



MOUNTAIN RESEARCH INITIATIVE
20TH ANNIVERSARY LECTURE SERIES

The stories that alpine treelines can tell - interpreting spatial patterns of treeline ecotones

Maaïke Bader, University of Marburg, Germany

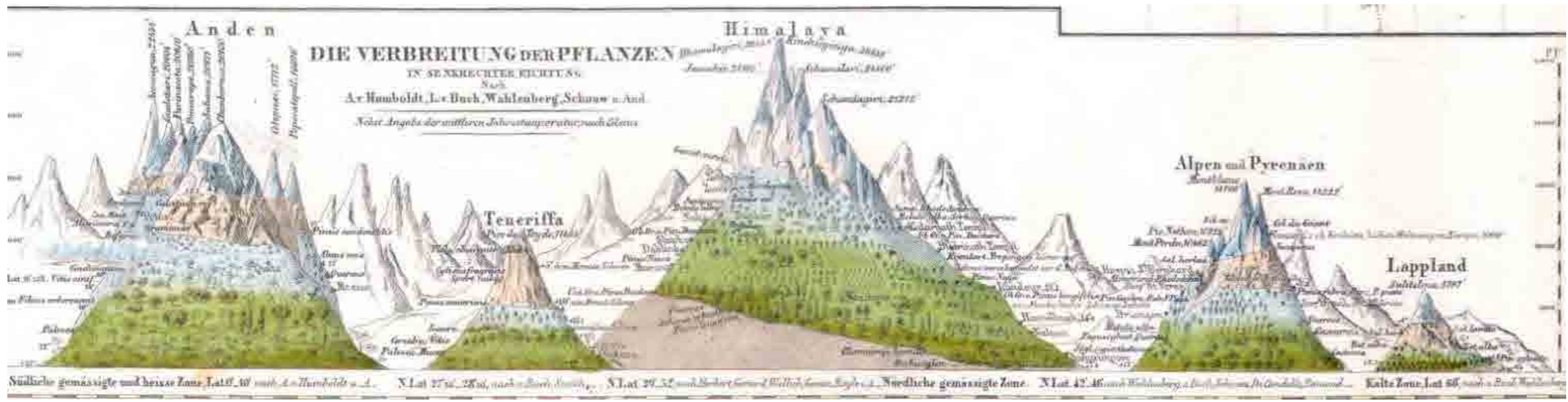
20 Years of Our Changing Mountains
www.mountainresearchinitiative.org



© Maaike Bader

Tree line elevation: the global pattern

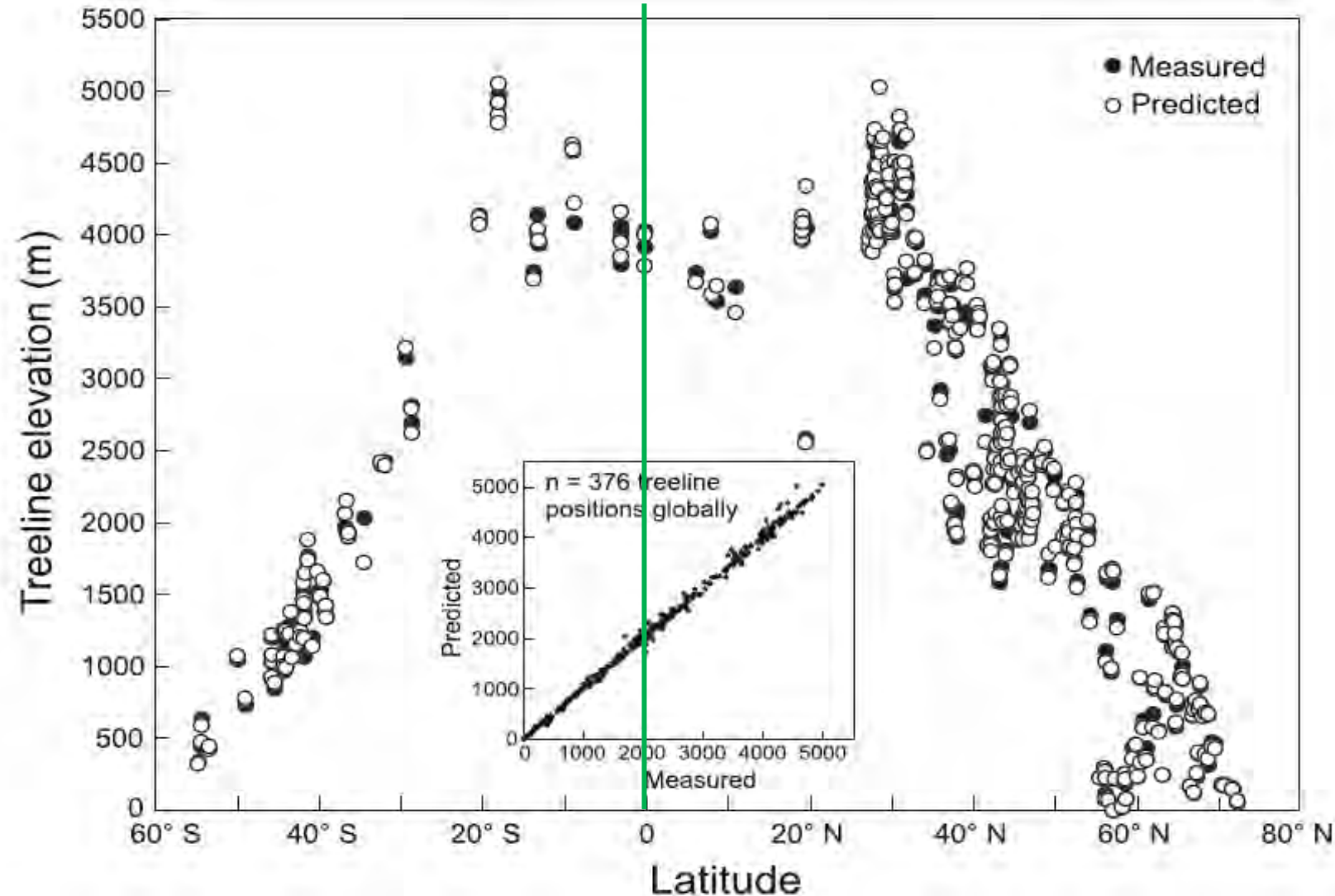
Classical observations



Bromme, T. (1854). Atlas zu Humboldt's Kosmos. Kraiss & Hoffmann, Stuttgart

Treeline elevation: the global pattern

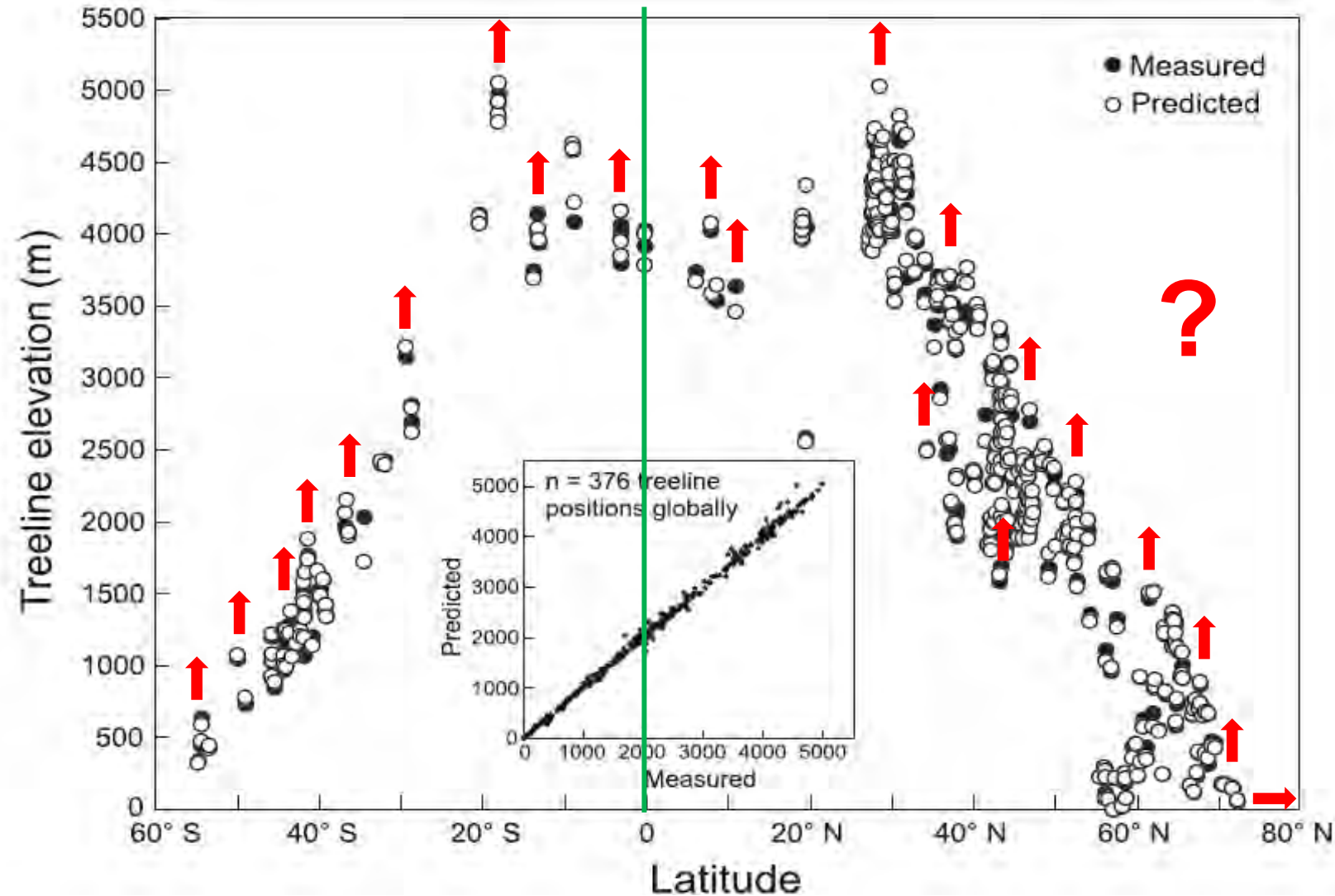
Climate-based model & remote-sensing-based observations



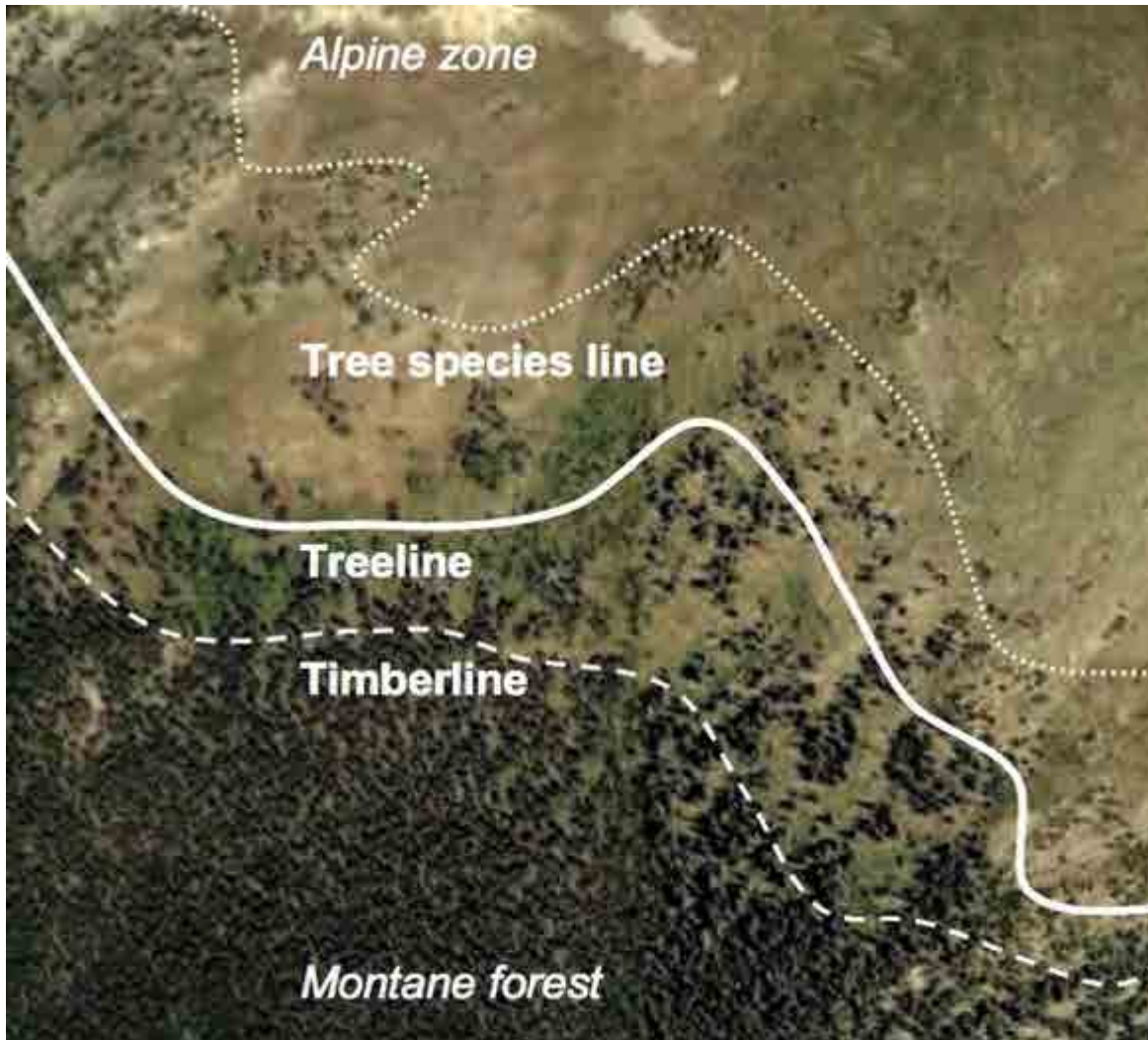
Best fitting model globally:
Growing season >94 days,
with a mean T of >6.4 °C

Tree line elevation: strongly climate controlled

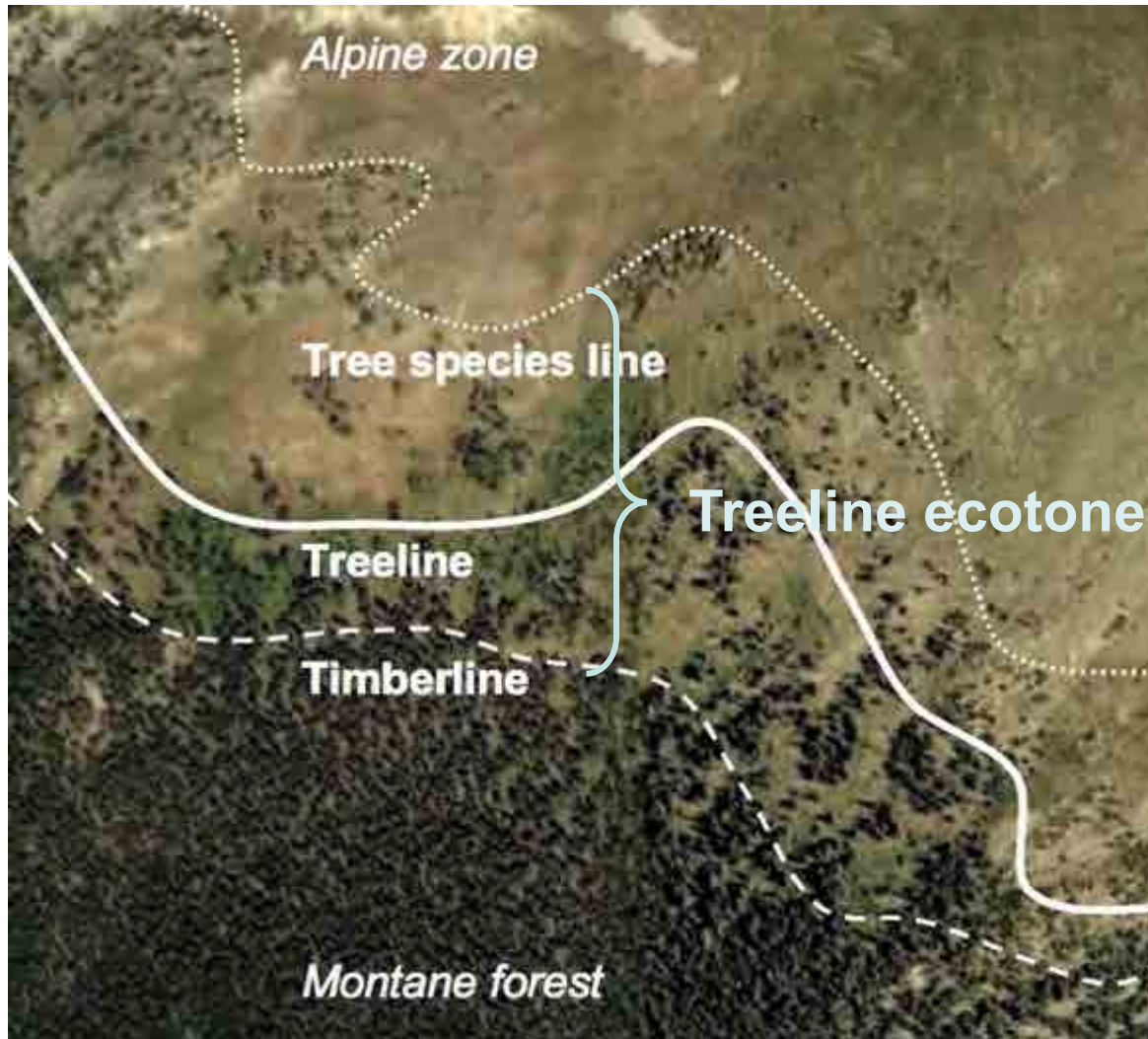
→ Strong climate-change response expected



What is a treeline? A line?



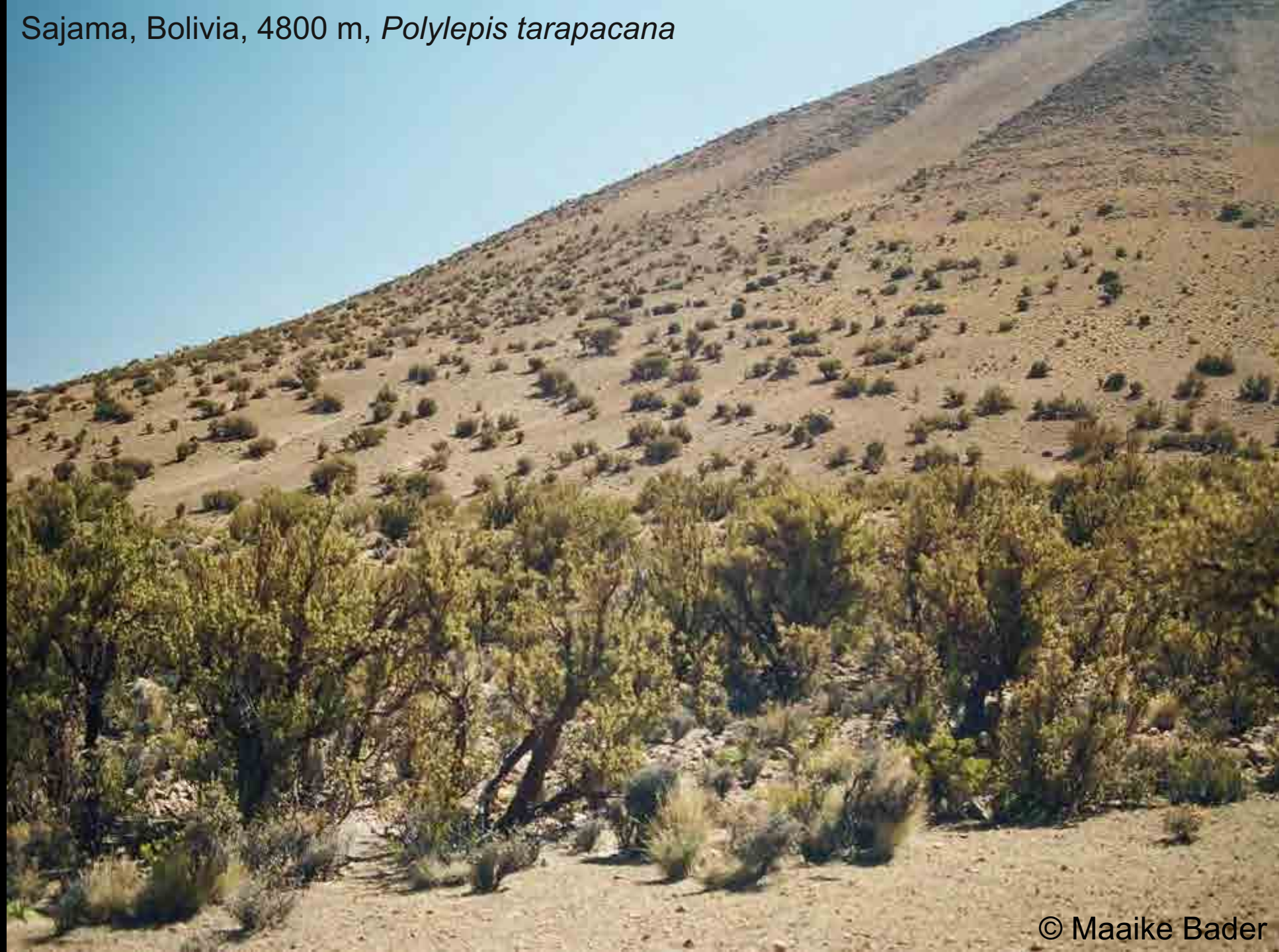
What is a treeline? A line?



→ ecotone
(‘alpine treeline ecotone’)

≠ potential treeline

Sajama, Bolivia, 4800 m, *Polylepis tarapacana*



Stavel Crastu, European Alps, *Larix decidua*, *Picea abies* (Photo: Matthias Jochner)



Ordessa, Pyrenees, *Pinus uncinata*



© Maaike Bader

Southern Alps, New Zealand, ca. 1400 m, *Nothofagus menziesii*

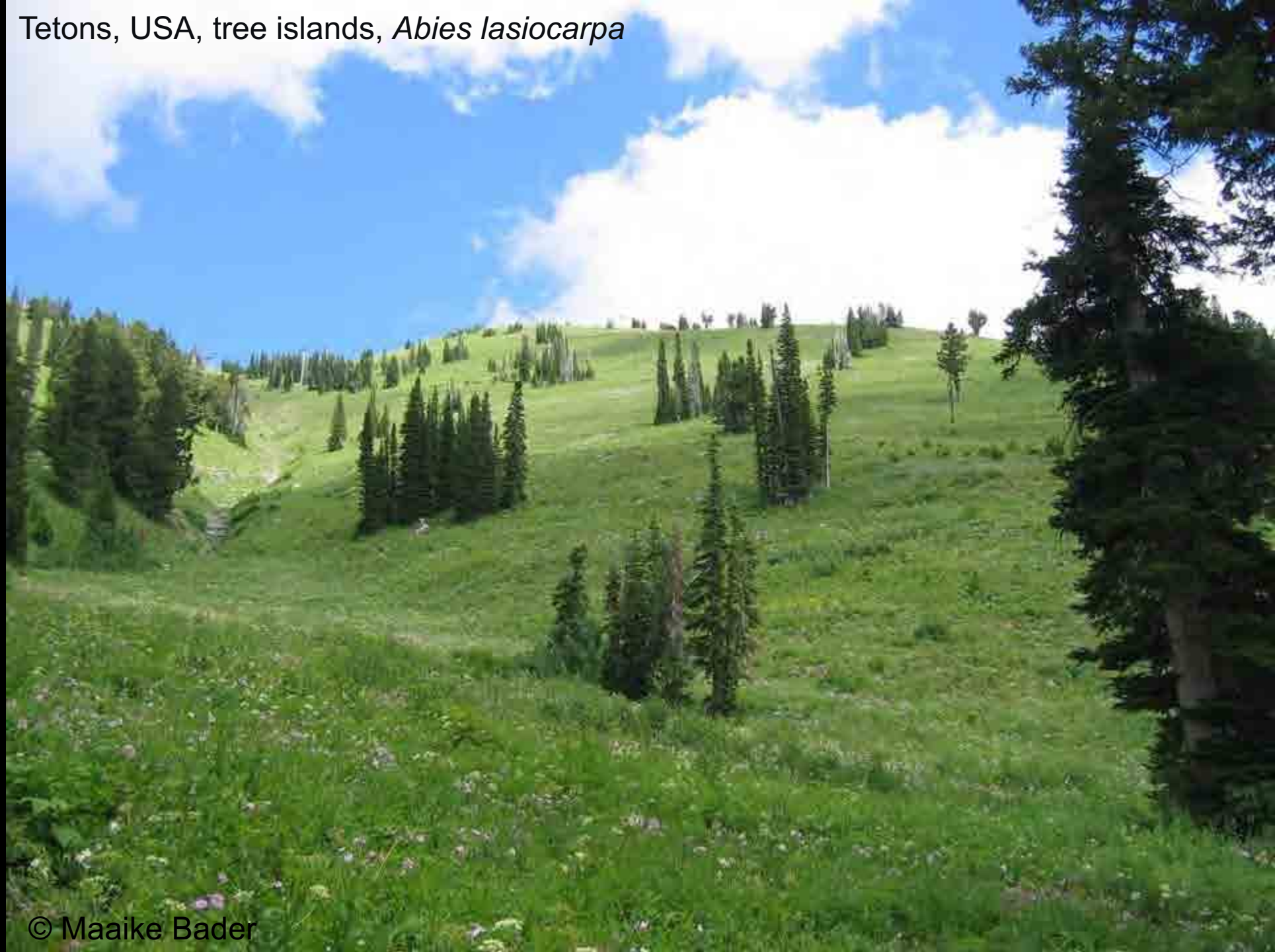


© Maaike Bader

Westside Southern Alps, NZ, ca 1300 m, 'podocarp-broadleaved' forest



Tetons, USA, tree islands, *Abies lasiocarpa*



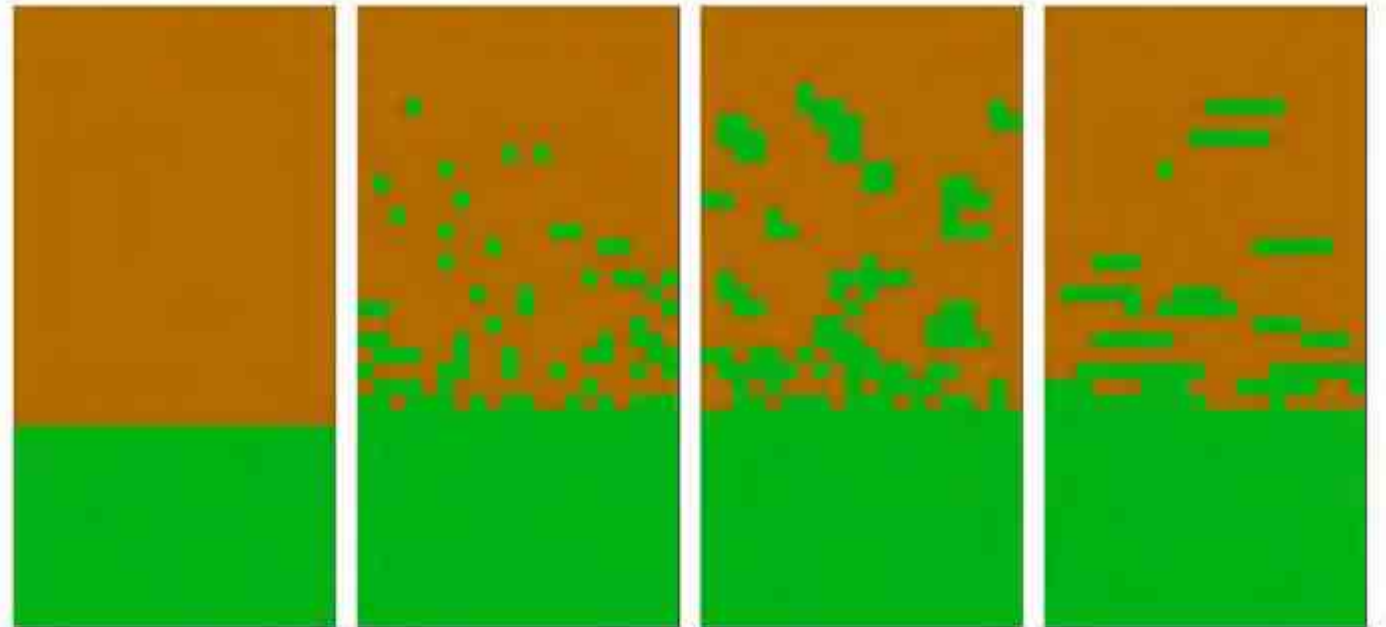
Capturing the variety in spatial patterns...



To relate them to underlying processes

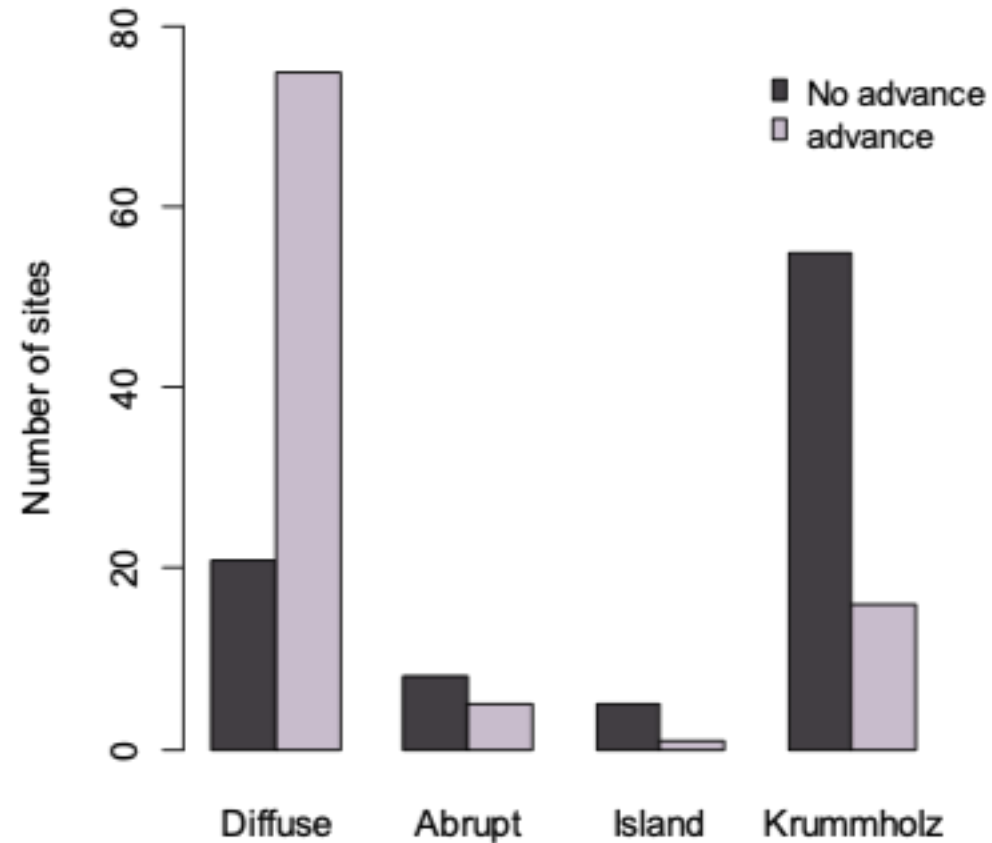
To improve communication

To recognise recurrent patterns and extrapolate research findings



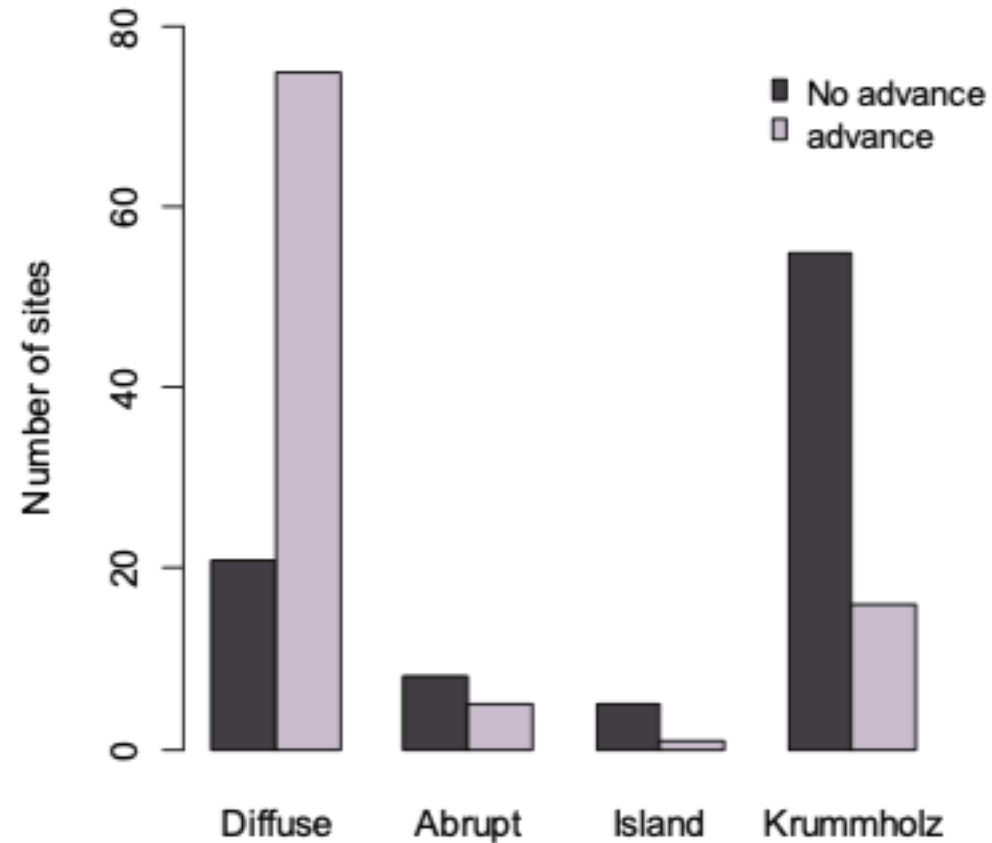
Pattern-dynamics relationships?

Treeline responses to climate change:



Pattern-dynamics relationships?

Treeline responses to climate change:



Treeline form	Ad- vance	No ad- vance
Abrupt n = 38	47%	53%
Diffuse n = 190	69%	31%
Krummholz n = 66	50%	50%



Pattern-dynamics relationships?

MRI synthesis workshop, Jaca (Spain) 2017

ECOGRAPHY

Review and synthesis

A global framework for linking alpine-treeline ecotone patterns to underlying processes

Maaïke Y. Bader, Luis D. Llambí, Bradley S. Case, Hannah L. Buckley, Johanna M. Toivonen, J. Julio Camarero, David M. Cairns, Carissa D. Brown, Thorsten Wiegand and Lynn M. Resler

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Ecography
44: 265–292, 2021
doi: 10.1111/ecog.05285

Globally, treeline ecotones vary from abrupt lines to extended zones of increasingly small, stunted and/or dispersed trees. These spatial patterns contain information about the processes that control treeline dynamics. Describing these patterns consistently along ecologically meaningful dimensions is needed for generalizing hypotheses and




Pattern-dynamics relationships?

MRI synthesis workshop followed up by...

sTreelines: joint effort to study spatial pattern emergence from ecological processes at alpine treelines

Theory and model development + global data collection

sDiv | synthesis centre of  iDiv

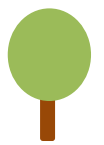
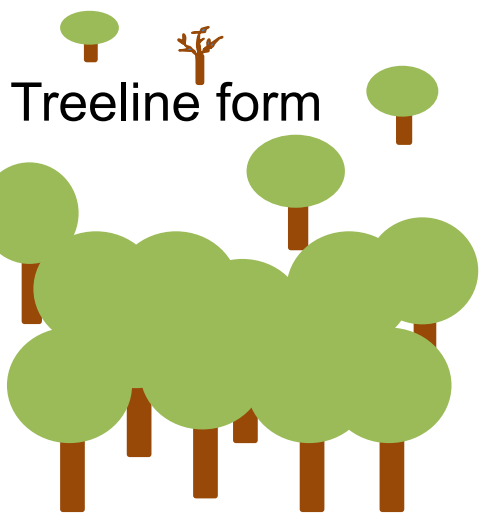


An aerial photograph of a mountain range. The mountains are covered in dense green forest, with a distinct treeline visible. The terrain is rugged, with many ridges and valleys. The sky is a clear, pale blue. The text is overlaid on a semi-transparent dark blue rectangular background.

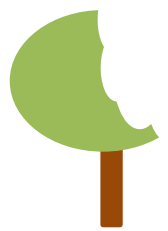
Research questions

- What processes control treeline spatial patterning and dynamics?
- How do treeline spatial patterns relate to dynamics?
- What causes regional differences in treeline pattern and elevation?
- How will different treelines respond to climatic changes?

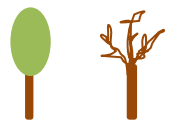
Conceptual model



Growth limitation



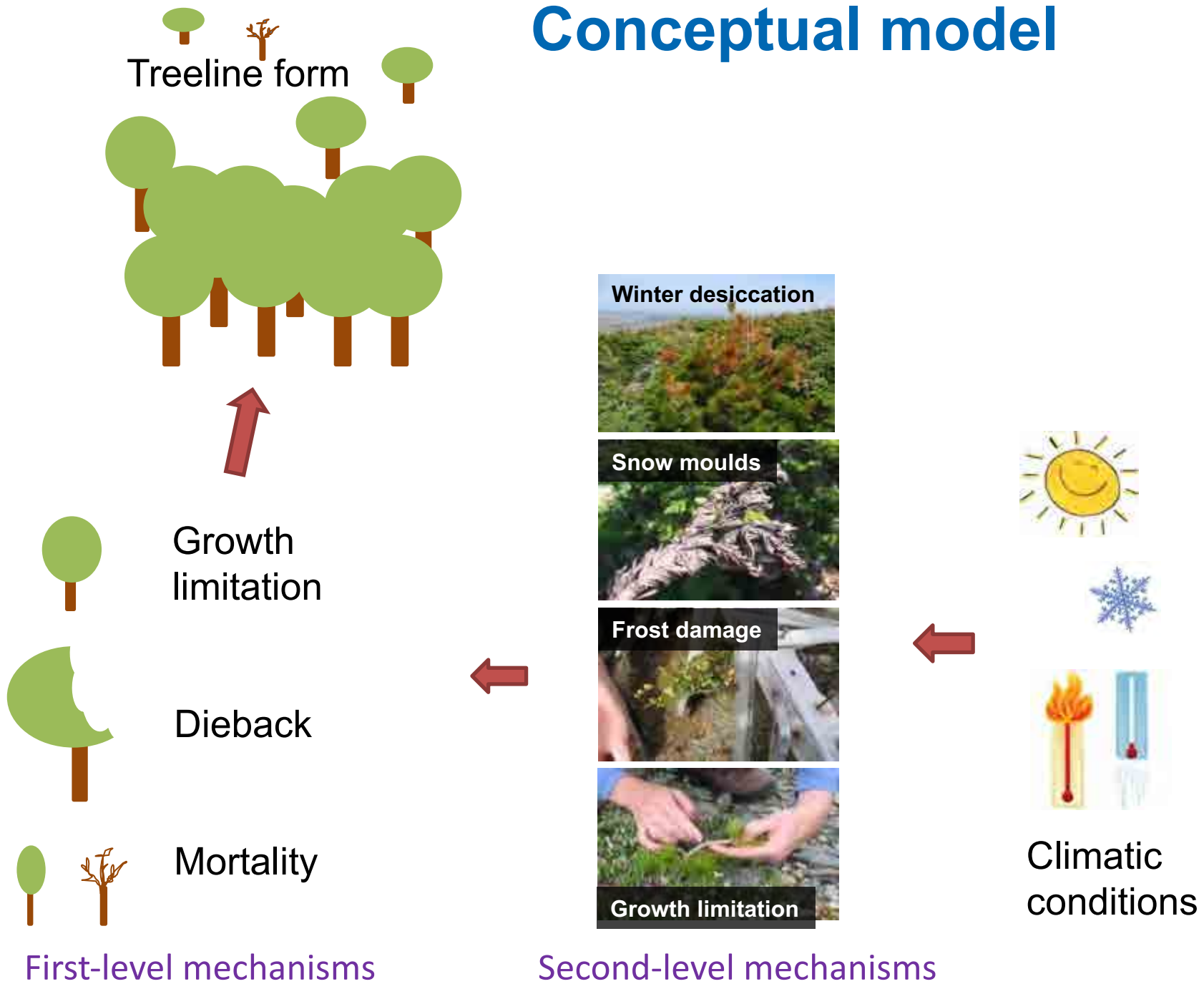
Dieback



Mortality

First-level mechanisms

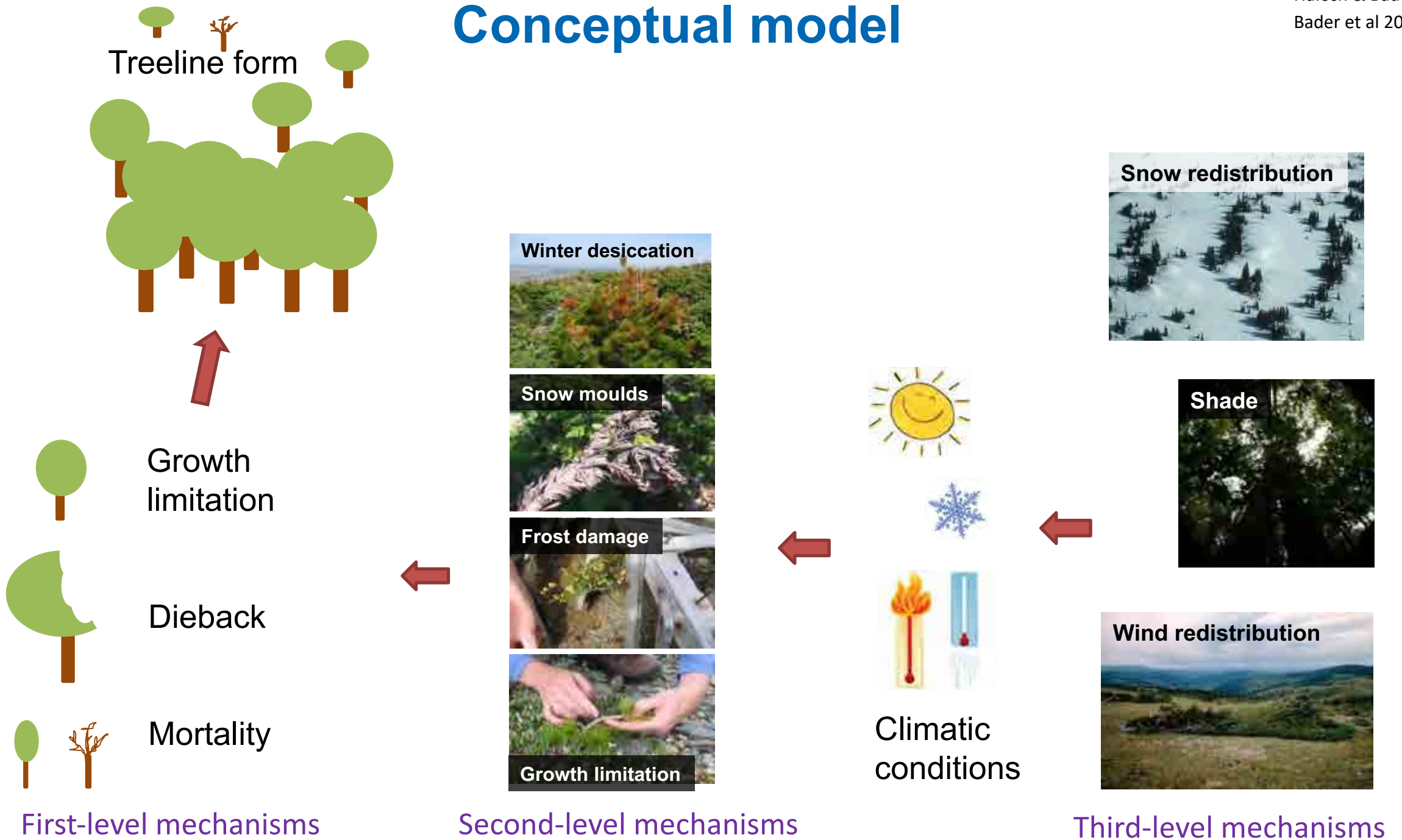
Conceptual model



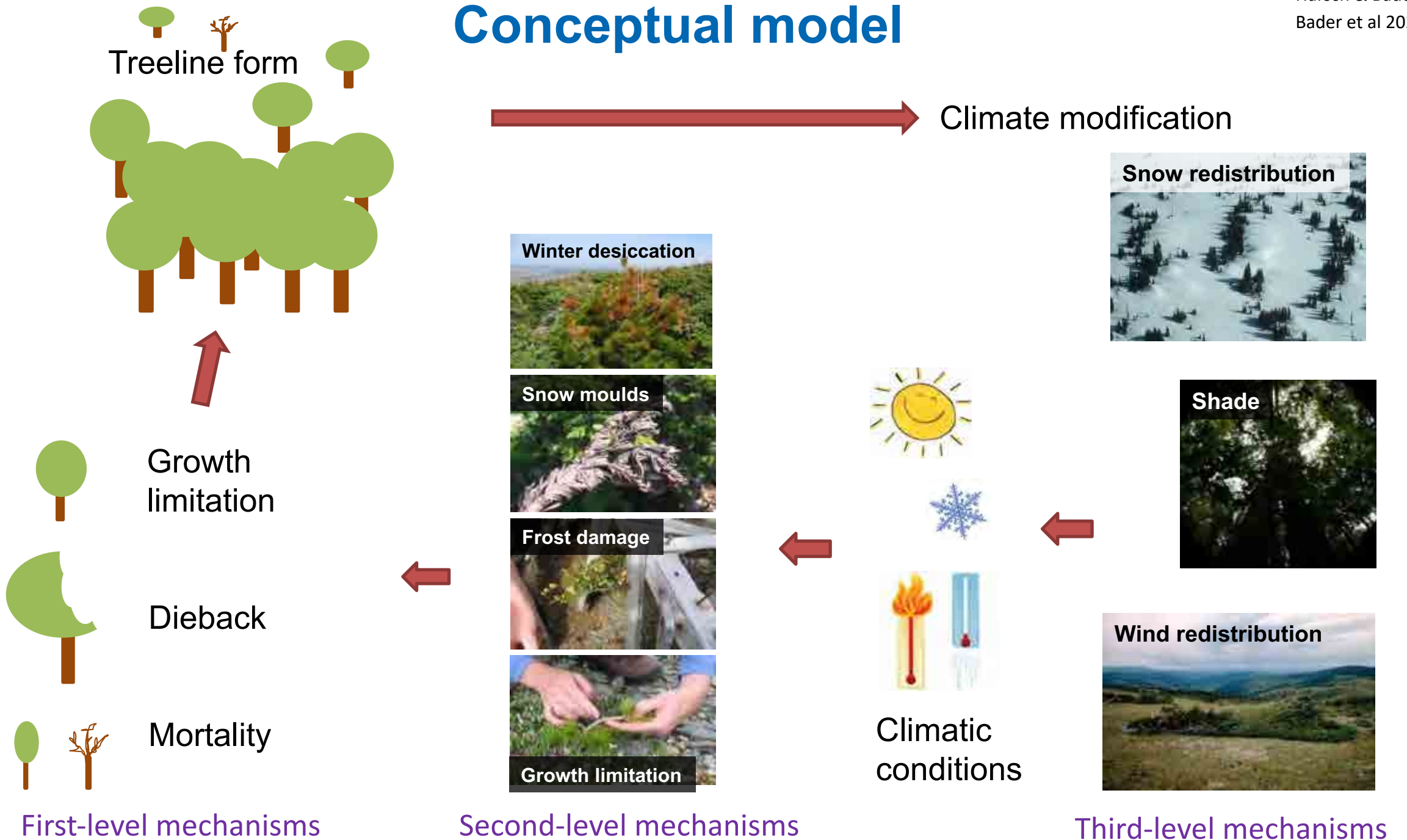
First-level mechanisms

Second-level mechanisms

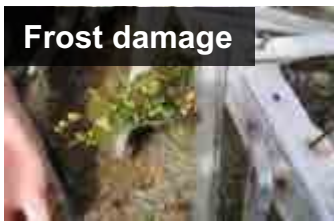
Conceptual model



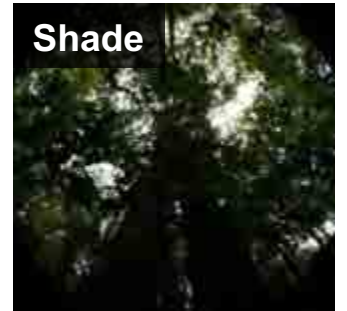
Conceptual model



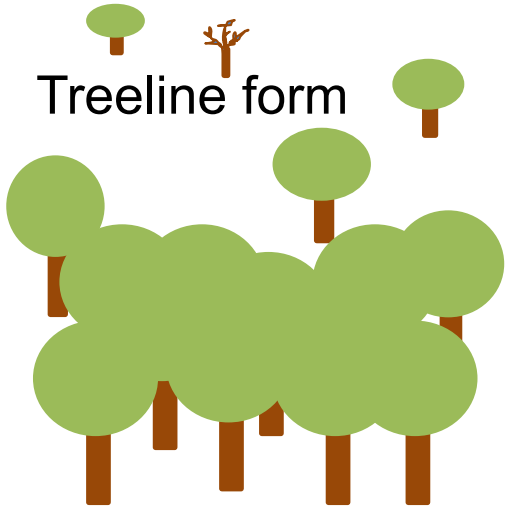
Climate modification



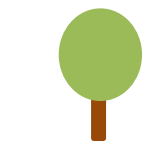
Climatic conditions



Tree line form



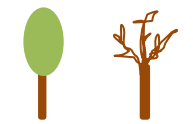
Growth limitation



Dieback



Mortality

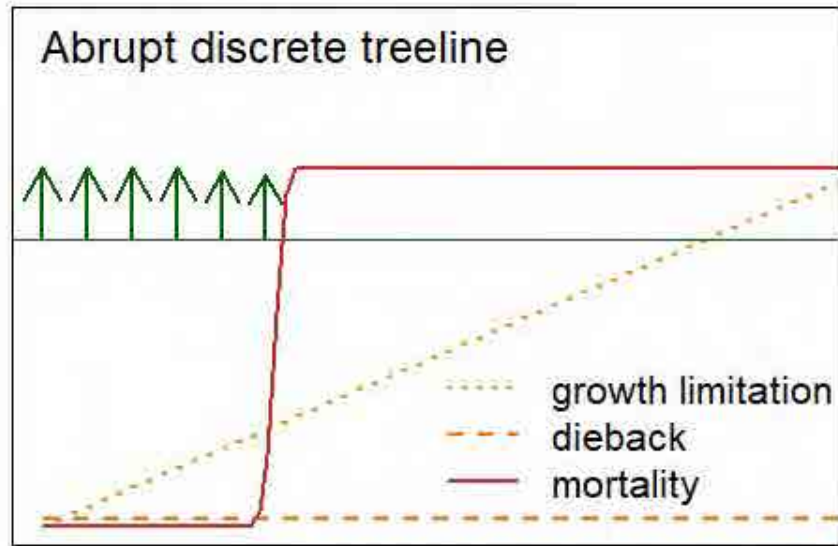
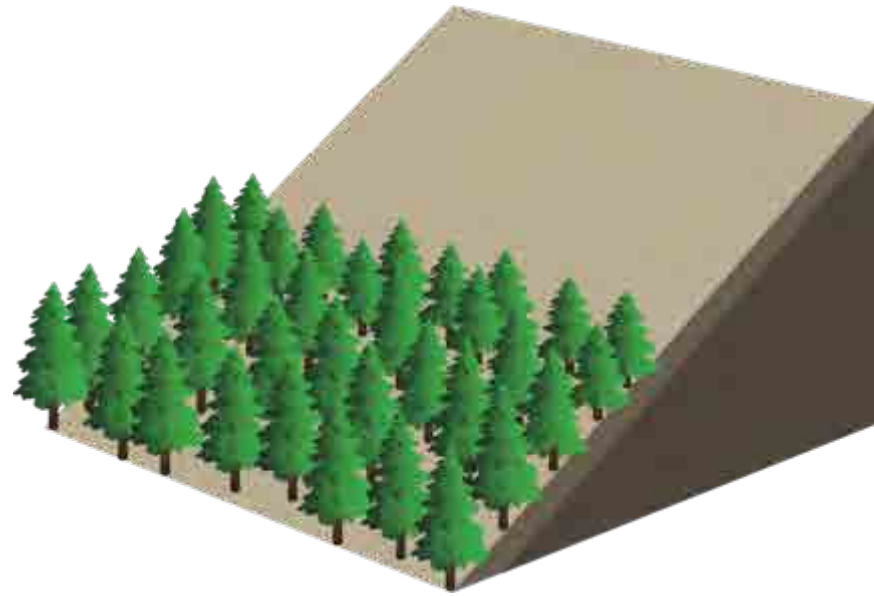


First-level mechanisms

Second-level mechanisms

Third-level mechanisms

New Zealand, Nothofagaceae

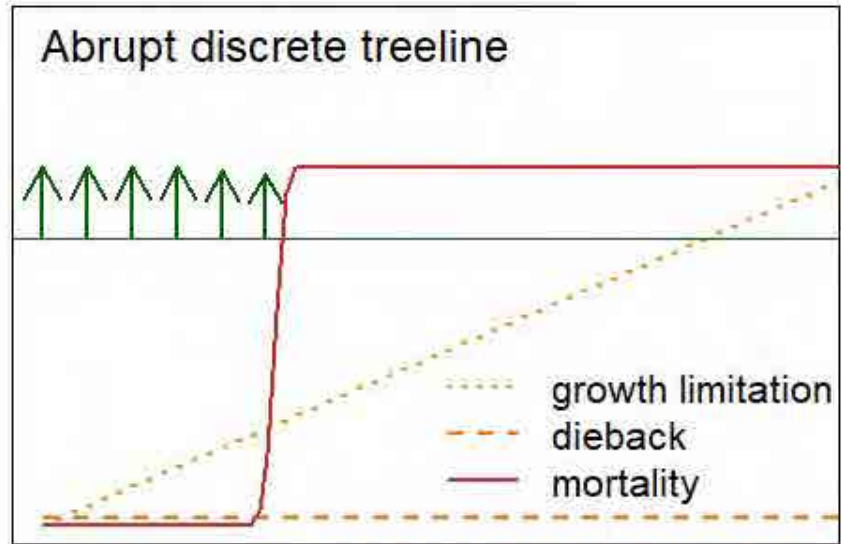
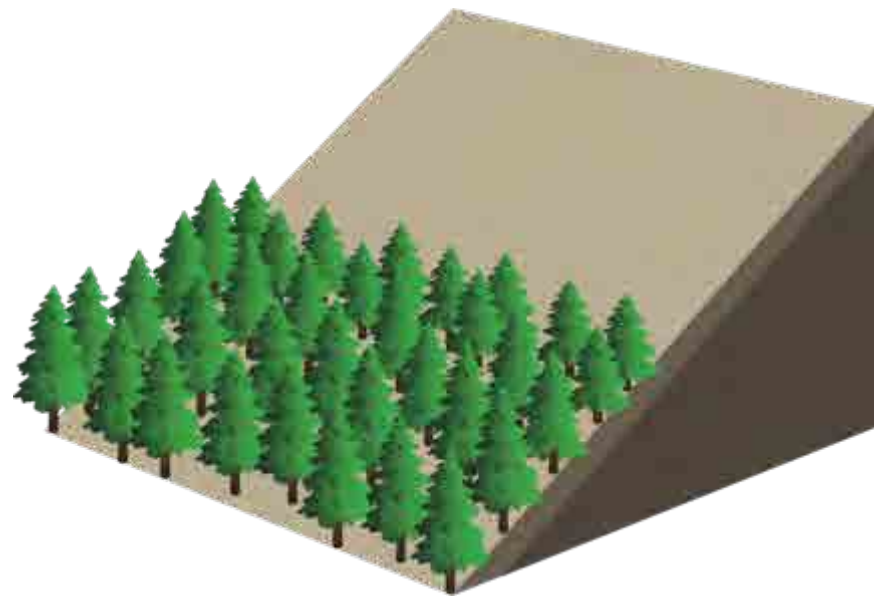


First-level mechanisms



Second-level mechanism

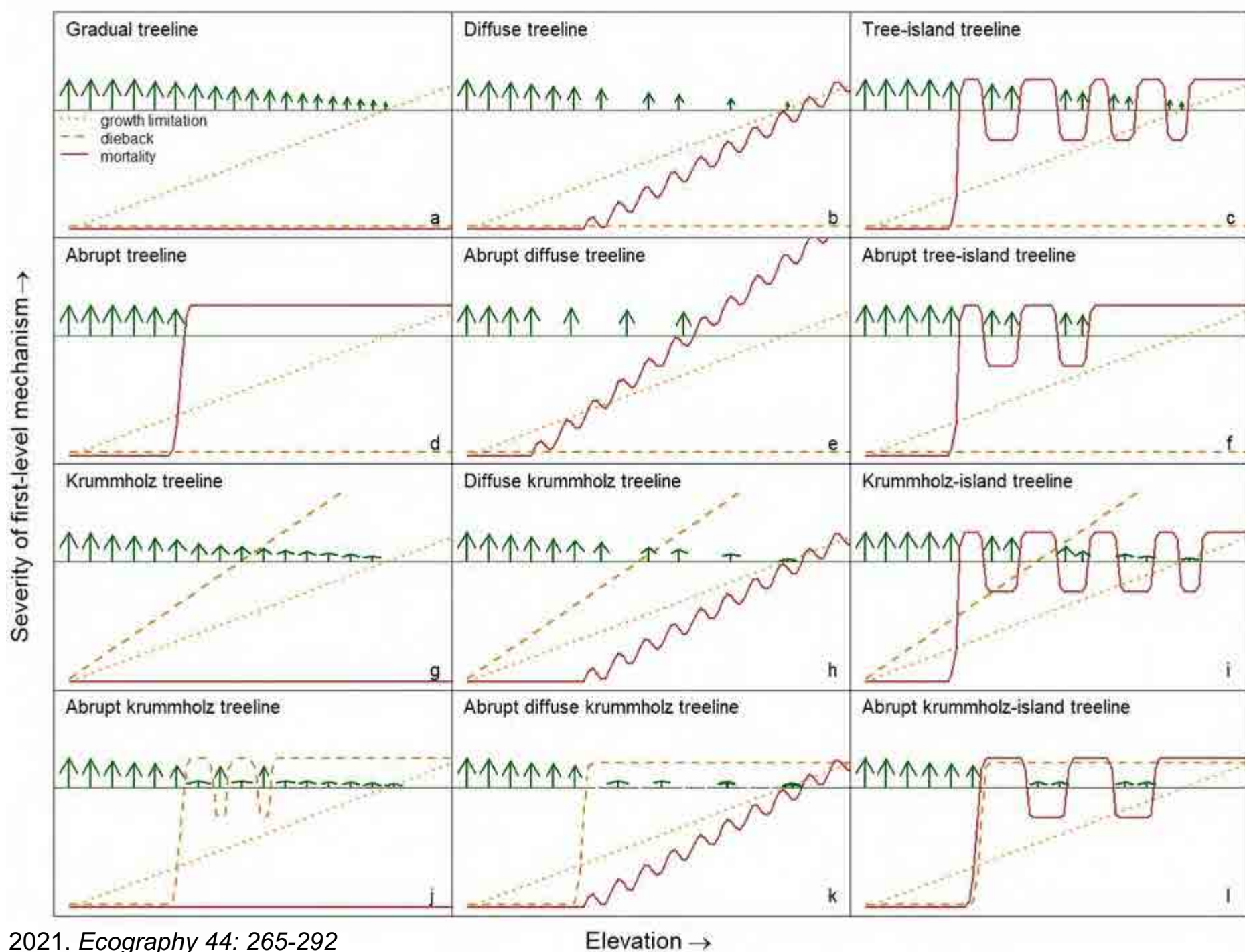
Ecuador, mixed cloud forest



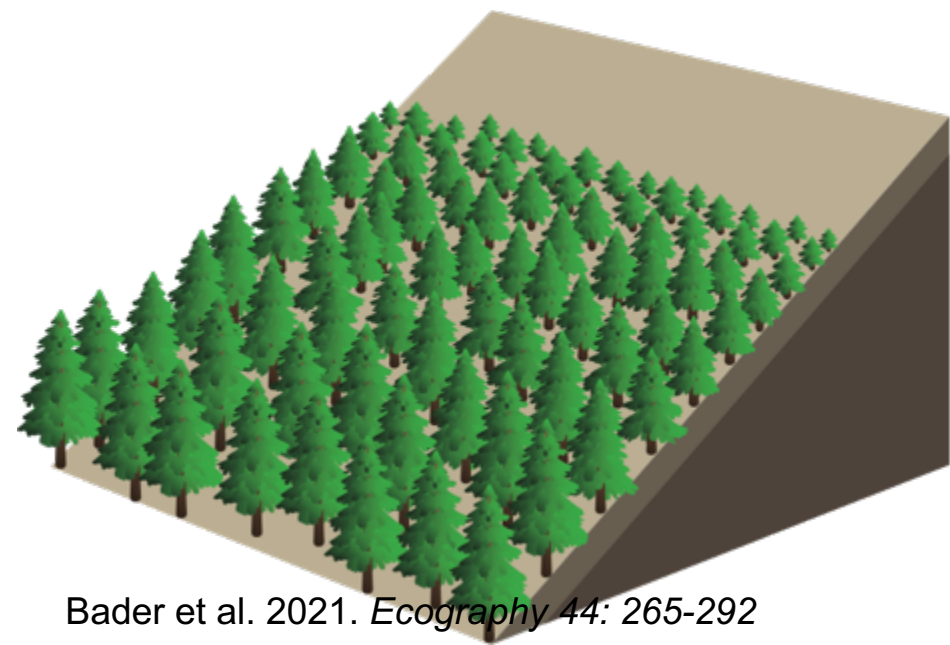
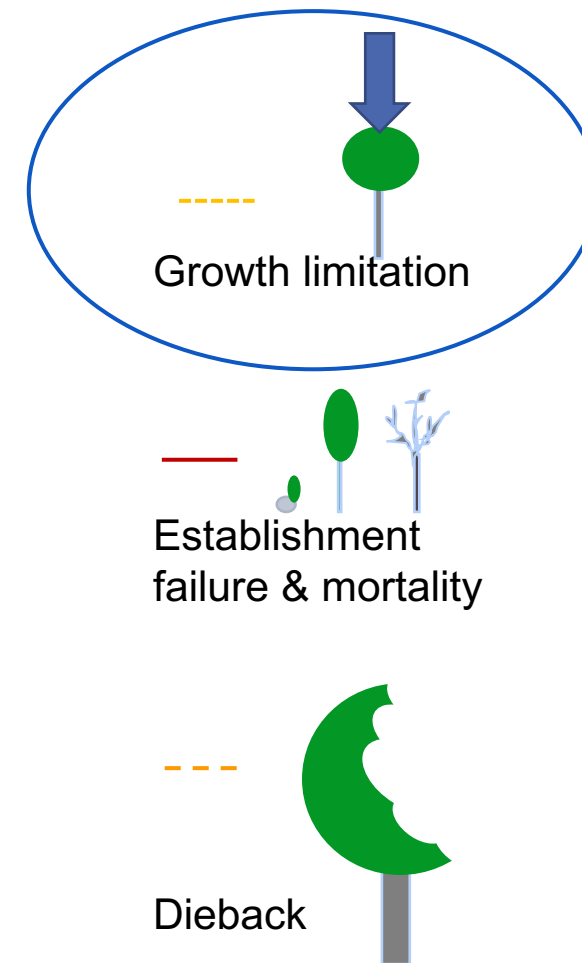
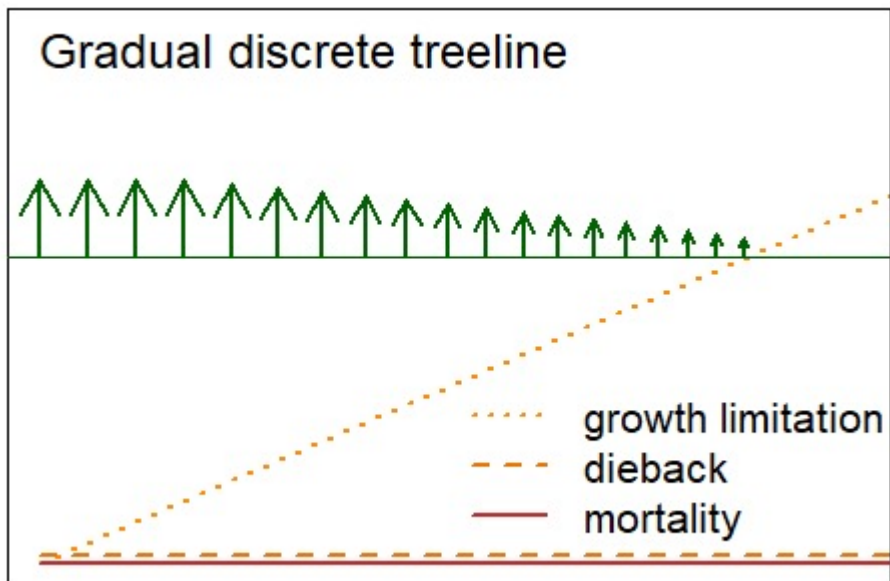
First-level mechanisms

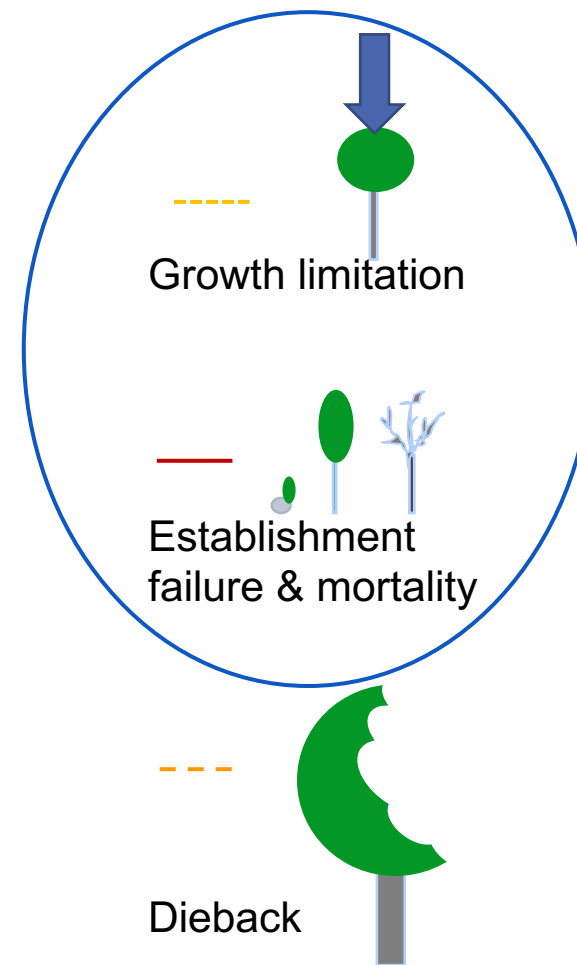
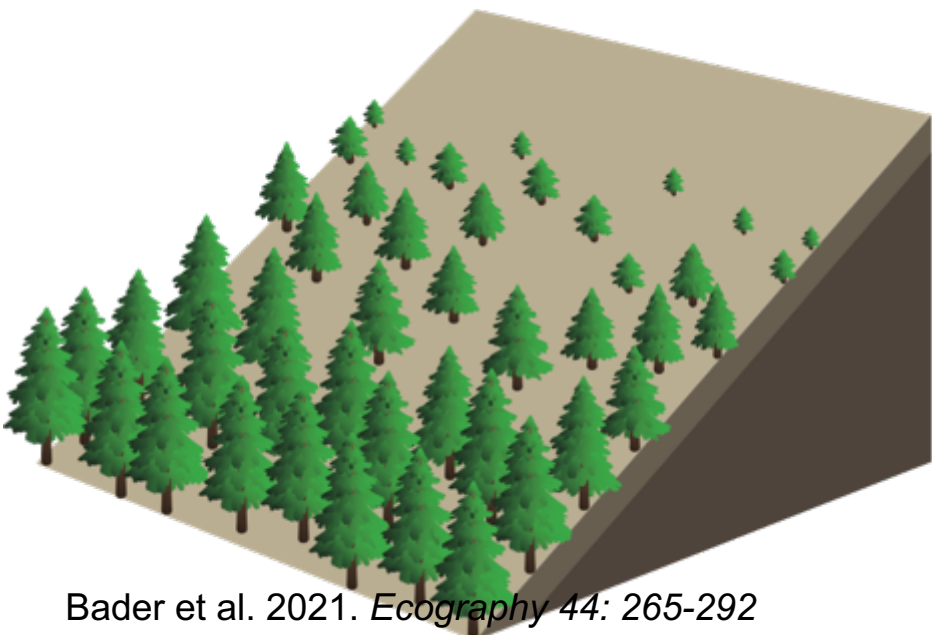
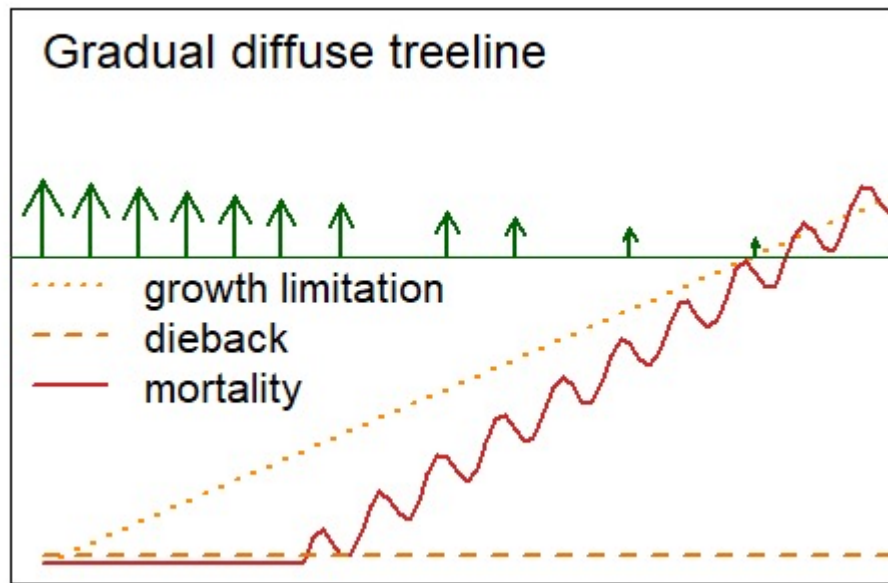


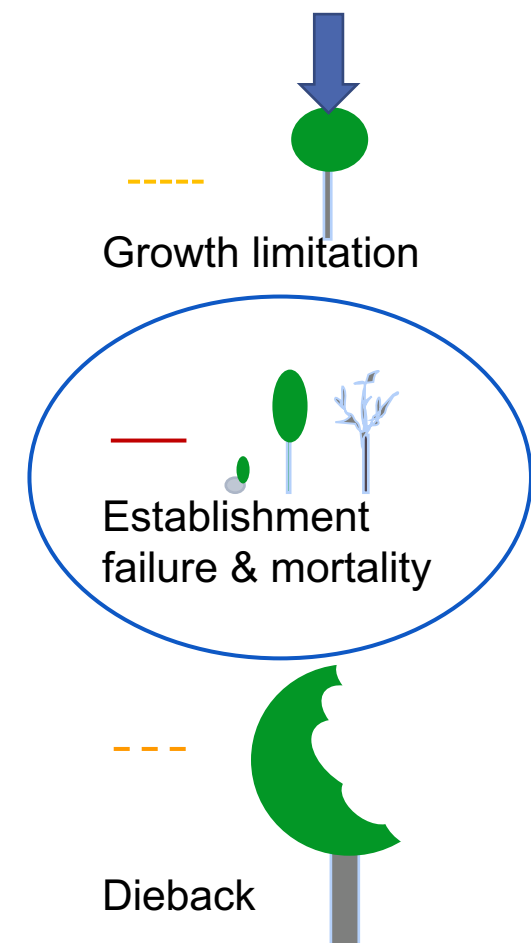
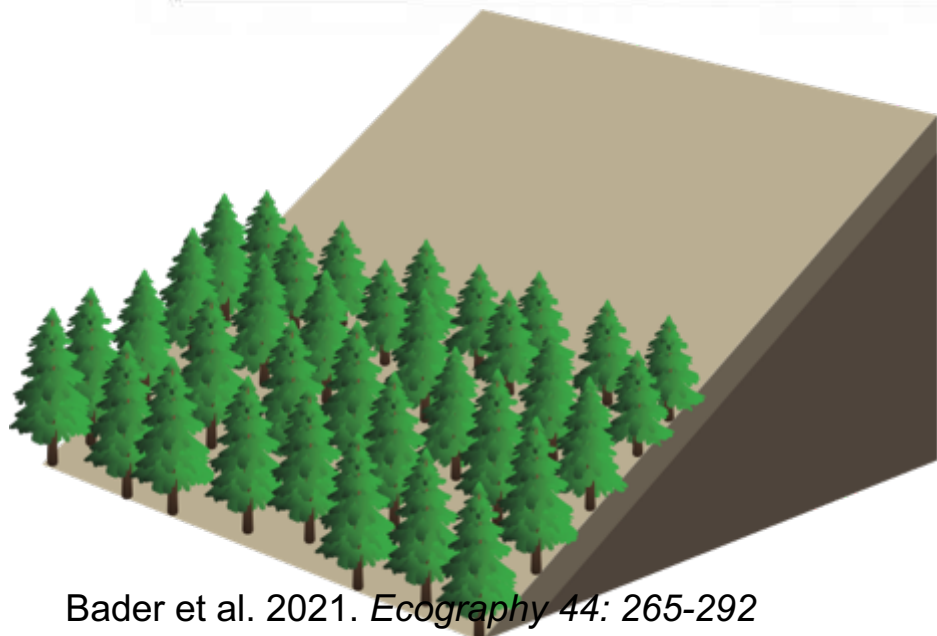
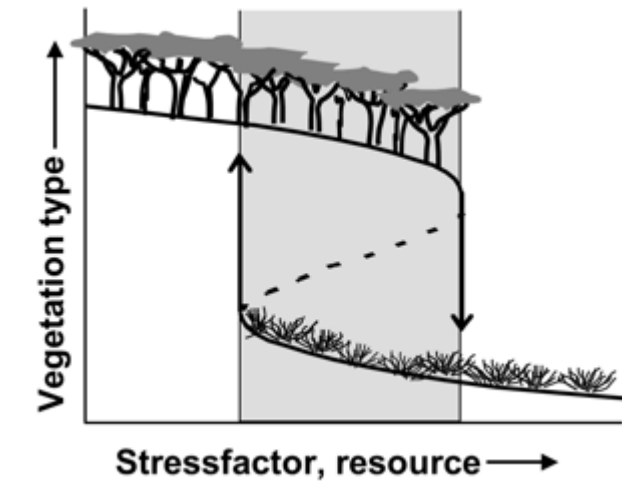
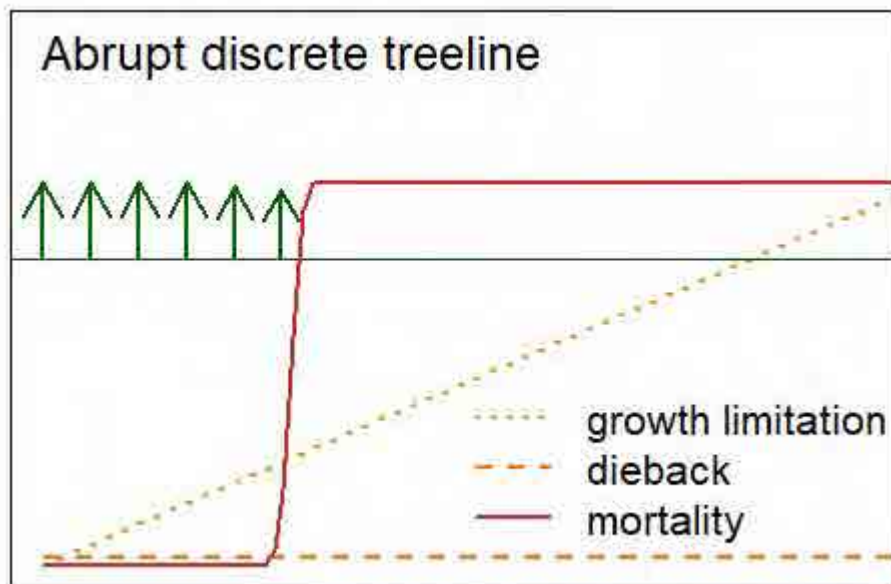
Second-level mechanism



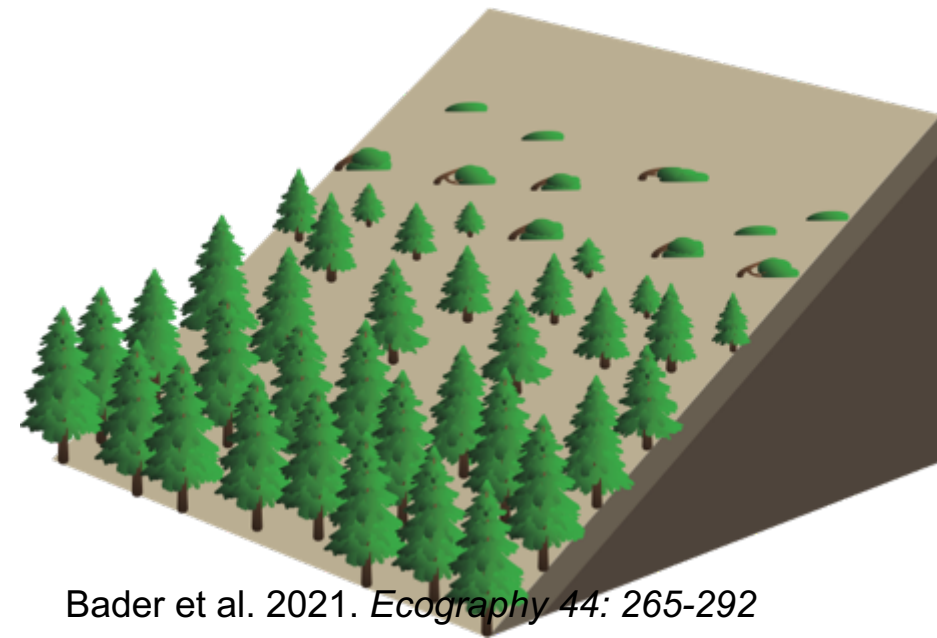
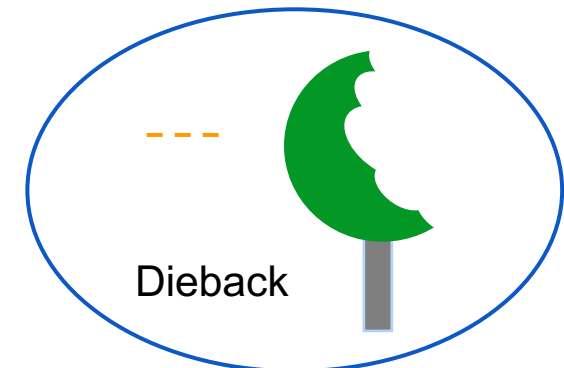
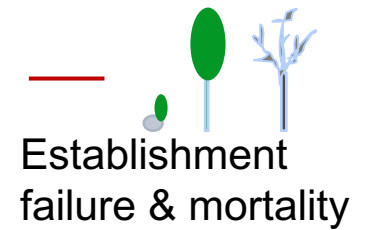
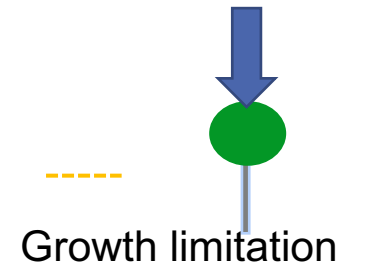
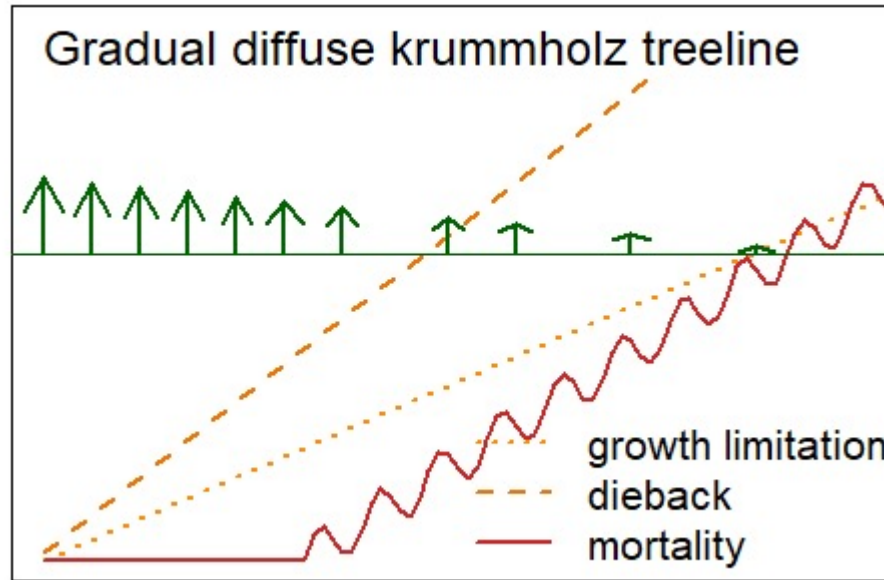
The null model!



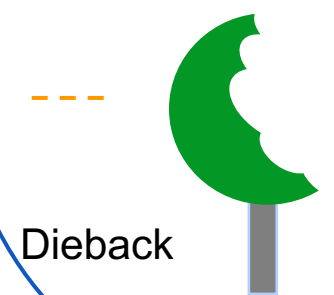
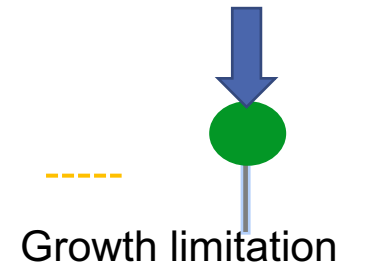
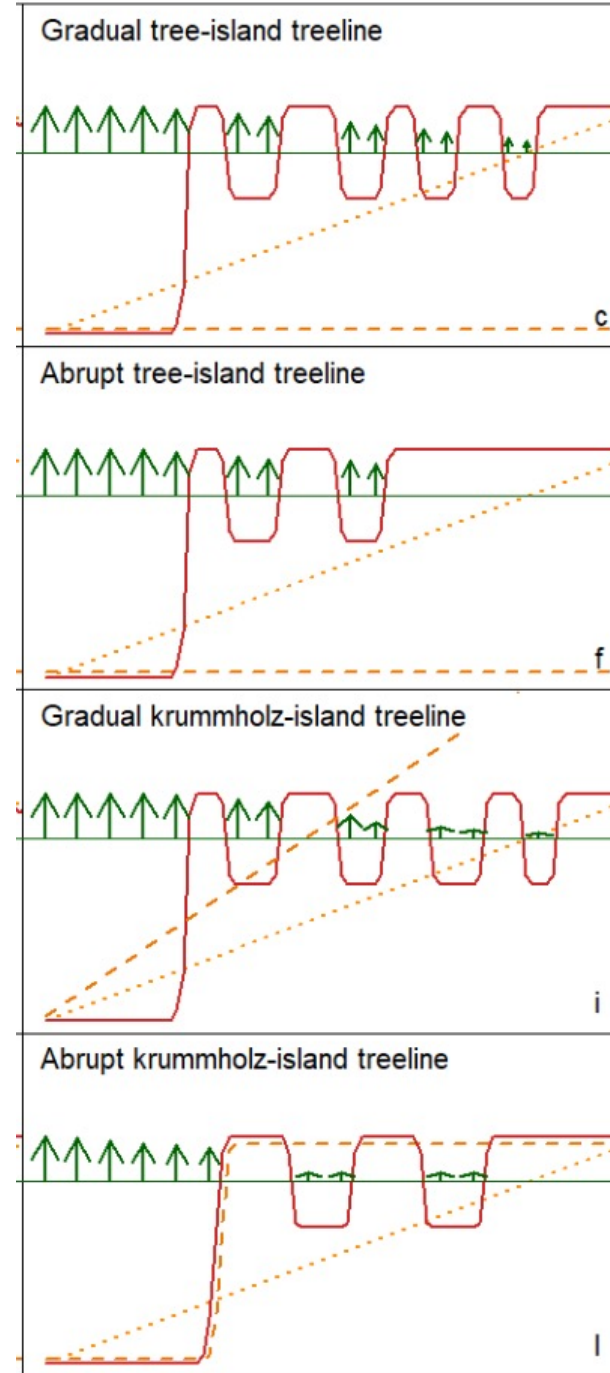
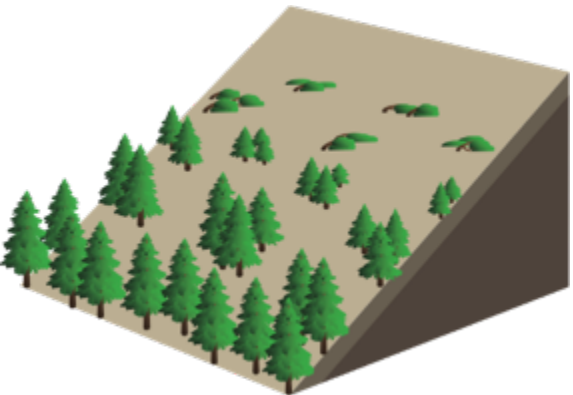
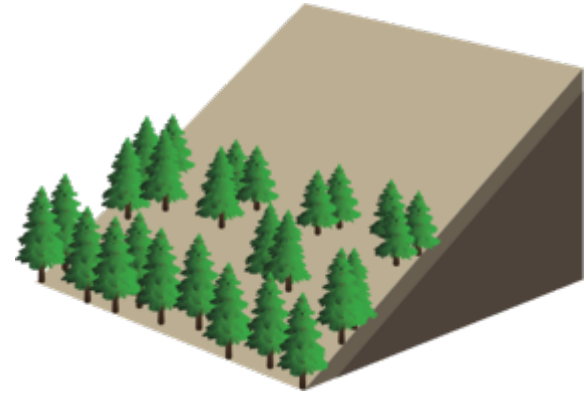




Krummholz treelines



Island treelines



How to study what processes cause these patterns?



Spatial Treeline Ecotone Model: STEM

- Individual-based: each tree is modelled individually in a spatial neighbourhood
- Pattern-oriented: trying to reproduce as many observed patterns (spatial, temporal, size-distributions, etc.) as possible

Step 1: model first-level mechanisms (demographic gradients & neighbour effects)

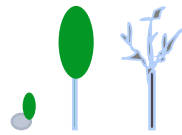
Step 2: model second-level mechanisms (climatic gradients & neighbour effects + plant responses)

Current status: STEM 1.0

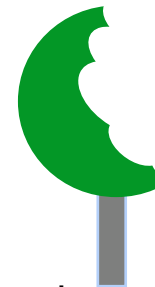
- Testing our conceptual model with a formal model
- First-level mechanisms only
- Creation of different patterns by changing **demographic gradients** and **neighbour interactions**
- Implemented in NetLogo
- General parameterisation with field data (next slide)



Growth limitation



Establishment failure & mortality



Dieback



Observed treeline patterns:

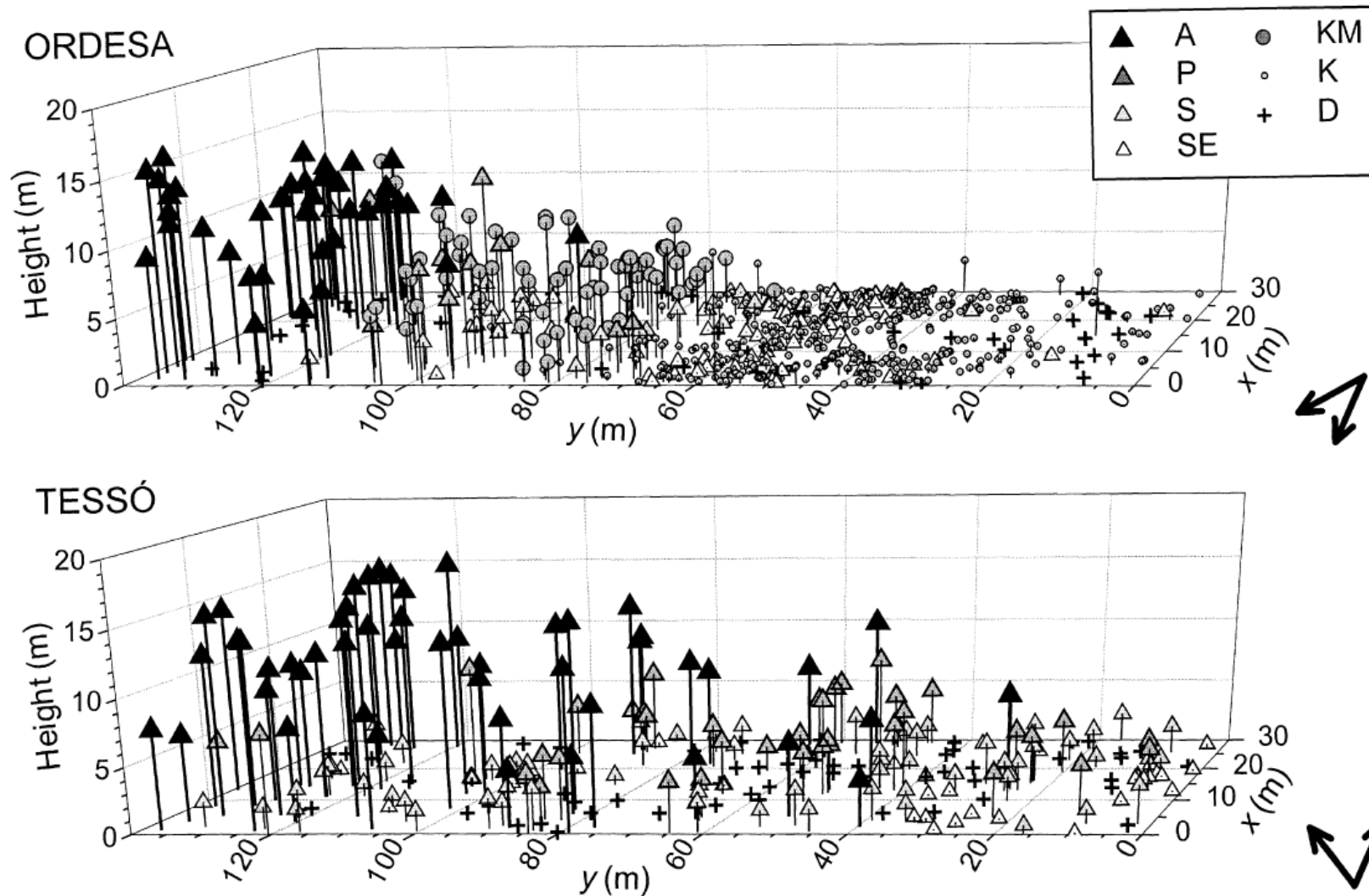
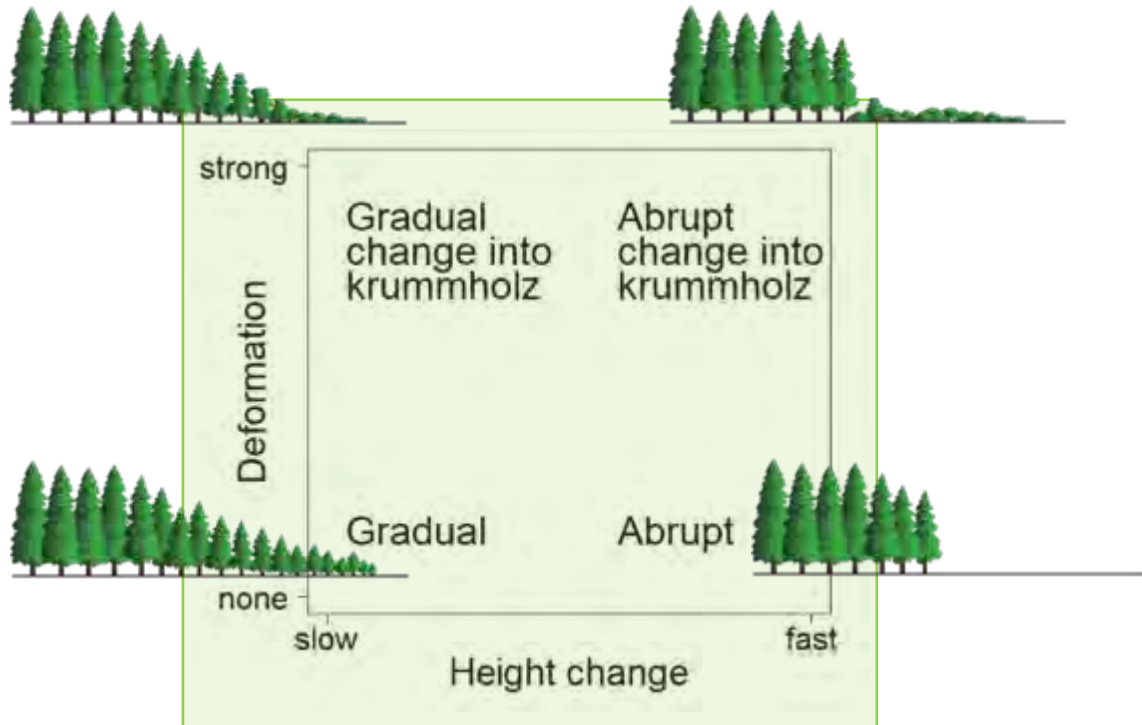
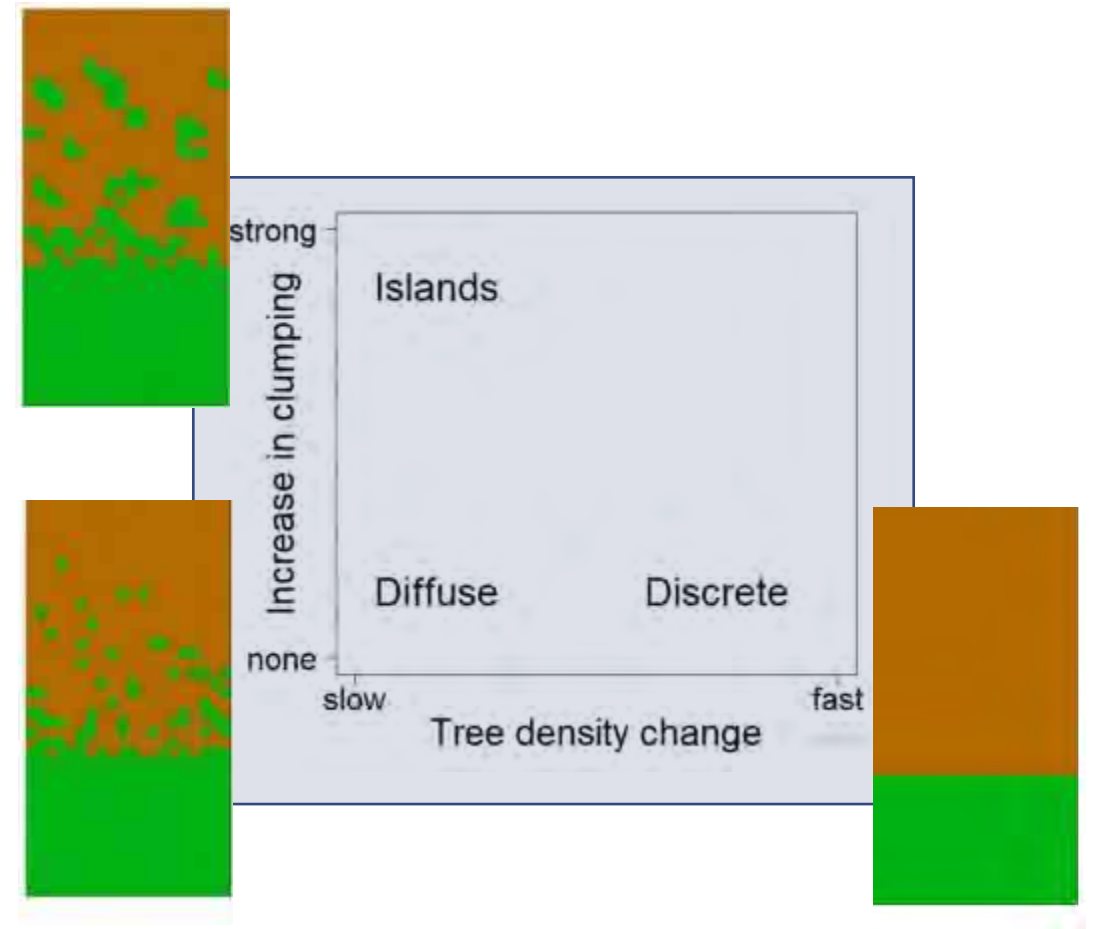


Fig. 1 in Camarero et al 2000 For Ecol Man. Spatial location and height of all individuals in two treeline sites. Abbreviations: adults (A), poles (P), saplings (S), seedlings (SE), dead trees (D), krummholz (K) and flagged krummholz (KM). The black arrows show the directions of the dominant winds

Spatial dimensions to describe patterns in model output and field data



Stature change

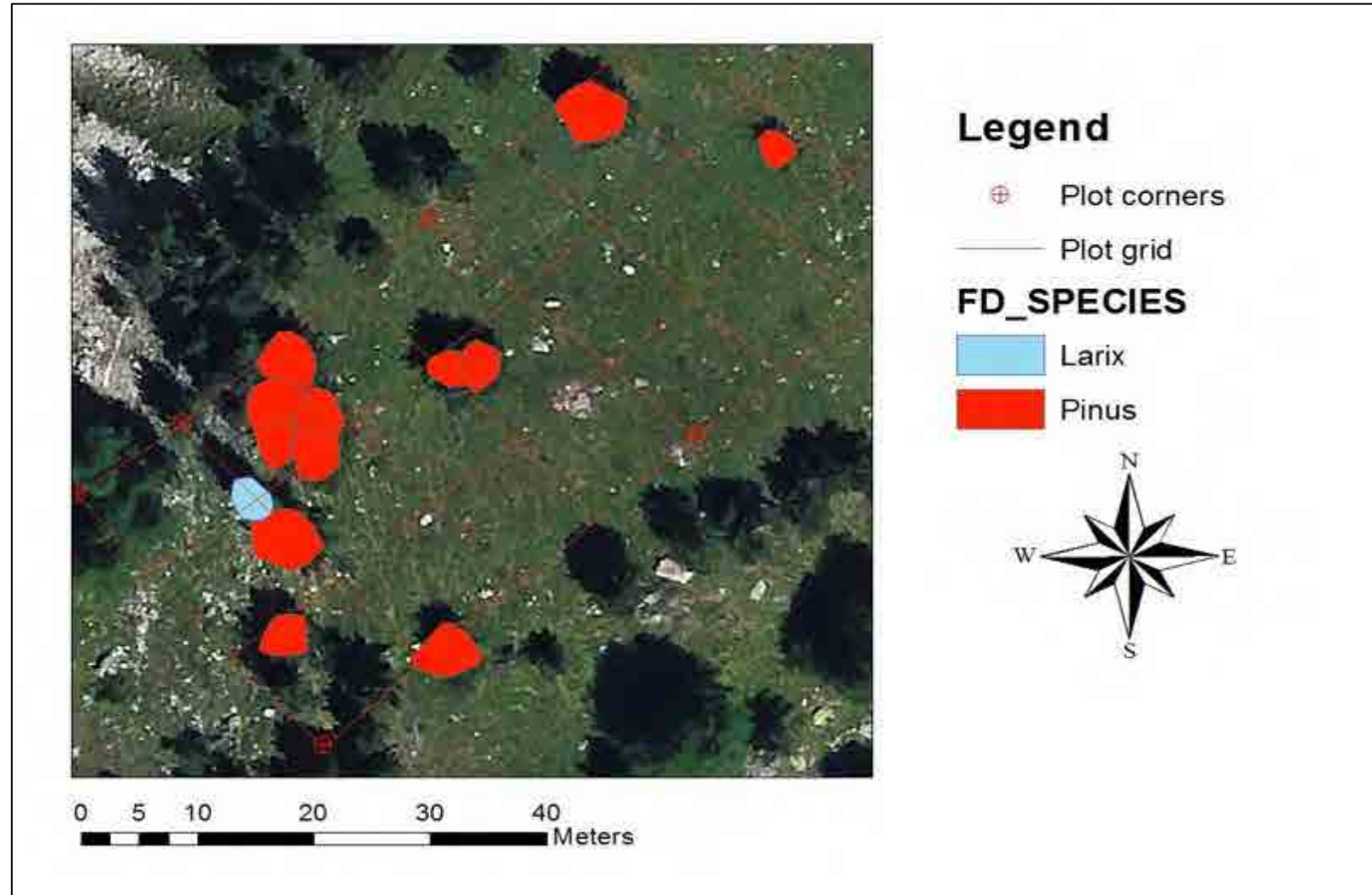


Pattern in the x-y plane

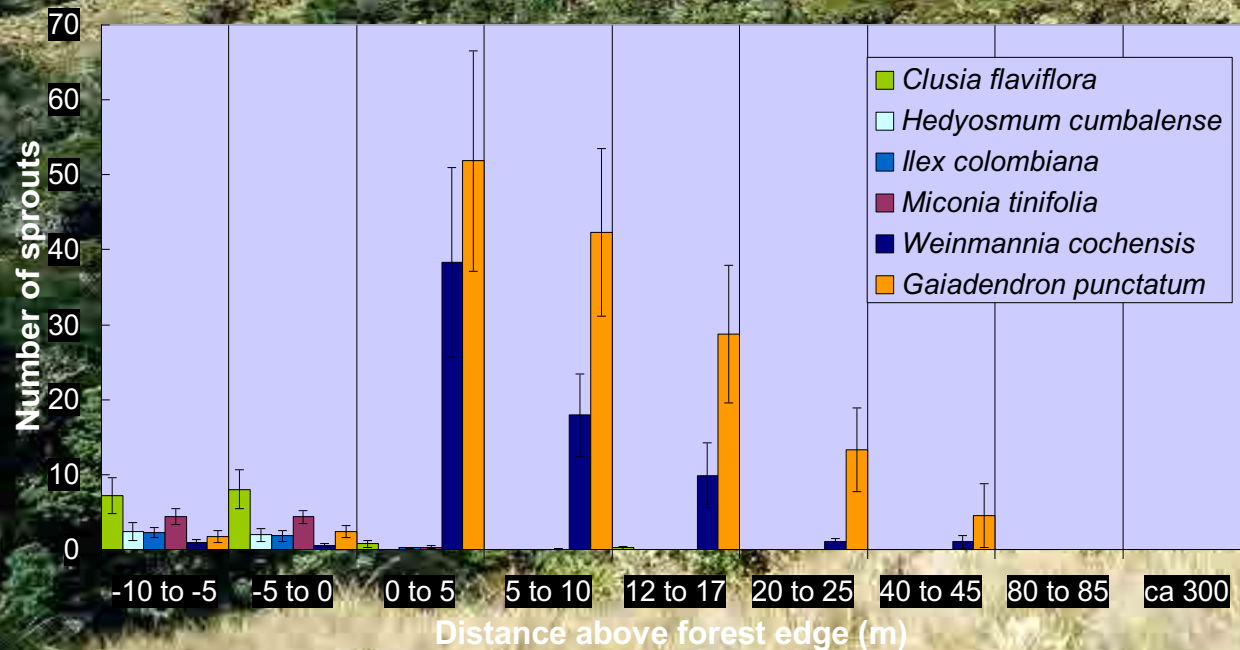
How to gather enough real patterns for comparing model results against?



Remote-sensing potential to map 3-D patterns



Partial patterns can also be valuable for pattern-oriented modelling



Layers Close

Legend

TreeLine locations

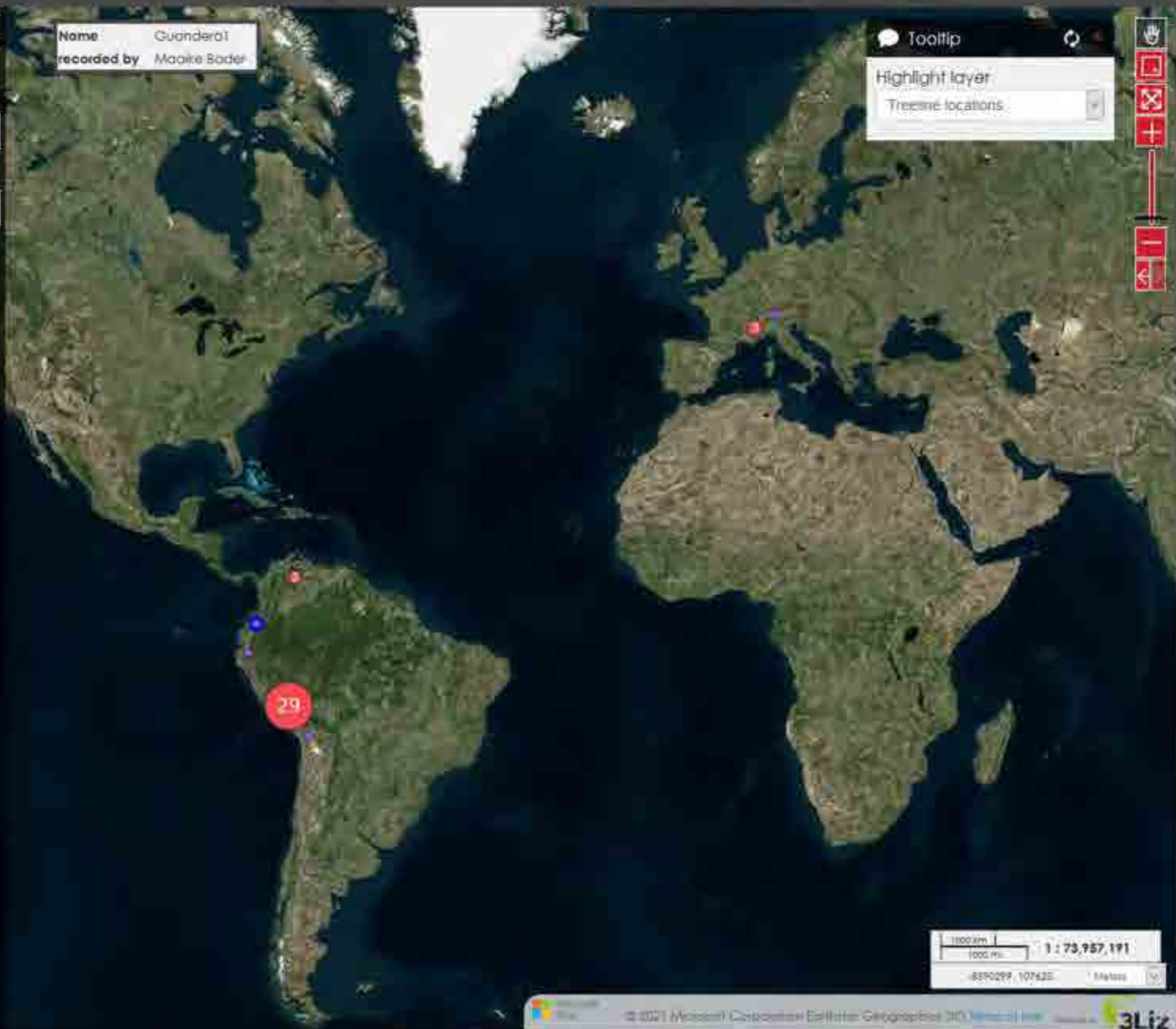
Base Layer

Bing Aerial

Name: Guandera1
recorded by: Maaike Bader


Tooltip

Highlight layer
TreeLine locations



Popup Close

TreeLine locations



© Maaike Bader

Guandera1 is located in the Andes, in Ecuador. The tree line ecotone is located at ca: 3670 m elevation.

Tree species: *Clusia multiflora*, *Weinmannia* sp., *Galadendron*, ...

Shrub species: *Diplostegium* sp.

1000 km
1000 mi
1 : 75,957,191
-85°02'99", 107°42'5"

[GO TO MAP](#)[METADATA](#)

ALPINE TREELINES ONLINE

A COMMUNITY-BASED INFORMATION FACILITY FOR ALPINE TREELINE RESEARCH

Explore map



Instructions




Resources




Network



With thanks to the team and our funders!

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Thank you for your attention

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