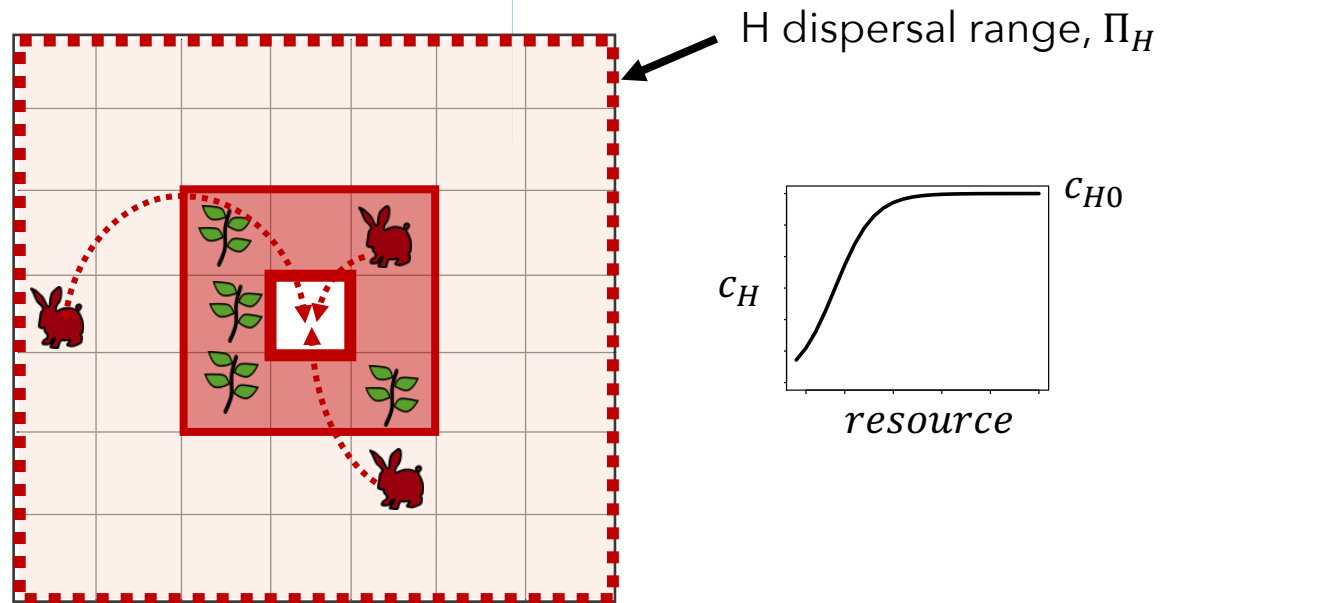
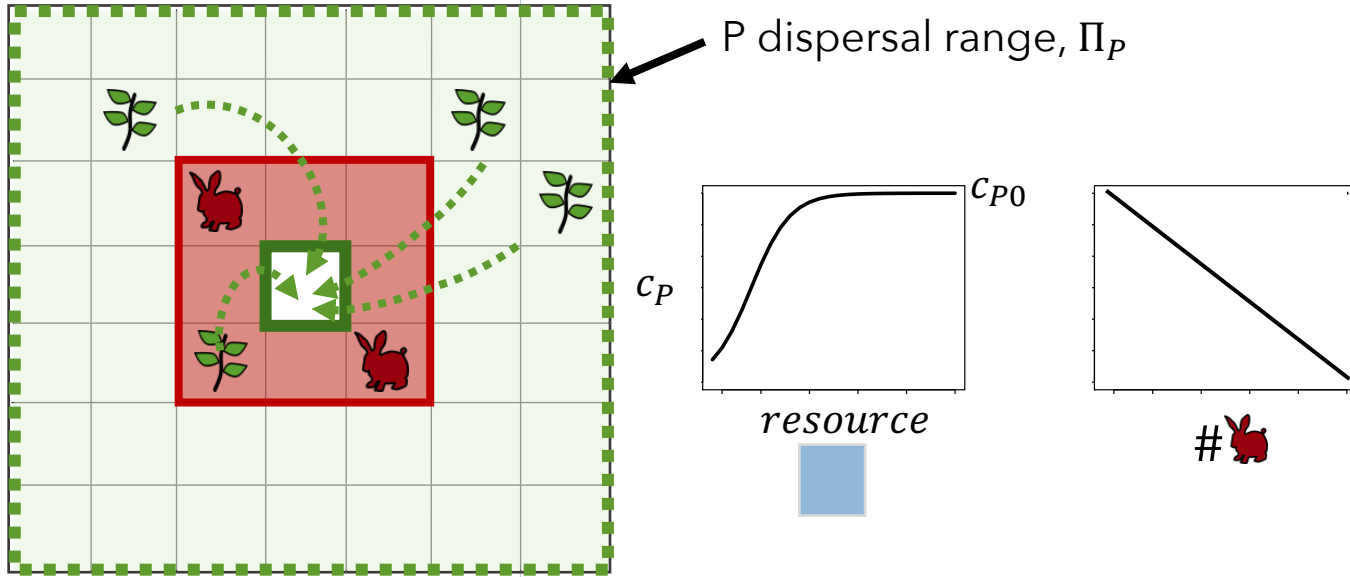


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THE MODEL

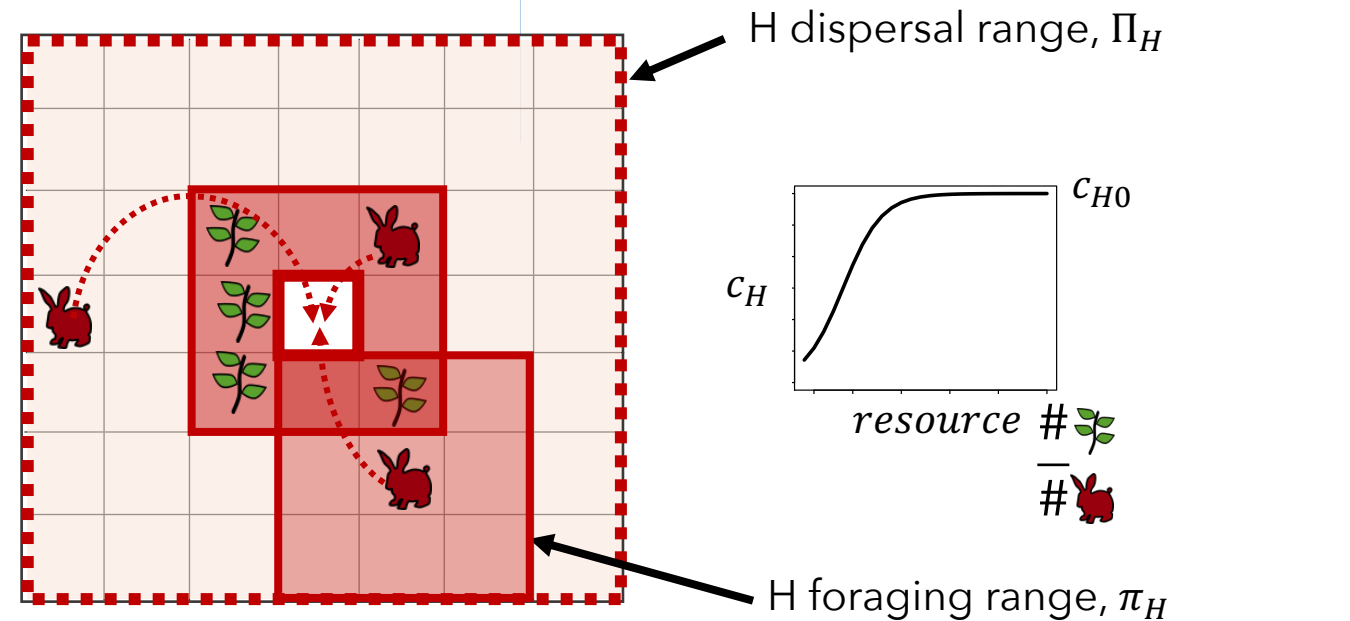
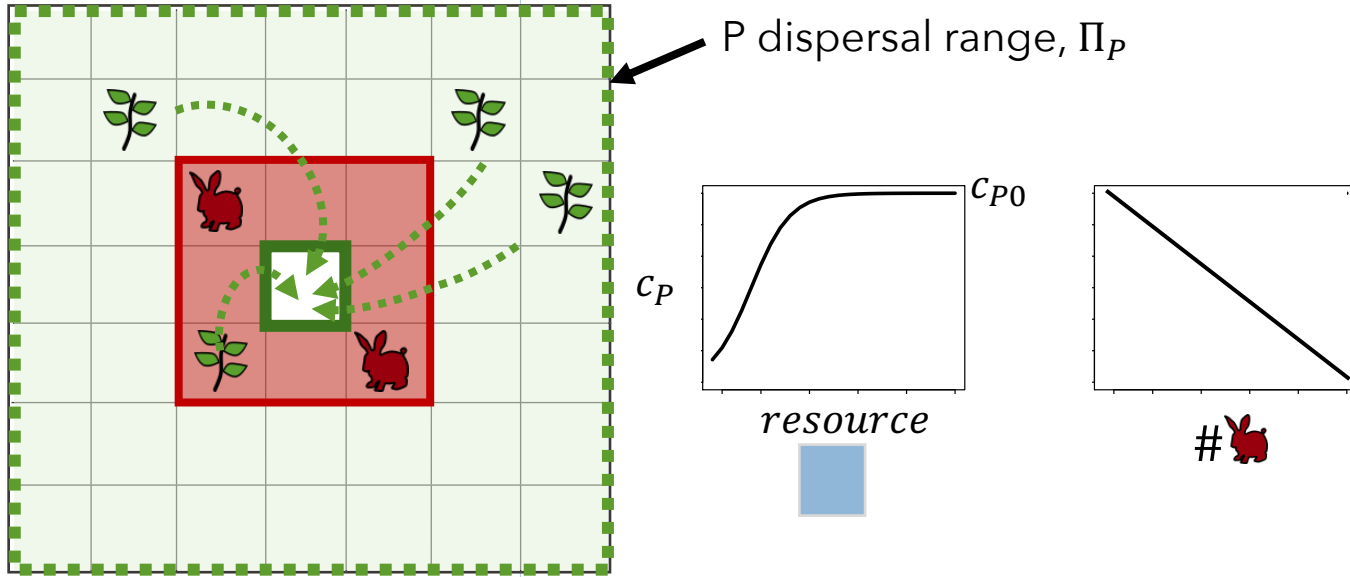


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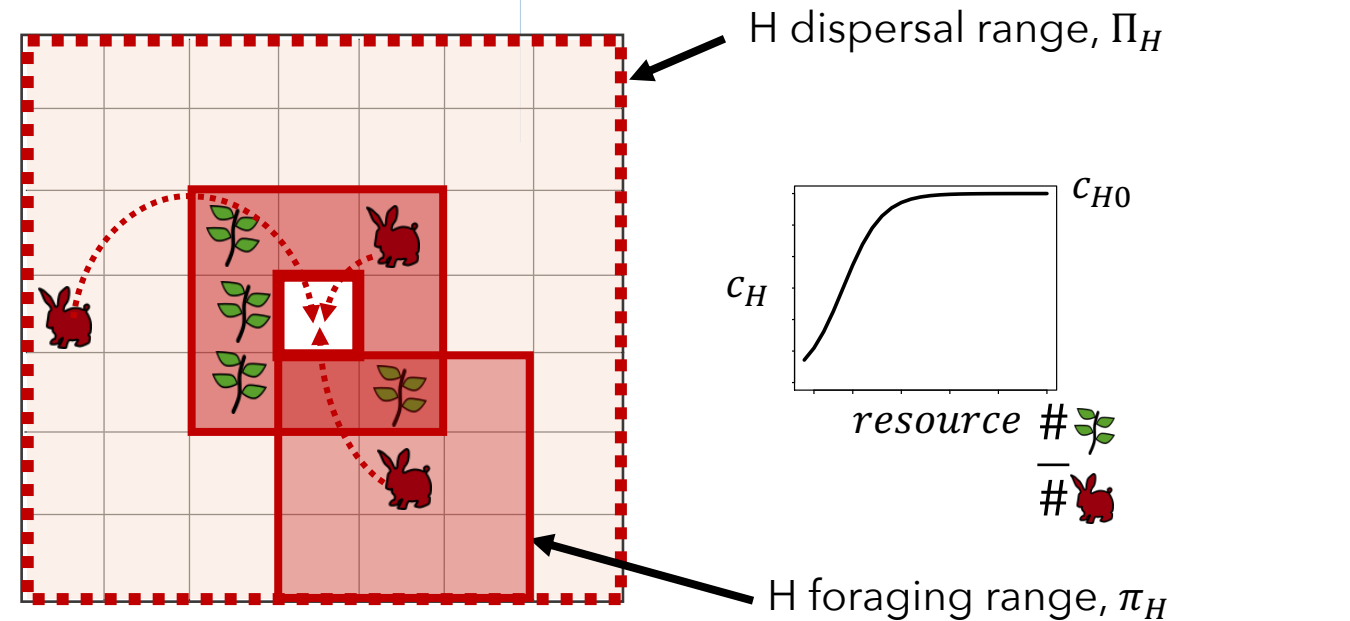
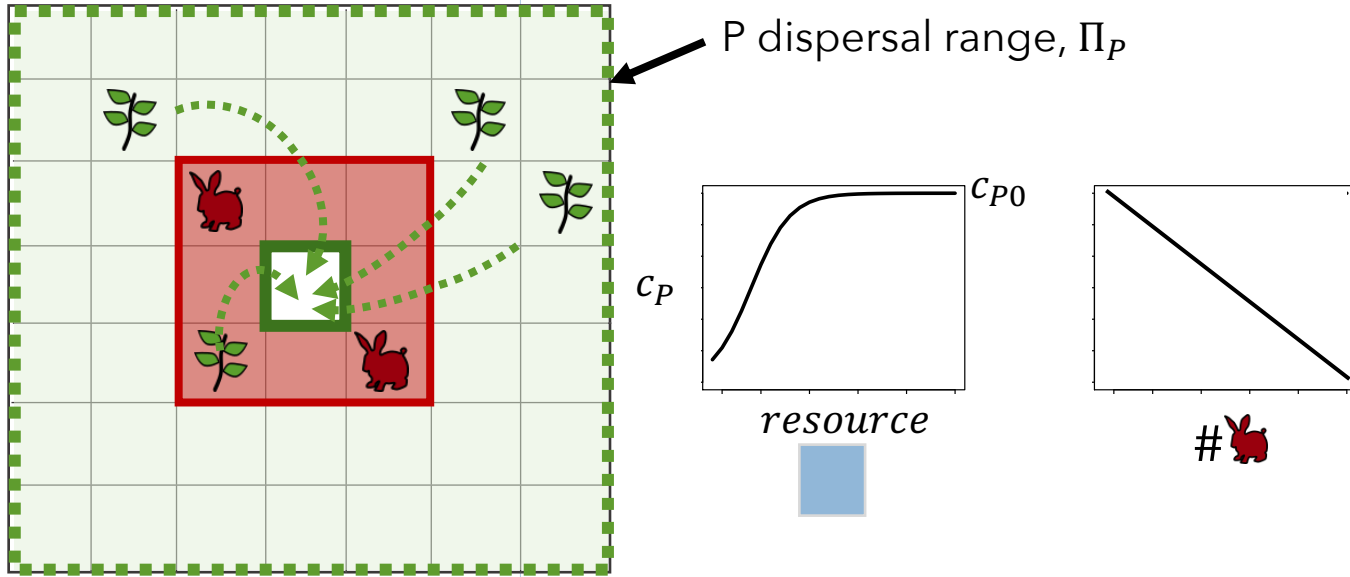


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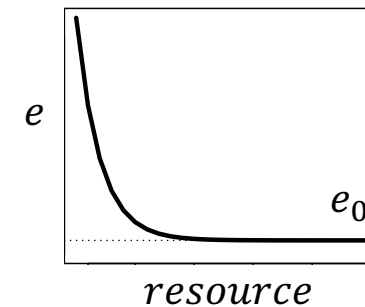
Colonization-extinction dynamics

Colonization, c , of an empty cell depends on

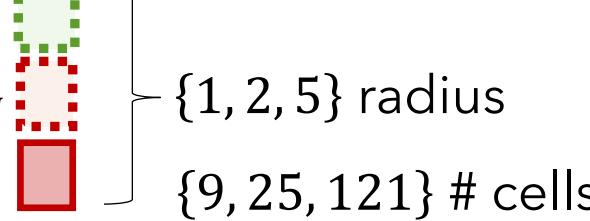
- basal colonisation rate, c_0
- proportion of colonizers in Π
- resource availability
- herbivory pressure (for P)

Extinction e of a population depends on

- random events (basal rate), e_0
- resource availability



SIMULATIONS AND ANALYSIS

- Q1** Plant dispersal range, Π_P
Herbivore dispersal range, Π_H
Herbivore foraging range, π_H
- 
- {1, 2, 5} radius
{9, 25, 121} # cells

Colonization- extinction
basal rates, c_0, e_0 : slow / fast

- Q2** Recycling levels : \emptyset low, high

With and without H

Full factorial x 25 replicates

SIMULATIONS AND ANALYSIS

Q1

Plant dispersal range, Π_P

Herbivore dispersal range, Π_H

Herbivore foraging range, π_H



{1, 2, 5} radius

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Q2

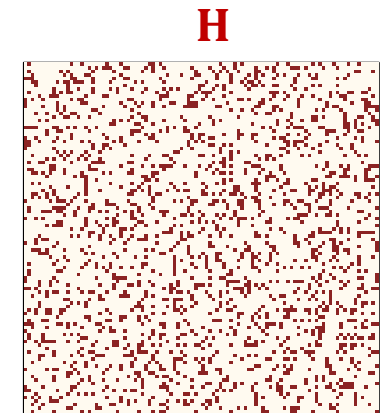
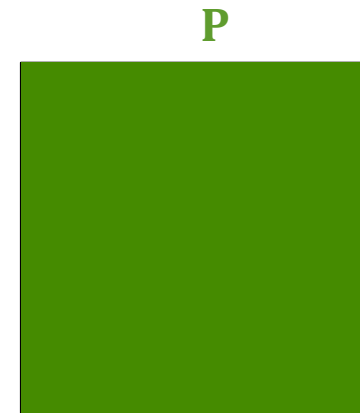
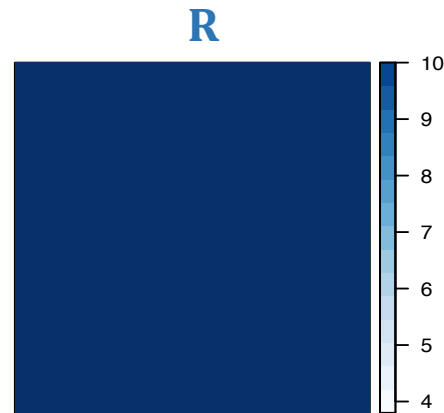
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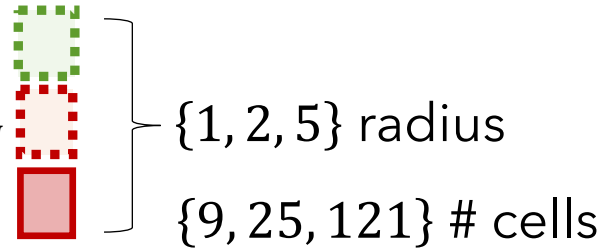
Start: $R = R_0; P = 1; H = 0.2$

300 time steps



SIMULATIONS AND ANALYSIS

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Herbivore foraging range, π_H



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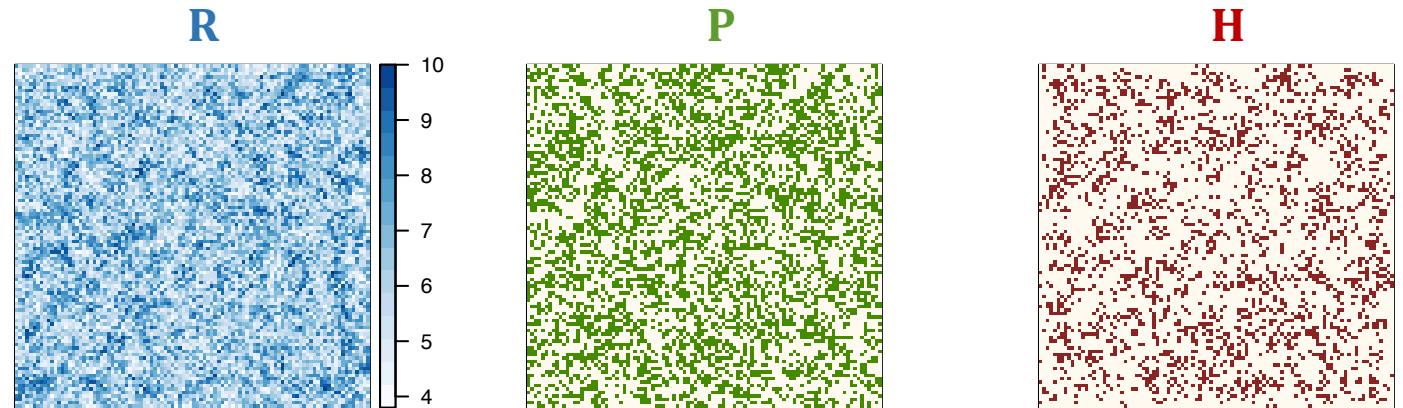
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SIMULATIONS AND ANALYSIS

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Herbivore dispersal range, Π_H
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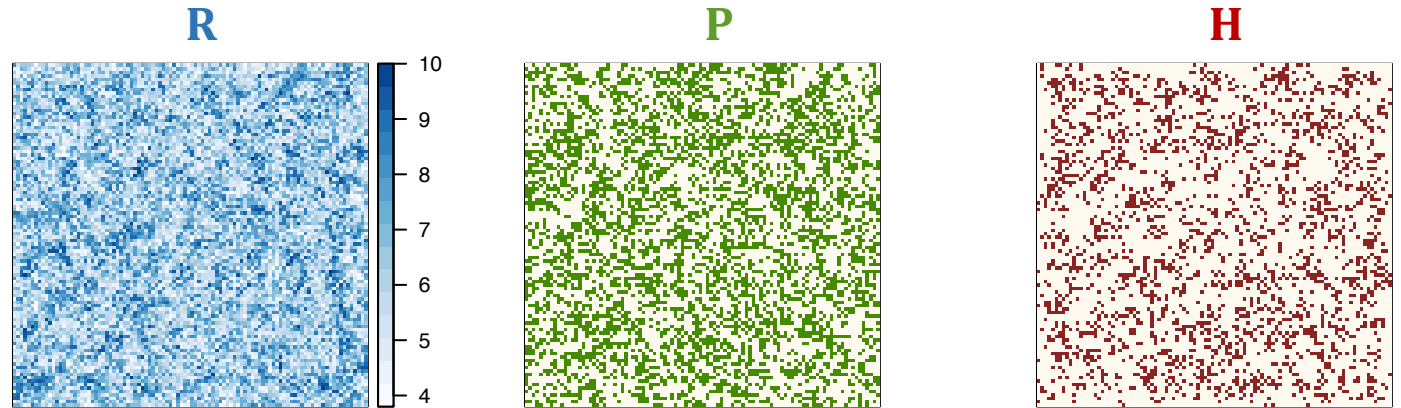
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Analyses on final landscapes

- Occupancy P, H , mean resource level \bar{R}
- Spatial autocorrelation of R:

Z-score of Moran index: deviation from null expectation (1000 randomizations)

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Analyses on final landscapes

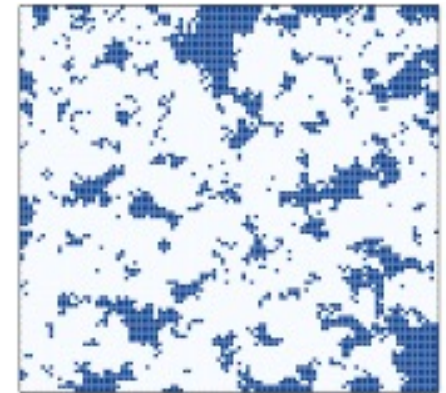
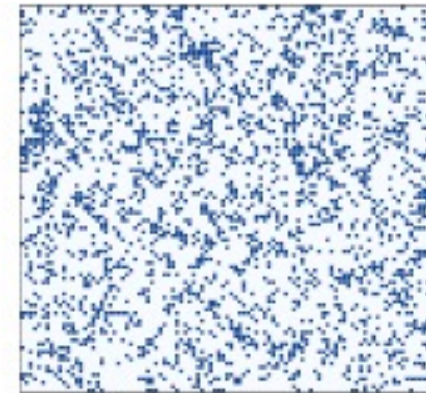
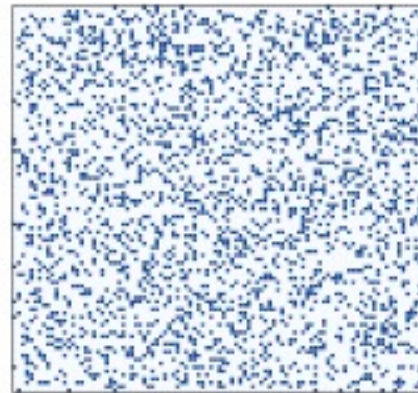
- Occupancy P, H , mean resource level
- Spatial autocorrelation of R:

Range of R auto-correlation

min

mean

max

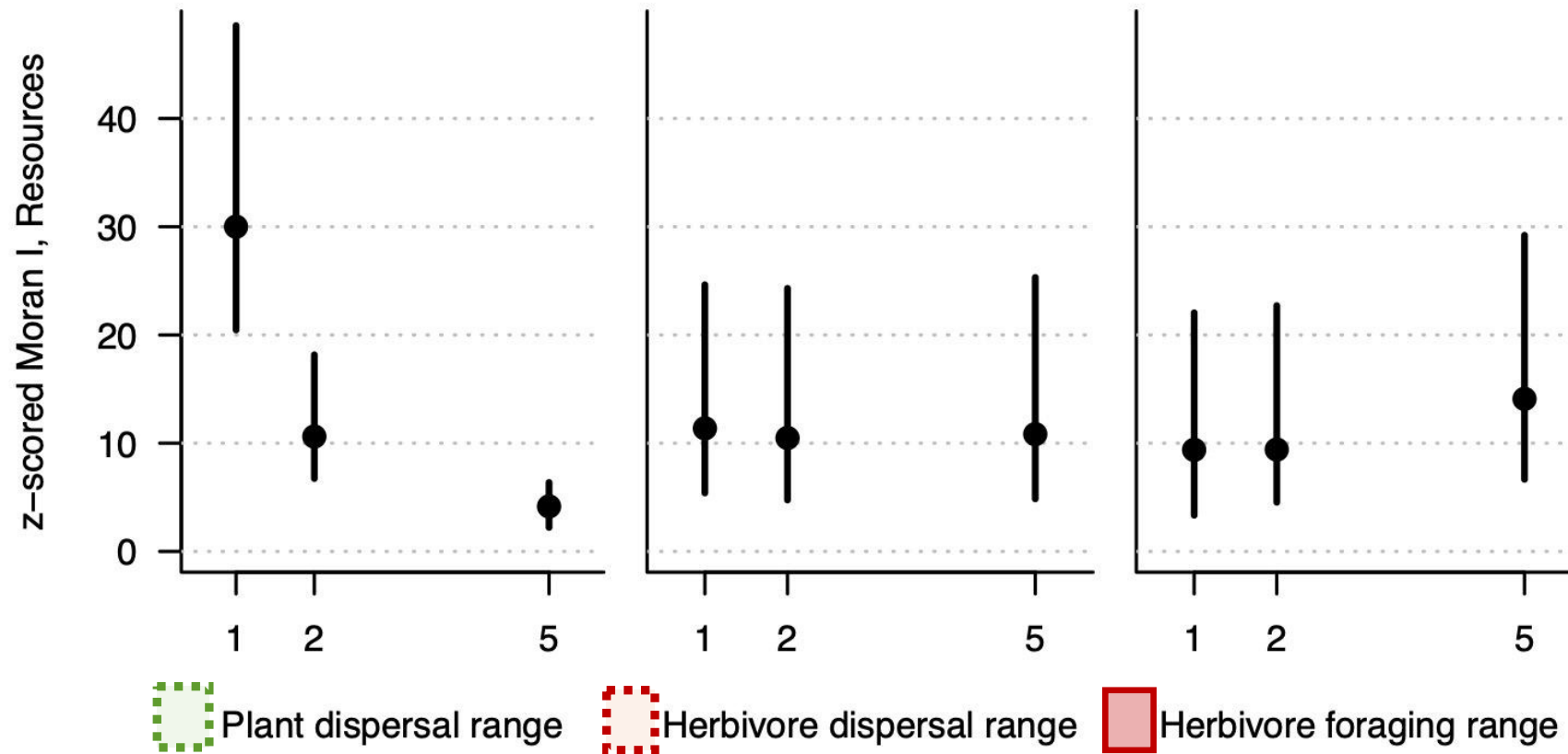


N

Z-score of Moran index: deviation from null expectation (1000 randomizations)

Results Q1

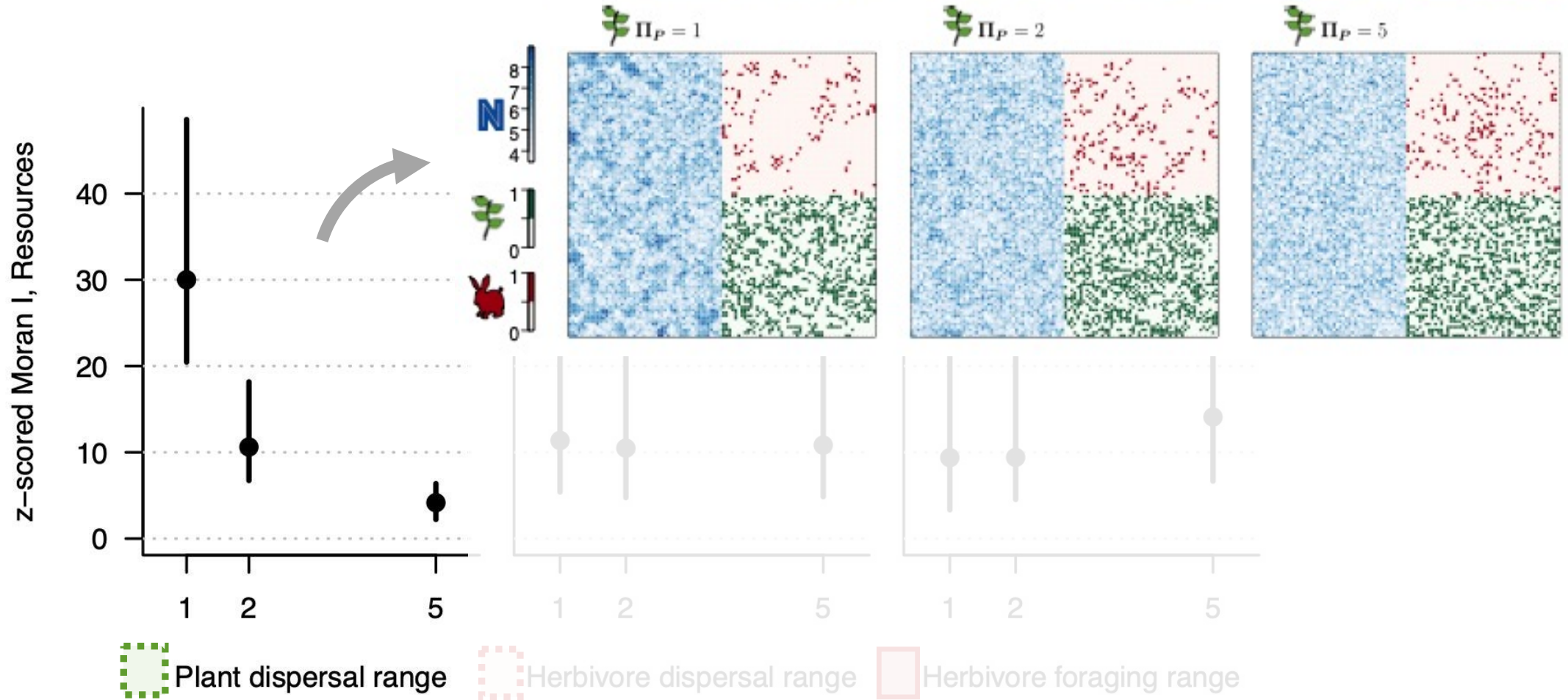
General effects of the ranges



Dominant effect of plant dispersal range → homogenizing effect

Results Q1

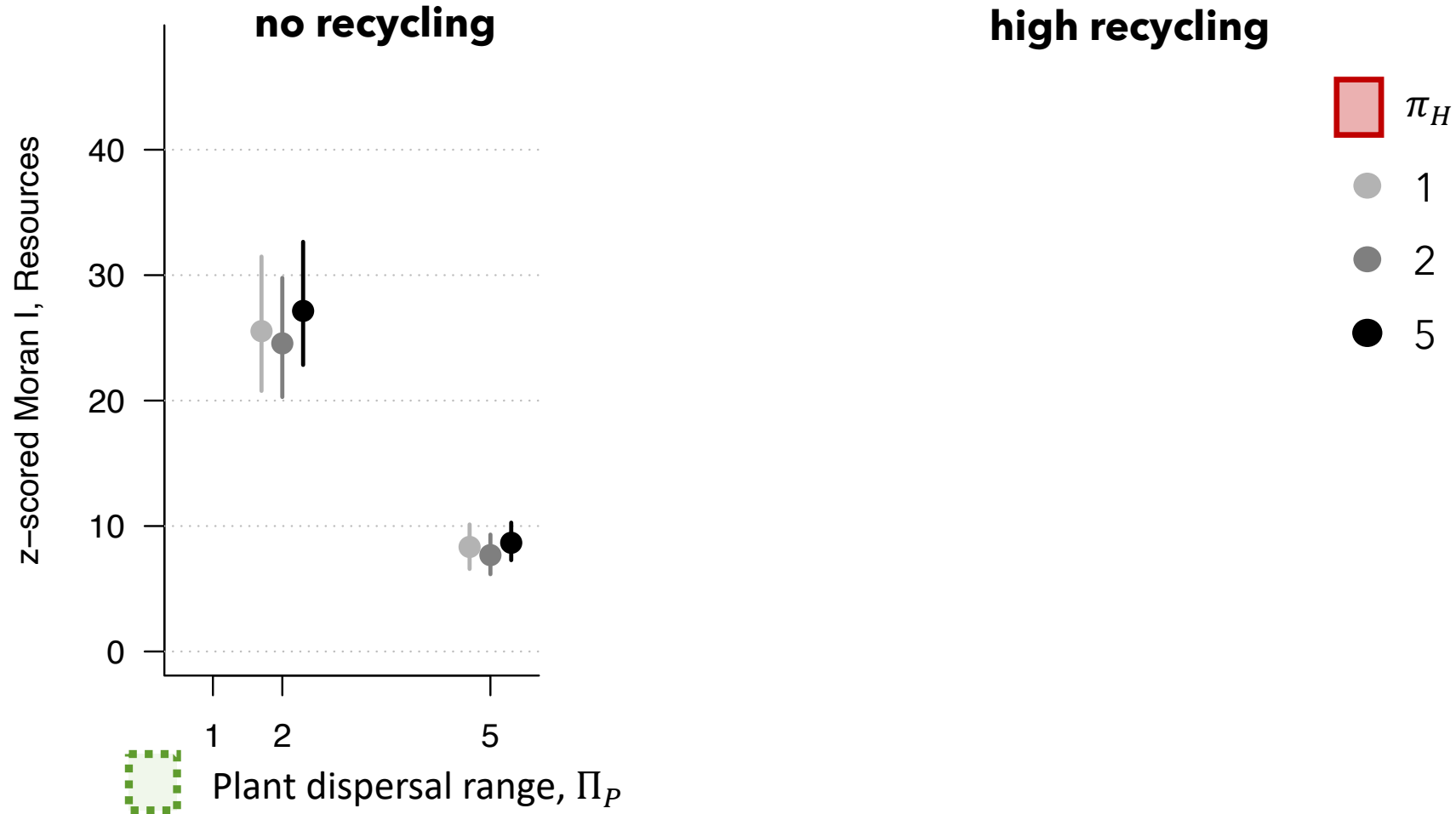
General effects of the ranges



Dominant effect of plant dispersal range → homogenizing effect
At low Π_P , plant escape less herbivory pressure and P and H decrease

Results Q2

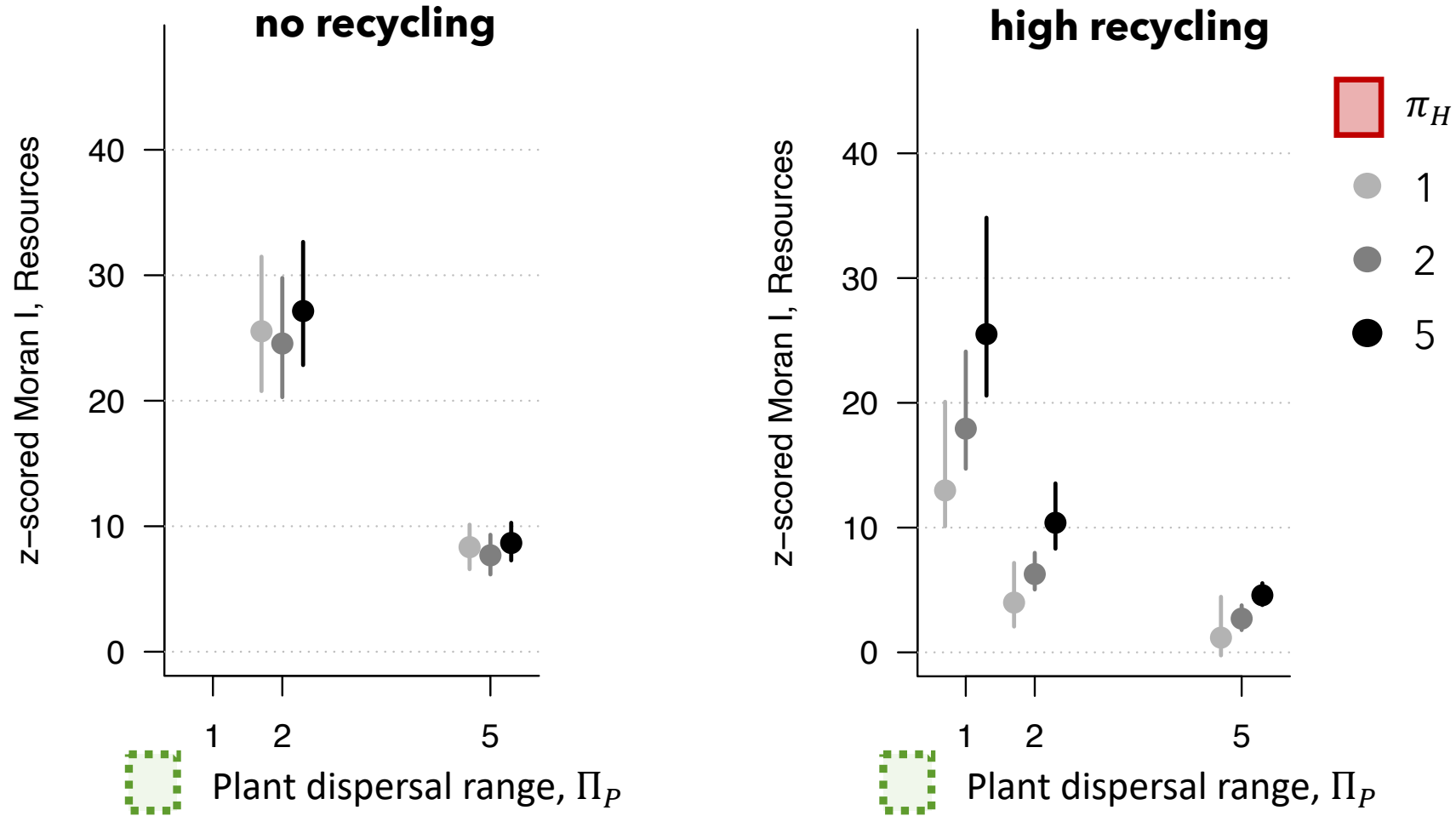
Interaction between herbivore foraging range and recycling



When recycling allow sufficient H , increasing π_H increases resource patchiness
Recycling decreases patchiness

Results Q2

Interaction between herbivore foraging range and recycling

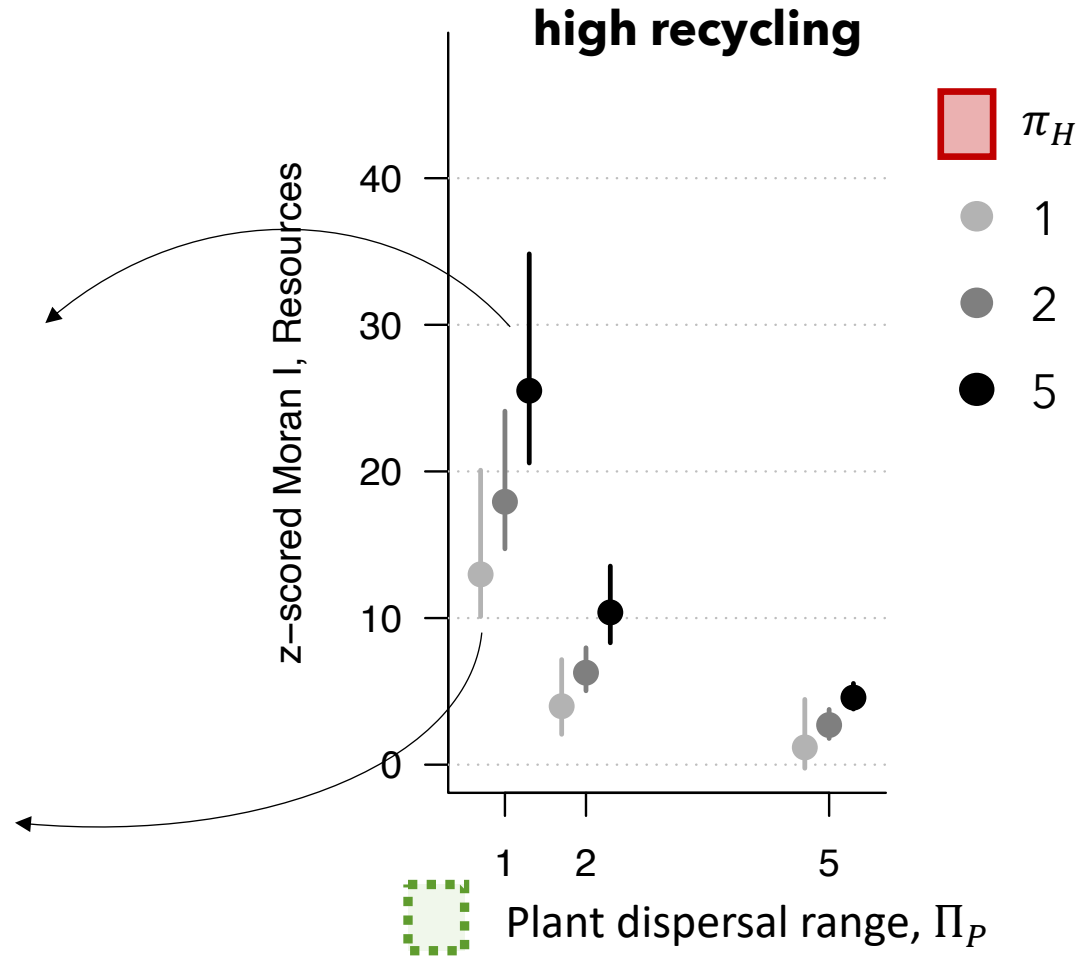
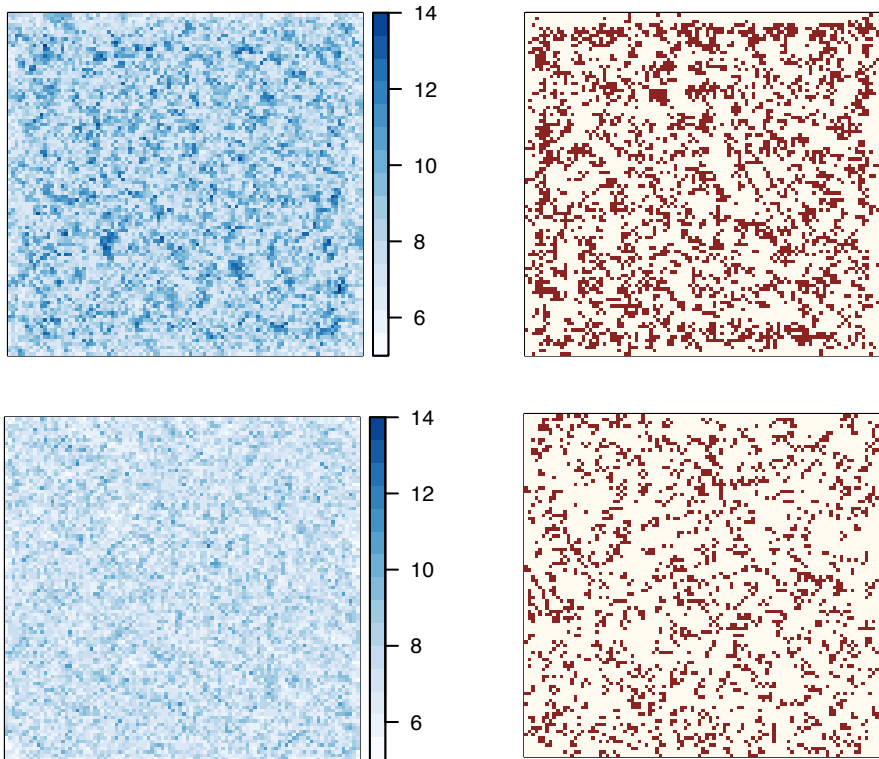


When recycling allow sufficient H , increasing π_H increases resource patchiness
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Results Q2

Interaction between herbivore foraging range and recycling

competition \rightarrow clustering +
higher $H \rightarrow$ more recycling

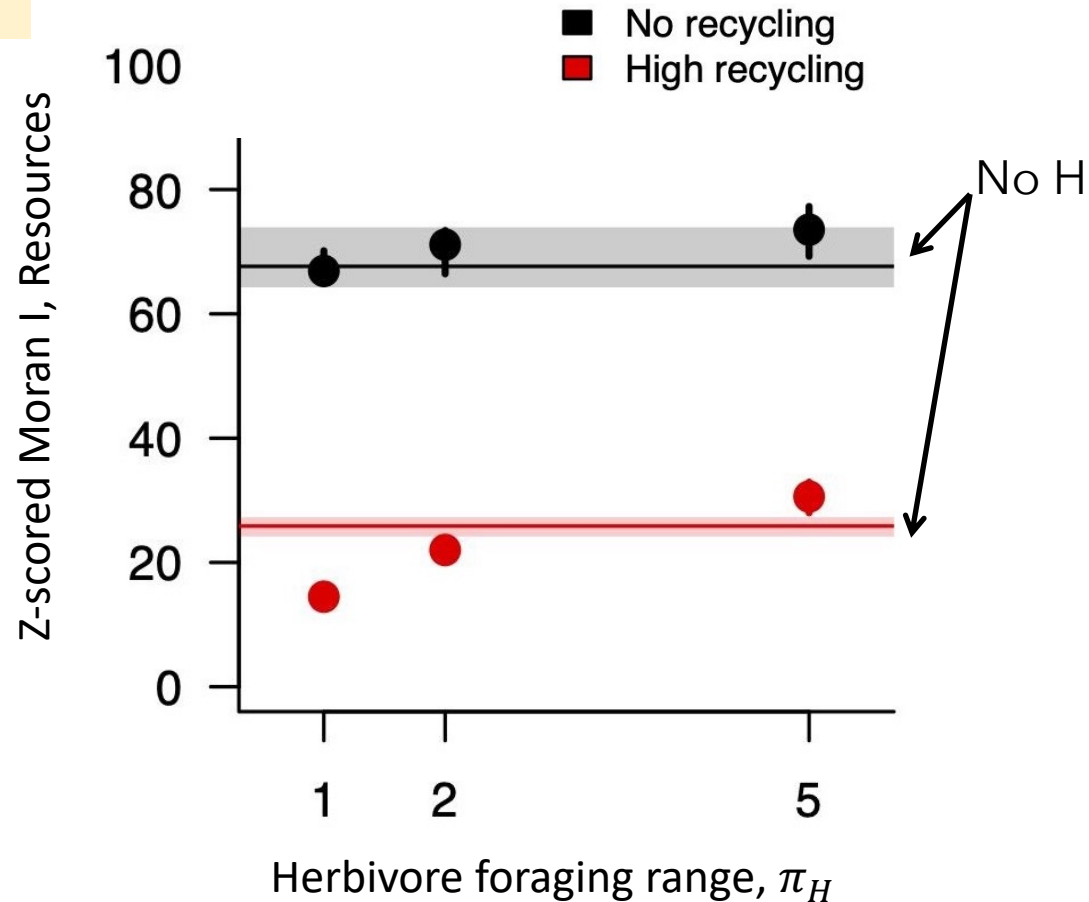


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Interaction between herbivore foraging range and recycling

case Slow
P - fast H

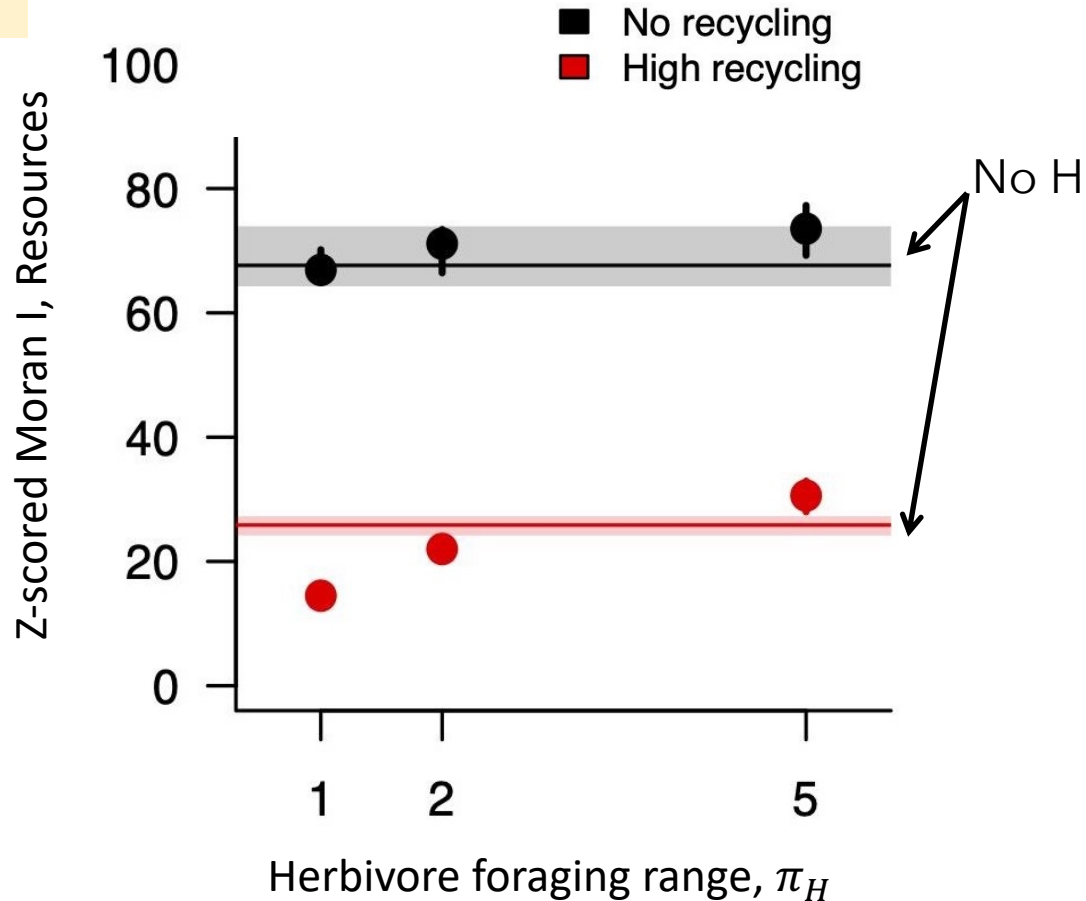


When recycling allow sufficient H , increasing π_H increases resource patchiness
Recycling decreases patchiness

Results Q2

Interaction between herbivore foraging range and recycling

case Slow
P - fast H



No recycling: no difference with no H

High recycling:

- small π_H decreases Moran I
- high π_H increases Moran I compared with no H

When recycling allow sufficient H , increasing π_H increases resource patchiness
Recycling decreases patchiness

Take home messages

Q1 High resource patchiness is generated by moderate plant occupancy and high population clustering:

- limited Plant dispersal
- high Herbivore foraging range

Q2 Recycling decreases resource patchiness but allow higher H occupancies

No effect of Herbivore dispersal range → have to track plant populations

Take home messages

Q1 High resource patchiness is generated by moderate plant occupancy and high population clustering:

- limited Plant dispersal
- high Herbivore foraging range

Q2 Recycling decreases resource patchiness but allow higher H occupancies

No effect of Herbivore dispersal range → have to track plant populations

Next step: Vary top-down interactions, integrate environmental heterogeneity

Funding and institution



Thank you !



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