Response of forest community functional diversity to the environment and its impact on productivity

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东北亚生物多样性
研究中心
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Research Pathway

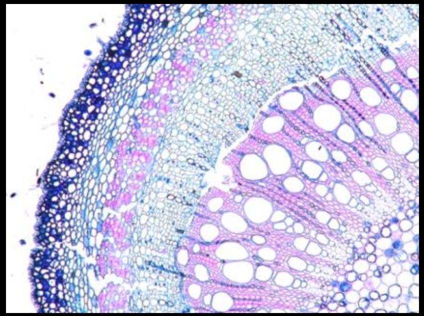
The adaptive mechanisms of plants to environmental changes based on structure and function

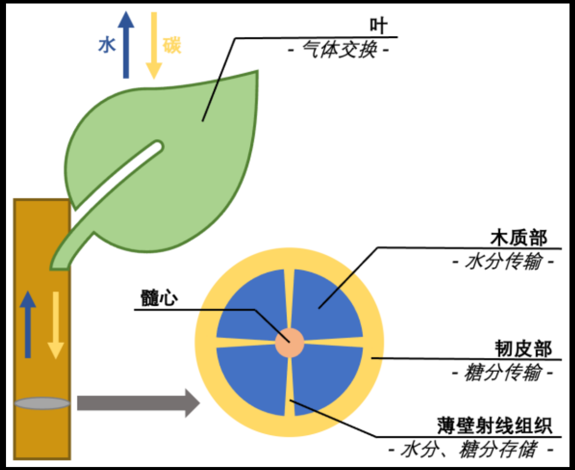
Community

Species

Individual

Cell

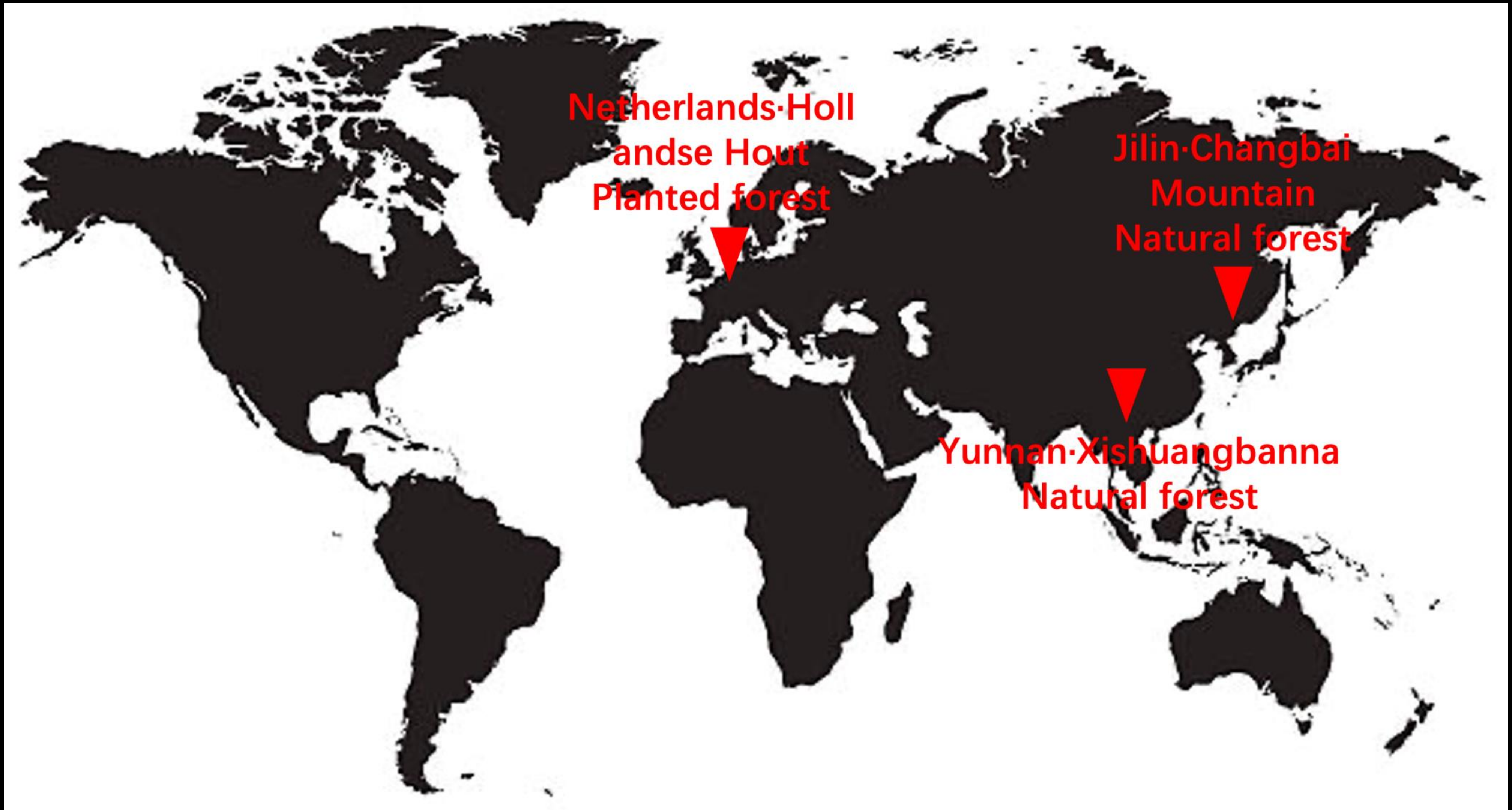




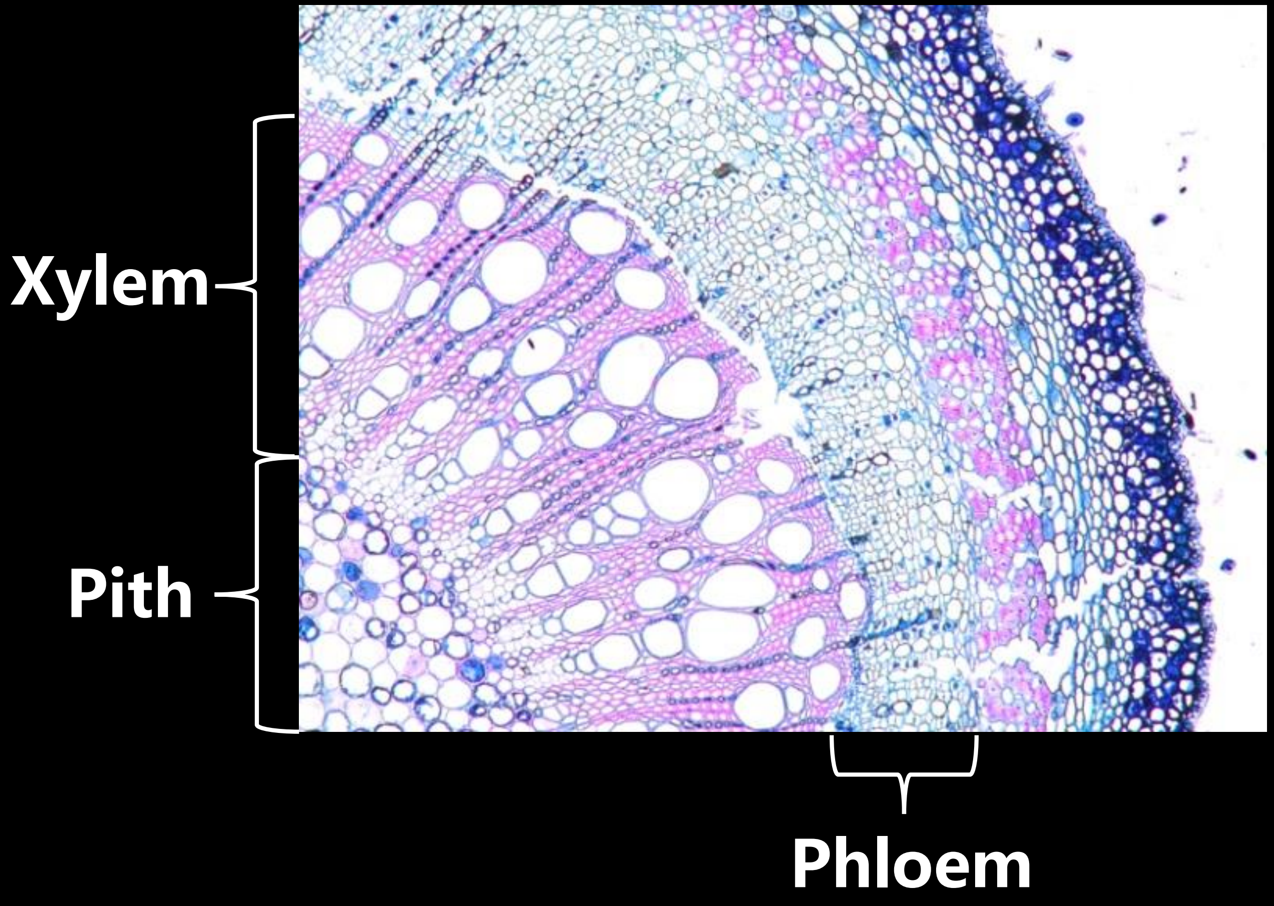
Question 1: How do co-existing canopy woody plants from different functional groups regulate their functional traits to adapt to the same environment?

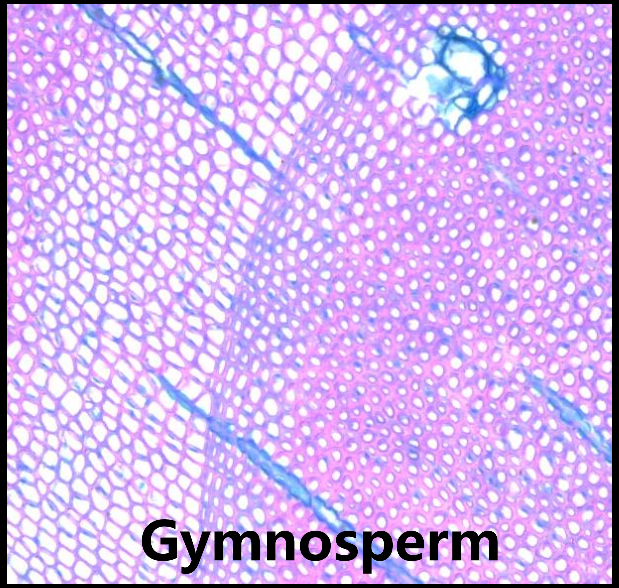
- Broadleaf vs. liana
- Broadleaf vs. conifer
- Light-demanding vs. shade-tolerance
- …

Research sites

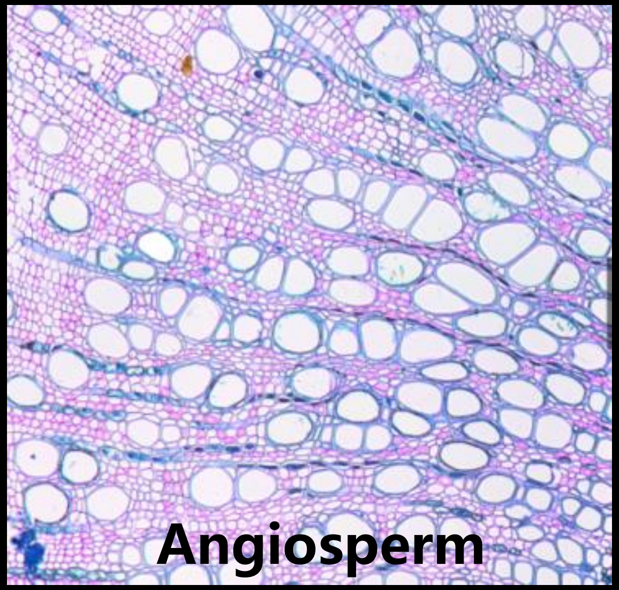


Cell-based initials





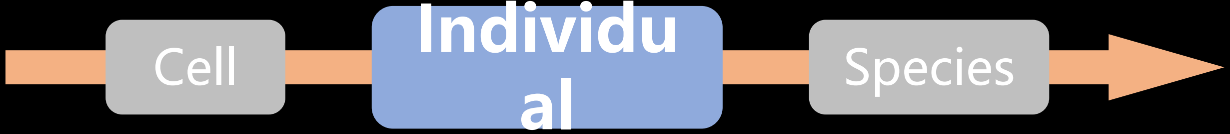
Tracheid



Vessel

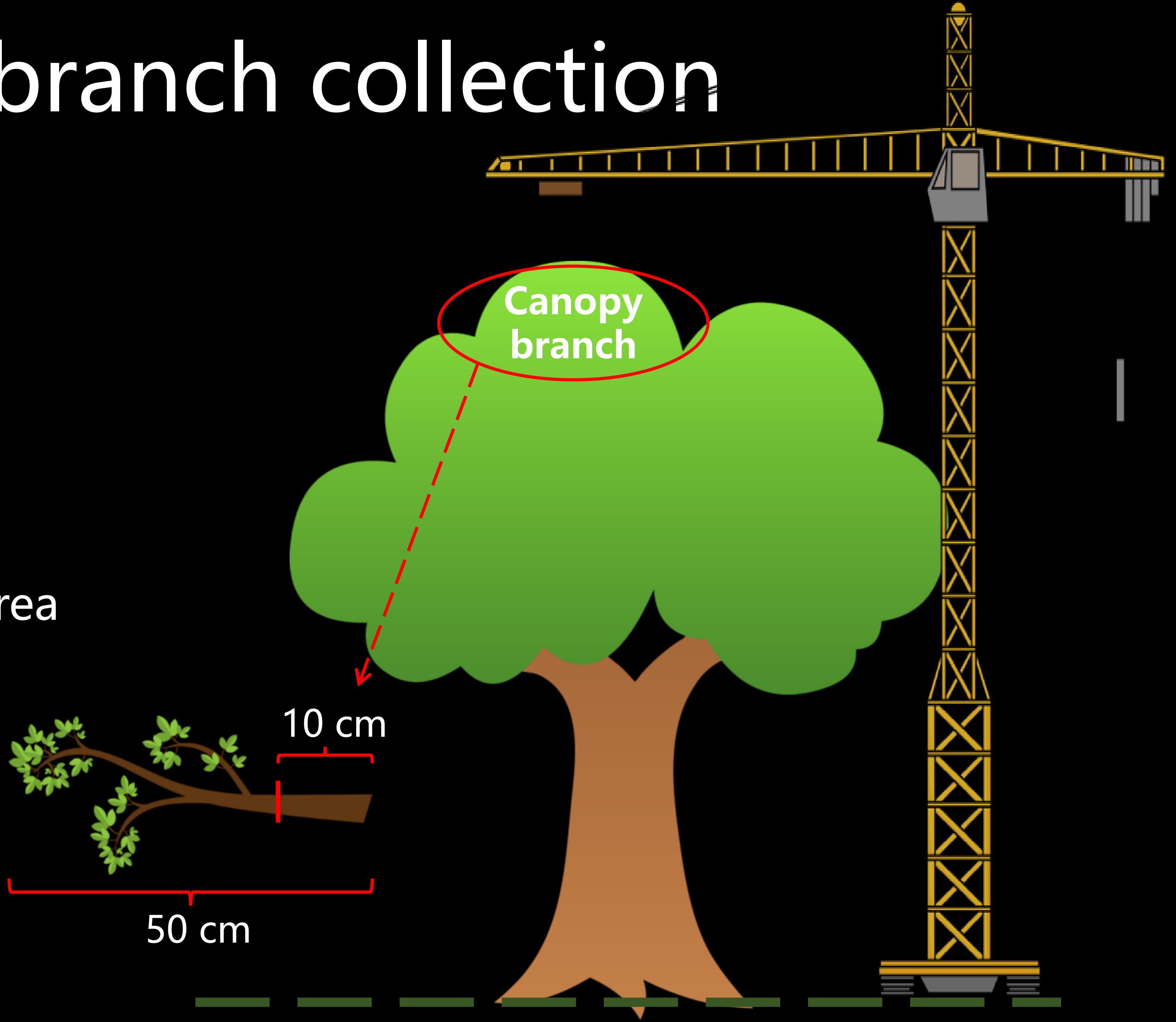
Functional ratios

- Xylem area : leaf area ratio
- Phloem area : leaf area ratio

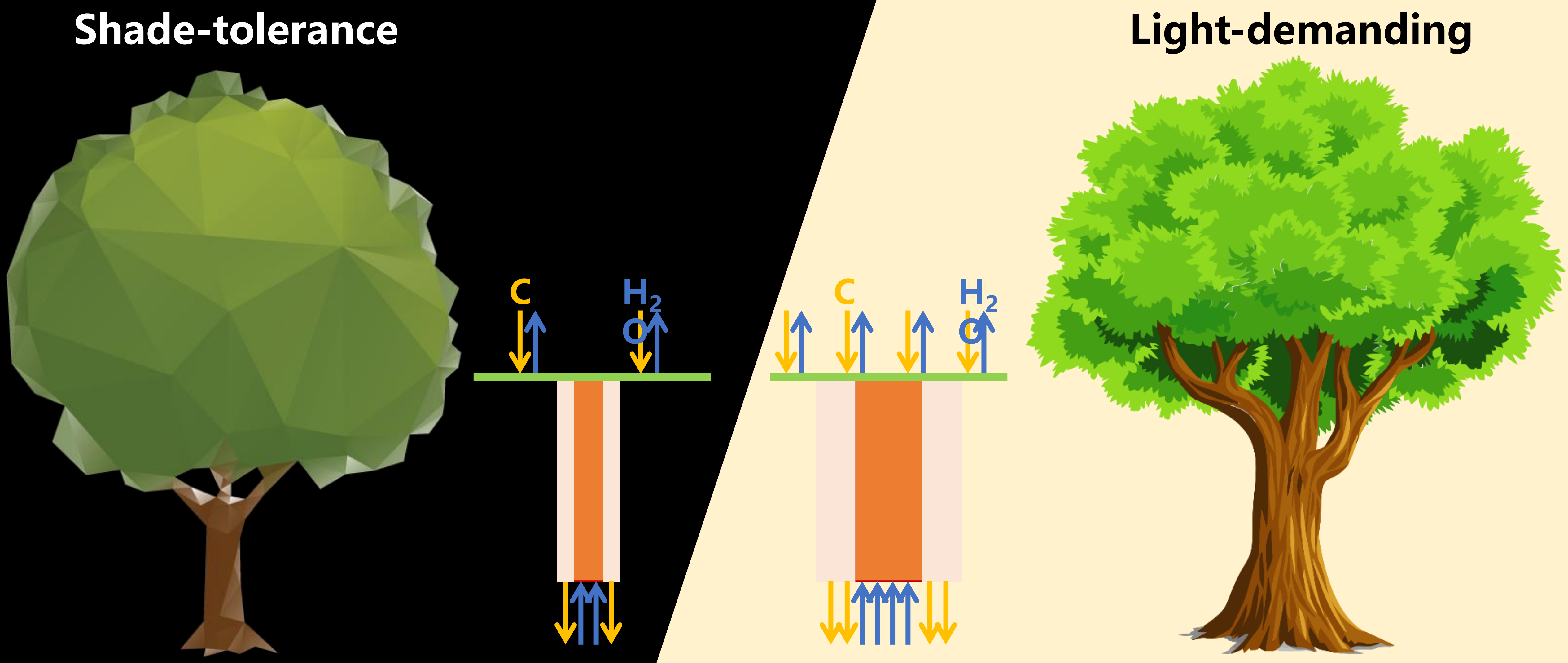


Standardized branch collection

- Leaf traits
  - Leaf area
  - SLA
- Anatomical traits
  - Xylem area
  - Phloem area
  - Ray parenchyma area
- Branch traits
  - H_{max}
  - P_{50}
  - MOR
- …



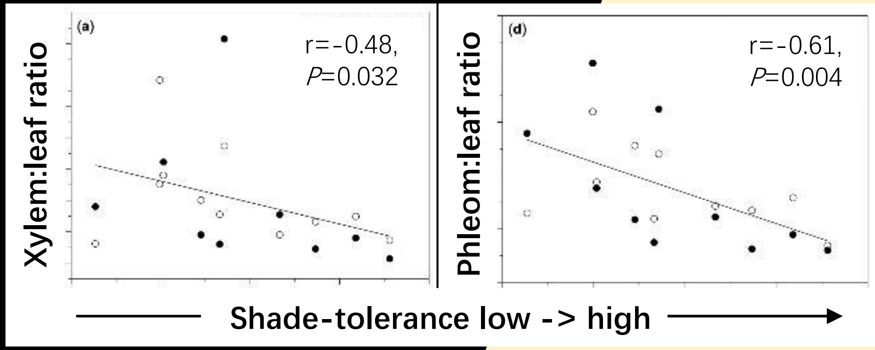
Result 1



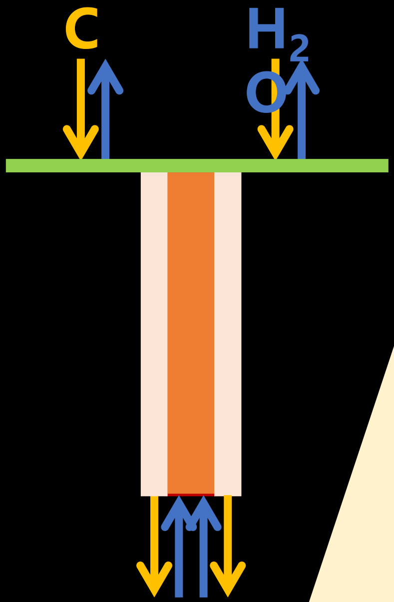
Result 1

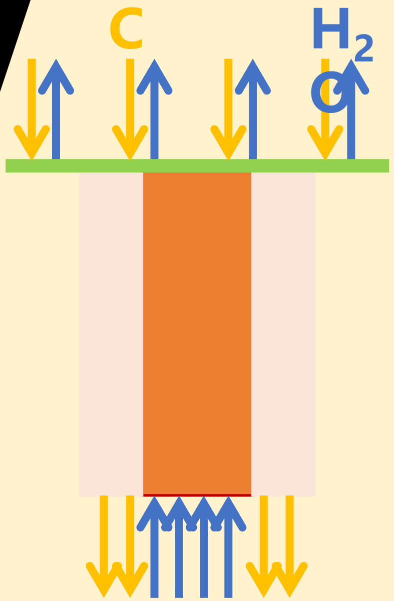
Shade-tolerance

Netherlands
temperate forest
10 deciduous broadleaf trees



Light-demanding



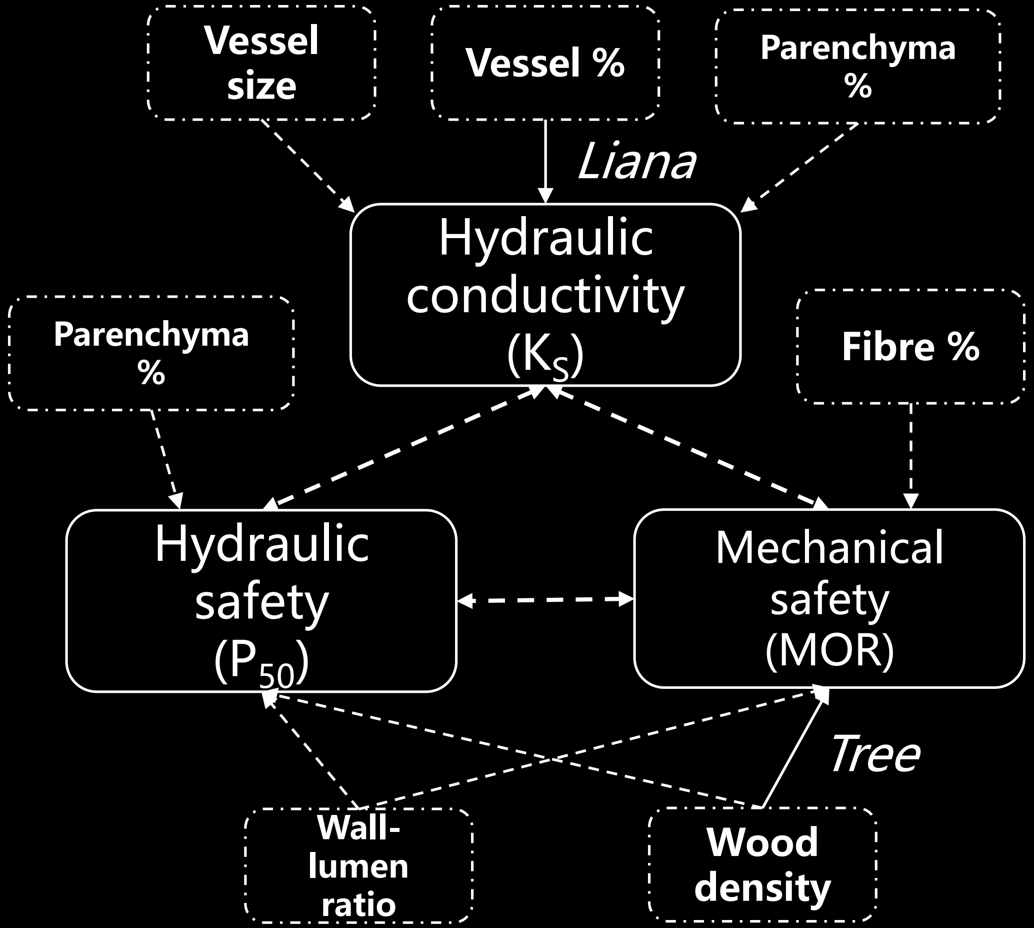


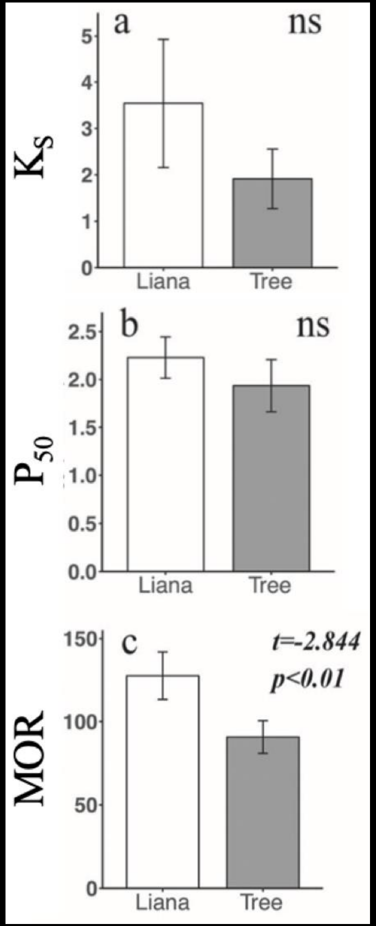
Conclusion 1

Canopy broadleaf trees can adapt to different light environments by adjusting the ratio between xylem, phloem, and leaf area.

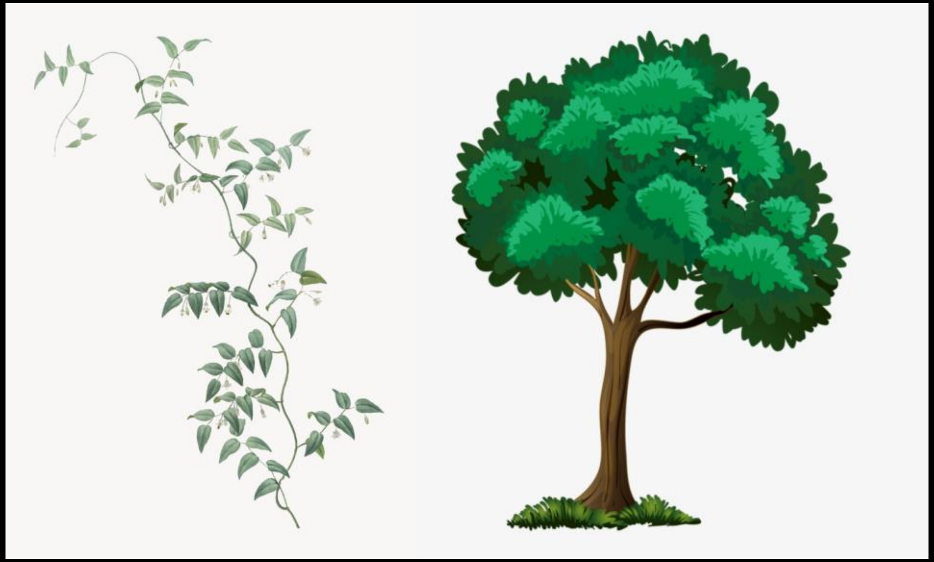
New Phytologist, 2016

Result 2





Xishuangbanna, tropical forest
12 liana species vs. 10 broadleaf tree species



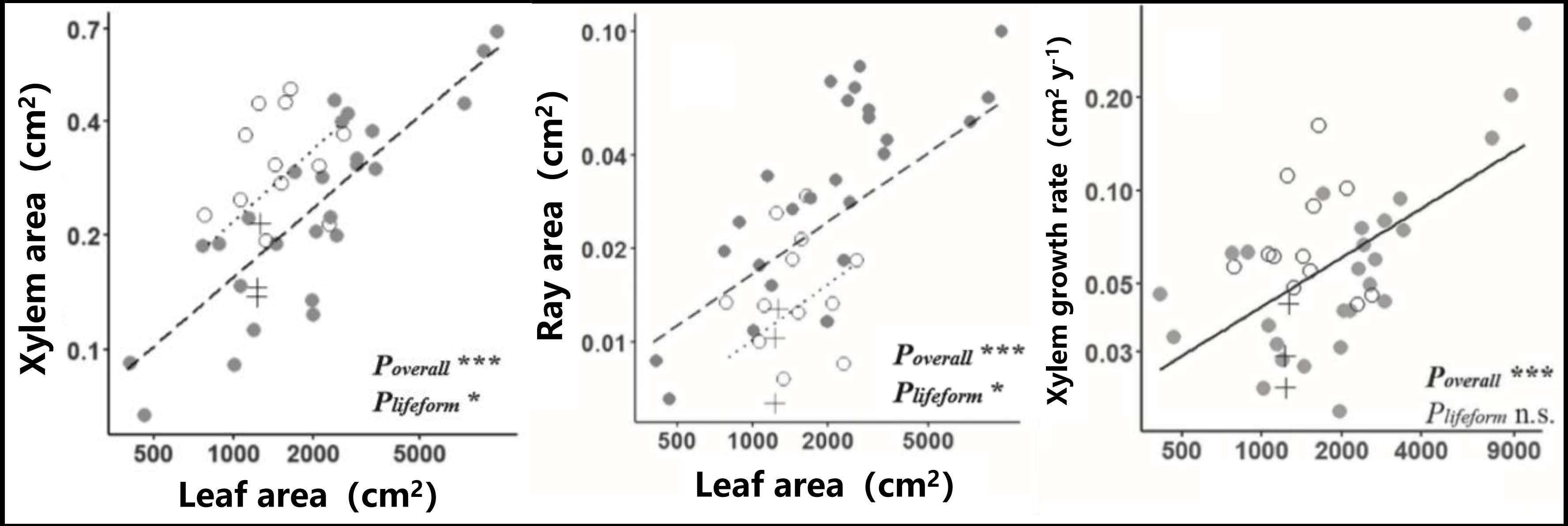
Liana Broadleaf tree

Conclusion 2

Canopy lianas and broadleaf trees converge in their hydraulic traits but diverge in their mechanical traits.

Tree Physiology, 2019

Result 3



Changbai Mountain, temperate forest
9 broadleaved tree species vs. 5 conifer species

Conclusion 3

Coniferous and broadleaf trees achieve coexistence in the same environment by differentially adjusting their strategies for allocating water and carbon resources relative to leaf area.

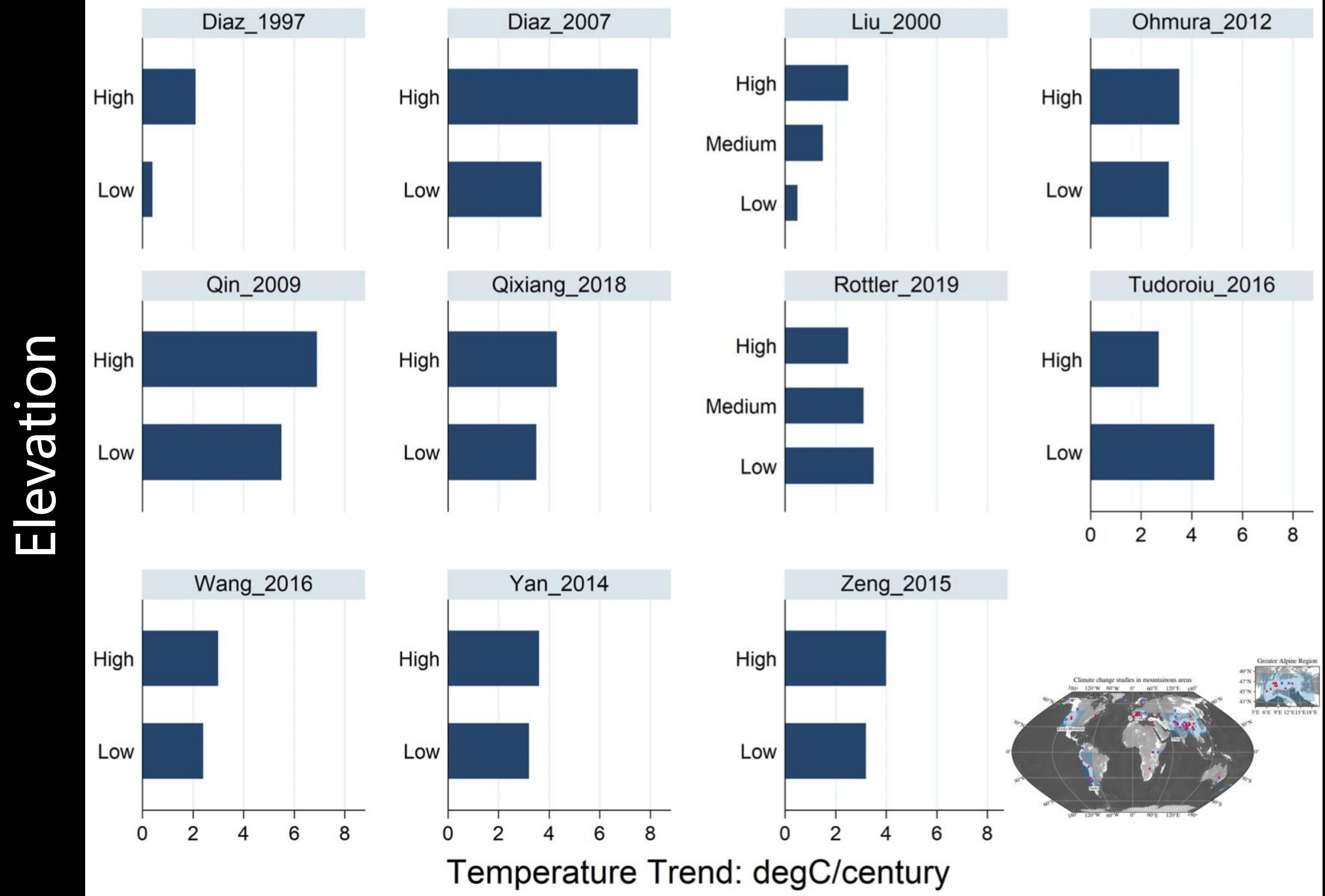
Tree Physiology, 2020

Answer to question 1

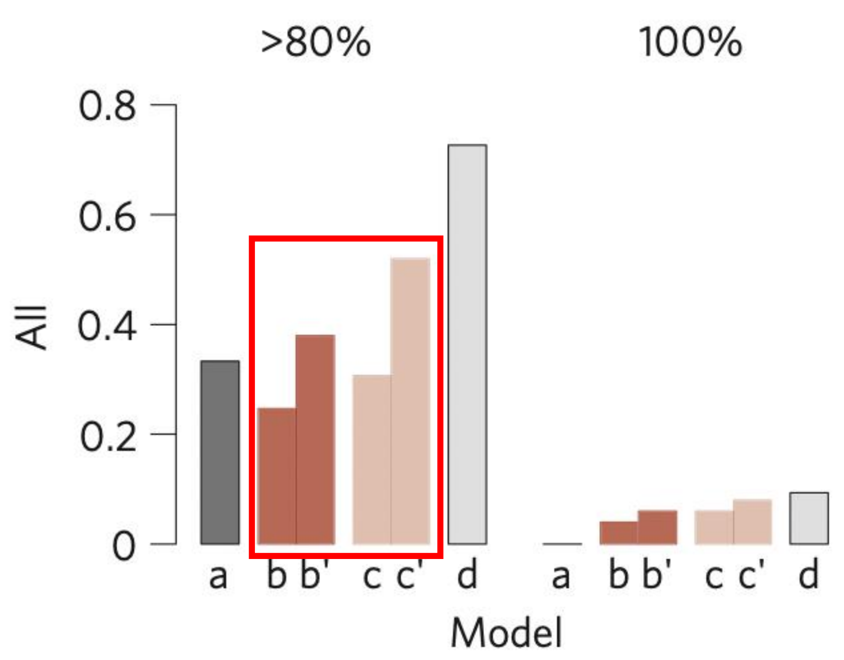
- Question 1: How do co-existing canopy species from different functional groups regulate their functional traits to adapt to the same environment?

- Answer: Co-existing canopy species adapt to the same environmental constraints by differentially regulating a core set of functional traits related to resource allocation, specifically the balance between xylem (water transport), phloem (carbon transport), and leaf area (carbon capture).

Question 2: How does community functional diversity respond to environmental change?



Climate Changes and Their Elevational Patterns in the Mountains of the World *Reviews of Geophysics*, 2022



Extinction debt of high-mountain plants under twenty-first-century climate change

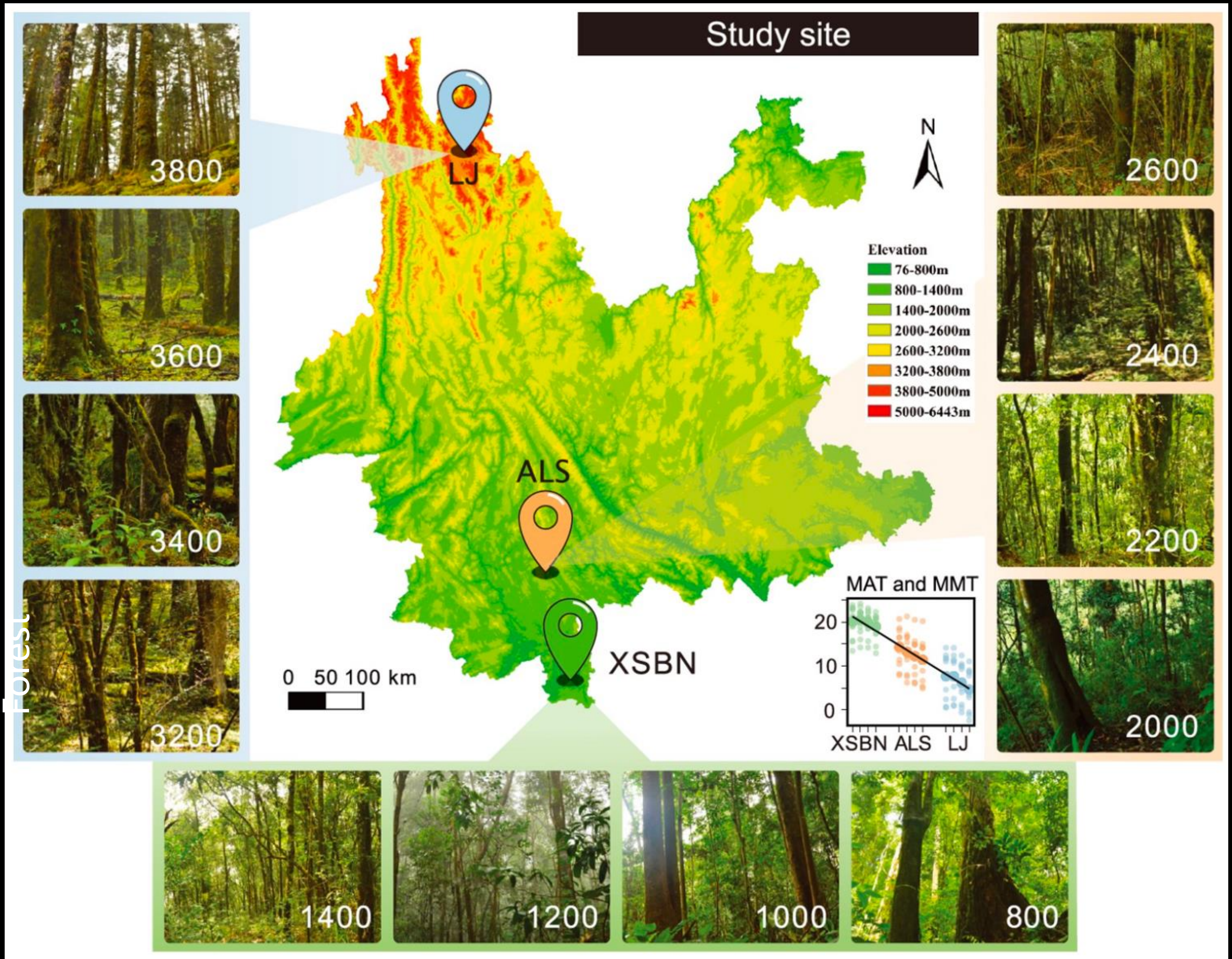
European Alps

Nature Climate Change, 2012

Site – Yunnan, Southwest China

- Xishuangbanna (XSBN)
- Ailao Mountain (ALS)
- Lijiang (LJ)

Subalpine Coniferous Forest



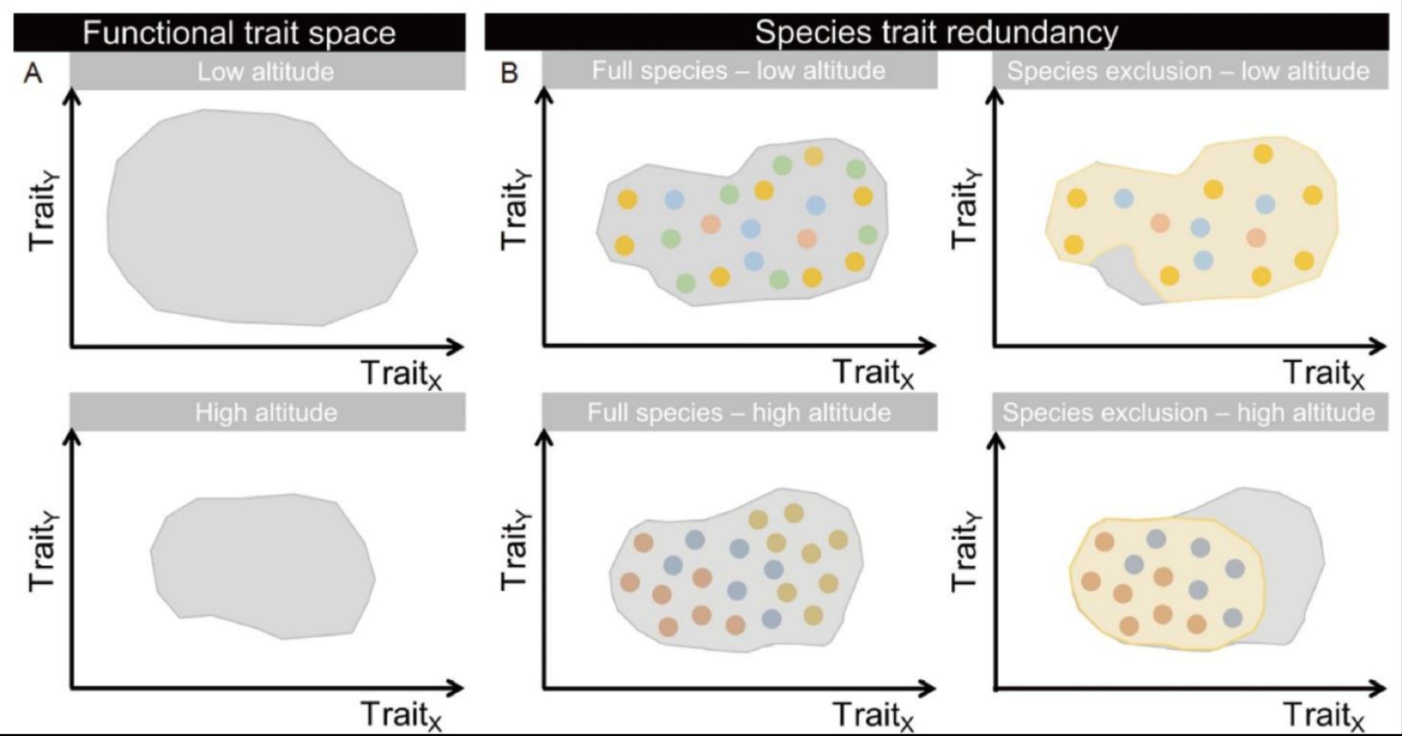
Montane Wet Evergreen Broadleaf Forest

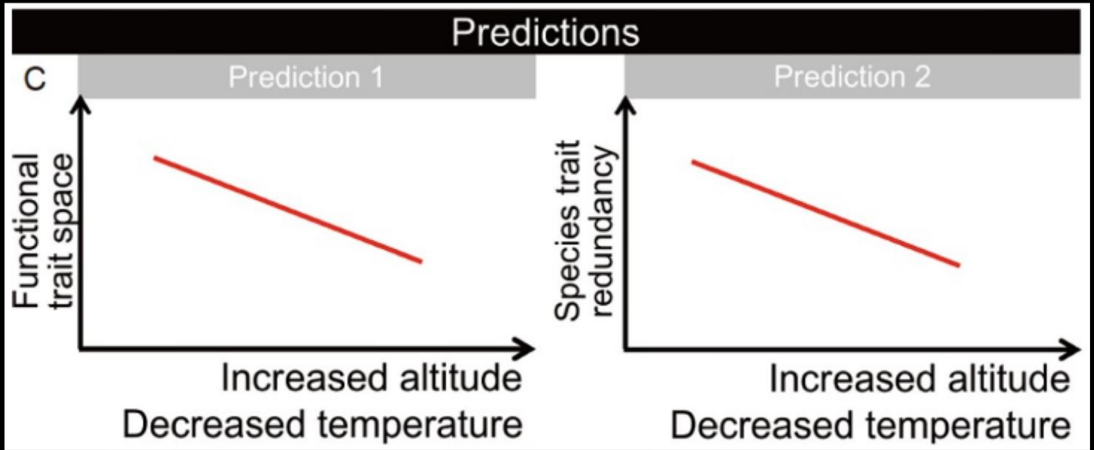
Tropical Monsoon Evergreen Broadleaf Forest

Hypothesis

- Rising elevation leads to colder temperatures and increased environmental stress, driving a decline in
  - community functional diversity
  - functional redundancy

Individua l → Species → Communit y

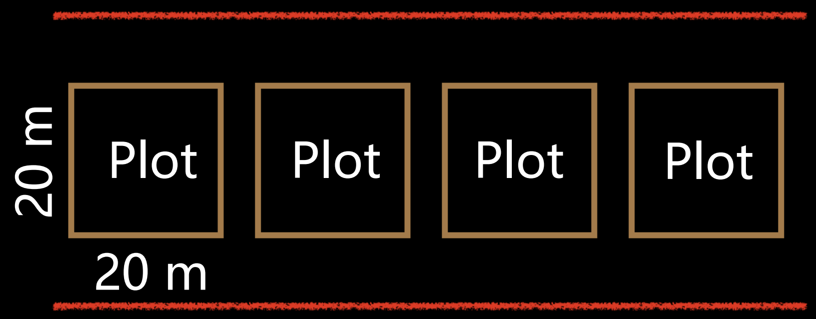




Field and lab work

- Sample collection
  - DBH > 5 cm tree individuals
  - 4 ~ 5 leaves
  - LA, SLA, leaf C, leaf N and leaf P

- 48 plots
- 1590 individuals
- 171 tree species， 55 families

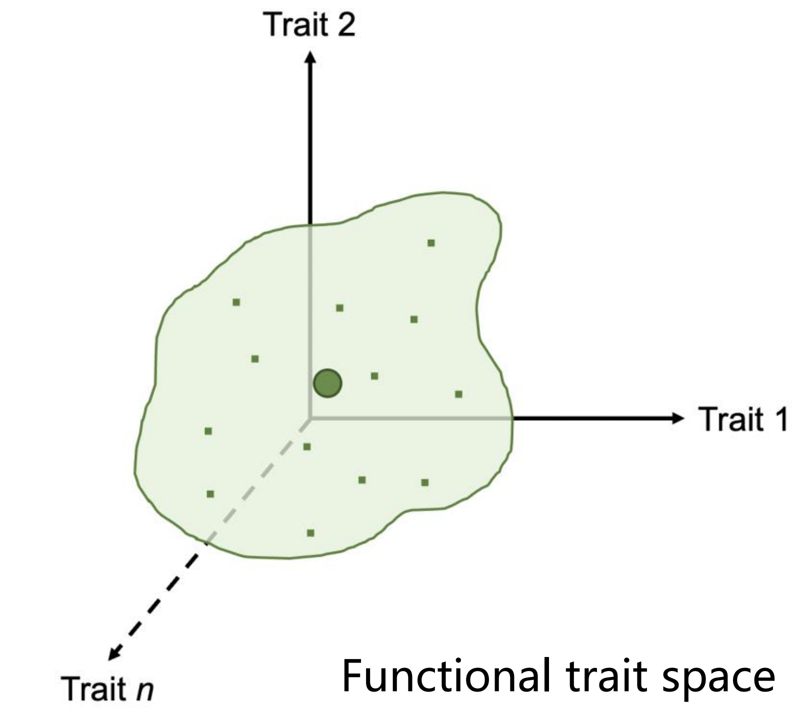


Hypervolume

- Multidimensional hypervolume is calculated to estimate community level functional diversity

- Hypervolume
  - STEP 1 – PC1, PC2，PC3 (88.6%)
  - STEP 2 – 85 individuals/altitude
  - STEP 3 – repeat 500 times

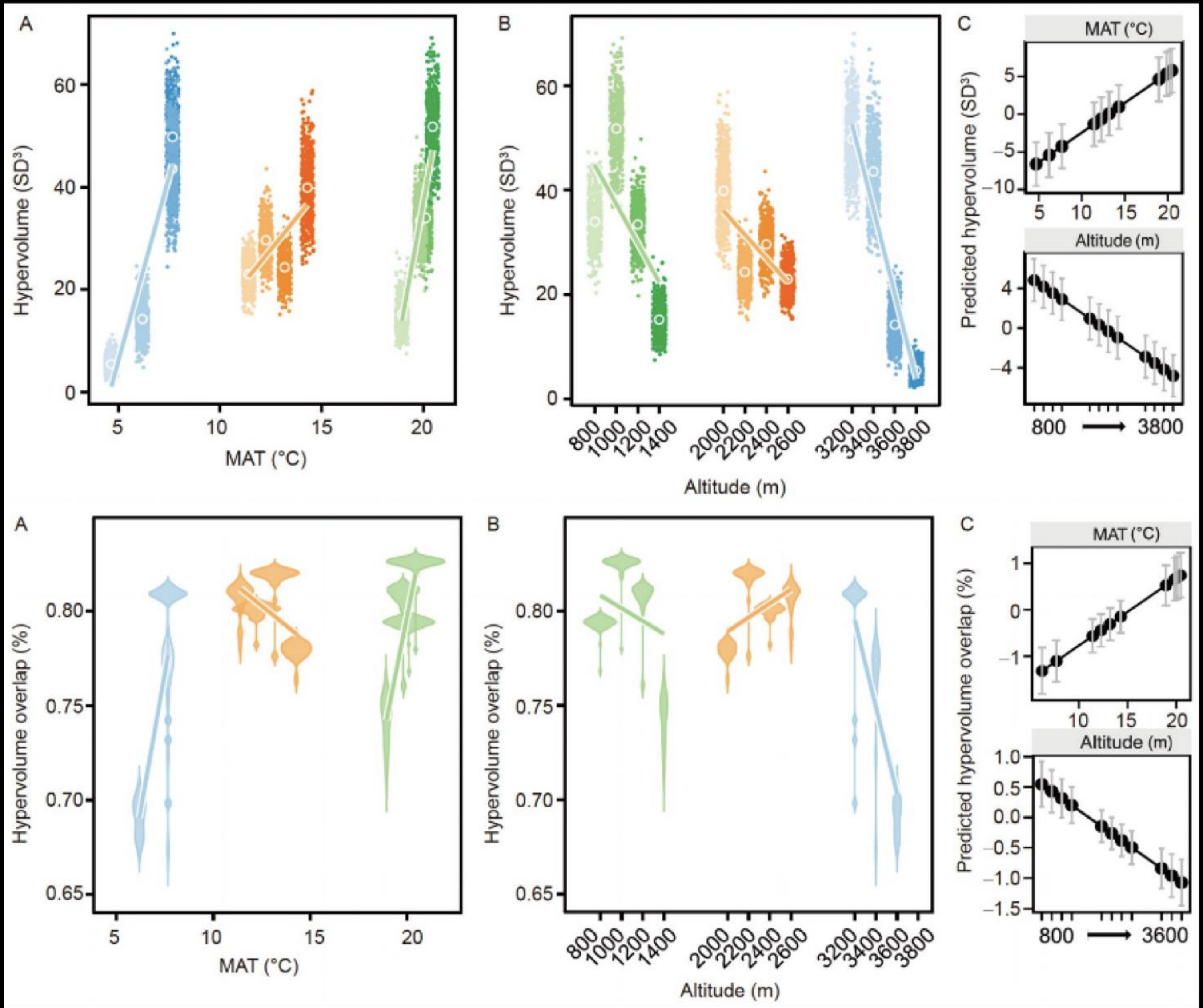
- Species redundancy
  - STEP 1 – exclude species one by one
  - STEP 2 – 60 individuals/altitude
  - STEP 3 – trait space overlap
  - STEP 4 – repeat 500 times



Functional trait space

Result

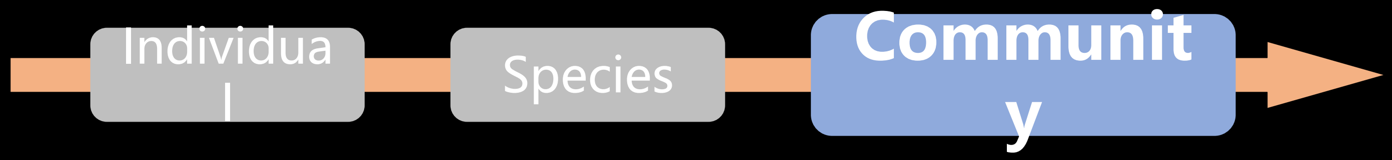
- With increasing altitudes, functional trait space decreased
- Species redundancy differed in different ecosystems



Conclusion

- Cold environments at high altitudes constrain both the functional trait space of plant communities and its range of variation across ecosystems. This suppression leads to a convergence in resource-use strategies among species, manifested as a smaller multidimensional functional hypervolume.

- The relationship between species' functional redundancy and elevation is not consistent across climate zones. As climate change intensifies, we can expect divergent shifts in functional redundancy within plant communities across different ecosystems.



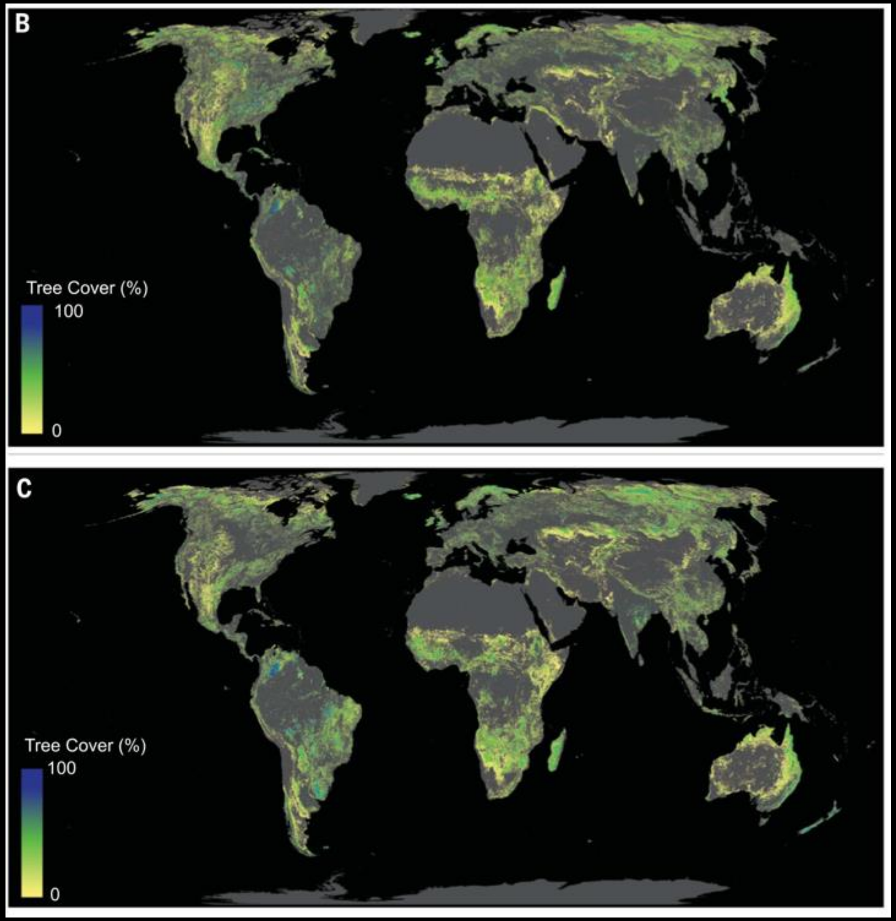
Science China Life Sciences, 2022

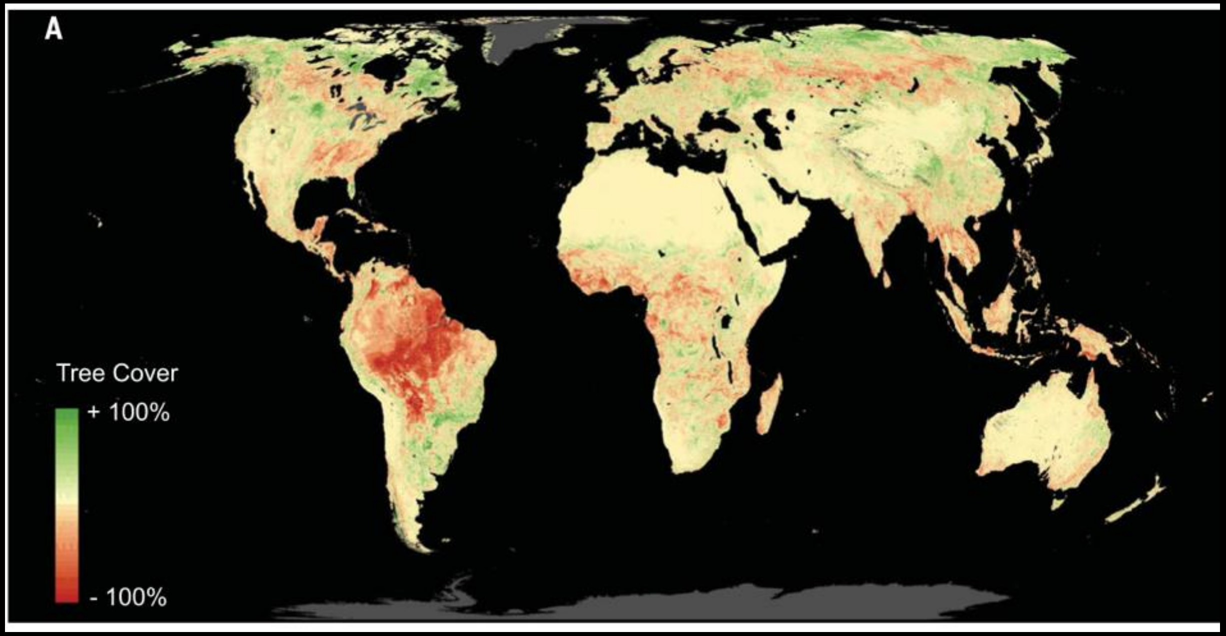
Answer to question 2

- Question 2: How does community functional diversity respond to environmental change?

- Answer: The response of functional diversity to environmental changes may vary across forest ecosystems. Under future climate change, conservation priority should be given to ecosystems exhibiting both low functional diversity and low functional redundancy, as these are more vulnerable and require urgent protection.

Question 3: What is the relative importance of species/ functional group richness versus composition for forest productivity?



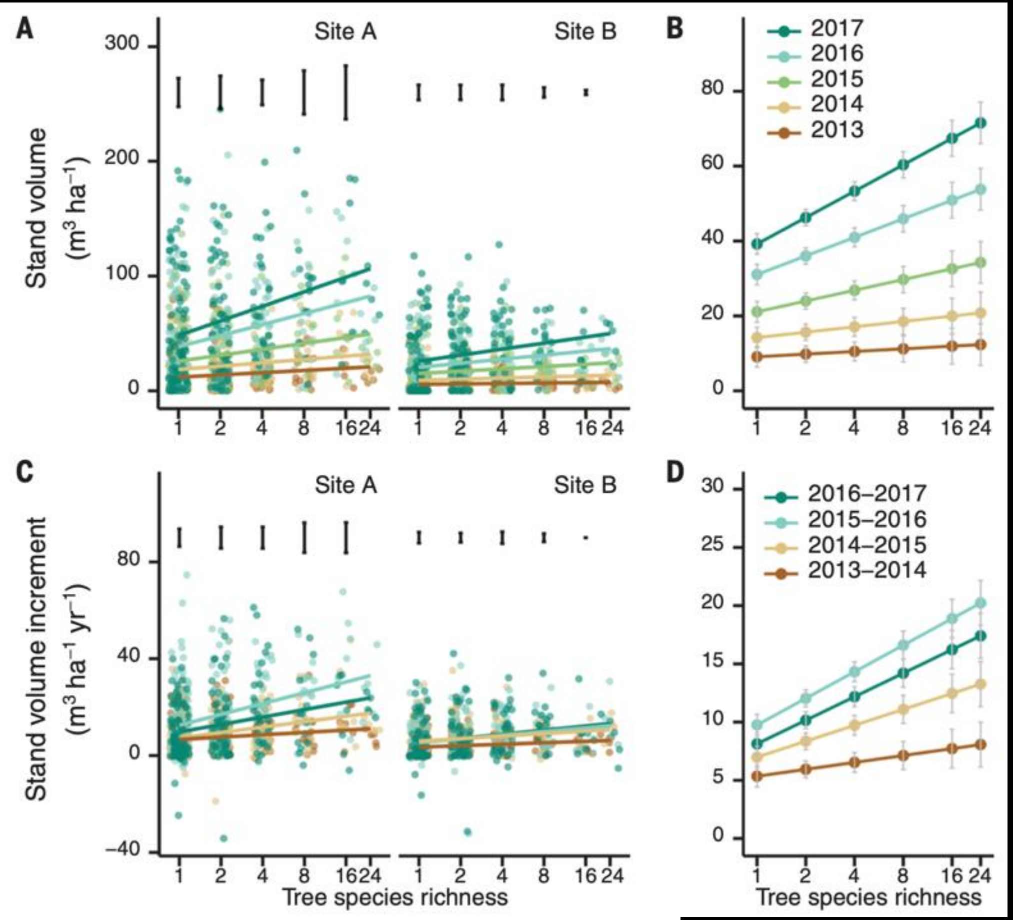


The global tree restoration potential

Jean-Francois Bastin[1*], Yelena Finegold[2], Claude Garcia[3,4], Danilo Mollicone[2], Marcelo Rezende[2], Devin Routh[1], Constantin M. Zohner[1], Thomas W. Crowther[1]

Science, 2019

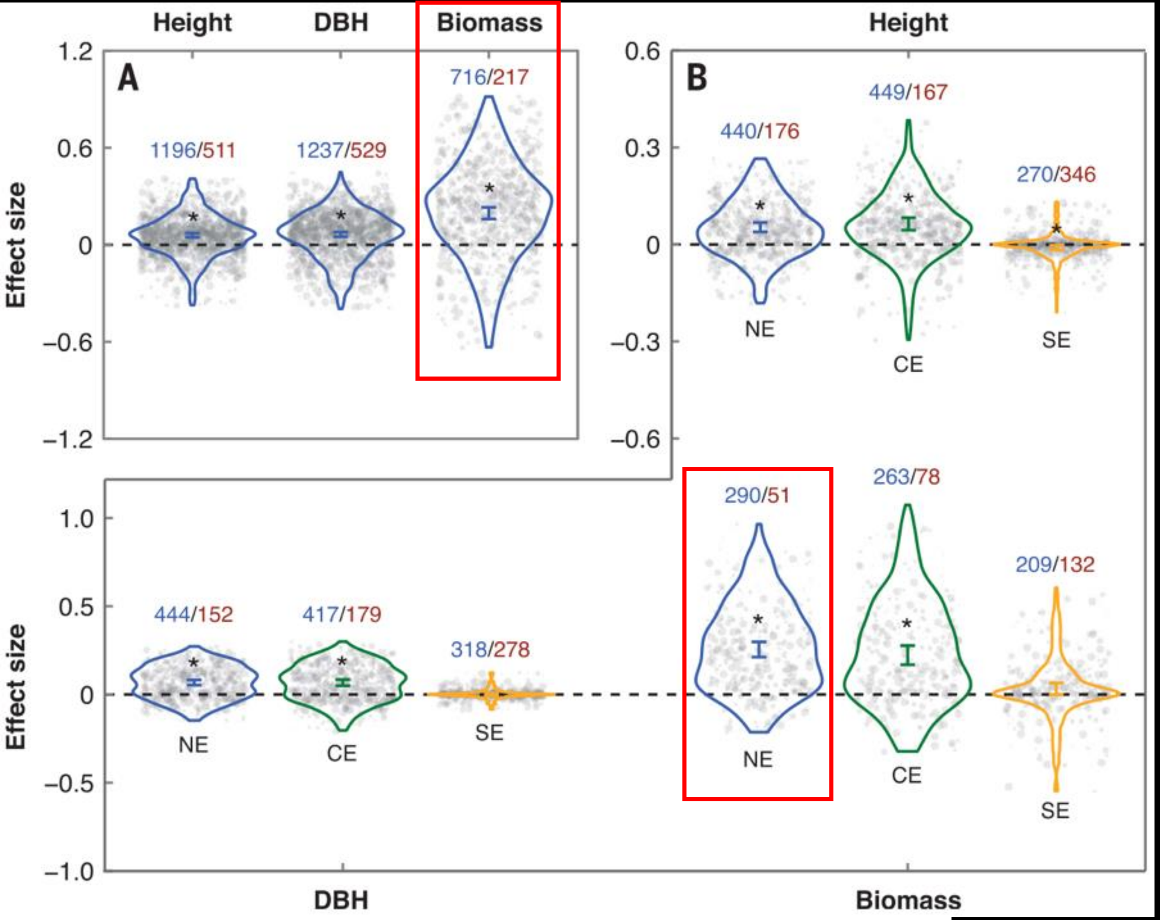
Effect of species richness on forest productivity



FOREST ECOLOGY

Impacts of species richness on productivity in a large-scale subtropical forest experiment

BEF-China
Science, 2018

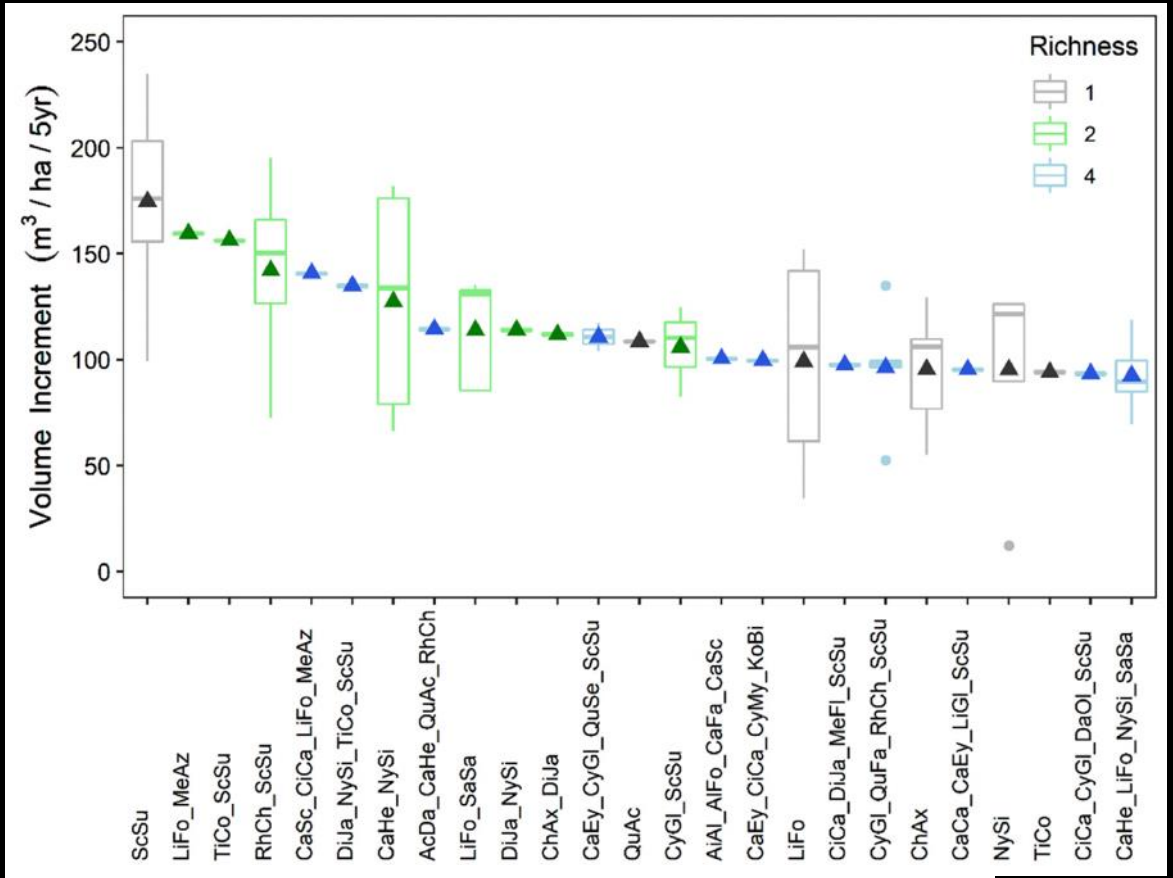


FORESTRY

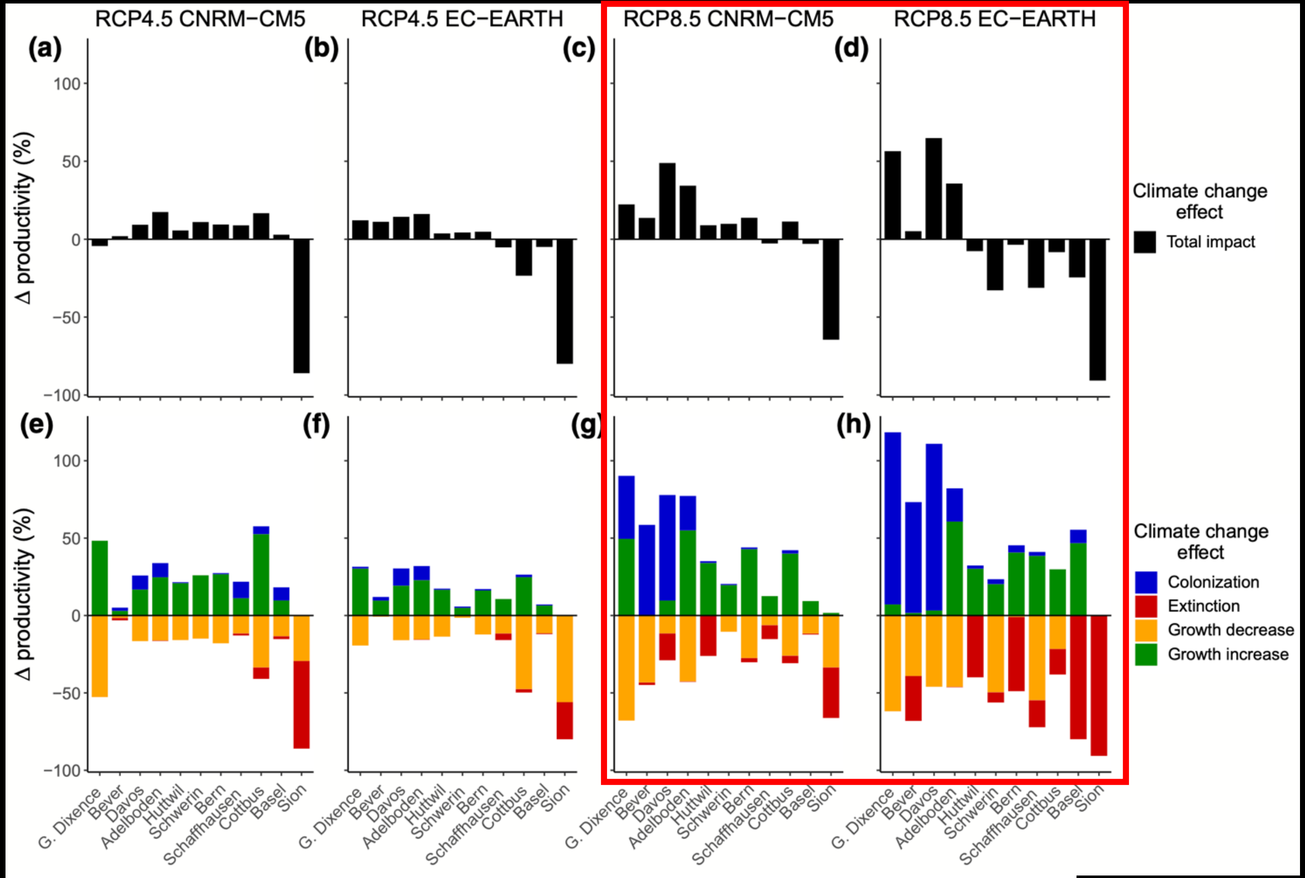
Multispecies forest plantations outyield monocultures across a broad range of conditions

Global
Science, 2022

Effect of species composition on forest productivity



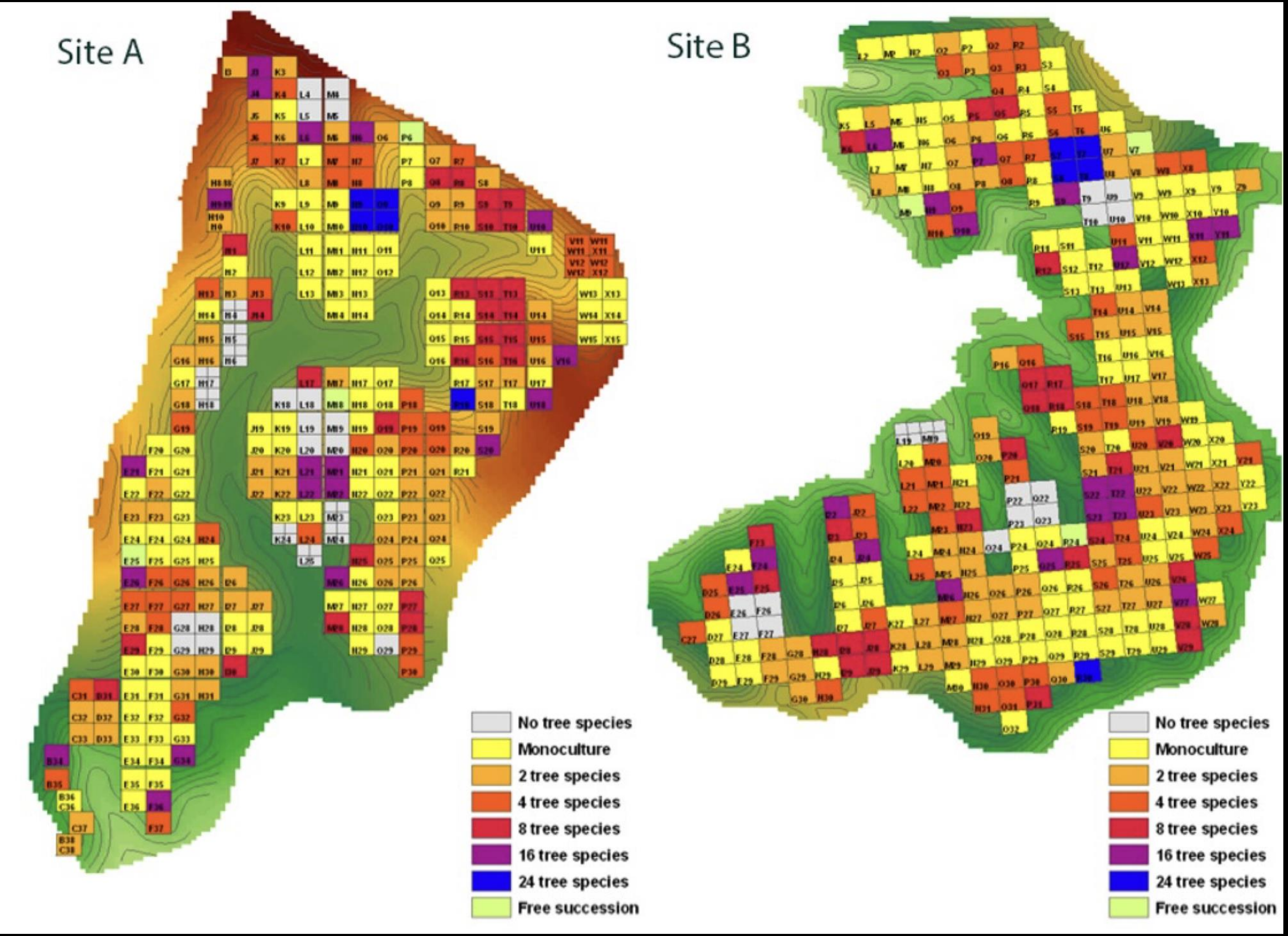
Species identity and composition effects on community productivity in a subtropical forest *BAE,* 2021



Climate change impacts on long-term forest productivity might be driven by species turnover rather than by changes in tree growth *GEB,* 2020

Site

- Monoculture
- 2, 4, 8, 16 and 24 mixed plantations

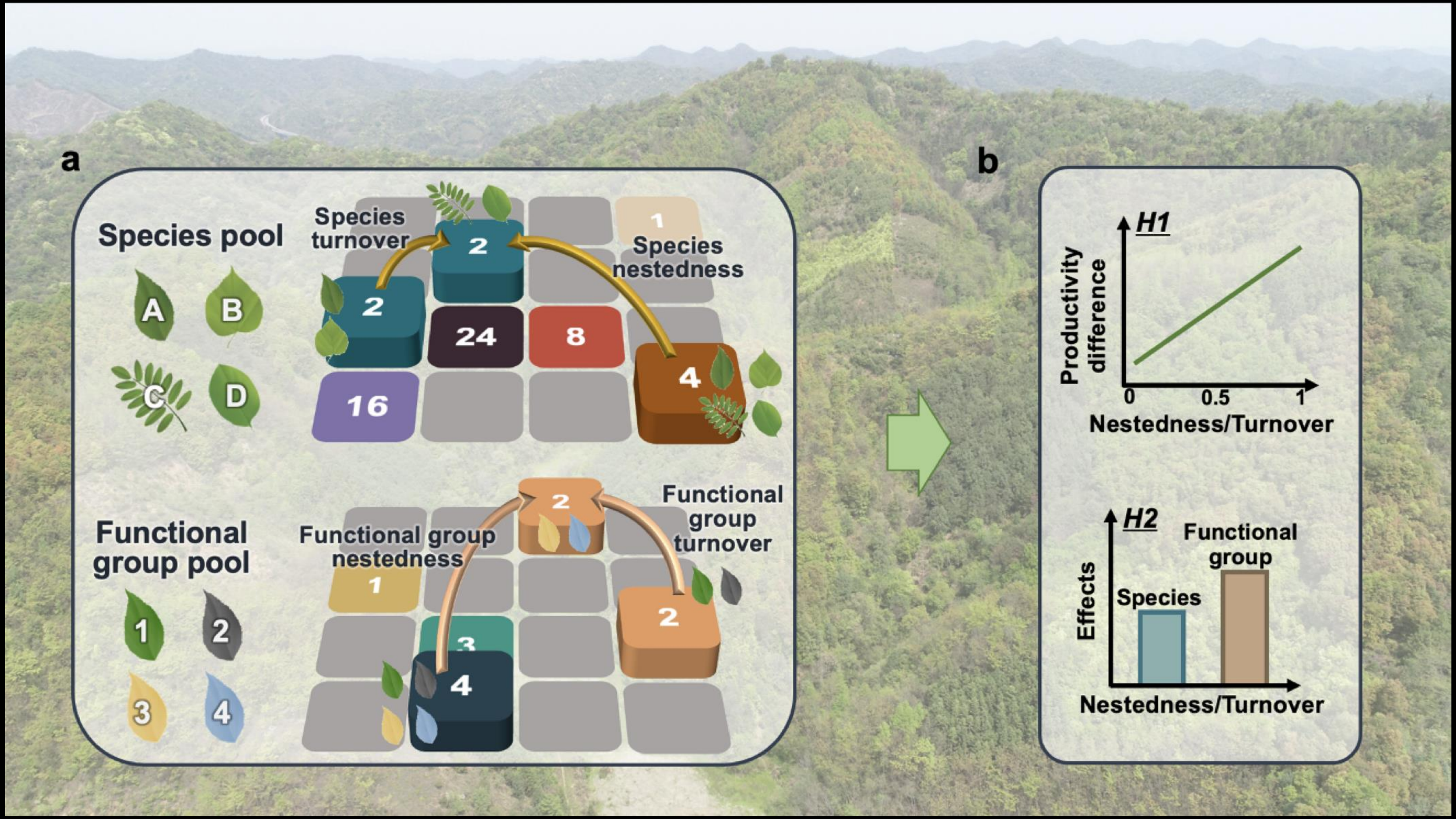


BEF-China, subtropical forest

Hypothesis

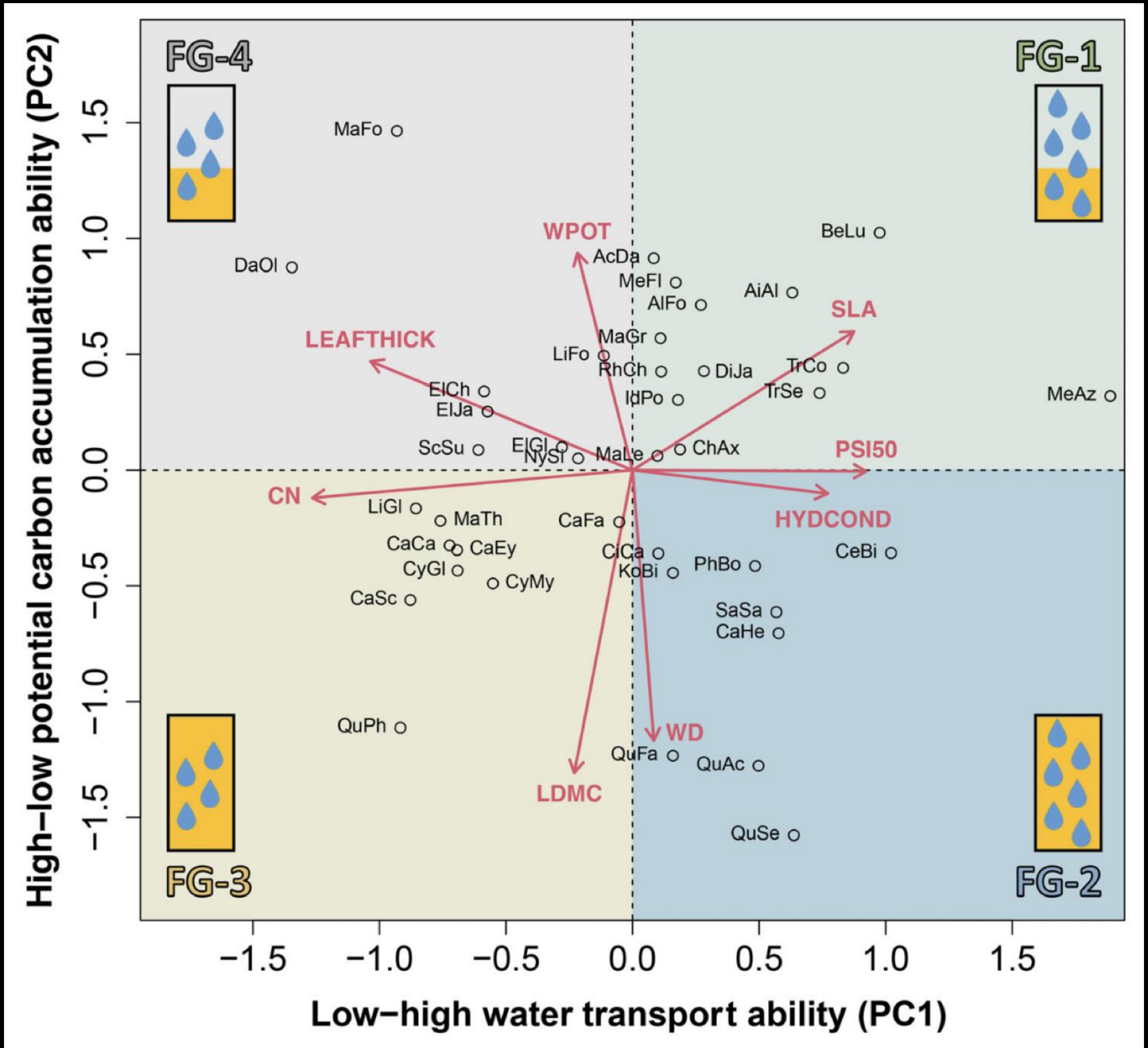
- As the nestedness and turnover of species/functional groups increase, the difference in productivity between plots also increases.

- The impact of functional group nestedness and turnover on plot productivity is greater than that at the species level.

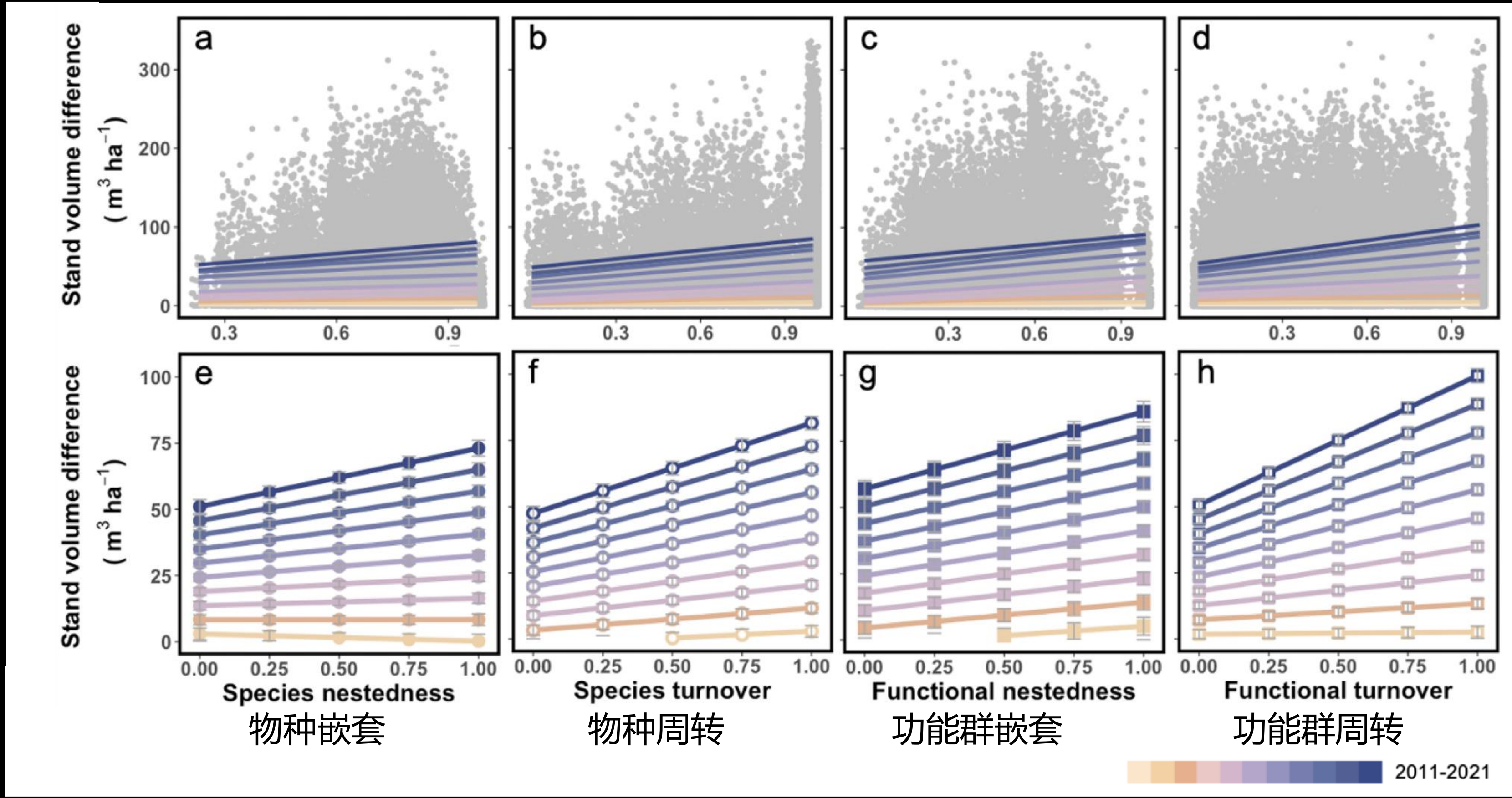


Methodology

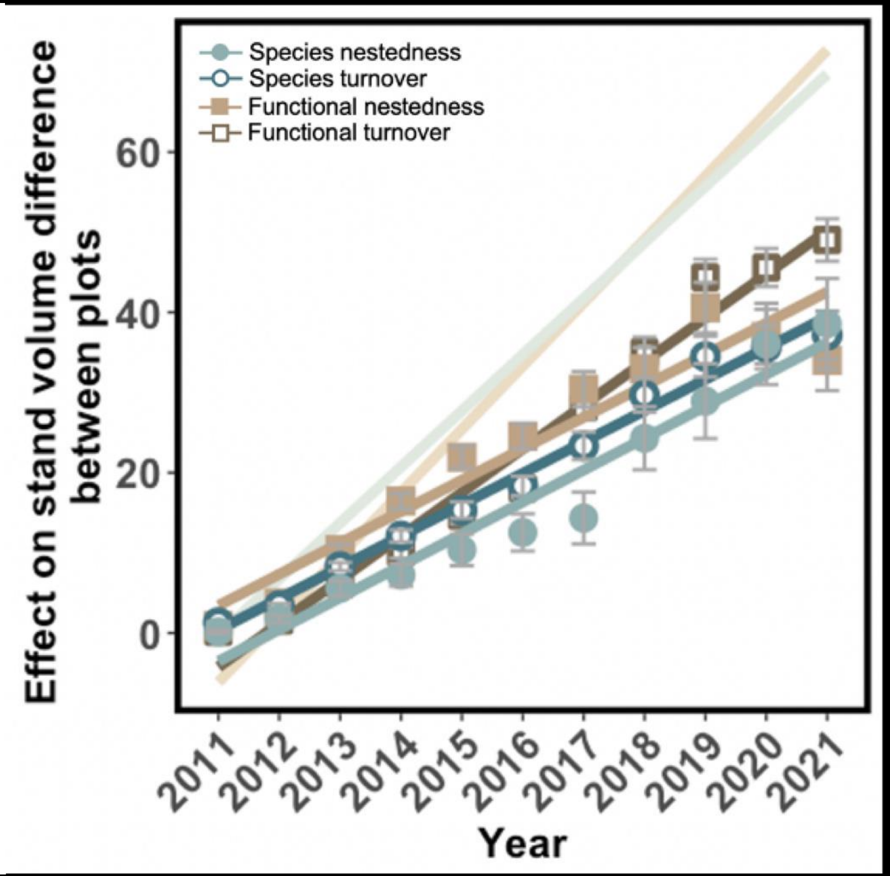
- Functional group:
  - STEP 1 – select 8 functional traits which relate to water transport and carbon fixation
  - STEP 2 – define functional groups by PCA
- Nestedness and turnover:
  - Bray–Curtis dissimilarity
- Plot productivity:
  - Stand volume = a - b × basal area × height
  - Time period: 2011-2021



Result



Stand volume difference (m^3 ha^-1)
a
b
c
d
e
f
g
h
Species nestedness
Species turnover
Functional nestedness
Functional turnover
物种嵌套
物种周转
功能群嵌套
功能群周转
2011-2021



Species nestedness
Species turnover
Functional nestedness
Functional turnover
Effect on stand volume difference between plots
Year
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021

Conclusion

- Both species/functional group richness and composition impact forest productivity, with the influence of functional diversity being significant and non-negligible.

New Physiologist,

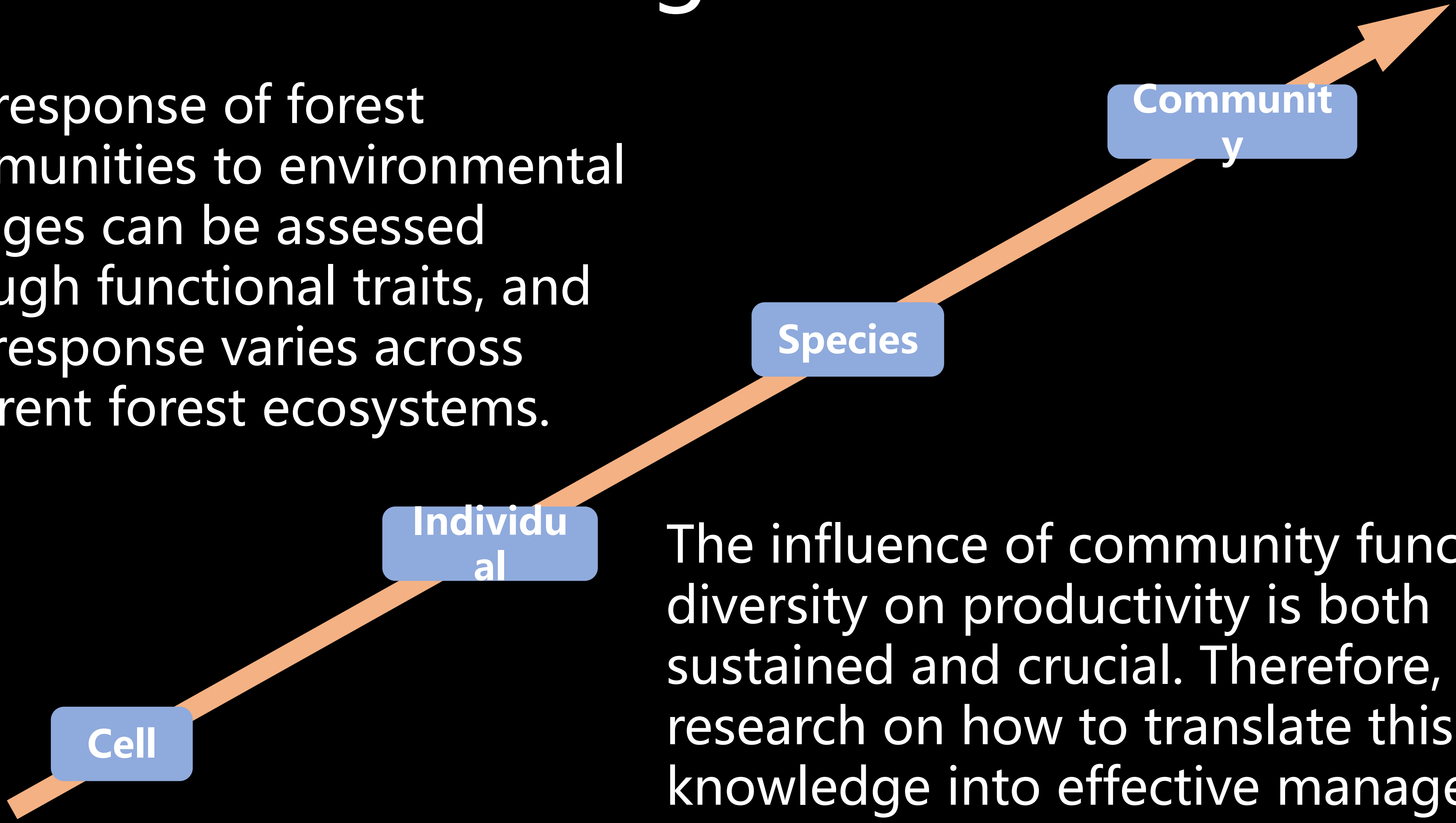
Answer to question 3

- Question 3: What is the relative importance of species/functional group richness versus composition for forest productivity?

- Answer: Given that species/functional group richness and composition are equally important for forest productivity, careful species selection in afforestation projects—aimed at creating complementary functional combinations—can significantly enhance productivity and should be a key consideration.

Take home massage

The response of forest communities to environmental changes can be assessed through functional traits, and this response varies across different forest ecosystems.



The influence of community functional diversity on productivity is both sustained and crucial. Therefore, research on how to translate this knowledge into effective management and conservation strategies requires significant strengthening.

Base of Life