Restoration of heathland ecosystems – opportunities and ecological constraints

15th European Heathland Workshop

Nijmegen/Dwingeloo - August 2017

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Outline

Variables affecting the restoration success:

Restoration targets:
- Abiotic conditions (pH, nutrient removal…)
- Invasive plant control
- Species diversity
- Counteract N inputs
- …

Landscape characteristics:
- Macroclimate
- Topography
- Site history …

Global change drivers:
- Climate change
- Nitrogen deposition
- Invasive species
- Habitat fragmentation …

Biotic/abiotic factors:
- Target species (traits)
- Population sizes
- Donor populations
- Species composition
- Soil conditions …

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- **Abiotic conditions** (pH, nutrient removal…)
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- …

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- **Nitrogen deposition**
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- **Habitat fragmentation** …

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- **Donor populations**
- Species composition
- Soil conditions …

Outline

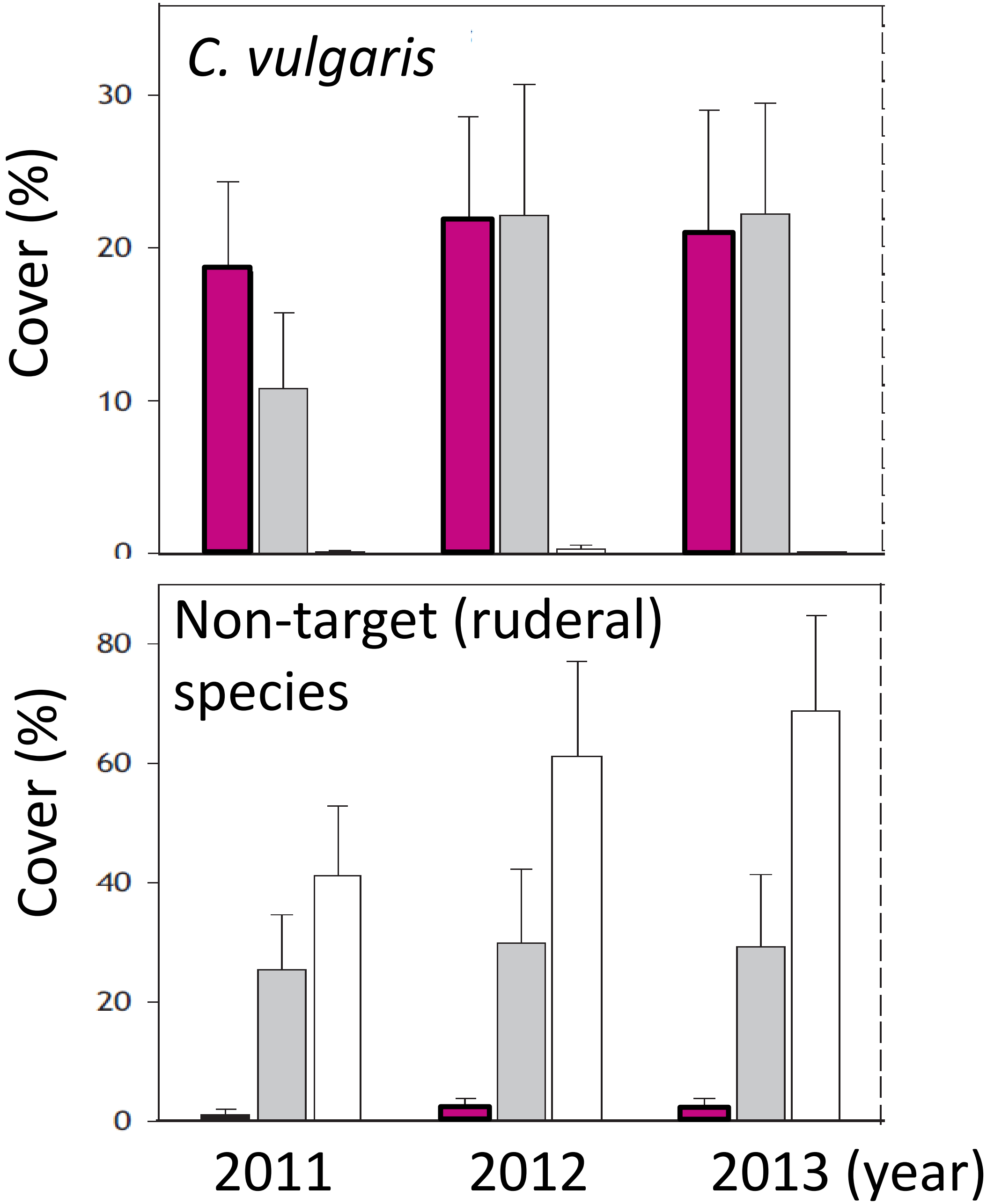
1 Restoration of heathland plant communities
- 1.1 Dispersal power
- 1.2 Critical populations sizes

2 Restoration of heathland animal communities (arthropods)
- 2.1 Example: Leafhoppers
- 2.2 Dispersal power and habitat fragmentation (beetles)

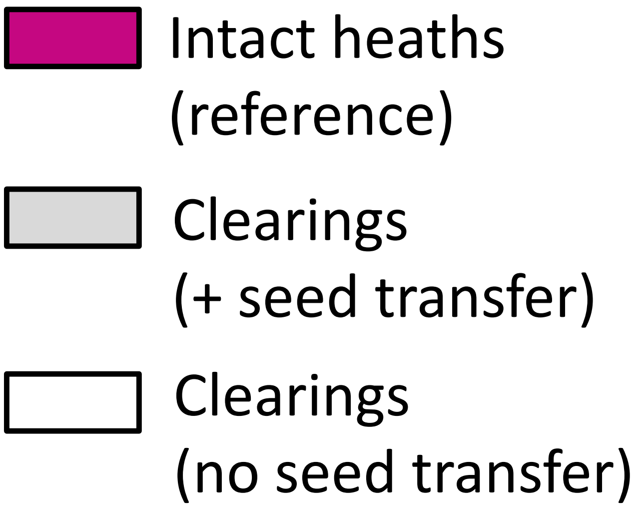
3 Effects of global change drivers – some examples
- 3.1 Nitrogen deposition
- 3.2 Climate change (interaction with N deposition)

4 Summary

Restoration of plant communities (montan heaths)



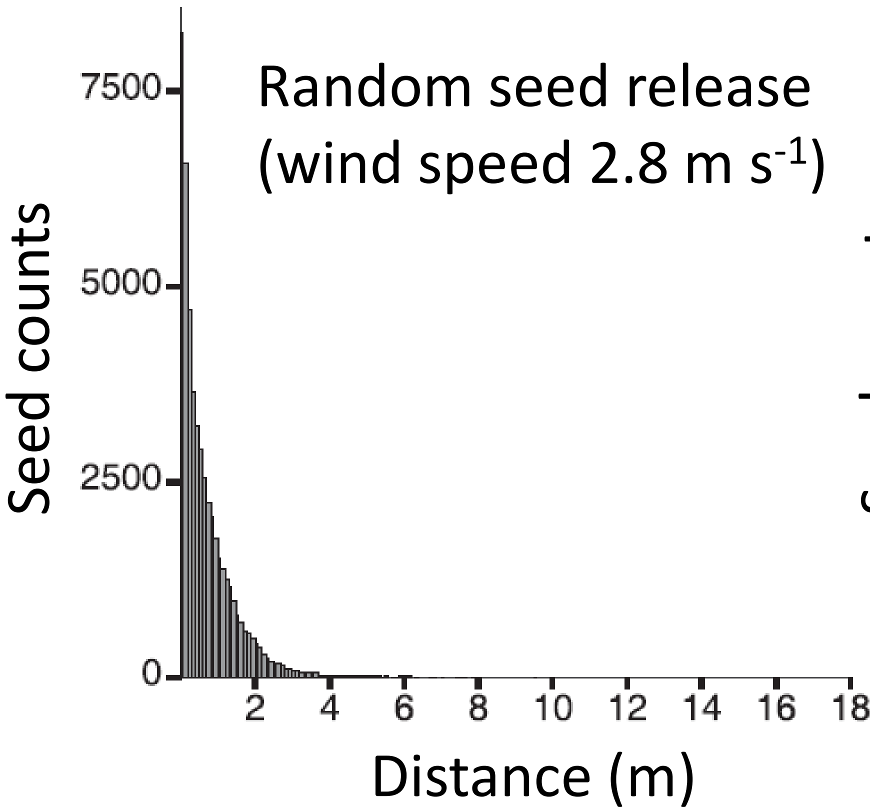
Initial situation:
- Spruce forest (clearings)
- > 50 years

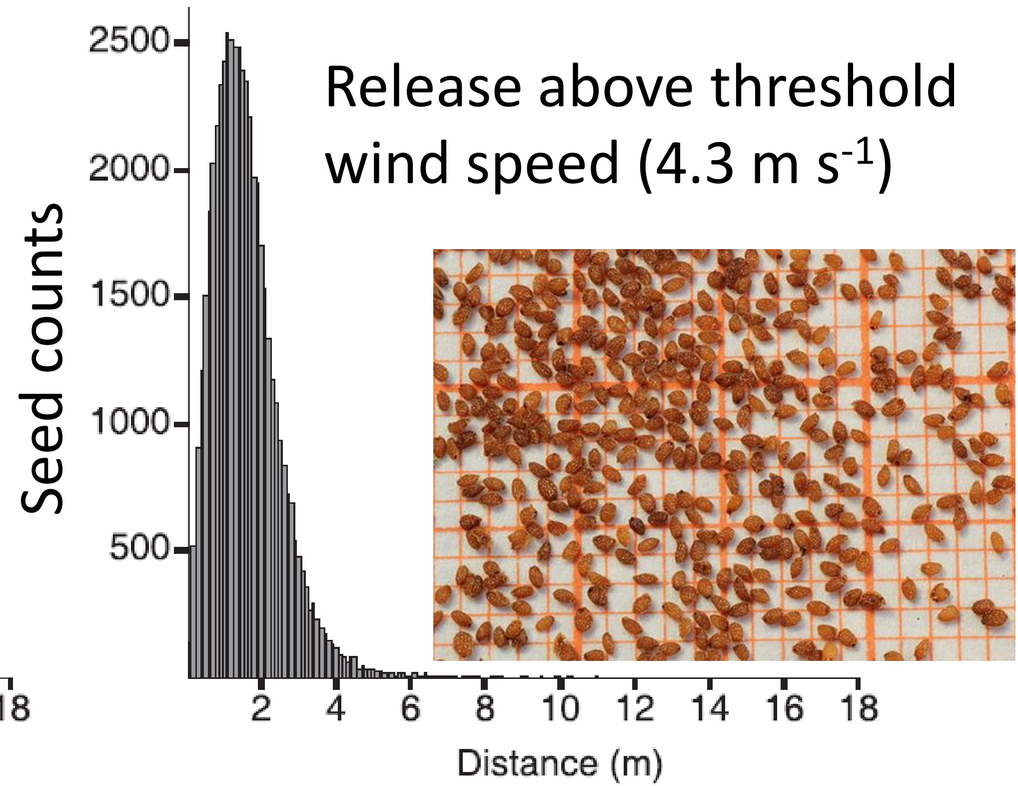


Borchard et al. (2017)

Limitations: Dispersal power of plants

Calluna vulgaris: Dispersal kernels (wind tunnel experiments)





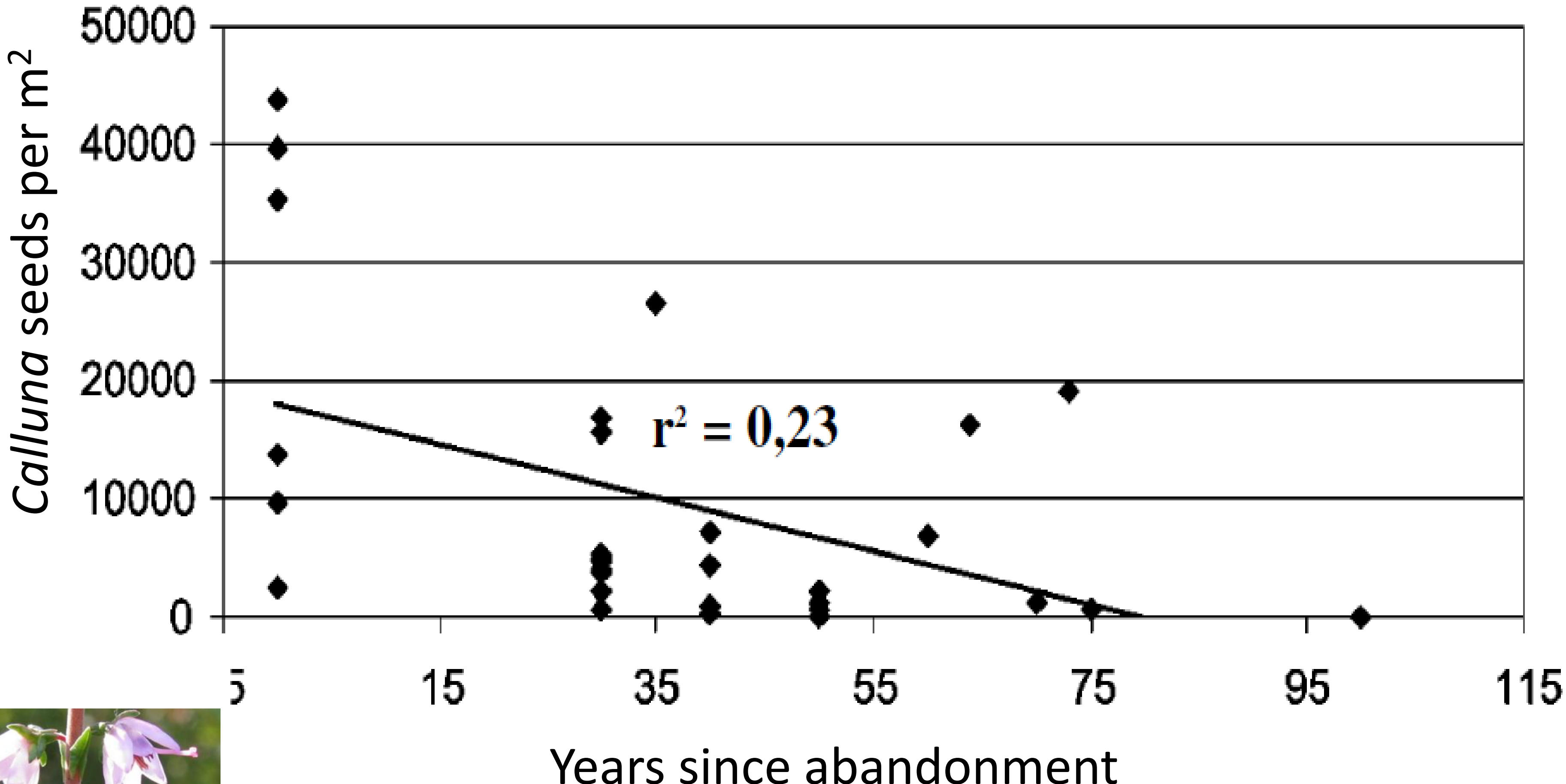
Soons & Bullock (2011)

Aerts et al. (1995)
Pywell et al. (1996)
Diemont (1996)
Bakker & Berendse (1999)
Pywell et al. (2011)

=> Low dispersal power of Calluna

Limitations: Seed density

Calluna vulgaris: Decreasing seed density with seed bank age



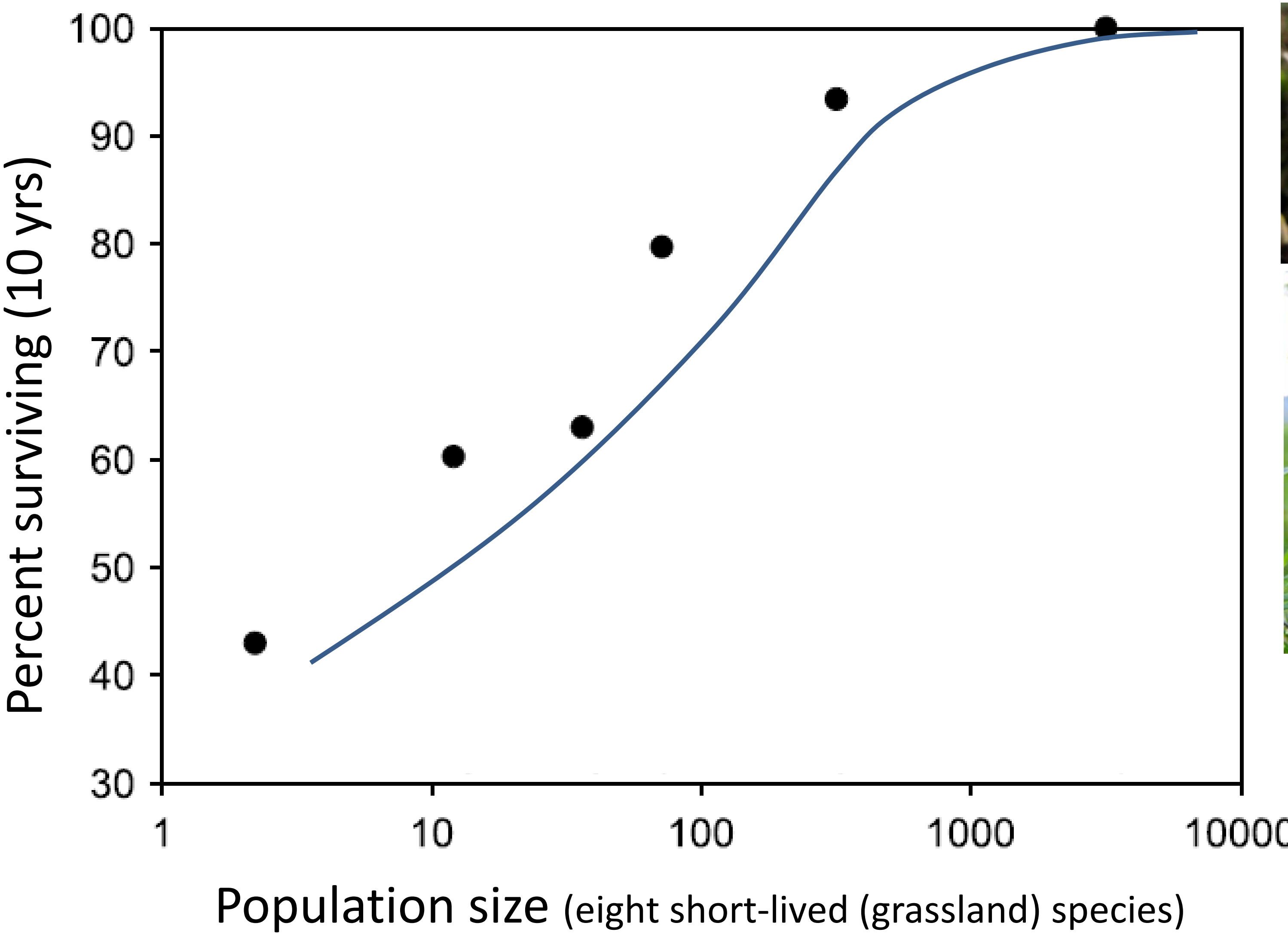
Calluna vulgaris

Bossuyt & Hermy (2003)

1.2

Limitations: Critical population sizes

Relationship between population size and survival rates (10 yrs)

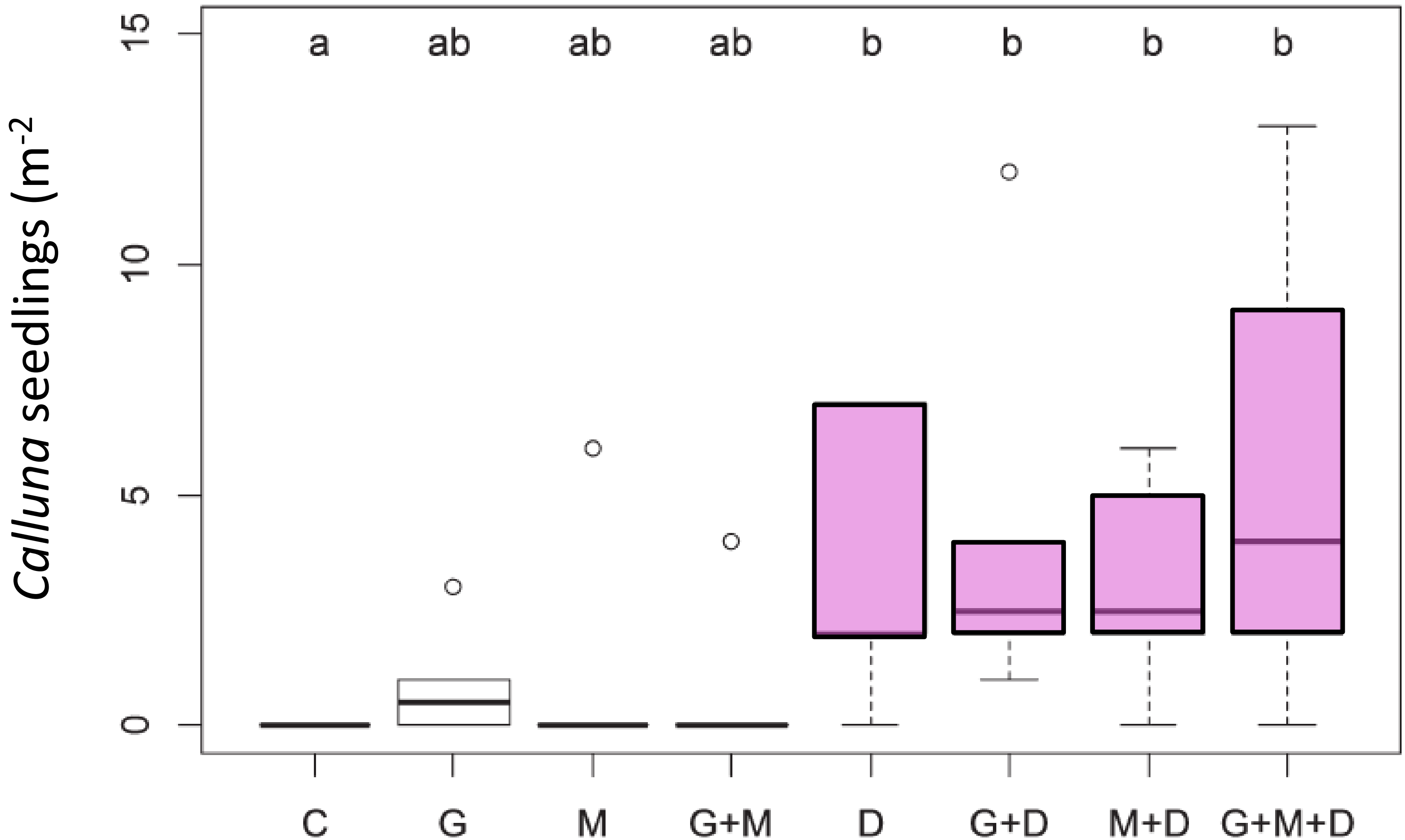


Gentiana spp.
Melampyrum spp.

Matthies et al. (2004)

1.2

Calluna gemination: Substrate-dependence



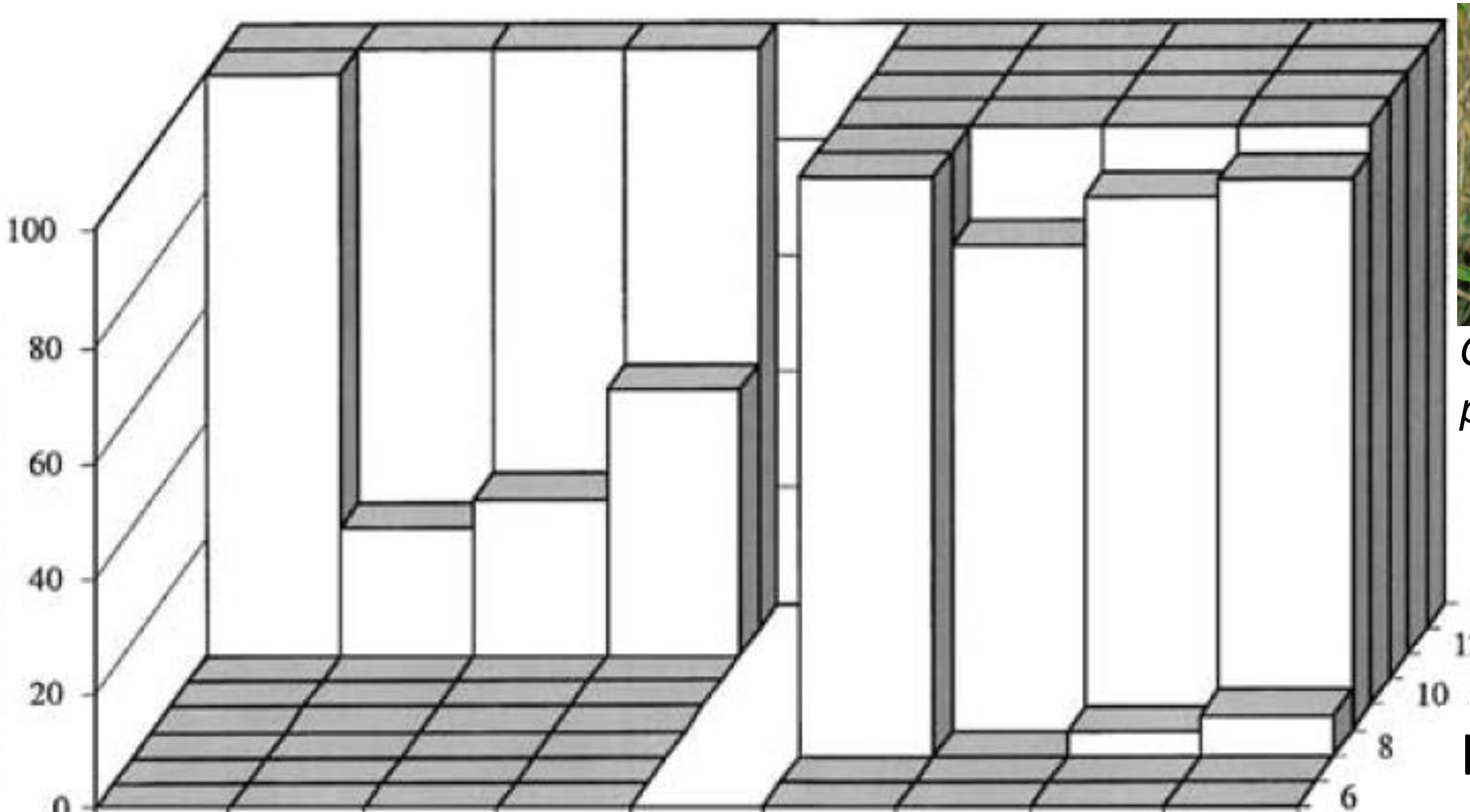
= Plots with „creation of bare soil“

Henning et al. (2017)

Population size and soil-disturbance

200 vs. 9 reproducing plants

Extinction probability (%)



Different disturbance regimes

Different disturbance regimes

Modeled scenarios

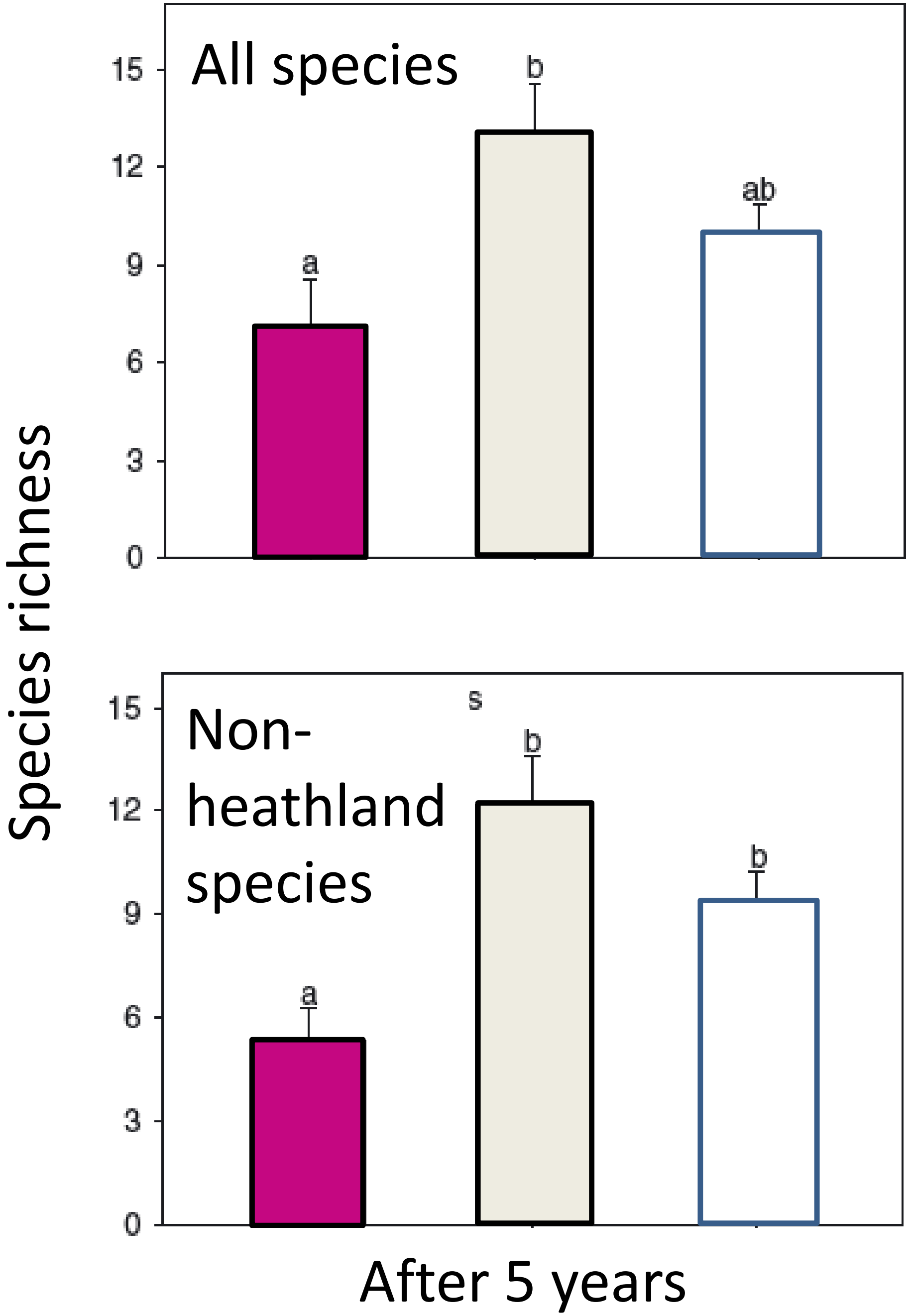
Intervals of soil disturbance (yrs.)

Gentiana pneumonanthe

Volis et al. (2005)

2.1

Restoration of animal communities:



Leafhoppers (Auchenorrhyncha)

Anoscopus albifrons

Initial situation:

- Spruce forest (clearings)
- > 50 years

Intact heaths (reference)

Clearings (+ seed transfer)

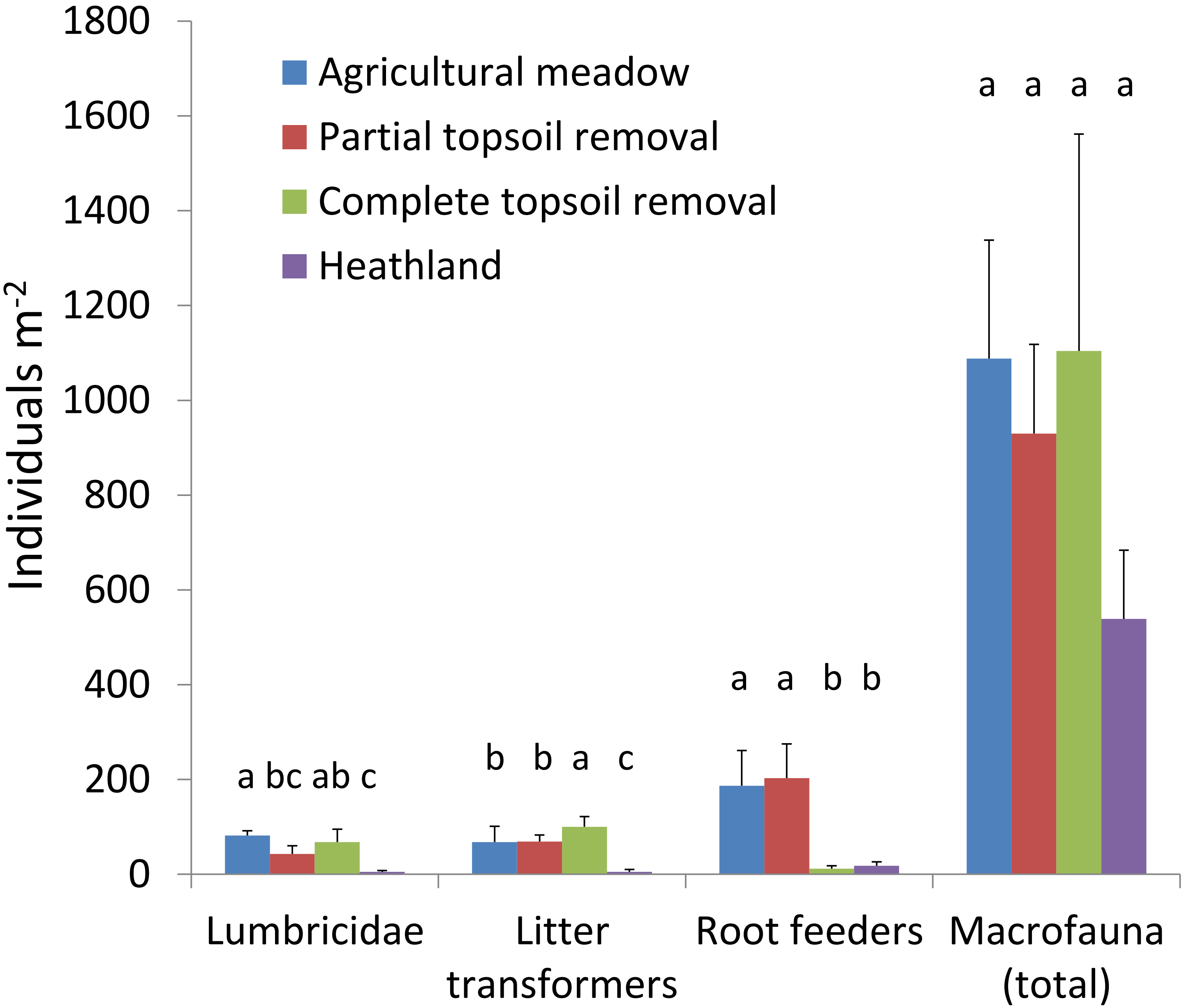
Clearings (no seed transfer)

Borchard et al. (2014a/b)

2.1

Restoration of the soil macrofauna

Density of functional groups (selected taxa, after 15 yrs)



Mites:

Species richness of oribatid mites higher in heaths

Frouz et al. (2009)

Problem: Fragmented landscapes

Example: *Peocilus lepidus*

- Medium-sized, stenotopic heathland species
- Brachypterous
- Migration distance: ~ 6m / day

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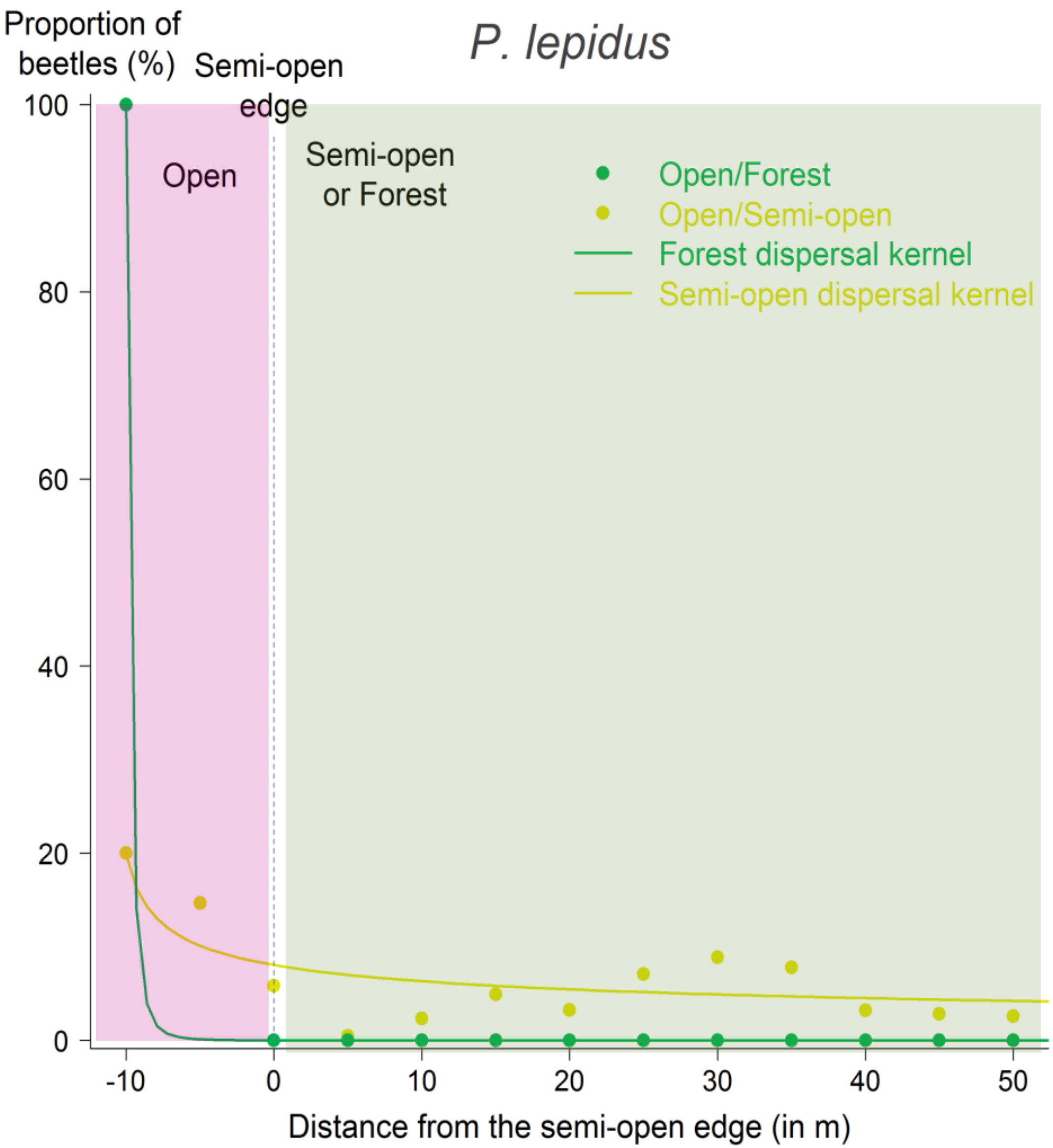
Assmann & Günther (2000)

Assmann et al. (2016)

Boutaud et al. (in prep.)

Problem: Fragmented landscapes

Dispersal kernel of *Peocilus lepidus*



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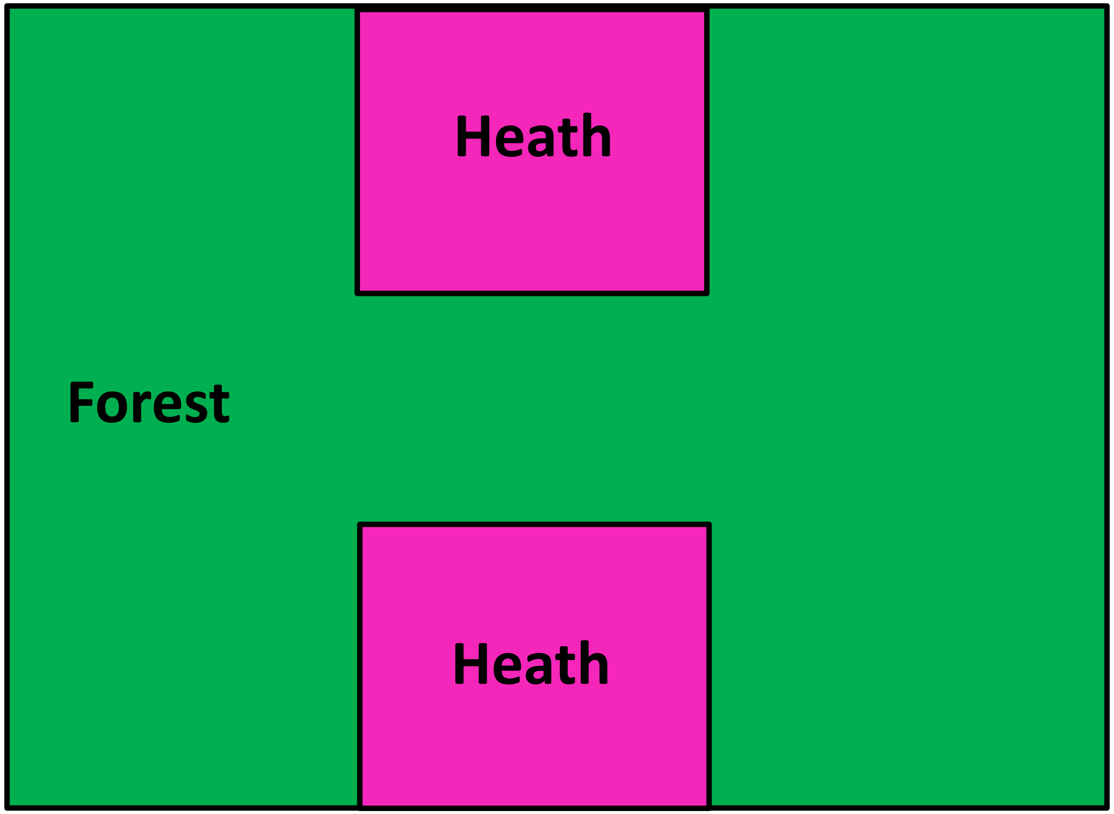
Assmann et al. (2016)
Boutaud et al. (in prep.)

2.2

Problem: Fragmented landscapes

Example: *Peocilus lepidus*

Habitat connection using dispersal corridors



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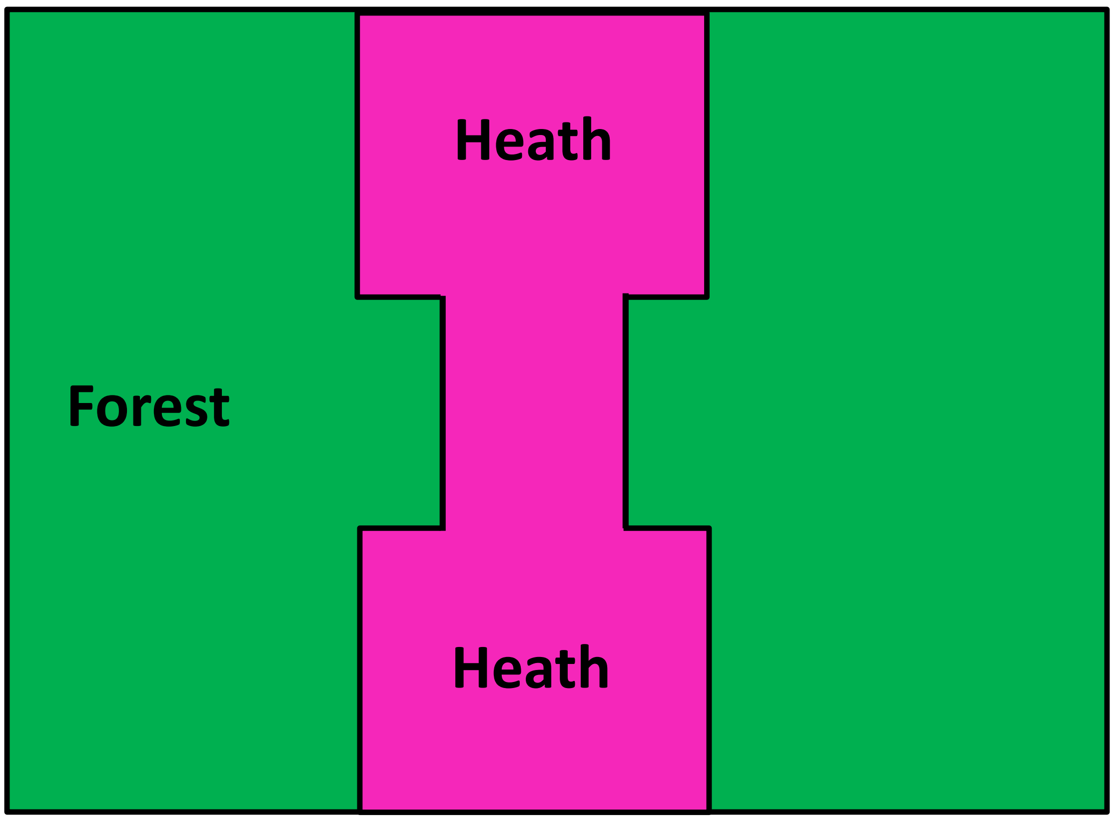

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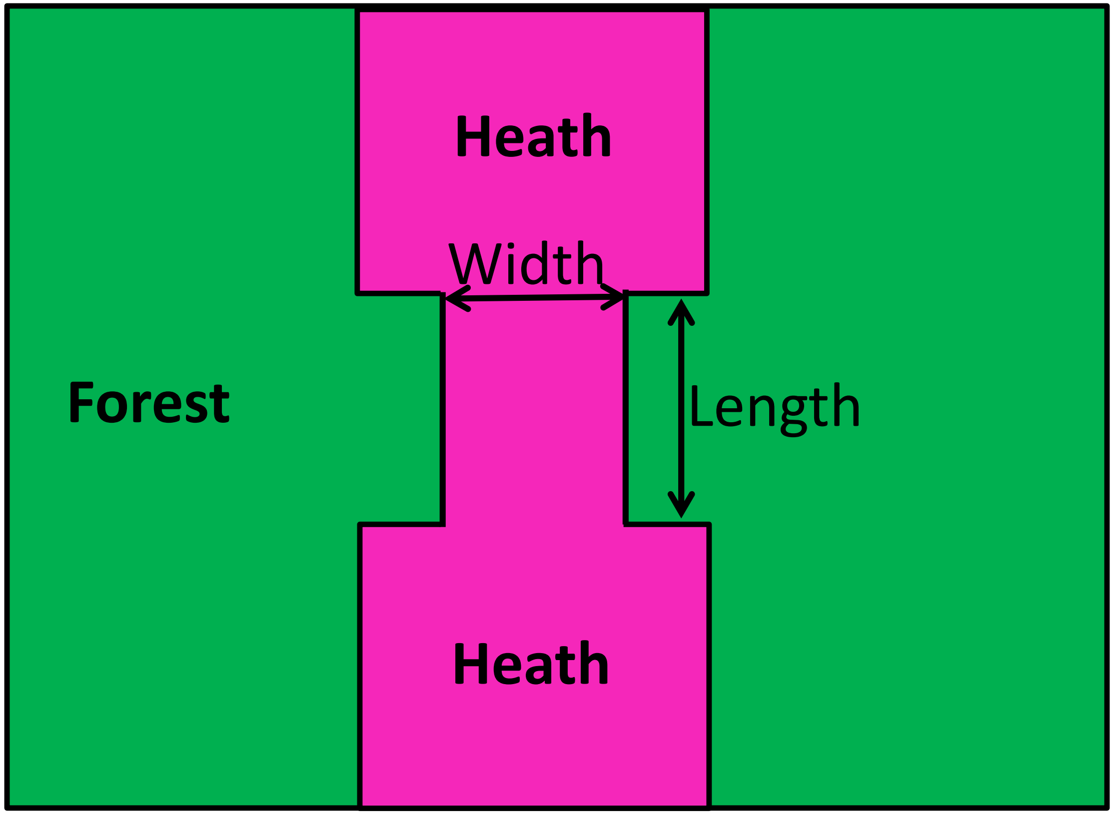

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Boutaud et al. (in prep.)

2.2

Problem: Fragmented landscapes

Example: *Peocilus lepidus*
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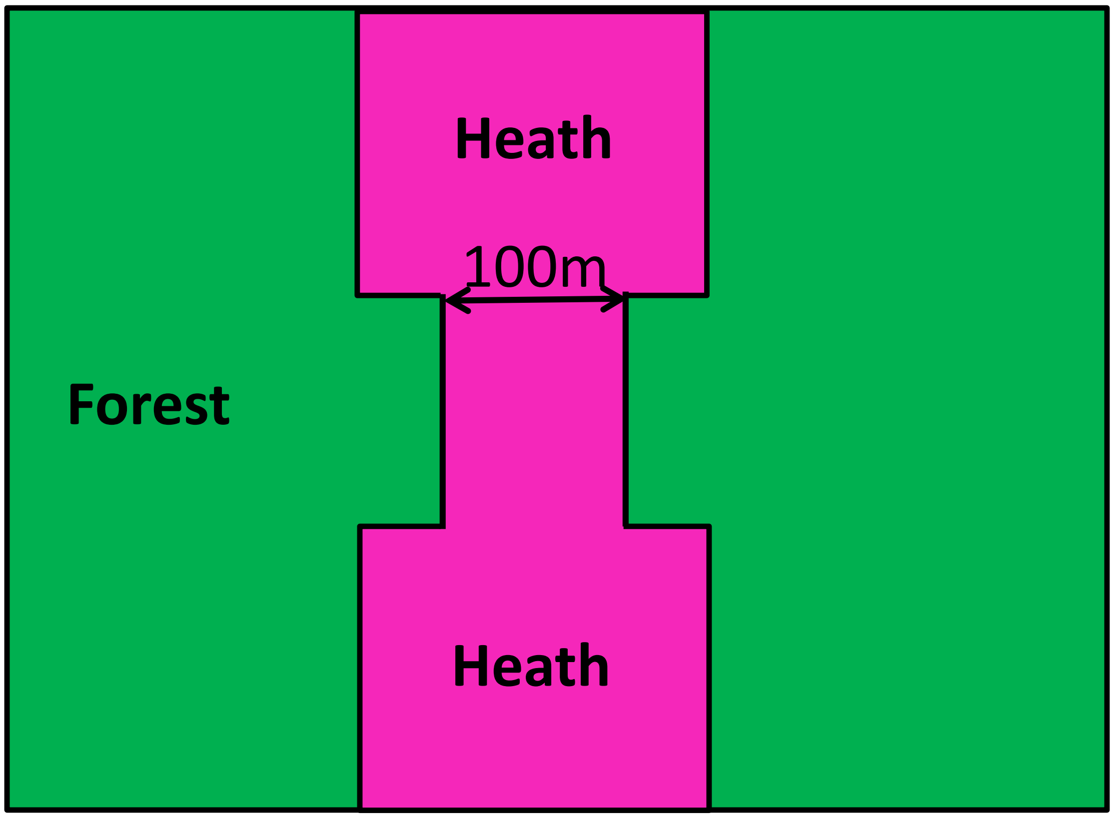

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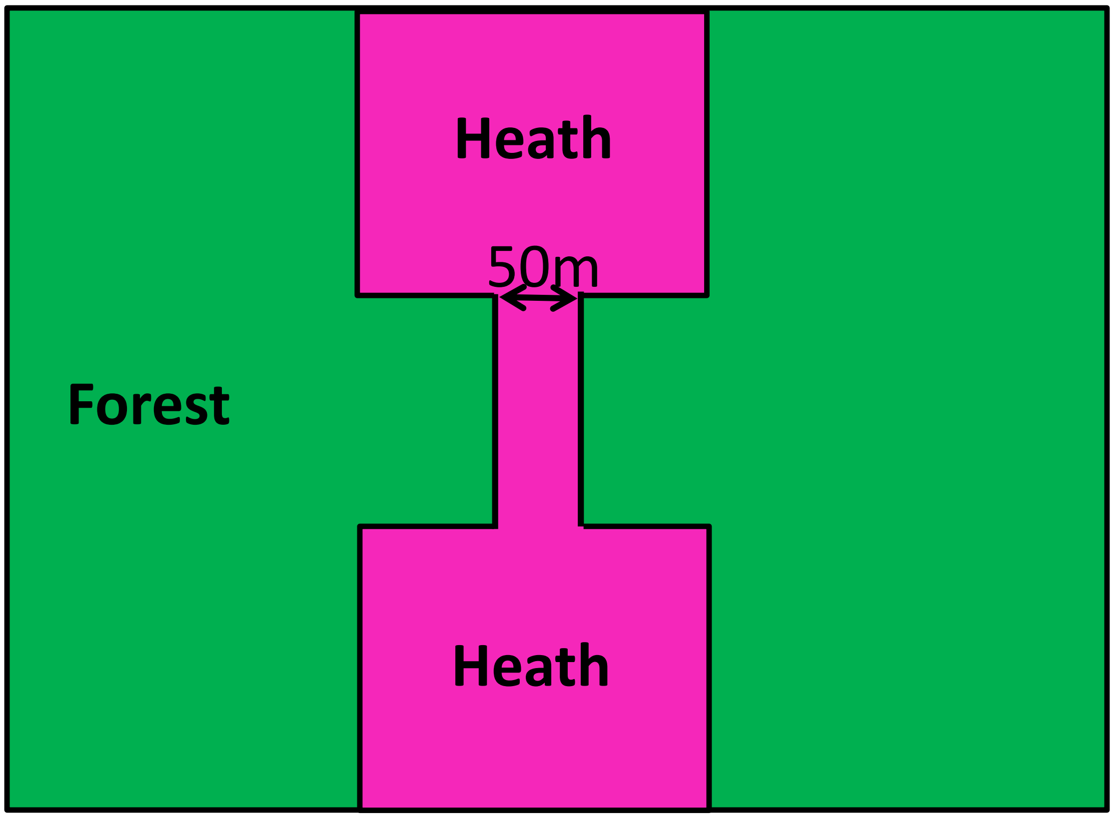

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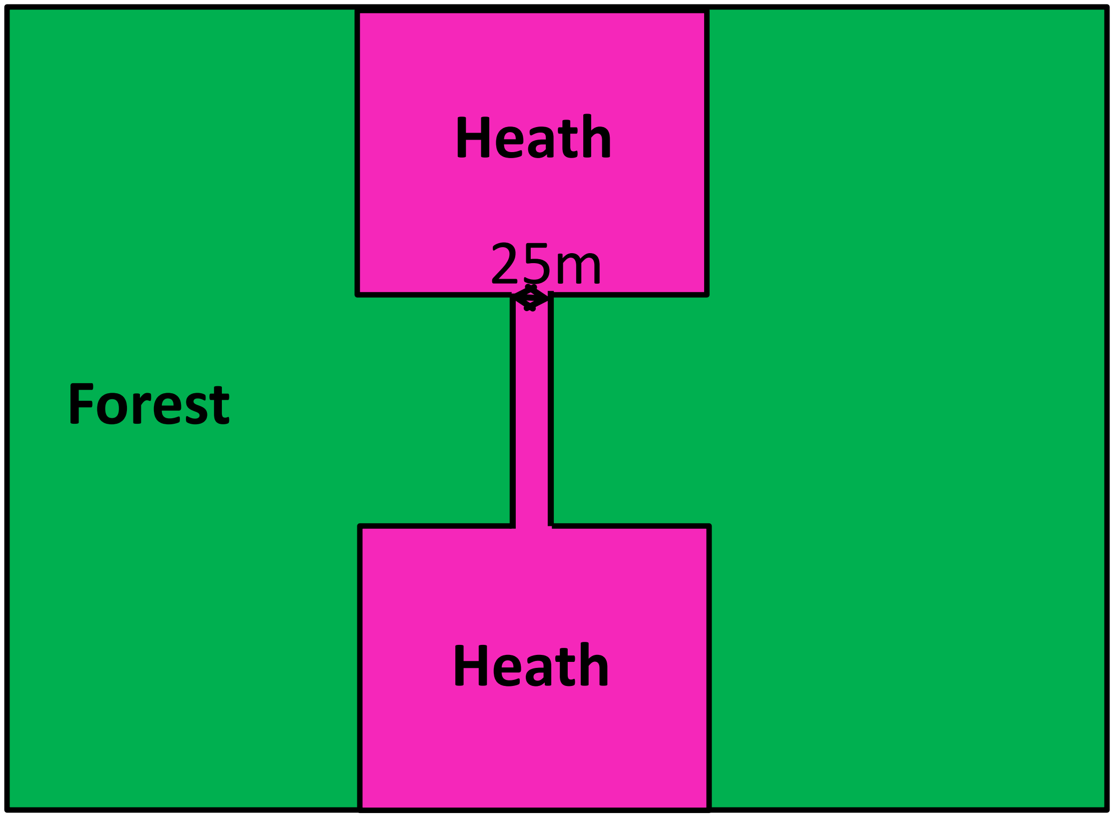

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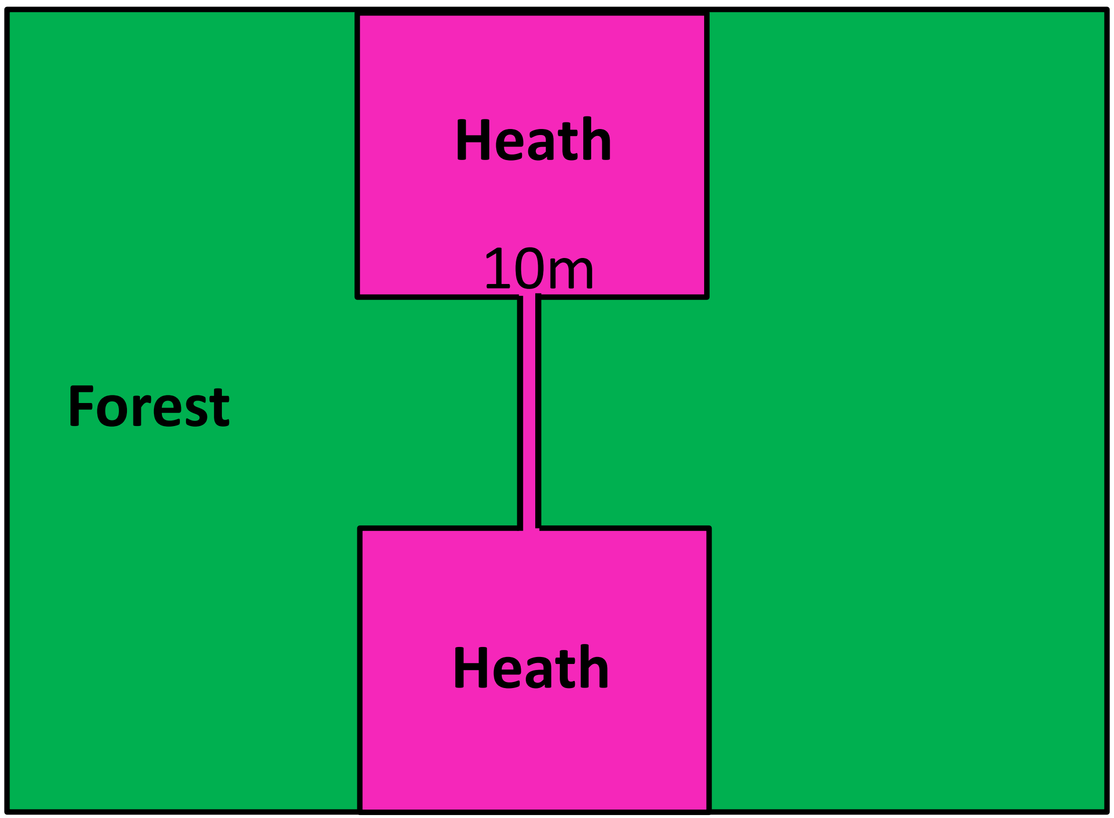

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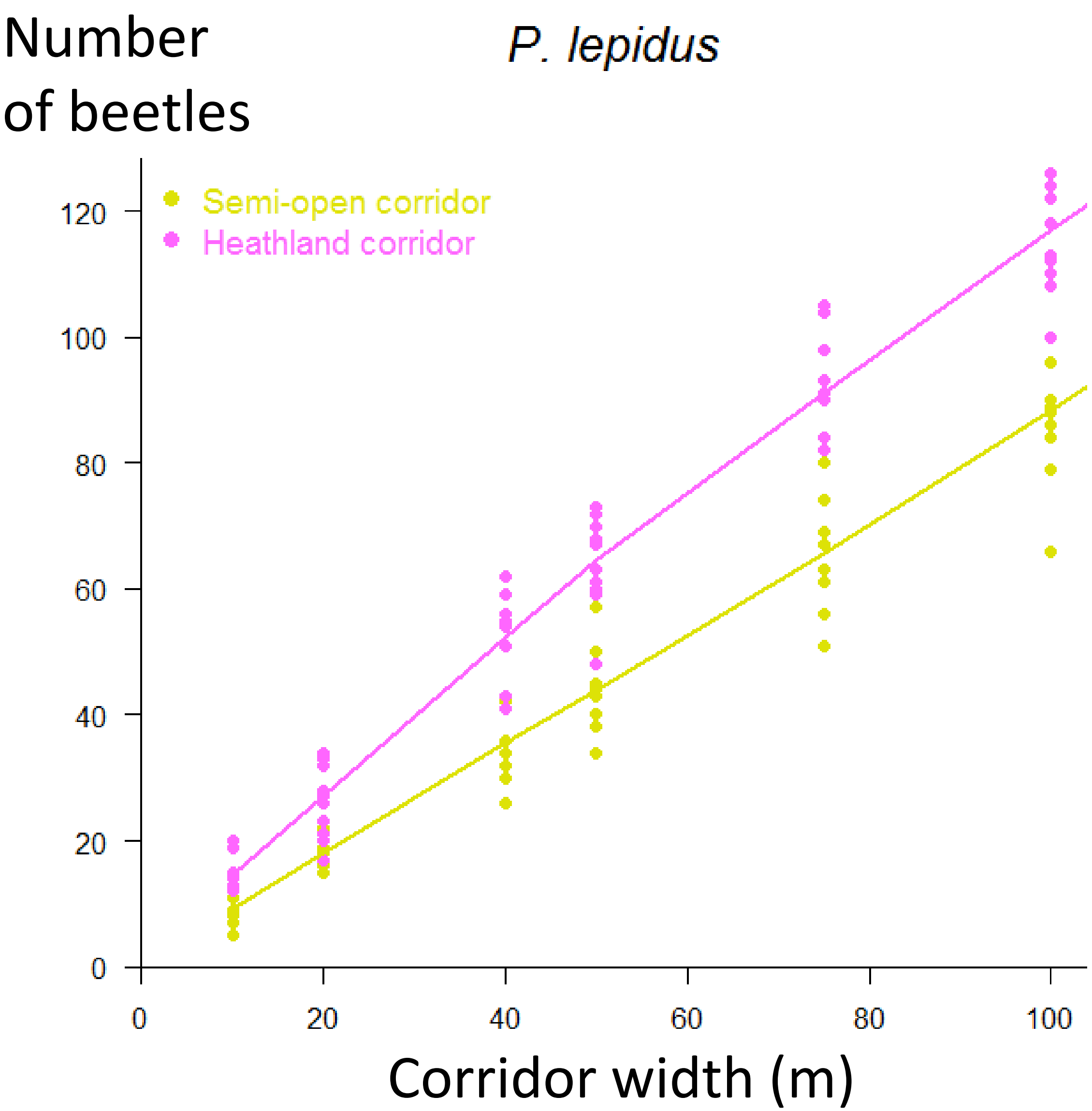
Assmann et al. (2016)

Boutaud et al. (in prep.)

Problem: Fragmented landscapes

Importance of corridor **width**:



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Methods:

- Software „DISPERS“ Vermeulen et al. (1994)
- Mark-capture experim.

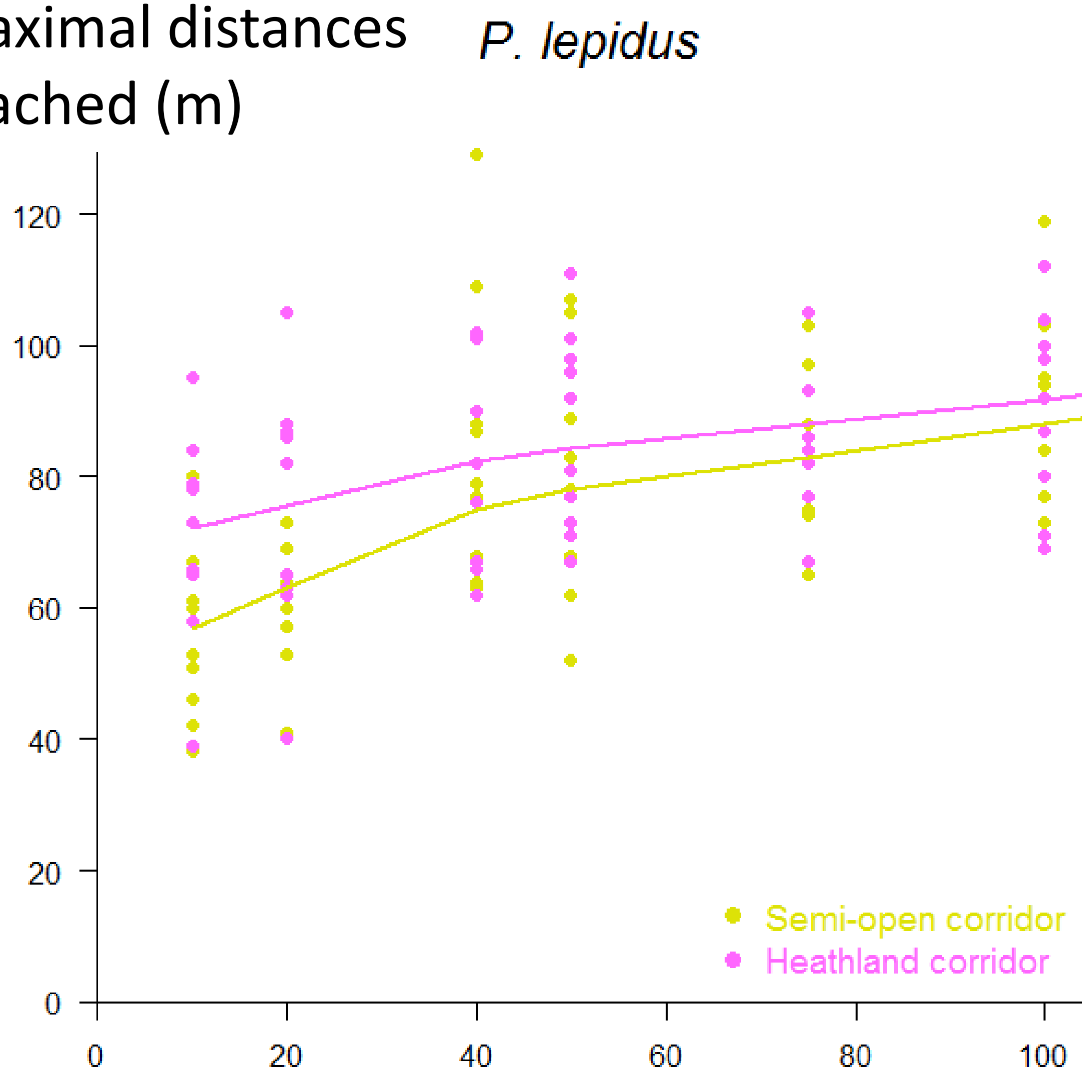
Assmann et al. (2016)

Boutaud et al. (in prep.)

Problem: Fragmented landscapes

Importance of corridor **length**:

Maximal distances reached (m)



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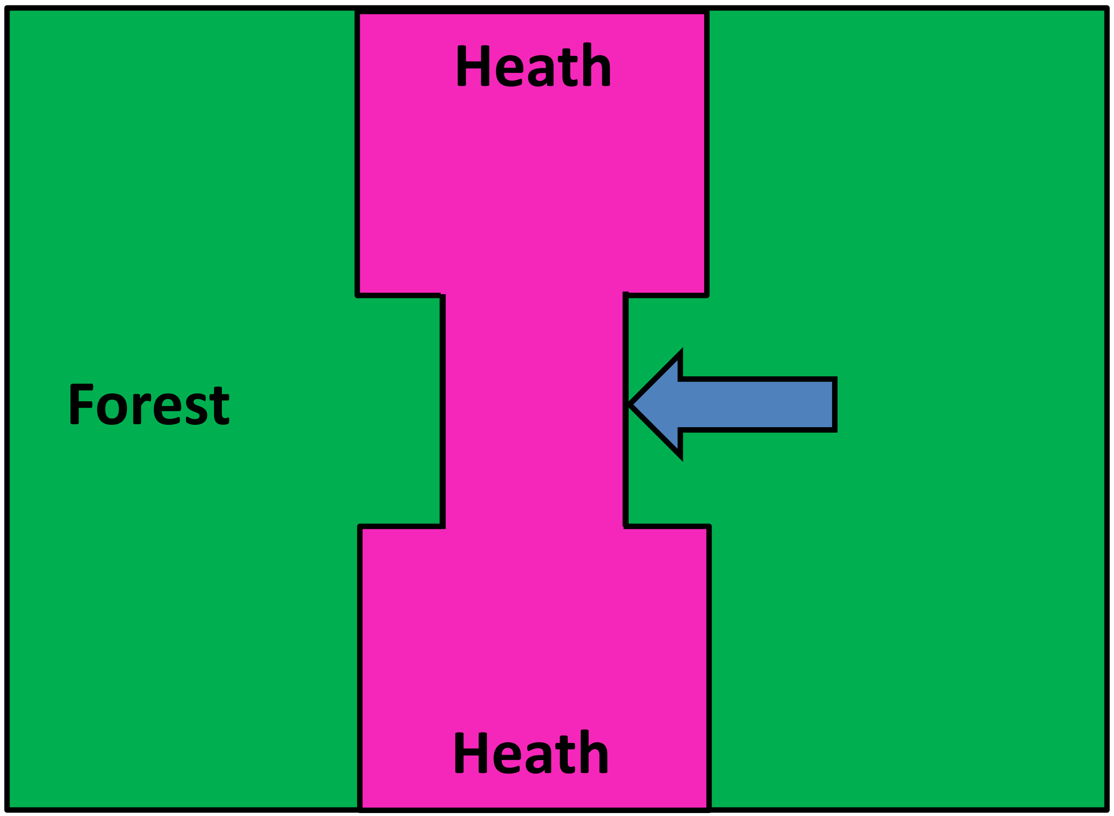
Boutaud et al. (in prep.)

Problem: Fragmented landscapes

Problem: Heath corridor causes a barrier for stenotopic forest species



Carabus glabratus

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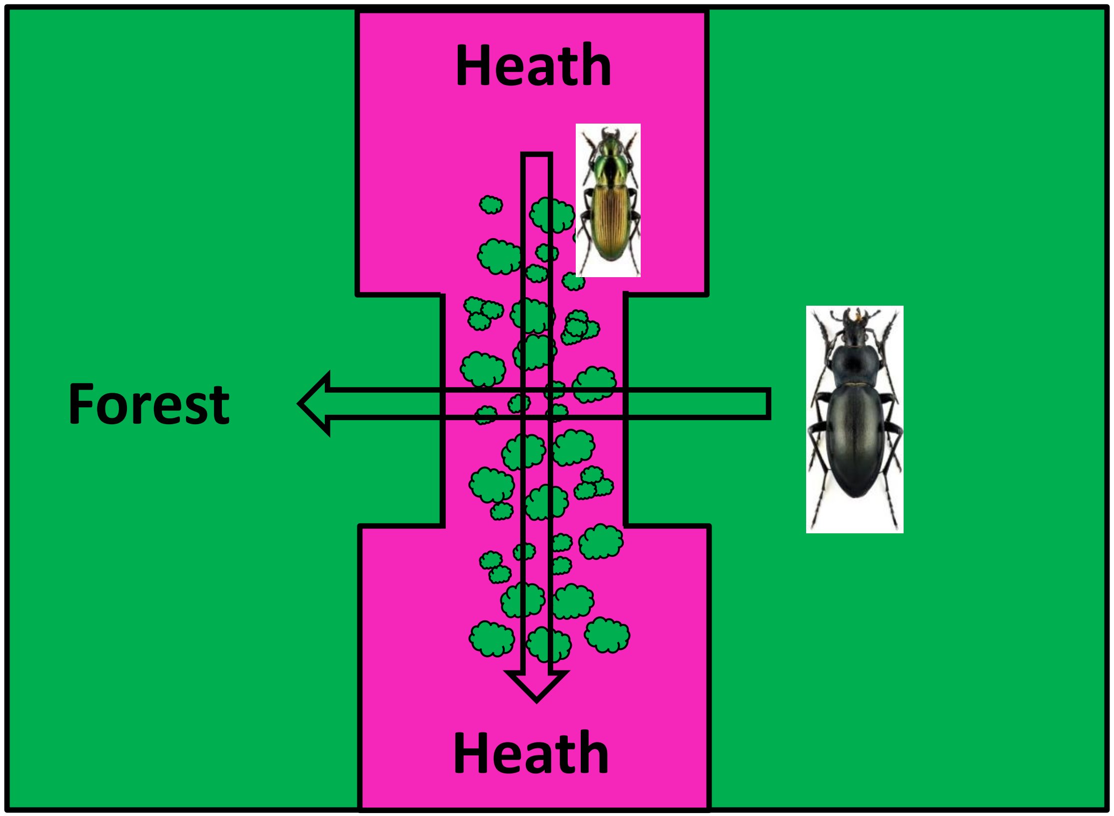
Eggers et al. (2010)

Problem: Fragmented landscapes

Problem: Heath corridor causes a barrier for stenotopic forest species („semi-open corridors“)



Carabus glabratus

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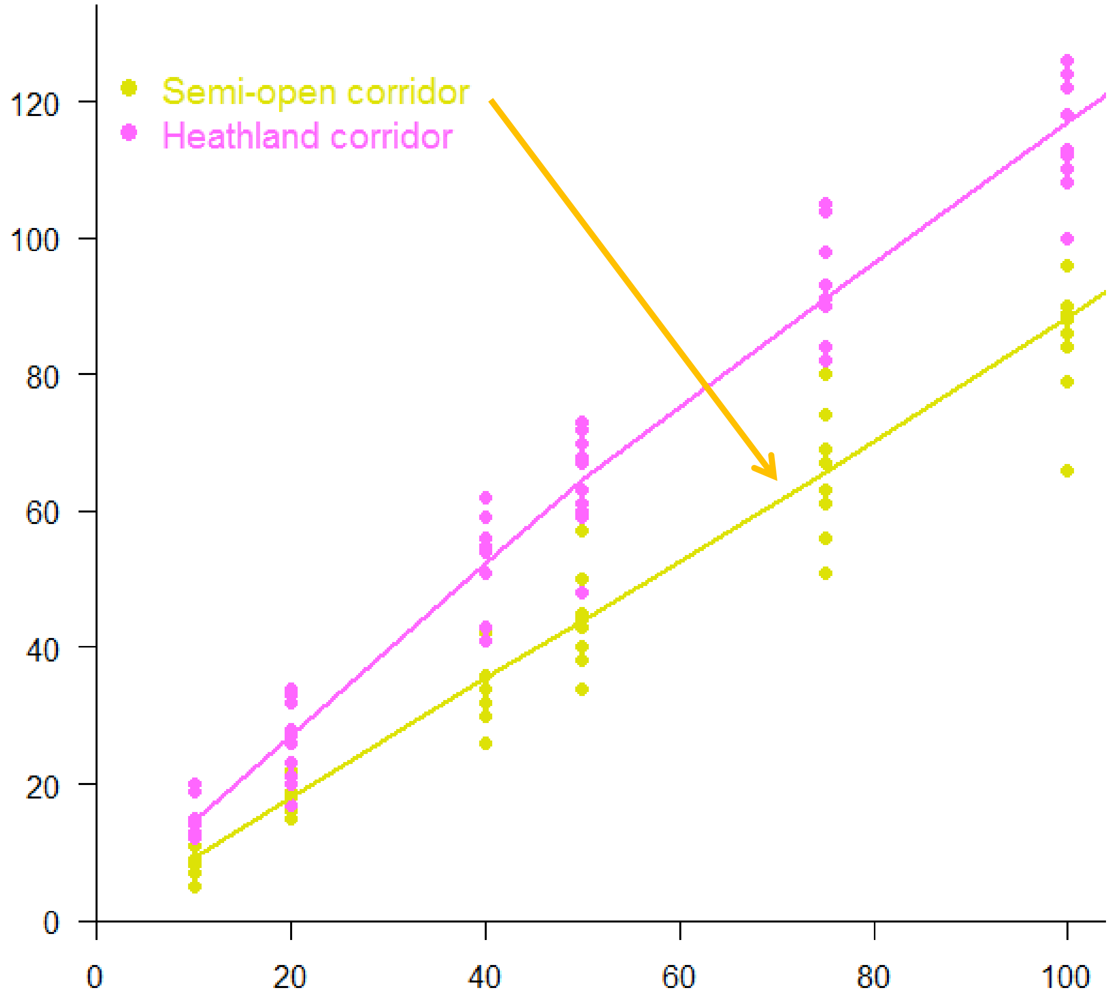
Eggers et al. (2010)

Problem: Fragmented landscapes

Number of beetles



Corridor width (m)

P. lepidus

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Methods:

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- Mark-capture experim.

Assmann et al. (2016)

Boutaud et al. (in prep.)

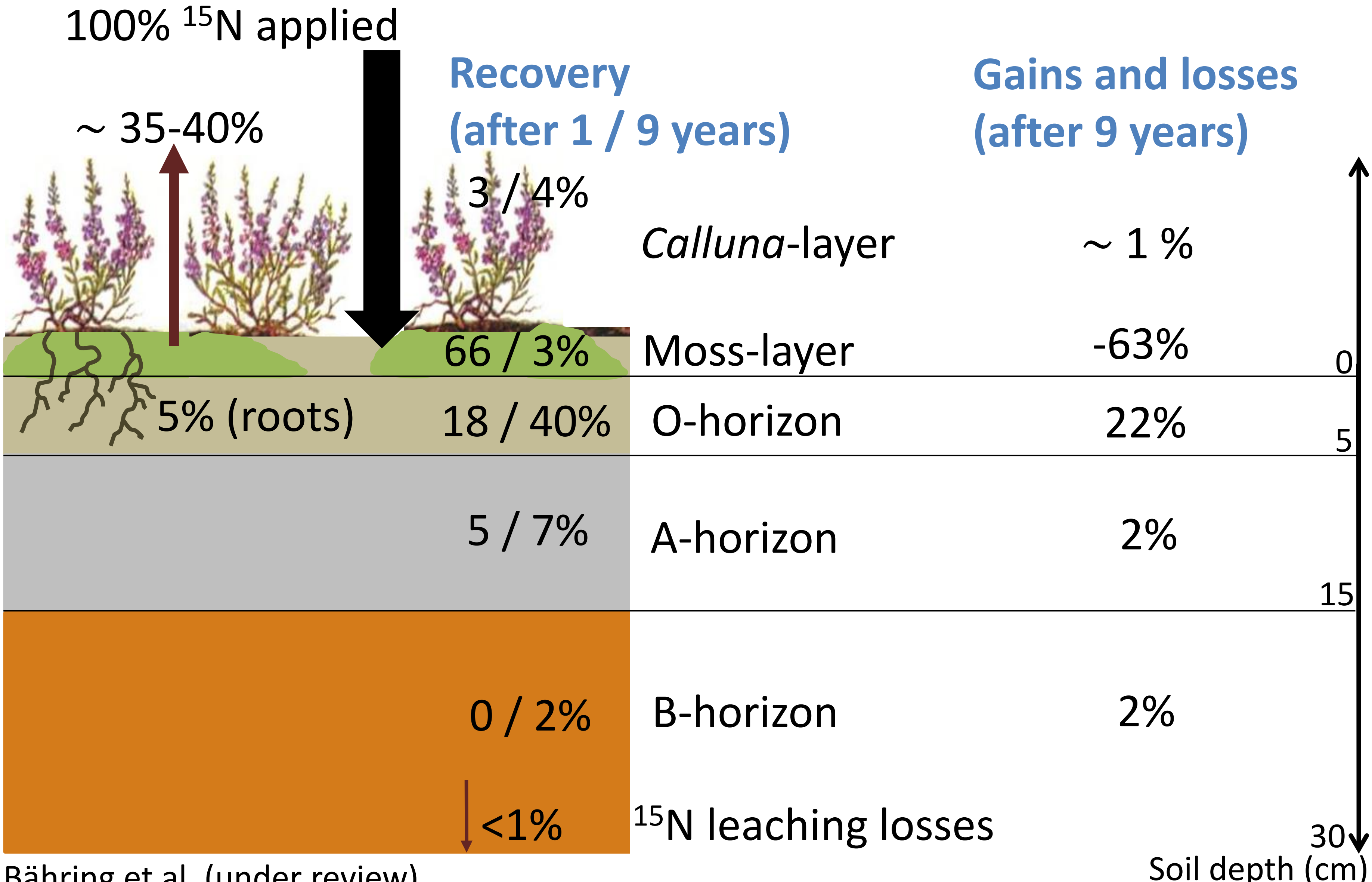
3.1

Global change: Adverse effects of nitrogen deposition

- Shifts in species composition / species loss — Stevens et al. (2006), Bobbink et al. (2010), Jones & Power (2012)
- Promotes heather beetle infestation — Brunsting & Heil (1985)
- Increasing frost sensitivity of *C. vulgaris* — Carroll et al. (1999)
- Decreasing mycorrhizal colonisation (N_{min} 12.0 g m^2 yr^{-1}) — Hofland-Zijlstra & Berendse (2009)
- …

3.1

Fate of nitrogen in a lowland heath (2007-2015)



Bähring et al. (under review)

3.1

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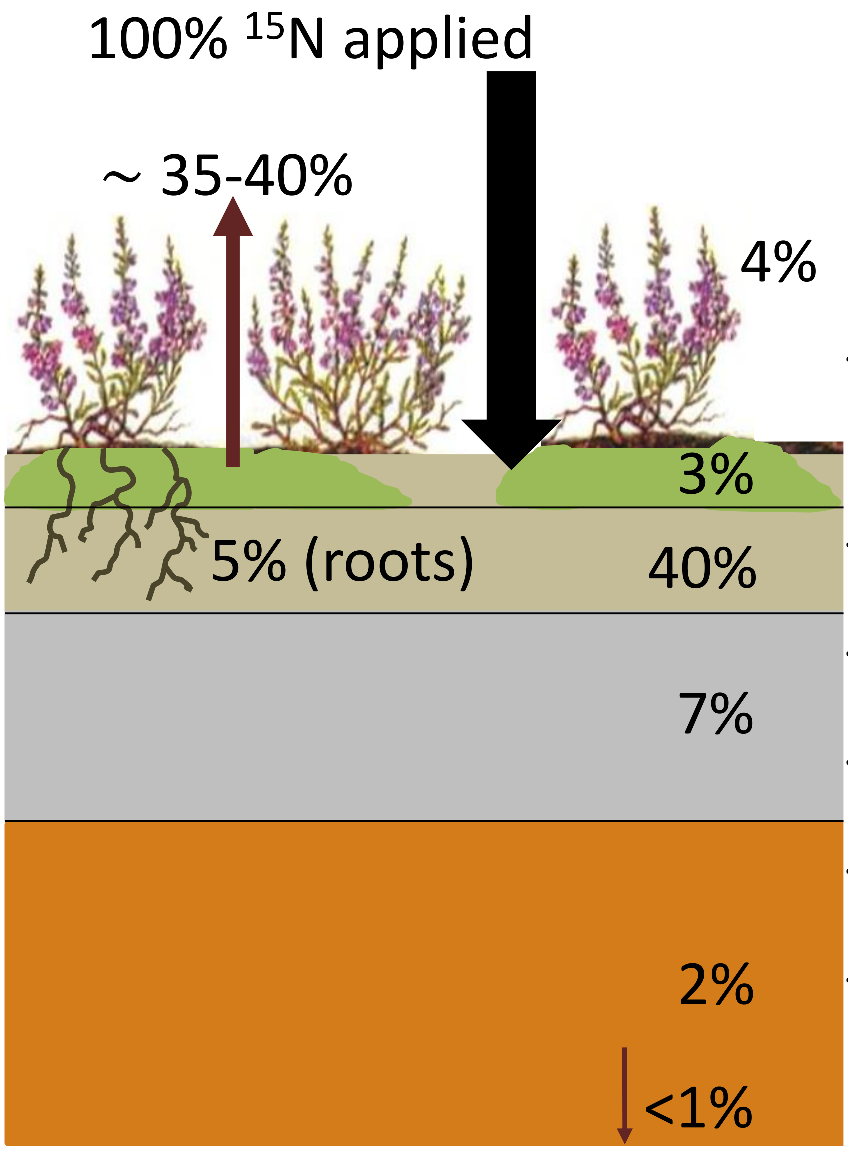
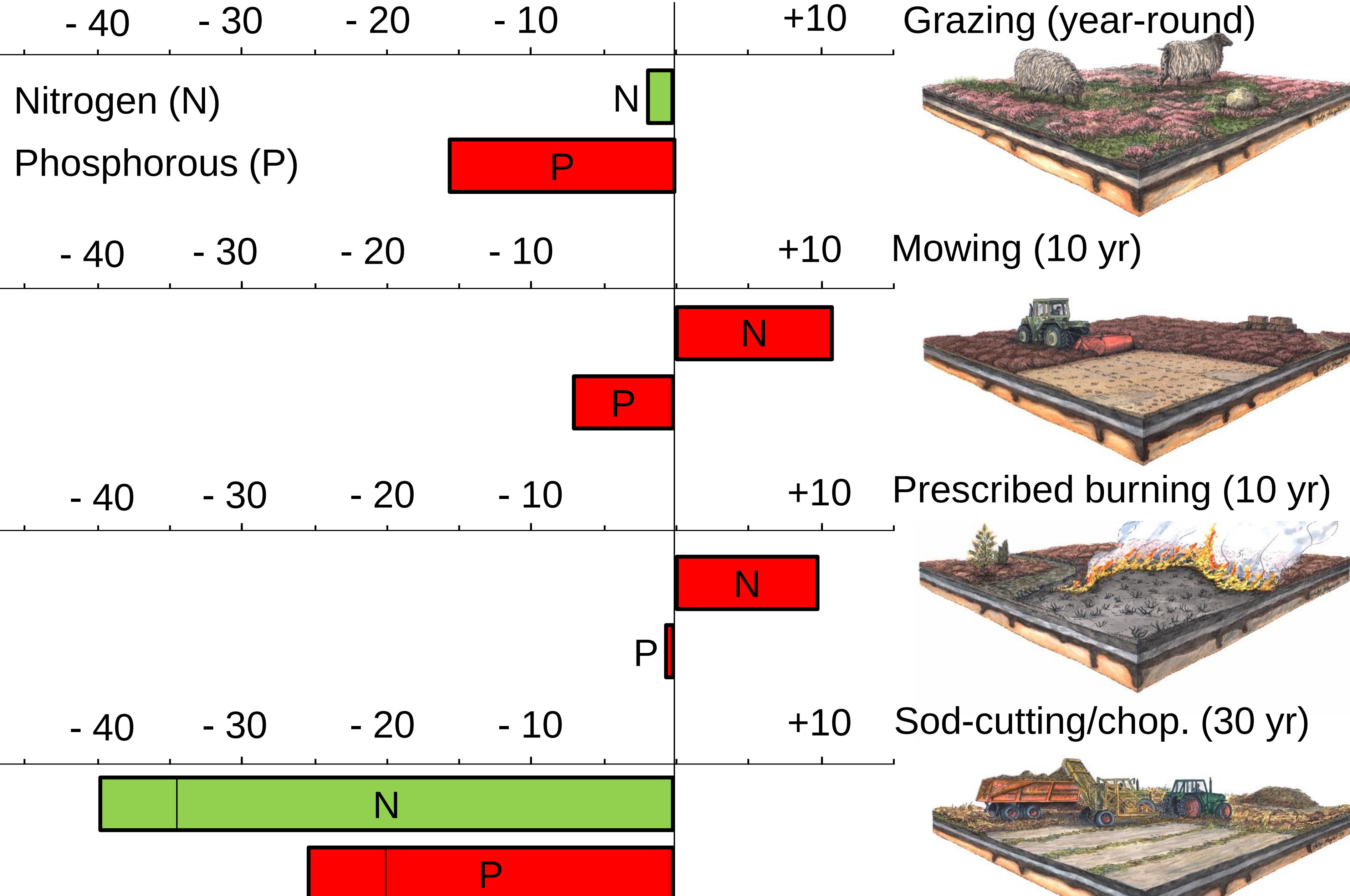


Bähring et al. (under review)

Management-relevant conclusions:

- 60% of airborne N remains in the ecosystem
- Heaths: high potential to sequester N
- > 57% of N is bioavailable
- Moss layer: capture-release function
- O-horizon important long-term sink
- High-intesity measures needed to affect O-horizon

3.1 Management impacts on nutrient budgets (N, P)

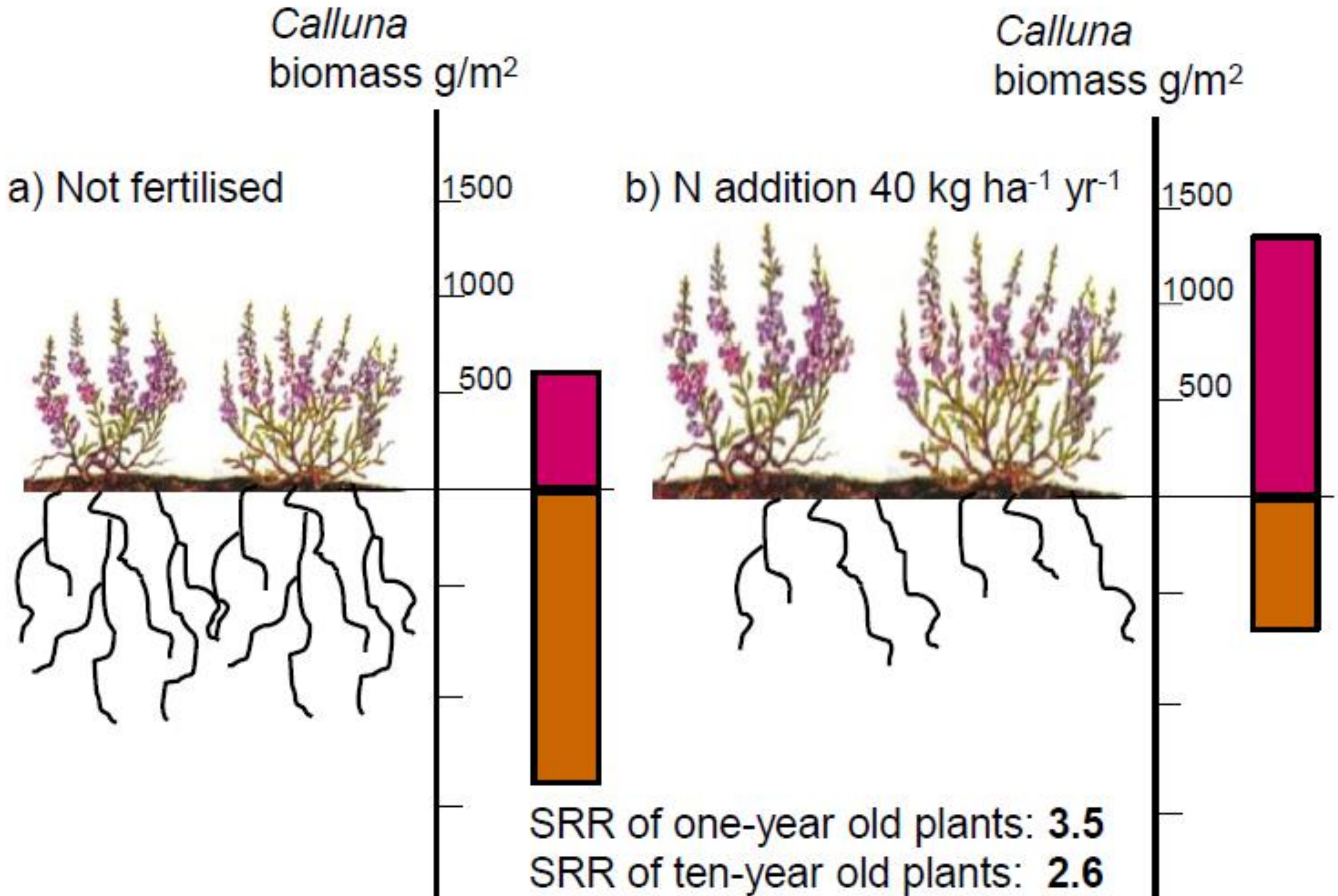


Härdtle et al. (2006)

3.2

Climate change: Interaction with N deposition

Nitrogen deposition increases drought sensitivity of *C. vulgaris*



Bähring et al. (unpubl. data)

3.2

Sensitivity of heather within its life cycle

High drought sensitivity of *C. vulgaris* in the pioneer phase

Shoot-root ratio
$\delta^{13}C$ signature

Pioneer phase
(1-5 yrs)

2.4
-29.6

Building phase
(5-12 yrs)

1.0
-31.5

Mature phase
(12-19yrs)

0.5
(-32.5)

Degener. phase
(20+ yrs)

0.3
(-32.8)

Gimingham (1972)
Meyer-Grünefeldt et al. (2015)

4 Summary

- There is no one-size-fits-all solution. Check combinations of different restoration/management measures (applied on small spatial scales).

Lüneburg Heath	Combat non-target species	Target community restoration	Effects on seed bank	Nitrogen removal	NP-ratio	Cost-benefit ratio	Appre-ciation
Grazing 	☺	☺	☺	☺	☹		☺
Mowing 		☺		☹	☹	☺	
Prescribed burn. 	☺			☹	☺		
Choppering 	☺	☺	☹	☺			☹
Sod-cutting 	☺	☺	☹	☺			☹

4 Summary

- There is no one-size-fits-all solution. Check combinations of different restoration/management measures (on small spatial scales).

- Be aware of trade-offs (ecological targets, ecosystem services …).

- Define clear restoration targets (+ monitor measurement effects).

- Be familiar with the ecology of target communities / target species.

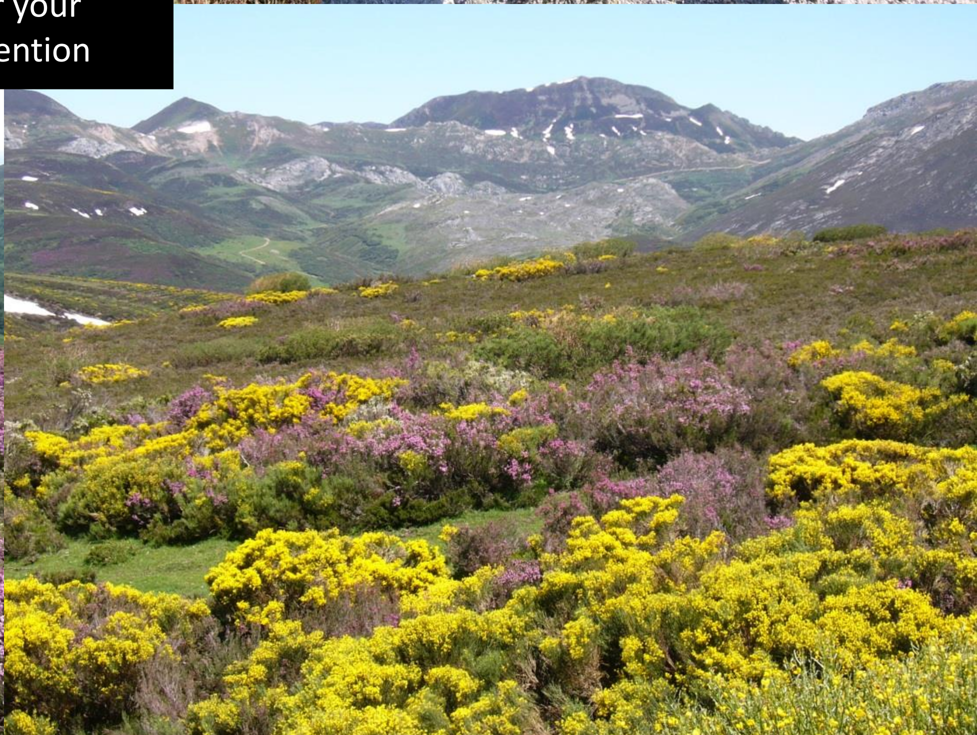
- Many species show low dispersal power: „assisted migration“.

- Connecting isolated habitats: Be aware of limitations of „linear corridors“ (check appropriateness of „semi-open corridors“).

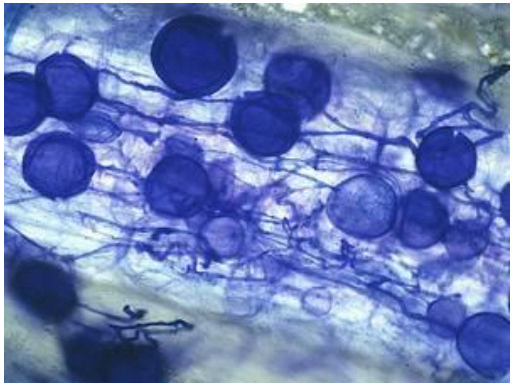
- N removal (in the long term) in areas with deposition rates > 10 kg ha^{-1} yr^{-1}. Avoid high P removal. The pioneer phase is highly senstitive to N-inputs.

- Be patient (... think in decadal-scales).

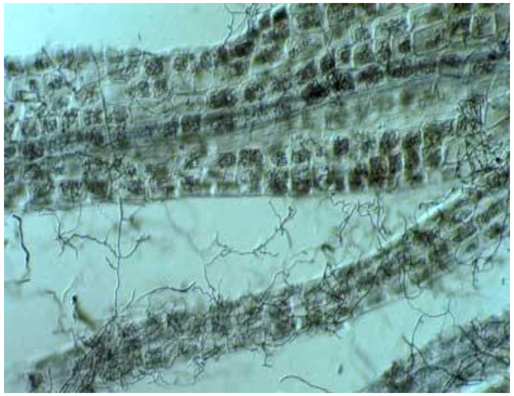
Many thanks
for your
attention



Effects of the mycorrhiza-type



arbuscular mycorrhiza → P-limitation

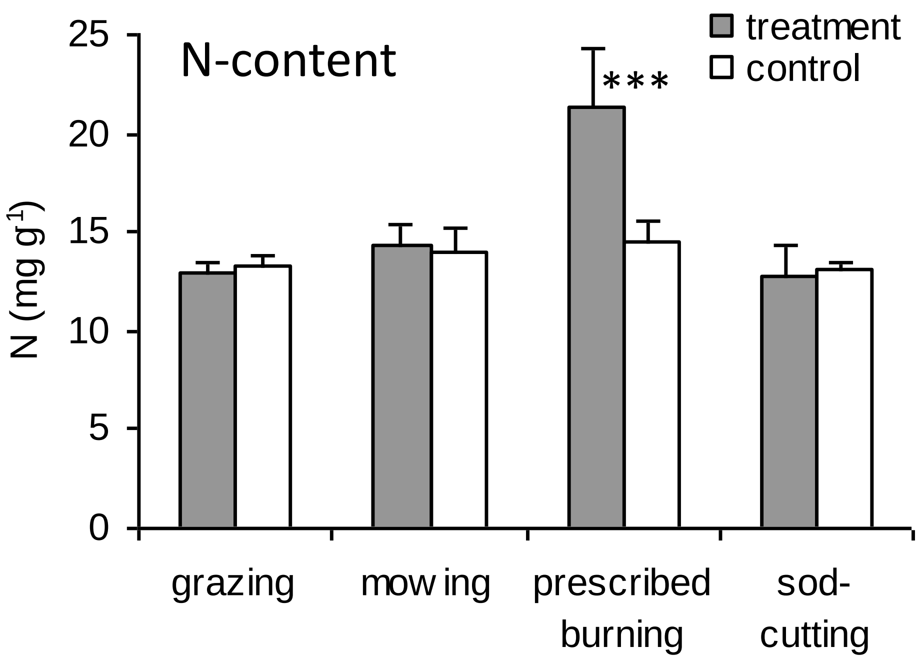


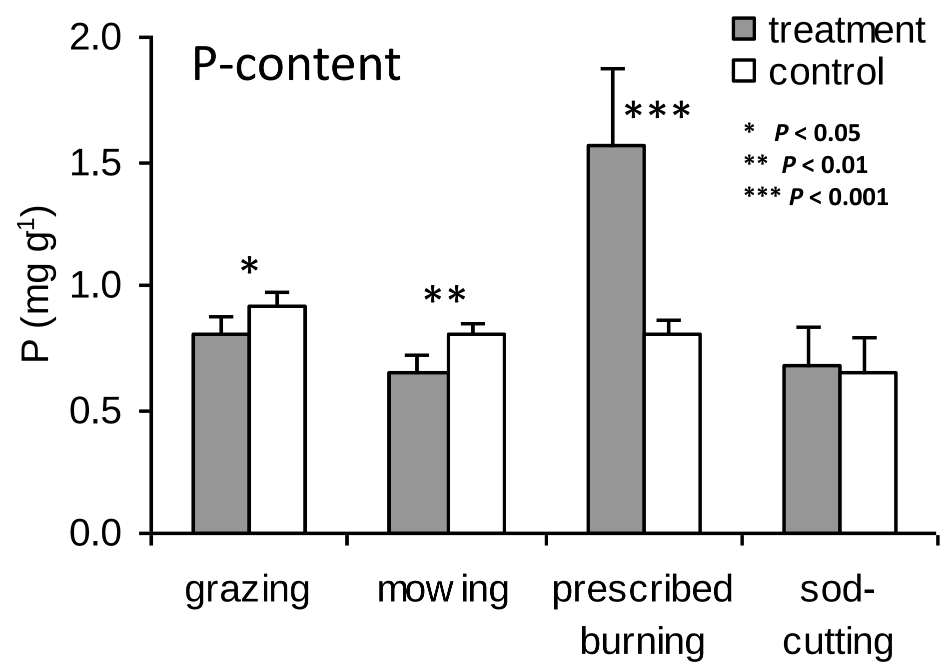
ericoid mycorrhira → N-limitation

Friedrich et al., 2011, Environ Pollut 159

Impact of management on *Calluna* shoot NP-ratios

Calluna-shoot N- and P-contents (measured after 5 years)



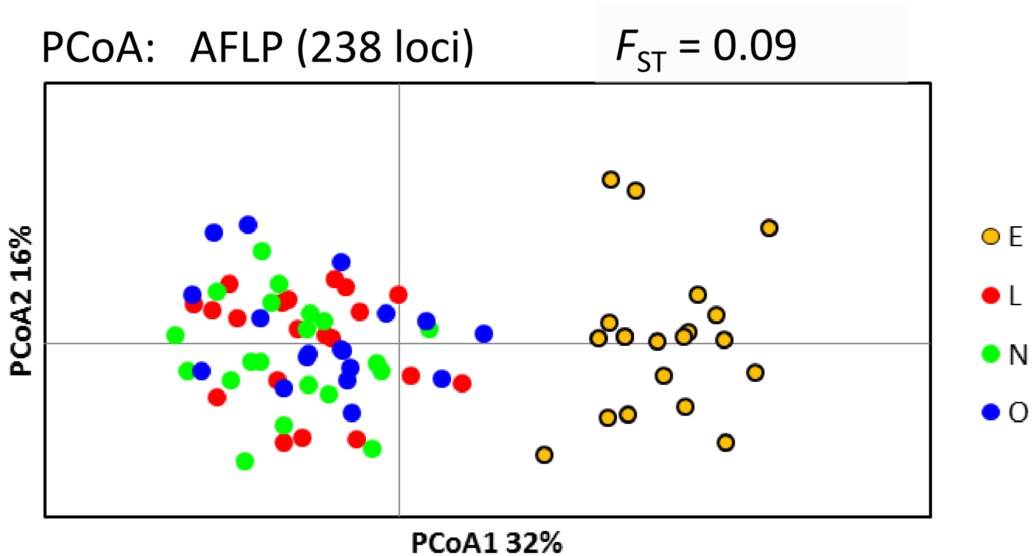


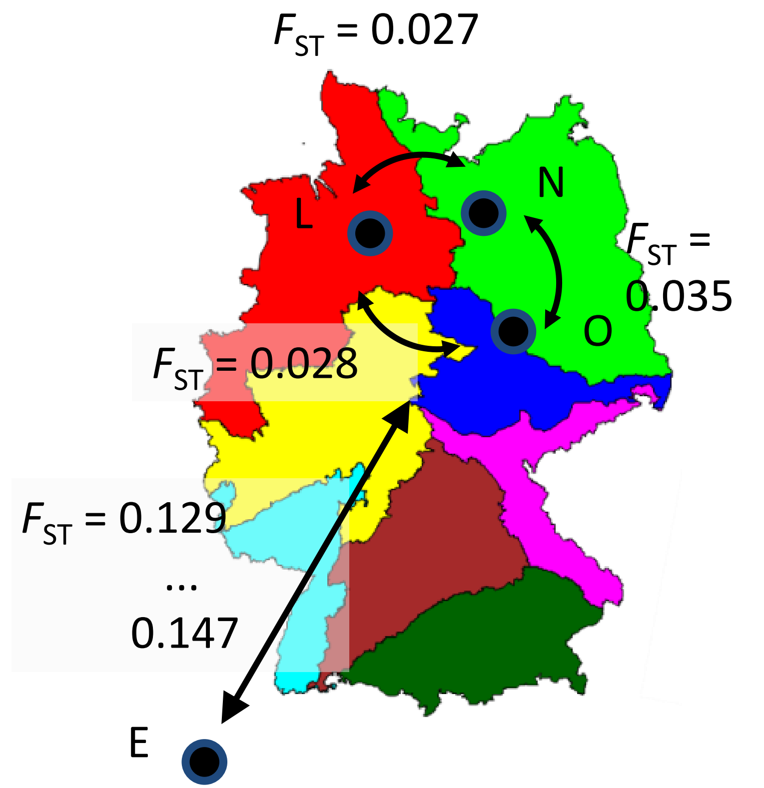
→ Poaceae – with arbuscular mycorrhiza (P-shortage)

→ Ericaceae – with ericoid mycorrhiza (N-shortage)

Hypotheses: high N:P ratios facilitates grass encroachment

Calluna vulgaris: Genetic differentiation (molecular markers)





→ **High differences between Spain and Germany**

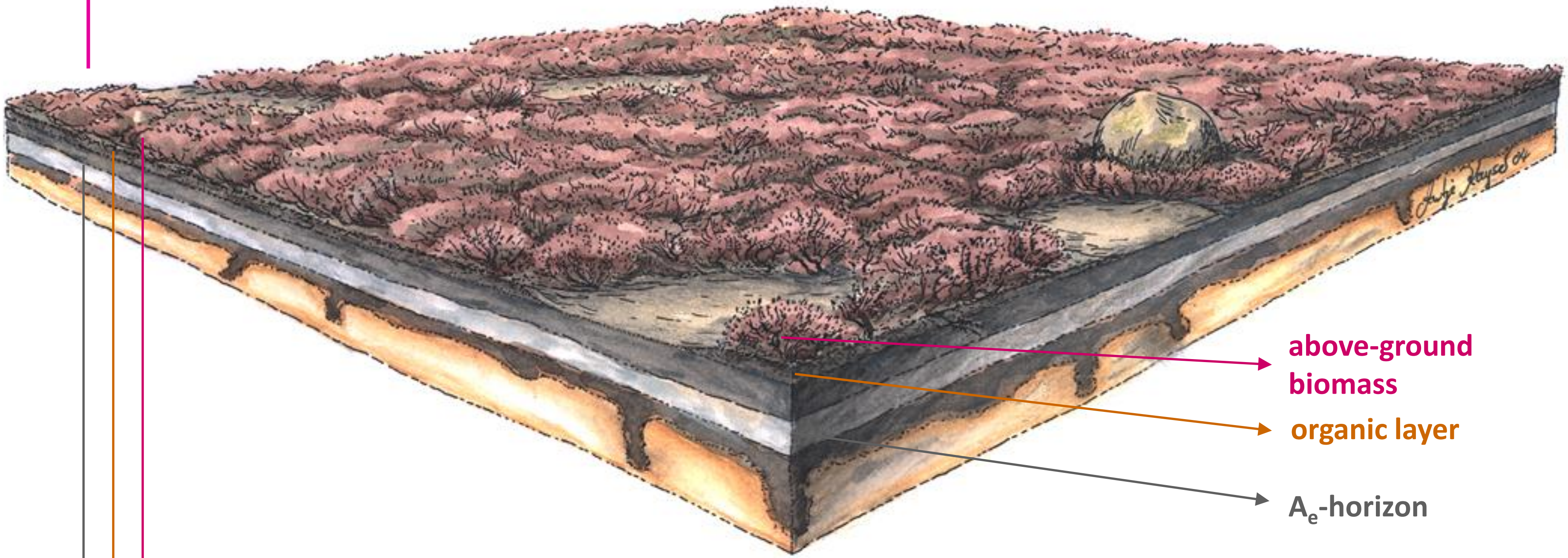
→ **Low differences between population in Germany**

Fixation index (F_{ST}) is a measure of population differentiation due to genetic structure. It is frequently estimated from genetic polymorphism data, such as microsatellites (measuring the variance of allele frequency at a given genetic locus). Durka et al. (unpubl. data)

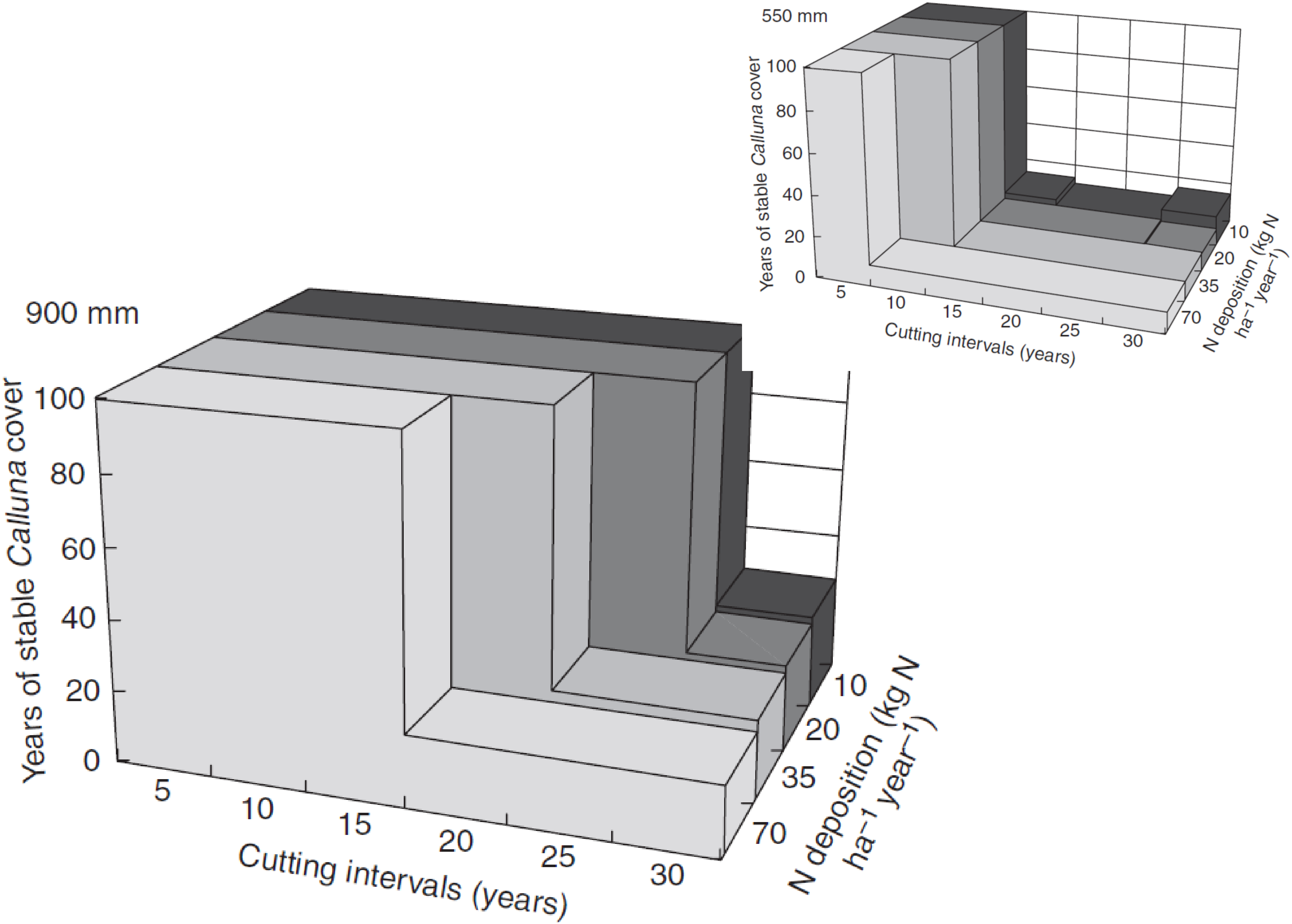
2 Management costs (Lüneburg Heath)

Costs per ha and yr		N-output (kg/€)
bis 360 €/ha		0,3
210 €/ha		0,1
bis 50 €/ha		1,9
3.350 €/ha		0,3
6.000 €/ha		0,3

4. Nutrient stores (Lüneburg Heath)



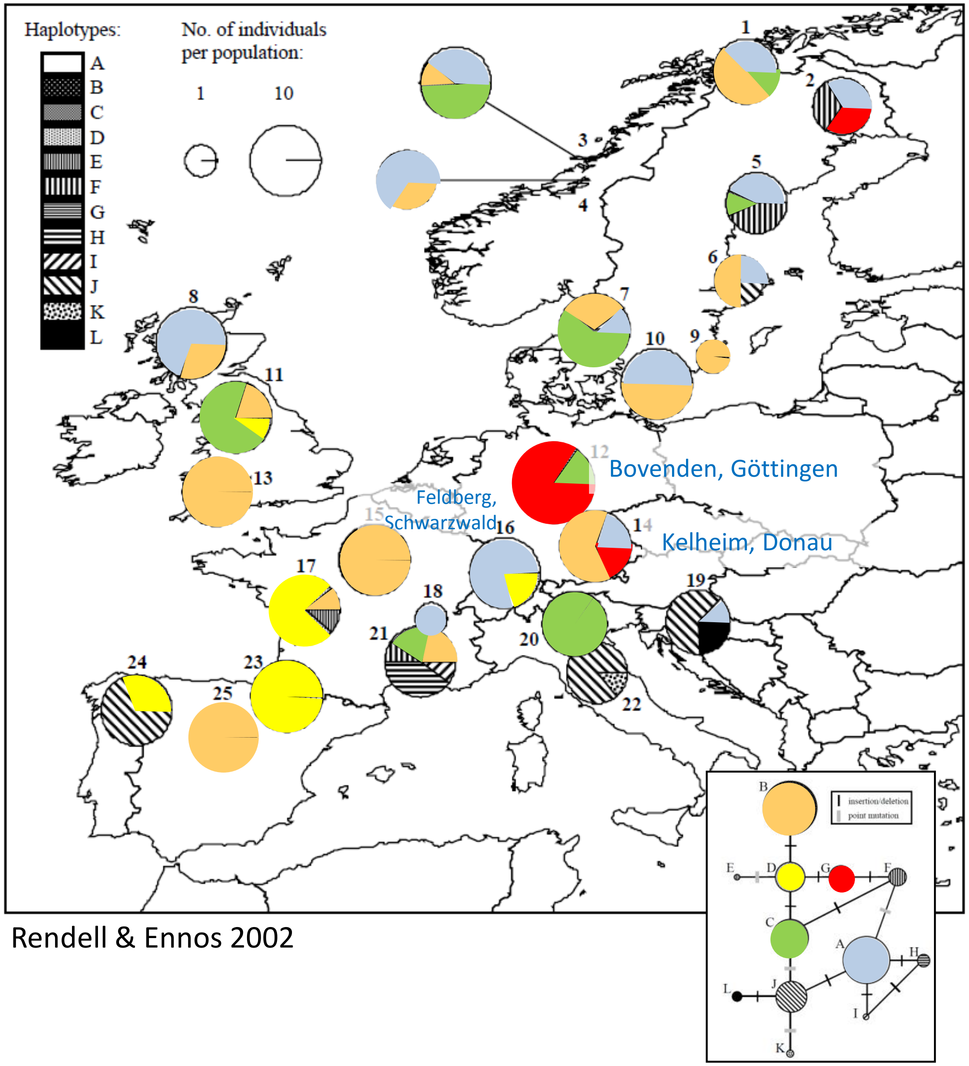
	weight (tons ha^{-1})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
biomass (SD) (n = 26)	11.5 – 19.0	179.3 (20.1)	11.6 (2.1)	51.3 (12.2)
organic layer (SD) (n = 12)	7.8	937.5 (93.8)	31.4 (4.1)	41.3 (4.0)
A-horizon (SD) (n = 8)	1404	1481.0 (217.8)	99.0 (8.6)	330.4 (57.7)



Fagúndez (2013), modified from Britton et al. (2001)

Calluna vulgaris: Chloroplasten-DNA-Variation

Chloroplast DNA

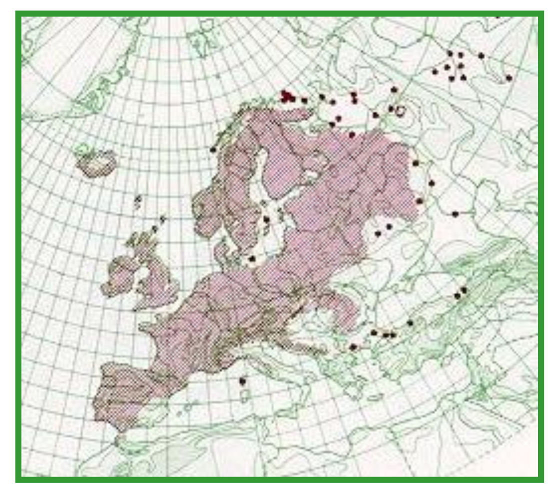


Rendell & Ennos 2002

+ Hohe genetische Variation in Populationen

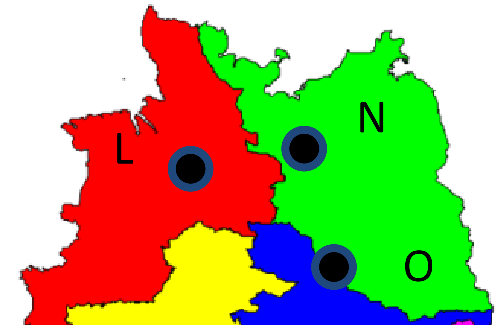
+ Starke genetische Differenzierung zwischen Populationen

In Deutschland gefundene Haplotypen kamen aus SW und möglicherweise aus O: Samenausbreitung!



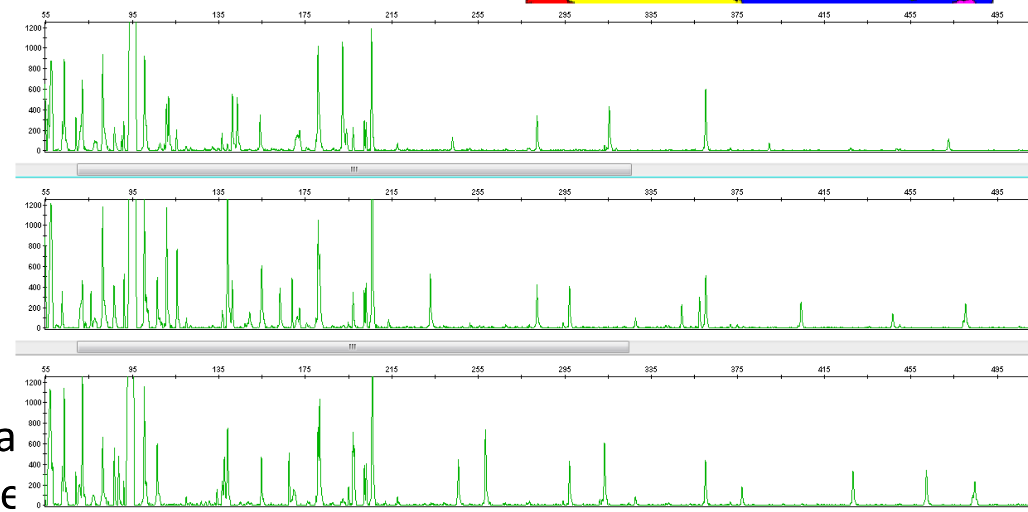
Calluna vulgaris: Genetische Variation

Durka, Härdtle et al. unpubl.

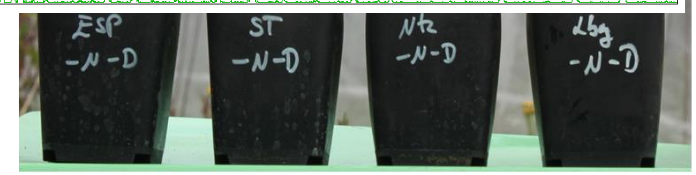


Herkünfte
L Lüneburger Heide
N Nemitzer Heide
O Oranienbaumer Heide
E La Majua, Spanien

Molekulare Marker-Analyse
4 Herkünfte x 20 Individuen
AFLP, 238 loci

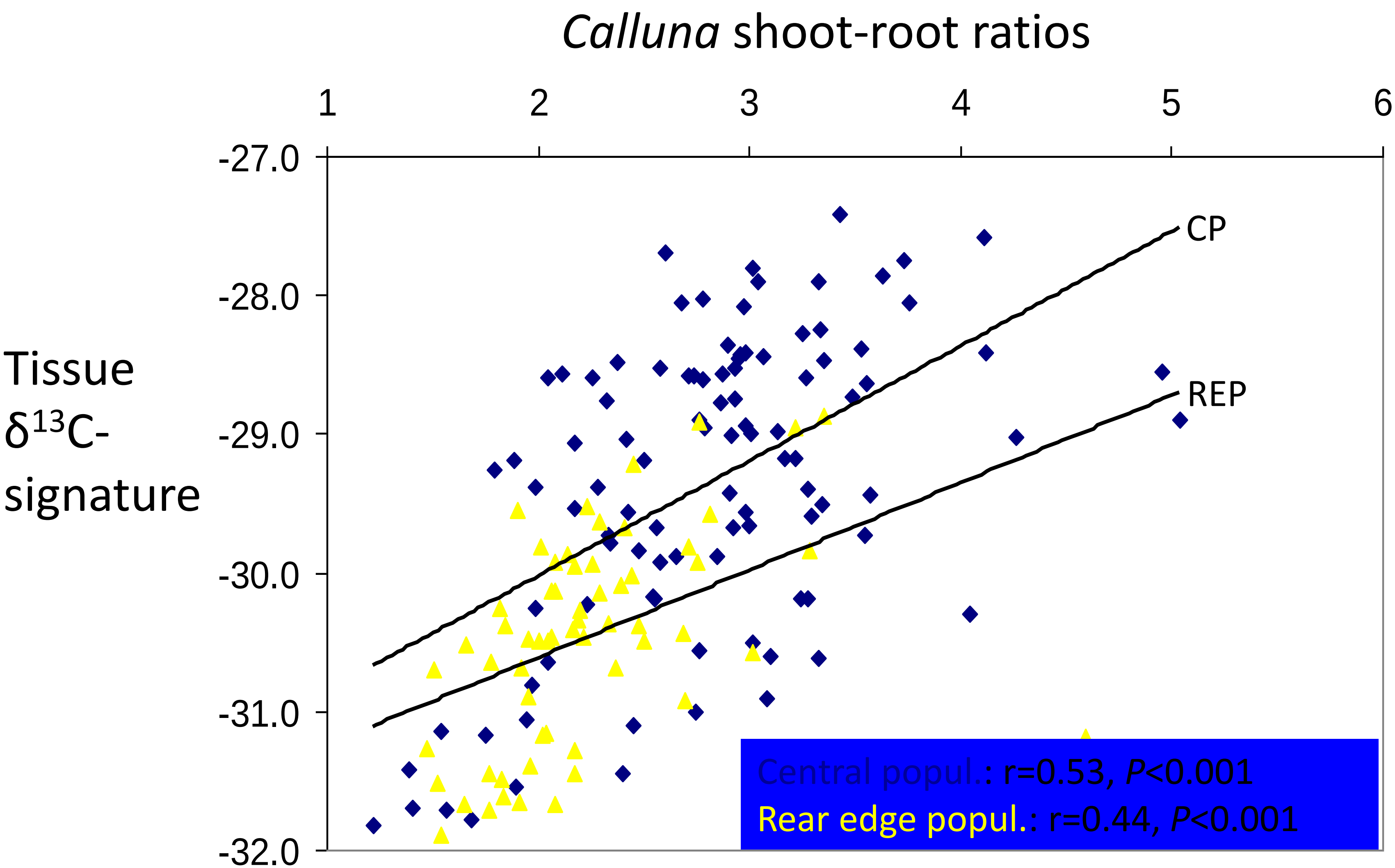


Gewächshaus-Experiment
4 Herkünfte x 10 Mutterpflanzen x 8 Na
x 4 Behandlungen (+/-N, +/-Trockenhe
→ AFLP Marker
→ Quantitative Genetik



ESP= Spanien | ST=Sachsen-Anhalt Oranienbaumer Heide | Ntz=Nemitzer Heide | Lbg=Lüneb. Heide

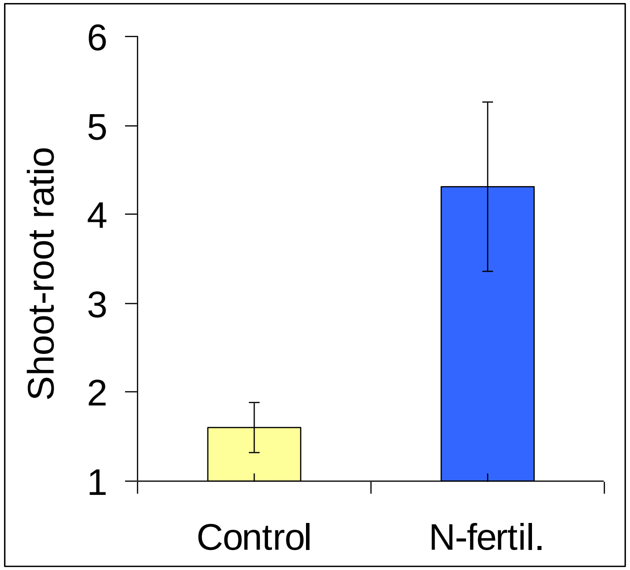
3 Interactions of global change drivers: Heathlands



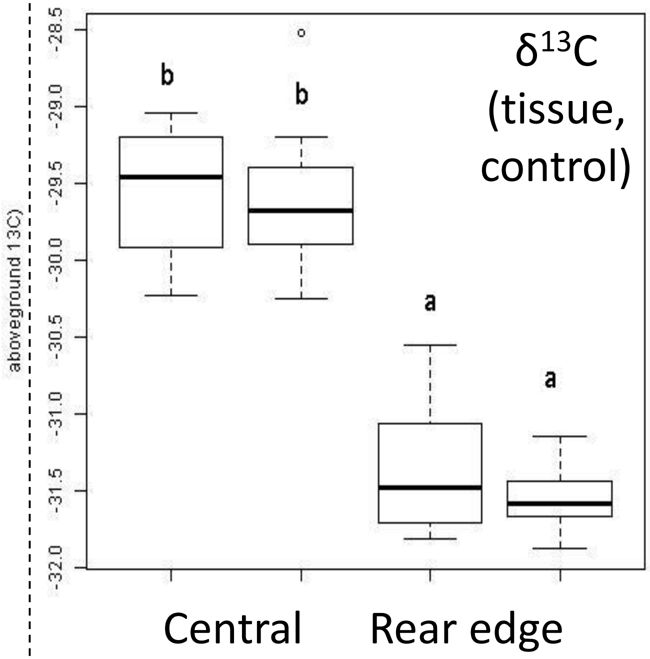
3 Interactions of global change drivers: Heathlands

Underlying mechanisms (*Calluna vulgaris*):

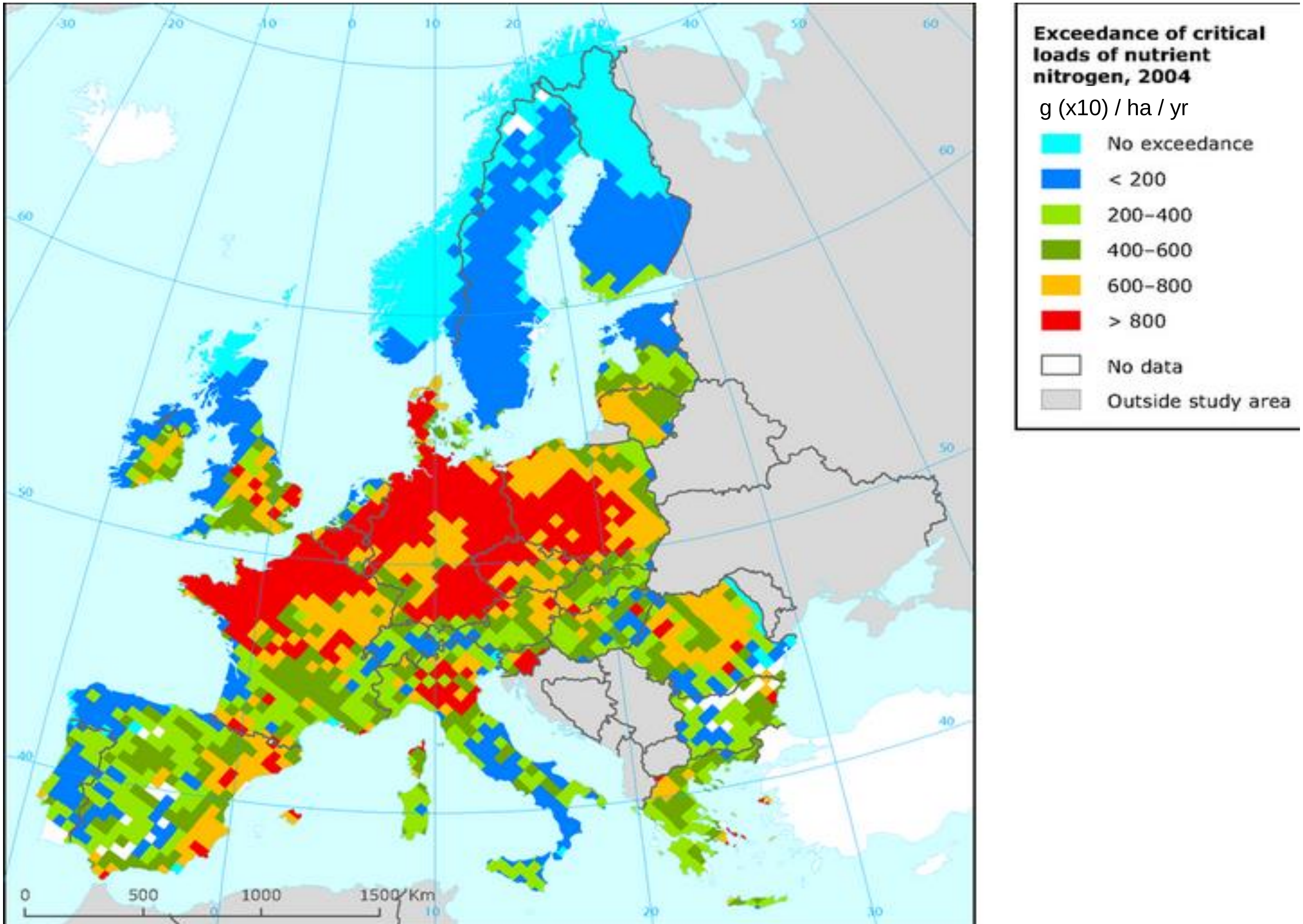
1) Increasing shoot-root ratios



3) Differing „stress tolerance“ among provenances

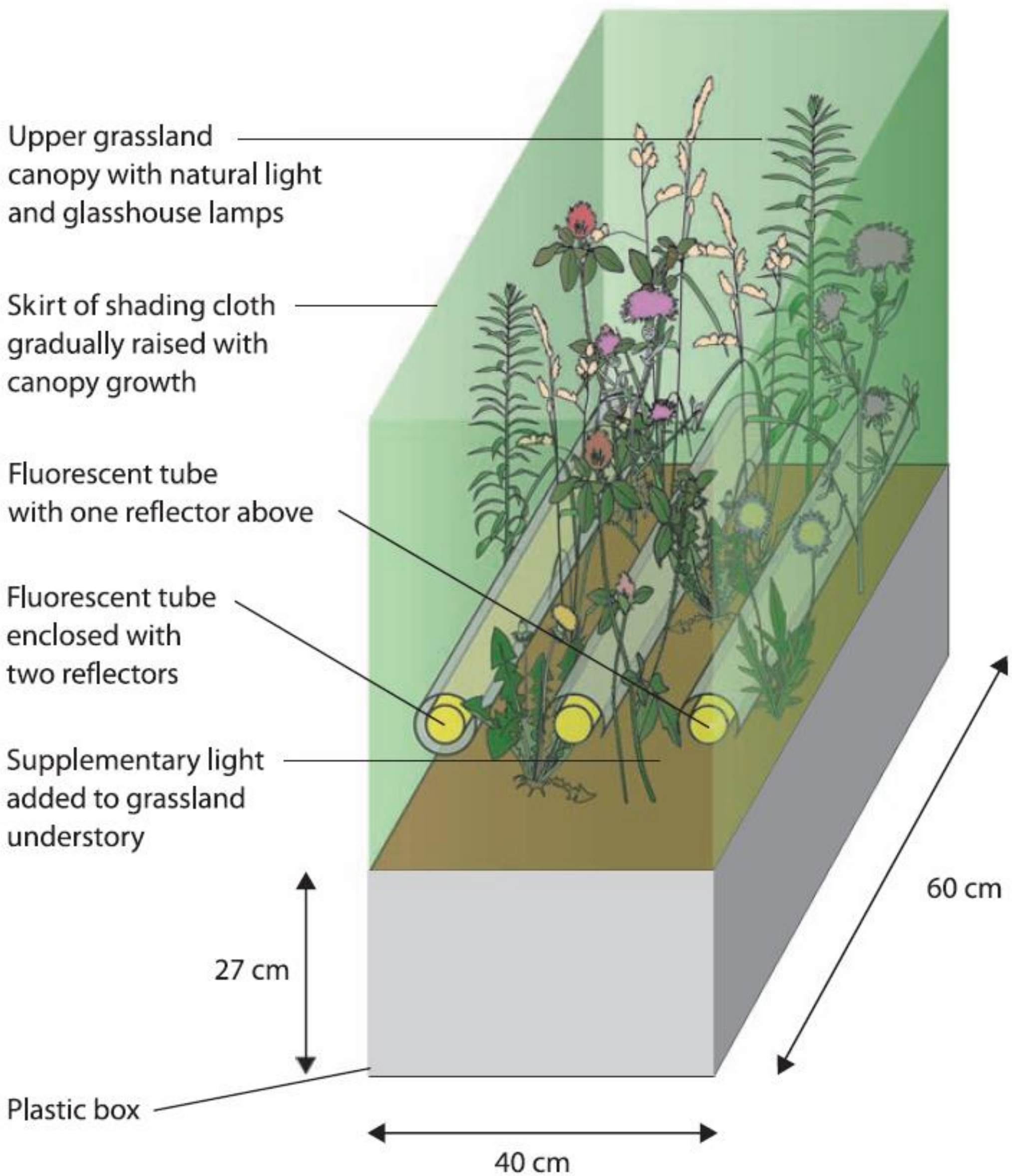


Überschreitung der „critical loads“ für Stickstoff:



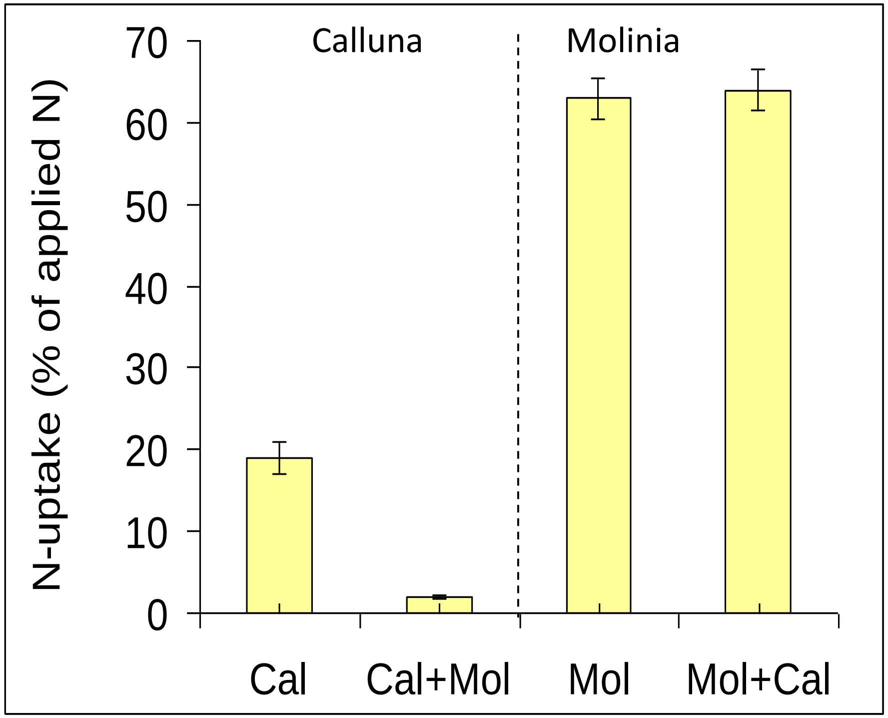
3.2 Artenwandel: Vergrasung von Heiden – Konkurrenz-Mechanismen

(1) Aboveground competition (light)

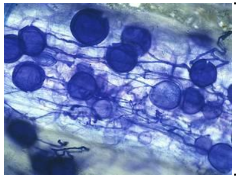


Hautier et al., 2009, Science 324

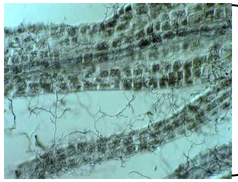
(2) Belowground competition (N)



(3) Mycorrhiza-type



arbuscular m. → P-limit.

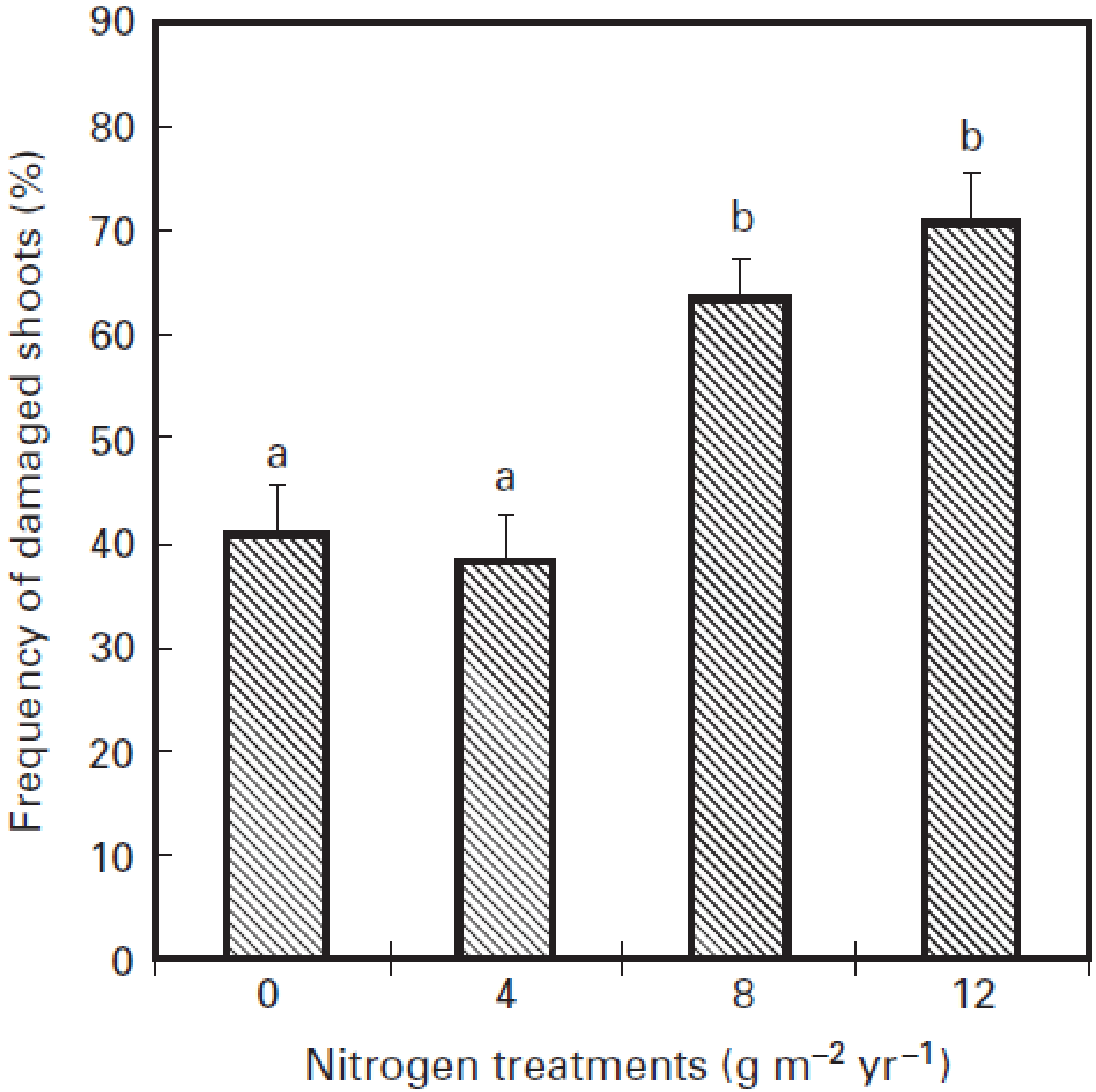


ericoid m. → N-limit.

Friedrich et al., 2011, Environ Pollut 159

3.1

Global change: Adverse effects of nitrogen deposition



s loss

Stevens et al. (2006)
Bobbink et al. (2010)
Jones & Power (2012)

Brunsting & Heil (1985)

ris

Carroll et al. (1999)

Hofland-Zijlstra & Berendse (2009)

3.1 Global change: Adverse effects of nitrogen deposition

- Shifts in species composition / species loss

Stevens et al. (2006)
Bobbink et al. (2010)
Jones & Power (2012)

on

Brunsting & Heil (1985)

lgaris

Carroll et al. (1999)

on

Hofland-Zijlstra & Berendse (2009)