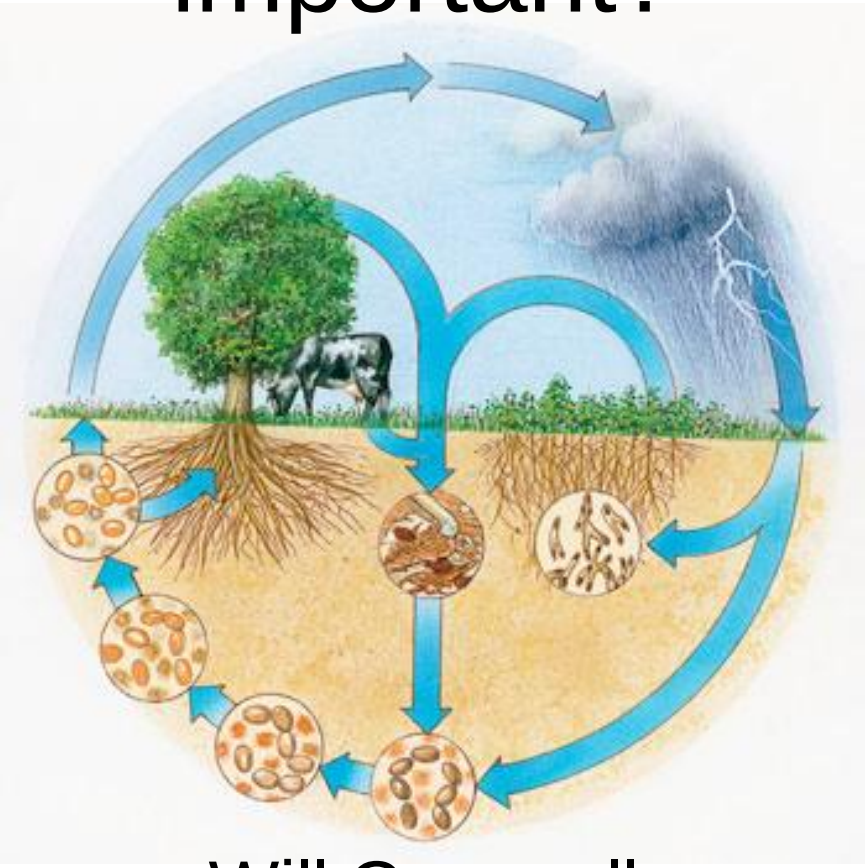
When are positive feedbacks important?



Will Cornwell

vrije Universiteit amsterdam

THE NATURE OF NUTRIENT LIMITATION IN PLANT COMMUNITIES

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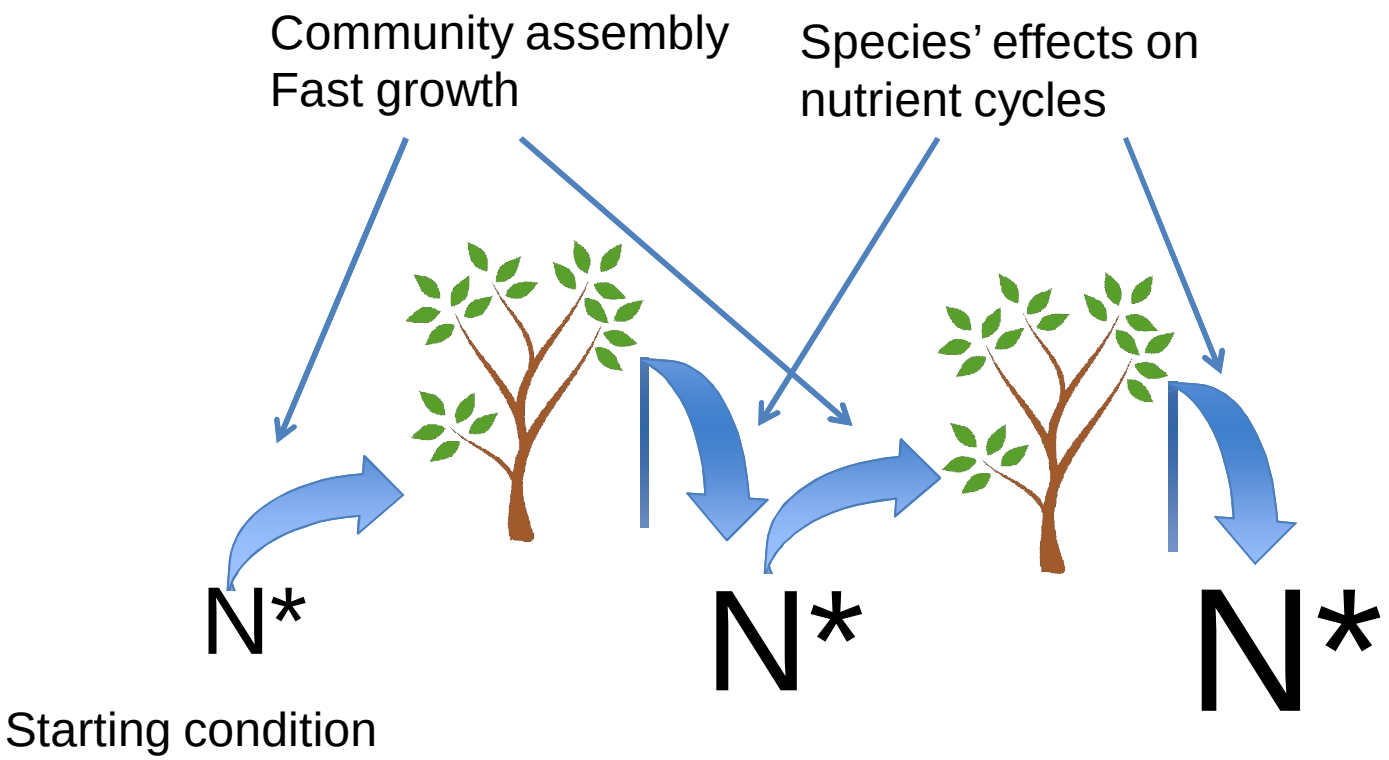
Inputs and outputs

ECOSYSTEM-LEVEL FEEDBACK

Ecosystem-level feedback that acts through the nutrient status of plants can alter both nutrient availability and nutrient limitation in natural ecosystems. We consider two of these, grazing and decomposition.

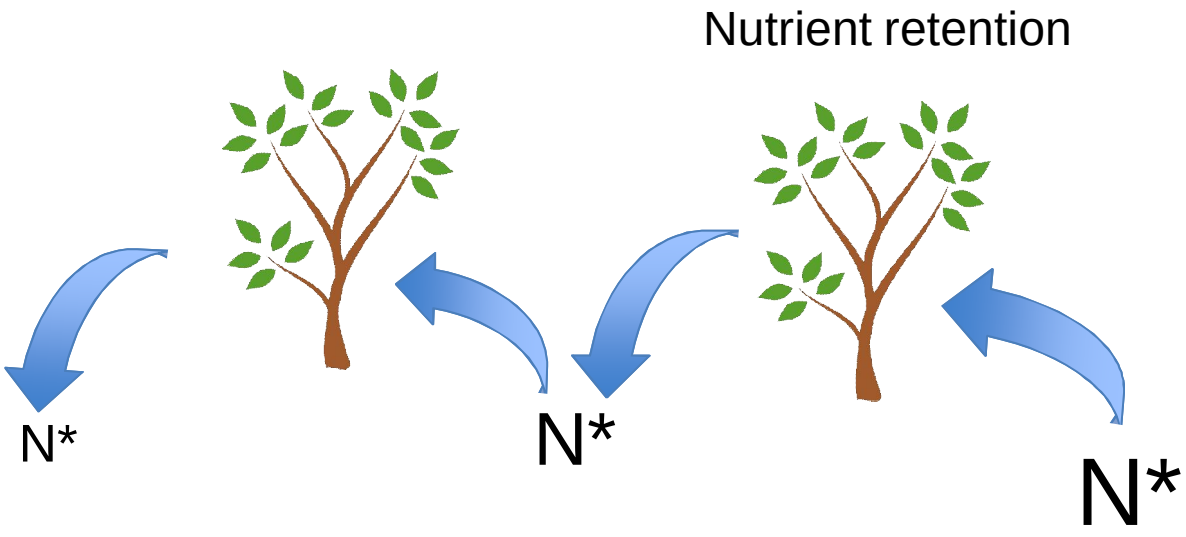

Community assembly
Fast growth
Species' effects on
nutrient cycles
N*
N*
N*
Starting condition

Community assembly

Traits of community

Nutrient availability

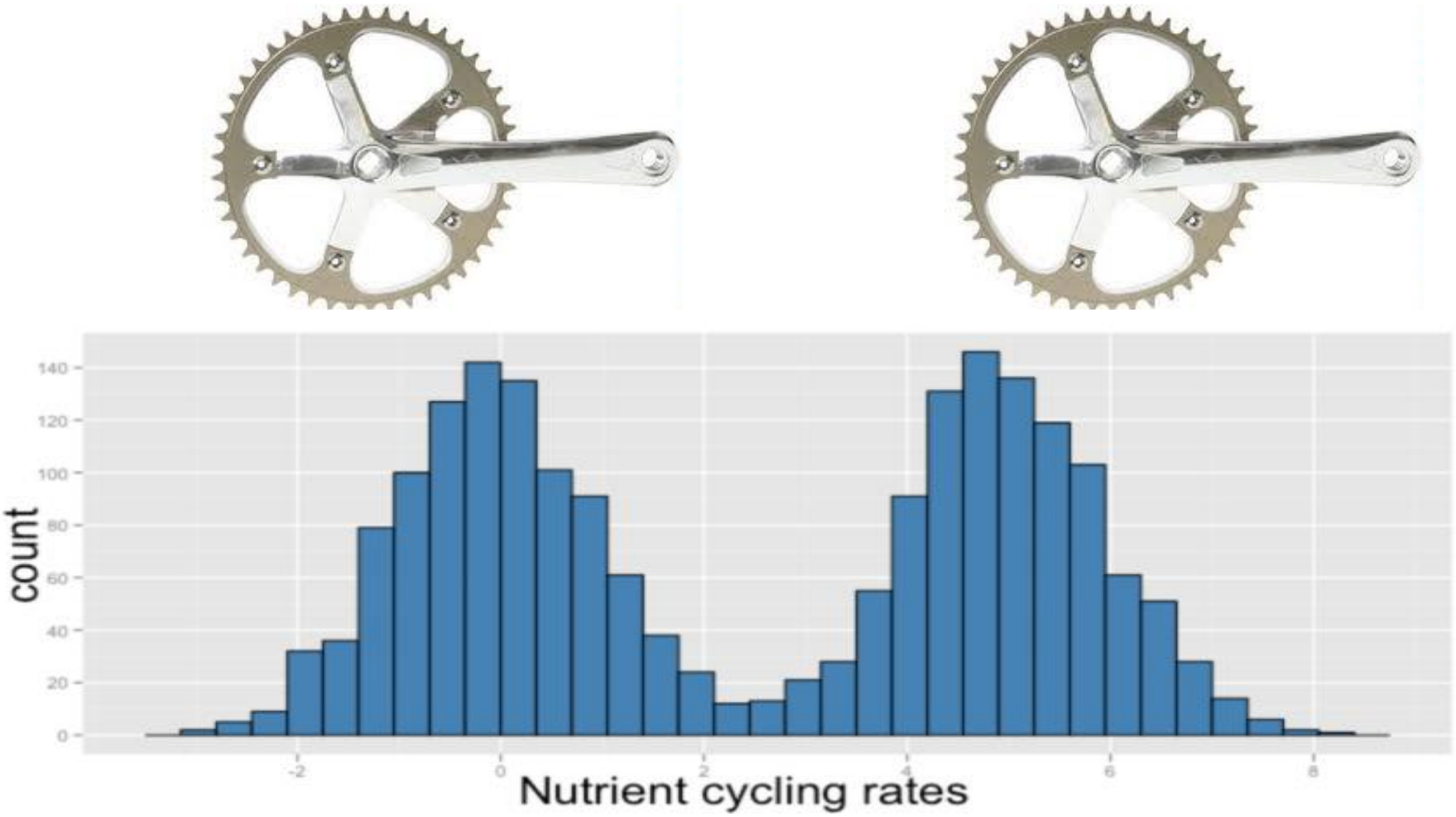
Species' effects on nutrient cycles


Nutrient retention
N*
N*
N*
Starting condition

Examples of feedbacks

Slow cycle feedback

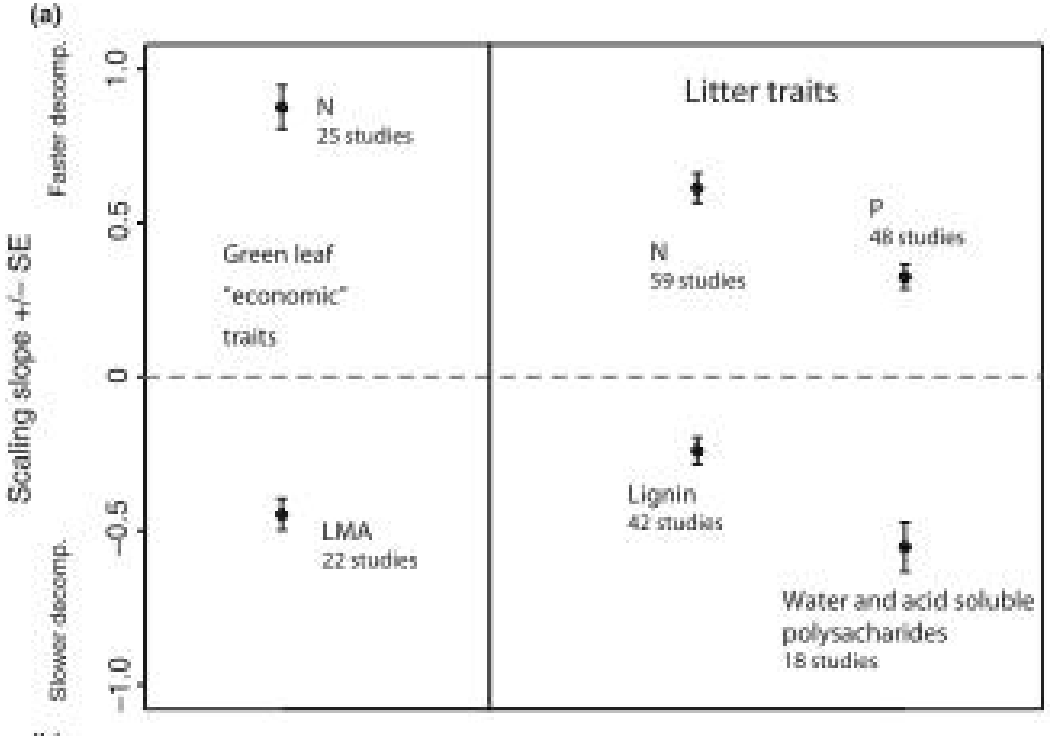
Fast cycle feedback



Effects of Plant Species on Nutrient Cycling

Sarah E. Hobbie

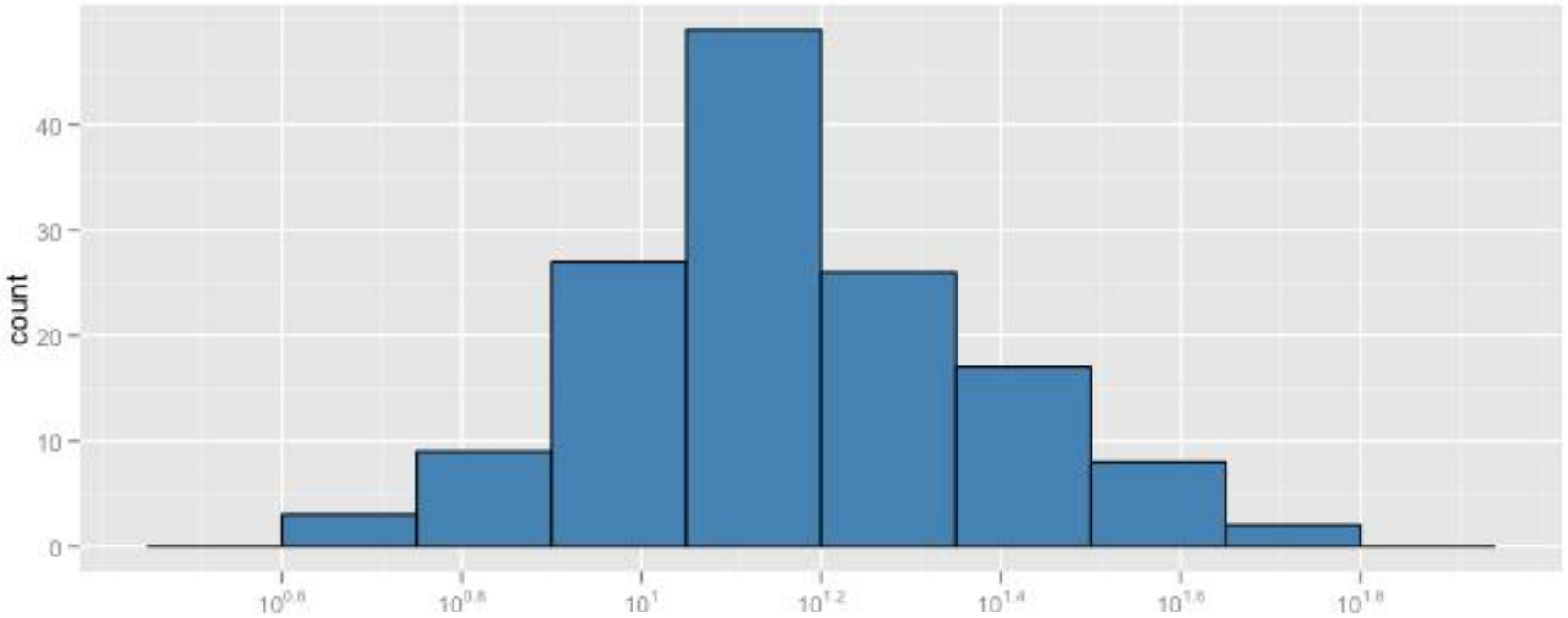
ents, the ultimate sink is whole-plant growth. Species from environments where soil nutrients are abundant allocate more to aboveground parts, have more rapid growth rates, and have higher rates



Globally an 18-fold difference among species within ecosystems (Cornwell et al. 2008)

But….

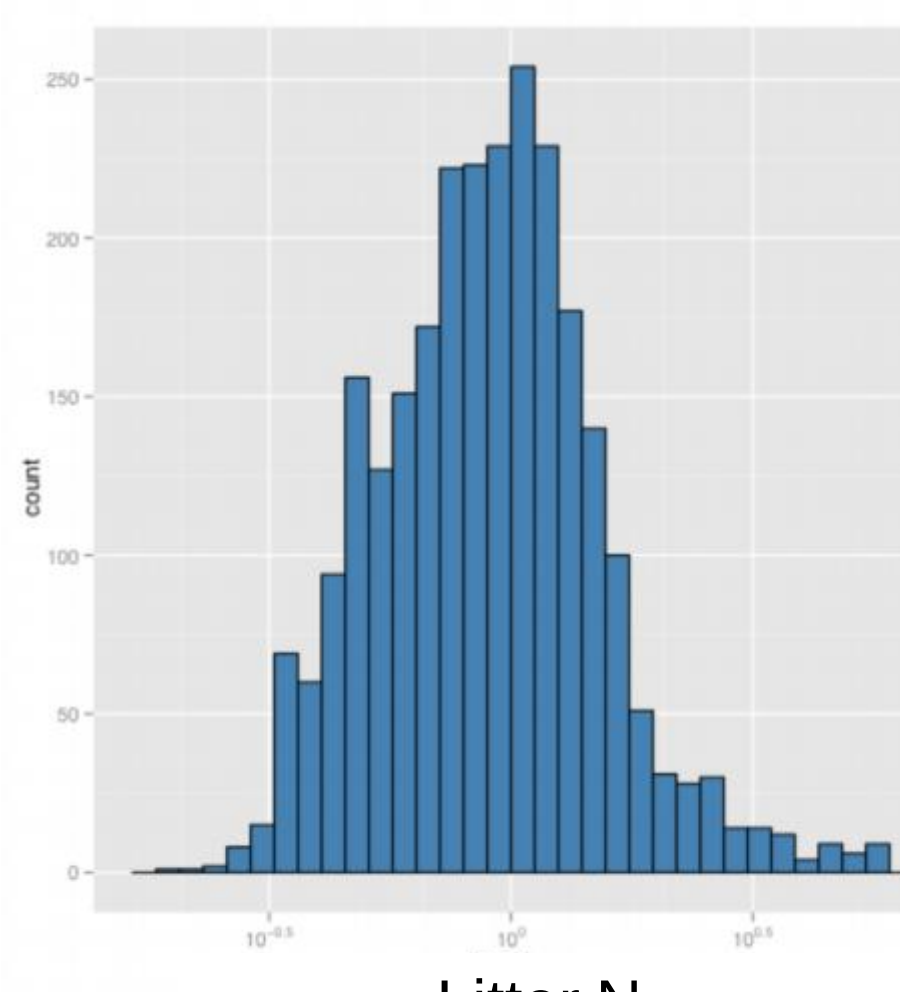
Soil Fertility



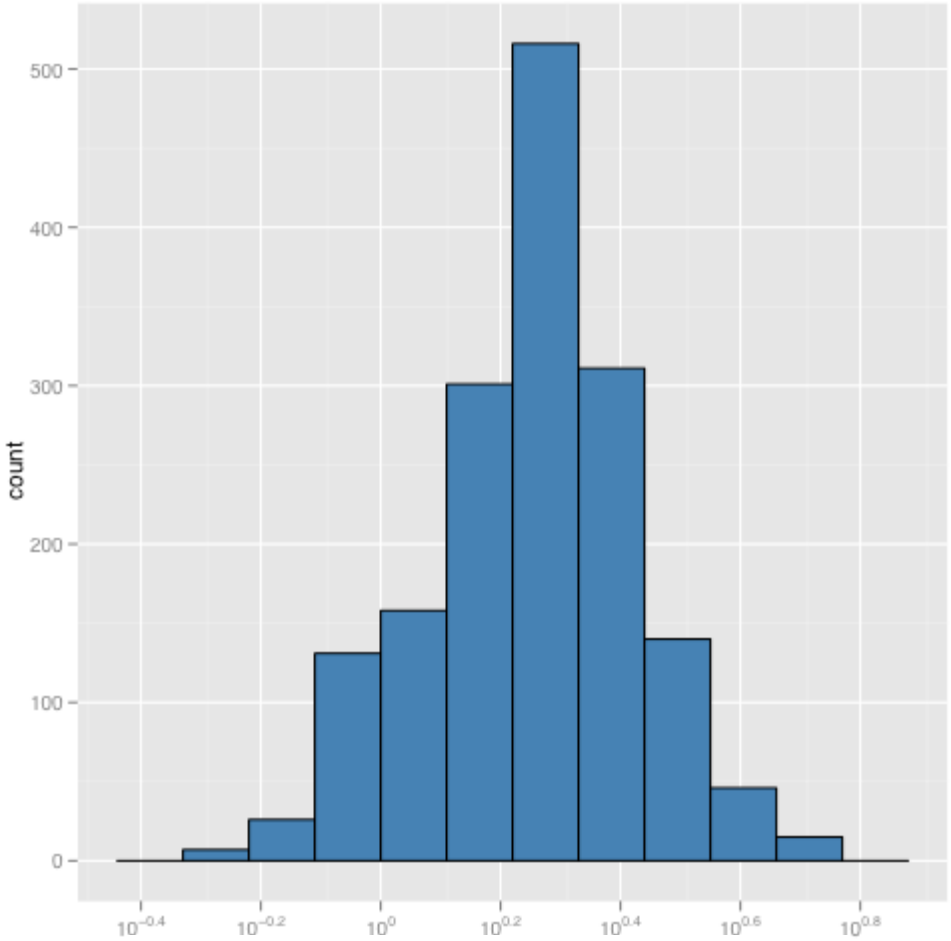
SOIL C:N

data from Ordonez et al. 2009

Plants



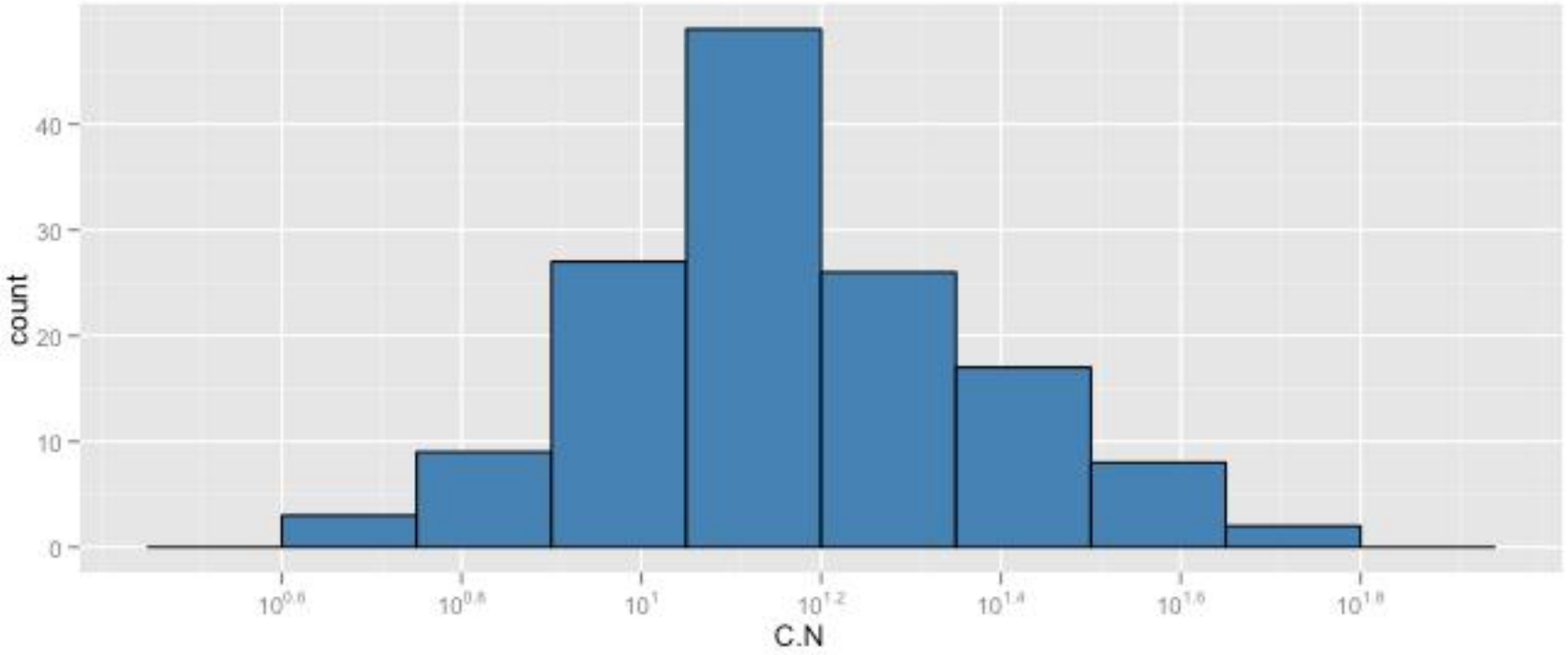
Litter N



Green N

data from Cornwell et al. 2008

How do we reconcile positive feedbacks with (log) normal distributions of fertility?



Community assembly

Traits of community

Nutrient availability

Species' effects on nutrient cycles

1) Water—the afterlife effects of water use efficiency

2) Game theory and the multi-species world

The trade of between NUE and WUE

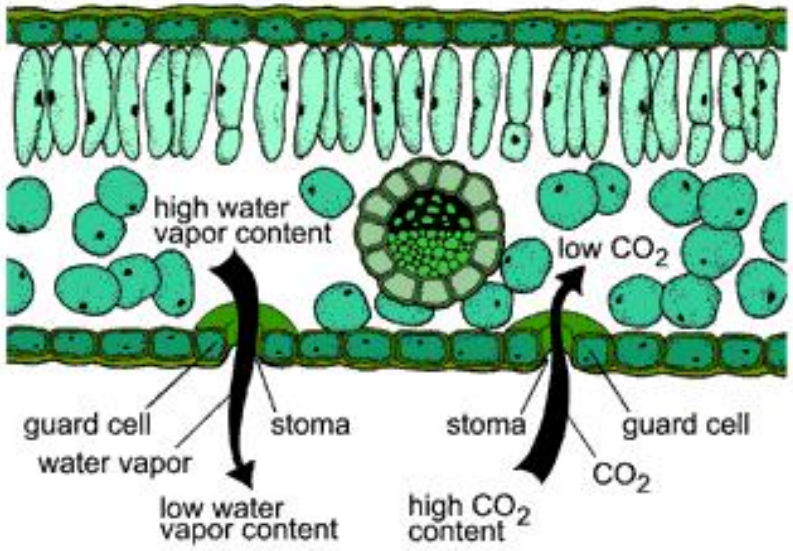
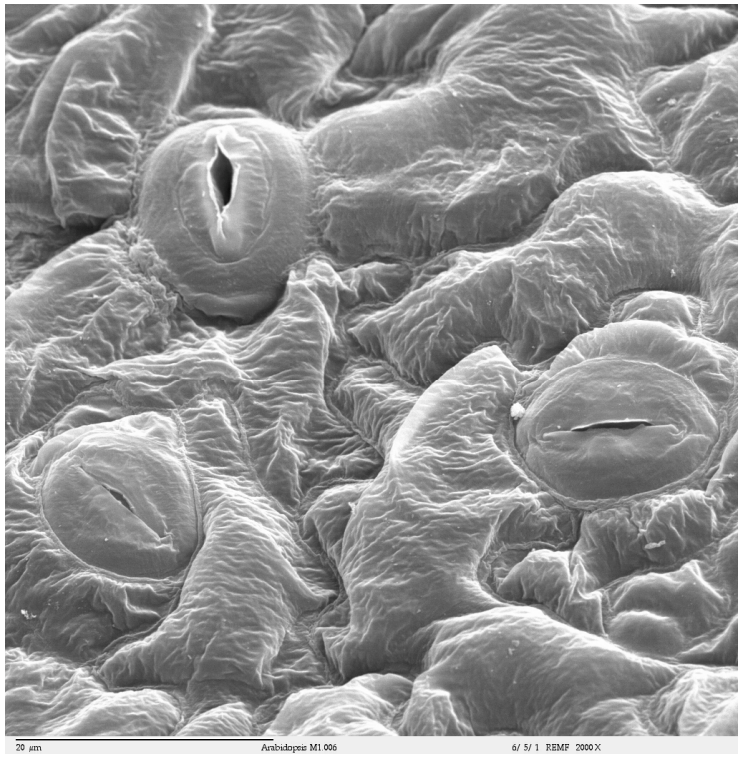
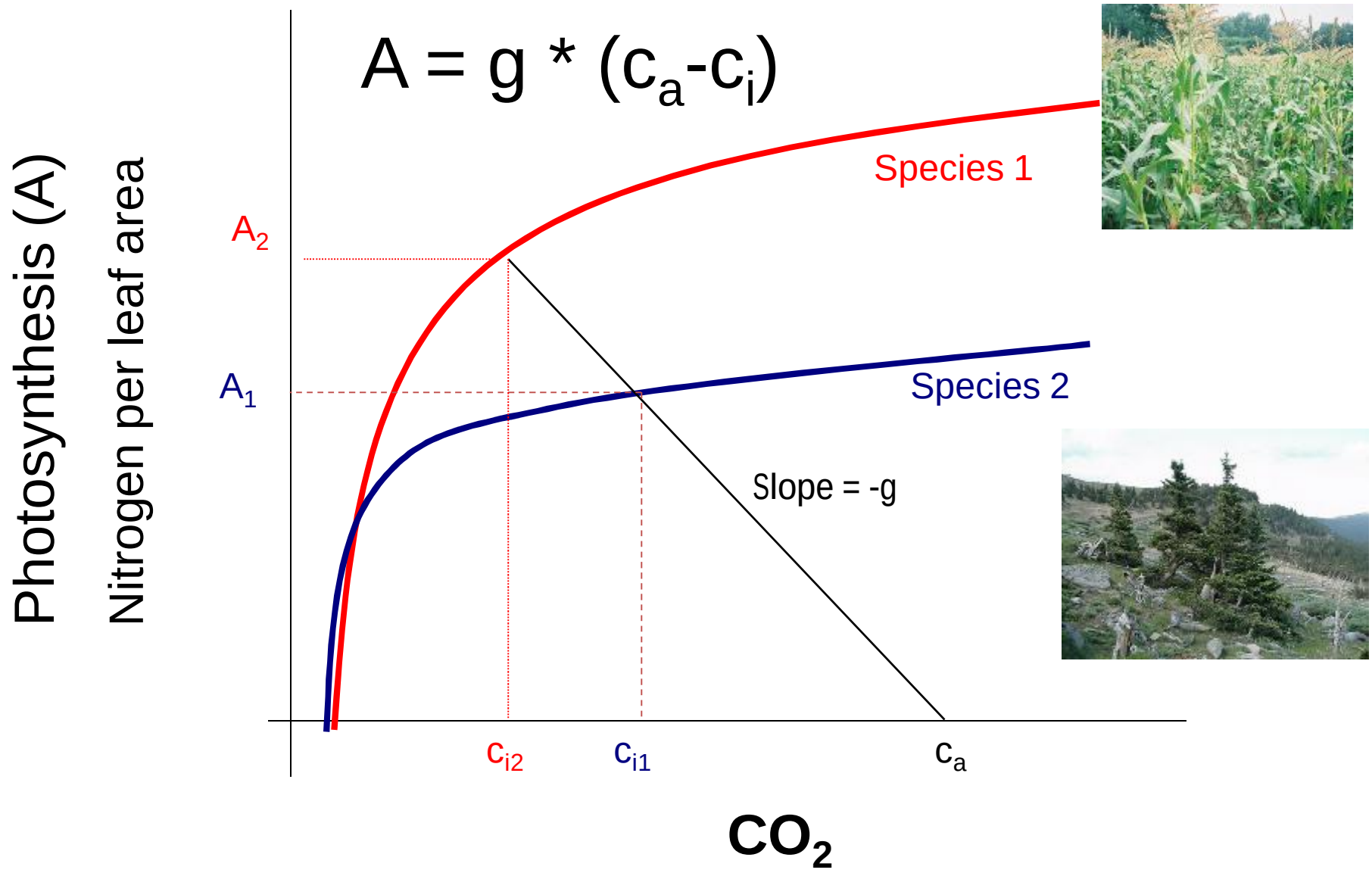


Figure 25. Stomata open to allow carbon dioxide (CO_2) to enter a leaf and water vapor to leave.



Field et al 1983


Photosynthesis (A)
Nitrogen per leaf area
A = g * (ca-ci)
Species 1
Species 2
A2
A1
Slope = -g
ci2
ci1
ca
CO2

Research Question

How do soil fertility and water availability interactively affect plant-ecosystem feedbacks?

Soil fertility

Precipitation

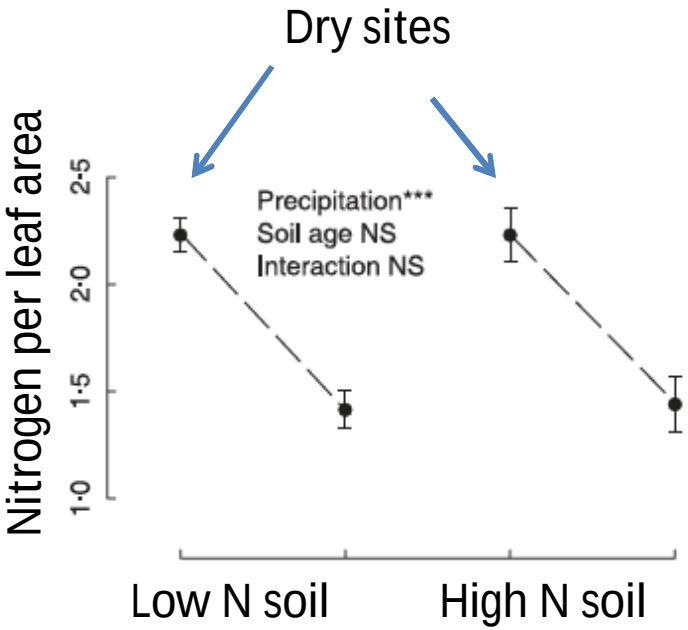
Low N, Wet	High N, Wet
Low N, Dry	High N, Dry

5400 mm/yr

650 mm/yr

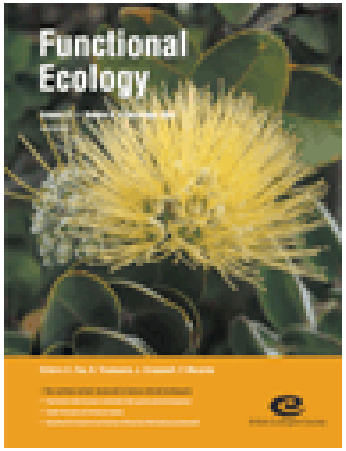

1859 lava flow

Leaves from dry sites have greater more N + photosynthetic capacity

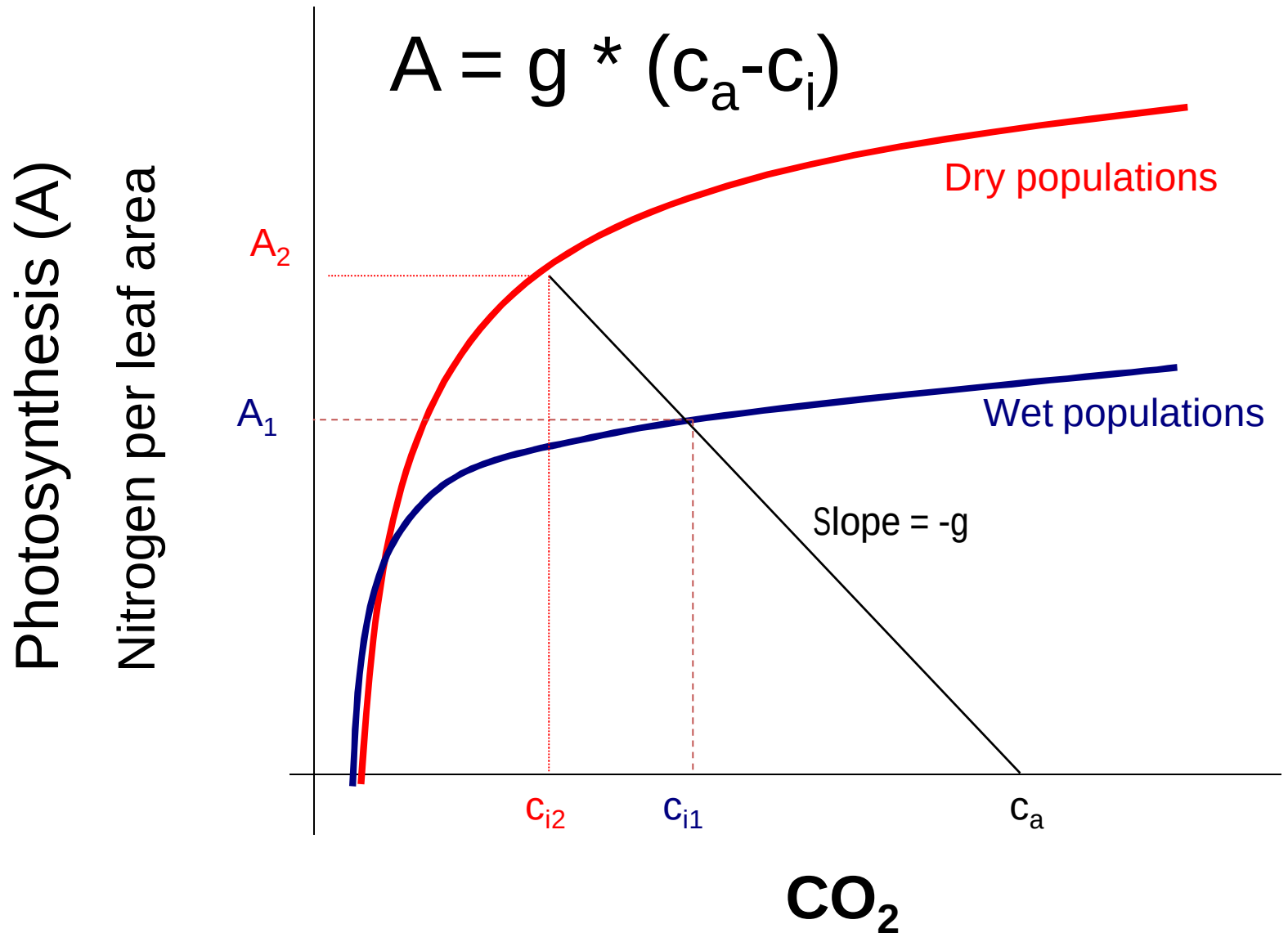


Dry versus wet

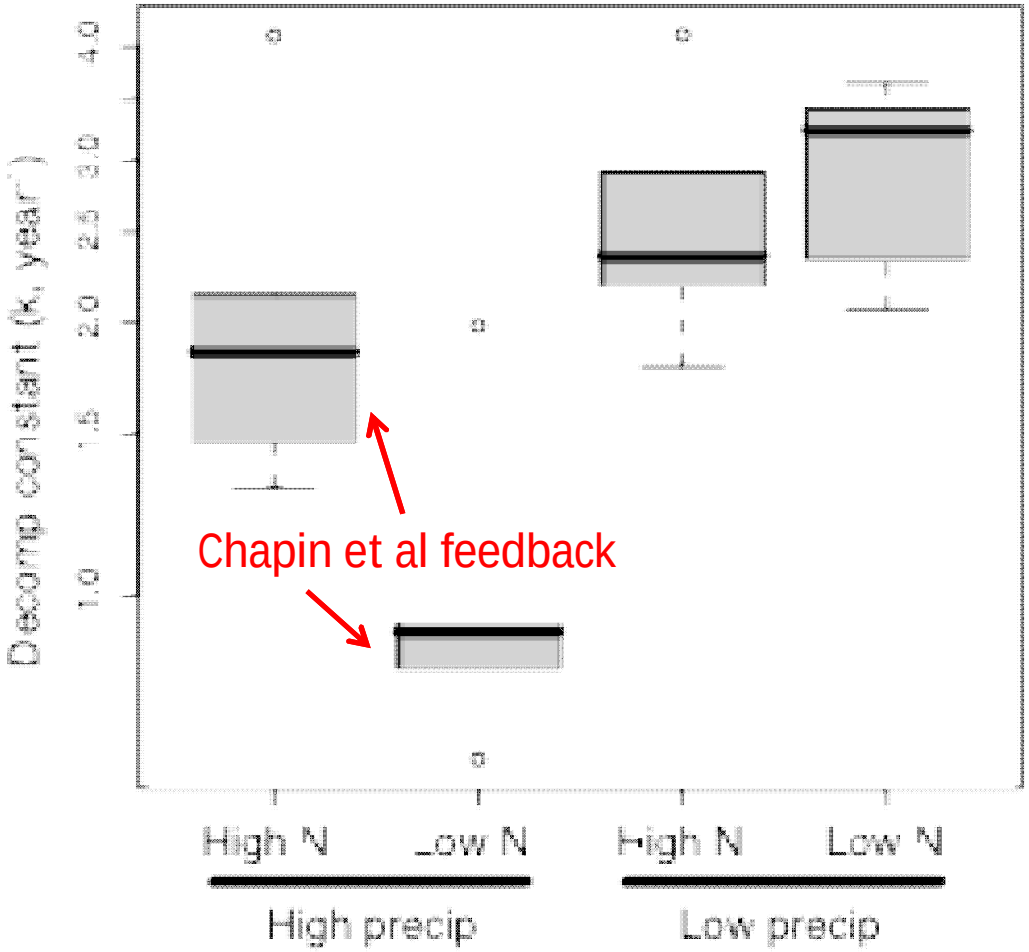
Narea	⇧***
Nmass	⇧**
Aarea	⇧***
Amass	⇧***
Vcmax	⇧**



Cornwell et al. 2007

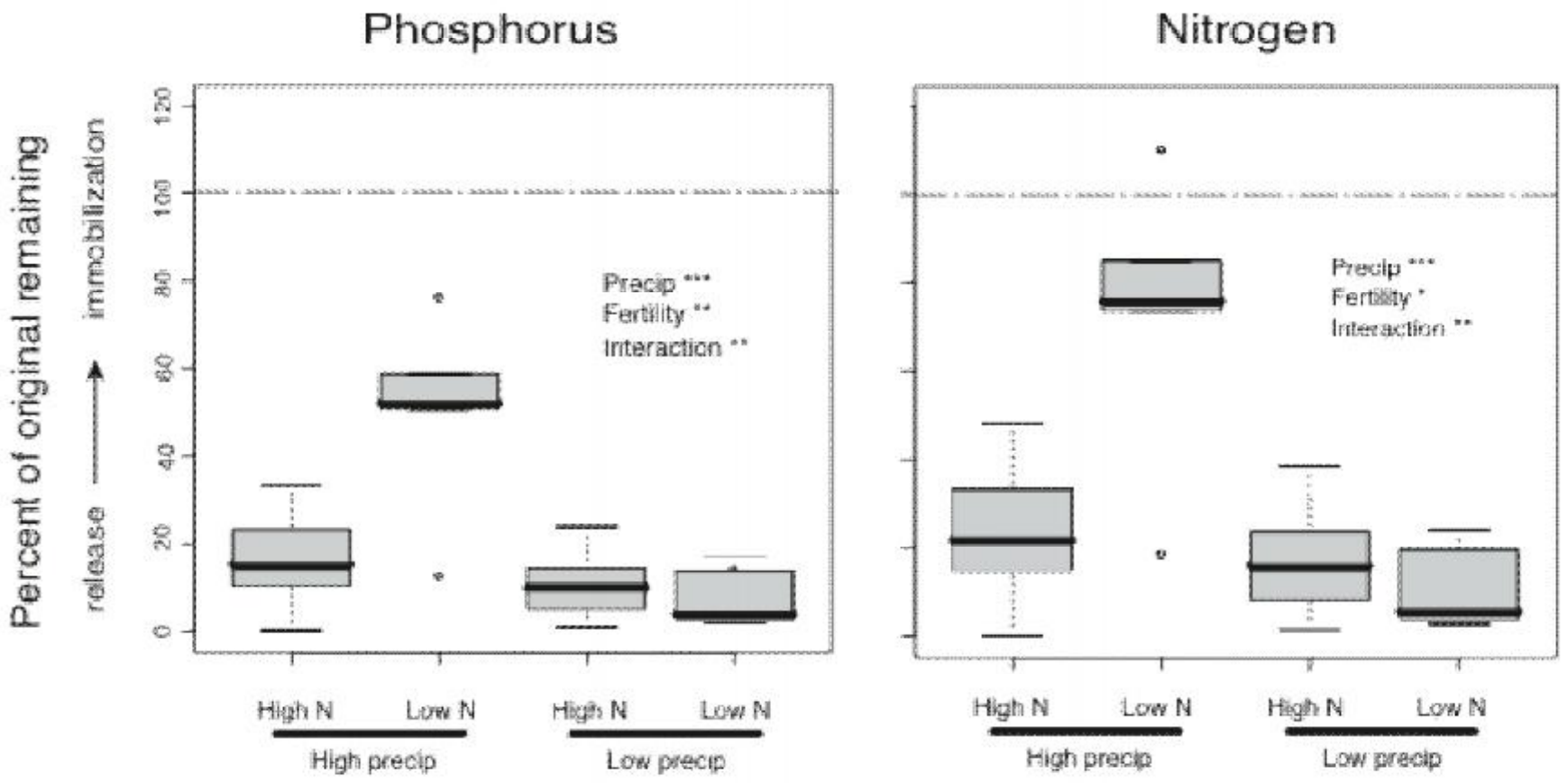

A = g * (ca-ci)
Photosynthesis (A)
Nitrogen per leaf area
Dry populations
Wet populations
A2
A1
Slope = -g
ci2
ci1
ca
CO2

Litter from arid places, even on poor soils, is highly decomposable



Common site decomposition

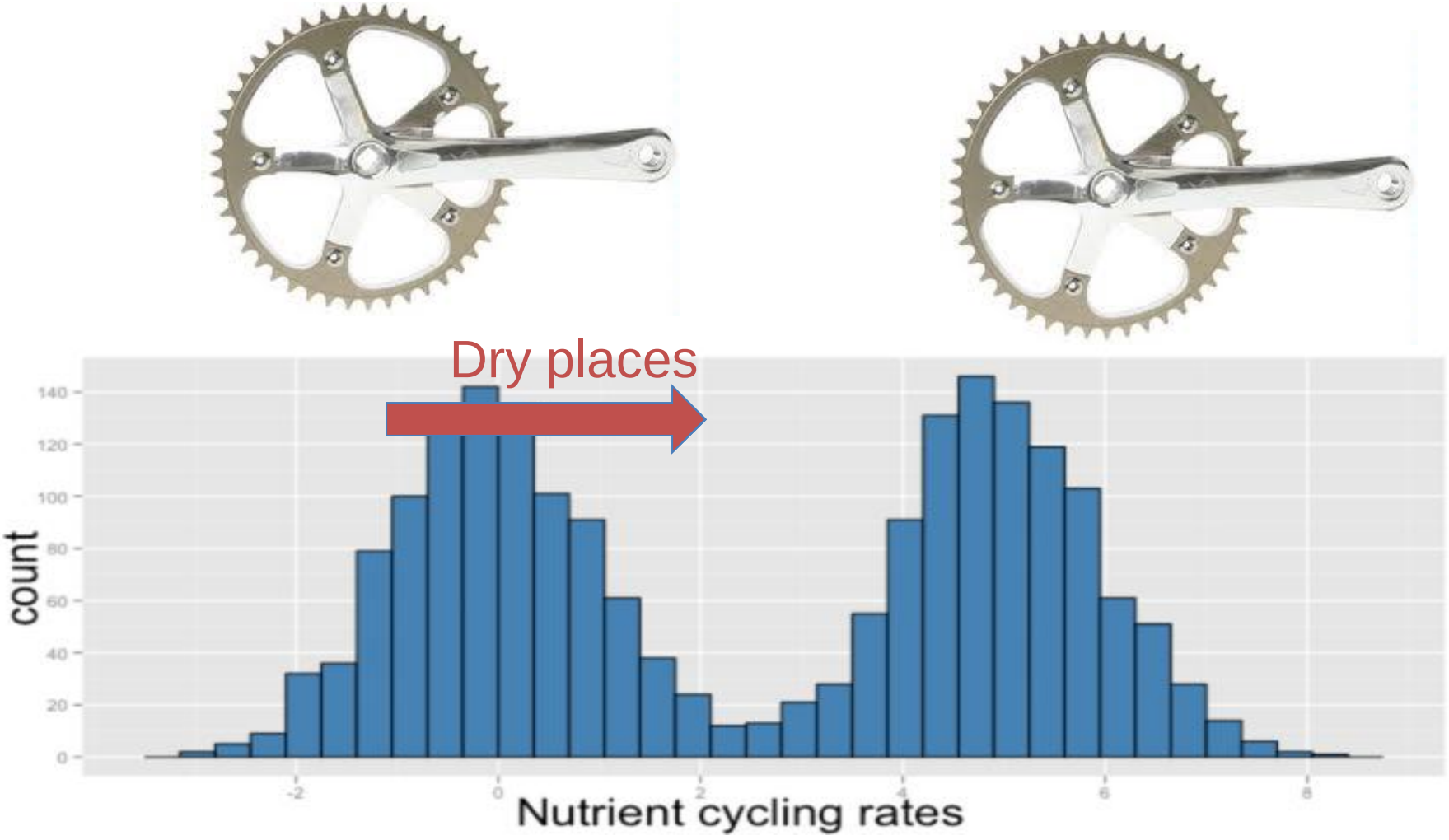
Litter from arid places, even on poor soils, release N and P quickly



The ubiquity of higher leaf N for evergreen species in dry places

Slow cycle feedback

Fast cycle feedback



Communities are not composed of one species

Coexistence models:

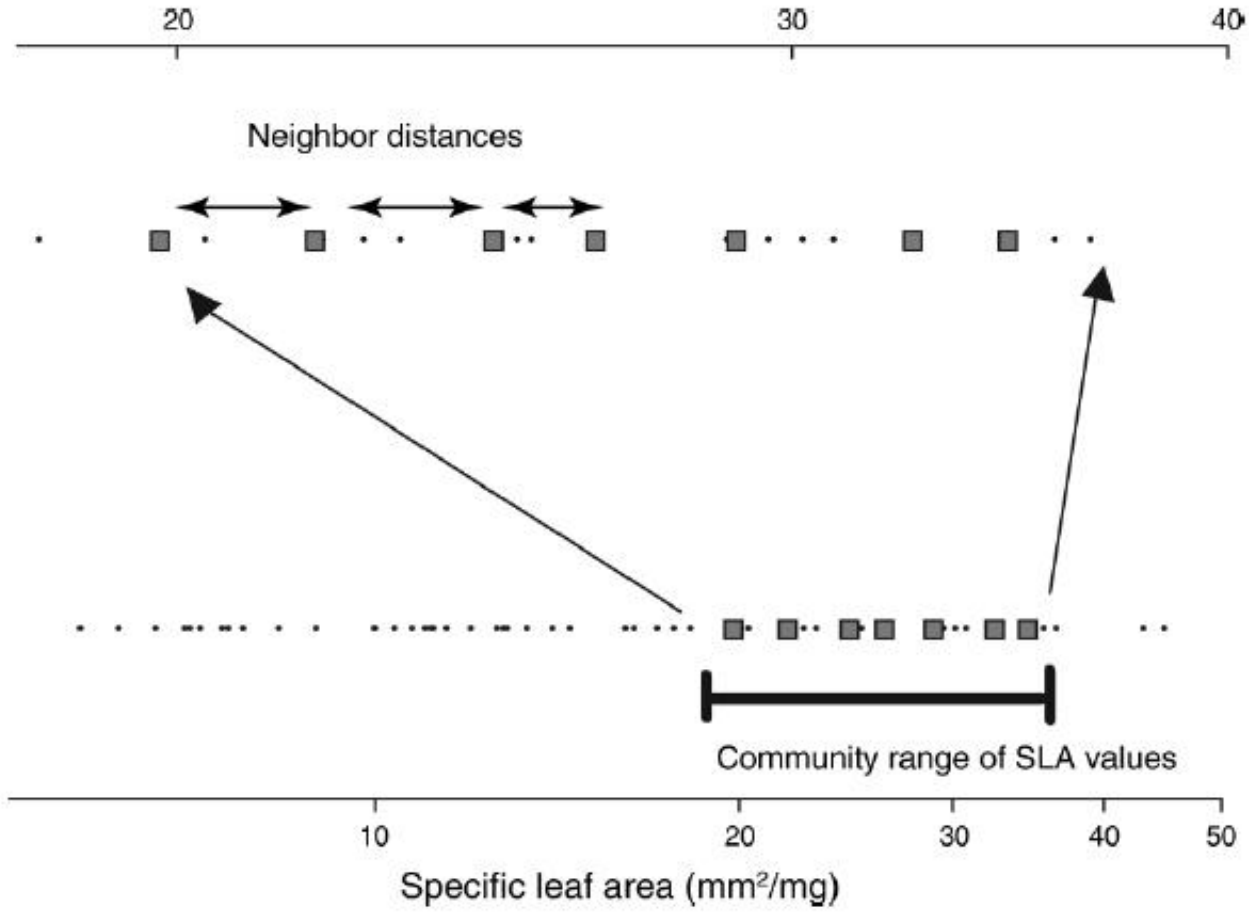
- Storage effect (Chesson)
- Colonization - competition (Tilman)
- Multiple resources (Tilman)

Competitive effects

- competition for light (height growth)

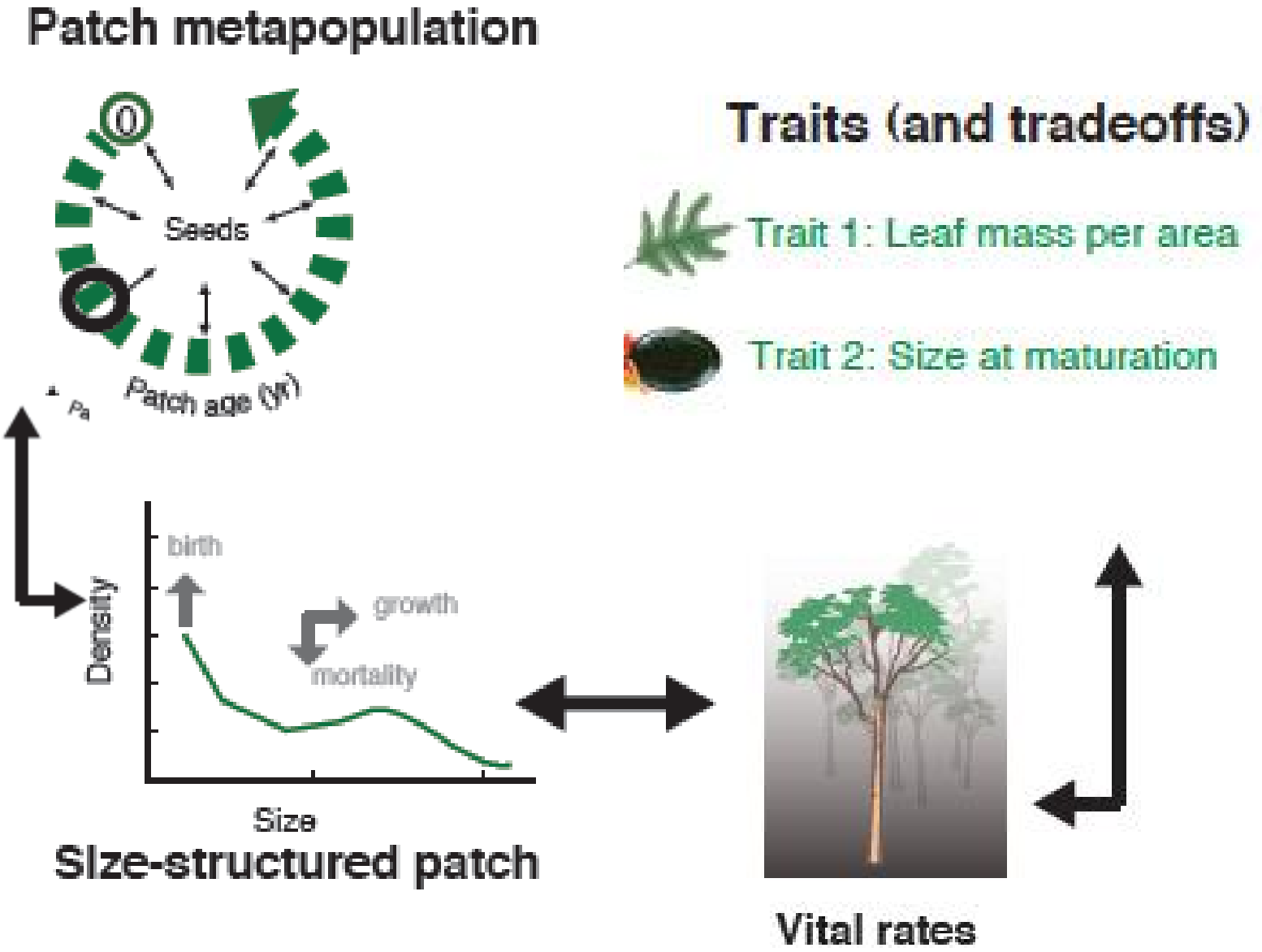
To date, conceptual models are difficult to translate to traits and, thus, effects on ecosystems

Despite competition, communities are not composed of one species

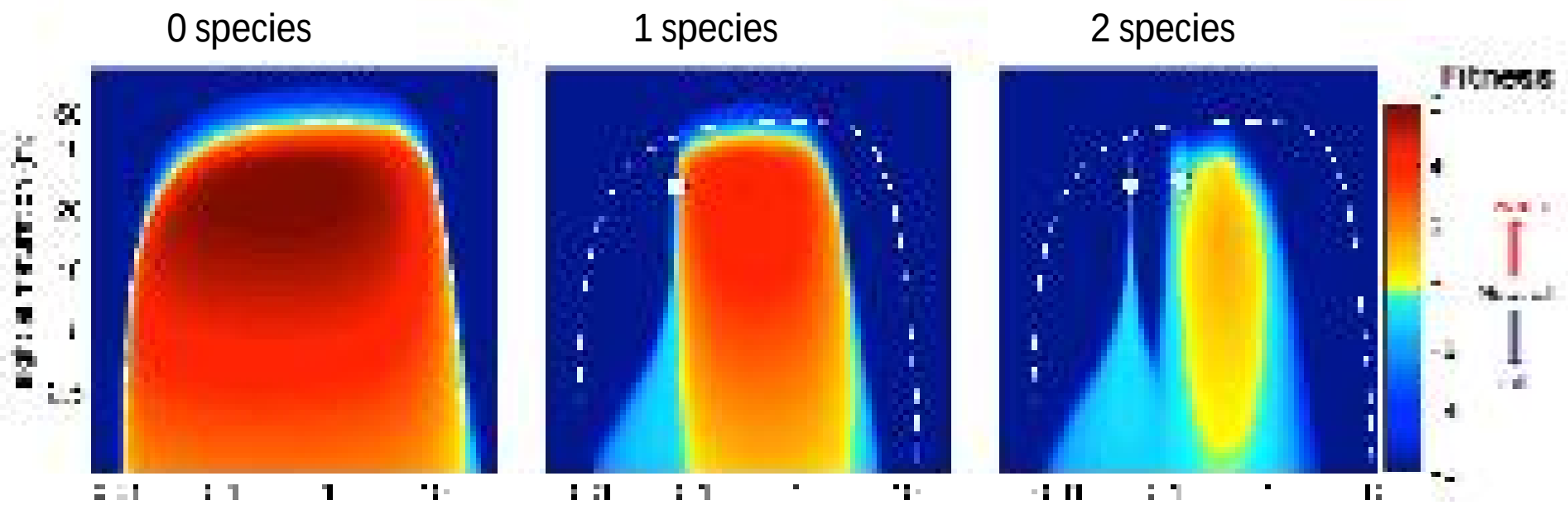


Cornwell and Ackerly 2009

Falster et al. 2011 + in prep



Regeneration in the shade leads to different ES traits



Shade regeneration leads to higher LMA with longer leaf lifespan—and slower decomposition

Falster et al 2011 and in prep

Internal niche dynamics (e.g. regeneration in the shade)

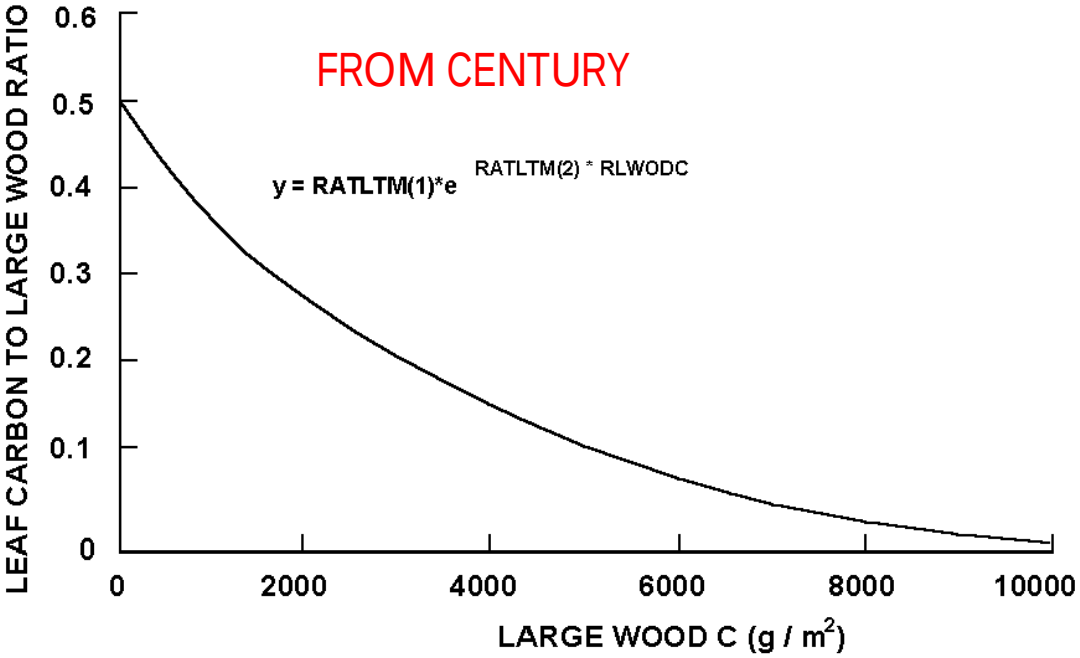
Community assembly

Nutrient availability

Traits of community

Species' effects on nutrient cycles

Increasing investment in wood with increased height growth



Wood has a biosphere residence time of 10-50+ times that of leaves
(Weedon et al 2008, Cornwell et al. 2009, Freschet et al in review)

Slow cycle feedback

1) Aridity

Fast cycle feedback

1) Sub-canopy niche dynamics
2) Increased allocation to structural C

Brakes on the positive feedback

Conclusion

Infertile, wet places with infrequent disturbance

Everywhere else

Fertile, low diversity places with disturbance that interferes with height growth

Closing Thoughts

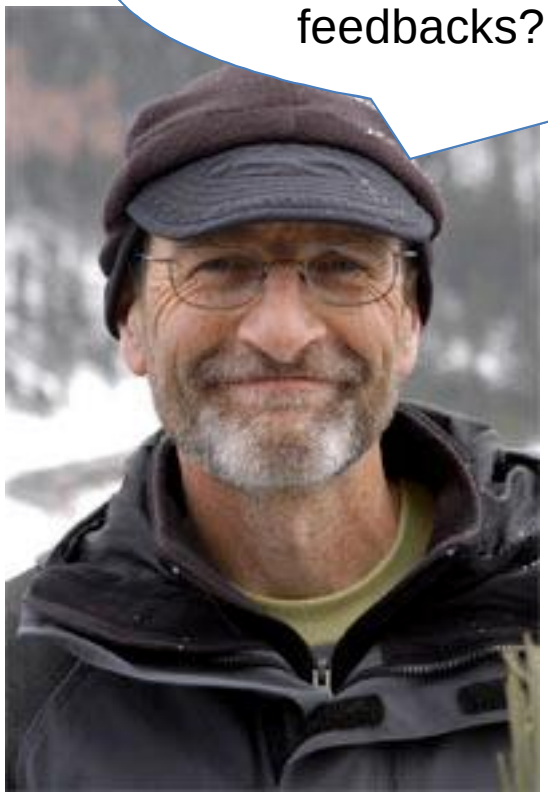
- Chapin et al. mechanisms are ubiquitous
- However, there are often strong breaks on this feedback with the relative strength of the brakes creating global variation in nutrient cycling rates
- Representing internal dynamics in a functional way requires both positive feedbacks and the constraints on those feedbacks

THANKS

Thanks to Peter van Bodegom, Bob Douma, Marika Makonen and Systems Ecology
for help with the talk and Peter Vitousek for the science

In 2002

What are the global limits on positive trait-ecosystem feedbacks?



Huh?