Plant traits, litter fates and decomposition rates

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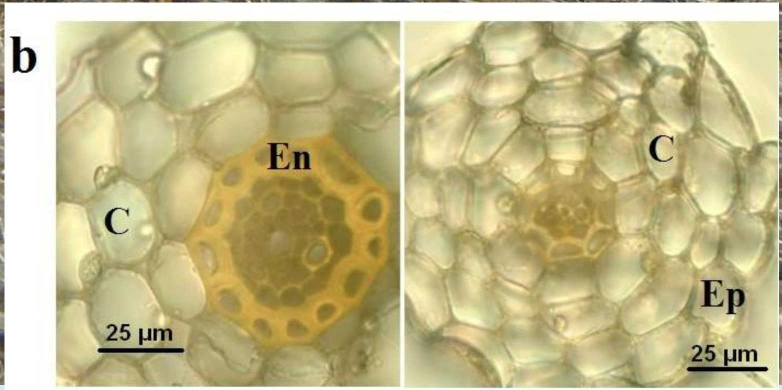
Defining functional traits as Response Traits and Effect Traits* may help us to predict effects of environmental changes on ecosystem functions *via changes in species composition*

* Lavorel & Garnier 2002 *Func. Ecol.*, Suding et al. 2008, *Global Change Biology*, Diaz et al. 2013 *Ecol. Evol.*

Response traits are functional traits that help a (plant) species to live in and respond to changes in its environment, e.g.:

- rooting depth
- seed size, seed number per plant
- drought tolerance
- capacity to resprout after fire
- nutrient uptake strategy

Snow roots in the Caucasus Mountains (Onipchenko et al. 2009 *Ecology Letters*): special N uptake strategy



Specific root length (length/mass)

C. conorhiza

- Snow roots 495 ± 65 m g^{-1}
- Soil roots 99 ± 3.6 m g^{-1} (P=0.0016)

99 local species in the same alpine belt

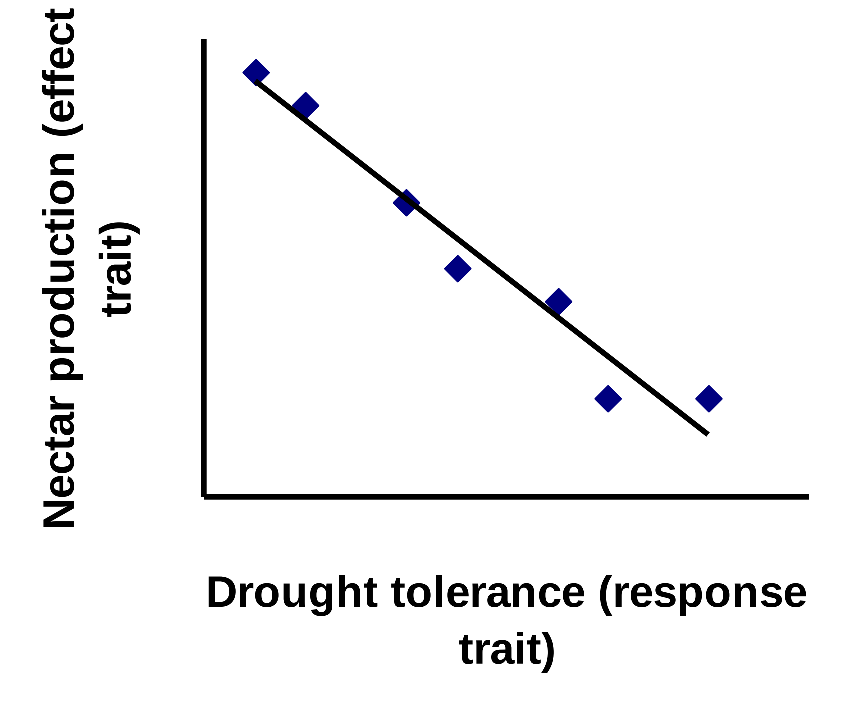
- Soil roots 106 ± 6.0 m g^{-1} (range 12 – 442)

Effect traits are traits that define the potential effect an organism has on a particular ecosystem process or function

E.g. amount of nectar a plant species produces per flower or per plant to attract pollinators:

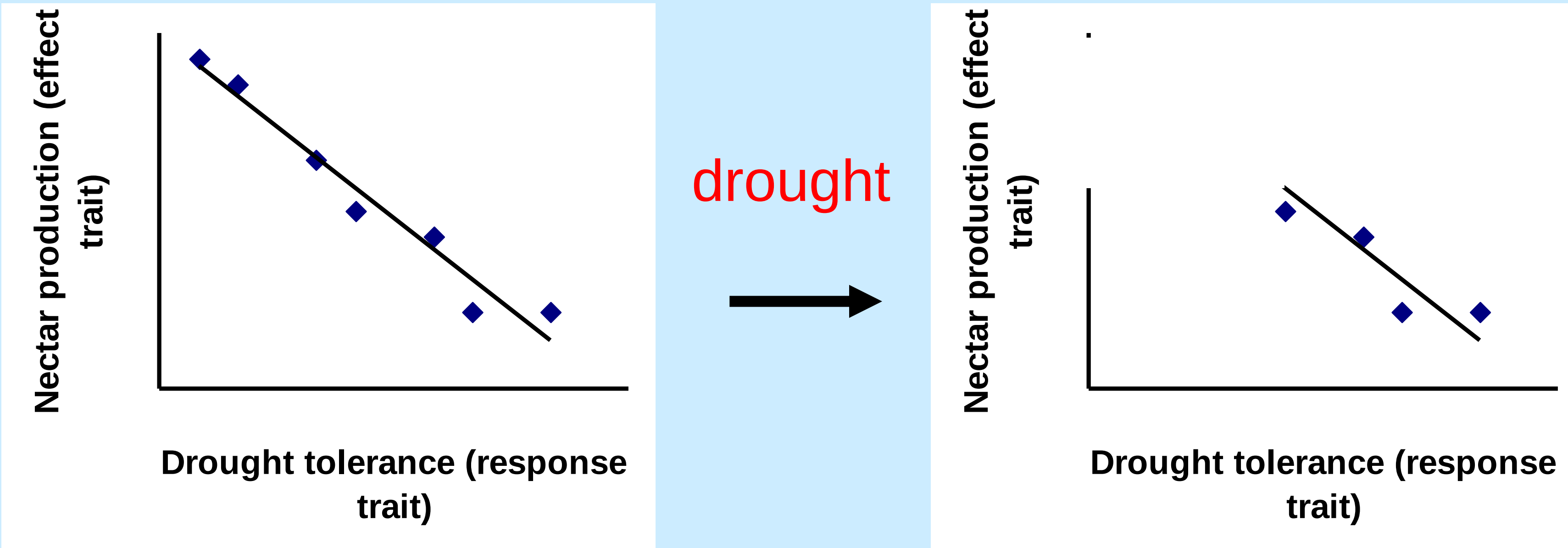
supports animal populations

How are response traits and effect traits linked among species in an ecosystem or a climatic region?



Imaginary example:

Negative relation between drought tolerance (response trait) and nectar production per flower (effect trait)



No species left with high nectar production → less nectar for bees if ecosystem dries up due to climate warming.

So: if strong correspondence in ranking among species for response traits and effect traits

↓

'vulnerability' of an ecosystem function to an environmental change

Diaz et al. 2013 *Ecol. Evol.*, Cornelissen & Makoto 2014 *Ecol. Res.*

Early-successional clonal plants protect sand dunes and people during the lifetime of the plant

Rhizomes of *Ammophila arenaria (marram grass)* in the Netherlands

The afterlife effects of rhizome traits may also be important for soil stability, carbon storage, nutrient turnover and water retention

Inner Mongolia, China

Cornelissen et al. 2014 *Ann. Bot*.

Can plant effect traits help predict surface fire regimes?

variation in gymnosperm (conifer) flammability

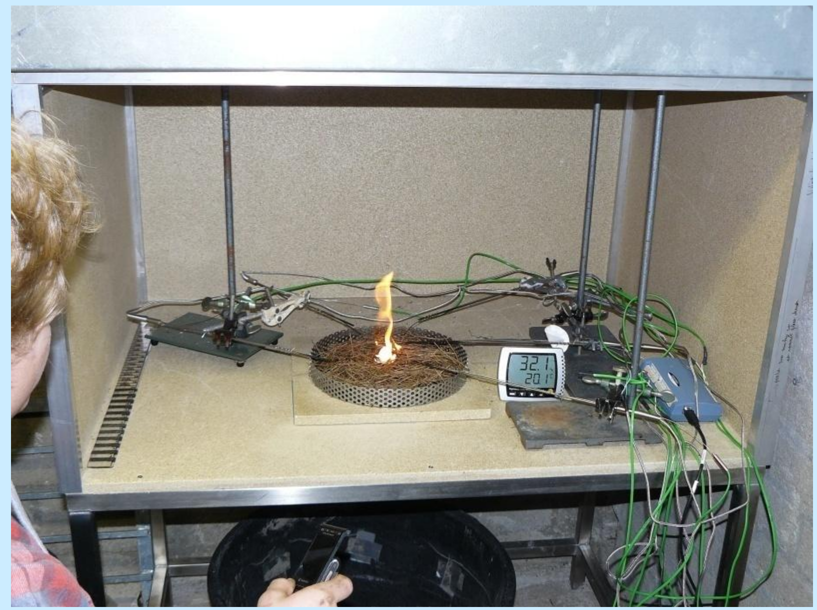
Collecting leaf litter from botanical gardens and (sub-) tropical greenhouses in the Netherlands

Collections of leaf litter of multiple gymnosperm species

FLARE

Fire Lab Amsterdam for Research in Ecology

vrije Universiteit amsterdam

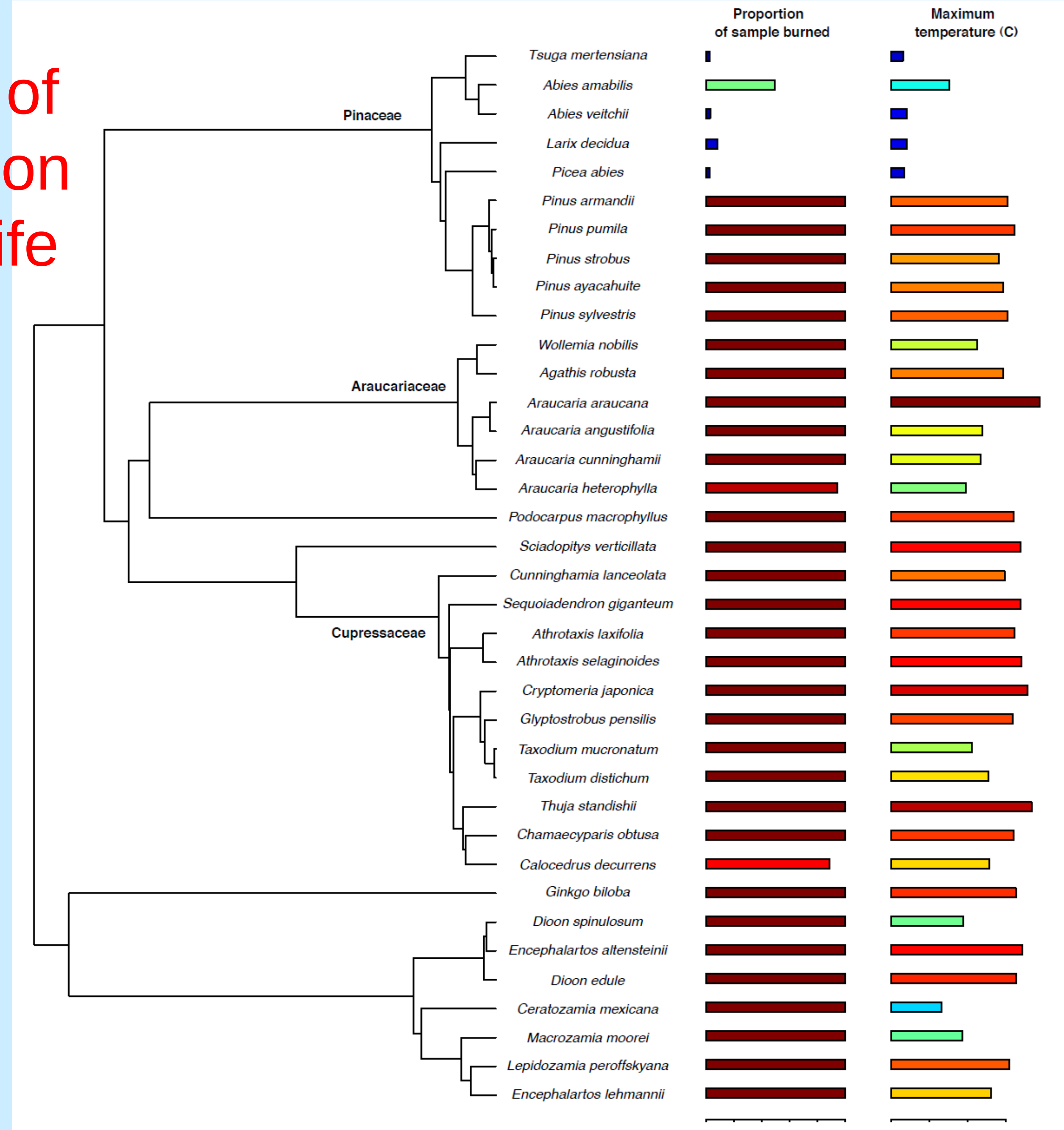


Screening species for flammability
in fuel beds of standard volume

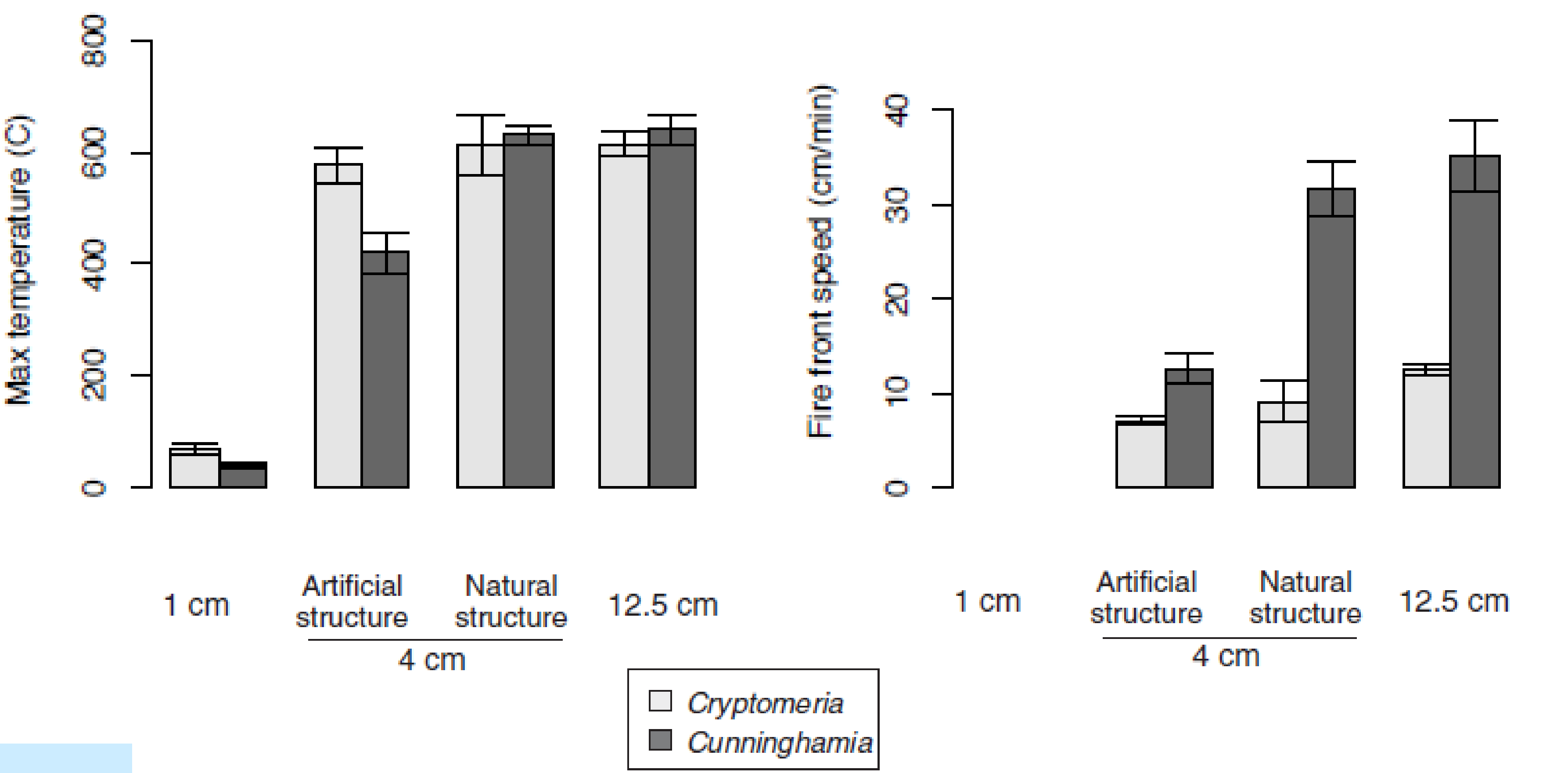
Flammability of gymosperms on the Tree of Life

Fuel beds of non-*Pinus* Pinaceae burn poorly.

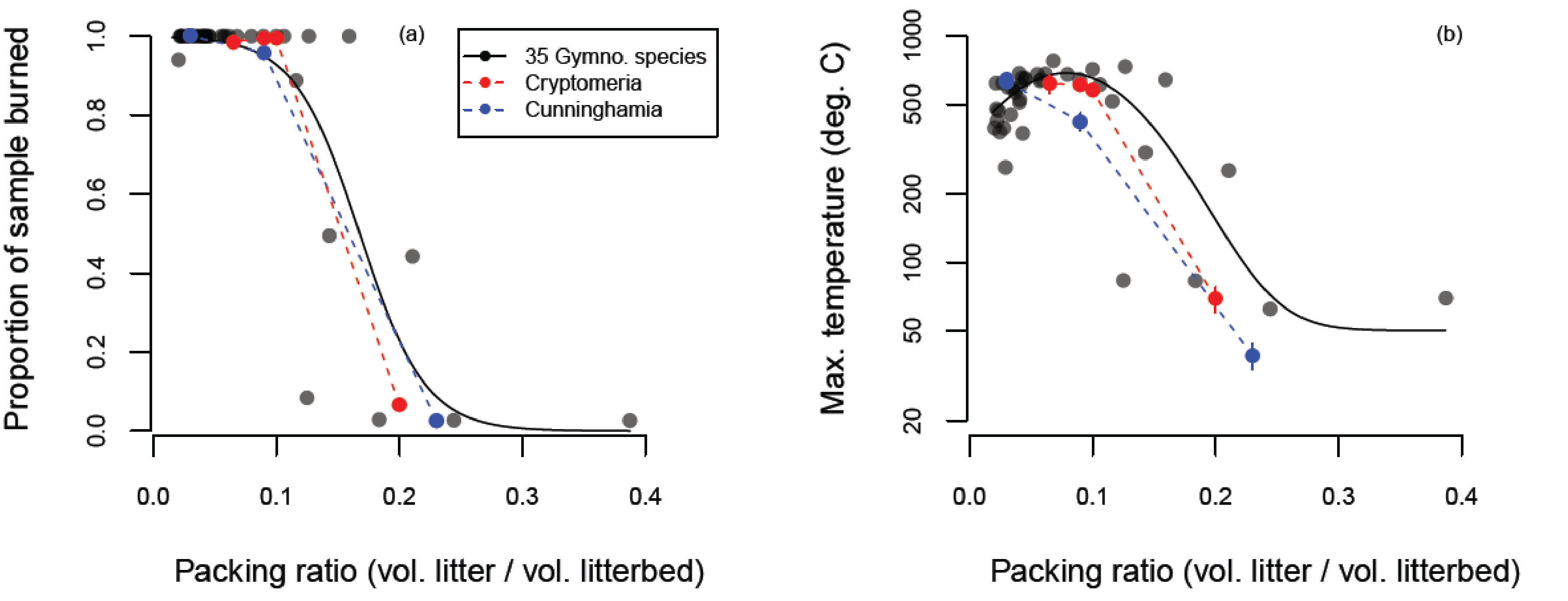
Hypothesis: small leaves (effect trait) → tight fuel packing → lack of O_2



Litter particle size determines flammability also within gymnosperm species (i.e. at given chemistry)



Small leaves → tight packing → low flammability both between and within species



Implications for wildfire regimes?

Cornwell et al. 2015 *New Phytologist*

Effect traits as predictors of litter decomposition rates

- The decomposition of dead plant material (litter) provides nutrients for plant growth and reduces soil carbon pools

- Decomposition rates depend on

1. abiotic environment (climate)
2. soil organisms (decomposers)
3. <u>litter quality: TRAITS</u>

Trait ''Afterlife'' Hypothesis:

- Leaves made for fast growth, e.g. large SLA (leaf area/mass; effect trait)
 → fast litter decomposition

- Leaves made for resource protection
→ slow decomposition

Empetrum nigrum, fast or slow?

Cornelissen et al. 1997 *New Phytol*., Quested et al. 2003 *Ecology*

We test this hypothesis using a ‘Common Garden’ approach*:

Screening the important plant species from an ecosystem or flora for litter mass loss rate *in the same environment at the same time*

→ decomposability

*Cornelissen 1996, *Journal of Ecology*

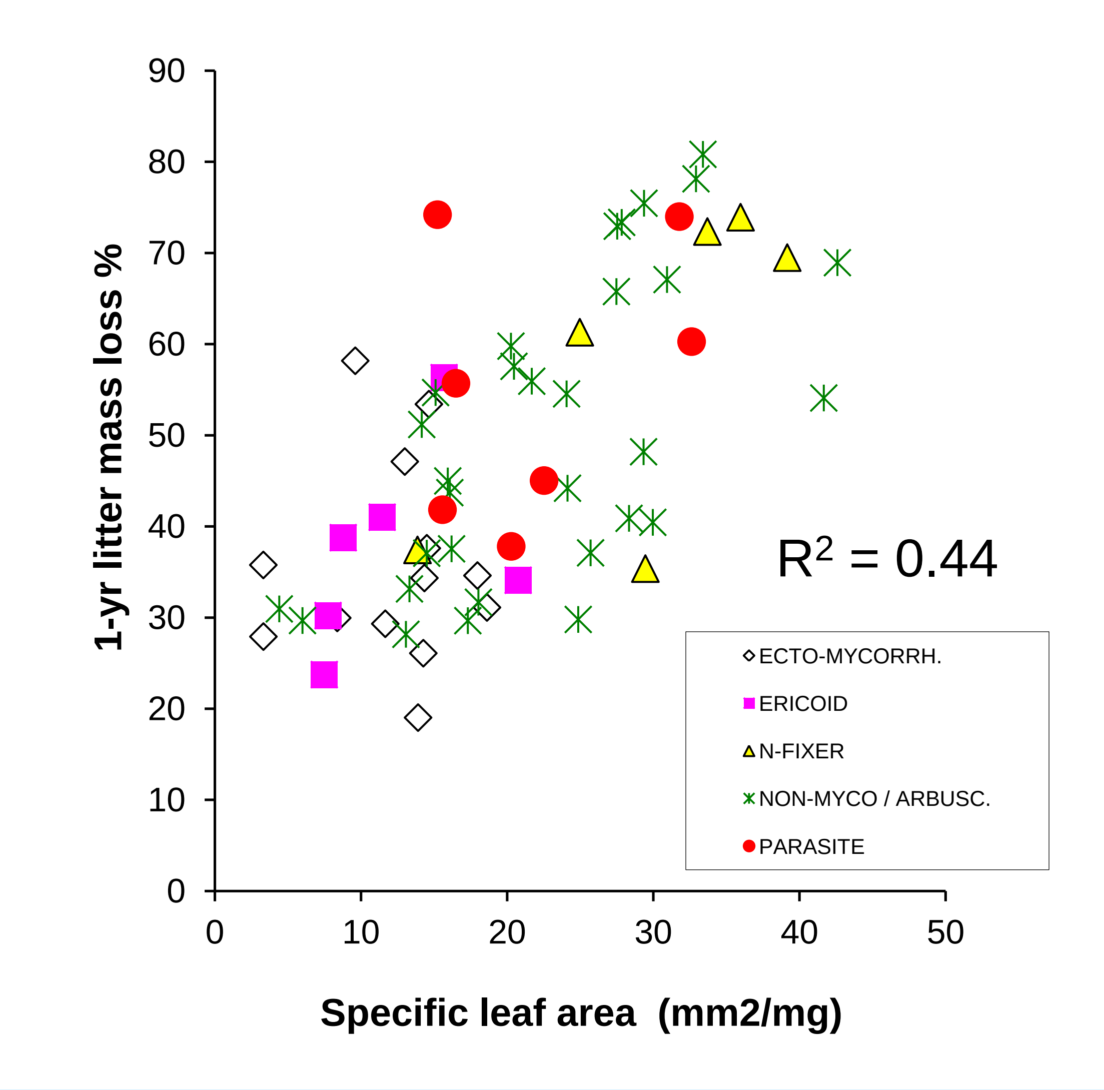
Abisko, N-Sweden

Methods: 1. Collecting new dead leaves

2. Clean, weigh and air-dry (check moisture content) and put in litterbag

3. Put litterbags in litterbed: semi-natural incubation

4. Collect, clean and re-weigh the litter samples: % mass loss

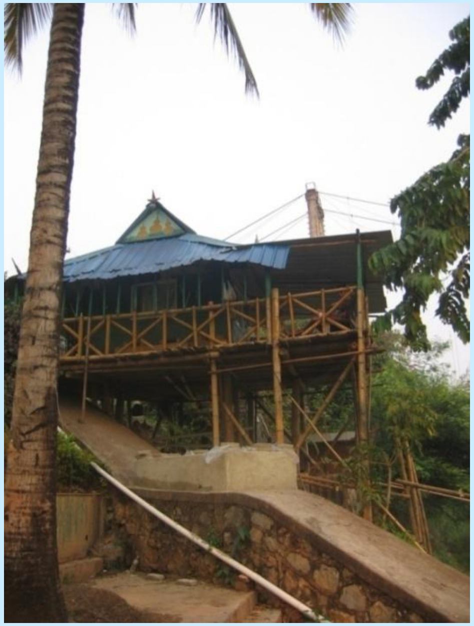


Specific leaf area is positively related to litter decomposability in a subarctic flora

Implication: vegetation species composition drives positive feedback between productivity and decomposition → fast carbon cycle

Cornelissen et al. 2006, *Oecologia*

Traits and decomposition: going bigger with bamboo stems in S China

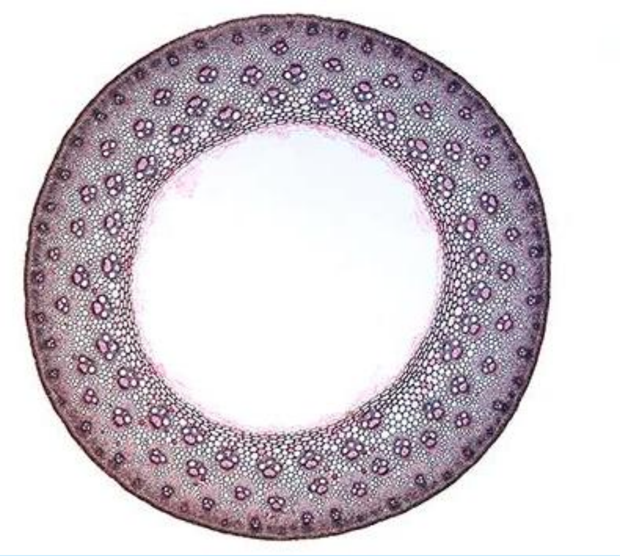


Bamboo distribution

C. 1500 species worldwide,
strongest presence in SE Asia;
in total a lot of carbon!

www.flaviodeslandes.com/bamboo.html

Bamboo wood characteristics



Culms: hollow structures with many tough vascular bundles

Resistant epidermis with waxy outside (cutin)

High in cellulose, also lignin, hemicellulose, pentosane (and silica, tannins)

Hypotheses

- Dead wood of bamboo is less decomposable than dead wood of eudicot or basal angiosperm trees

- Wood density and dry matter content are effect traits that predict decomposition rates of bamboo and other trees

Role of termites in such relationships?

Termites and wood turnover in S China…

Method: litterbed experiment

- Incubating many species, in litterbags, in the same litter medium, at the same time; measure proportional mass loss over time intervals

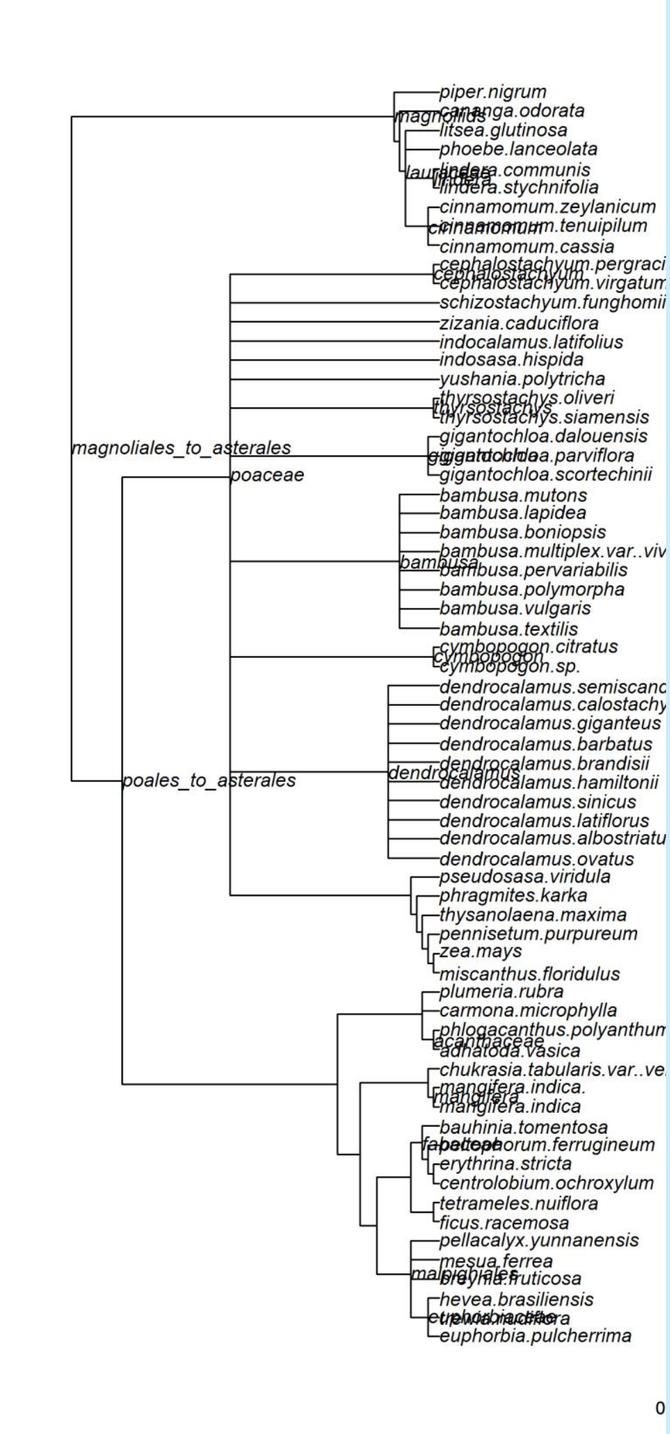
- Formula *k*-value (fractional mass loss year^{-1})
  - X_t → dry mass after *t* decomposition
  - X_0 → initial dry mass
  - t → time period of decomposition

$$k = -\ln\left(\frac{X_t}{X_0}\right) \Big/ t$$

High k value means fast decomposition

Where?

- Xishuangbanna Tropical Botanical Garden, Menglun, S China



Basal angiosperms

Bamboos

Non-bamboo Poaceae (grasses)

Eudicots

Which?

We sampled dead stems of 66 species across the angiosperm phylogeny

How? (1)

Collecting Litter samples

How? (2)

Preparing litter samples (subsamples for trait measurements)

Stem diameter classes: 6, 30, 70, 150 mm

How? (3)

Preparing litterbag samples

How? (4)

Preparing the litterbed

How? (5)

3 blocks, each with 1 replicate of each species of each diameter for each harvest





How? (6) Harvests and termite damage

Three termite 'bite classes':

0 No damage

1 Slight damage

2 Strong damage

How? (7)

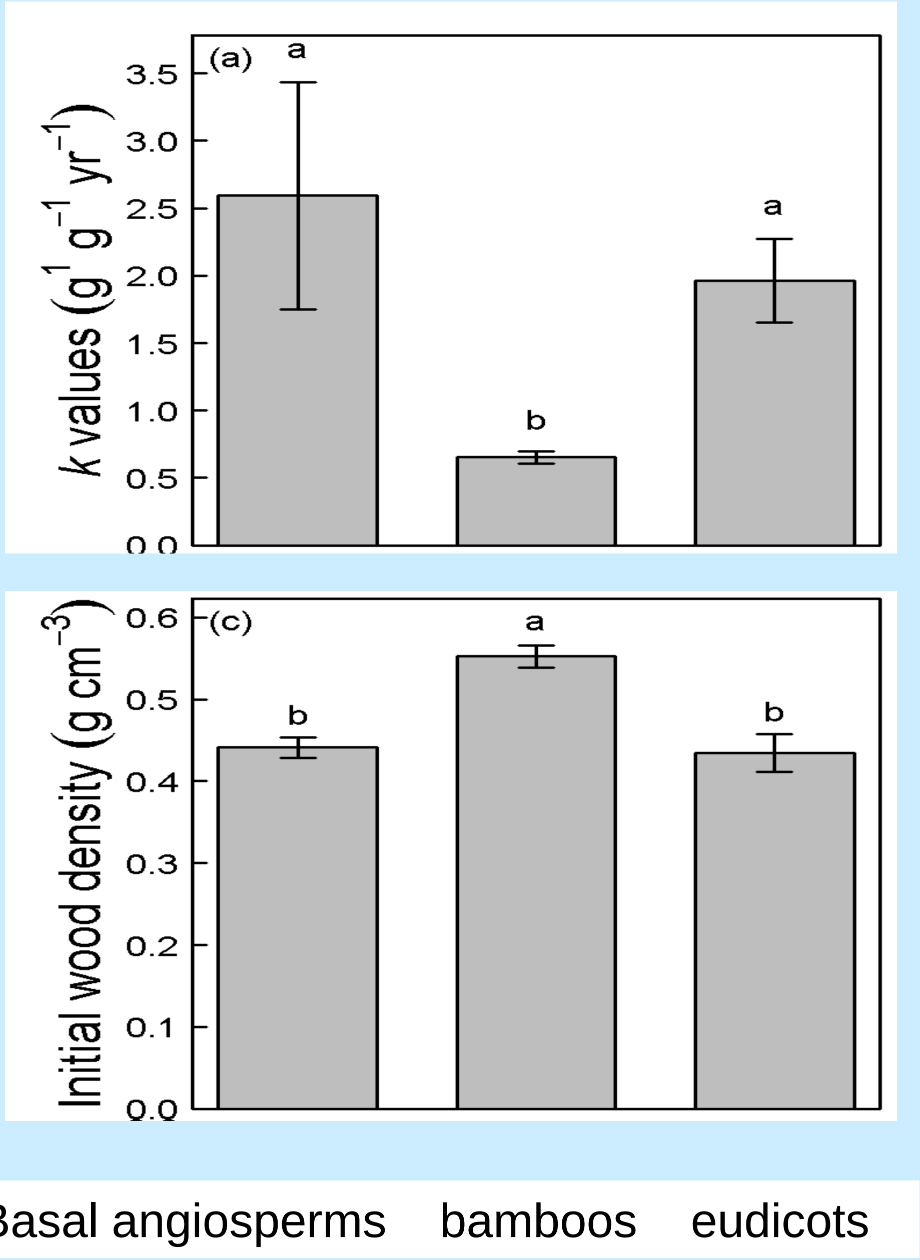
Painstakingly cleaning up the samples (termite mud…)

Results

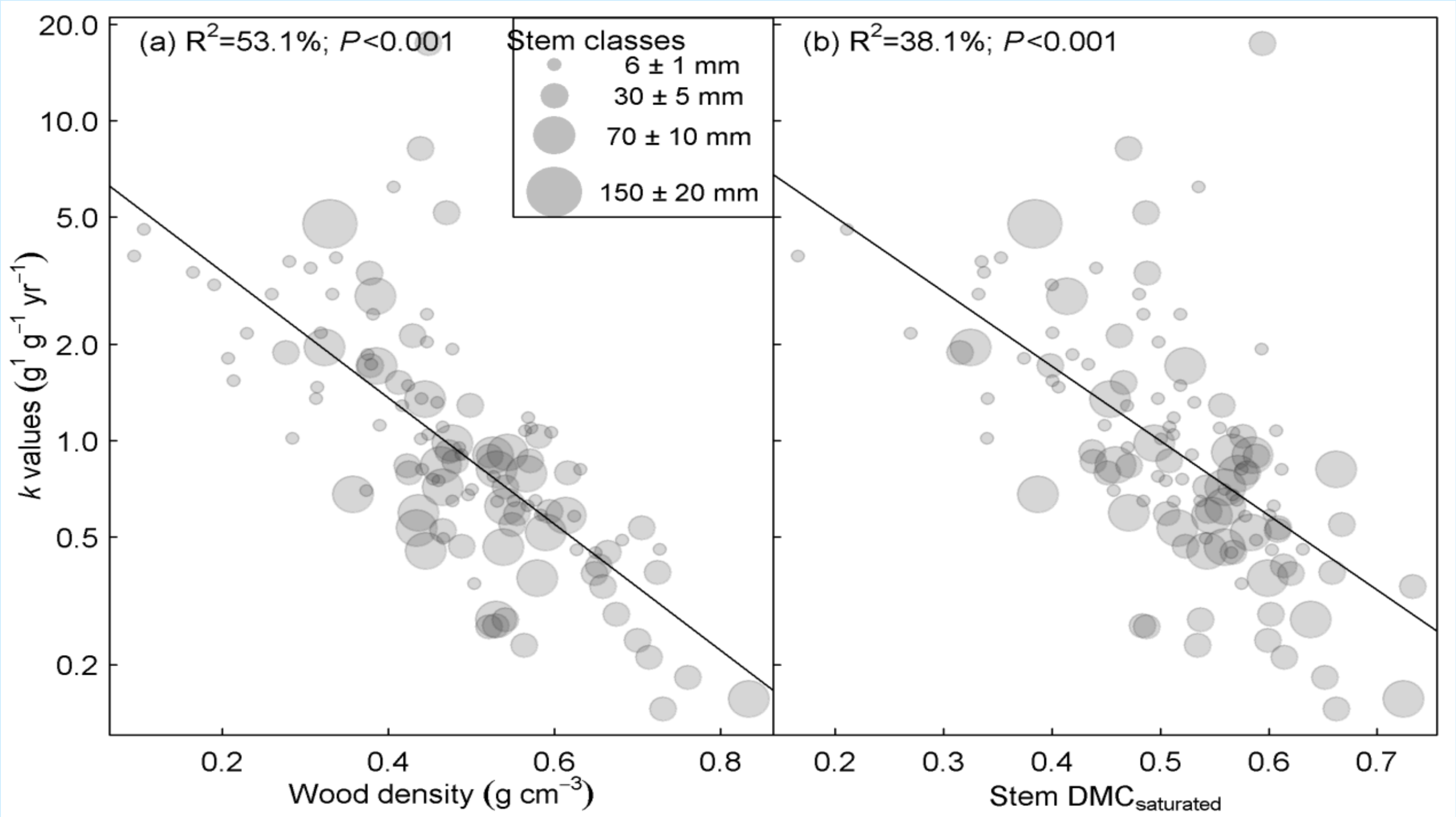
Bamboos have slightly *higher wood density* and *much lower decomposition rates* than wood of basal angiosperms or eudicot trees

Hypothesis 1 YES

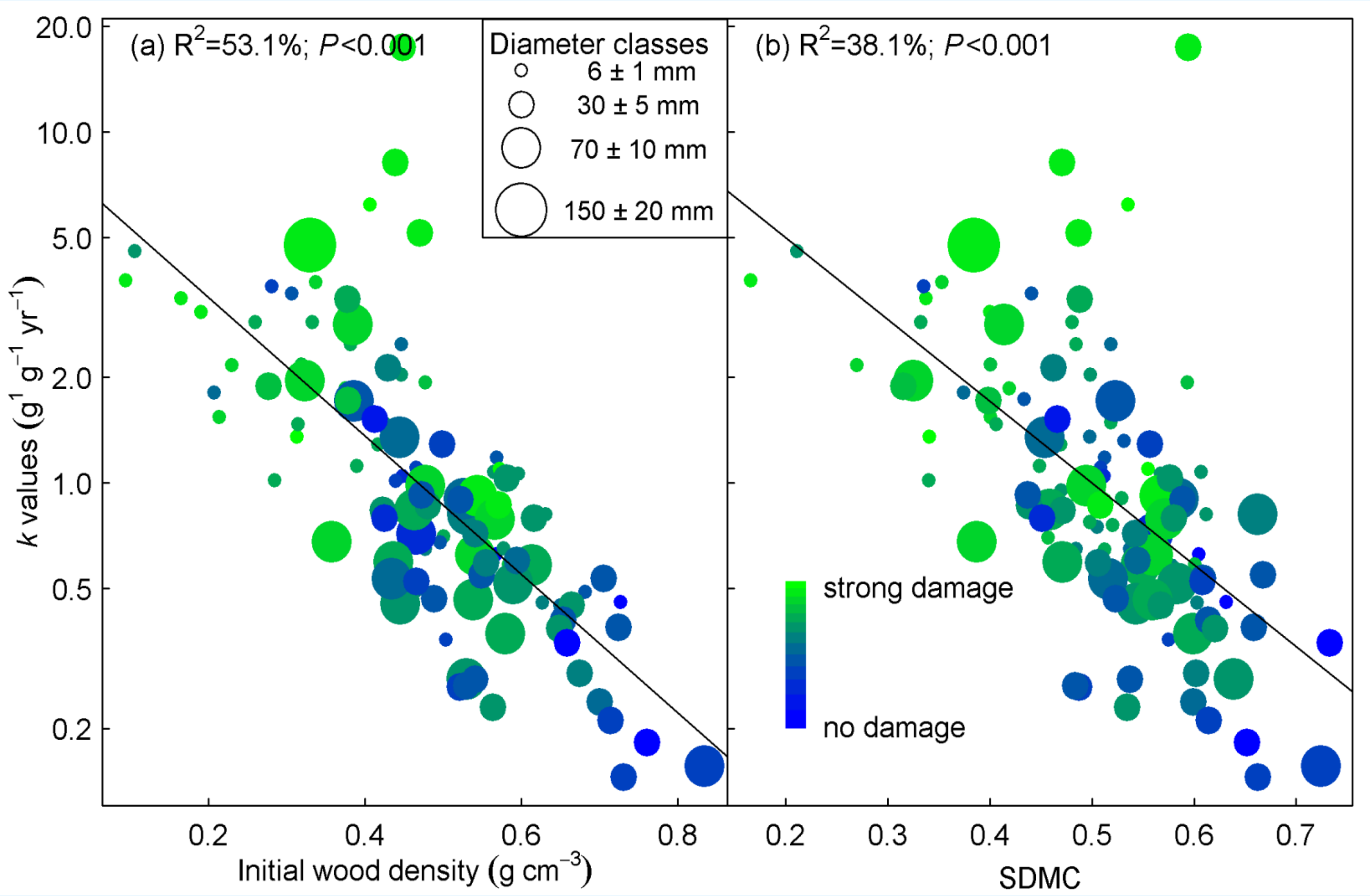
Liu et al. 2015 *J. Ecol.*



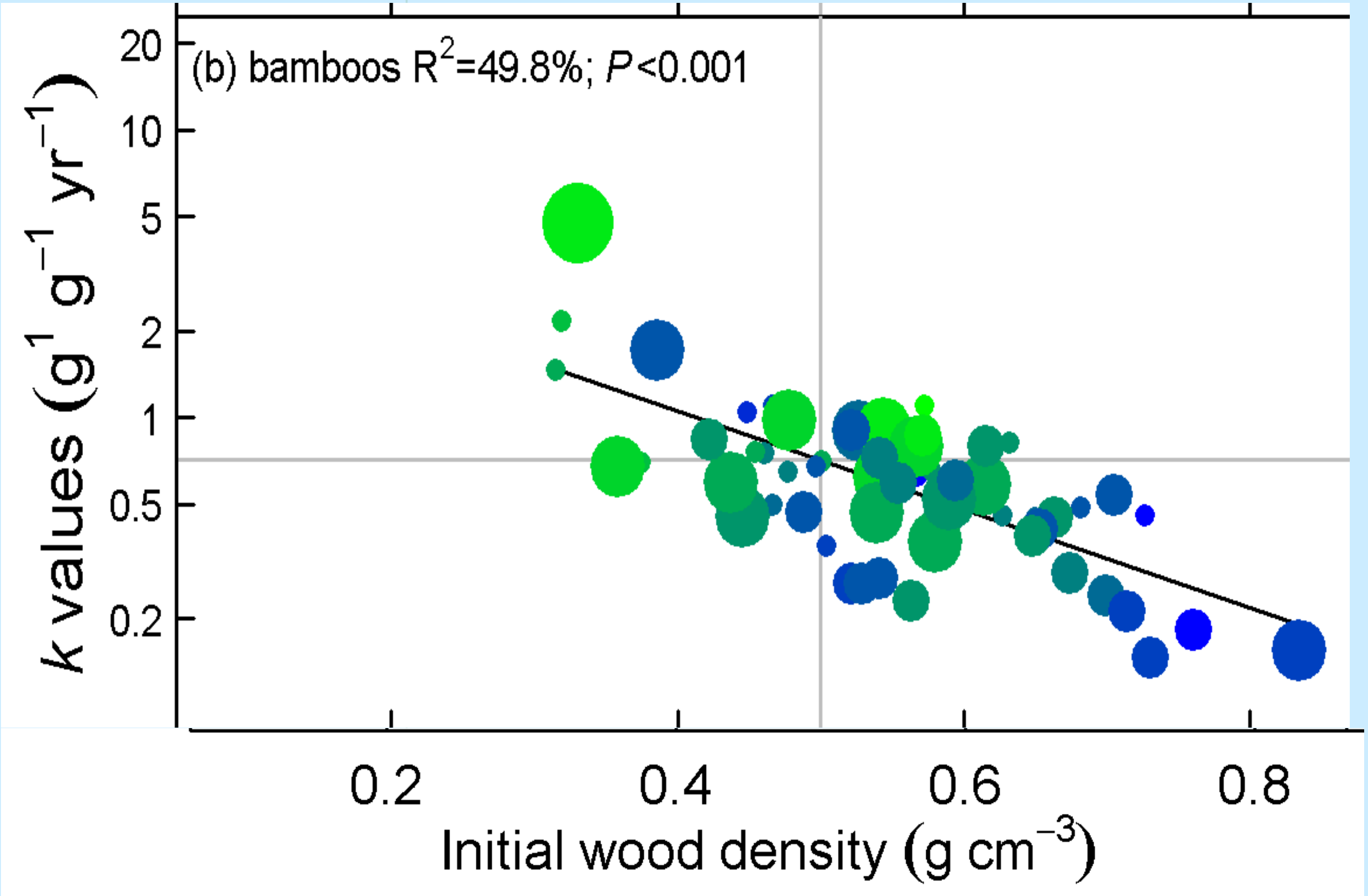
Initial wood density and dry matter content (negatively) predict decomposition rate, independently of diameter, across species (Hypothesis 2 YES)



The negative relationship between initial wood density or dry matter content and decomposition rate is *partly due to termite consumption*!



The same contribution of termites to stem decomposition as dependent on initial wood density is also seen within bamboos alone



Unexpected key finding:

Termites preferentially attack low density (low DMC) wood → *positive feedback on microbial decomposition* [1]

This feedback will *amplify* the negative relationship of wood density (or dry matter content) and microbial decomposition rates found in previous studies[1,2,3]

[1] Liu et al. 2015 J. Ecol.; [2] Freschet et al. 2011 *J. Ecol.*;
[3] Pietsch et al. 2014 *Global Ecology and Biogeography*

Traits and decomposition: going even bigger

LOGLIFE!

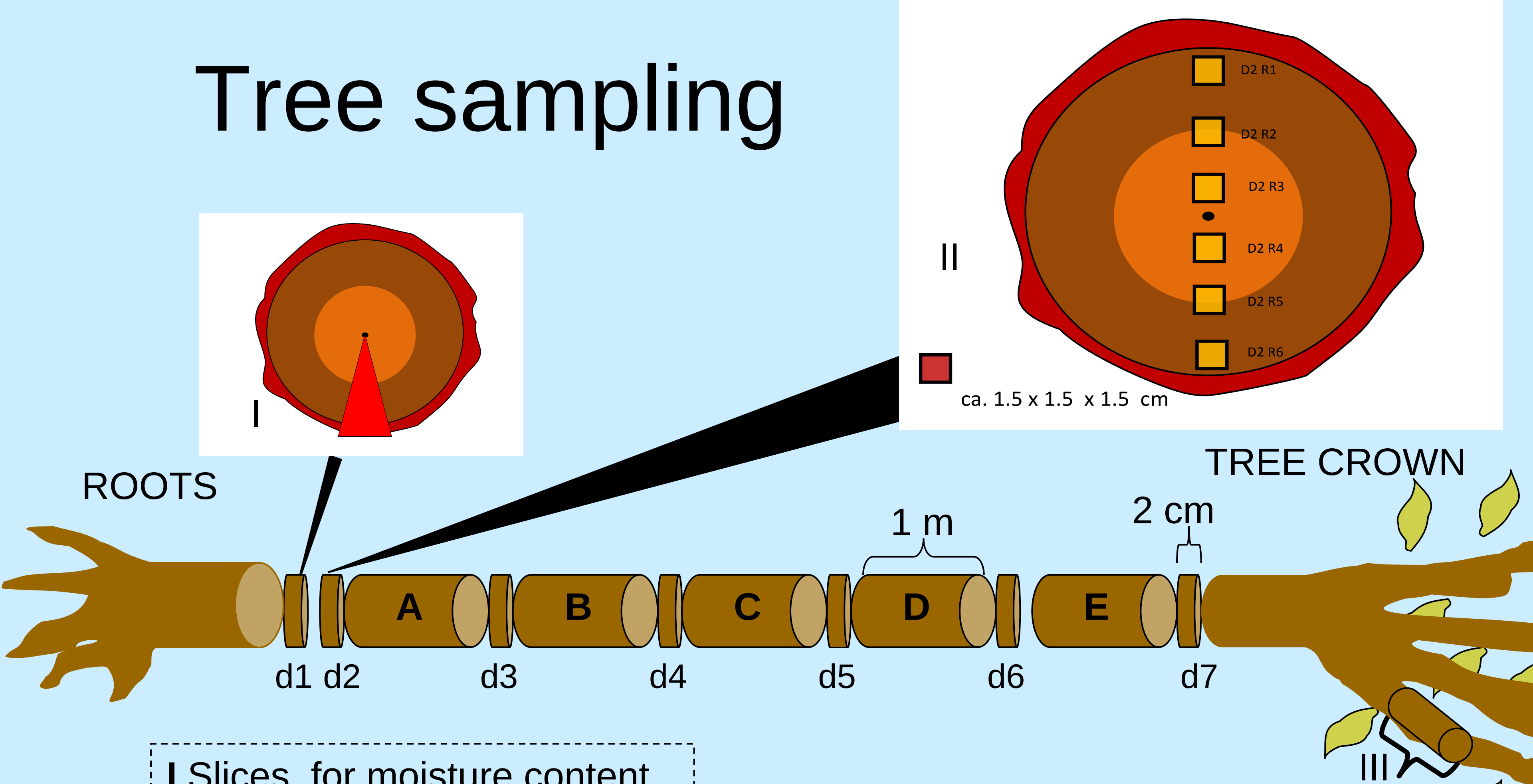
LOGLIFE

- Large logs of 25 Dutch tree species in 2 contrasting ‘common garden’ sites
- Measuring wood traits of these species
- Long-term (16-yr) monitoring of decomposition, microbial communities, wood structure and chemistry (effect traits), associated biodiversity

Cornelissen et al. *2012 Ambio*




Tree sampling

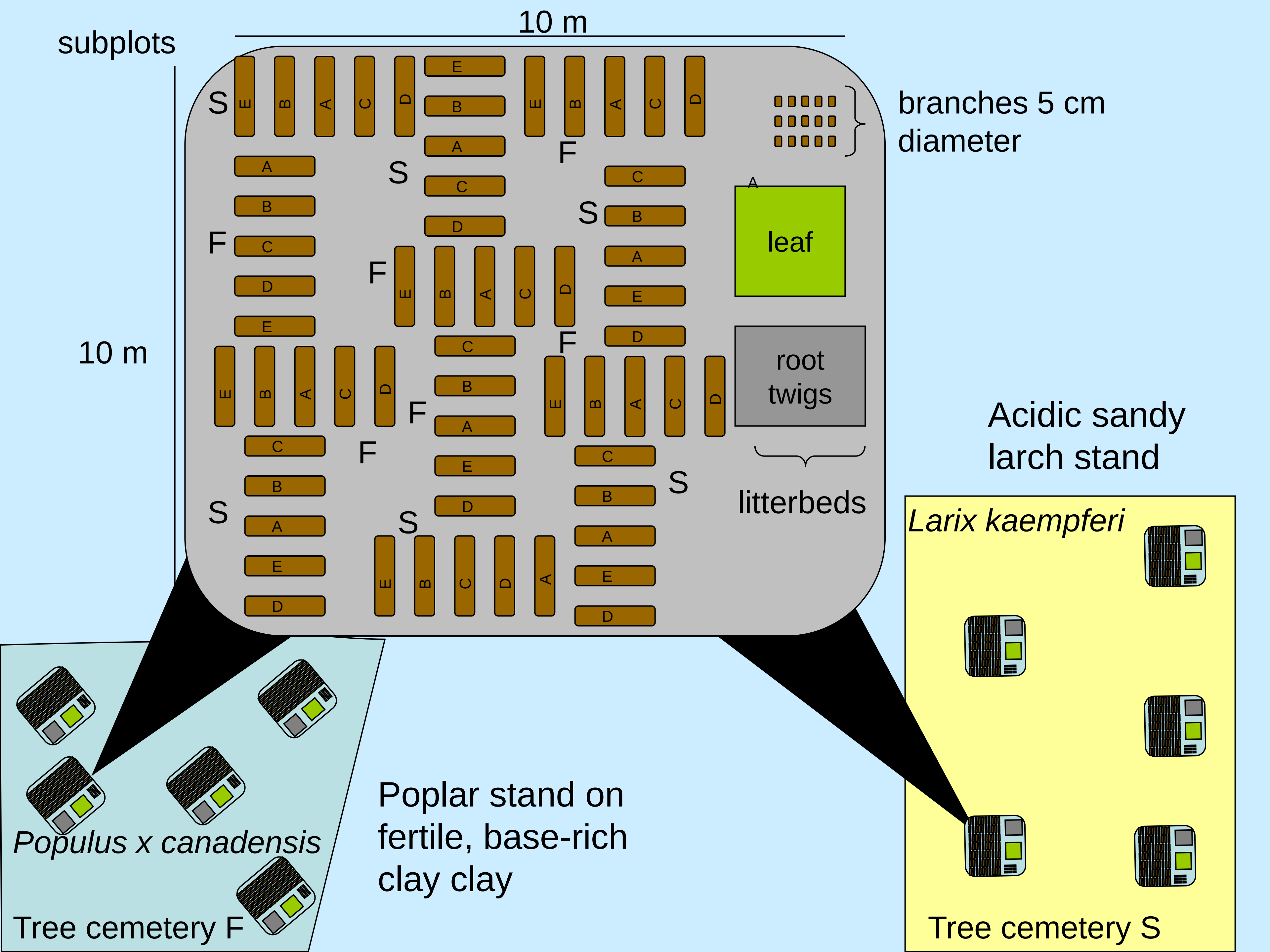


I Slices for moisture content, c-fractionation, lignin, wood density, other traits

II triangular sections for fungal research in freezer

III 11 branch pieces (20cm long , 5 cm diameter)

+ Collection of terminal twigs for litterbags


10 m
subplots
10 m
S
F
branches 5 cm diameter
leaf
root twigs
litterbeds
Acidic sandy larch stand
Larix kaempferi
Tree cemetery S
Poplar stand on fertile, base-rich clay clay
Populus x canadensis
Tree cemetery F

LOGLIFE: 1 km of logs of 25 tree species

(plus branches, twigs leaves, roots)

1-year harvest: relationships between bark traits and invertebrate animal community composition

55 logs (11 species×5 rep)

Bark traits

- Bark Looseness
- Outer bark thickness
- Ratio inner to outer bark
- Fissure index
- Puncturability

Fauna clades

- Annelida 
- Chilopoda 
- Coleoptera 
- Diplopoda
- Diptera 
- Isopoda 

Bark traits differ among tree species

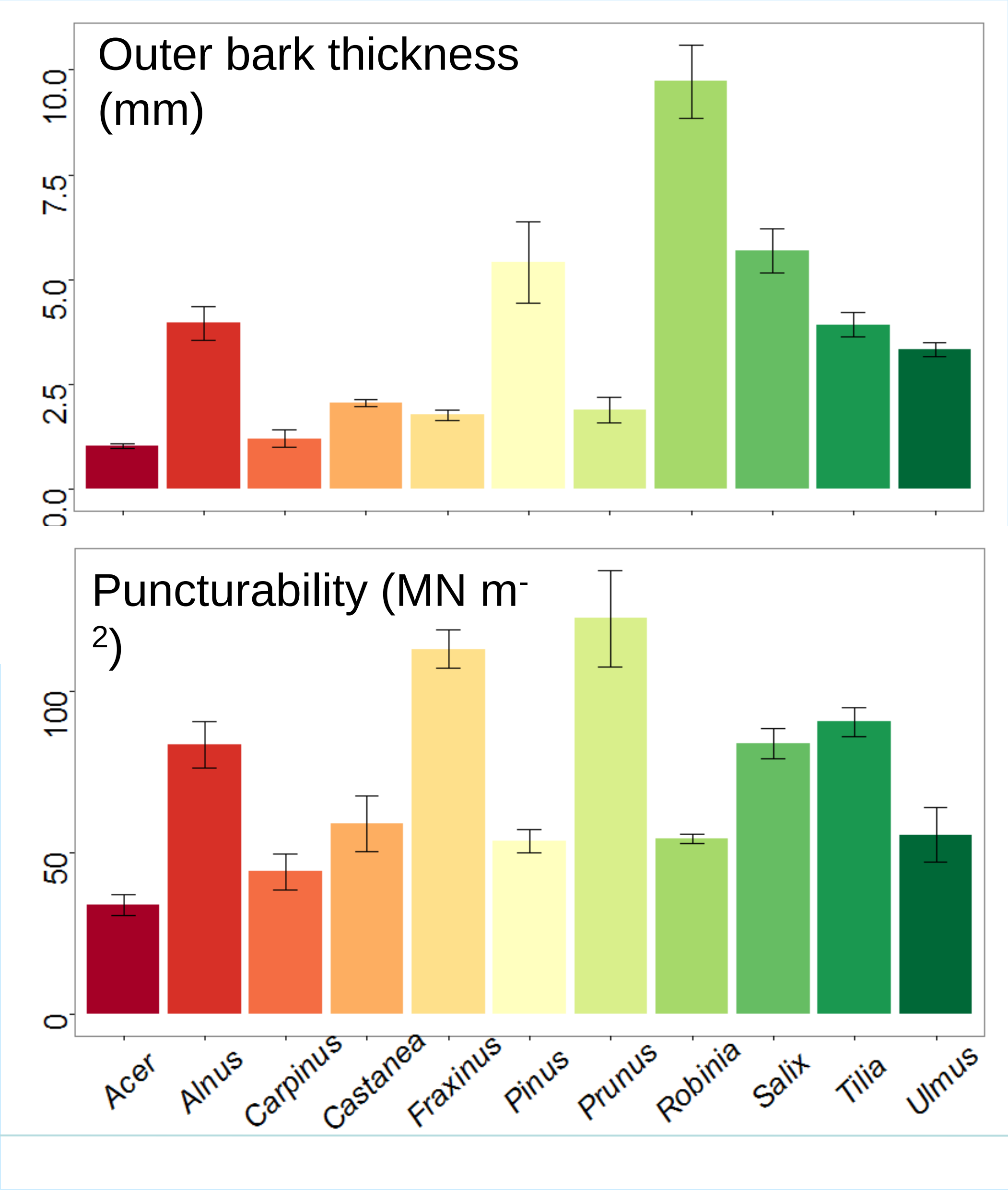
Relative Bark Looseness
($F_{10,44}$ = 7.69, P < 0.001)

Outer bark thickness
($F_{10,44}$ = 36.52, P <0.001)

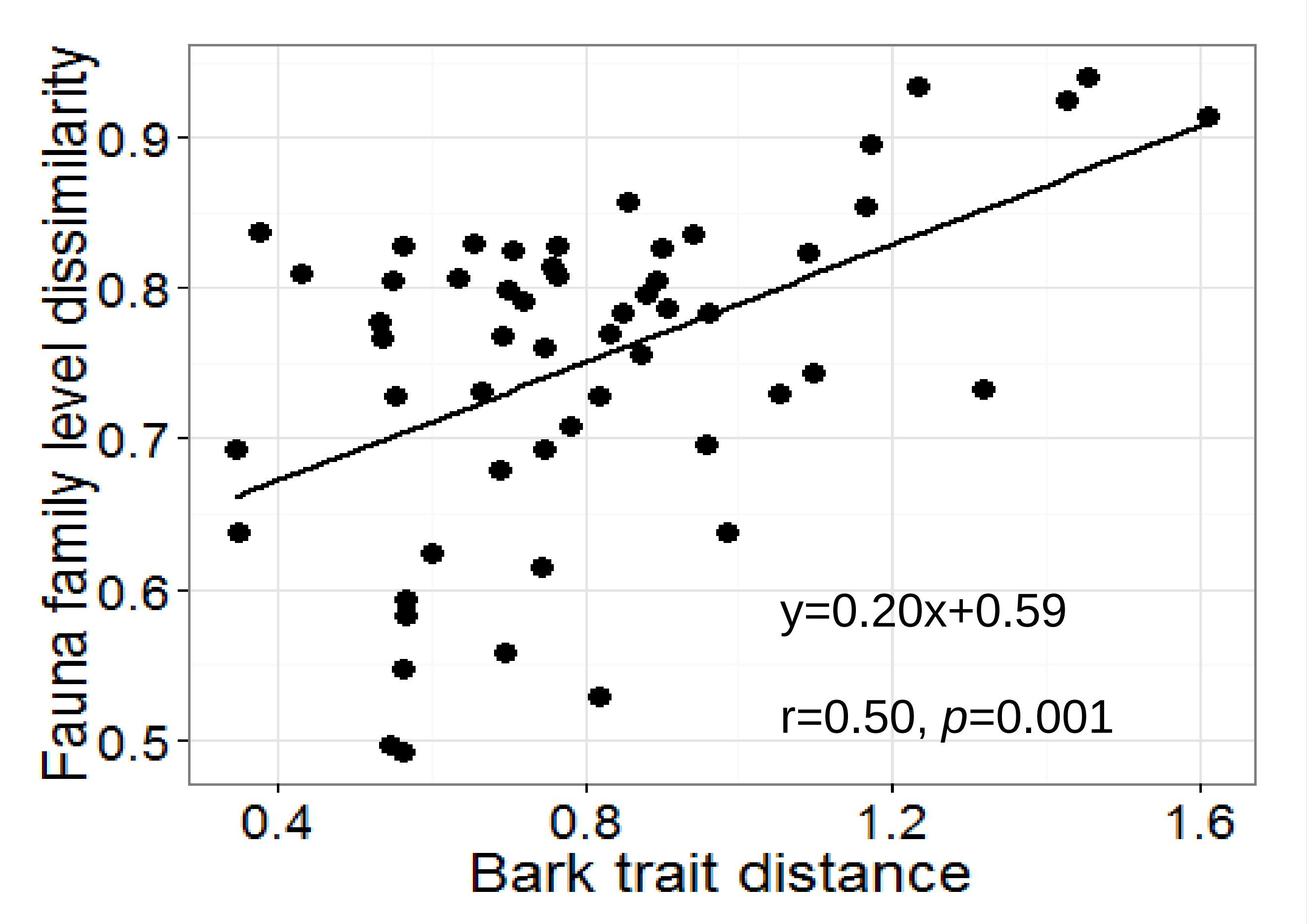
Ratio of inner to outer bark
($F_{10,44}$ = 8.36, P < 0.001)

Fissure index
($F_{10,44}$ =51.88, P < 0.001)

Puncturability
($F_{10,44}$ =16.25, P < 0.001)



Bark trait dissimilarity begets invertebrate community dissimilarity



Zuo et a. 2016 *Functional Ecology*

Conclusion:

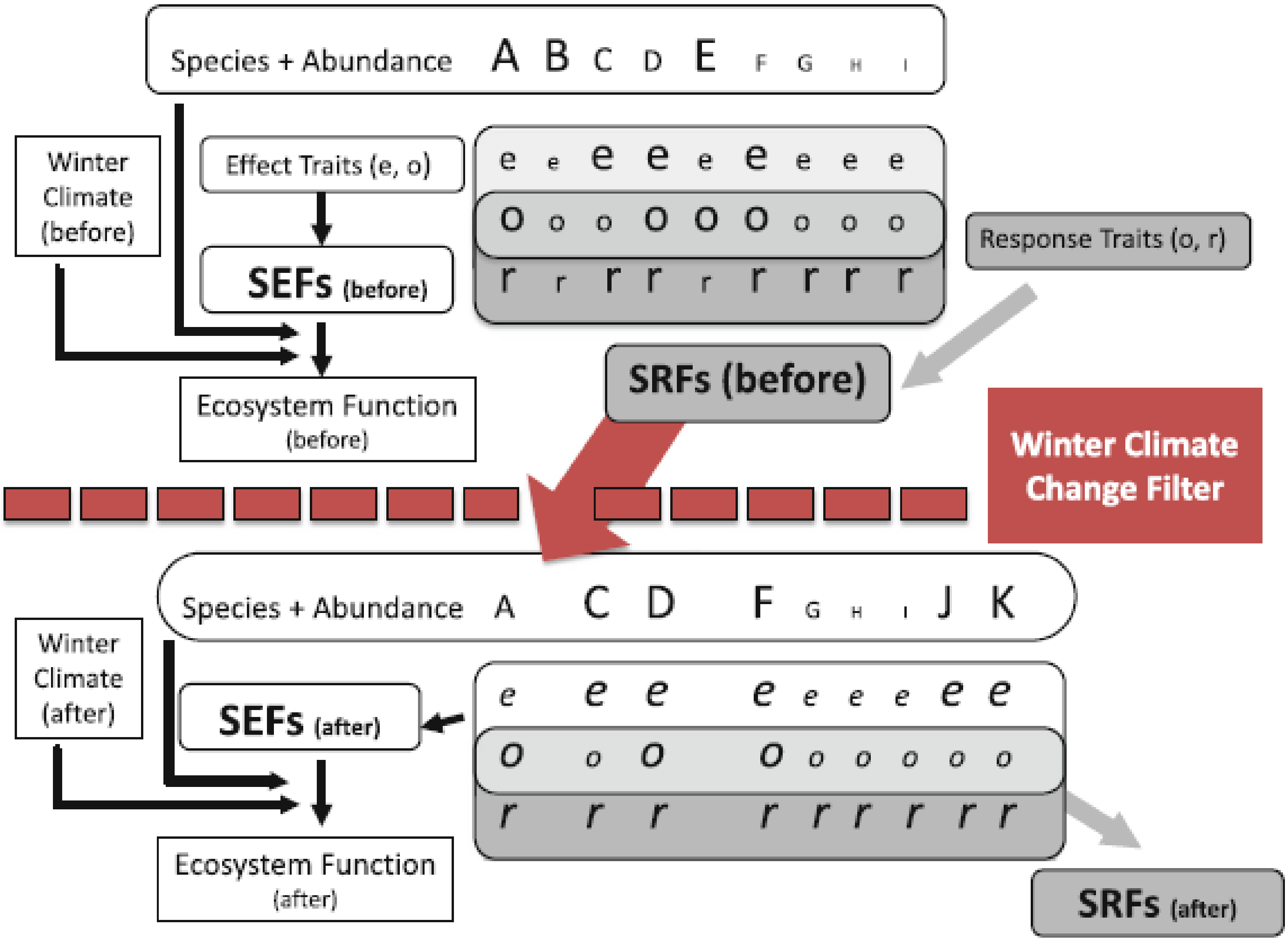
Measuring effect traits can help to understand the role of plant species composition in ecosystem functions (e.g. soil stability, fire regime, decomposition, biodiversity support)

Next steps

- test this role in the field, account for abundances

- make linkages between response and effect traits across species to predict effects of environmental changes on ecosystem functions

(see Cornelissen & Makoto 2014, *Ecological Research*)



Cornelissen & Makoto 2014 *Ecological Research*

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Francesco de Bello, Nagore Garcia and University of South Bohemia for the kind invitation!

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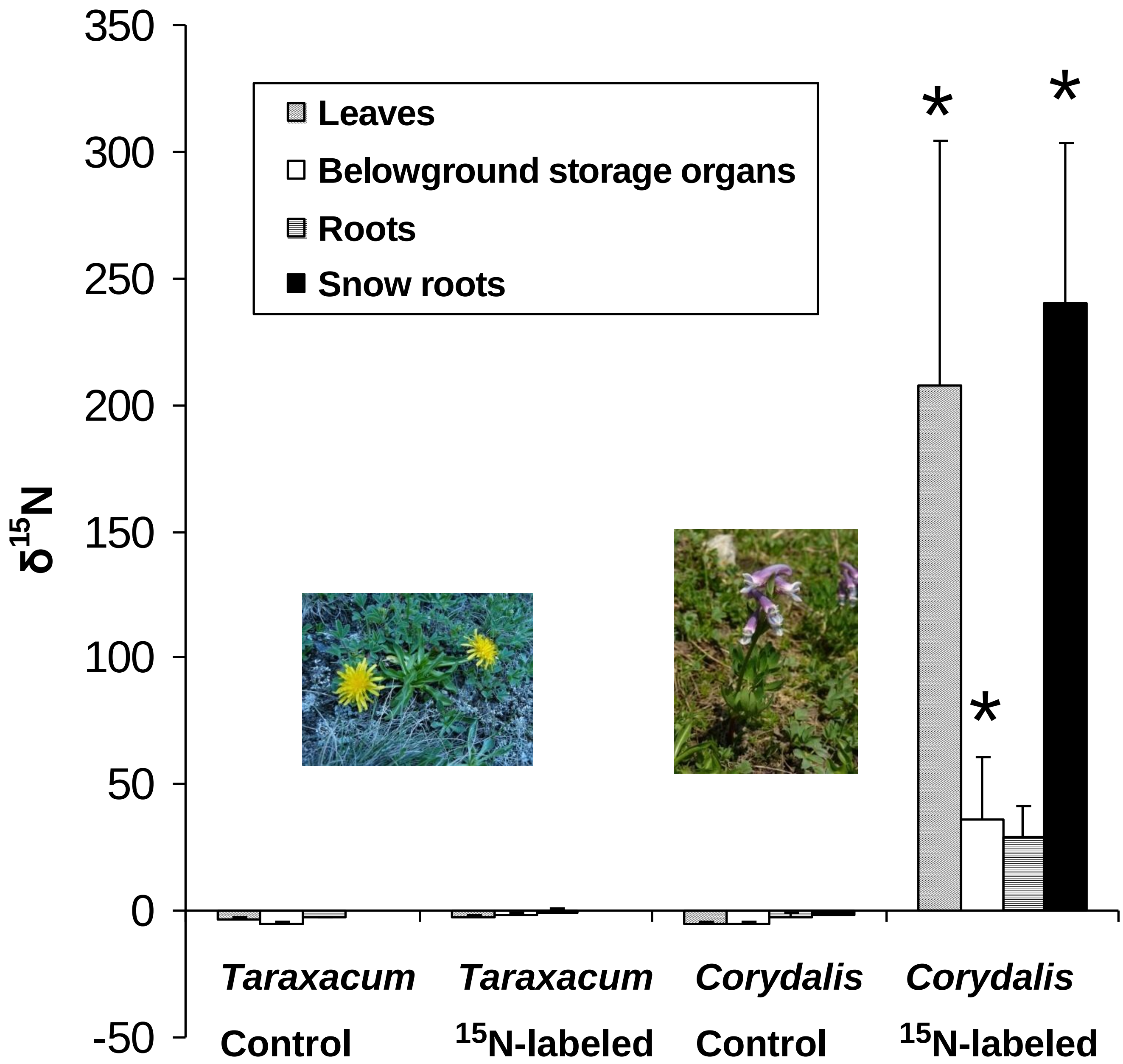
^{15}N snow-bed labeling experiment

- 4 plots with 98% enriched NH_4^+ NO_3^- (4 L, 140 mg N / plot)

- 4 control plots (paired)

(15 July 2008)

Mann-Whitney U test: * P<0.05



Onipchenko et al. 2009 *Ecology Letters*

Effects of stem diameter class, species, harvest time and termite damage class on fraction of stem litter mass loss (likelihood ratio test on random effects in a linear mixed effects model, with sequential nesting factors).

Variables	Chi square	Df	*P*	Explained variance (%)
Diameter class	5.28	1	0.022	5.4
Species	18.13	1	<0.001	17.1
Harvest time	2.85	1	0.091	9.6
Termite damage	207.26	1	<0.001	53.4

Direct relationships between initial wood traits and termite attack