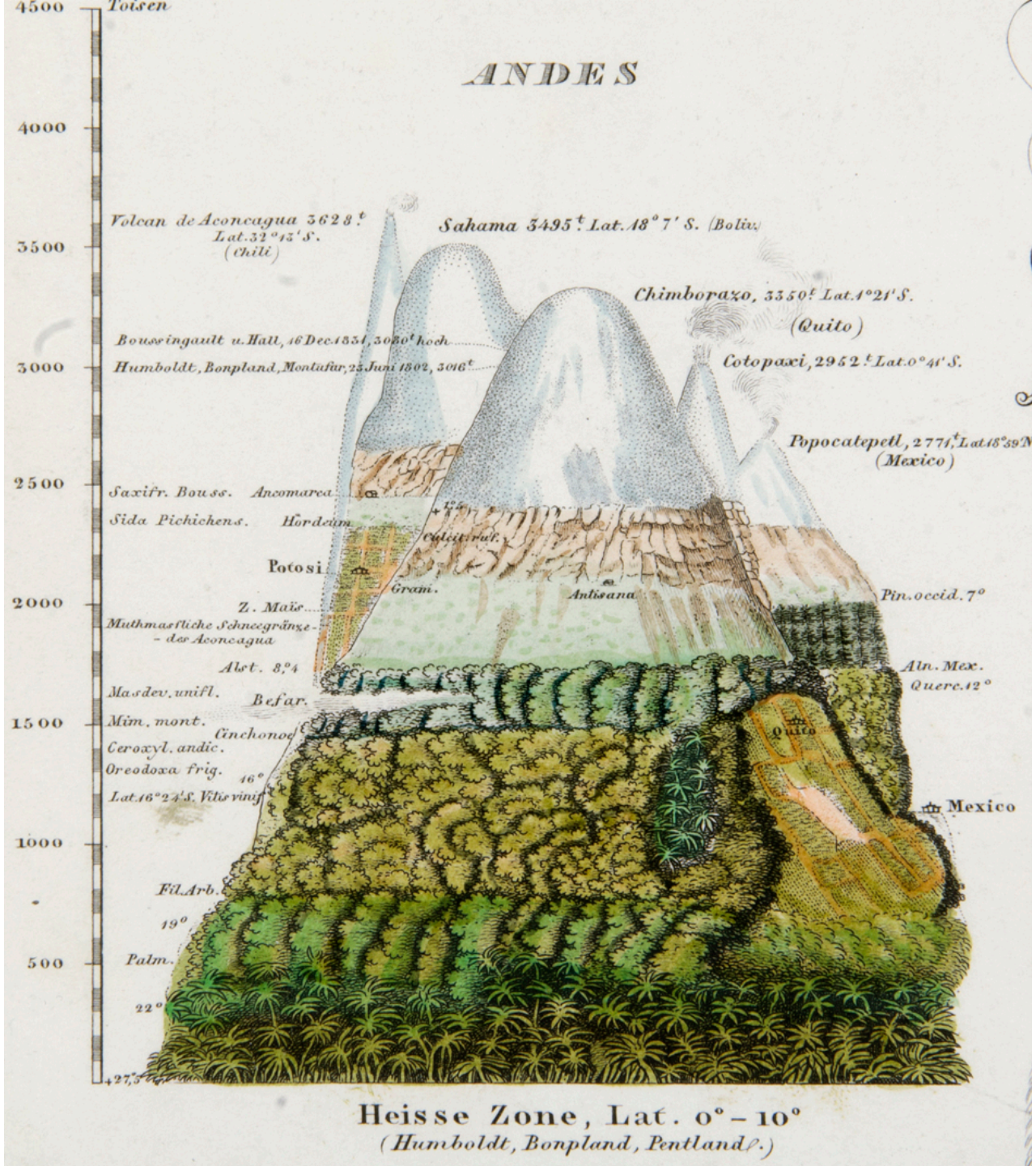
CCSD Center for Conservation and Sustainable Development

Missouri Botanical Garden

Climate change effects on Andean and Amazonian forests

William Farfan-Rios
Living Earth Collaborative Postdoctoral Fellow, Washington University in Saint Louis
Center for Conservation and Sustainable Development, Missouri Botanical Garden

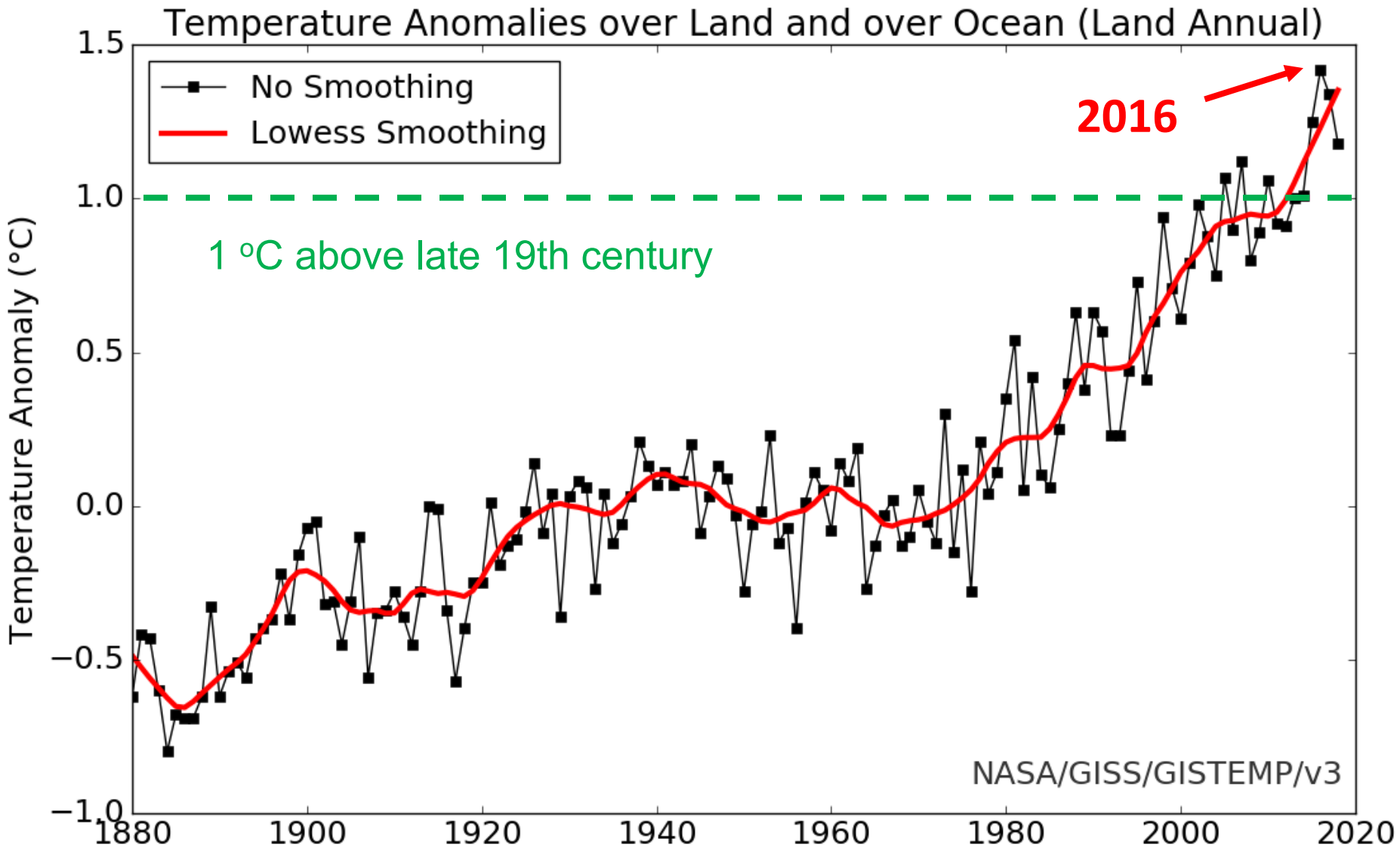
Miles Silman [1], Ken Feeley [2], Yadvinder Malhi[3] , Karina Garcia [1], Norma Salinas [4], Mark Bush [5], Patrick Meir [6], Sassan Saatchi [7], Oliver Phillips [8], Tim Baker [8] , Abel Monteagudo [8]
1 Wake Forest University, 2 Florida International University, 3 Oxford University, 4 Pontificia Universidad Católica del Perú, 5 Florida Institute of Technology, 6 University of Edinburgh, 7 Jet Propulsion Laboratory, 8 University of Leeds



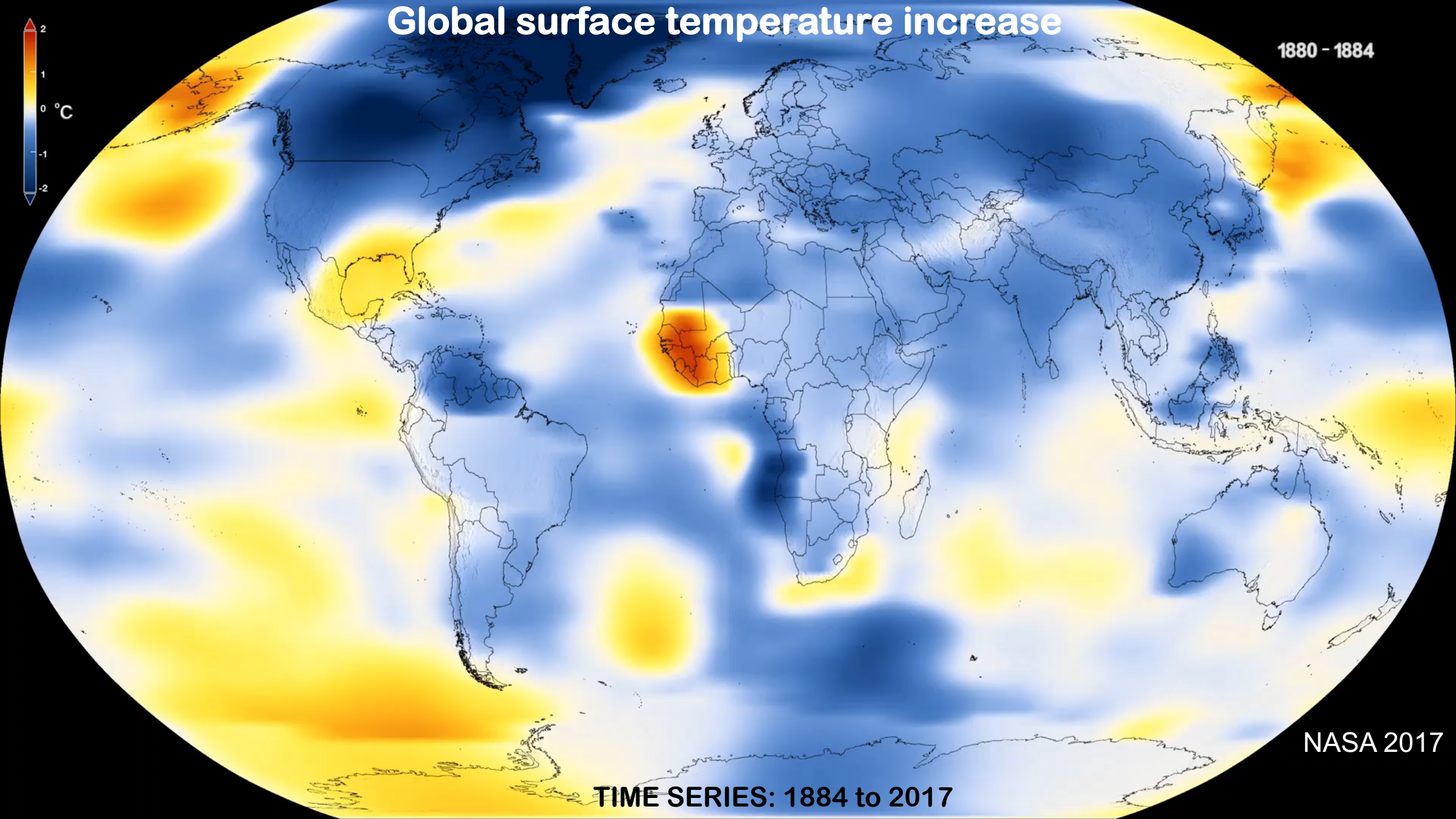
Alexander Humboldt, 1805


Species are distributed along environmental gradients
Courtesy: Adrian Tejedor

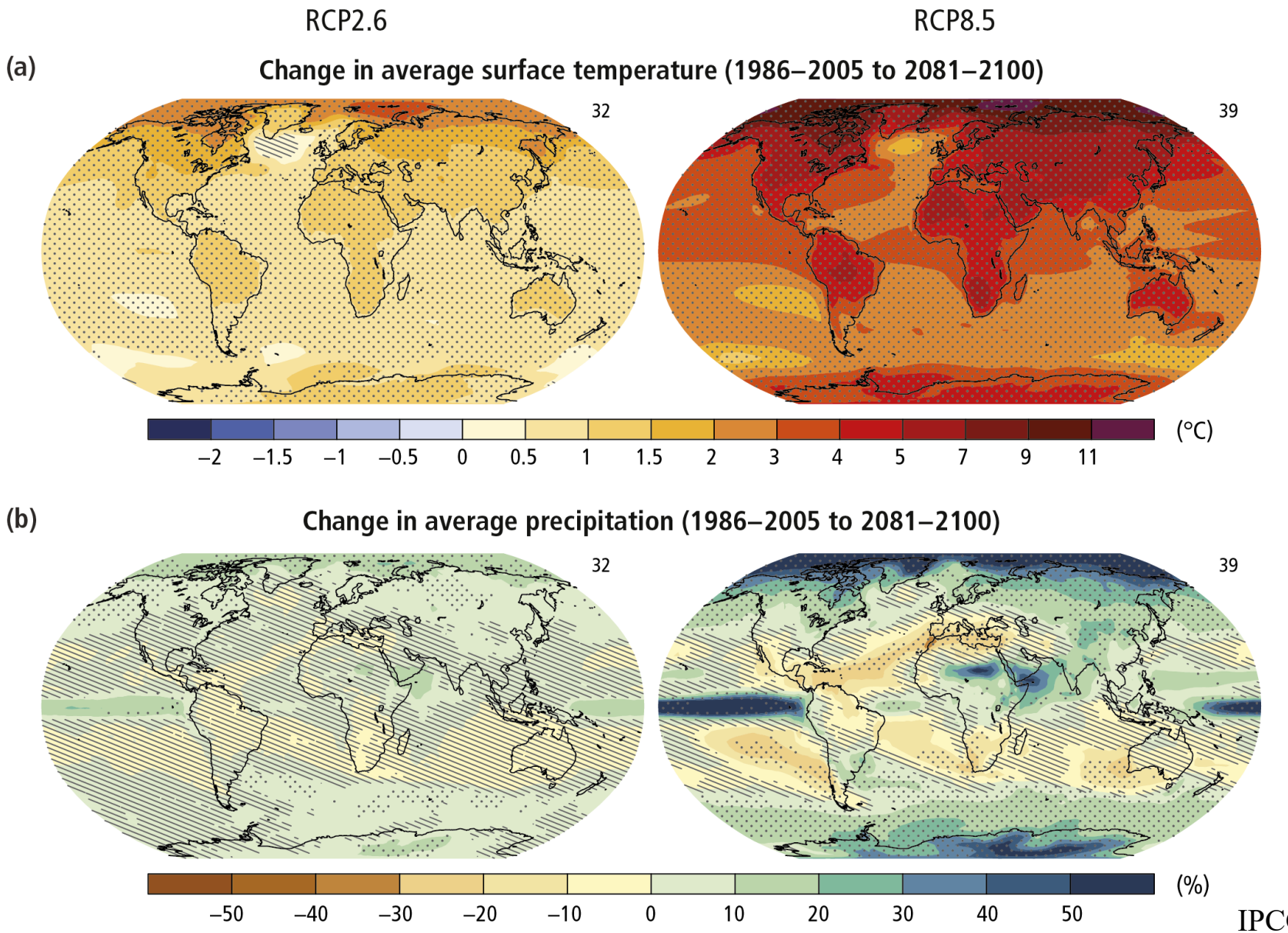
Current climate change



Global surface temperature increase



Projections of surface temperatures



IPCC 2014

- Tropical forests are highly vulnerable to climate change
- Species with narrow climatic ranges
- Biodiversity hotspot and high endemism
- We depend on them


Today

How are tropical forests responding to climate change?

1. Introduction to the Andes-to-Amazon elevational gradient in Southern Peru
    - General trends along the gradient

2. Are species shifting their distributional ranges?
    - Species migration

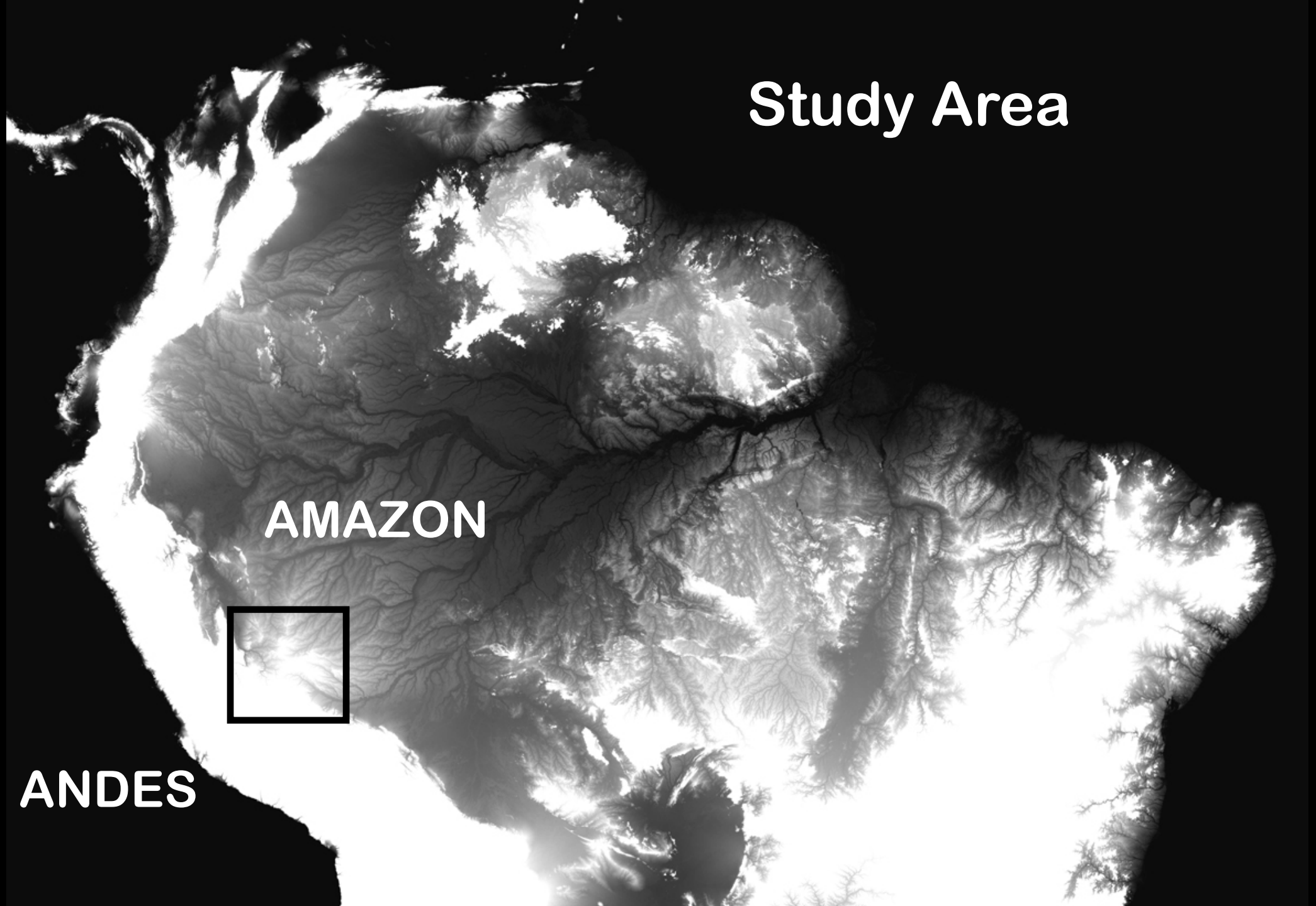
3. Are the changes in tree demography and species distribution affecting ecosystem function?
    - Carbon dynamics

How are tropical forests responding to climate change?

1. Introduction to the Andes-to-Amazon elevational gradient in Southern Peru
    - General trends along the gradient

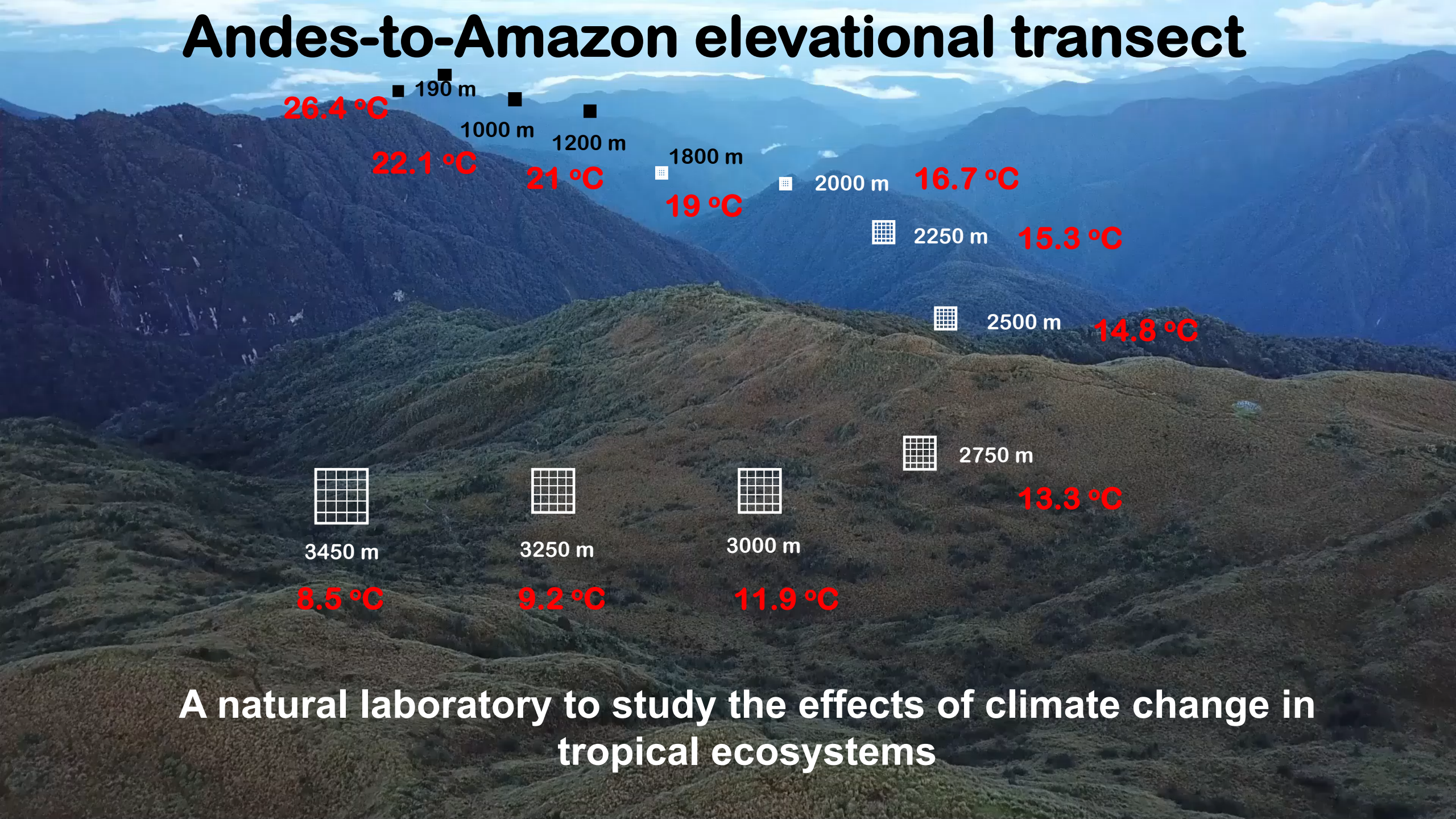
2. Are species shifting their distributional ranges?
    - Species migration

3. Are the changes in tree demography and species distribution affecting ecosystem function?
    - Carbon dynamics

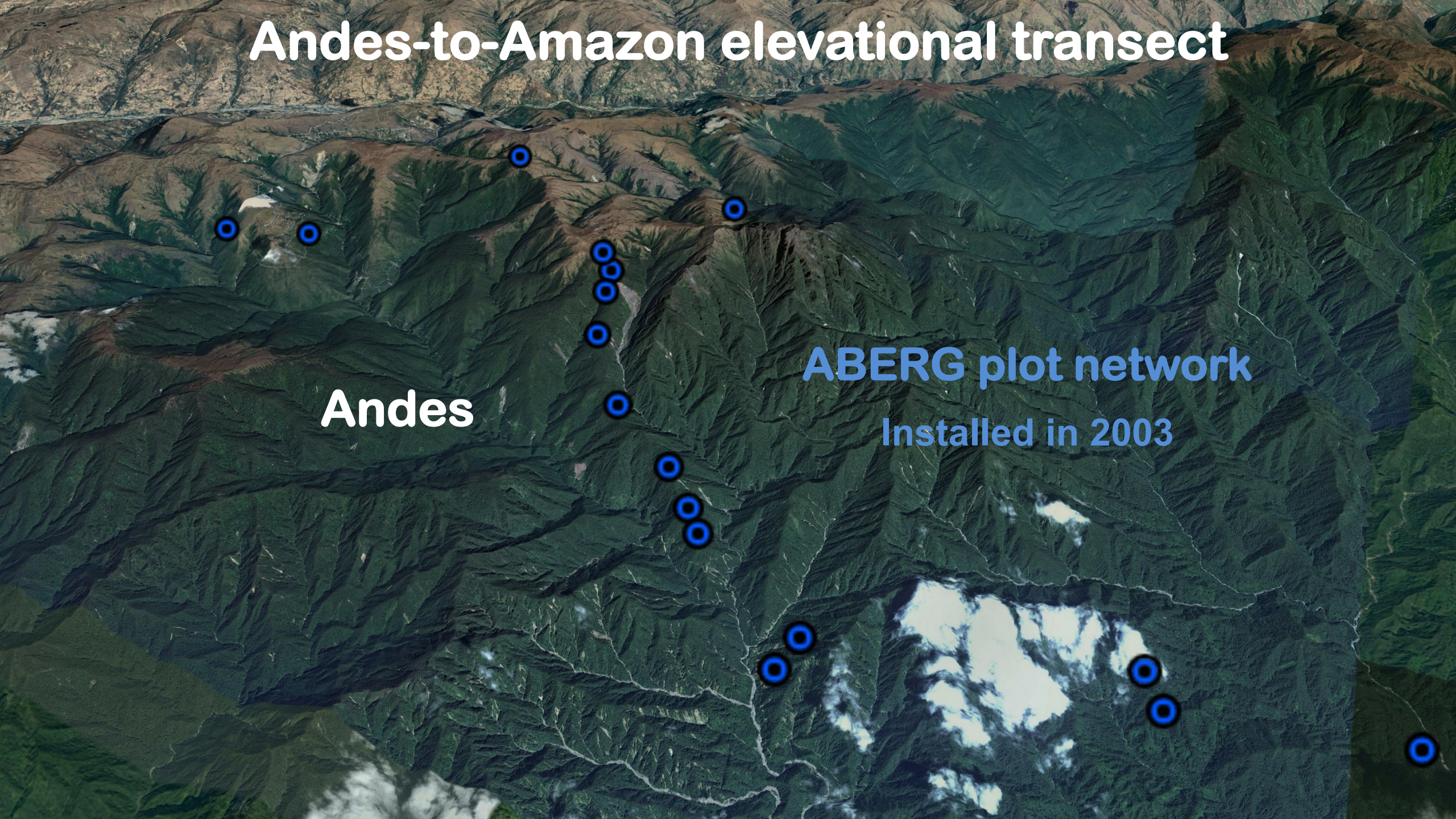

Study Area
AMAZON
ANDES


Courtesy: Adrian Tejedor

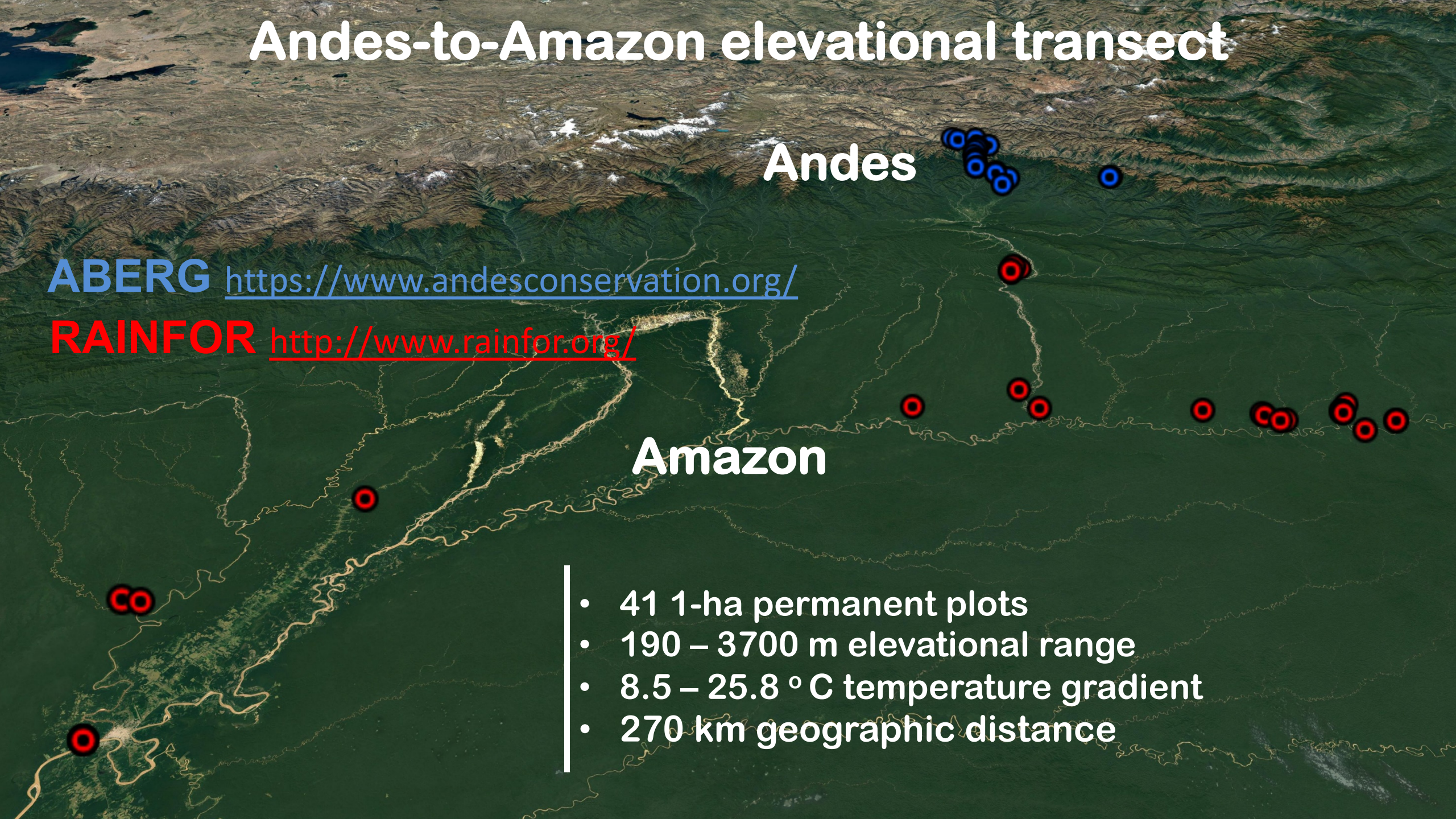
Andes-to-Amazon elevational transect



A natural laboratory to study the effects of climate change in tropical ecosystems


Andes-to-Amazon elevational transect
Andes
ABERG plot network
Installed in 2003

Andes-to-Amazon elevational transect



ABERG https://www.andesconservation.org/

RAINFOR http://www.rainfor.org/

- 41 1-ha permanent plots
- 190 – 3700 m elevational range
- 8.5 – 25.8 ºC temperature gradient
- 270 km geographic distance













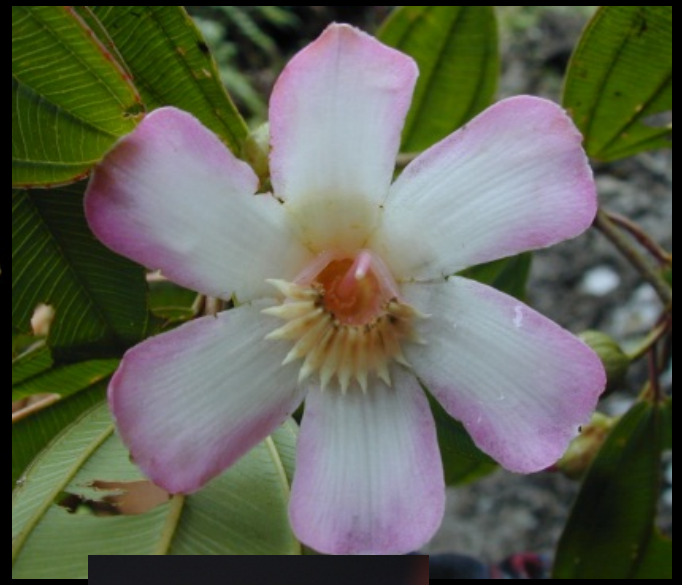
@W_FarfanRios

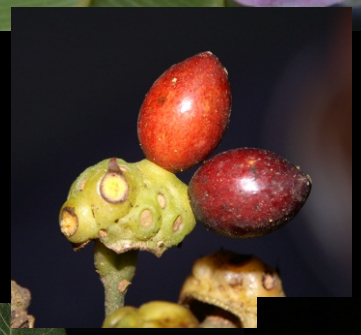

≥ 10cm DBH


≥10cm DBH


≥ 10cm DBH

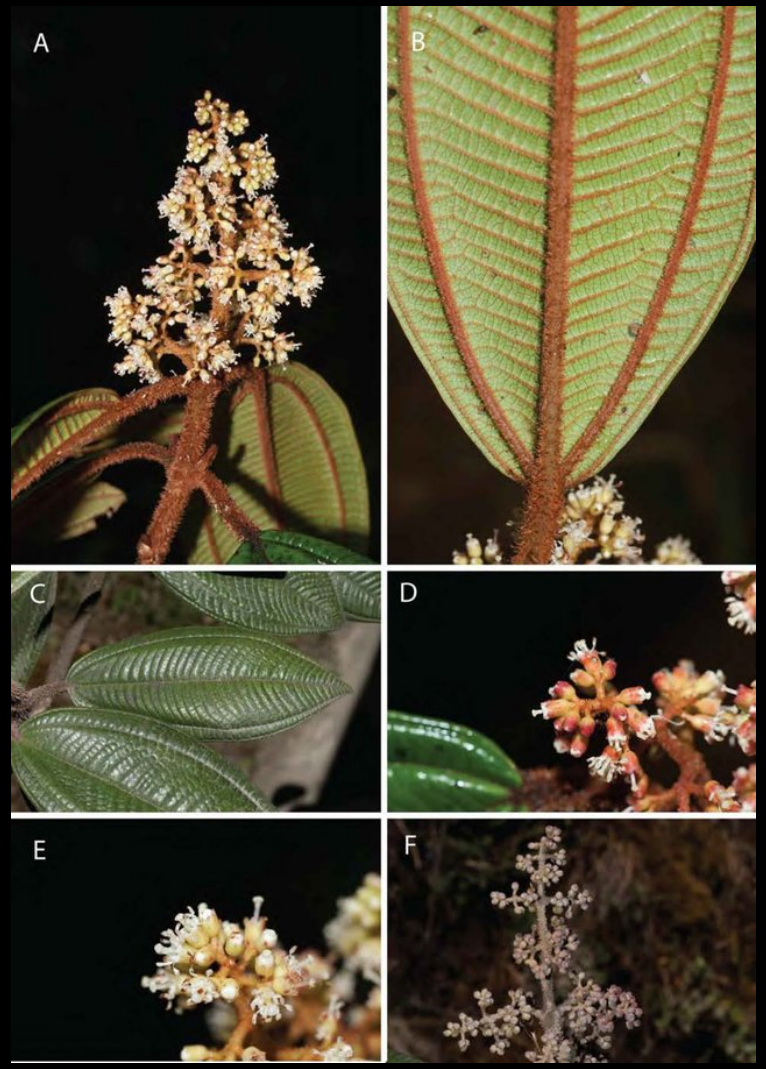

DBH, 43.4...






ANACARDIACEAE
CARDIOPTERIDACEAE
Compandaceae
CARYOCARACEAE
Nantenus

New tree species from the transect

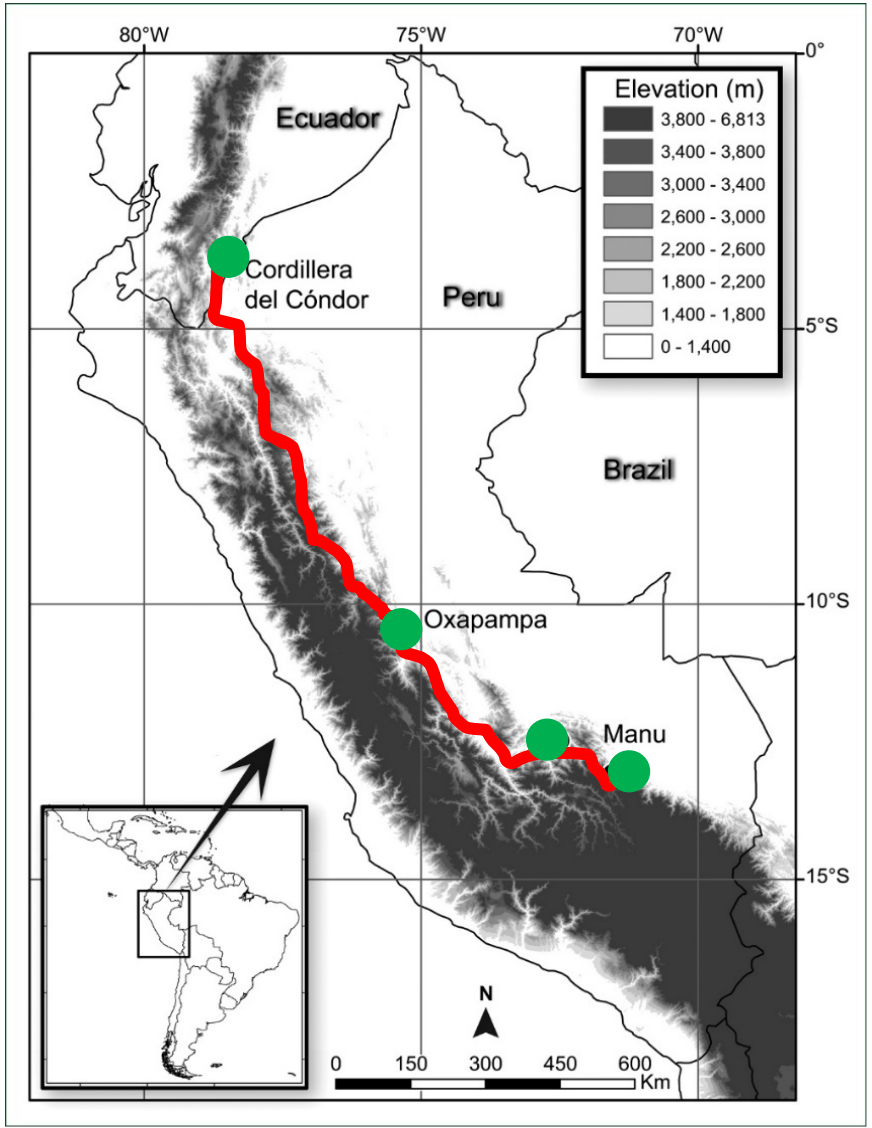


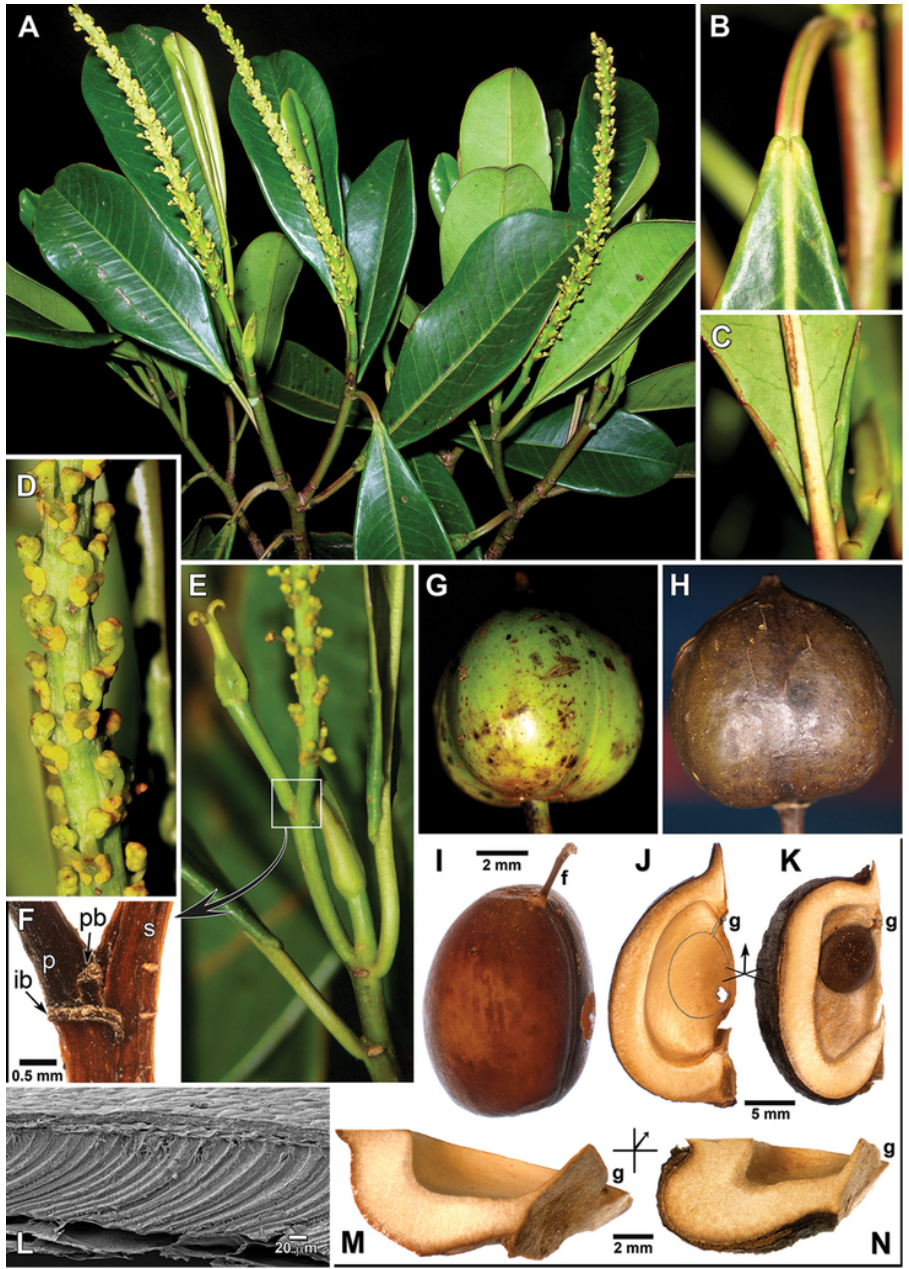
Miconia farfanii Burke & Michelang., sp. nov

Guatteria cuscoensis Maas & Westra, sp. nov.

Incadendron esseri Wurdack & Farfan-Rios, **gen. & sp. nov.**

- **Canopy tree, > 20 m height**
- **> 50 cm diameter**





Incadendron esseri Wurdack & Farfan-Rios, **gen. & sp. nov.**

- Equivalent to finding a new oak or new aspen tree

BOTANY ONE
News and Views on Plant Biology and Ecology

How does a tree hide? Incadendron was concealed in the Andes forest

By **Dale Maylea** - September 14, 2017

Hidden in plain sight - that's how researchers describe their discovery of a new genus of large forest tree commonly found, yet previously scientifically unknown, in the tropical Andes.

Suddenly a 100-foot Tall Tree Is Noticed in Andes, Turns Out to Be New Genu

Incadendron, on the Incan trail, joins the likes of the giganti tree noticed in Madagascar, a monkey with dark gonads and a lot of ants

HAARETZ

By Ruth Schuster | Sep 13, 2017

Send me email alerts

Perú 21

Inicio > Fotogalerías | Último minuto | Política | Opinión | Lima | Perú | Mundo | Cultura

¡Gran hallazgo! Científicos descubren el Incadendron, el árbol de los incas [FOTOS]

Smithsonian Insider
Bringing you everything under the sun

Home | Art | History & Culture | Science & Nature | Research News

Home / Science & Nature / Plants /

Remarkable new tree species was "hidden in plain sight" in the Andes

In Plants, Research News, Science & Nature / 13 September 2017

LE FIGARO.fr

Découverte d'un géant végétal sur un ancien chemin des Incas au Pérou

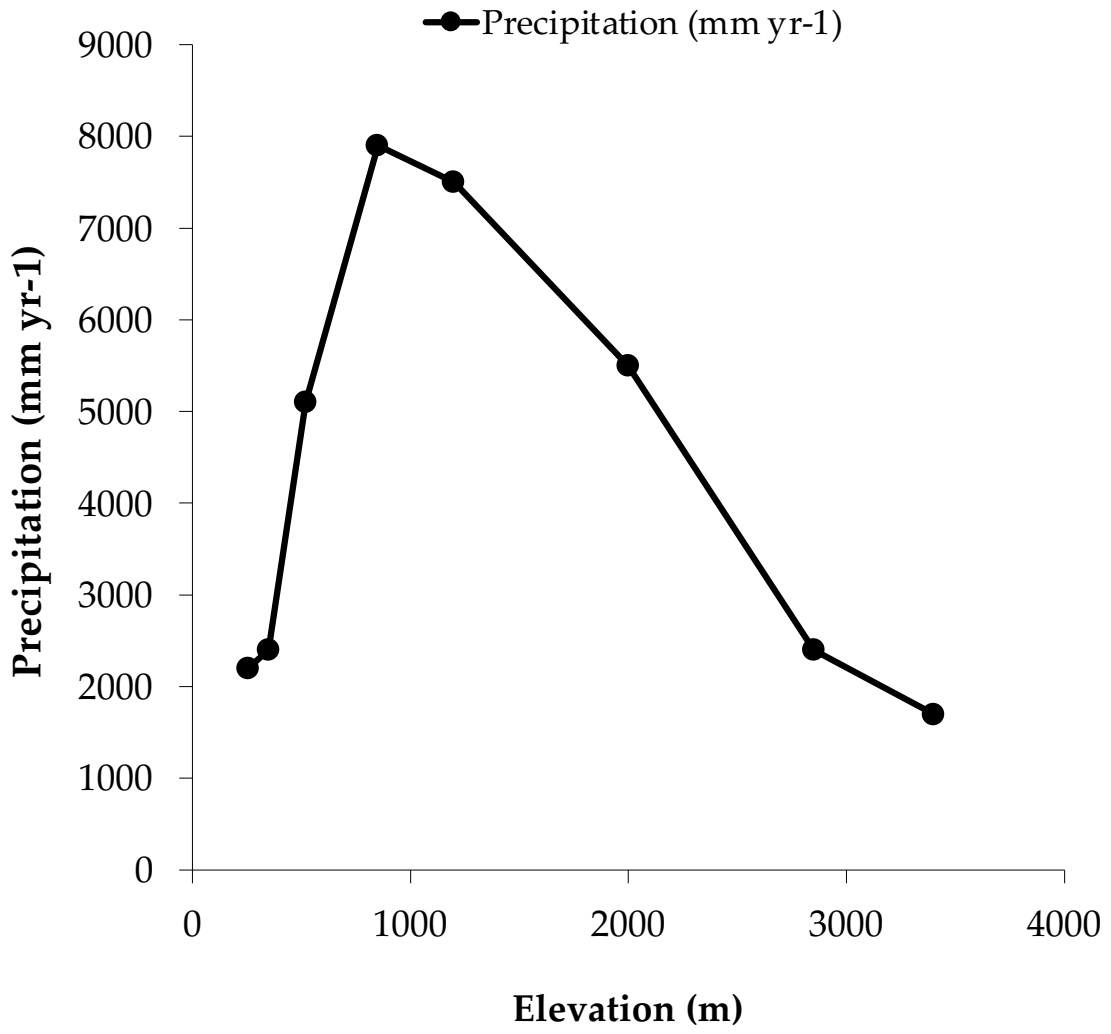
Par Jean-Luc Nothias | Publié le 13/09/2017 à 11:24

SCIENCE NEWS SEPT. 7, 2017 / 11:40 AM

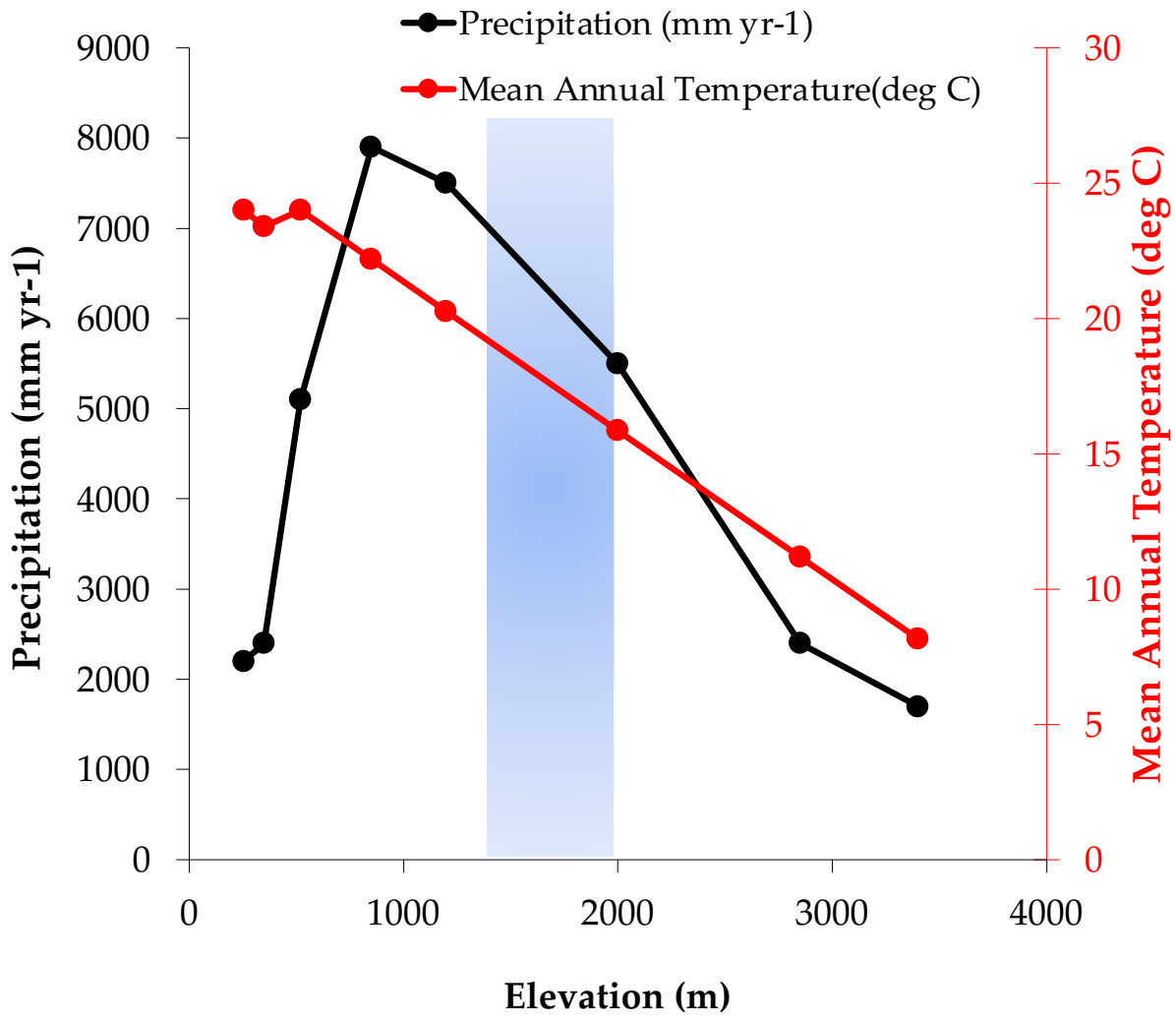
Researchers discover new tree genus in the Andes

"Incadendron tells us a lot about how little we understand life on our planet," researcher Miles Silman said.

Climate along the elevational gradient

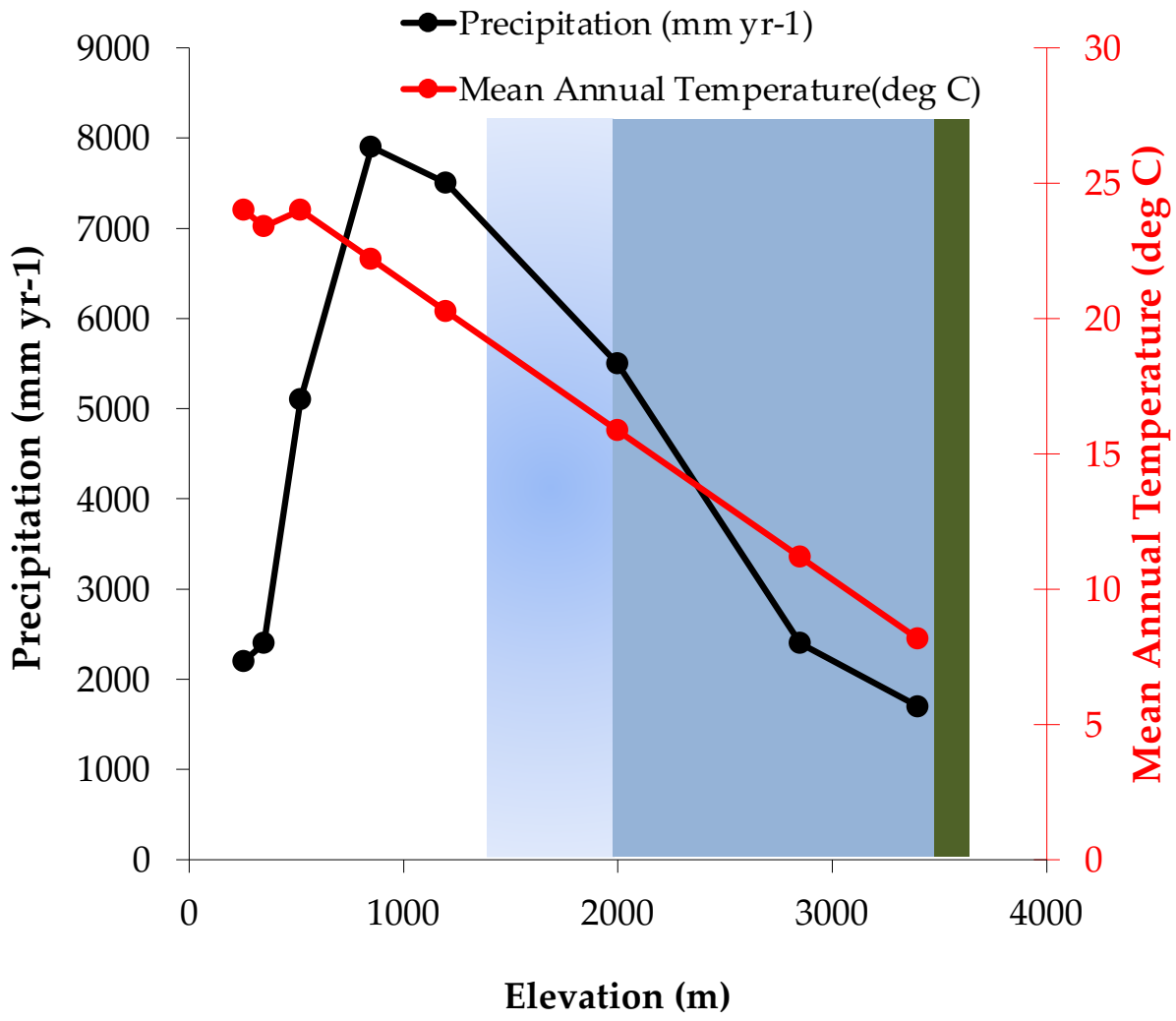


Climate along the elevational gradient




Cloud base

Climate along the gradient



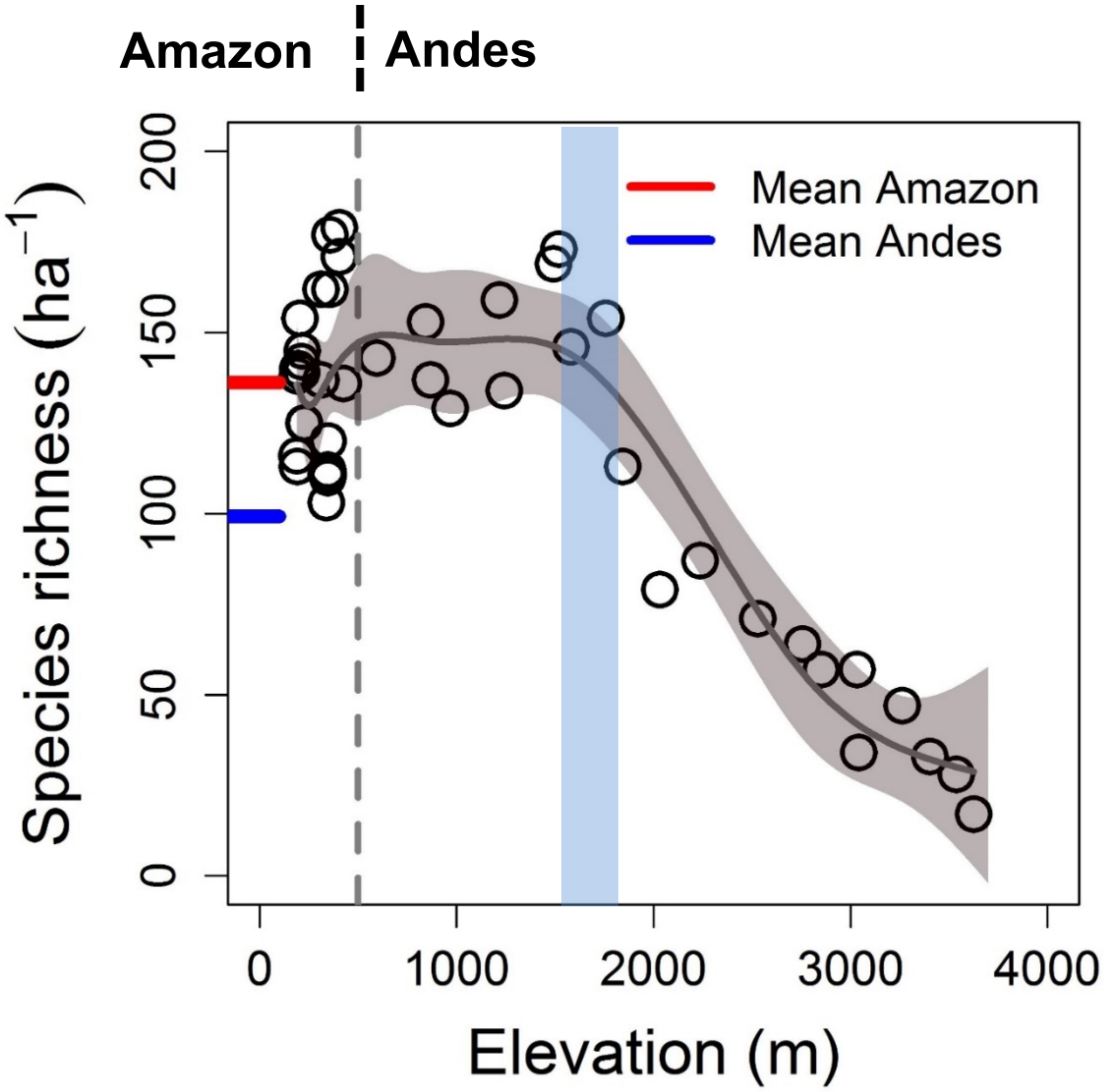
Lapse rate

5.5 ºC / 1000 m

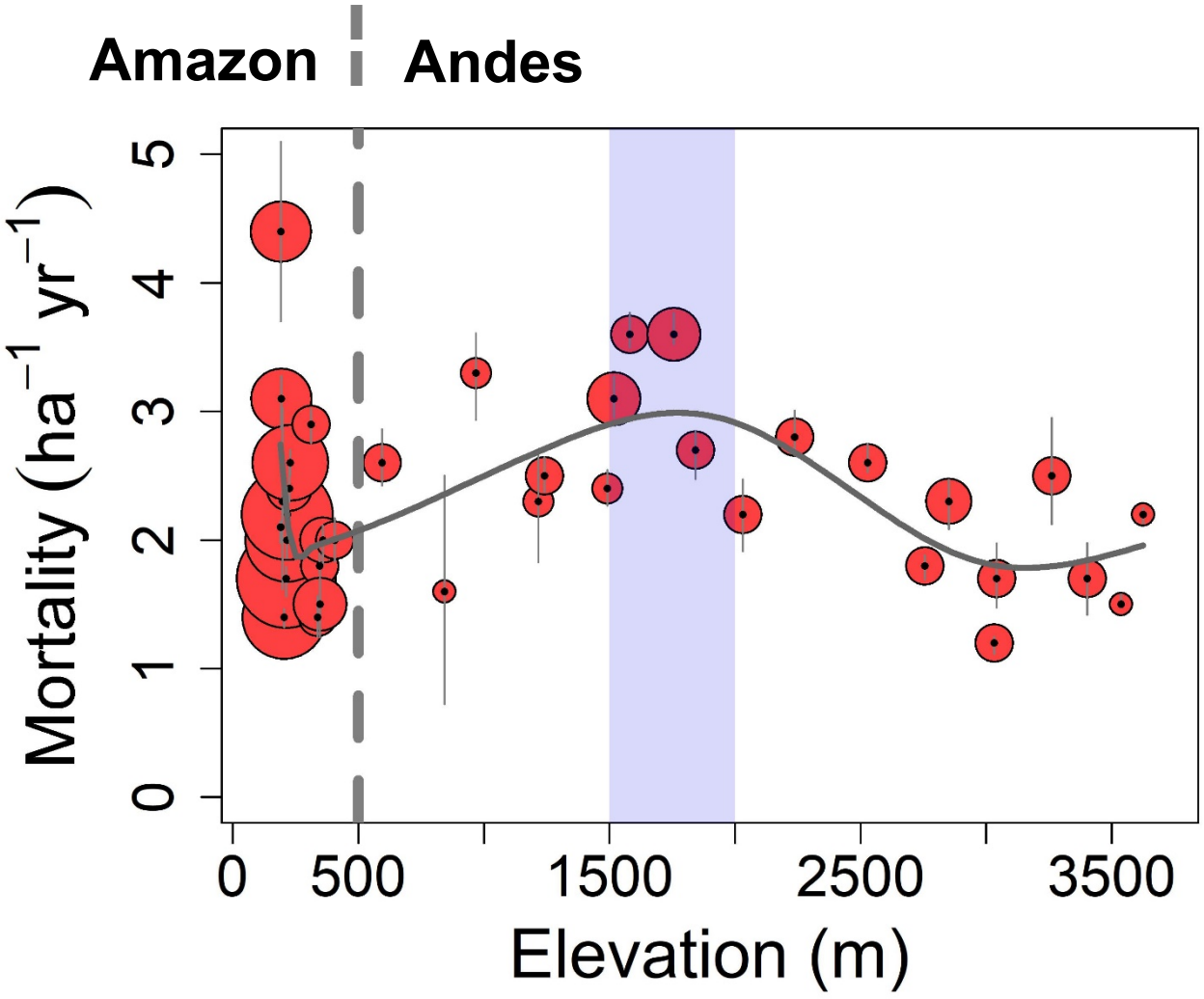
Forest inventory data

- 1979 – 2017 (38 years)
- Recensused every 2 – 4 years
- Trees, tree ferns, palms, lianas ≥ 10 DBH
- 42,631 individuals
- 1,902 species

Species richness constant to ~1700 m, then decreases



High tree mortality around cloud base

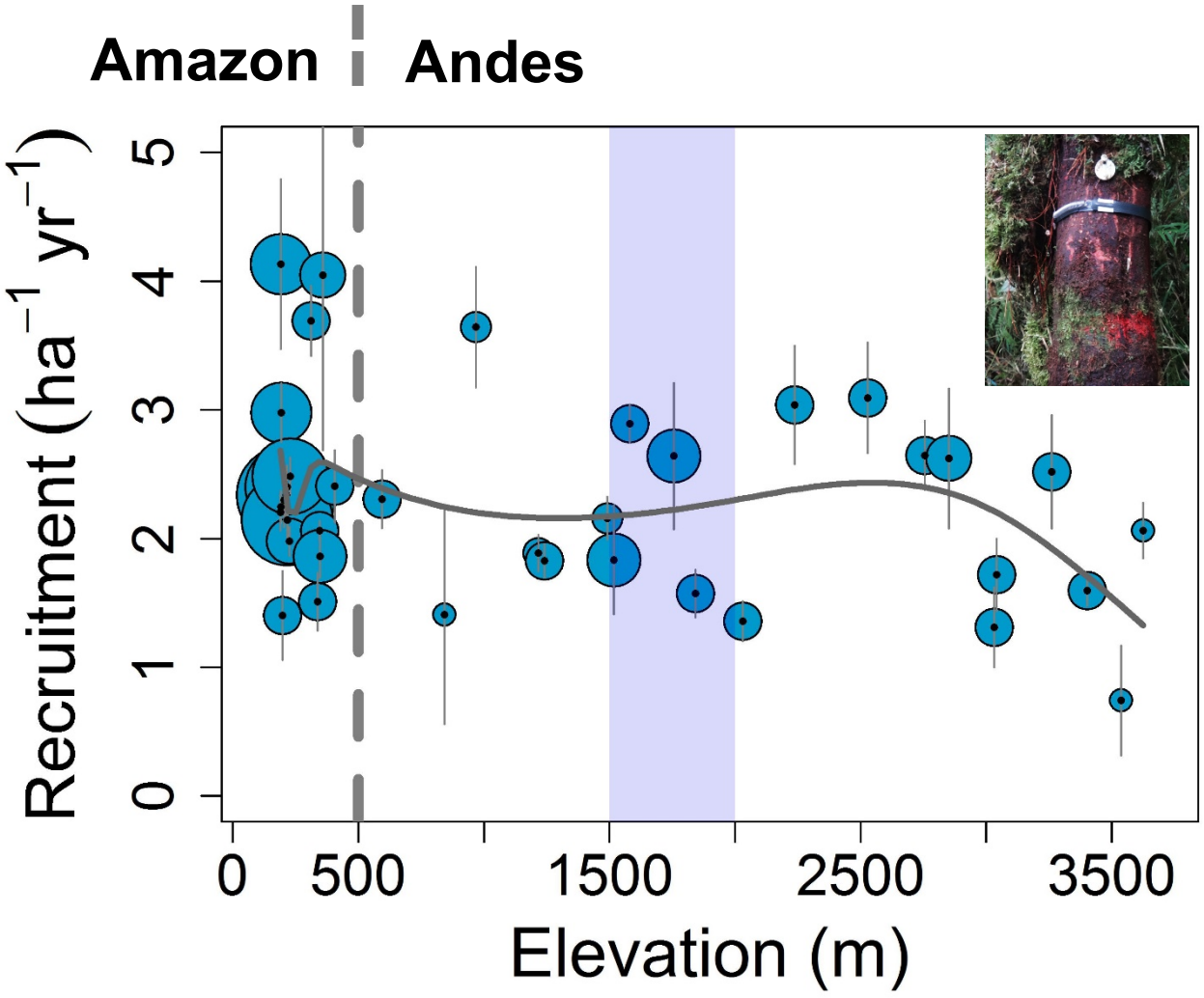


Mean: + 2.3 % yr $^{-1}$

Andes: + 2.4 % yr $^{-1}$

Amazon: + 2.2 % yr $^{-1}$

No trend in tree recruitment rates

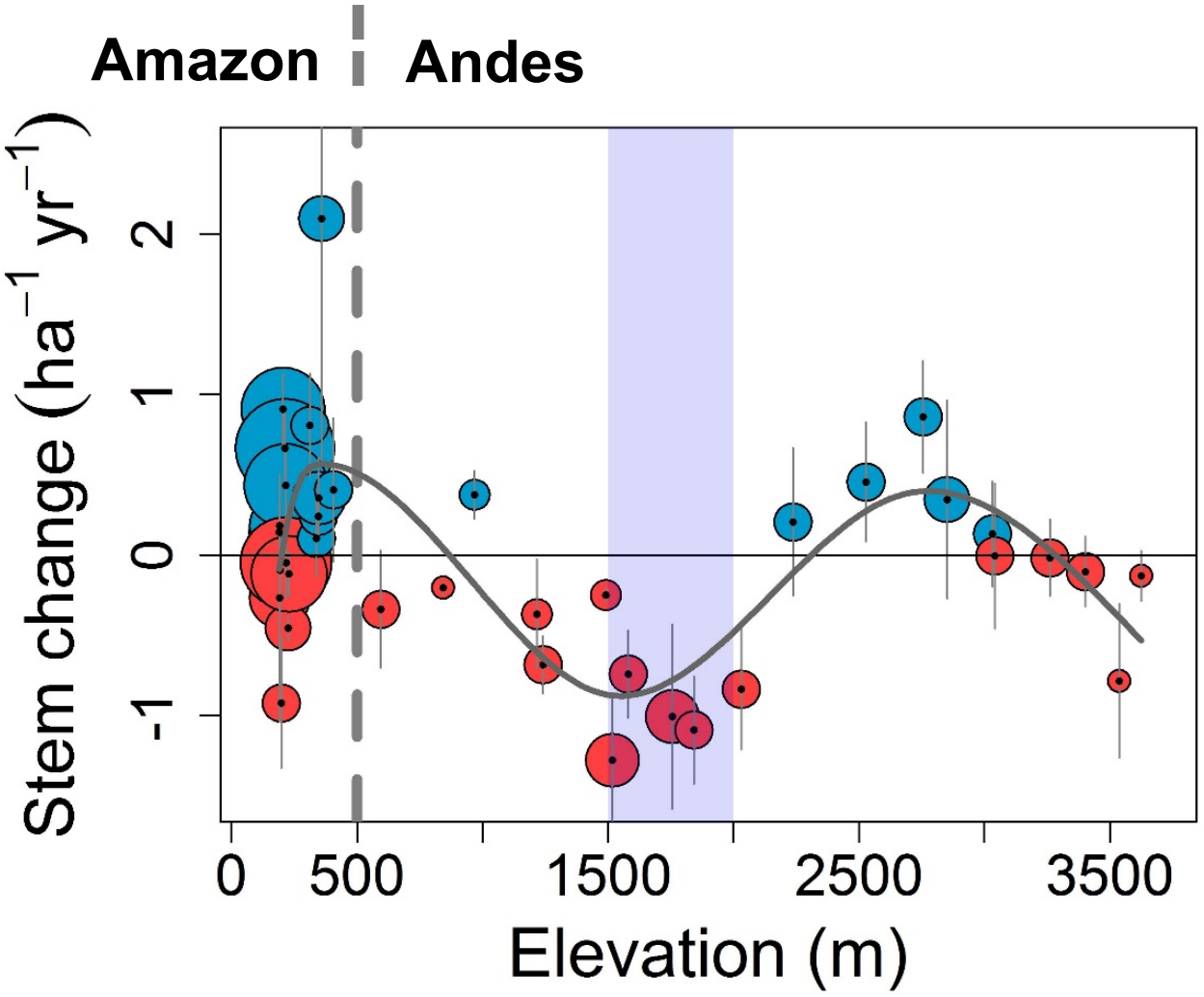


Mean: + 2.3 % yr $^{-1}$

Andes: + 2.1 % yr $^{-1}$

Amazon: + 2.5 % yr $^{-1}$

Tree stem density decline around the cloud base



Mean: - 0.03 % yr $^{-1}$

Andes: - 0.3 % yr $^{-1}$

Amazon: + 0.3 % yr $^{-1}$

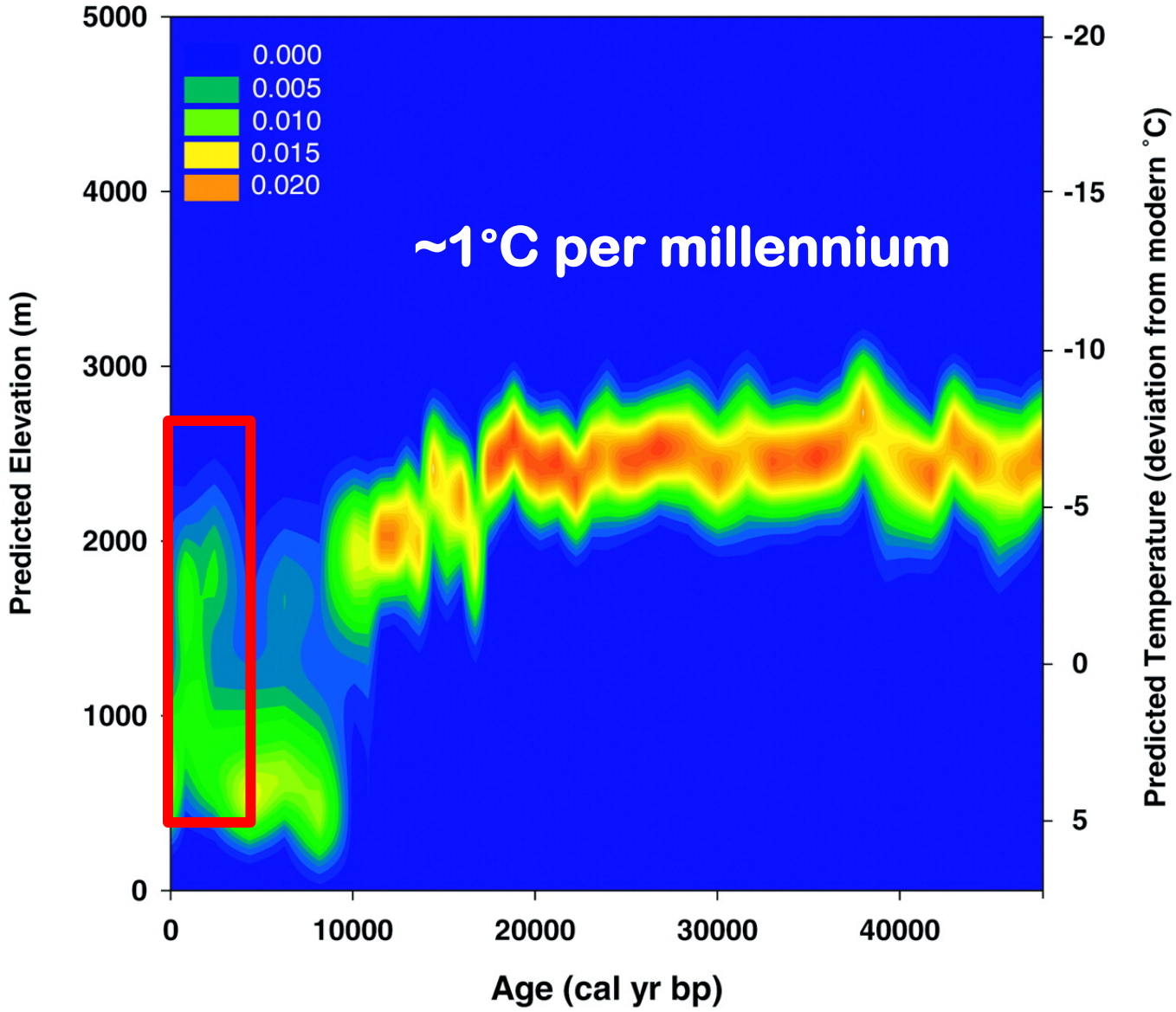
How are tropical forests responding to climate change?

1. Introduction to the Andes-to-Amazon elevational gradient in Southern Peru
    - General trends along the gradient

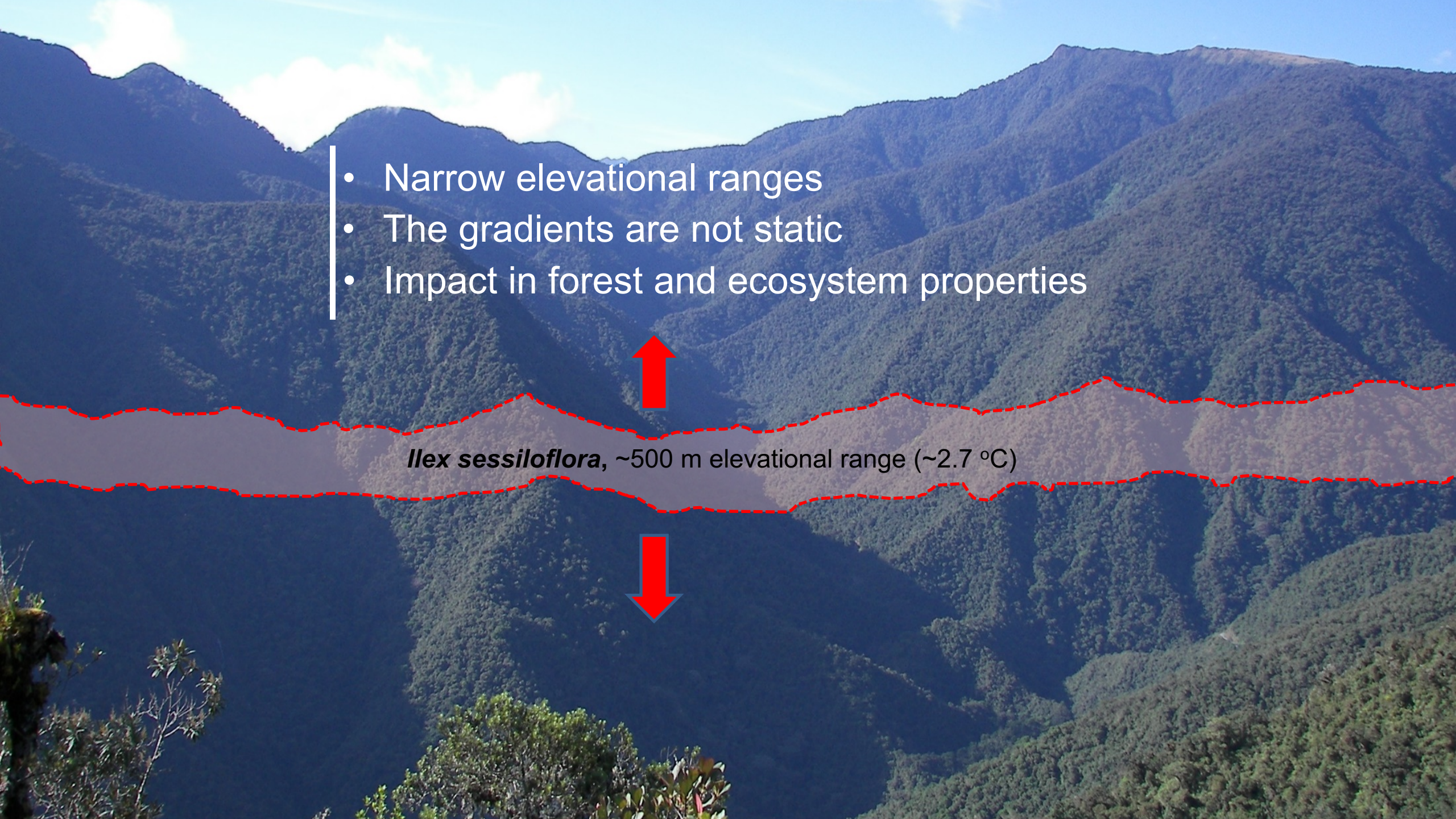
2. Are species shifting their distributional ranges?
    - Species migration

3. Are the changes in tree demography and species distribution affecting ecosystem function?
    - Carbon dynamics

Paleo evidence for species migration



Bush, Silman, Urrego. 2004

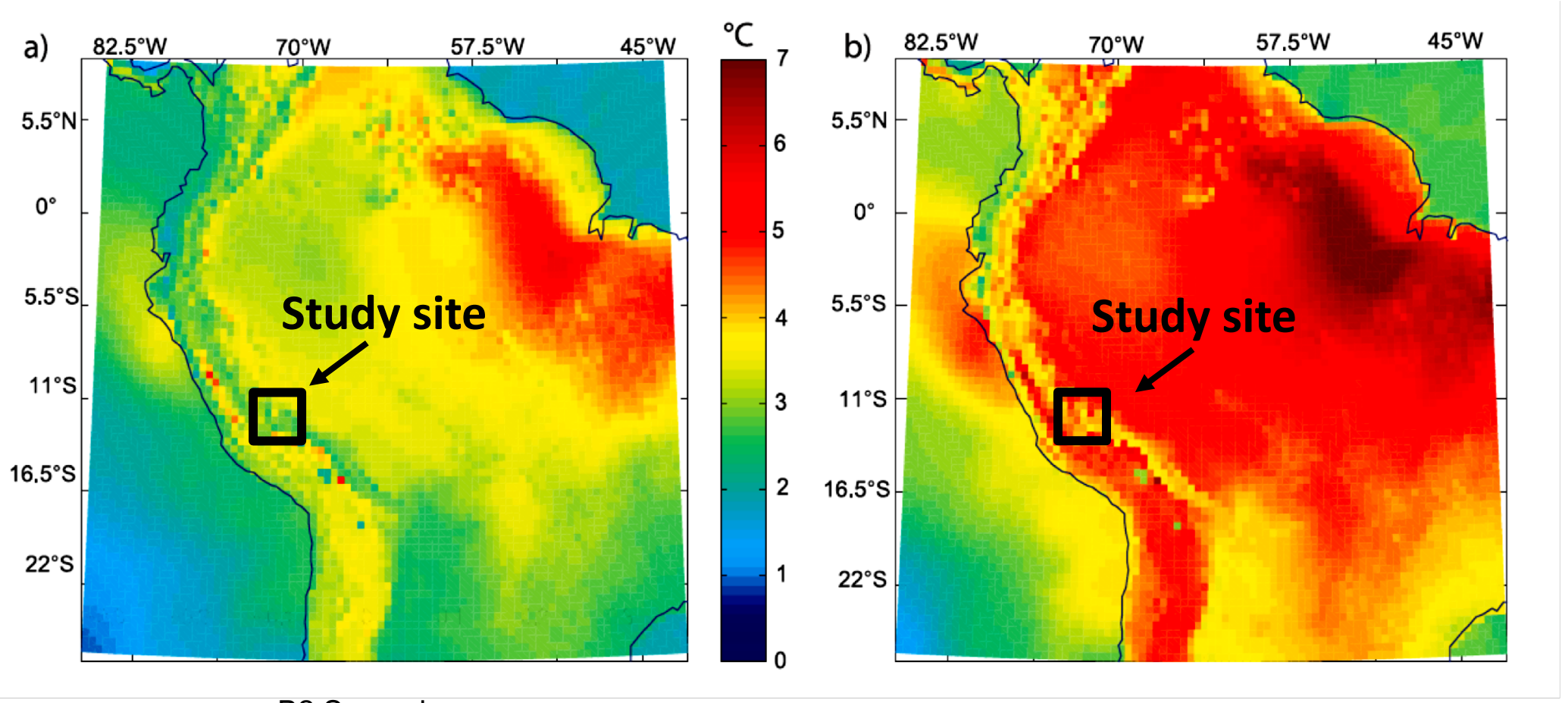

• Narrow elevational ranges
• The gradients are not static
• Impact in forest and ecosystem properties
***Ilex sessiloflora*, ~500 m elevational range (~2.7 °C)**

Andes-to-Amazon elevational transect

Observed temperature increase

0.03 - 0.05 °C year $^{-1}$ since 1950s

Temperature projections for southeastern Peru



B2 Scenario

A2 Scenario

> 4.5 ºC

Urrutia and Vuille, 2009

2. Are species shifting their distributional ranges?

Thermophilization hypothesis (community)

Wisdom of the crowd

Migration hypothesis (taxon-based)

Population shifts

Thermophilization process

Climate change

Shifts of species distribution

(+)

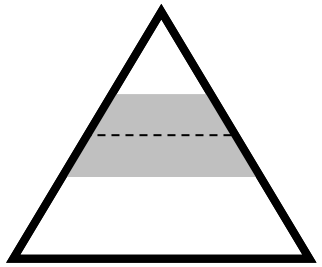
Warm-adapted

Cold-adapted

(-)

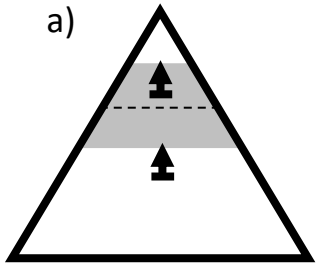
Coupling demography with migration shifts

Elevational range of species



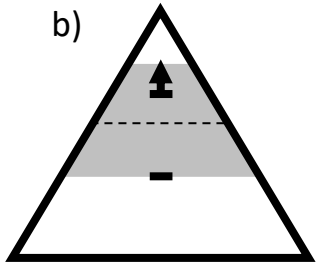
Global warming

a)



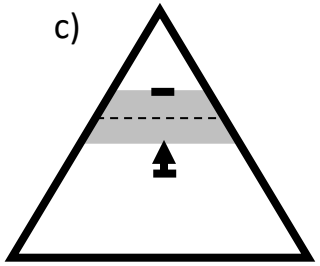
Shifting range
Upper limit recruitment same rate as lower limit mortality

b)



Expanding range
Upper limit recruitment greater than lower limit mortality rate

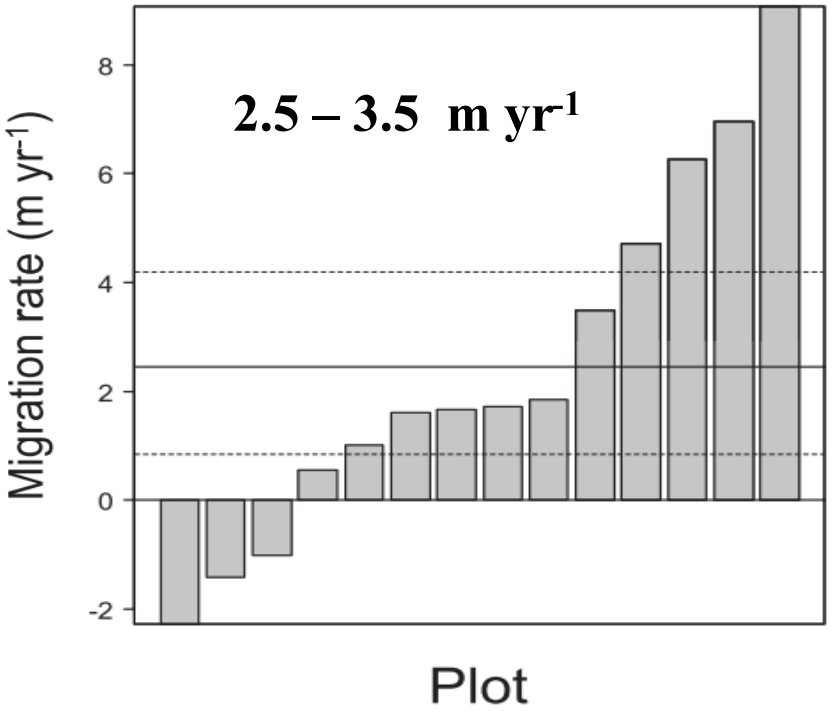
c)

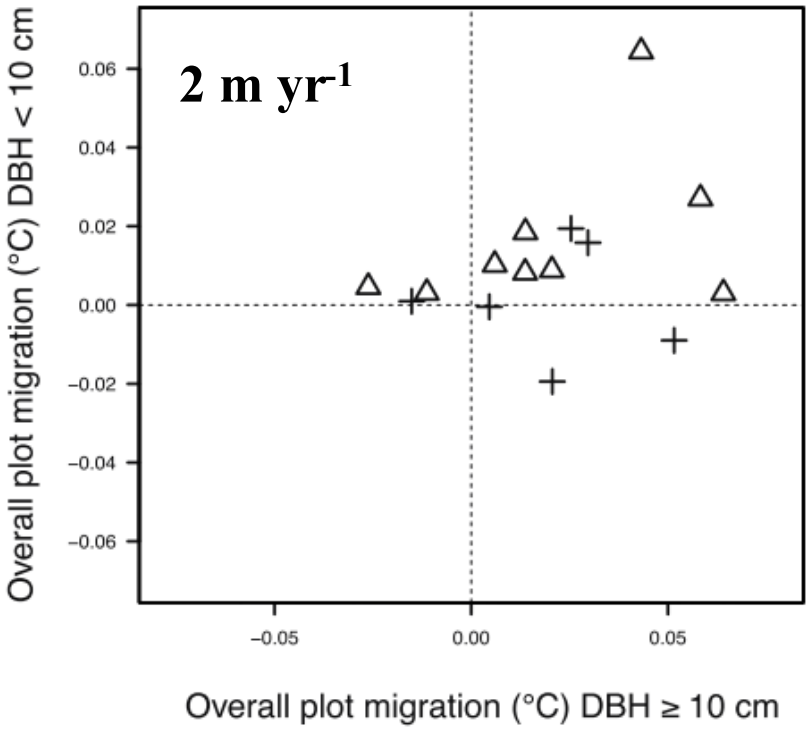


Contracting range
Lower limit mortality greater than upper limit recruitment rate

Plant species migration in the Andes

Andean plots over 500 m elevation

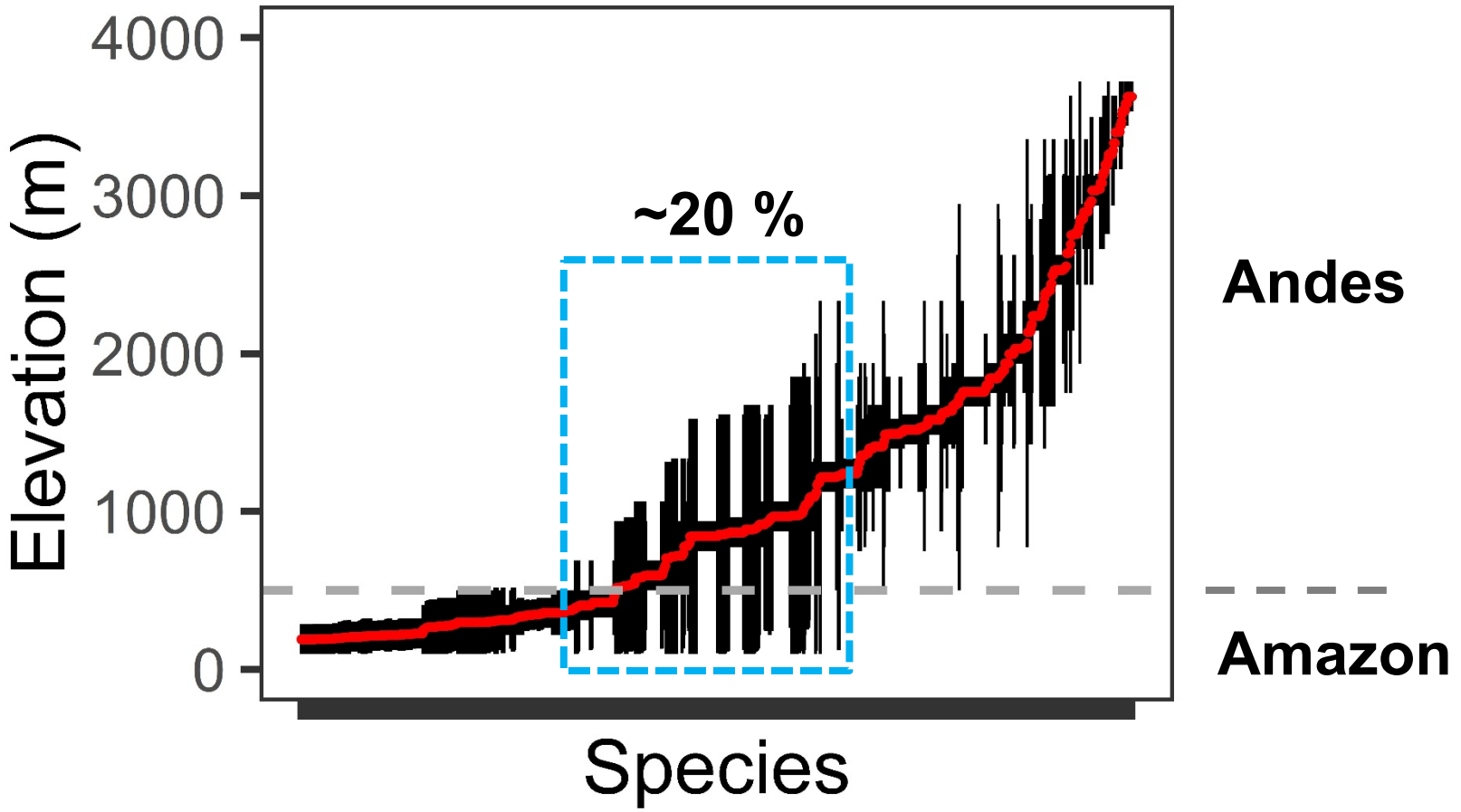




Feeley, Silman *et al.,* 2011

Duke *et al.,* 2015

But, maybe there are some caveats with those results



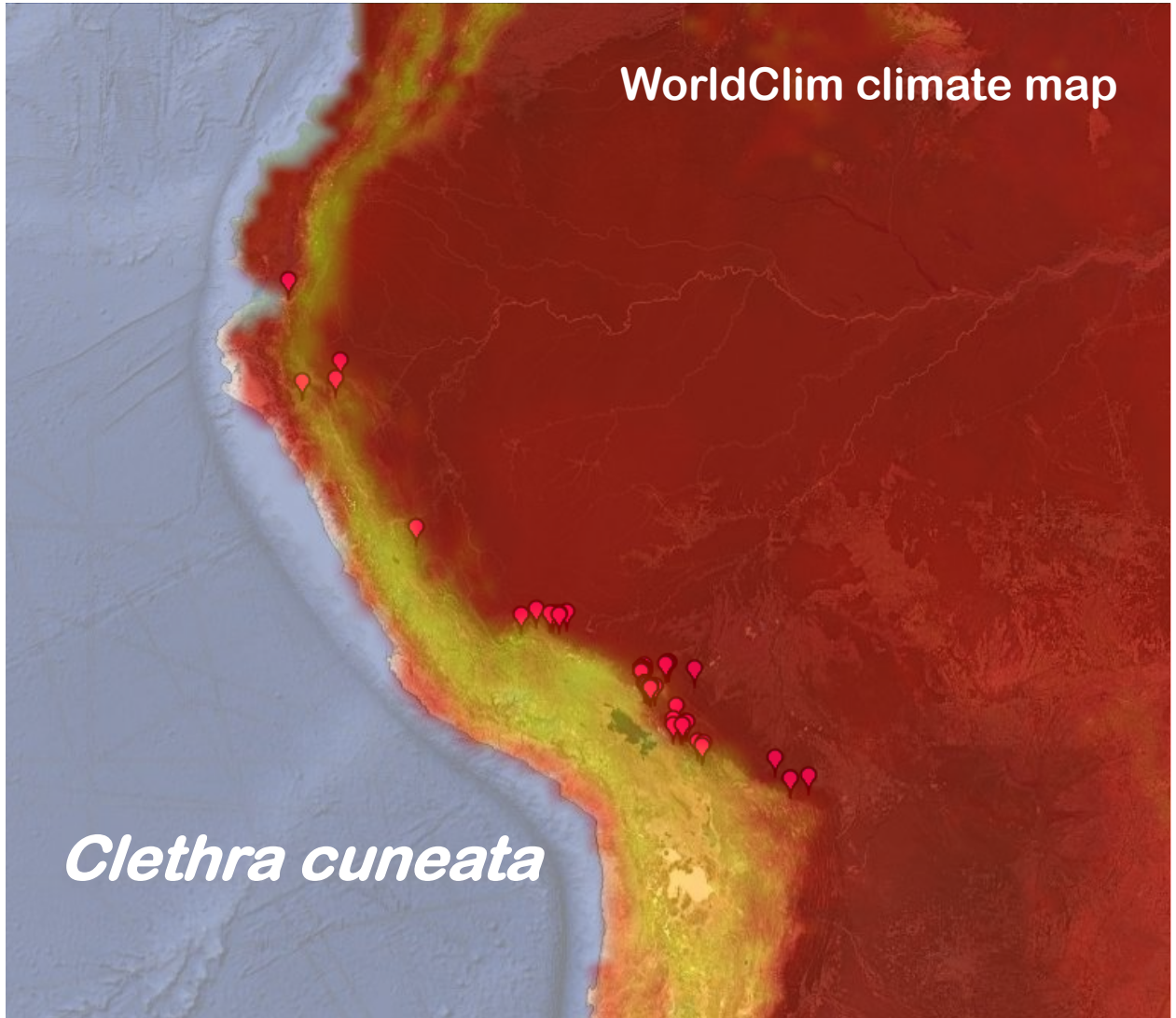

1
BA=0.07 m²ha⁻¹
2
BA=1.04 m²ha⁻¹
3
BA=0.01 m²ha⁻¹
But, some trees are more equal than others

Thermophilization calculations

- **Community thermal migration rates (thermophilization)**
  - **Species thermal optima distributions**
    - BIEN/GBIF collections records (minimum 10 collections)

Species thermal optima distributions

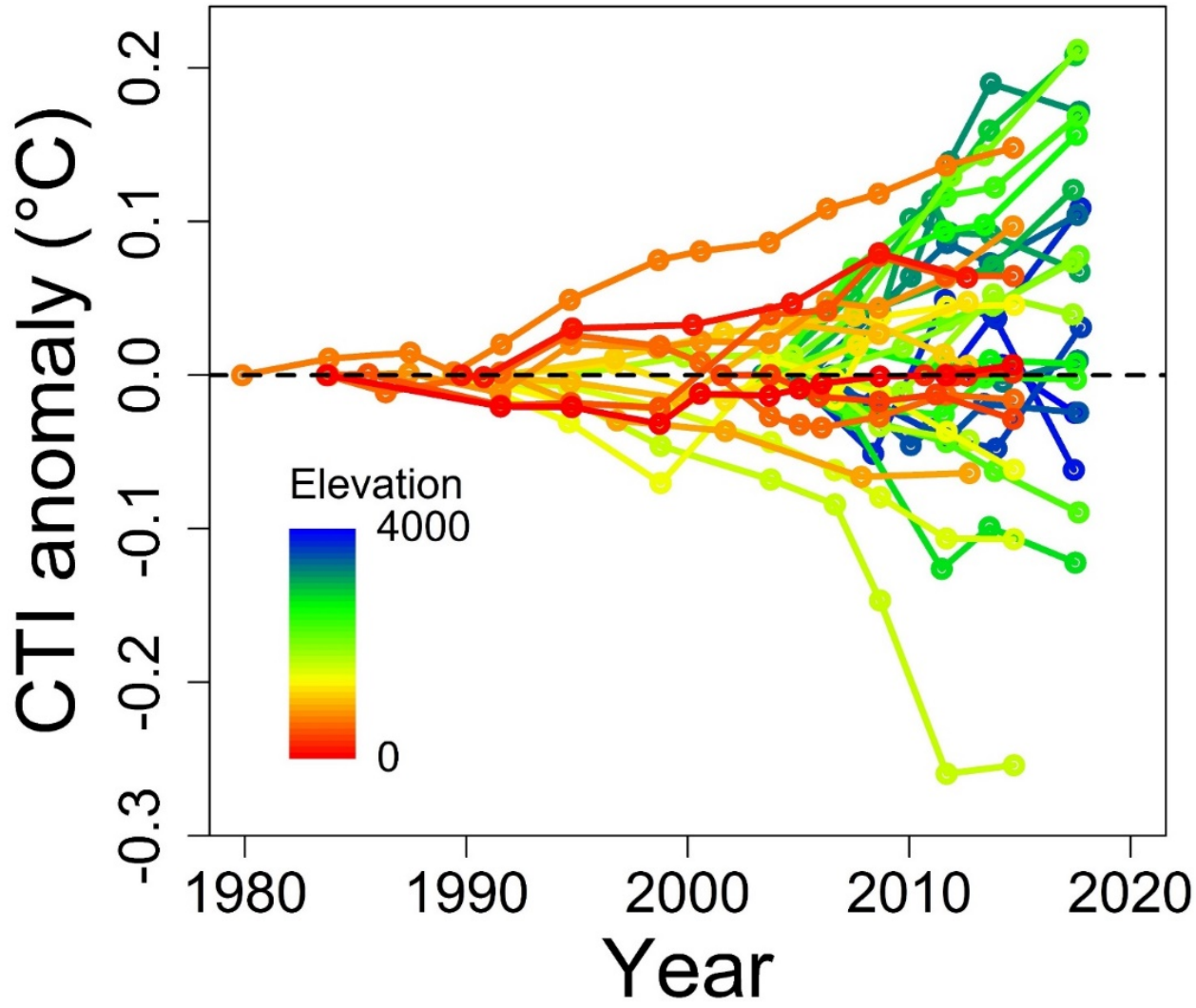
- Downloaded all available georeferenced BIEN/GBIF herbarium records
- The mean annual temperatures (MAT) from WorldClim climate map



Thermophilization calculations

- **Community thermal migration rates (thermophilization)**
  - **Species thermal optima distributions**
    - BIEN/GBIF collections records (minimum 10 collections)
  - **Community temperature index (CTI)**
    - Average thermal optima weighted basal area
  - **Thermophilization rates**
    - Net change in CTI values for each plot over all consecutive censuses
- **Species thermal migration rates**
  - **Most abundant species**
    - ≥ 50 individuals, ≥ 2 plots

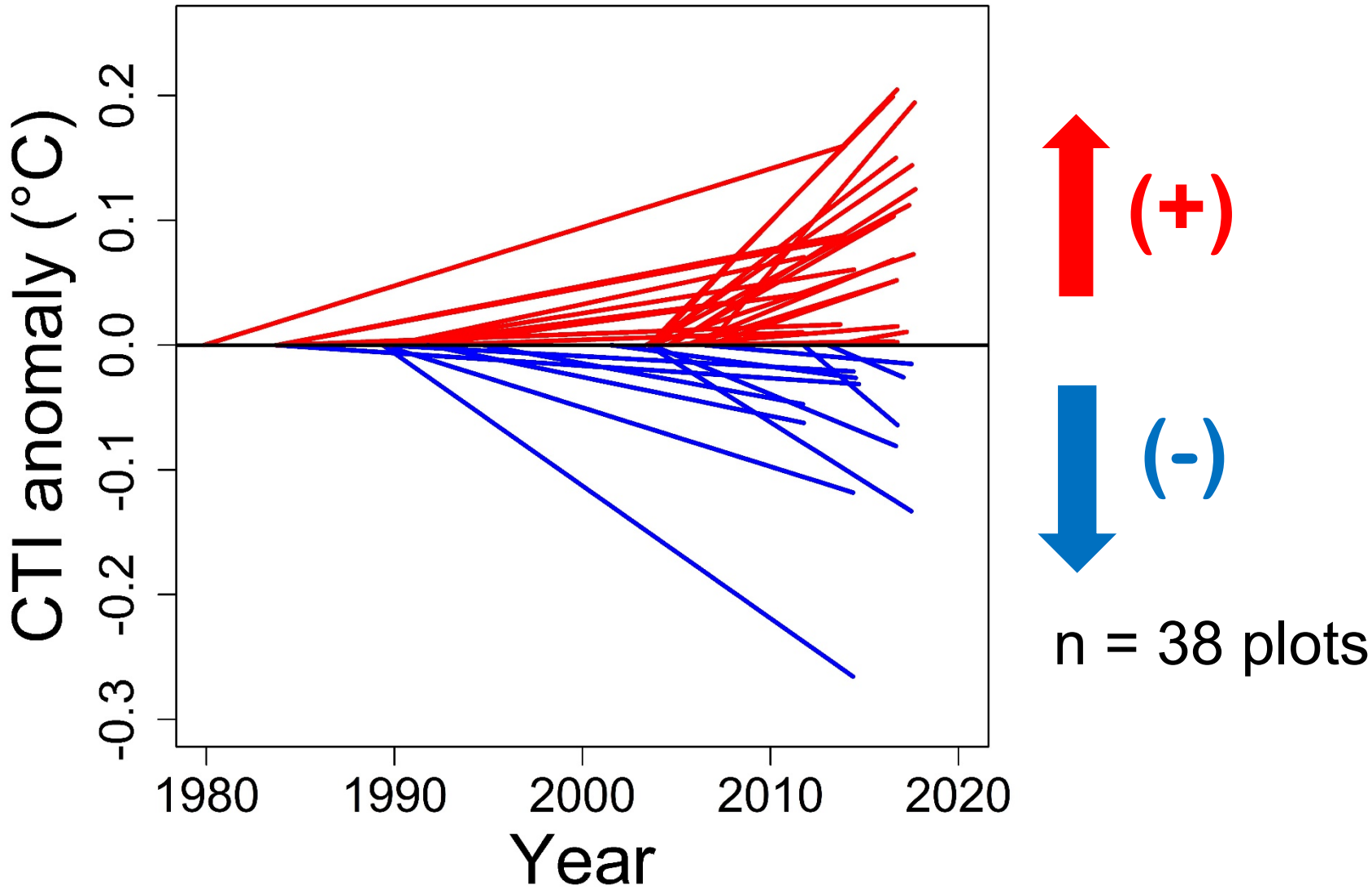
Evidence of thermophilization (TR)



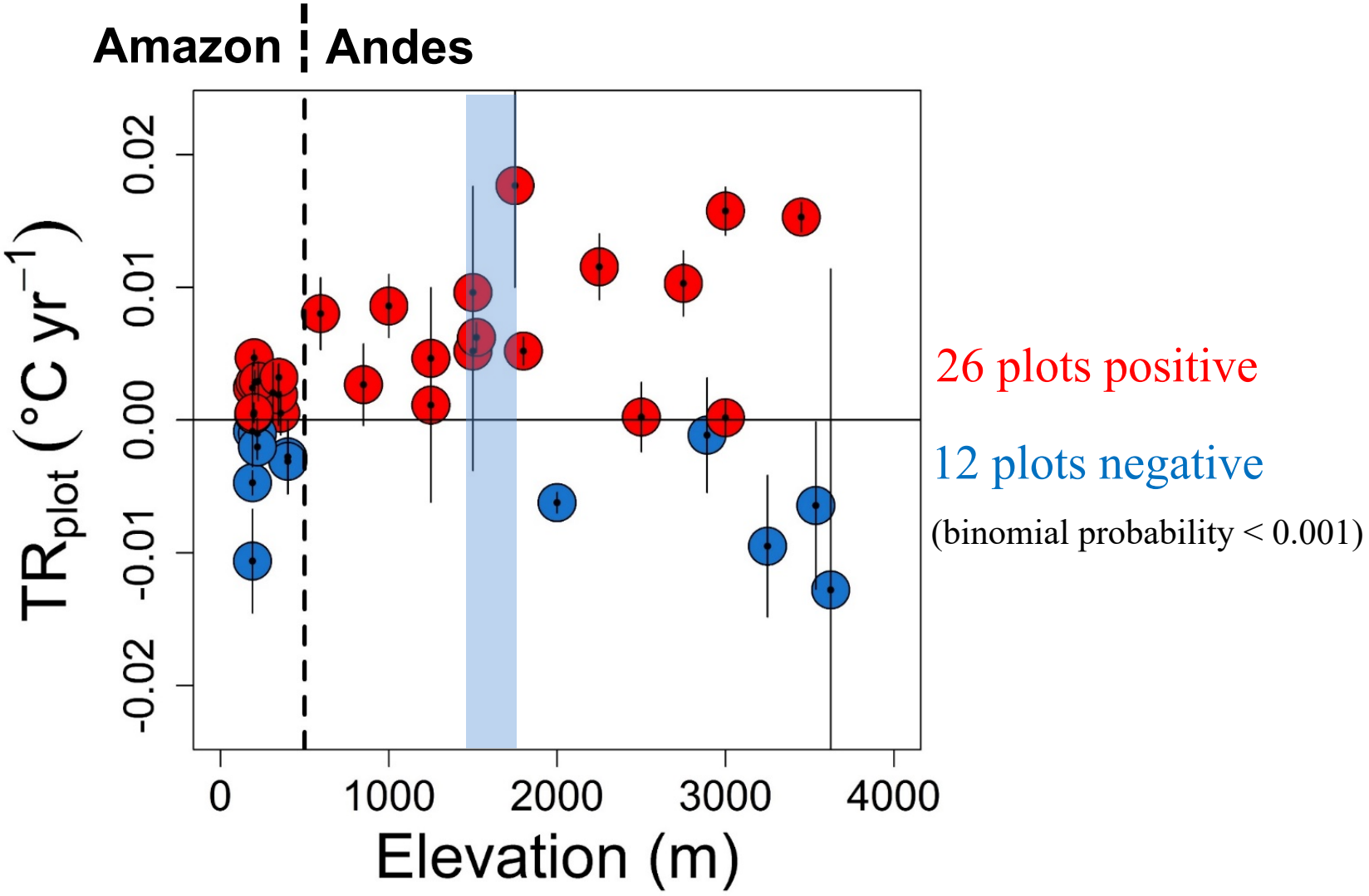
(+)

n = 38 plots

Evidence of thermophilization (TR)



Positive community thermophilization

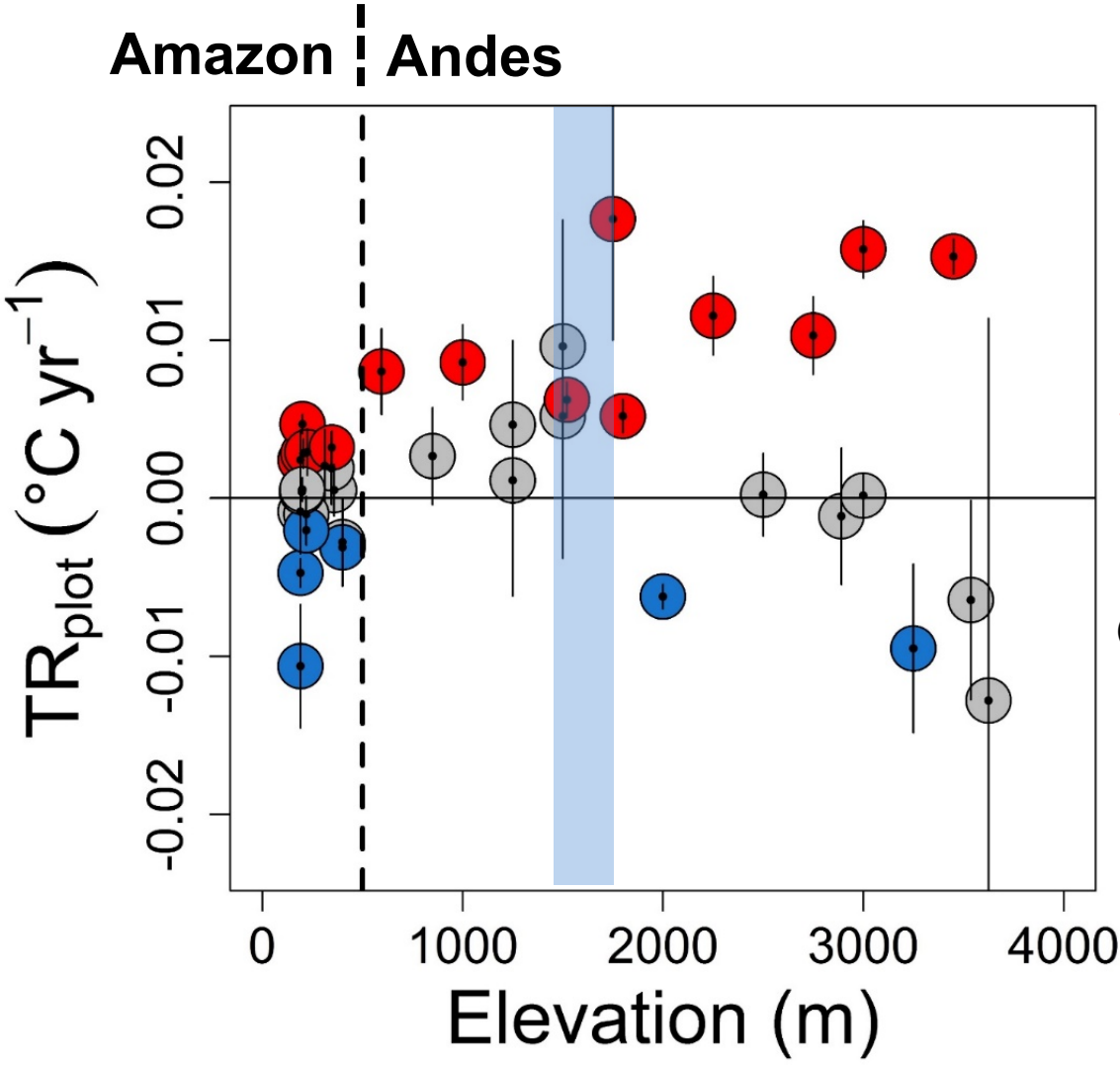


26 plots positive

12 plots negative

(binomial probability < 0.001)

Positive community thermophilization

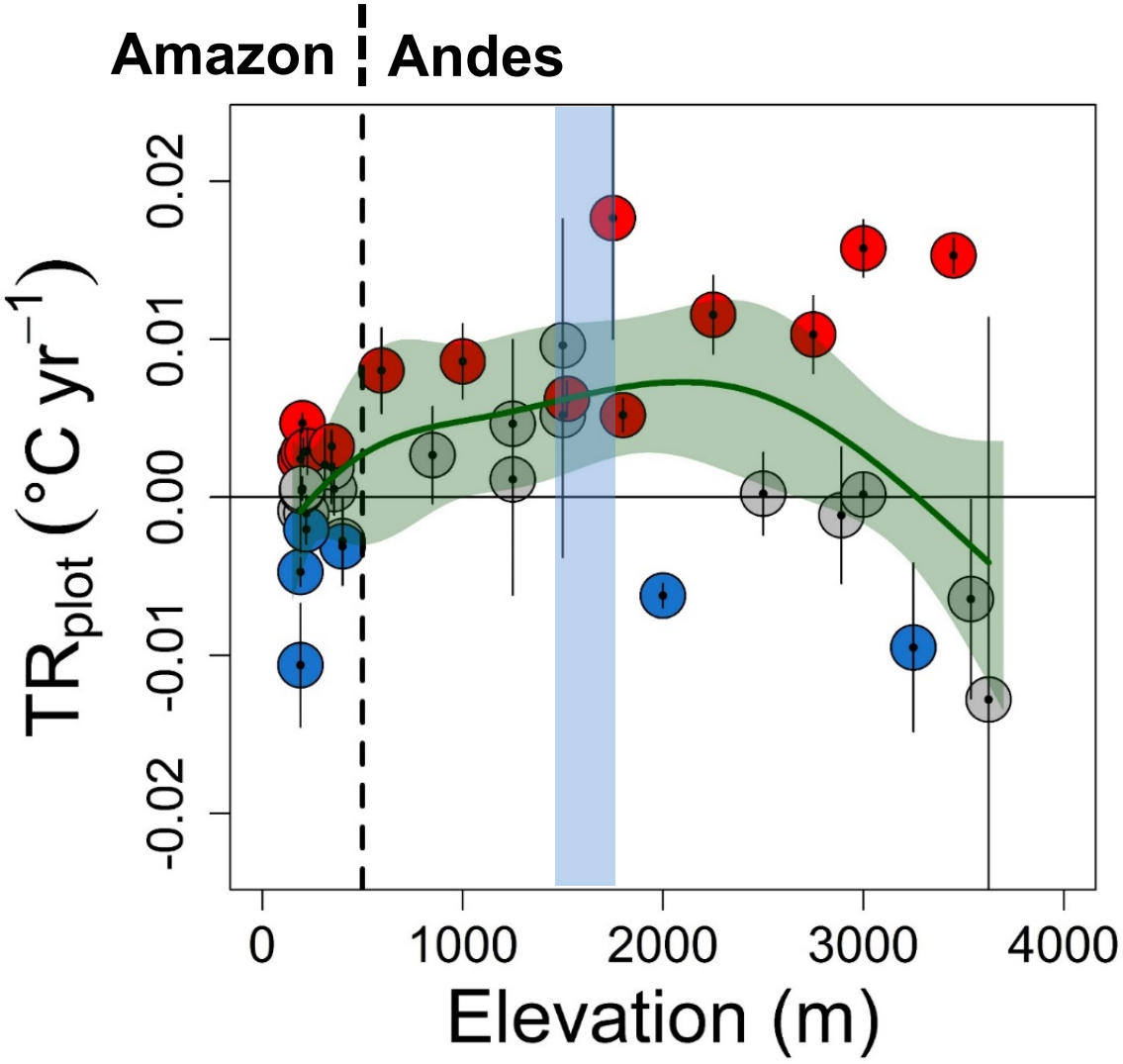


13 positive significant

6 negative significant

(binomial probability < 0.001)

Positive community thermophilization



Overall mean

0.0023 °C yr $^{-1}$

0.43 m yr $^{-1}$

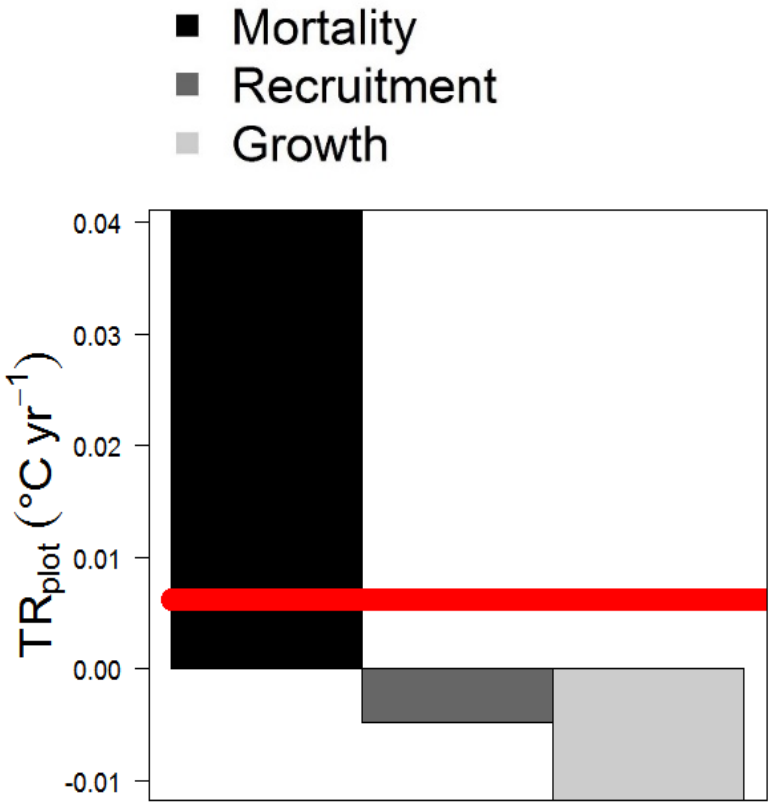
Amazon = **-0.0002** °C yr $^{-1}$

= **-0.04** m yr $^{-1}$

Andes = **0.0044** °C yr $^{-1}$

= **0.80** m yr $^{-1}$

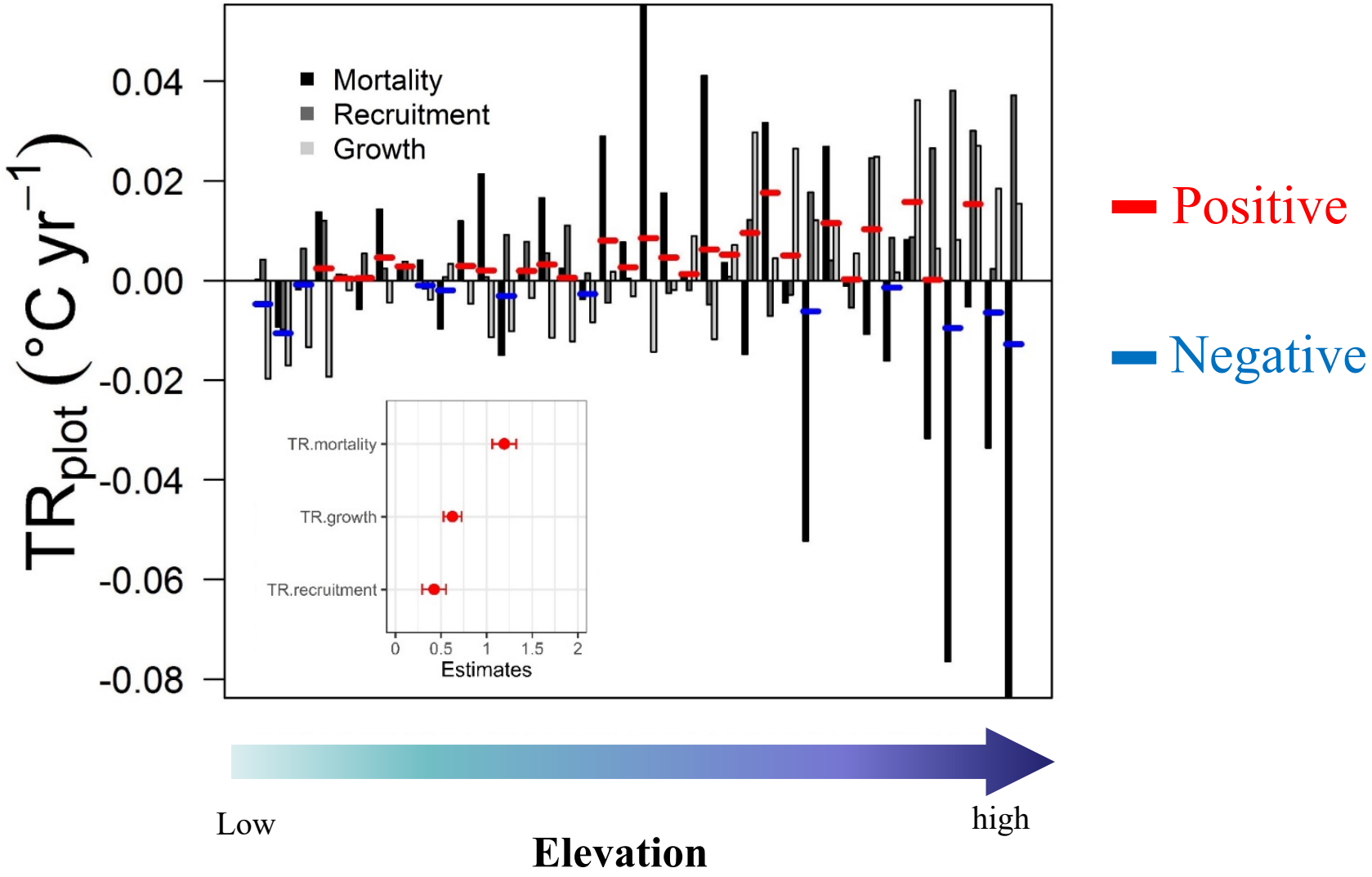
Contribution of demographic processes to thermophilization



Positive

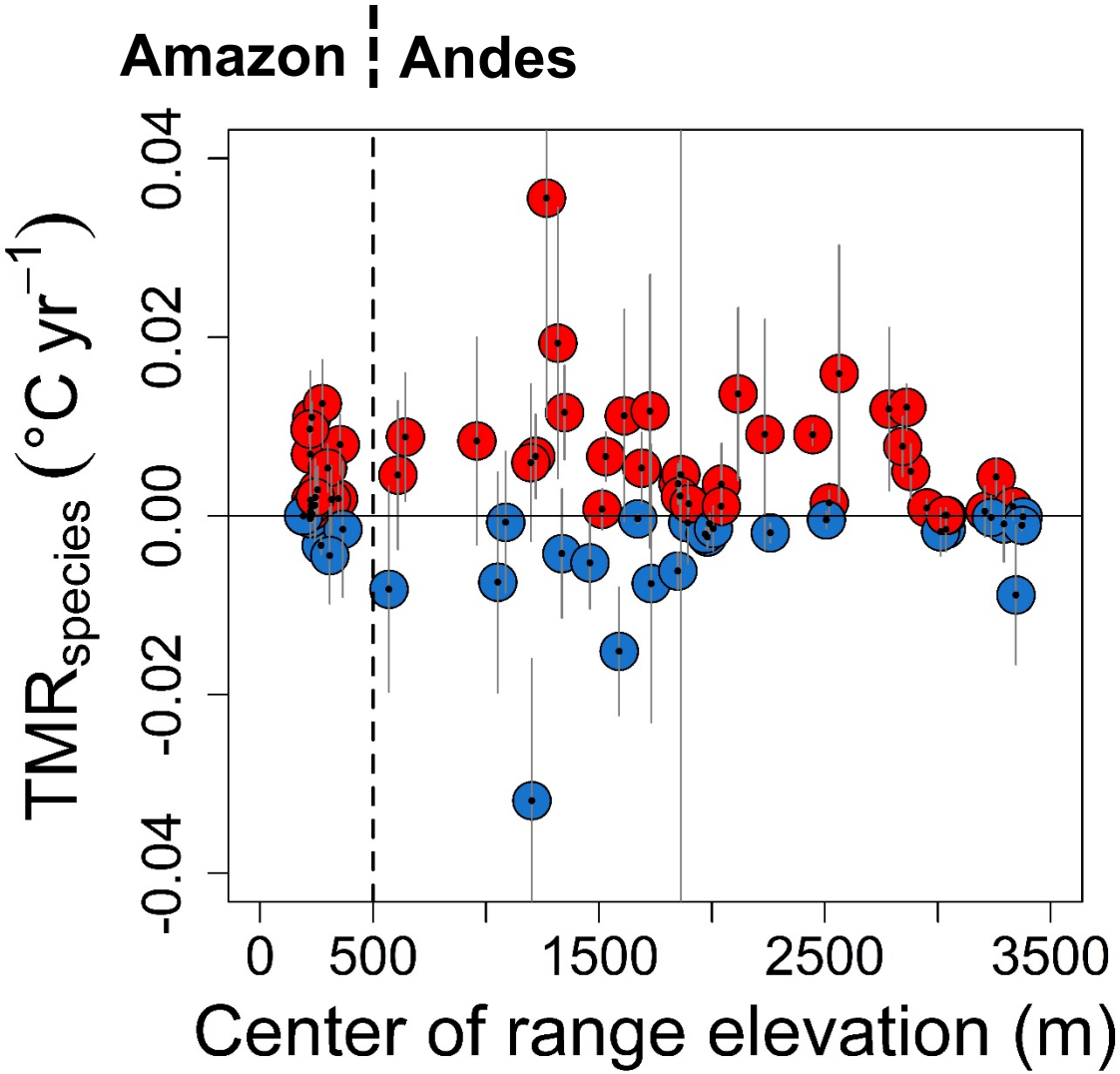
SAI-01

Tree mortality drives thermophilization



But, plots are made up of species

Few species have significant migration rates

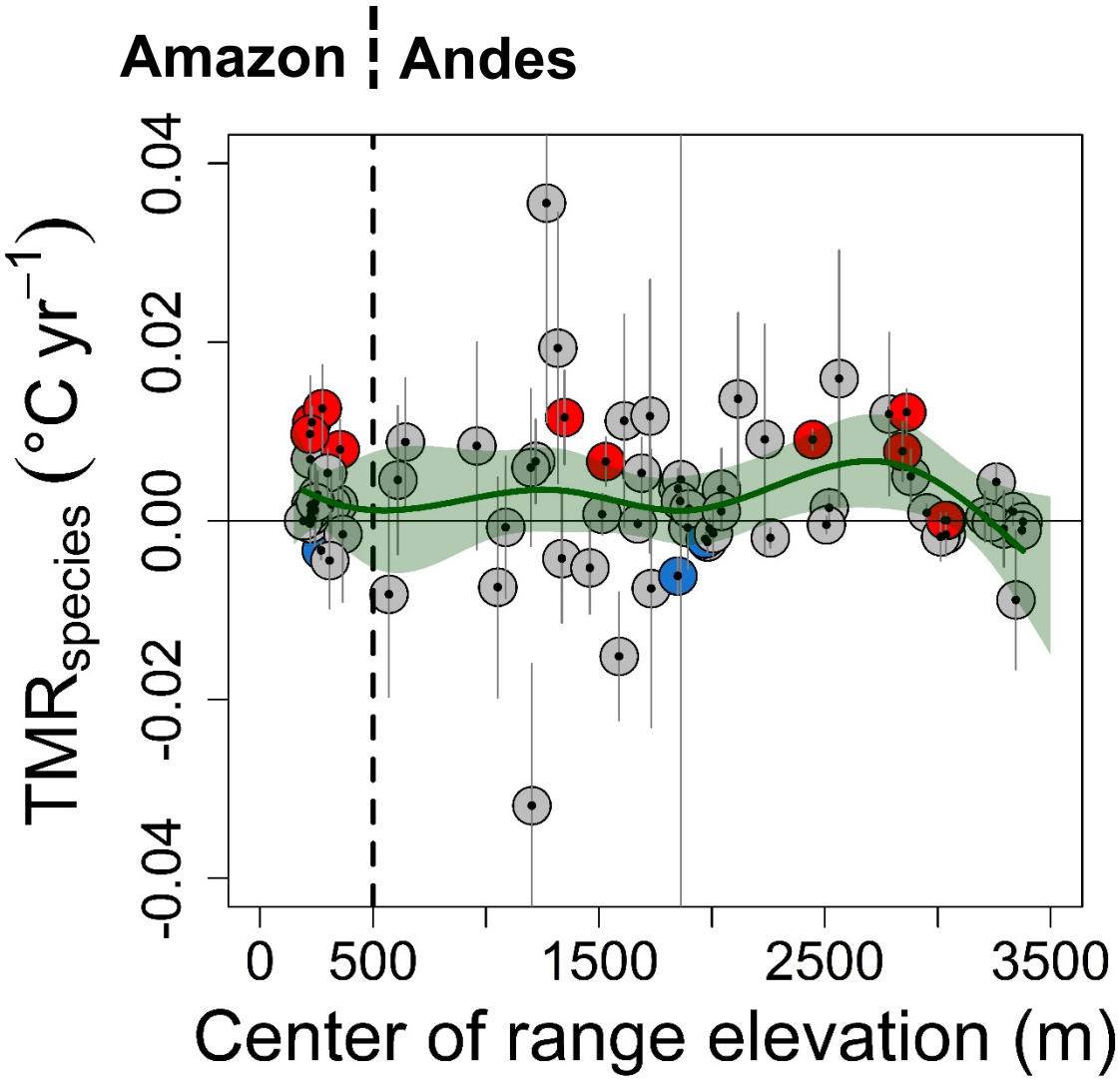


≥ 50 individuals
≥ 2 plots

n = 79 species
62 positive migration
38 negative migration

(binomial probability < 0.001)

Few species have significant migration rates



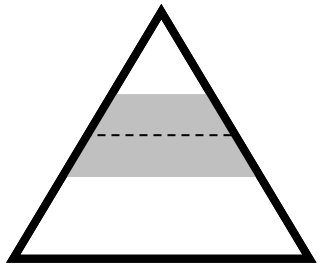
≥ 50 individuals
≥ 2 plots

n = 79 species
10 positive significant migration
3 negative significant migration
(binomial probability < 0.001)

Overall mean
0.0024 °C yr^{-1}
0.44 m yr^{-1}

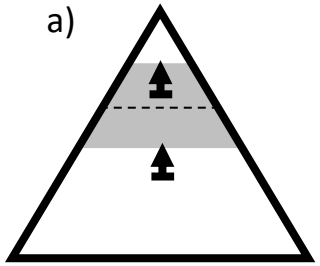
Coupling demography with migration shifts

Elevational range of species



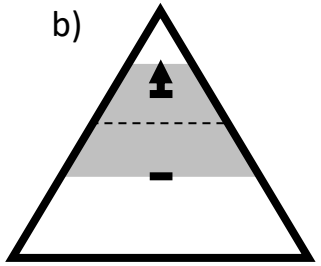
Global warming

a)



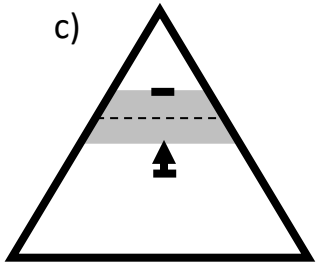
Shifting range
Upper limit recruitment same rate as lower limit mortality

b)



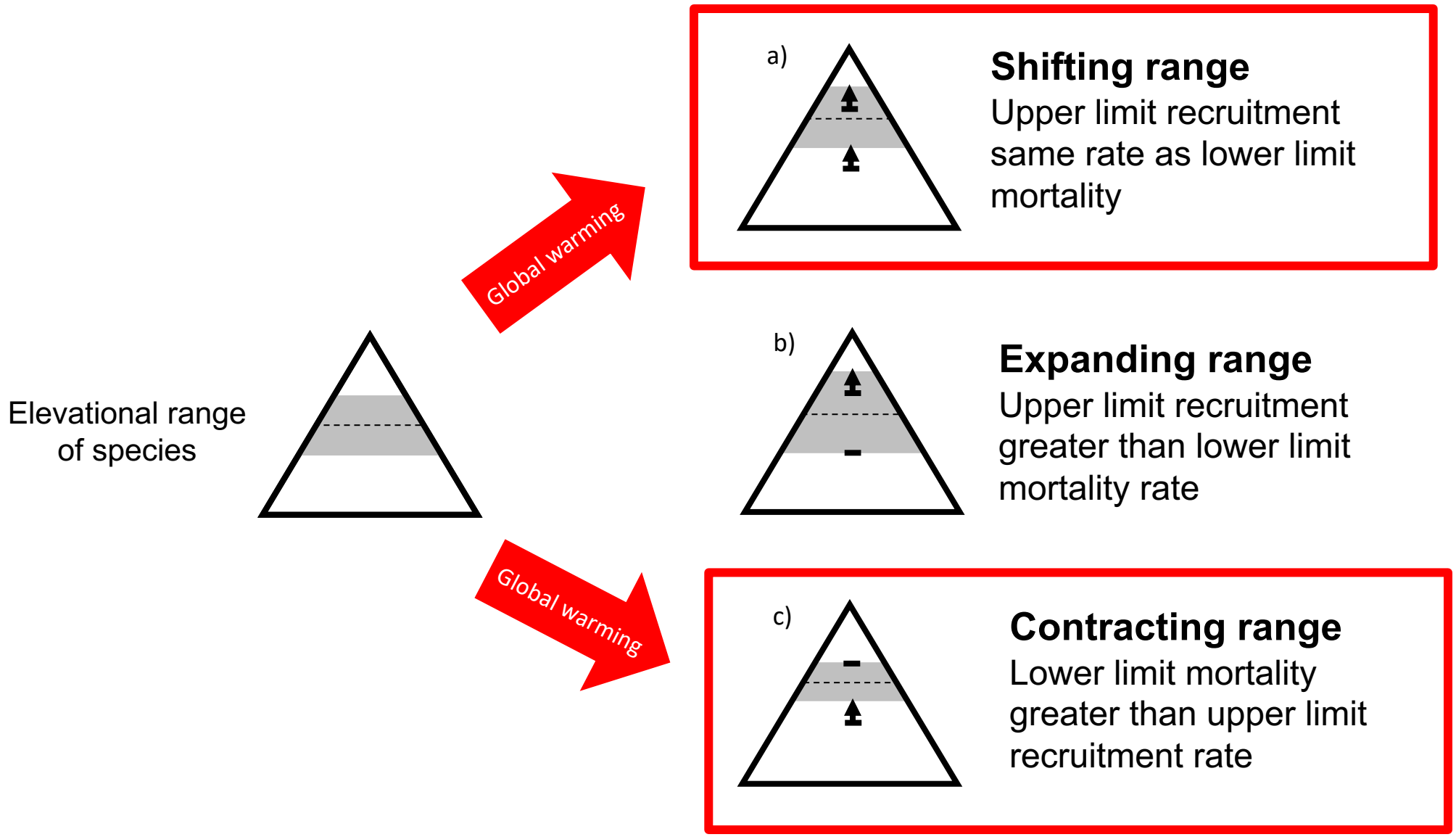
Expanding range
Upper limit recruitment greater than lower limit mortality rate

c)



Contracting range
Lower limit mortality greater than upper limit recruitment rate

Coupling demography with migration shifts



Species migration summary

- Trees are moving up, but slower that we thought
- Andean trees are migrating faster than Amazonian trees
- Largest changes in thermophilization was due tree mortality
- Not in equilibrium with current or future rates of climate change:
  - Past ~ 0.2 – 0.7 m yr^{-1}
  - Current ~0.4 m yr^{-1}
  - Future ~9 m yr^{-1}

How are tropical forests responding to climate change?

1. Introduction to the Andes-to-Amazon elevational gradient in Southern Peru
   - General trends along the gradient

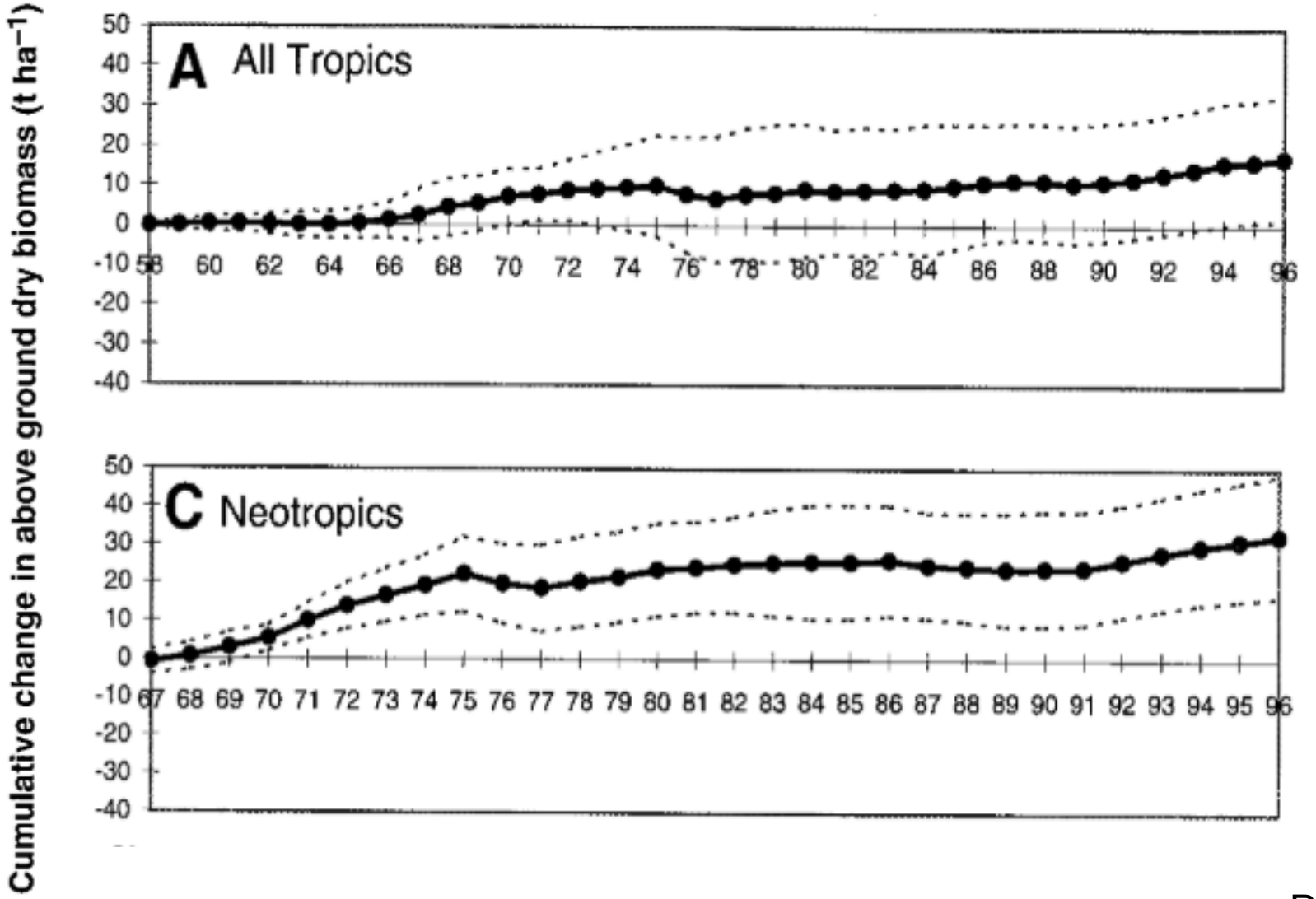
2. Are species shifting their distributional ranges?
   - Species migration

3. Are the changes in tree demography and species distribution affecting ecosystem function?
   - **Carbon dynamics**


Tropical forest stores 55% of the carbon


We need to keep that amount of carbon
on this trees to mitigate global warming

Increase in carbon accumulation over time



Phillips *et al.,* 1998

Tree above ground biomass estimations

$$AGB_{est} = 0.0673 \times (\rho D^2 H)^{0.976} \times 0.5$$

Wood density

Diameter

Tree height

Chave *et al.*, 2014

But, there are two problems with this allometry

Problem 2: No wood density data across the Andes

Wood density
Dry weight per unit volume of wood

- **Essential in plant function**
  - Mechanical support
  - Physiology, structural properties and mechanisms of defense
- **Important in the growth - mortality tradeoff**

Comprehensive data set along the Andes

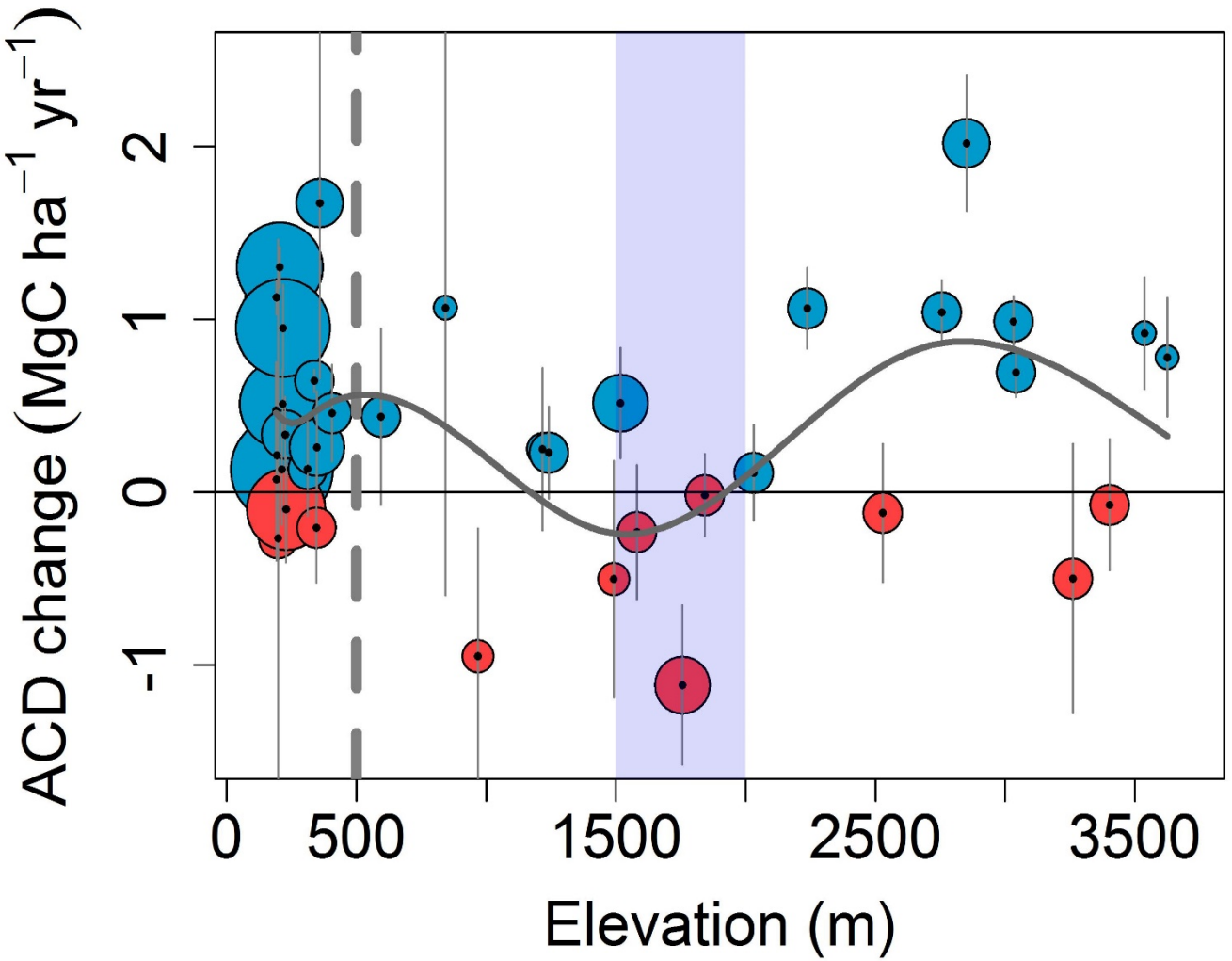
Locally collected samples

- 300 - 3700 m elevational gradient
- 59 sites
- Trees, tree ferns, palms
- 893 core samples
- 314 species

Problem 1: Tree height in the Andes

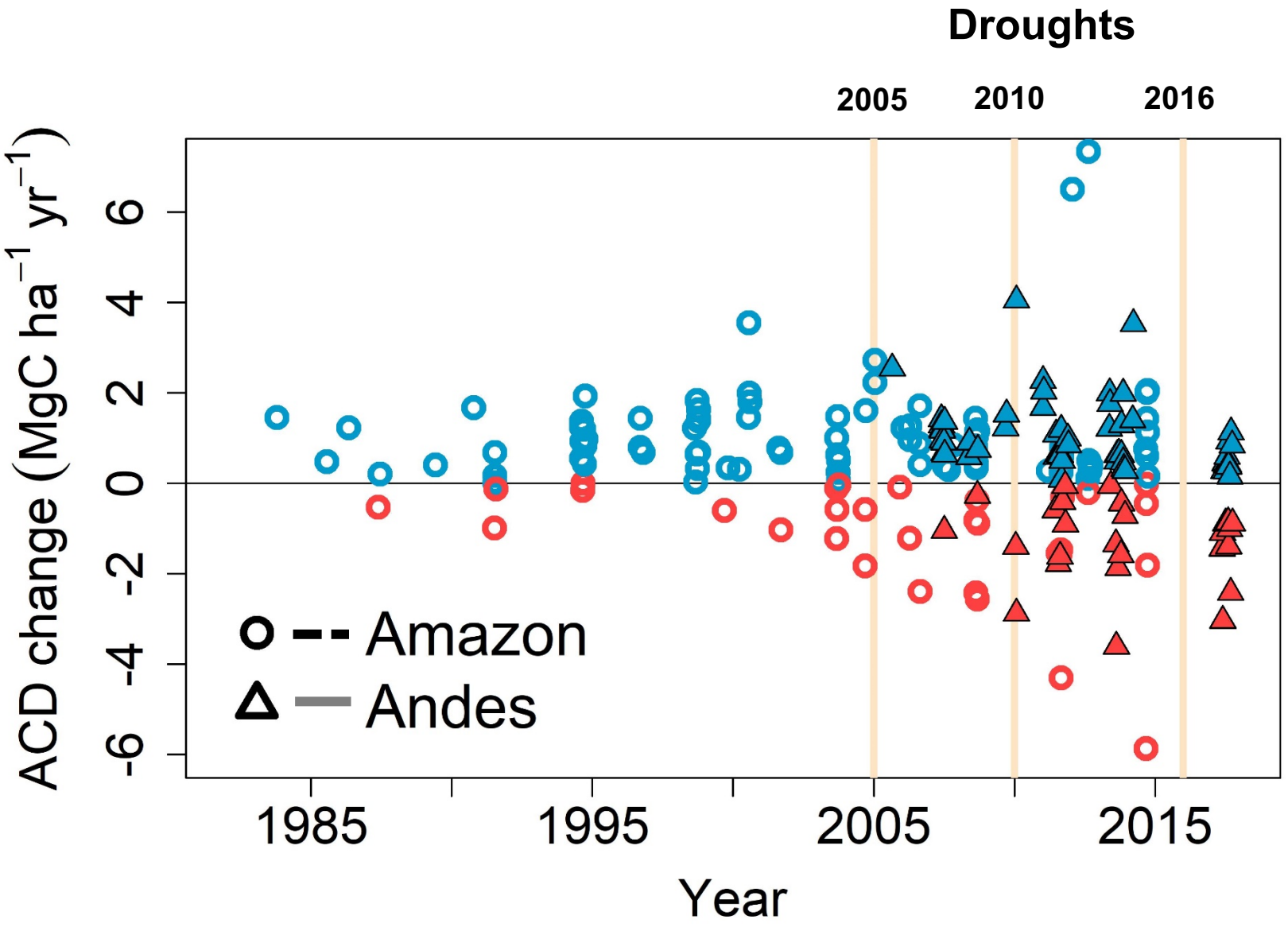
- 10,661 stems measured
- Significant difference in length vs height for Andean trees

No trend of carbon accumulation along the gradient



n = 38 plots

Carbon accumulation over time



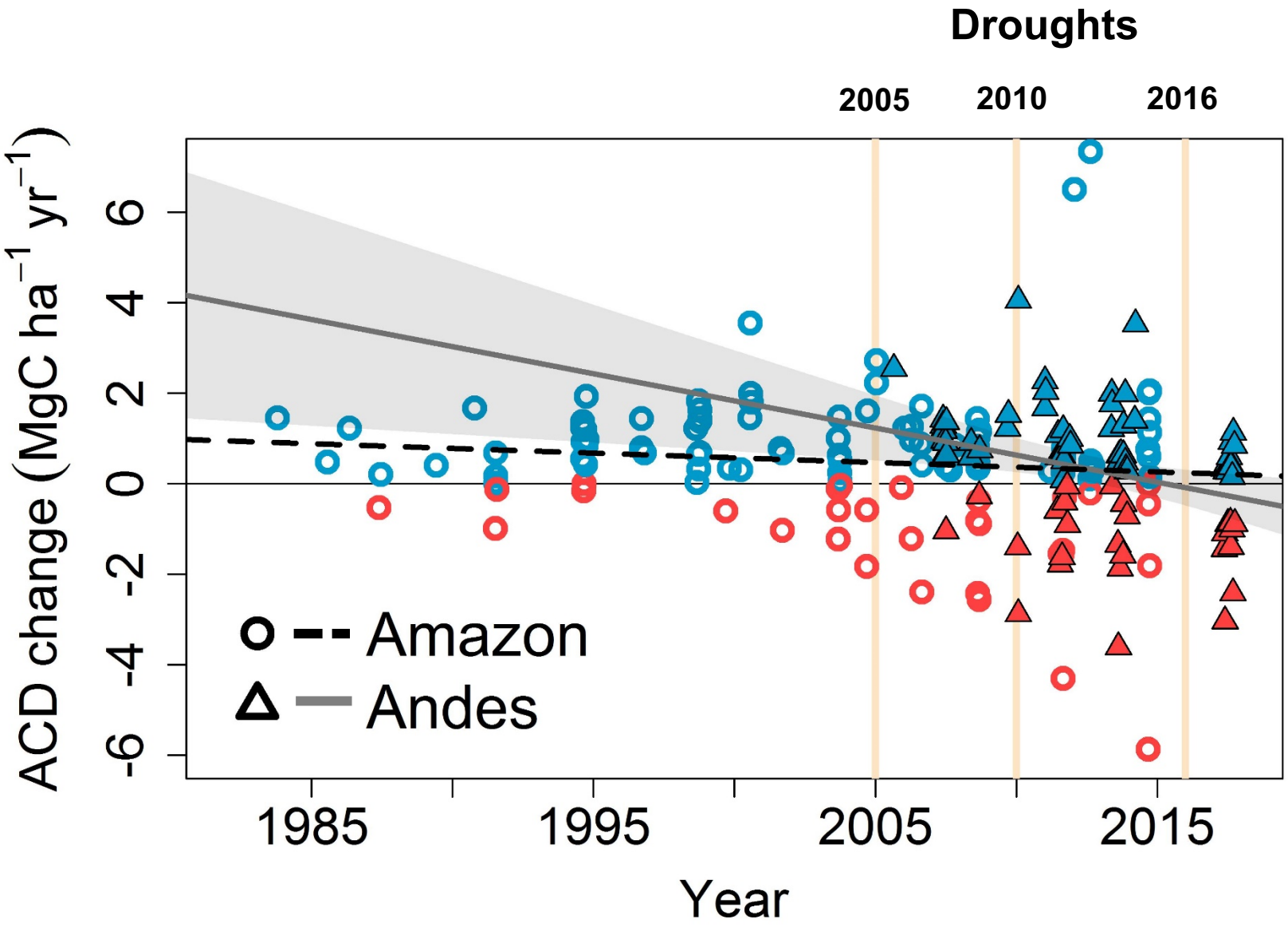
n = 38 plots
38 years

Mean carbon net change

Andes: **0.31** Mg C ha^{-1} yr^{-1}

Amazon: **0.45** Mg C ha^{-1} yr^{-1}

Long-term decreasing trend in carbon accumulation



n = 38 plots
38 years

Mean carbon net change

Andes: **0.31** Mg C ha^{-1} yr^{-1}

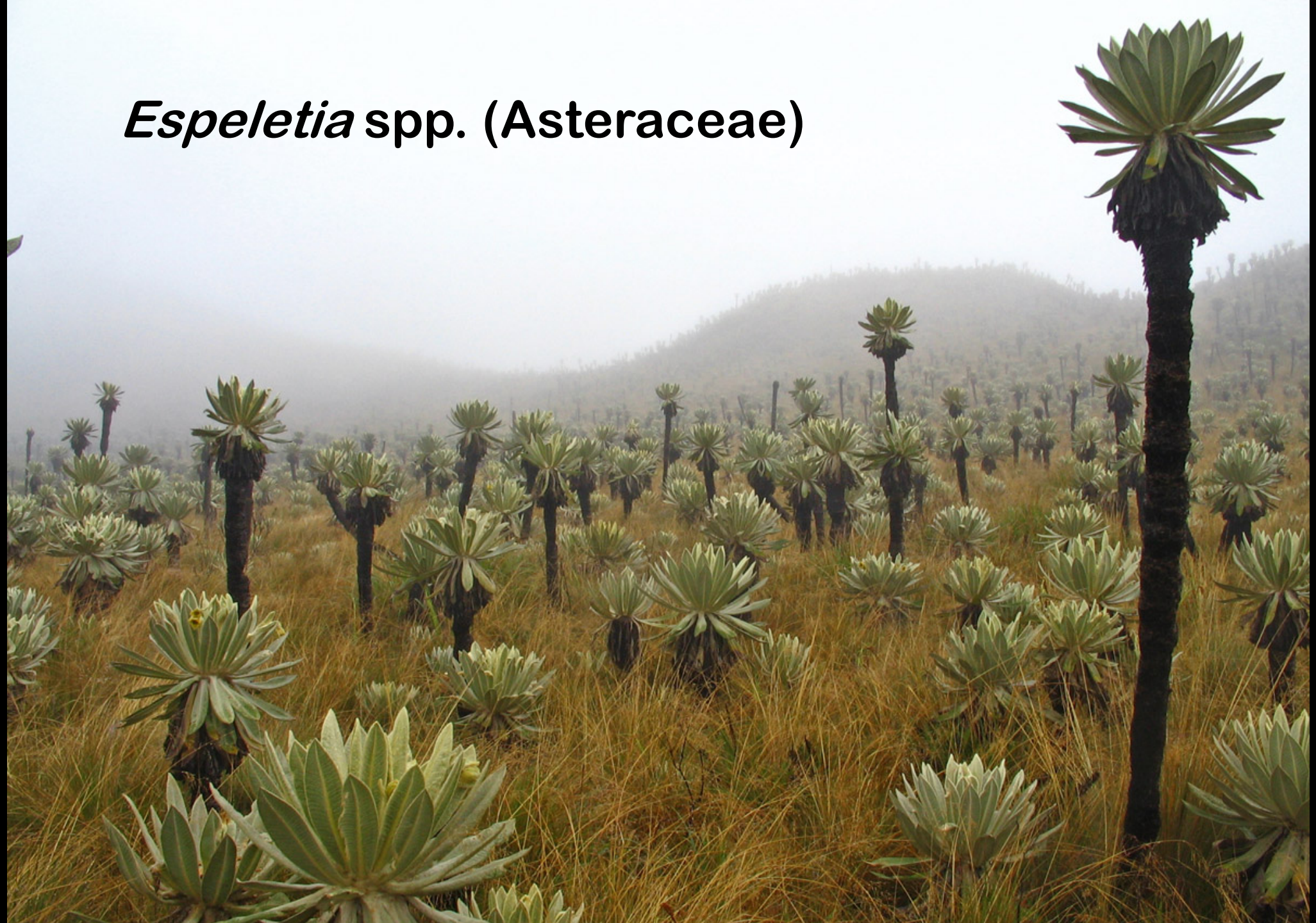
Amazon: **0.45** Mg C ha^{-1} yr^{-1}

Carbon dynamics summary

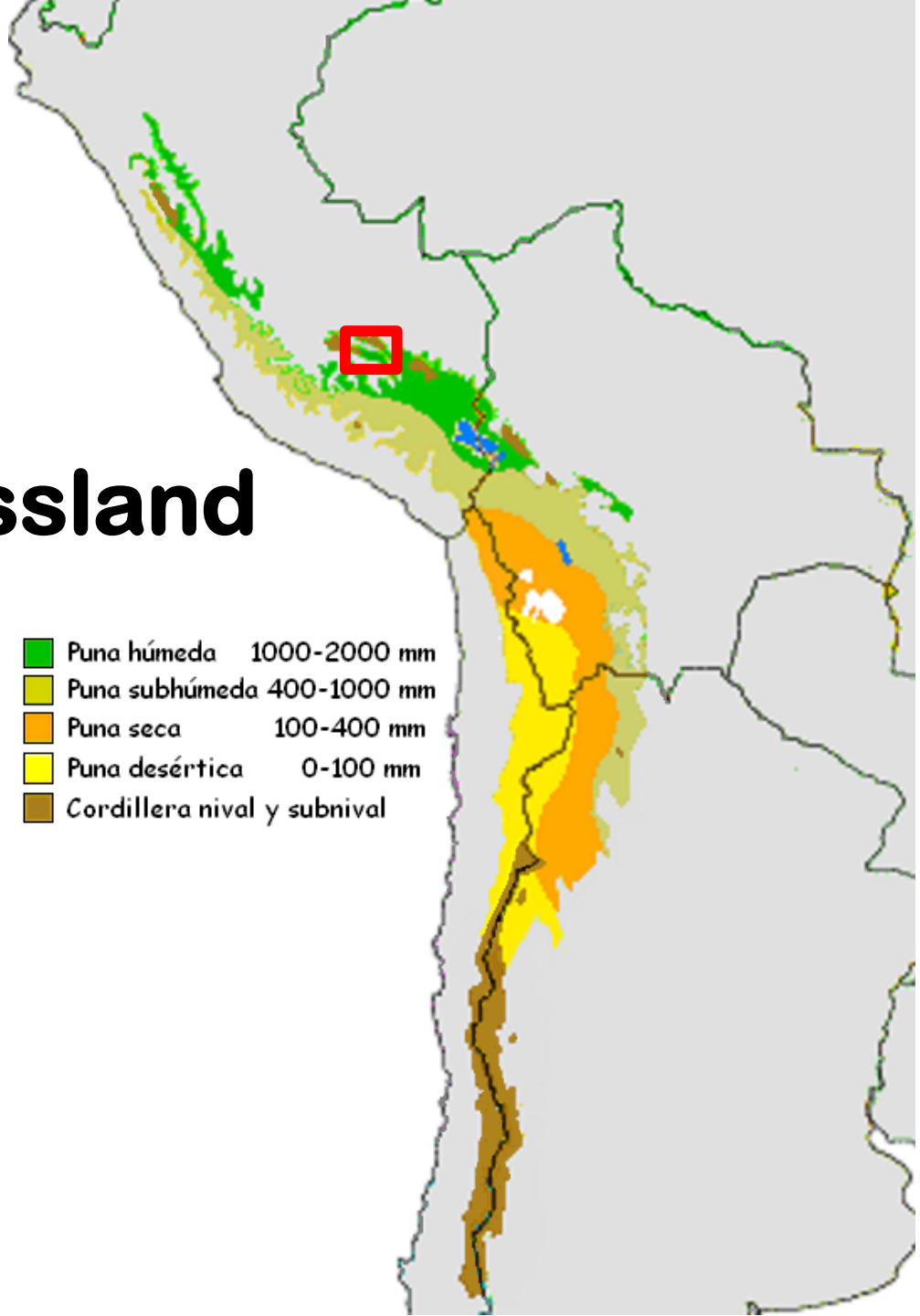
- Carbon loss between 1000 m and the cloud base along the gradient.
- Andean-Amazonian forests are acting as a small net carbon sink
- Lon-term decreasing trend of carbon accumulation over 38 years


LIVING EARTH COLLABORATIVE
Washington University in St. Louis
Venezuela
Colombia
Ecuador
AMAZON
ANDES
Peru
Bolivia
Argentina

Tropical Andes eco-regions

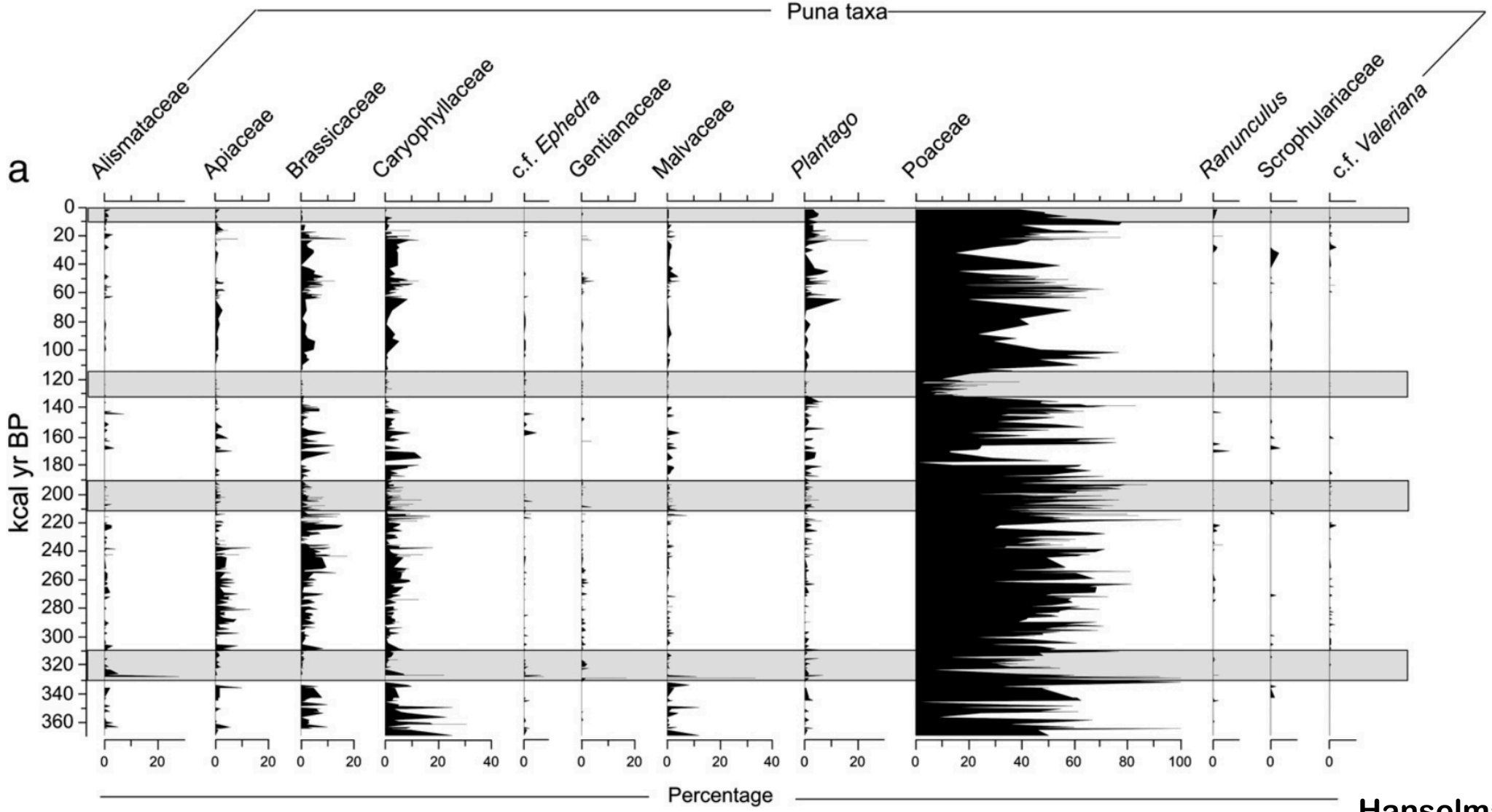

Espeletia spp. (Asteraceae)

Puna grassland



Puna paleo-data:

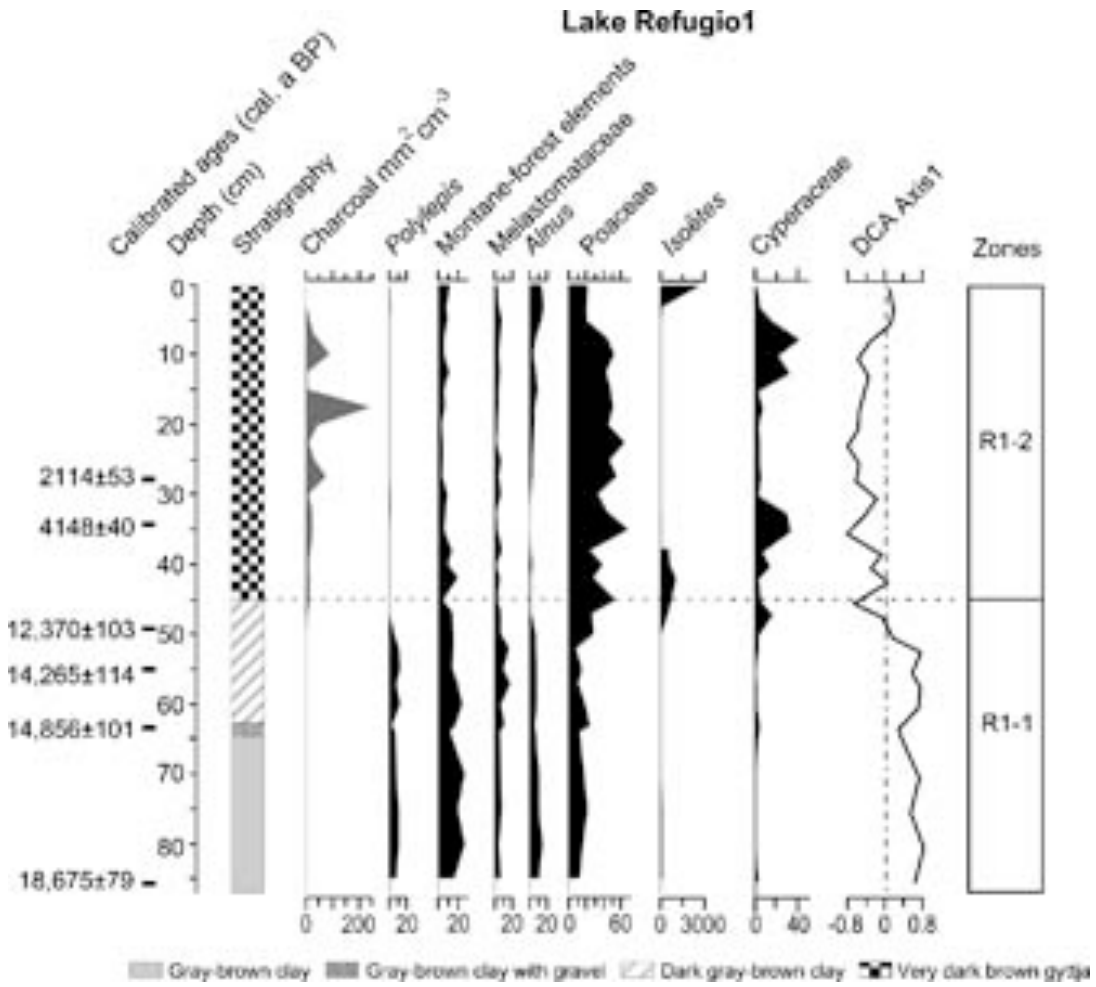
- Representation of pollen taxa (370,000 yrs)



Hanselman et al. 2011

Puna paleo-data:

- Representation of pollen taxa (~18,000 yrs)



- Polylepis tree line between 16,000-12,000

- Increase fires after 12,000 yrs due droughts
  - Decline in Polylepis
  - Expand puna

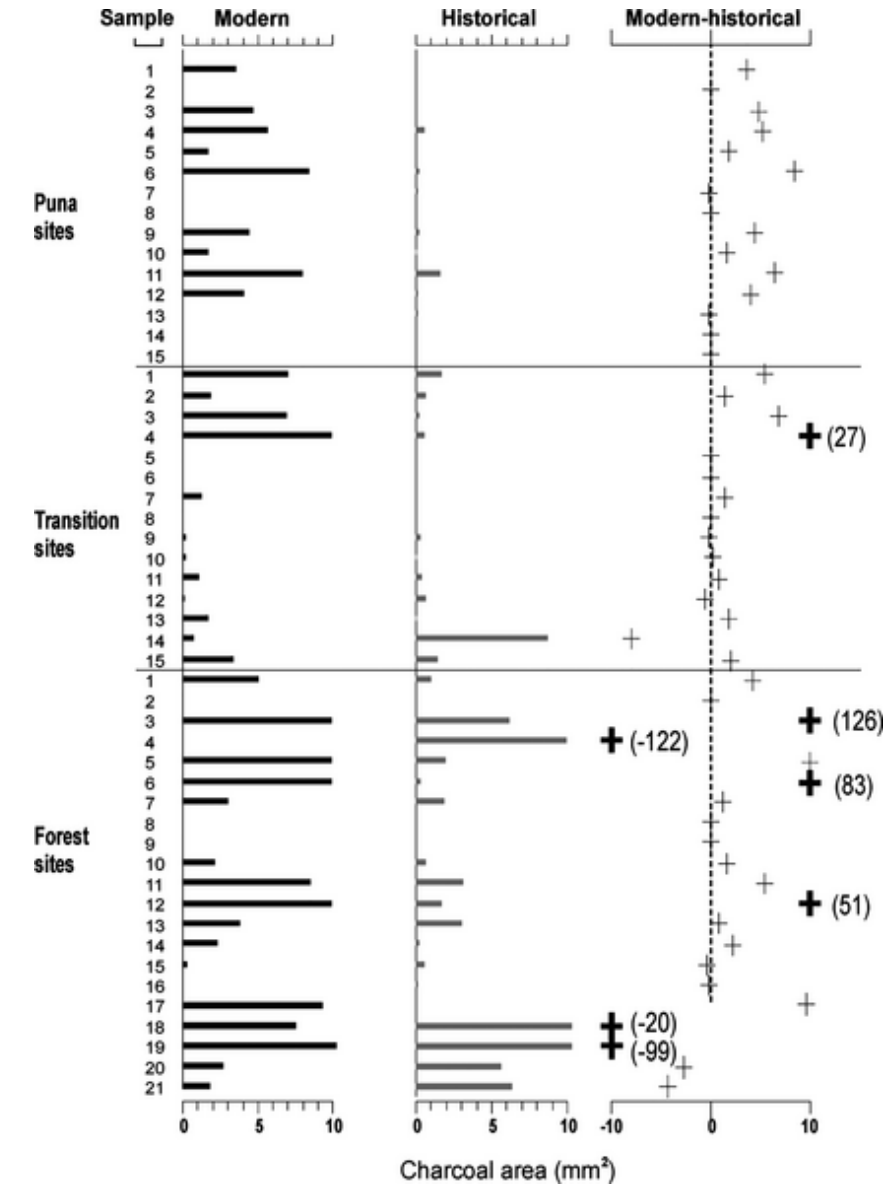
- Return wet conditions after 4,400 yrs
  - Forest did not return
  - Fire maintain grasslands dominate landscape

- Humans induce fire activity during late Holocene

Urrego et al. 2011

Puna paleo-data:

- Representation of charcoal (2,000 yrs)



- Southern Peru (Refugio lake – Manu Park)

- Forest degradation due increase in fire activity

- Fire-tolerant species spreading upslope.

Urrego et al. 2015