Linking leaf elemental traits to biomass across forest biomes in the Himalayas

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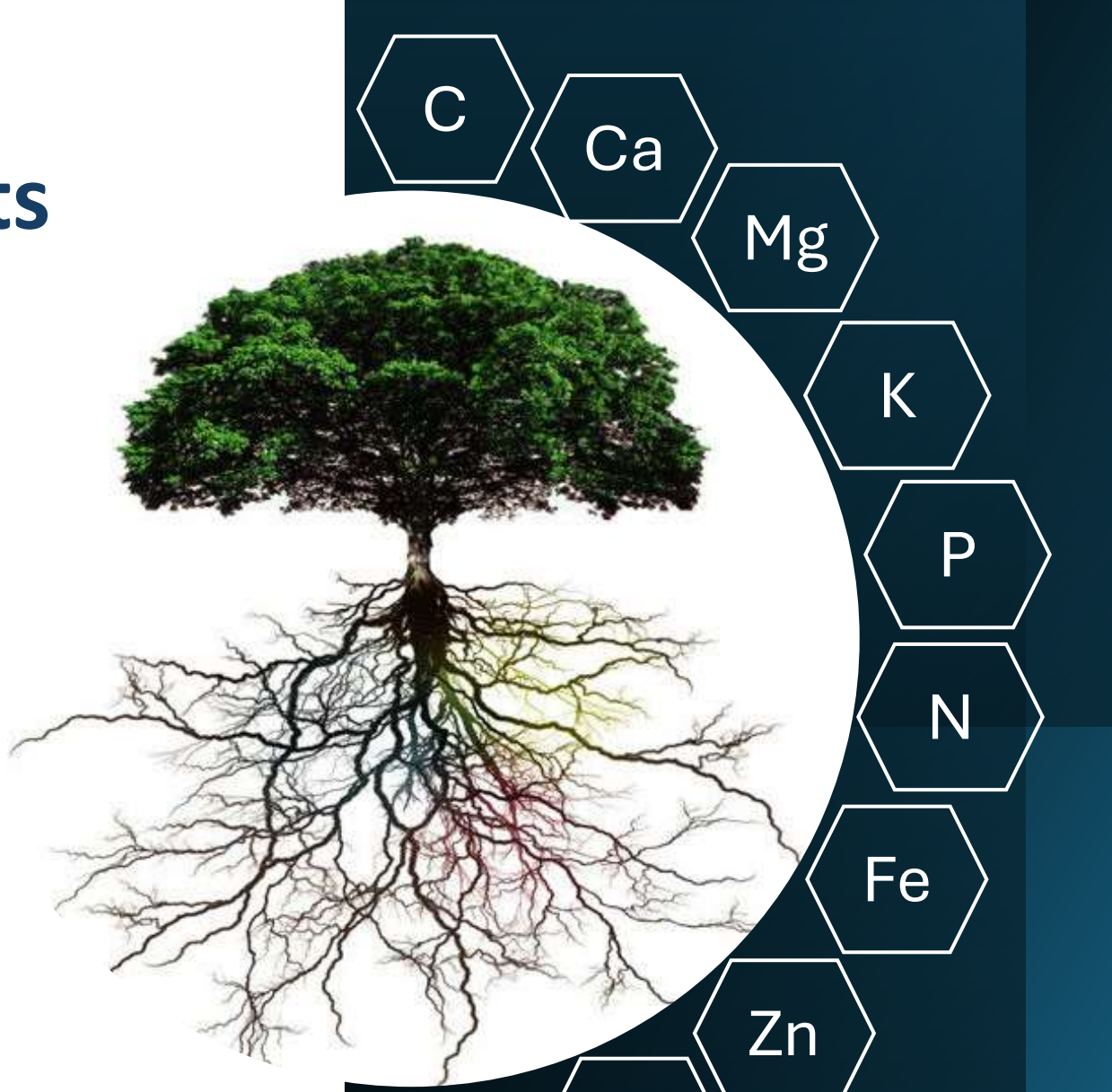

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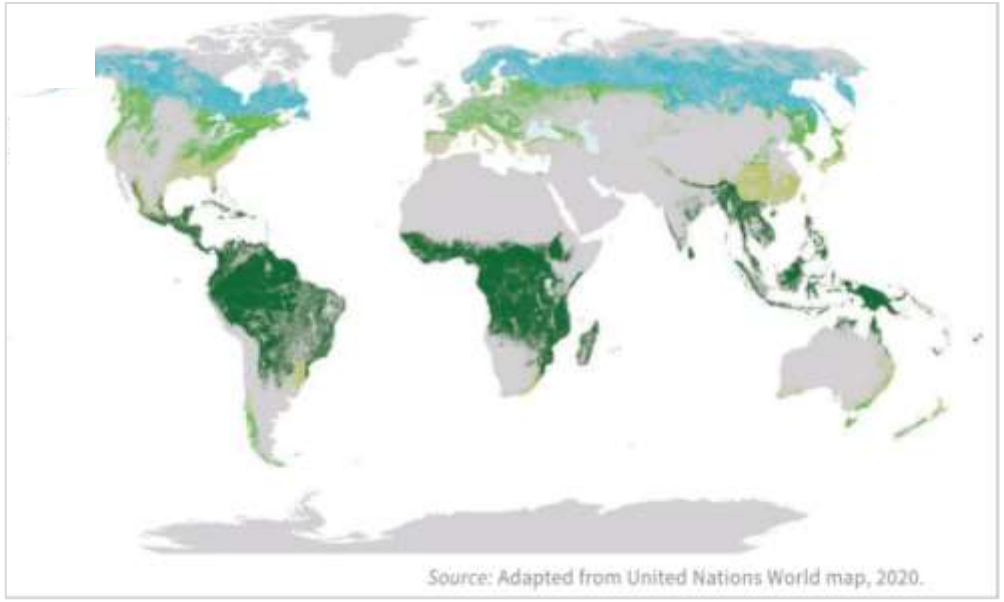
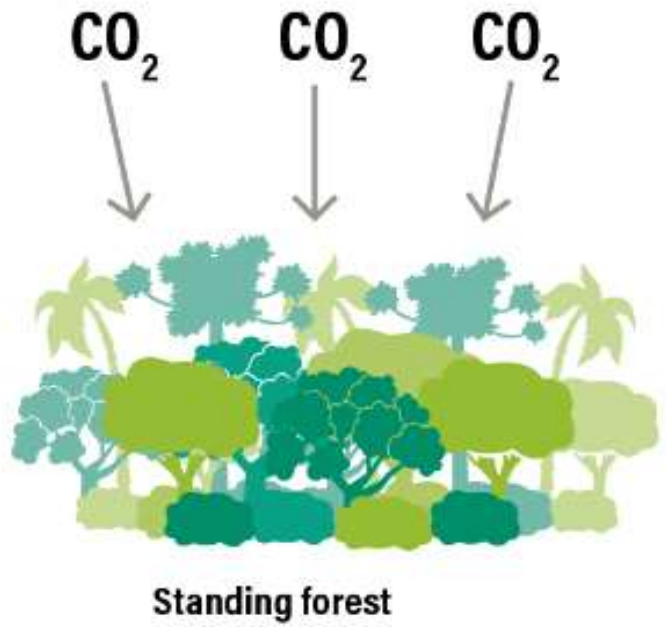
2nd May 2024

Forest and its importance



Biomes

Boreal	Temperate	Subtropical	Tropical
27%	16%	11%	45%

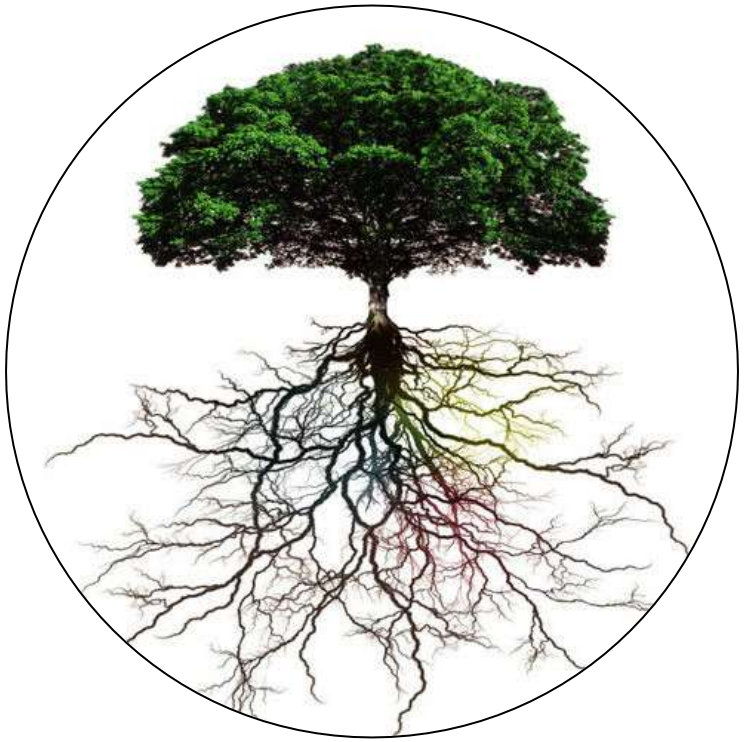


Source: Global Forest Watch

- Forests accounts for 31% of total land area (FAO 2020)
- Biomass, 42% of terrestrial carbon storage (Pan et al. 2011)

❑ Element & biomass

Multiple elements constrain biomass



Biomass accumulation

Photosynthesis Carbon uptake

C

Ca

K

P

Mg

N

Fe

Cu

Mn

Functions

- Structure, defense
- Osmoregulation
- Photoprotection
- Growth
- Photosynthesis
- Enzymatic activities

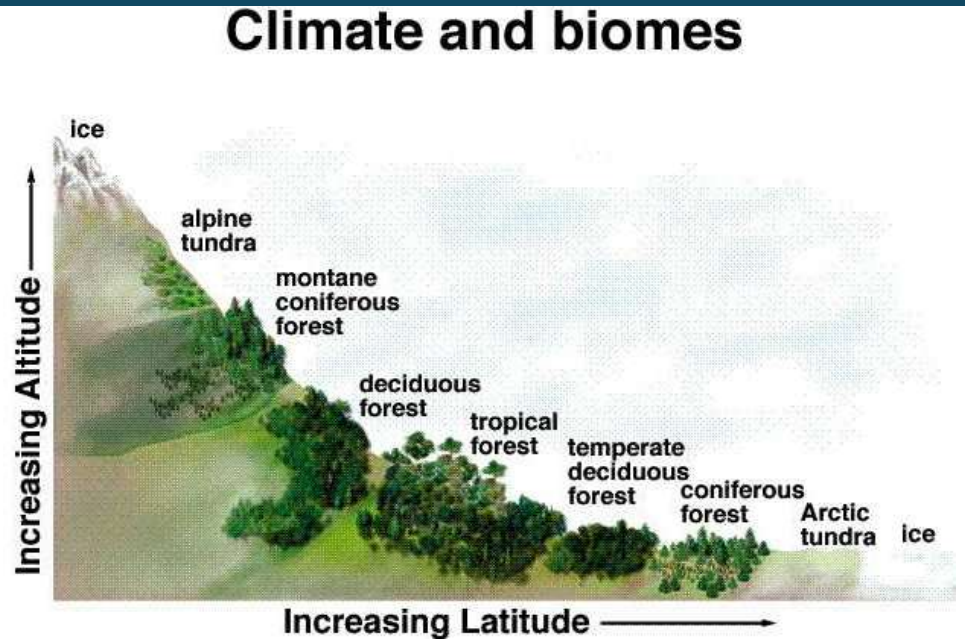
❑ Functional diversity & biomass

Leaf N and P-based traits

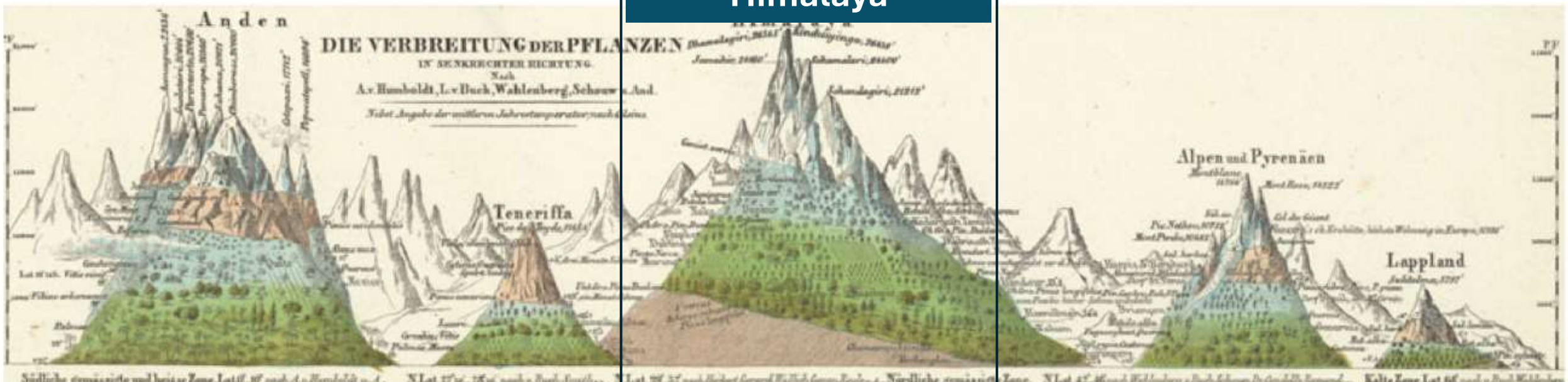
Trait dominance **Mass-ratio effect**	**Trait divergence** **Complementarity effect**
• Traits associated with dominant species promote biomass (Grime 1998)	• Variety of traits promotes biomass through greater resource utilization (Tilman et al. 1997)
• Reflected by community-weighted mean (CWM) (Garnier et al. 2004)	• Reflected by functional divergence (FDvar) (Mason et al. 2003)

- Differ with biomes and environmental conditions (Ding & Zang 2021)
- How their relative change modulates biomass along elevations

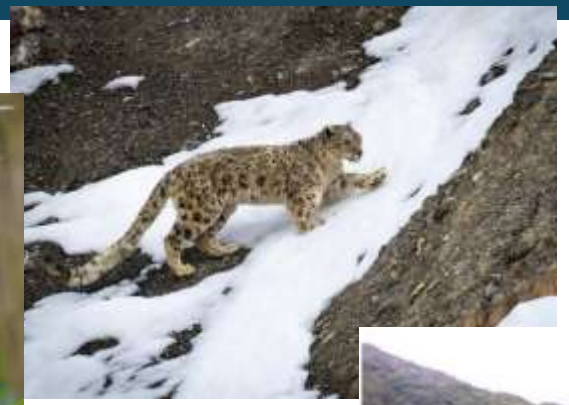
❑ Across the Himalayas

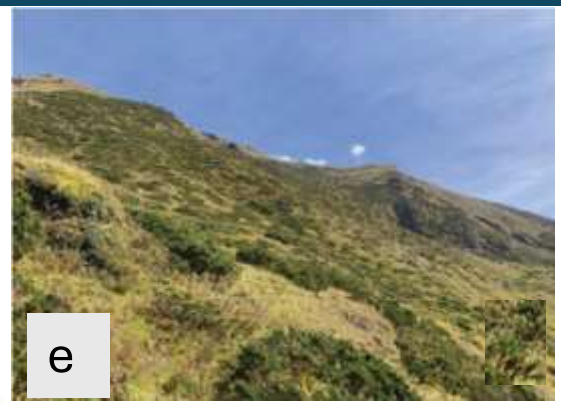


Himalaya



Across the Himalayas





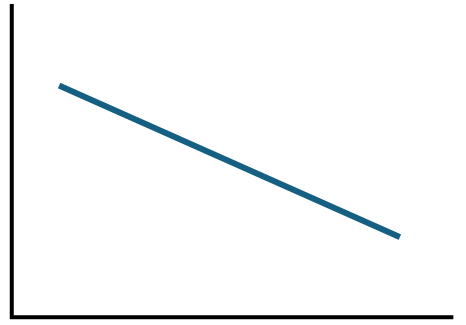
Alpine

Sub-alpine

Warm and Cool-Temperate

Sub-tropical

Tropical



Increasing elevation →

❑ Objectives & Hypothesis

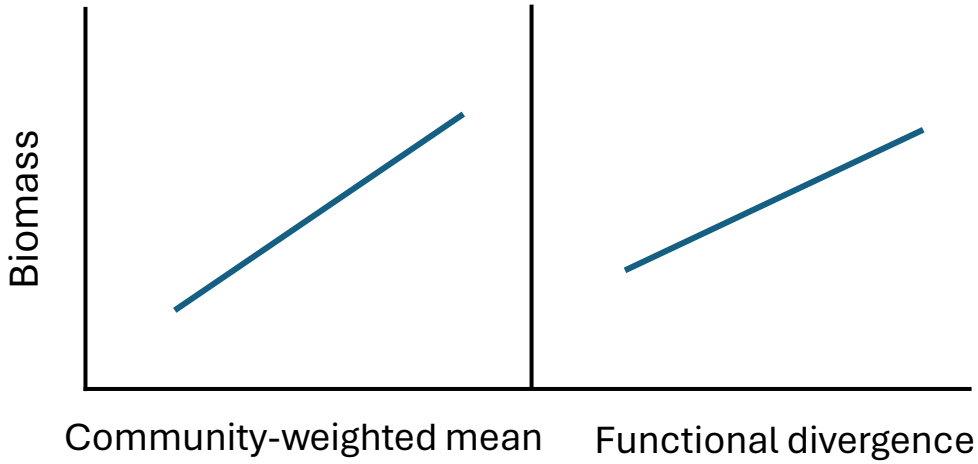
Objectives

To assess how the distribution and diversity of leaf elements in trees regulate forest biomass along broad elevational gradients in the central Himalayas.

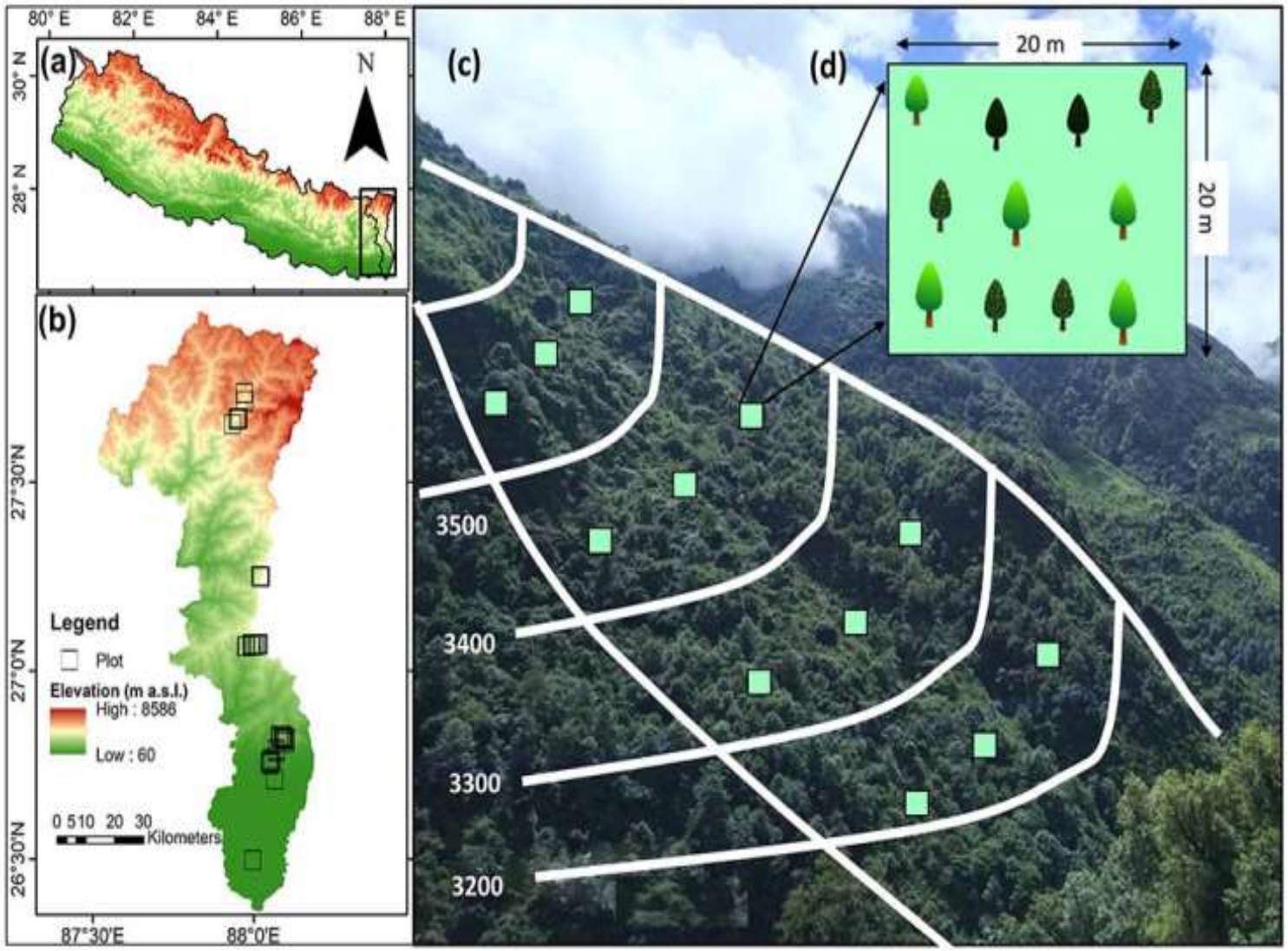
Hypotheses

1. Increase in mass-ratio and complementarity in leaf elemental traits leads to higher forest biomass

2. The directions and relative strength change along elevation, resulting in strong positive effects of mass-ratio and complementarity on biomass in the lower and higher elevations, respectively



❑ Study area



Example of the plot distribution along elevation

Kangchenjunga Landscape, central Himalayas, Nepal

- Broad bioclimatic gradient from tropical to alpine (80-4200 m asl)
- Sampling year: 2017-2018
- 3 plots in every 100 m asl
- Trees with diameter at breast height ≥5 cm, tree height
- 4170 trees, 126 species

❑ Trait coverage and analysis

3-5 individuals per species

1

Leaf sampling

2

Sample processing
- Oven drying
- Grinding

3

Elemental analyzer

4

Inductively coupled plasma optical emission spectrometer

10 elements

Carbon
Nitrogen

1,859 trees
116 species
126 plots

Phosphorus
Potassium
Calcium
Magnesium
Copper
Zinc
Iron
Manganese

5

a) Trait dominance

Community-weighted mean

$$CWM = \sum_{i=1}^{n} p_i \times x_i$$

b) Trait divergence

$$FD_{var} = \frac{2}{\pi} \arctan(5V)$$

❑ Biomass estimation

→ **Stem biomass**

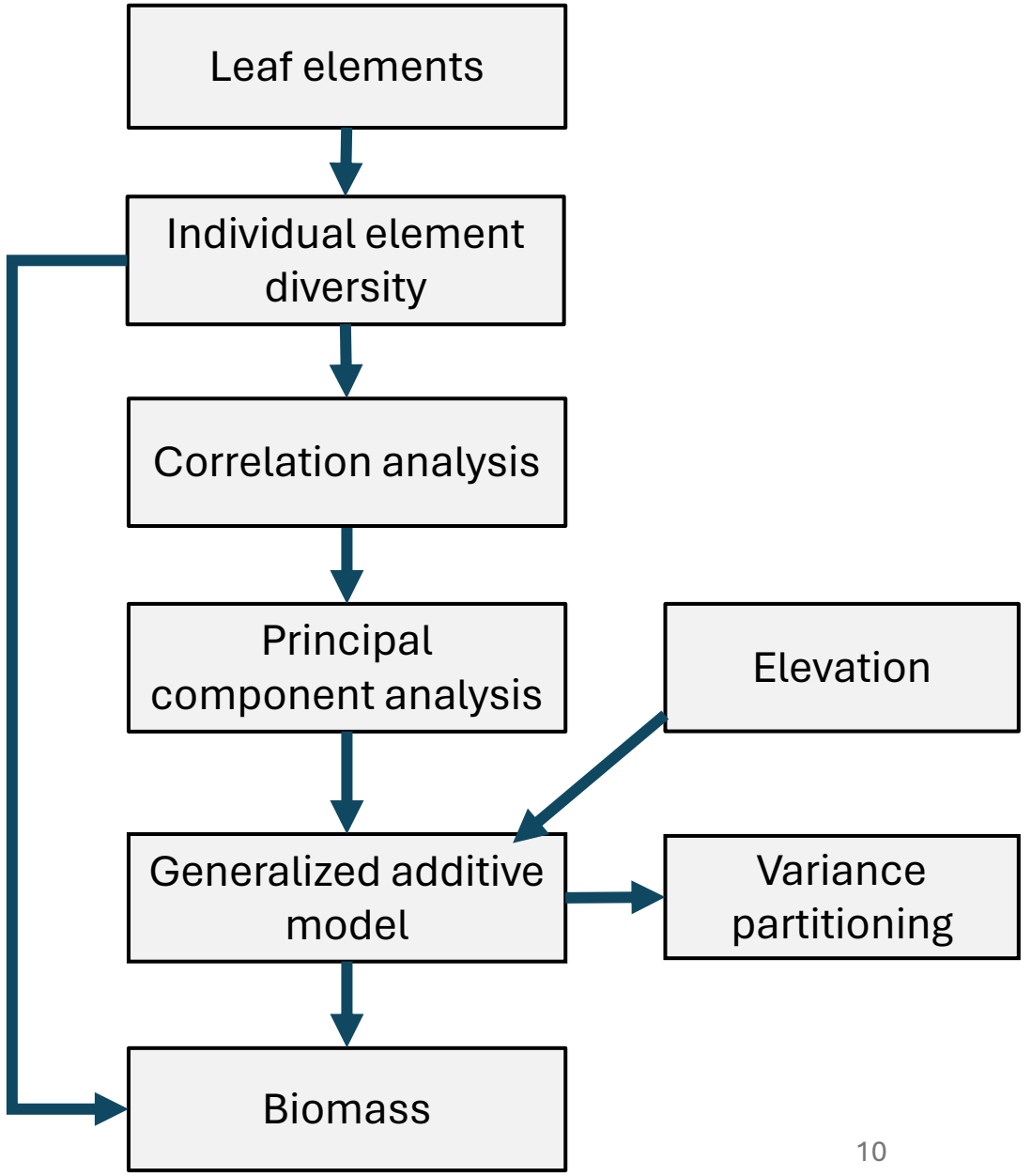
→ **Branch biomass**

→ **Leaf biomass**

→ **Root biomass**

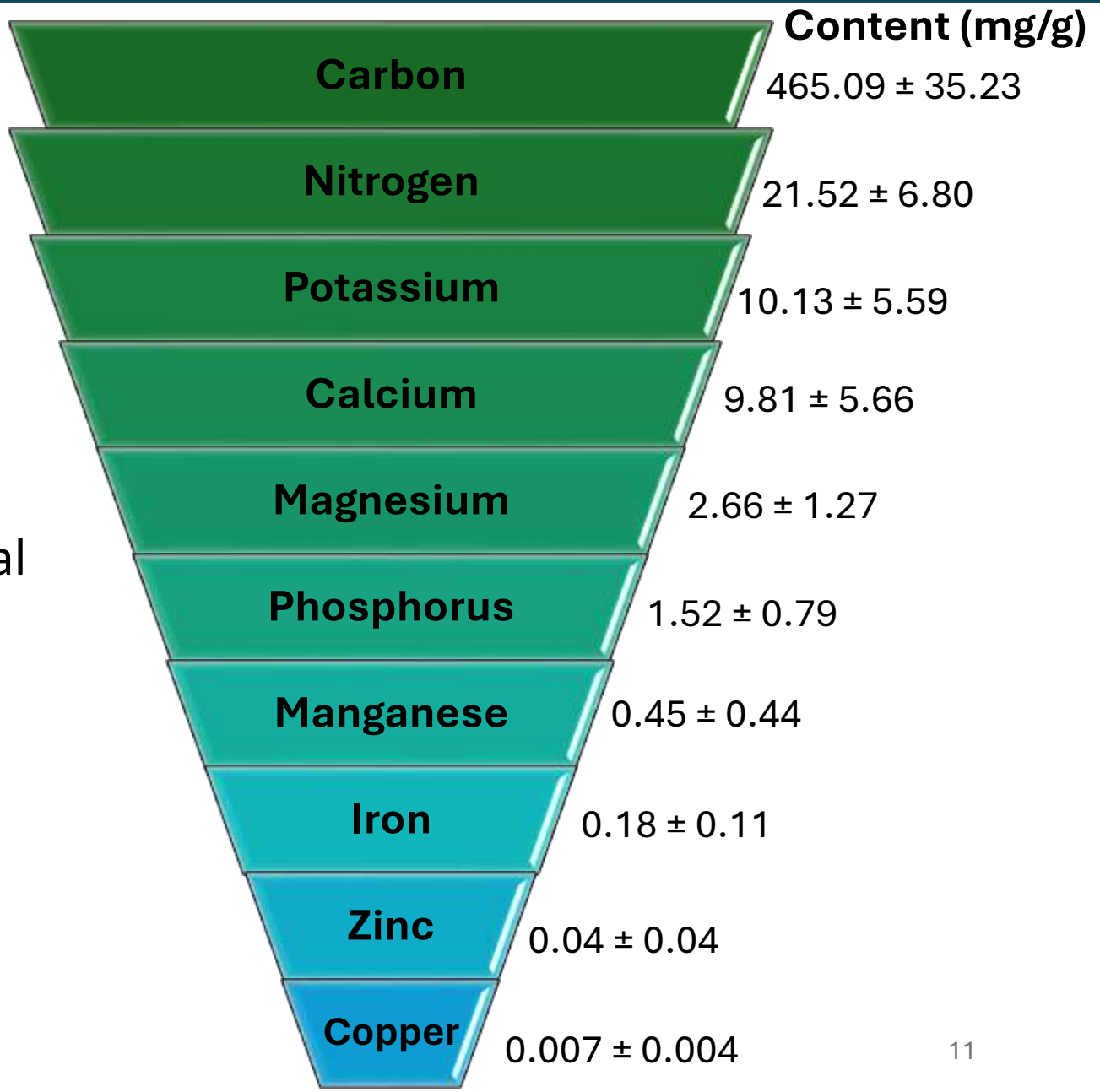
→ **Total biomass**

❑ Statistical approach



❑ Results

- High nutrients in the alpine
- Low nutrients in the warm-temperate
- Similar nutrient in tropical and subtropical

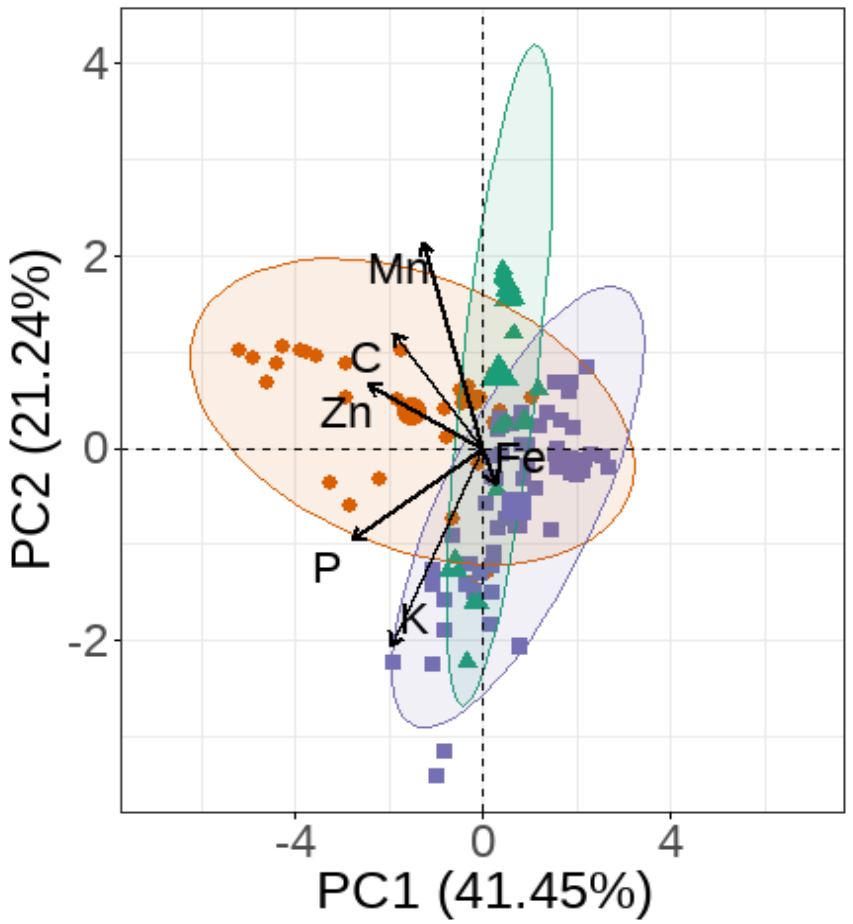


Results and Discussion

- Multiple elements affecting biomass

Community-weighted mean

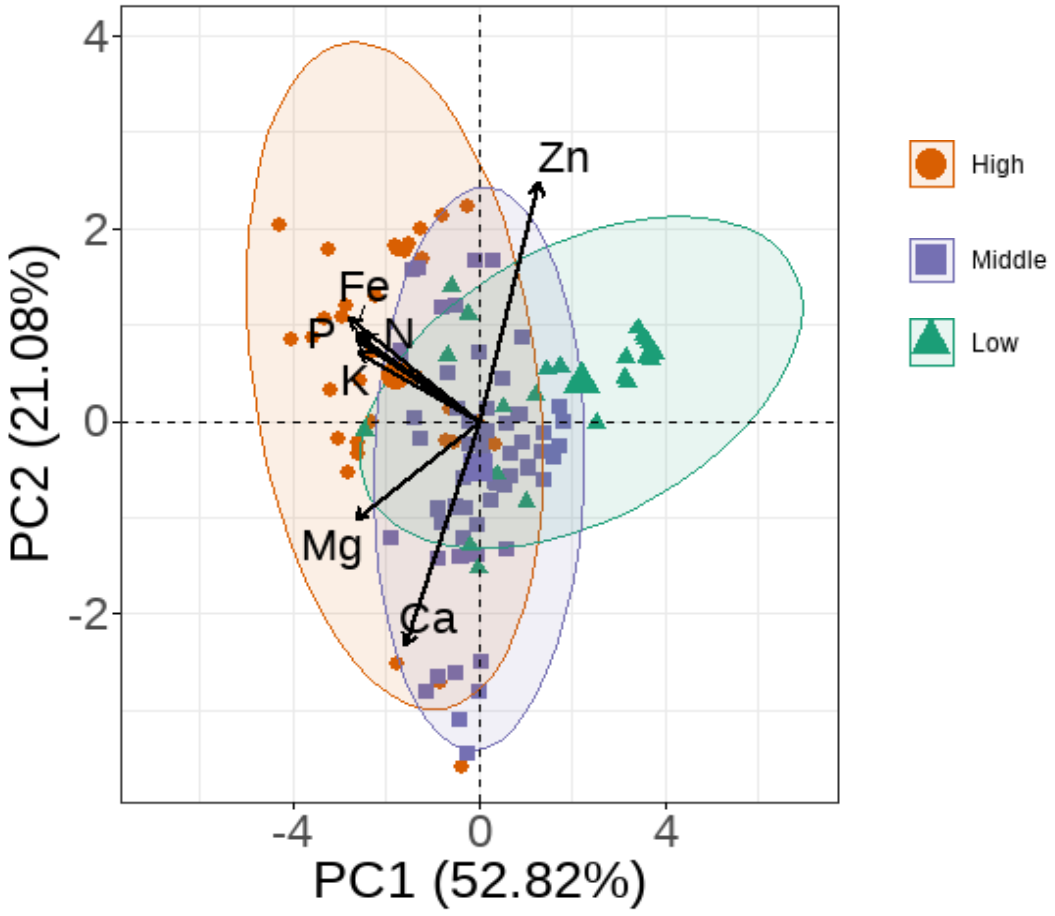
Mn
K



P, Zn

Functional divergence

Zn
Ca



N,P, K, Mg, Fe

❑ Results and Discussion

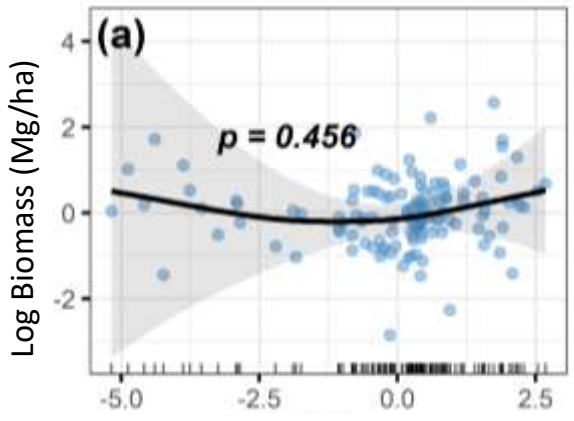
Variables	Deviation Explained (%)
Elevation	1.50
Community-weighted mean of PC1	1.60
Community-weighted mean of PC2	4.20*
Functional diversity of PC2	4.30**
Elevation × Community-weighted mean of PC1	20.10***
Elevation × Community-weighted mean of PC2	2.20*
Elevation × Functional diversity of PC2	12.80***

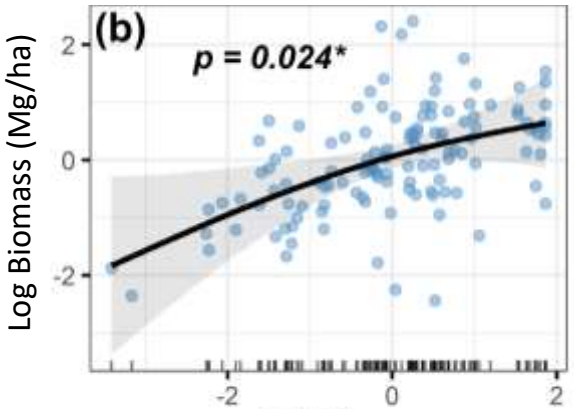
Individual traits explained 0.05 % to 21% of the variance

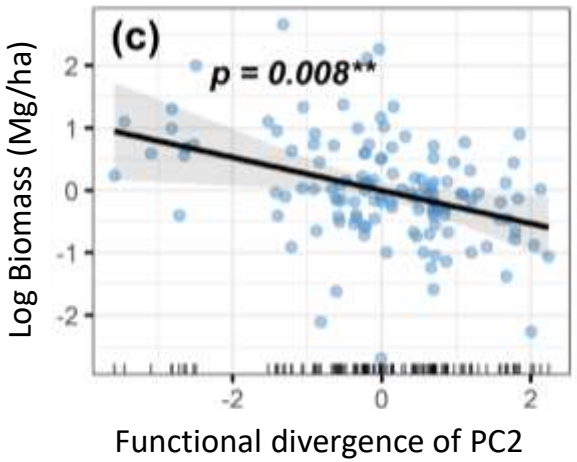
Strong interactive effect on biomass

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

❑ Relation between biomass and functional diversity

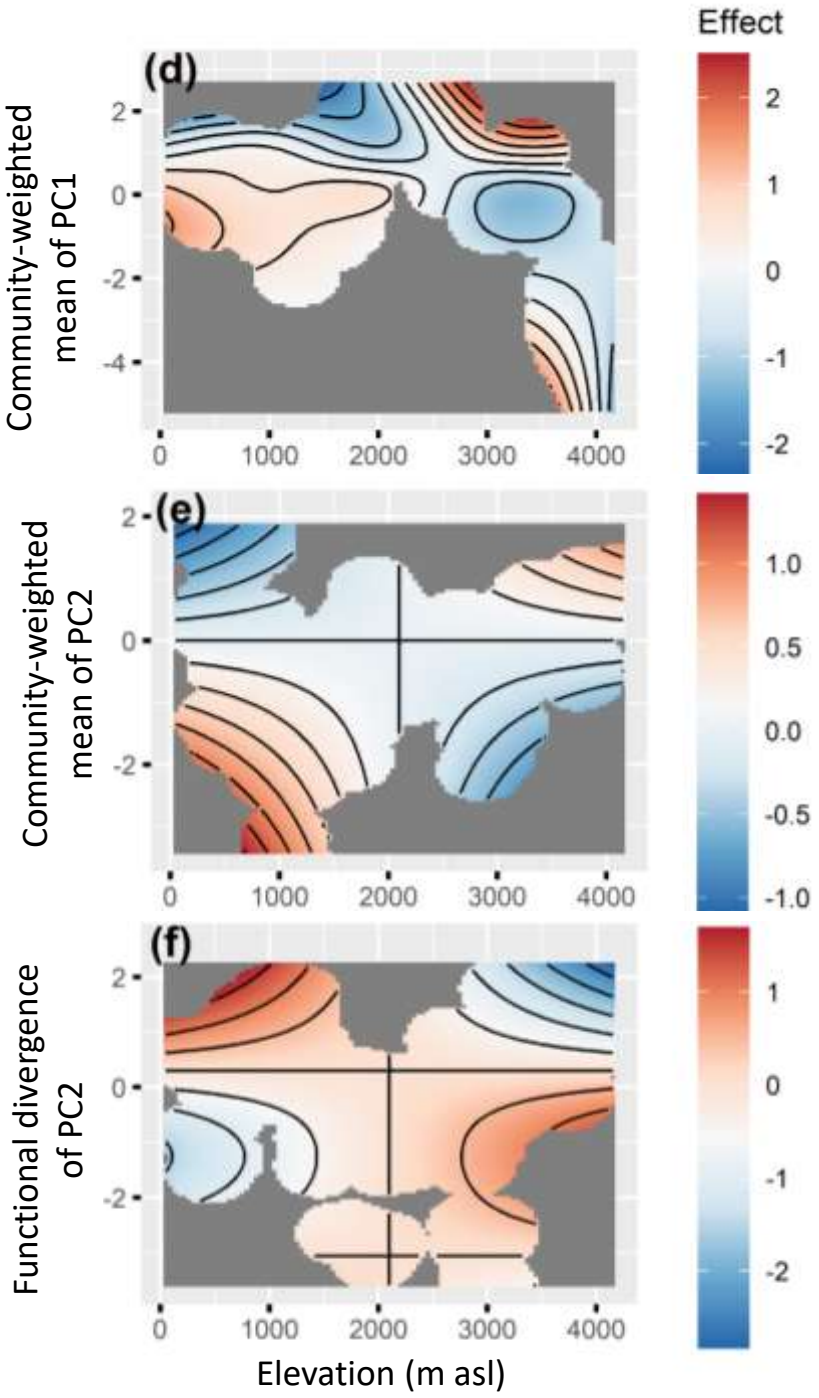






Hypothesis 1:

- Increasing trait dominance and decreasing trait variety linked to increasing forest biomass, support the mass-ratio hypothesis (Grime 1998)
  - ✓ locally abundant species favor high utilization of nutrient resources
  - ✓ dominant species play major role in maintaining biomass



❑ Interactive effect on biomass

Low elevation

- High mass-ratio (CWM_{PC1} & CWM_{PC2}) -> competition → marginal or negative effect on biomass
- High complementarity -> increase biomass

Middle elevation

- ↑mass-ratio (CWM_{PC1}) and ↓ complementarity (FD_{PC2})
- Promote biomass in temperate → Competition favor dominant species

High elevation

- ↑ complementarity → facilitation under stress (Callaway et al. 2002)
- High physiological maintenance to cold and growth constraints may lower biomass

Hypothesis 2: Elevation governs the strength of mass-ratio and complementarity effects

❑ Conclusion

- Widening trait diversity can enhance species adaptability to changing environmental conditions; it reduces biomass accumulation, especially in high-elevation, stressful sites
- Multiple elements, important traits for understanding the functional role of ecosystem functioning
- Incorporating soil nutrients along elevation

THANK YOU

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https://doi.org/10.1007/s11430-023-1271-4

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Received August 3, 2023; revised January 19, 2024; accepted February 2, 2024; published online April 11, 2024

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