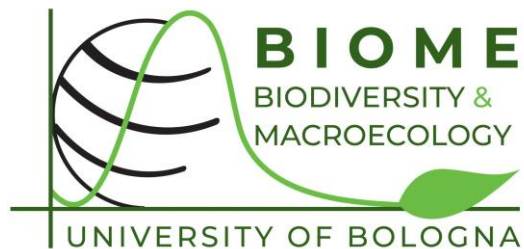




ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA



Assessing the role of structurally complex forests as climatic refugia for plant biodiversity

Georg J. A. Hähn

Supervisor: Francesco M. Sabatini

Co-supervisor: Alessandro Chiarucci

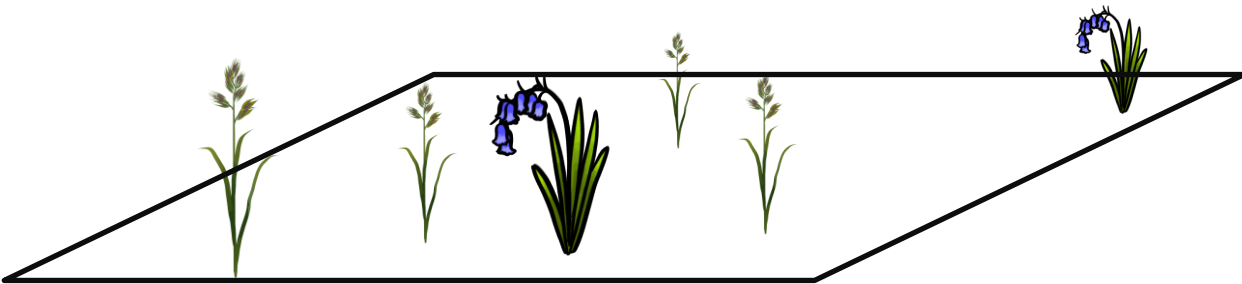
Department of Biological, Geological, and Environmental Sciences

1,726



General Introduction

1,437

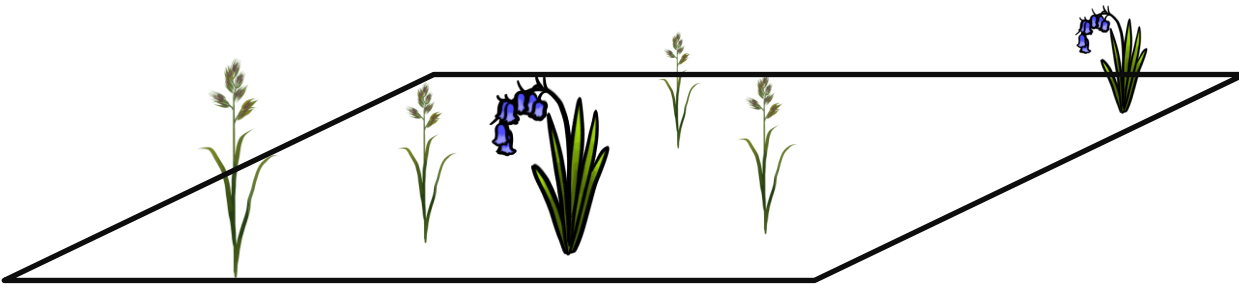


General Introduction

N & P concentrations up to 30% higher in herb foliage than in trees

Rapid decomposition and high turnover rate facilitates efficient recycling of nutrients

Spring ephemeral species: nutrient uptake before deciduous canopy develops



General Introduction

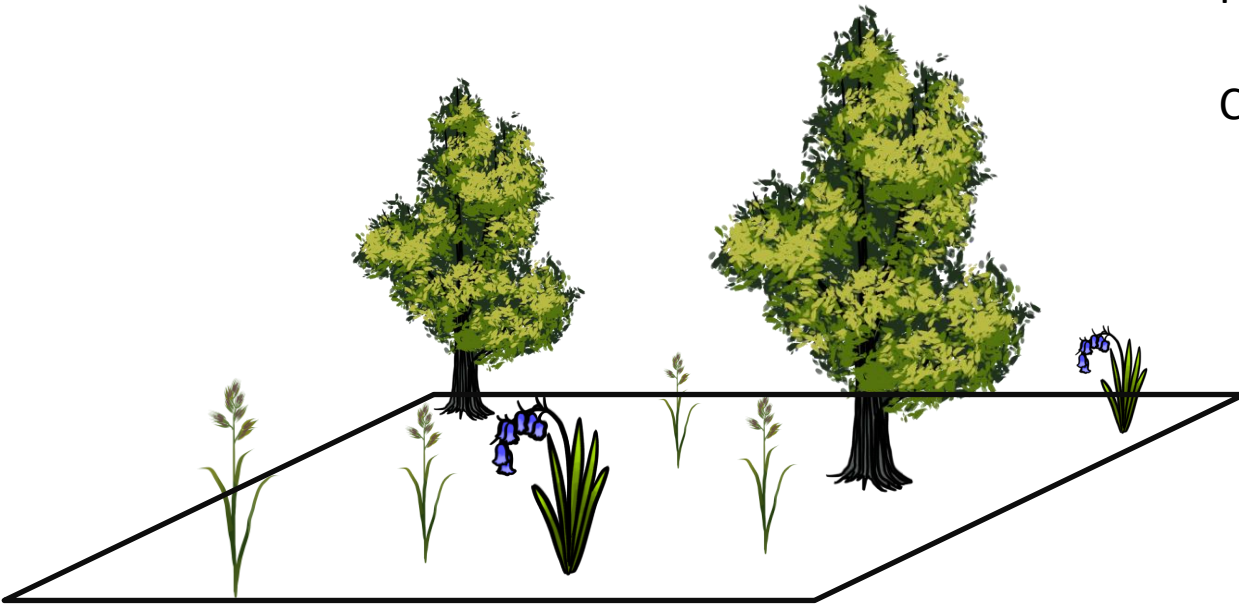
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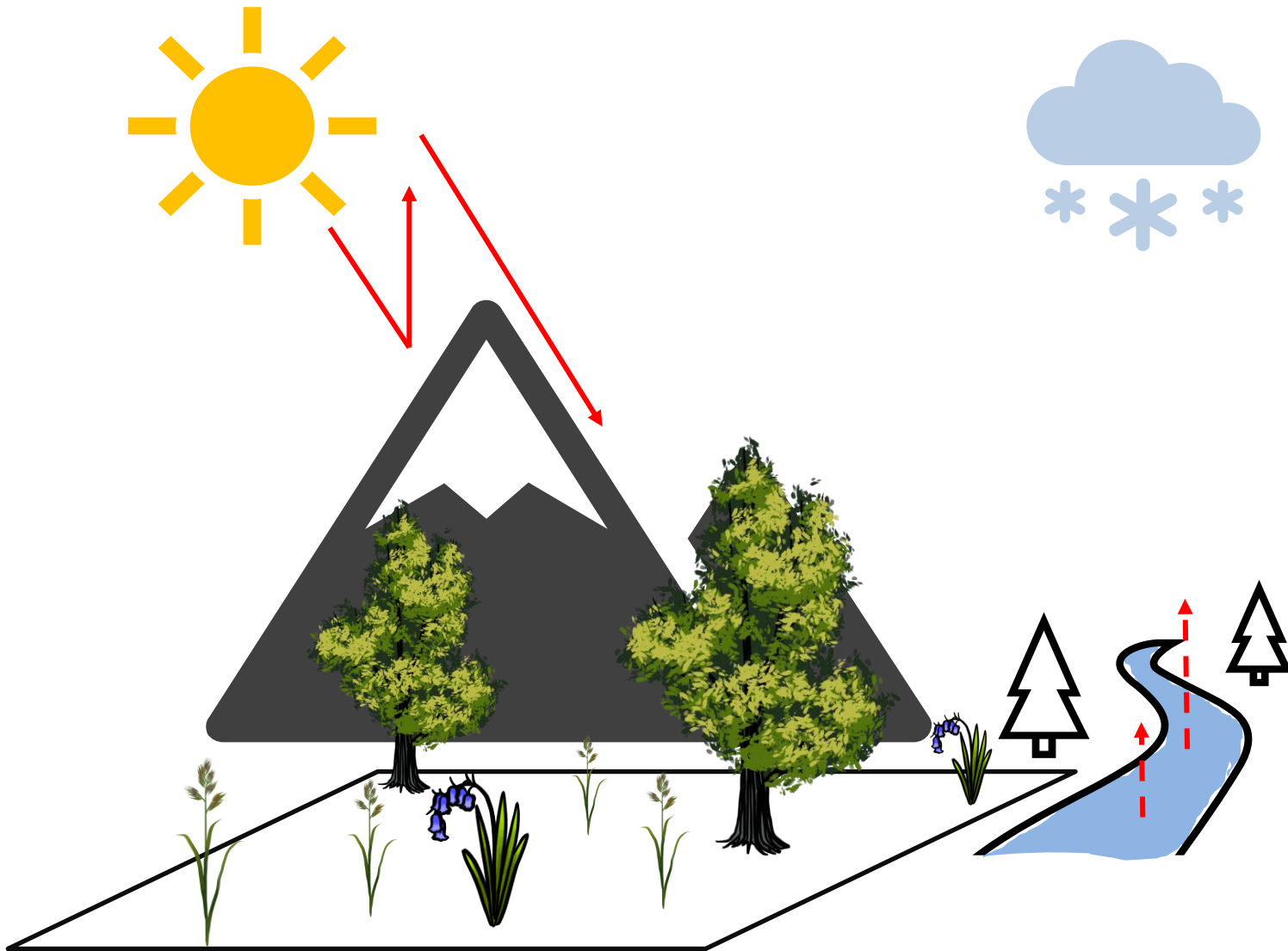
Spring ephemeral species: nutrient uptake before deciduous canopy develops

Herbaceous species define tree seedling habitat

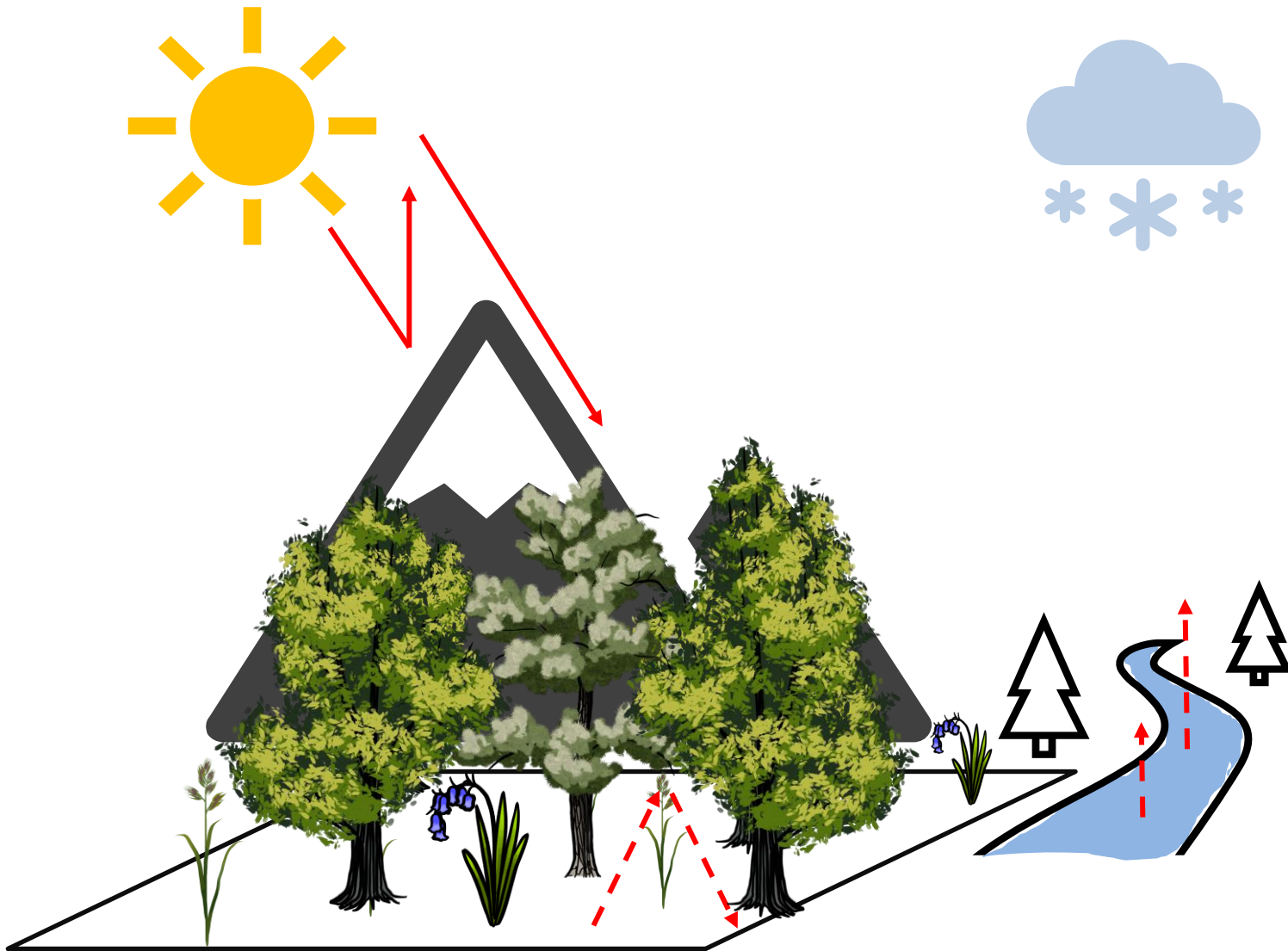
Competition can determine the forest which will be established



General Introduction

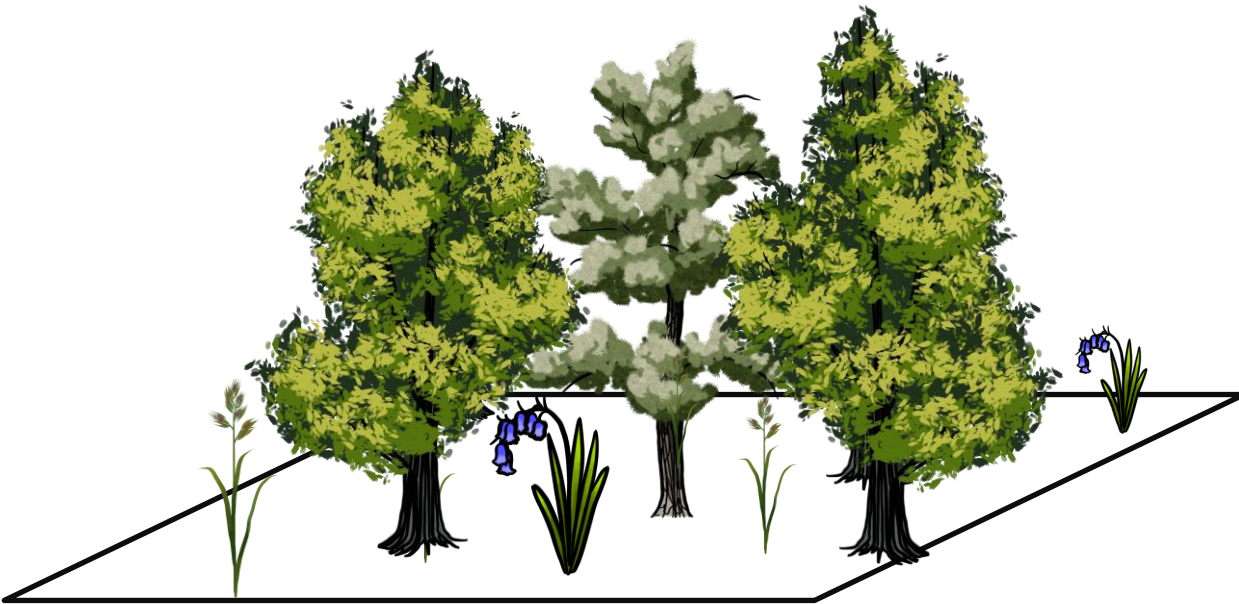


General Introduction



Chapter 1 - Protecting old-growth forests as biotic microrefugia amid climate change

Georg J. A. Hähn, Vanessa Berger, Helge Bruelheide, Alessandro Chiarucci, Michele Di Musciano, Víctor González-García, Borja Jiménez-Alfaro, Michael Köhler, Tobias Kummerle, Juri Nascimbene & Francesco Maria Sabatini
Under review in Conservation Science & Policy.



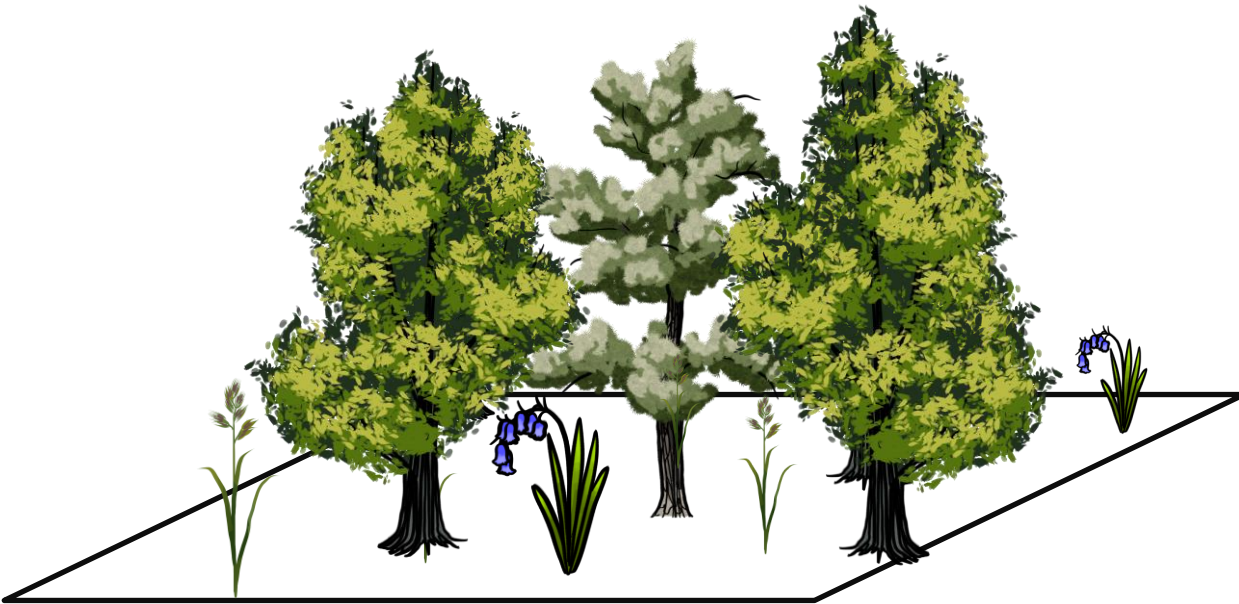
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Protection requires:

Buffer areas to reduce edge effects

Manage younger stands to develop OGF characteristics



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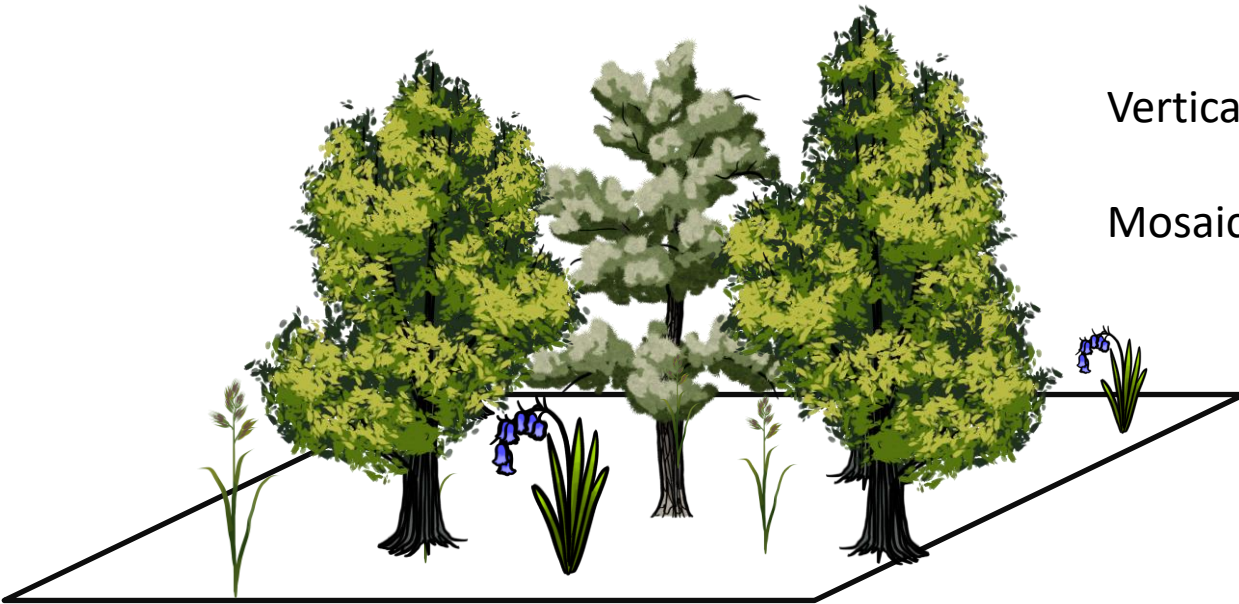
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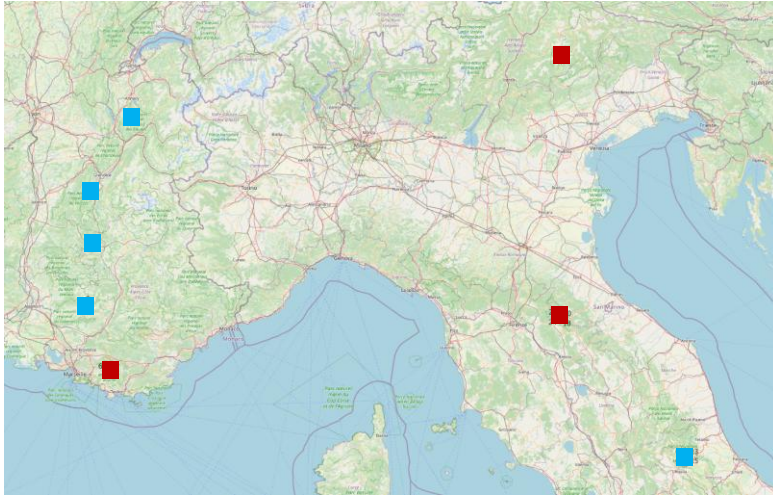
Manage younger stands to develop OGF characteristics

Vertical and horizontal heterogeneity promotes biodiversity across taxa

Mosaic of microhabitats promotes understorey diversity
→ stability of turnovers

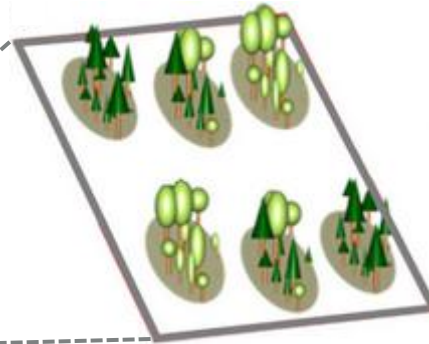
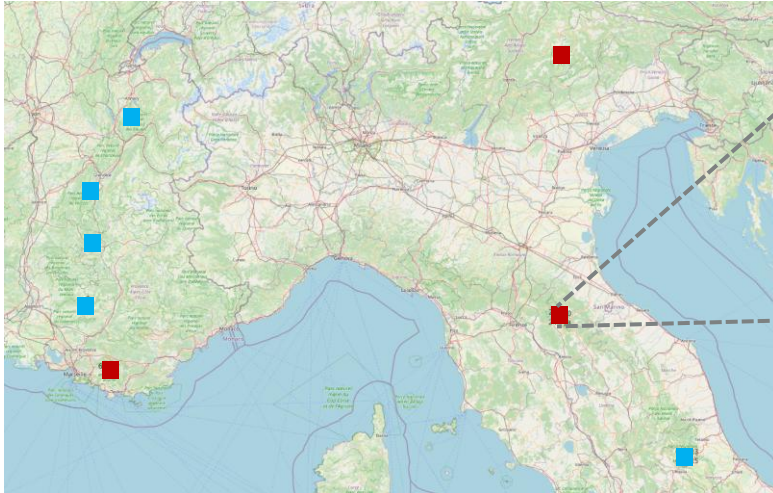


Chapter 2 – Stand structure, microclimate & understory



Established 2024 ■ 2025 ■

Chapter 2 – Stand structure, microclimate & understory

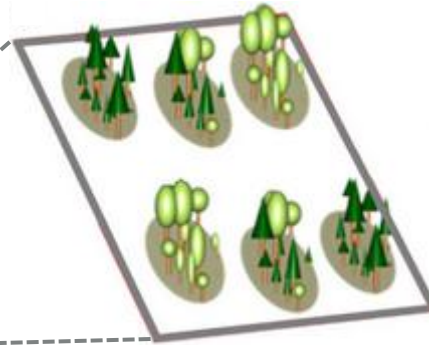
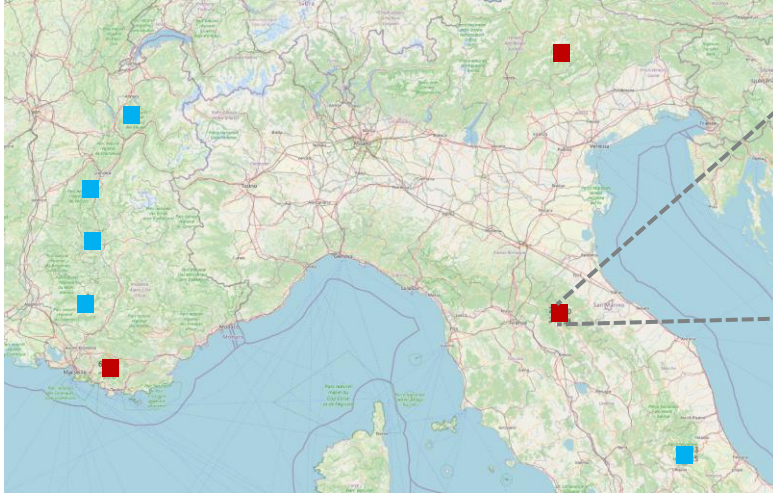


= **72** (Italy) + **30** (France)
= **102 Vegetation plots**



TMS logger in Sasso Fratino 05/2024

Chapter 2 – Stand structure, microclimate & understory

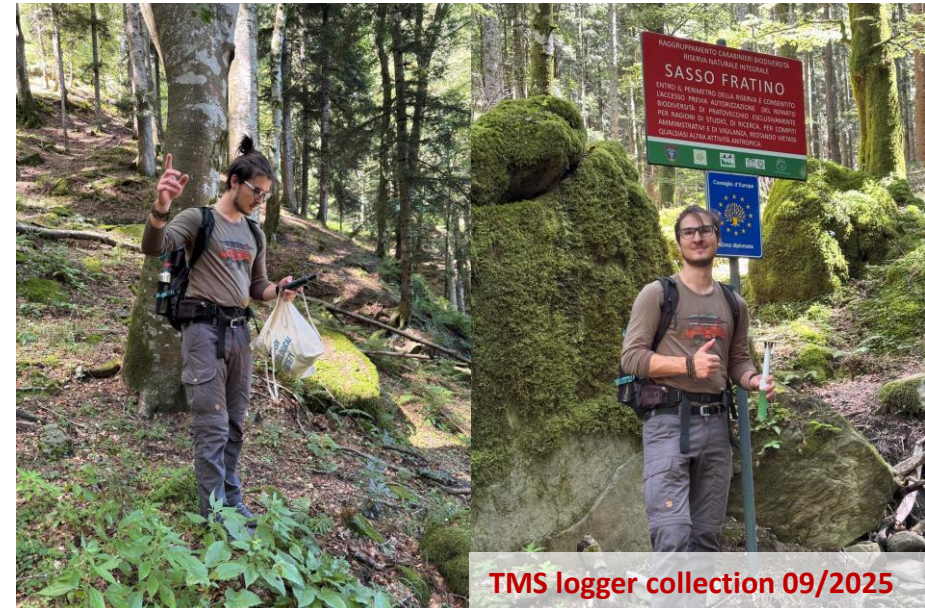


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- Microclimate Temperature/Moisture Sensor (TMS) in the centre
- Terrestrial Laser Scan 1.5m above TMS → Stand Structural Complexity
- Tree diameter → stand biomass
- Hemispherical Densiometer → light availability



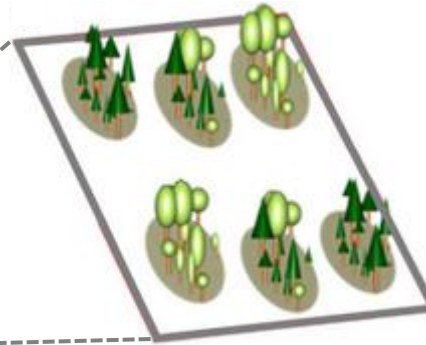
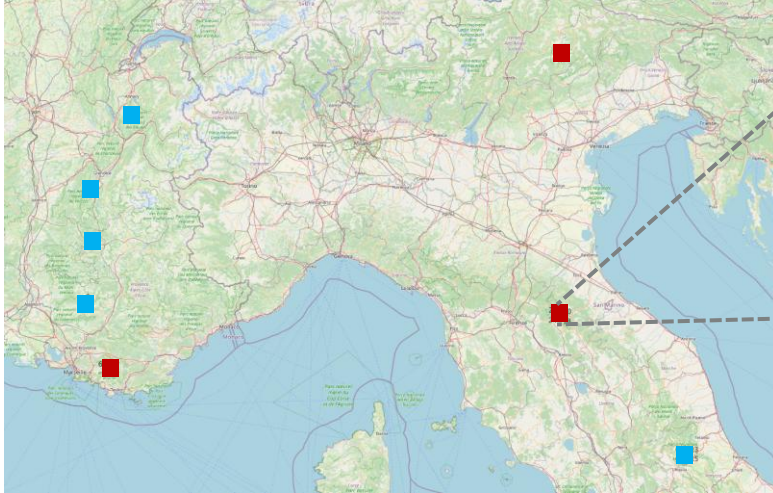
TMS logger in Sasso Fratino 05/2024



TMS logger collection 09/2025



Chapter 2 – Stand structure, microclimate & understory



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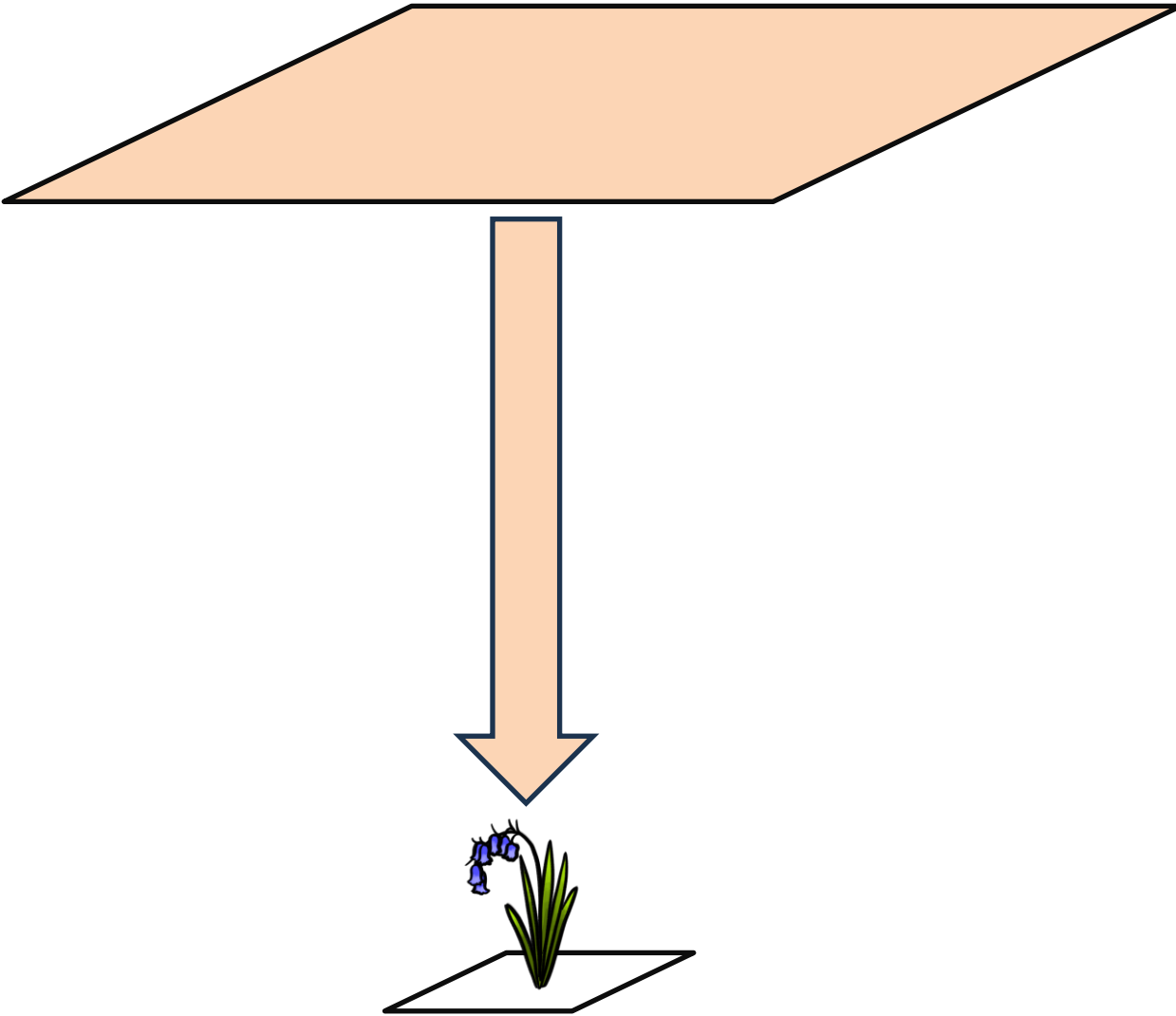
TMS logger in Sasso Fratino 05/2024



TMS logger collection 09/2025

Next step: Are species turnovers linked to changes in microclimate and stand structural complexity?

Chapter 3 – Placing plant communities in their microenvironments: Forest composition for accurate microclimate predictions

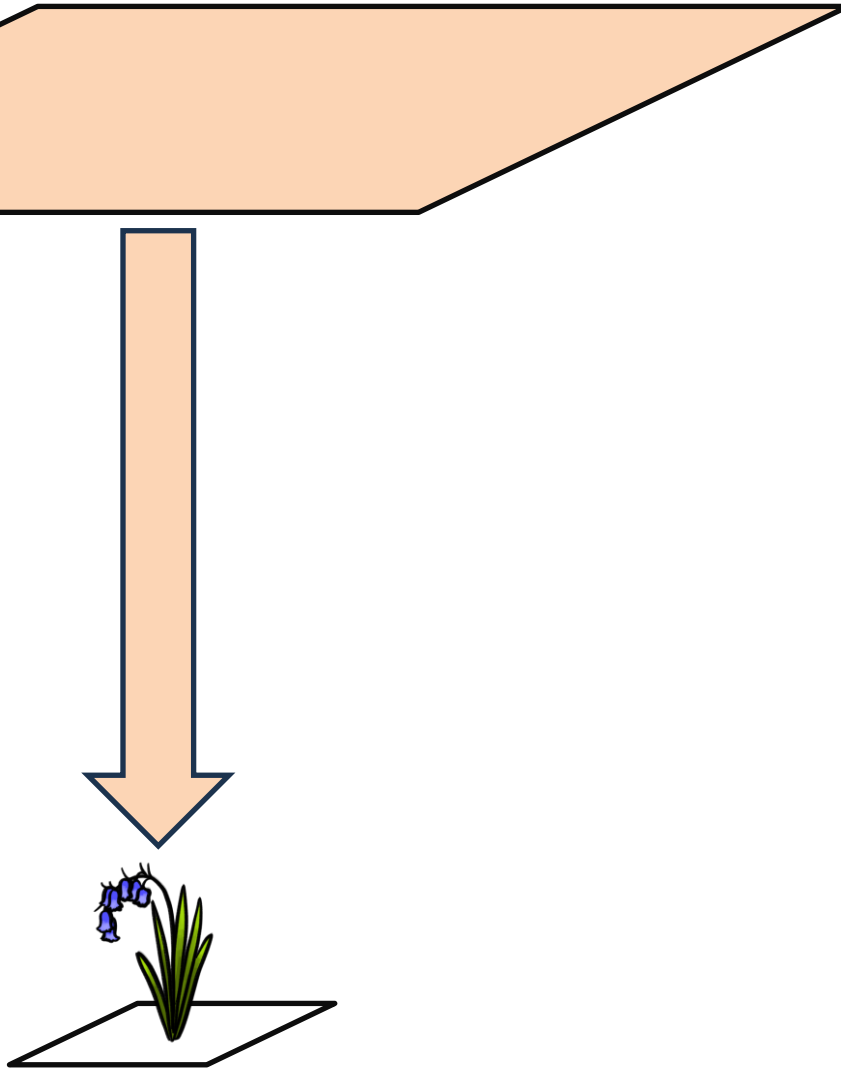


Chapter 3 – Placing plant communities in their microenvironments: Forest composition for accurate microclimate predictions

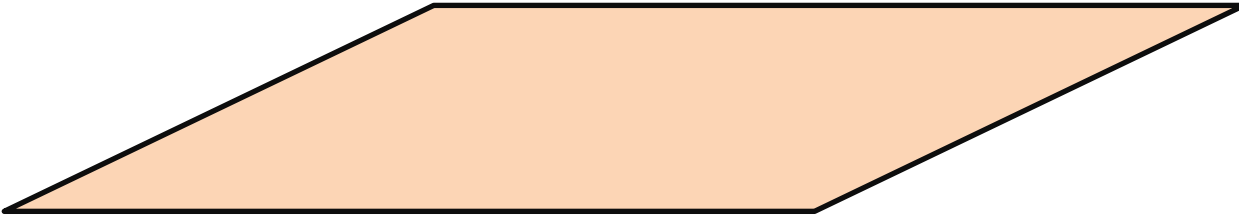
Abiotic data: Climate - ERA 5

Spatial resolution: 9 km

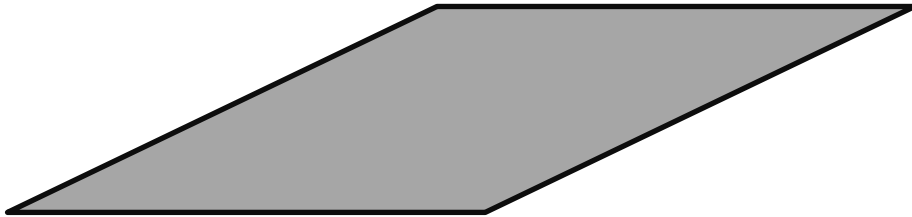
Temporal resolution: hourly from 1950 to yesterday



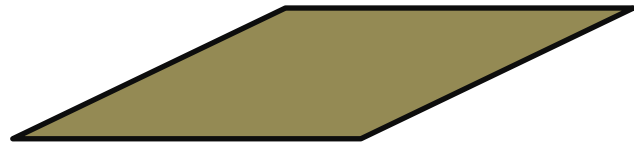
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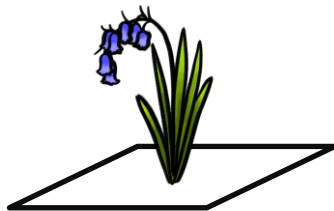
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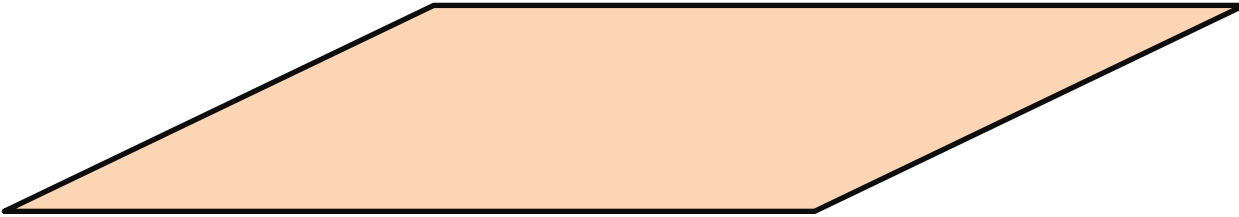
Abiotic data: Digital elevation model
Spatial resolution: 30 m
Temporal resolution: N/A



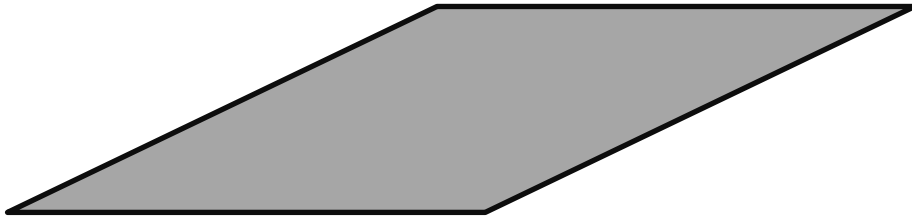
Abiotic data: Soil conditions
Spatial resolution: 1 km
Temporal resolution: N/A



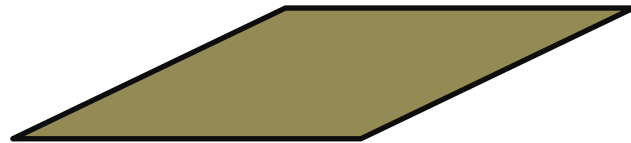
Chapter 3 – Placing plant communities in their microenvironments: Forest composition for accurate microclimate predictions



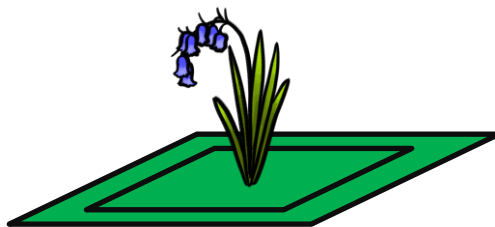
Abiotic data: Climate - ERA 5
Spatial resolution: 9 km
Temporal resolution: hourly from 1950 to yesterday



Abiotic data: Digital elevation model
Spatial resolution: 30 m
Temporal resolution: N/A



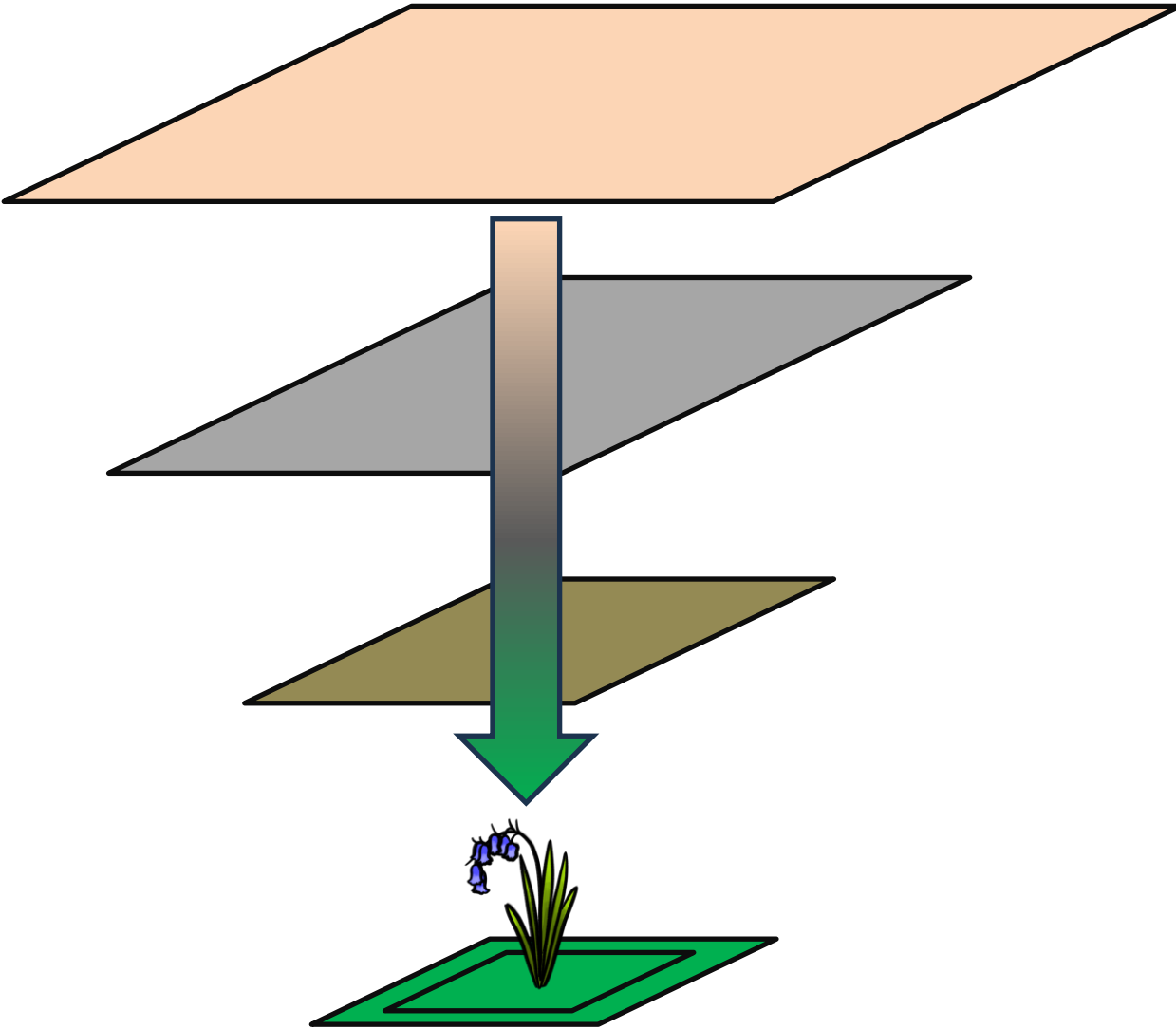
Abiotic data: Soil conditions
Spatial resolution: 1 km
Temporal resolution: N/A



Biotic data: Forest / Canopy buffering

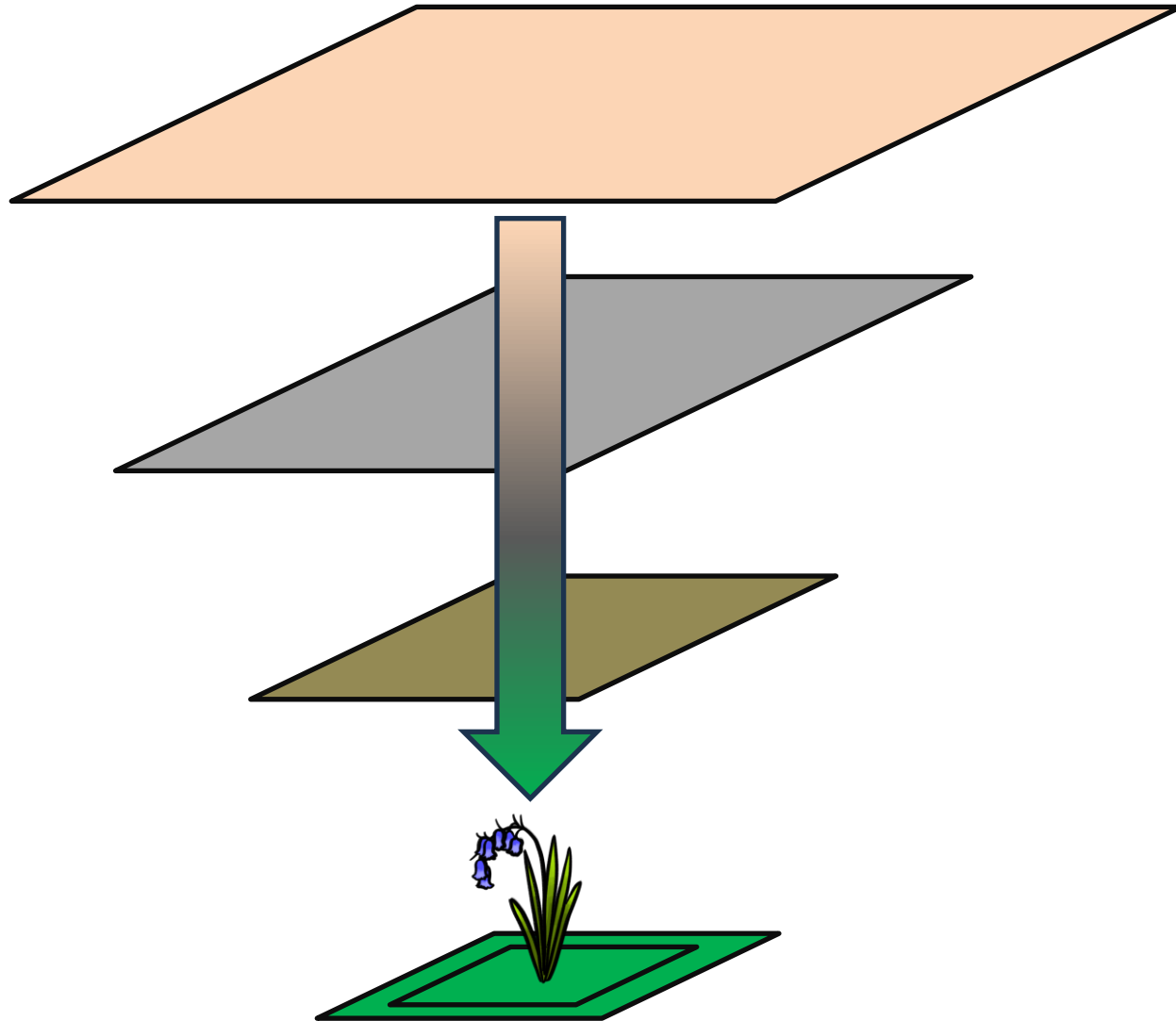
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Mechanistic microclimate model (*microclimf*, Ilya Maclean)



Chapter 3 – Placing plant communities in their microenvironments: Forest composition for accurate microclimate predictions

Mechanistic microclimate model (*microclimf*, Ilya Maclean)



8 biotic characteristics

Canopy buffering: leaf area index (LAI) most important

Remote sensed data from 2000 onwards



Chapter 3 – Placing plant communities in their microenvironments: Forest composition for accurate microclimate predictions

Forest types:

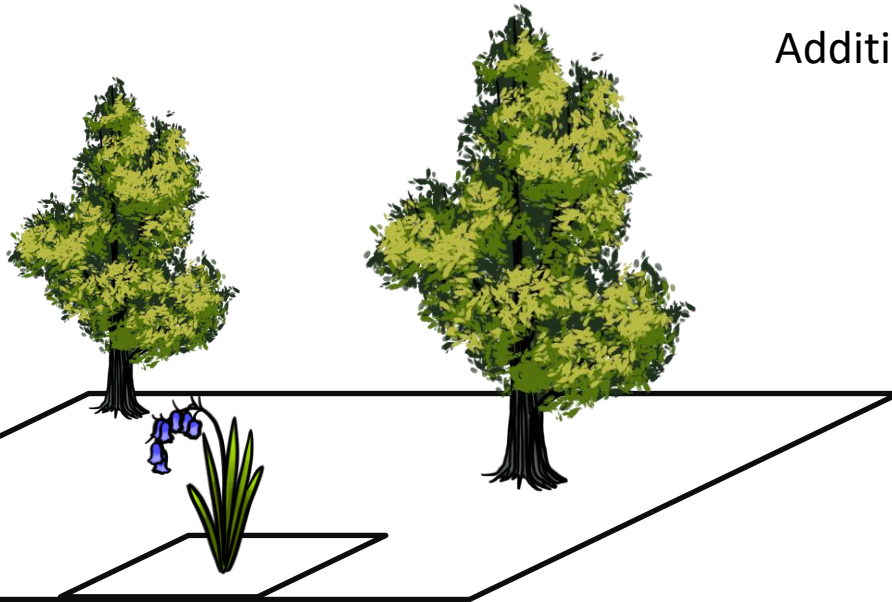
Deciduous broadleaf forest, Evergreen broadleaf forest,
Deciduous needleleaf forest, Evergreen needleleaf forest,
Mixed Forest

Classify vegetation plots by tree species leaf phenology

Additional parameter improvements:

$LAI = \text{maximum possible LAI} * \text{Canopy cover}$

Leaf diameter \approx CWM diameter
 $\approx 2 * \sqrt{\text{area} / \pi}$



95324328_T1

adj. $R^2 = 0.75$

adj. $R^2 = 0.87$

Temperature [°C]

Source

- Observed climate
- Observed microclimate
- Predicted microclimate

30
20
10
0
-10

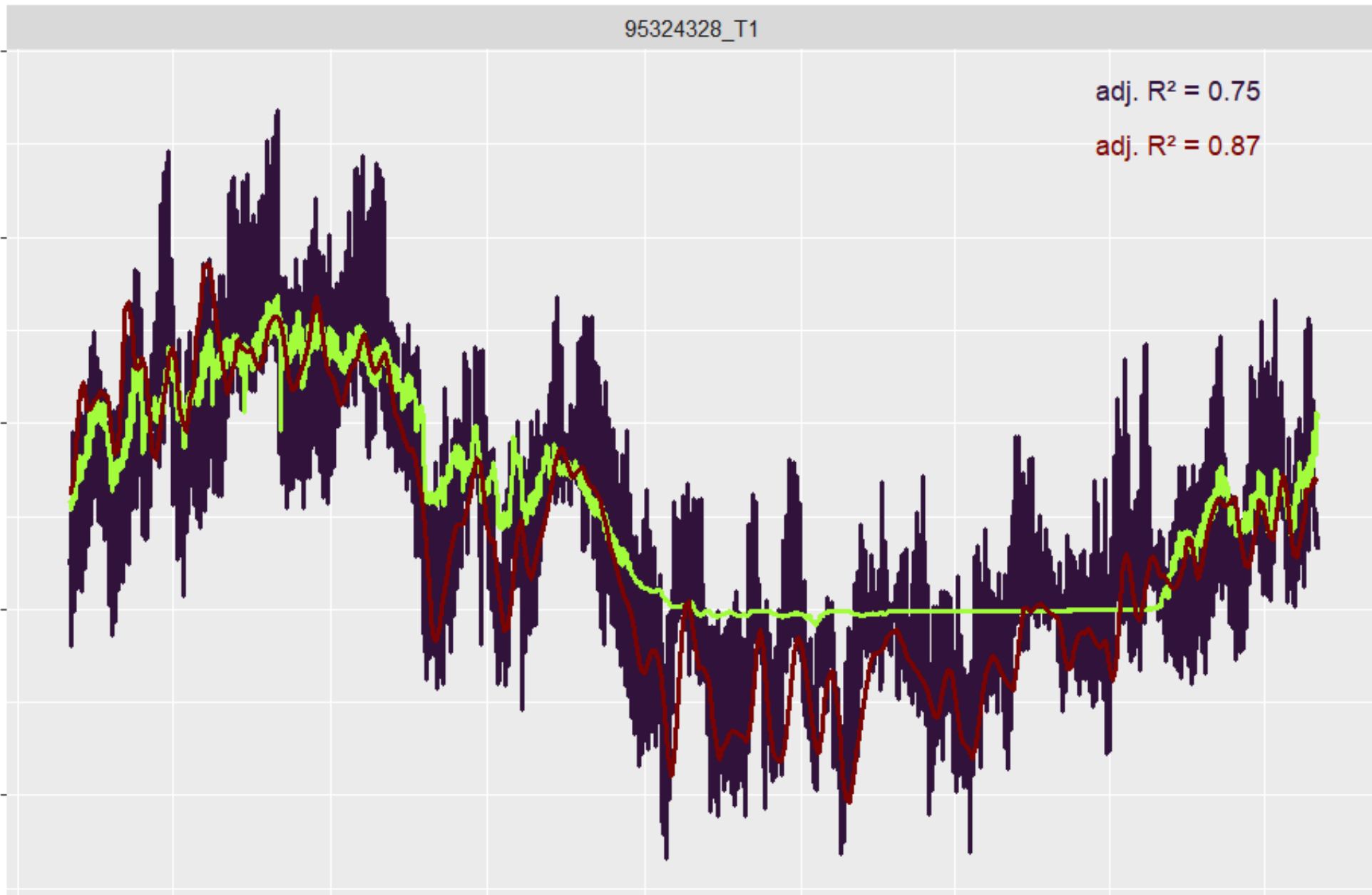
Jul 2024

Oct 2024

Jan 2025

Apr 2025

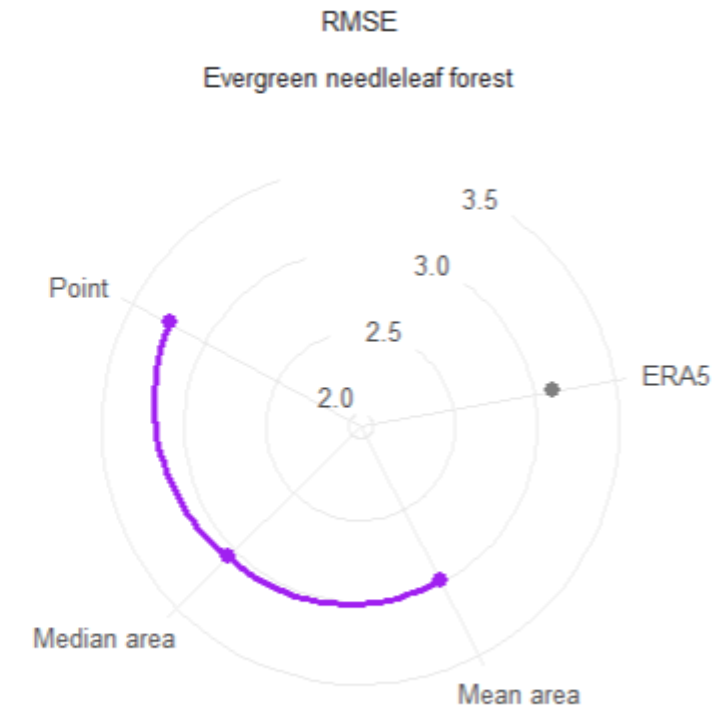
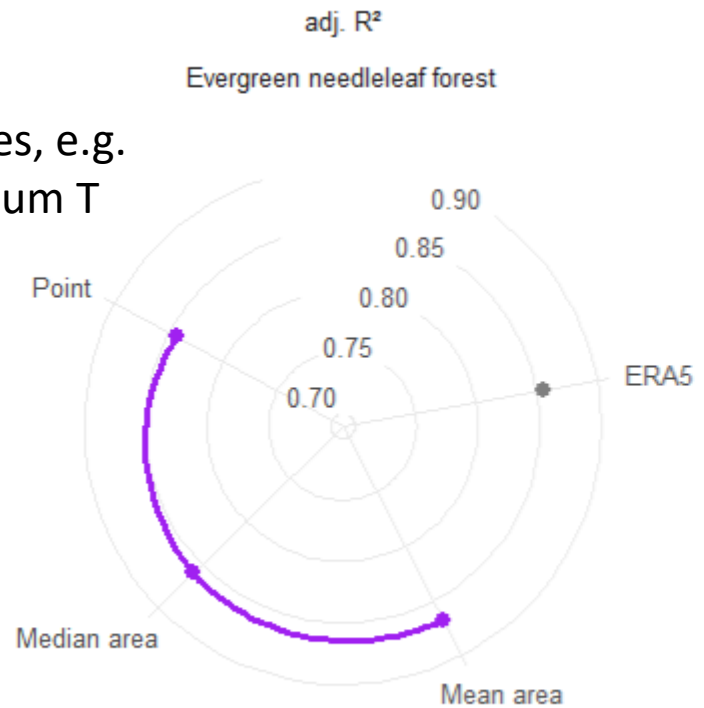
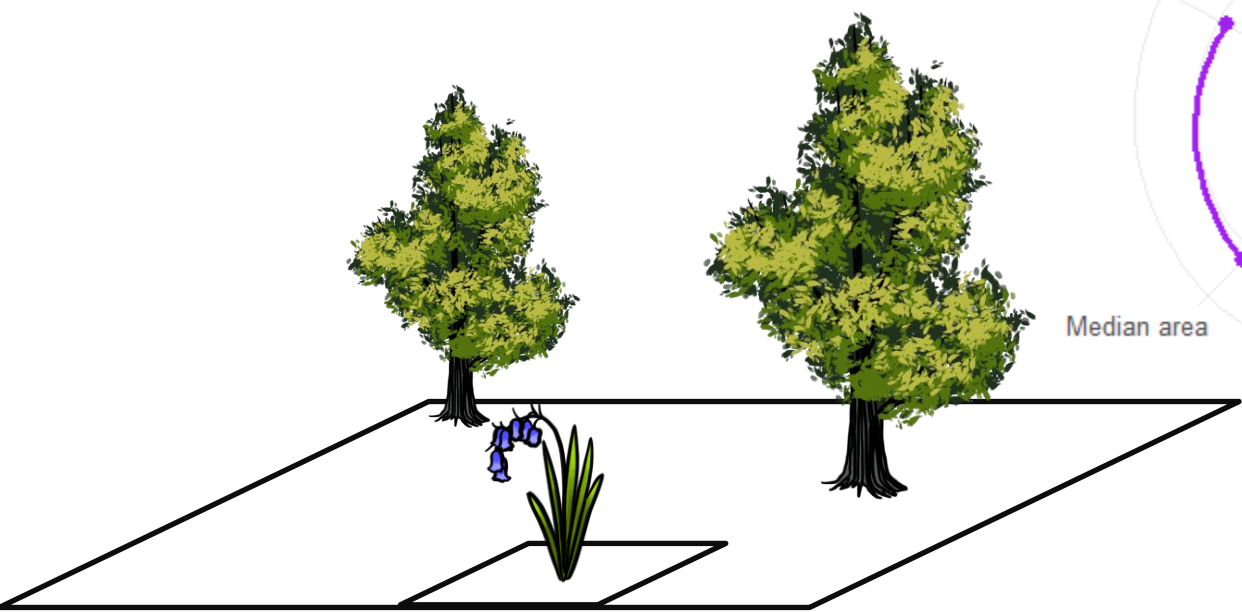
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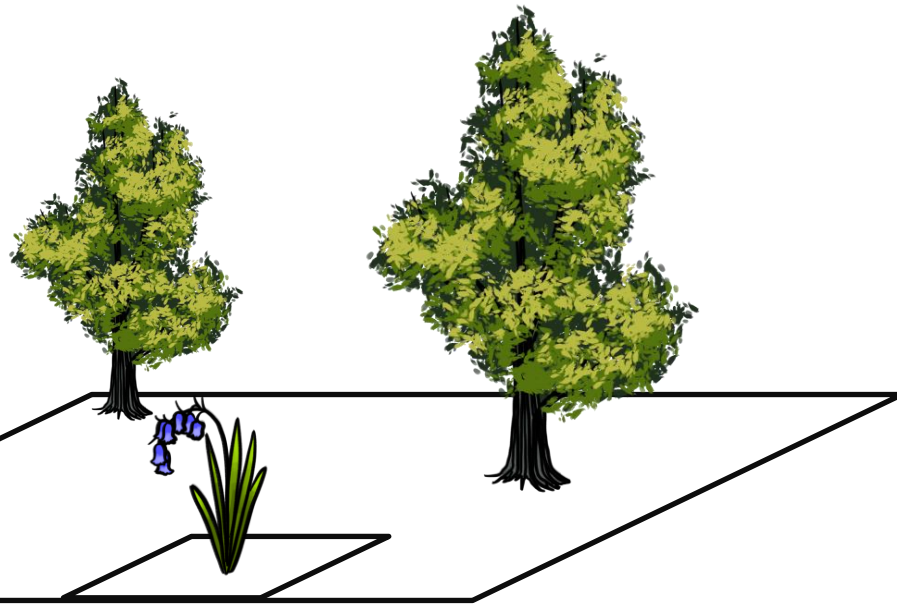
Chapter 3 – Placing plant communities in their microenvironments: Forest composition for accurate microclimate predictions

Prediction for ~700 forest sites
with ~2000 temperature sensors
(SoilTemp/MDB)

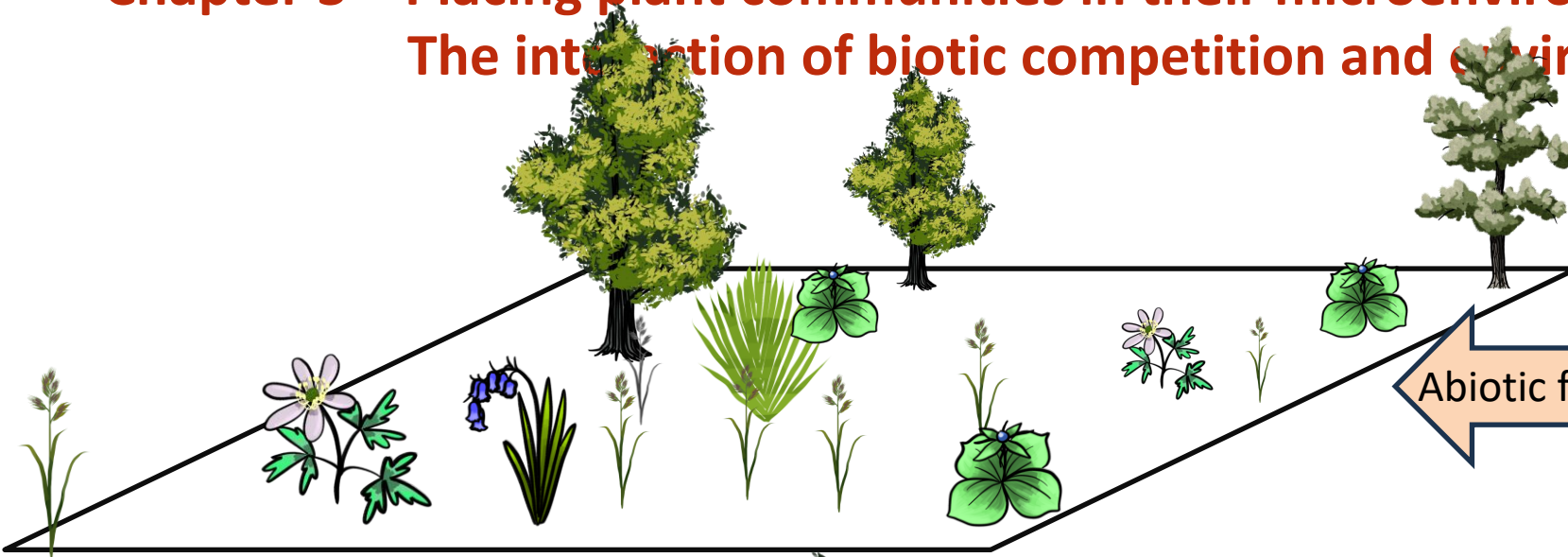
Validation of hourly data and climate values, e.g.
monthly & yearly mean, maximum, minimum T



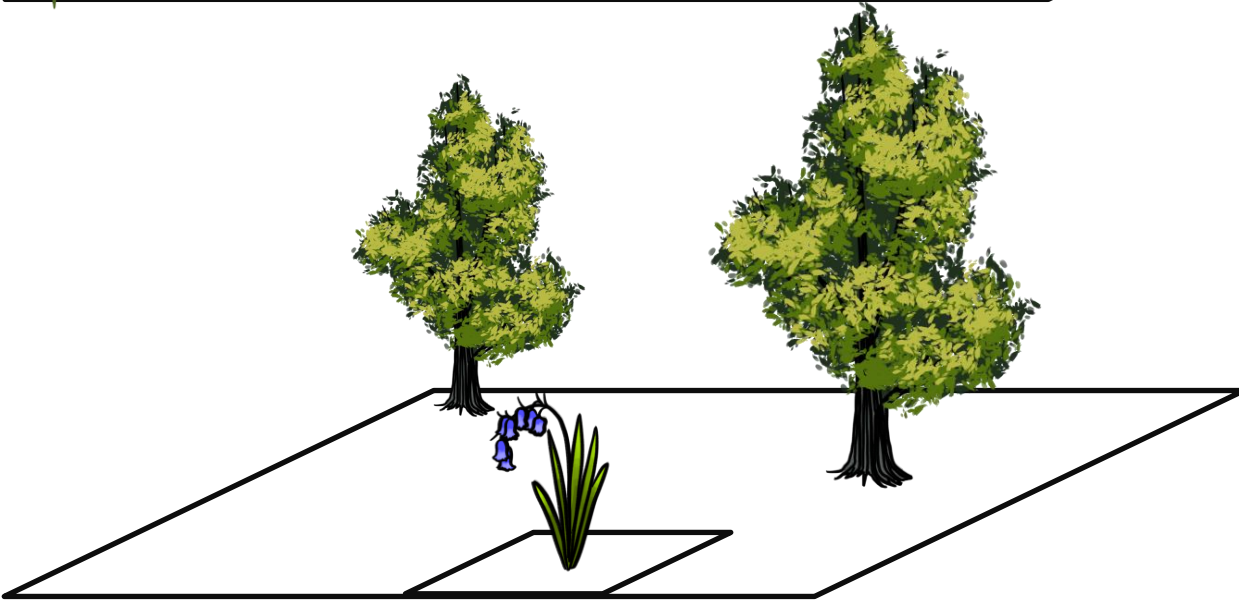
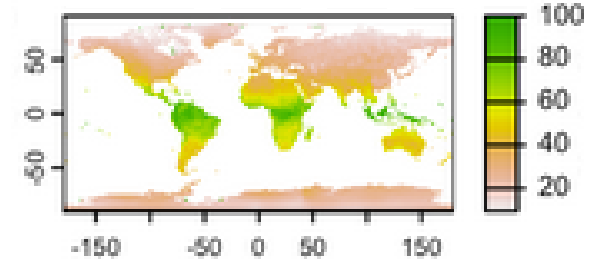
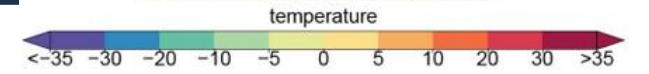
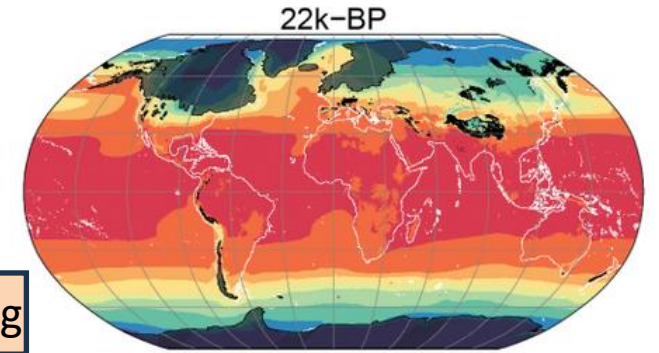
Chapter 3 – Placing plant communities in their microenvironments: The interaction of biotic competition and environmental filtering.



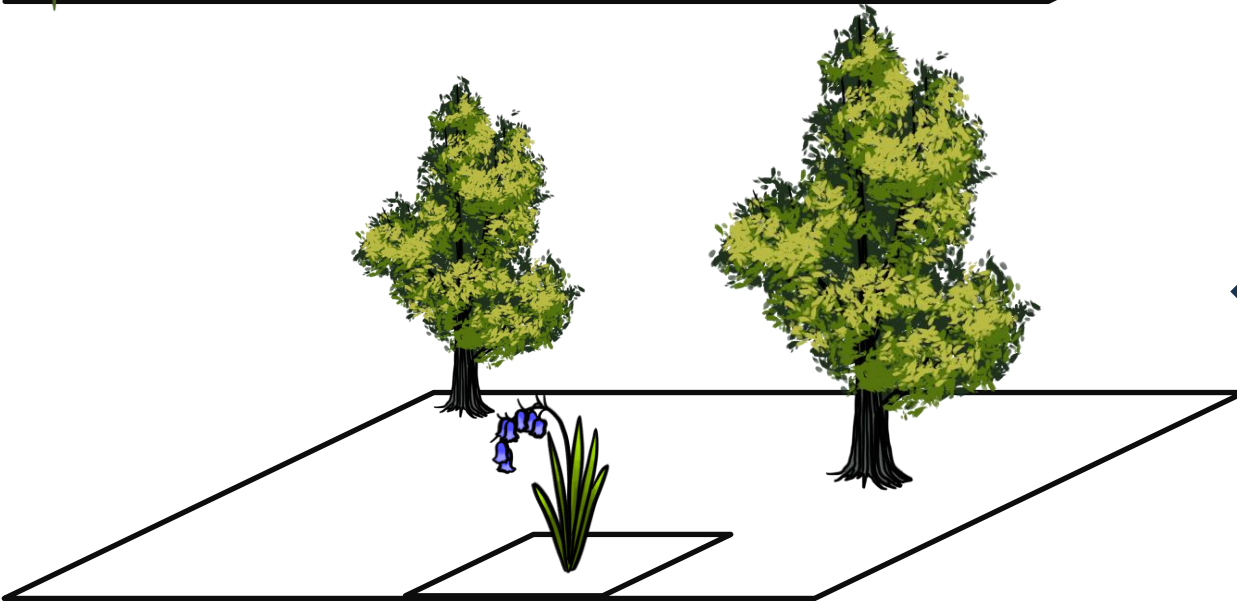
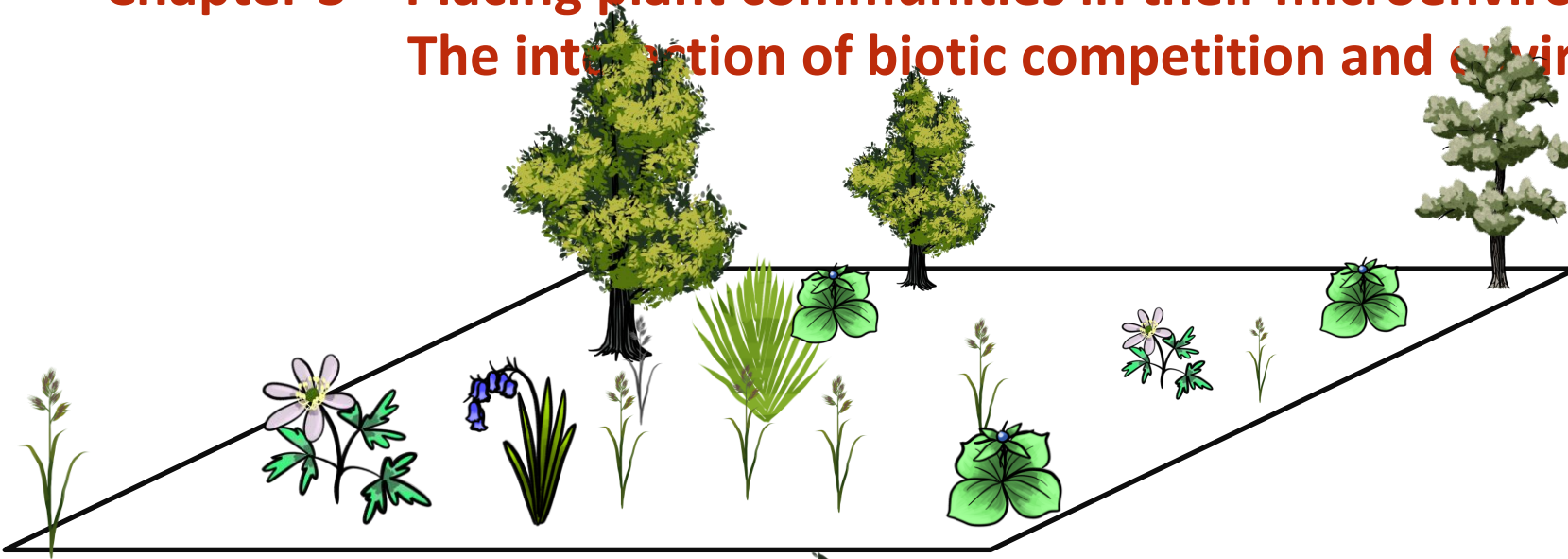
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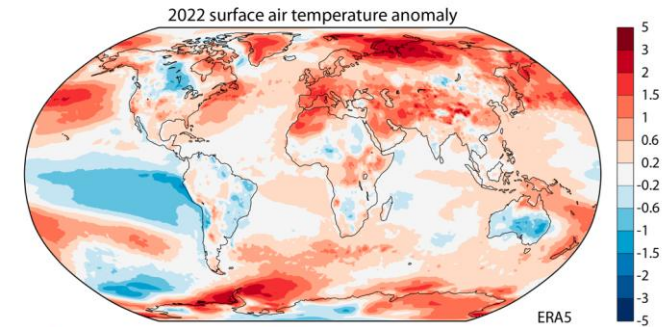
Abiotic filtering



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Abiotic filtering



Copernicus Climate Change Service
Climate Indicators | 2022

PROGRAMME OF THE EUROPEAN UNION

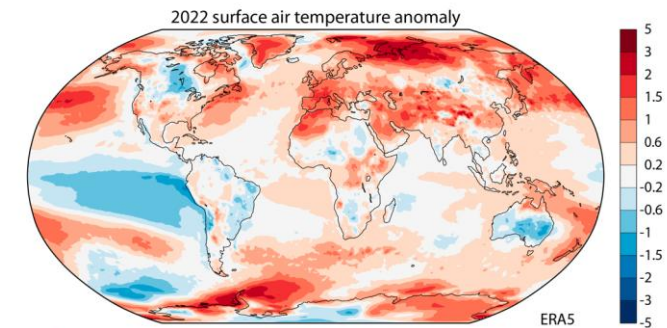
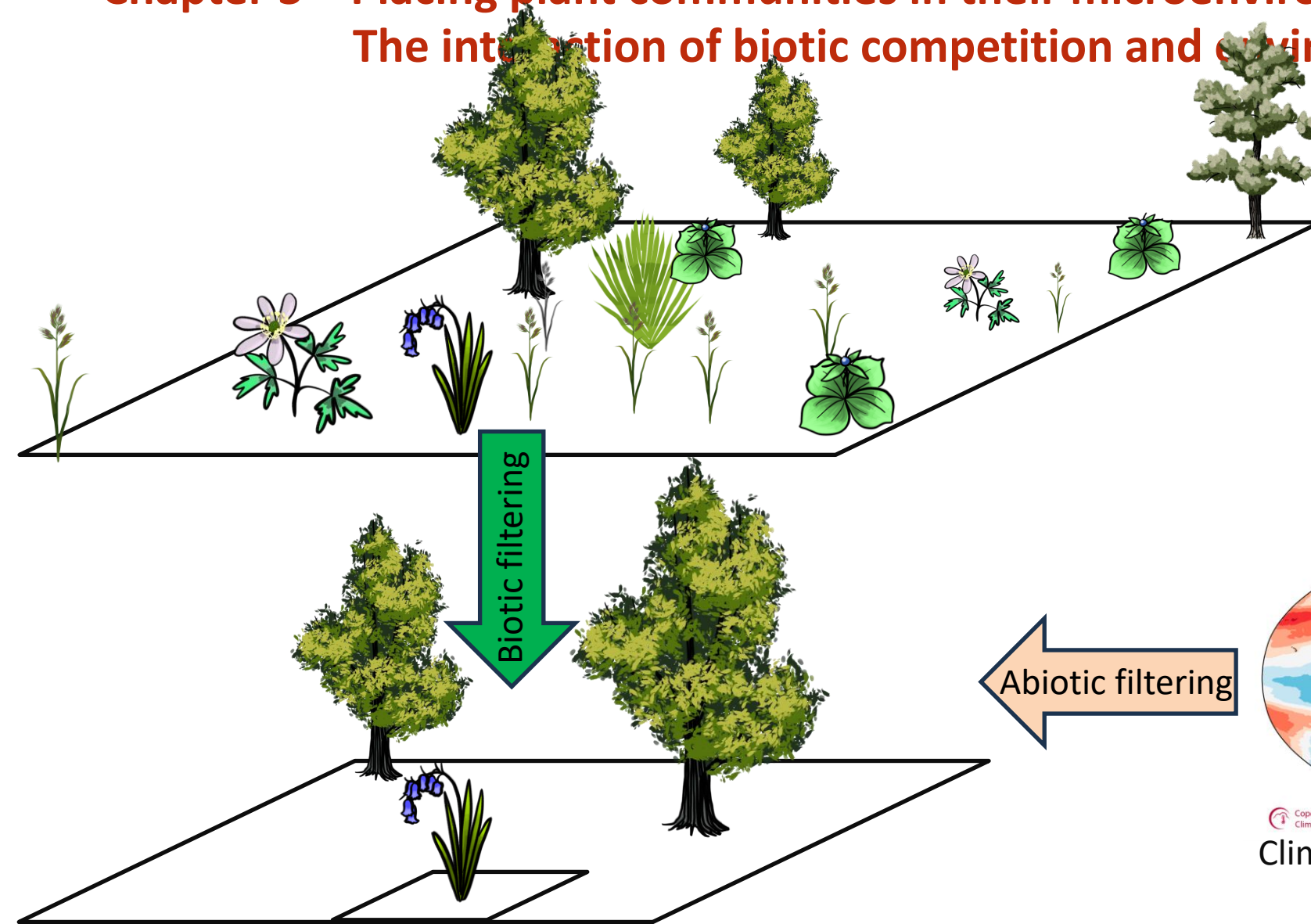
Copernicus

ECMWF

Climate events close to sampling



Chapter 3 – Placing plant communities in their microenvironments: The interaction of biotic competition and environmental filtering.



Copernicus Climate Change Service
Climate Indicators | 2022

PROGRAMME OF
THE EUROPEAN UNION

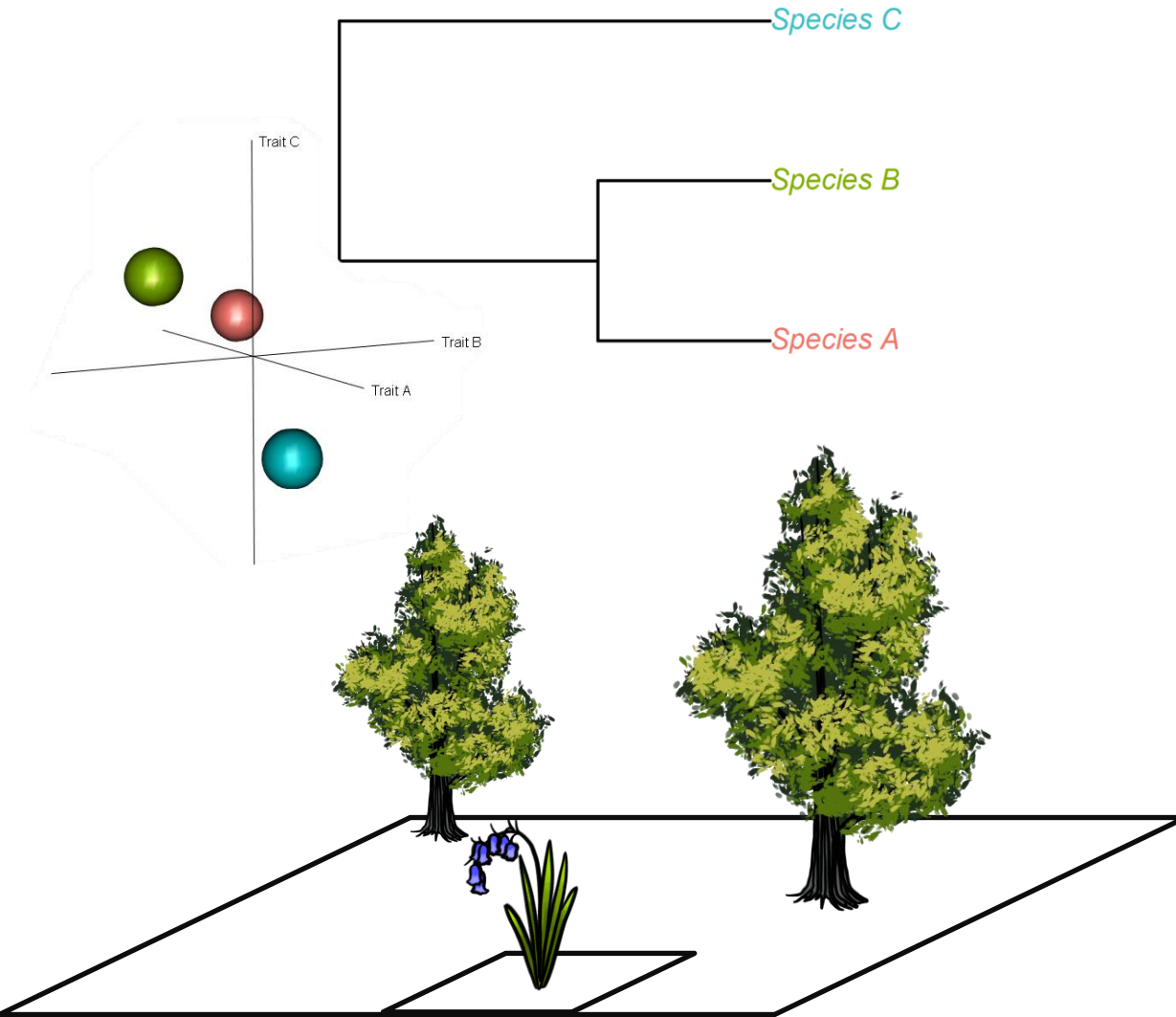
Copernicus
EUROPEAN COMMISSION

ECMWF

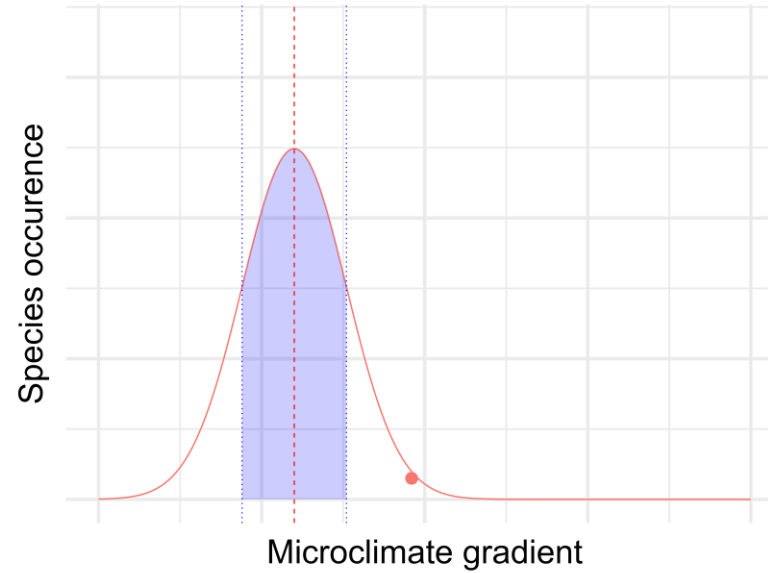
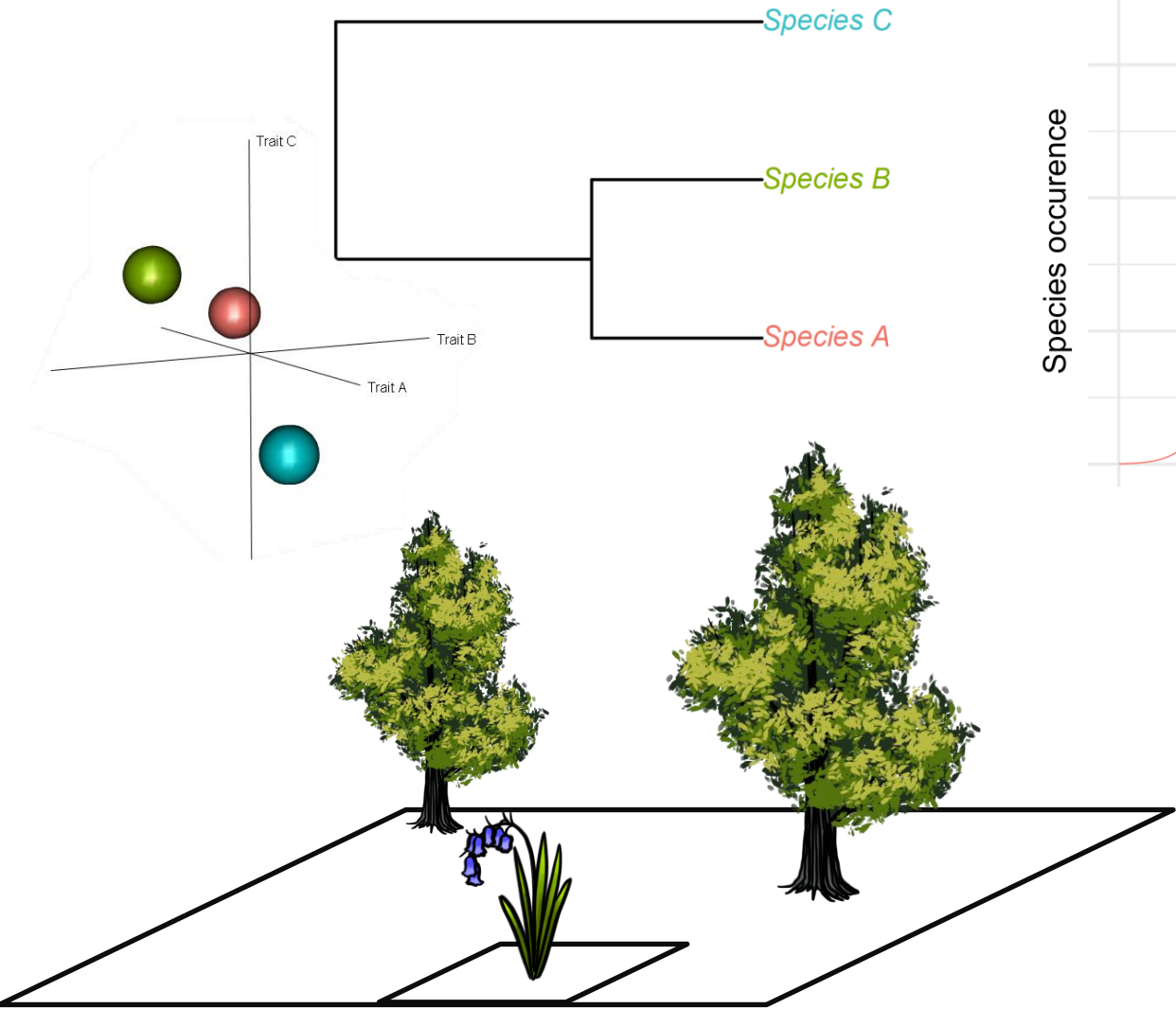
Climate events close to sampling



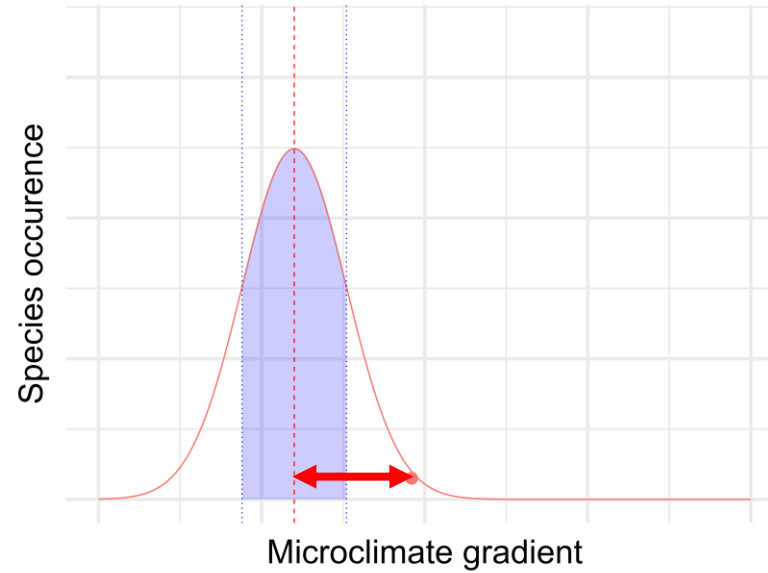
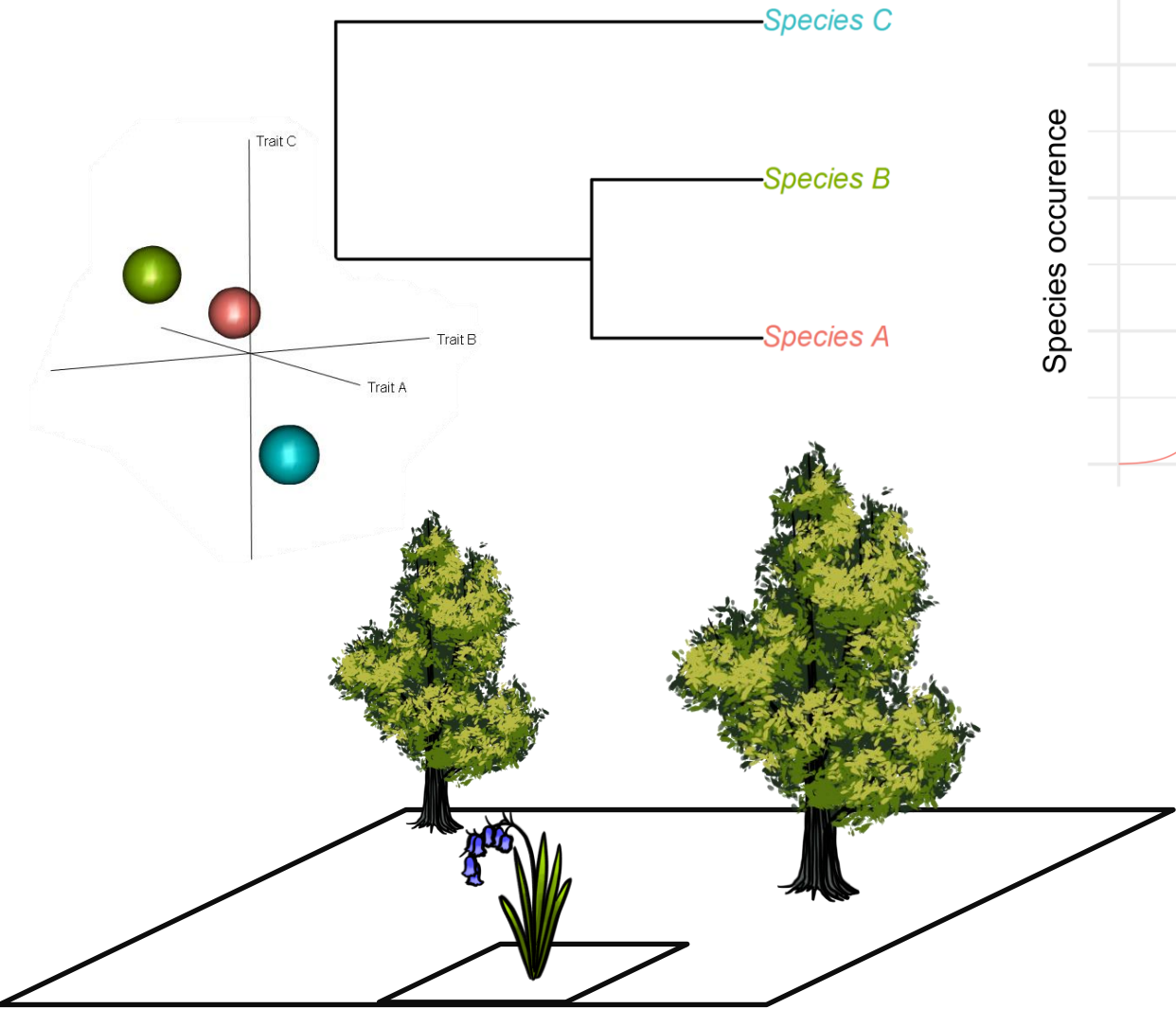
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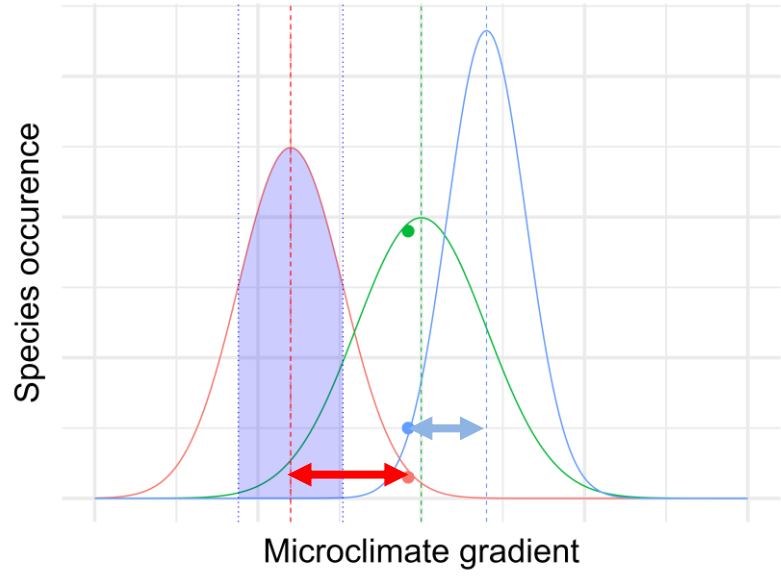
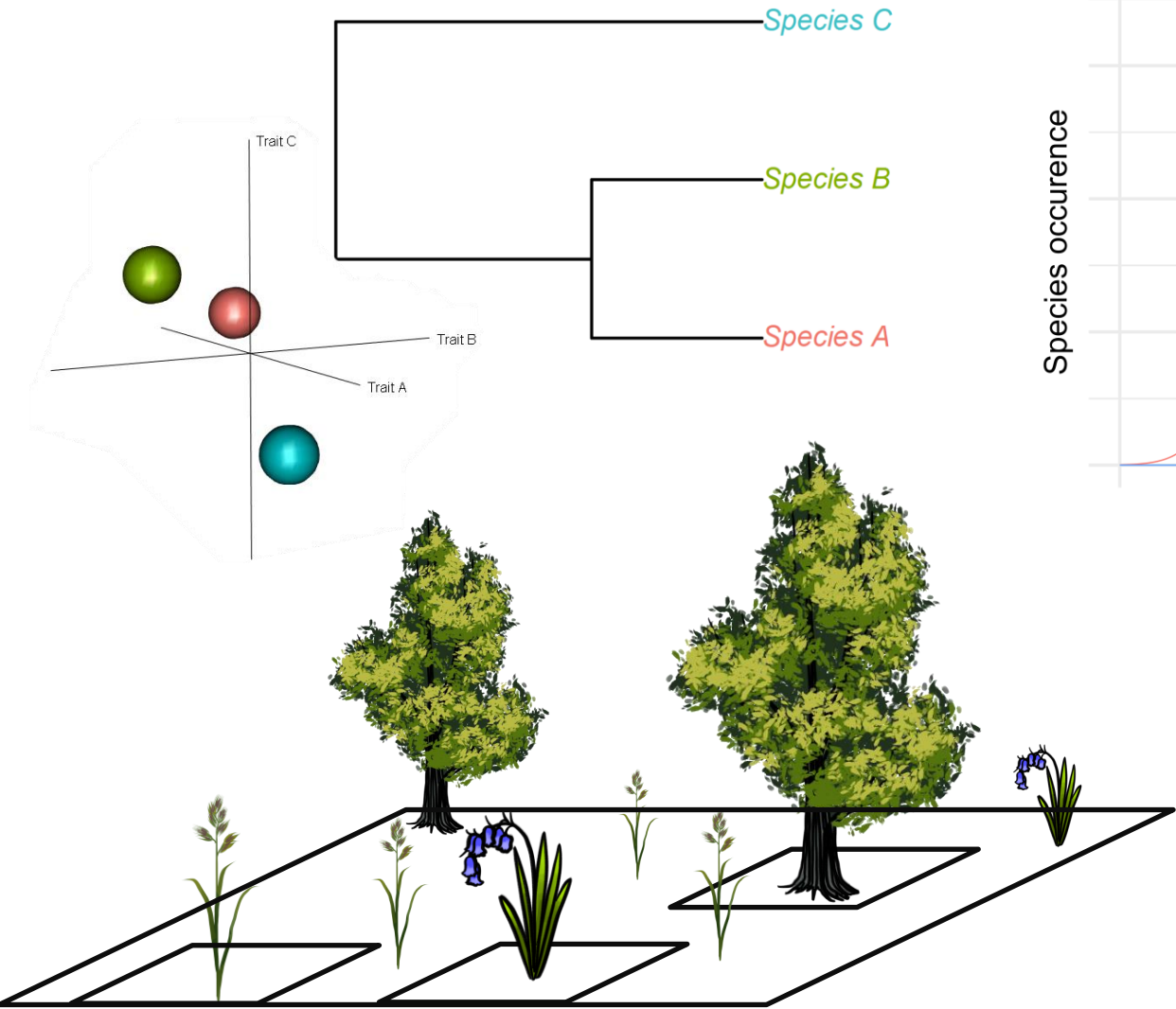
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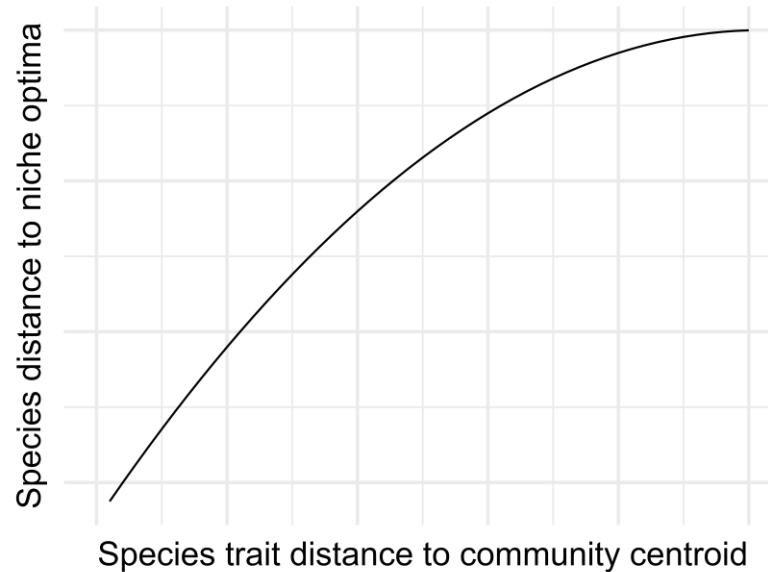
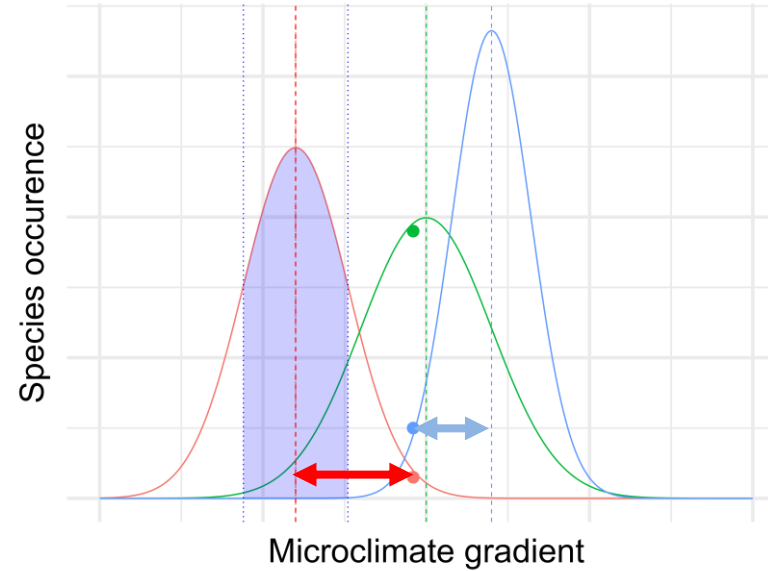
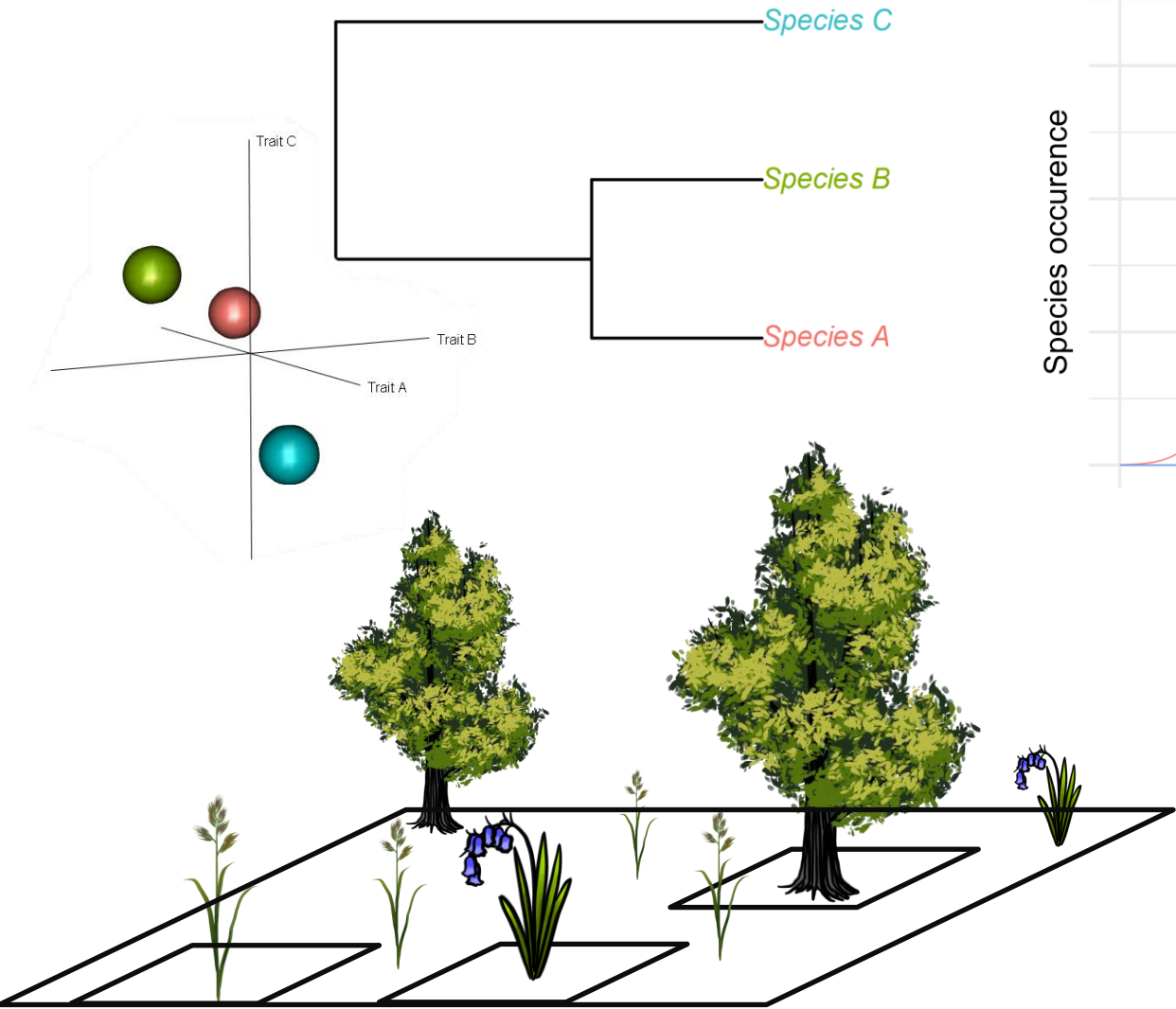
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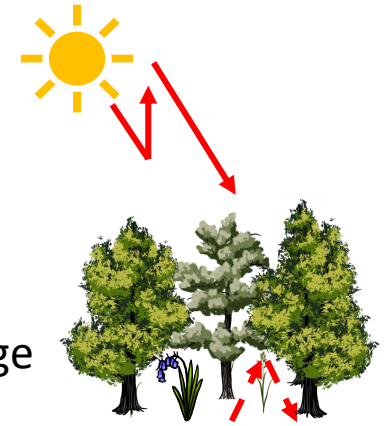


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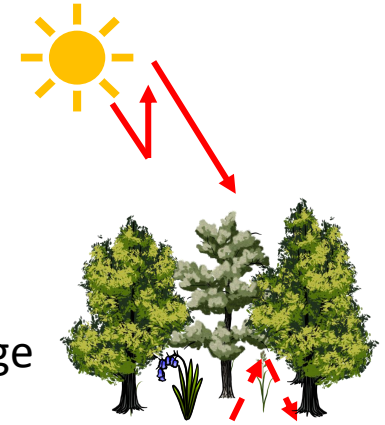


Summary

- Old-growth forests are cool and can act as climate refugia under climate change
- Understory species need further consideration in forest management and protection



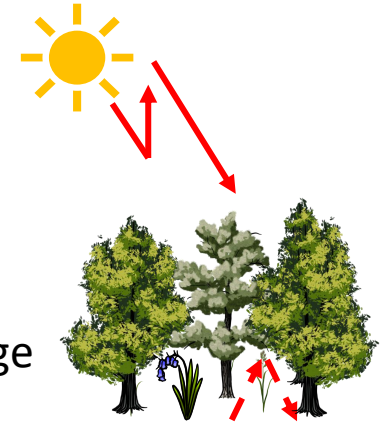
Summary



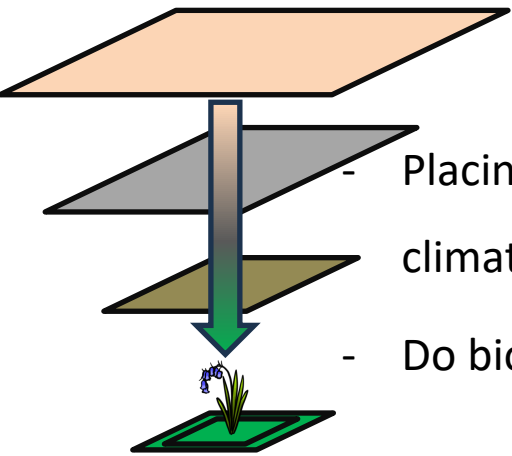
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- Placing understory species in their true abiotic environment allows better understanding of climate change effects
- Do biotic interaction limit the range of a species?

