

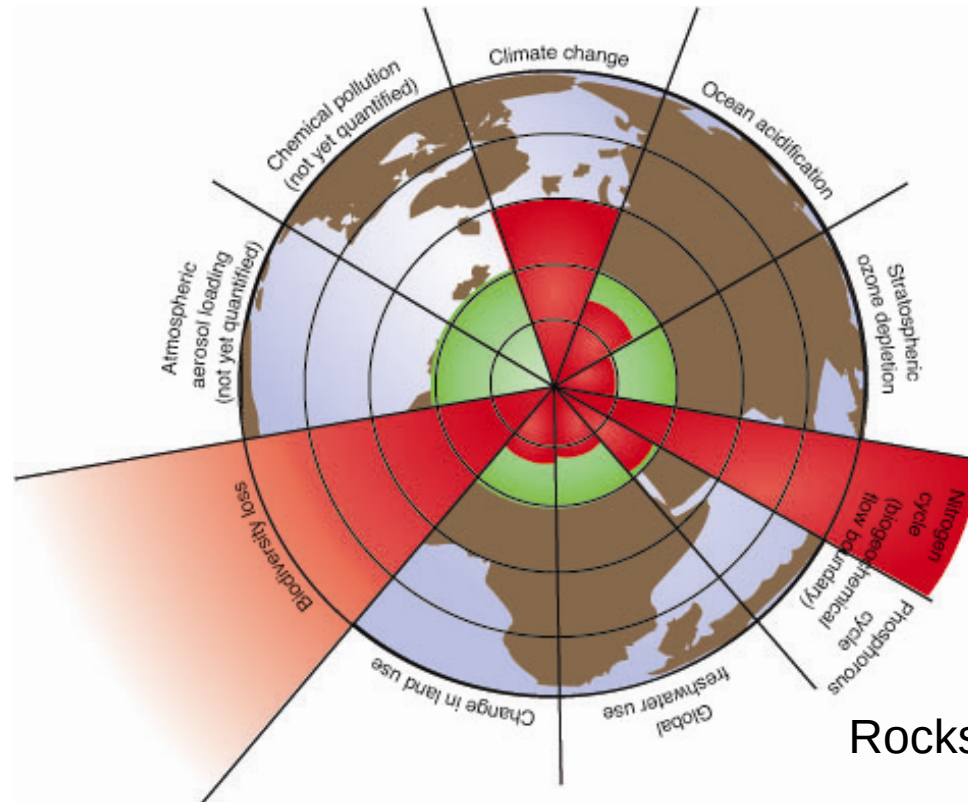
The cascade of uncertainty in modeling forest ecosystem responses to environmental change



Christopher Reyer

Petra Lasch-Born, Felicitas Suckow, Martin Gutsch, Aline Murawski, Tobias Pilz + MOTIVE team

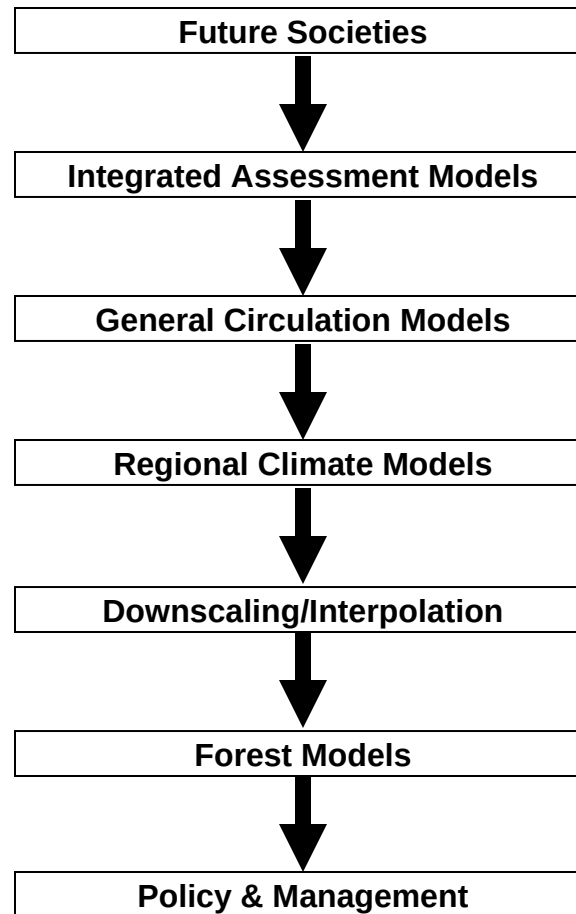
Planetary boundaries require sustainable management of social-ecological systems...



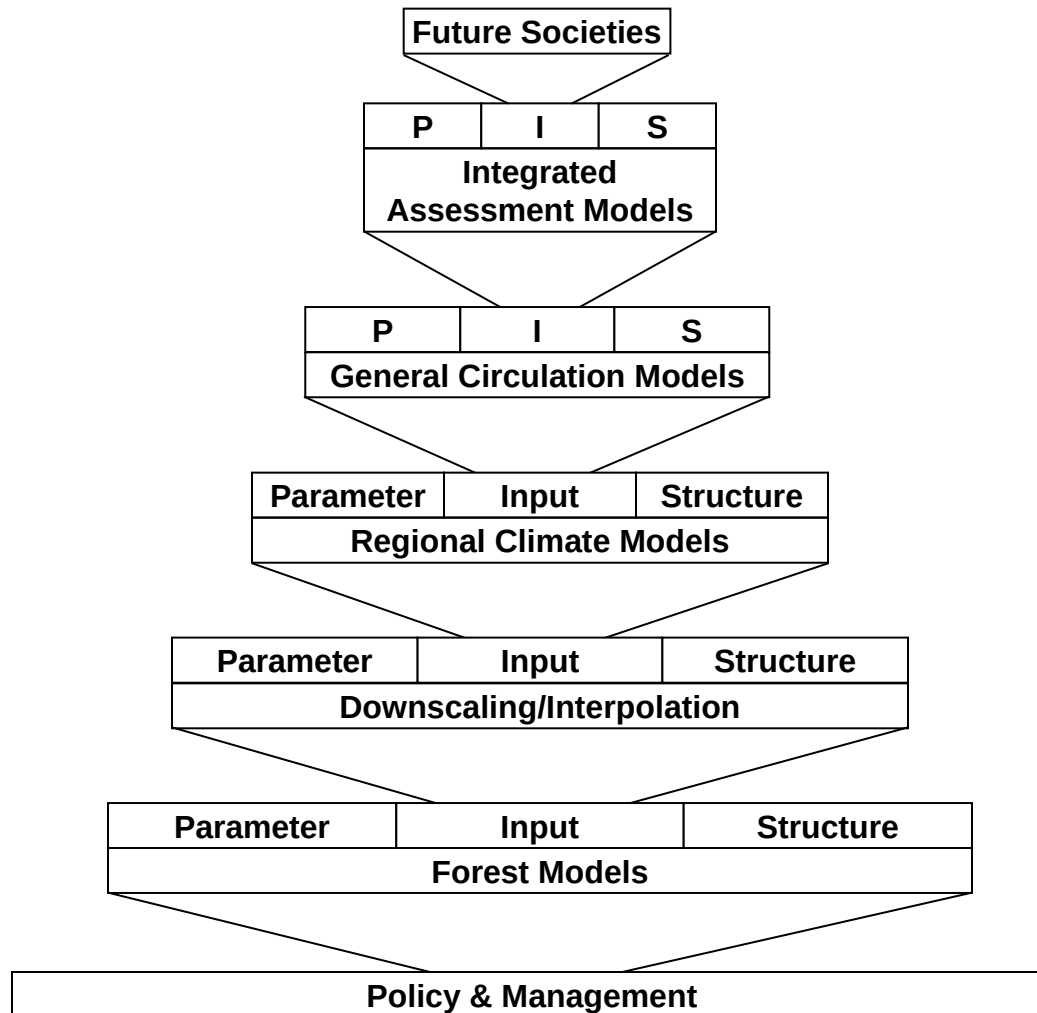
Rockström et al. 2009

...this requires projecting the impacts of environmental change using model chains

Model chain: Forests



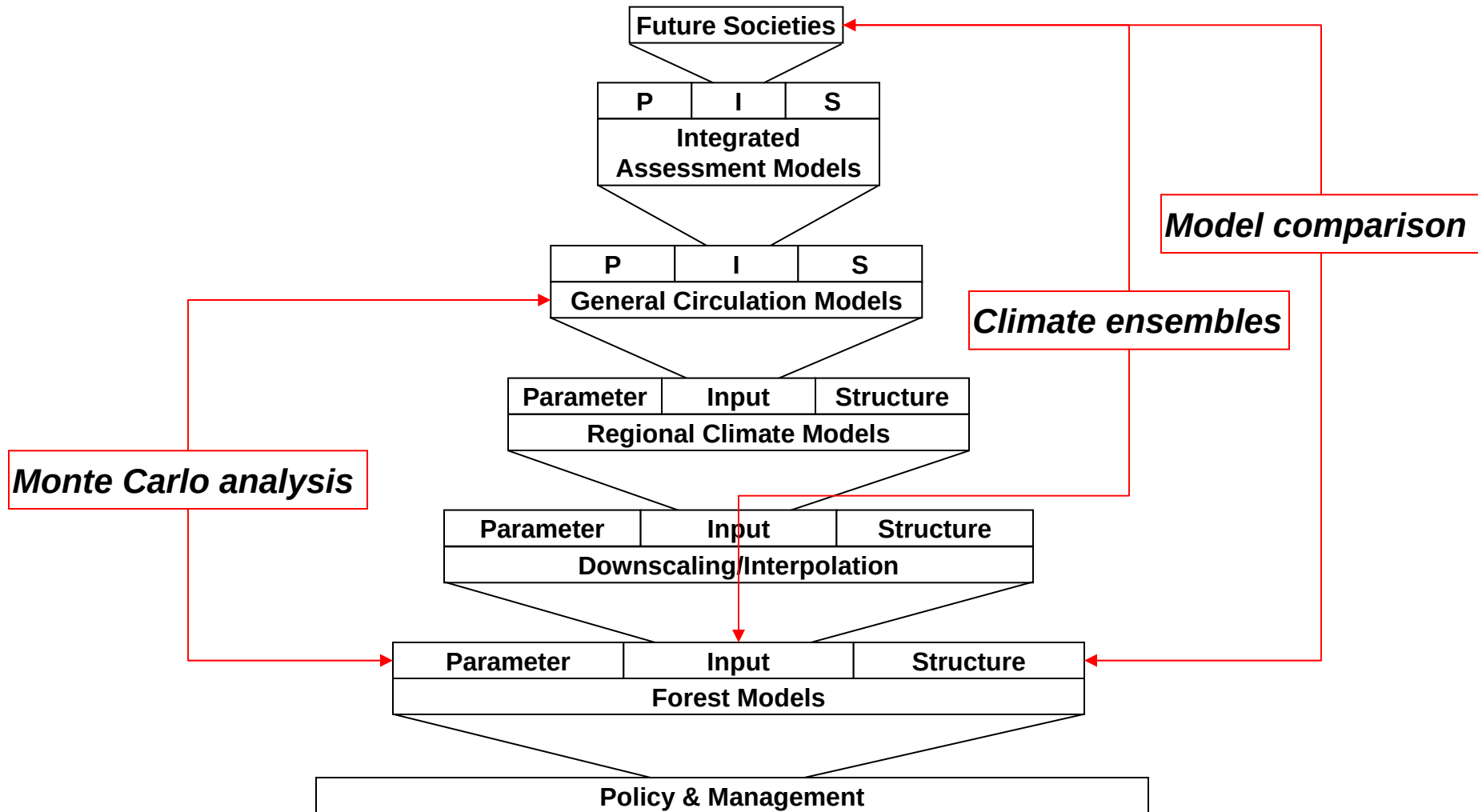
The cascade of uncertainty



Objective & Research question

- ➔ to explore the cascade of uncertainties in forest ecosystem modeling
- ➔ How do parameter, input and structural uncertainties affect projections of the effects of environmental change on forest ecosystems?

The cascade of uncertainty: Today



Structural uncertainty - Model comparisons

to review forest productivity changes
by process-based forest stand models
under environmental change scenarios

→ Reyer C, P Lasch, M Gutsch (to be submitted) *Projections of changes in forest productivity and carbon pools under environmental change – A review of modeling studies.*

Methods: Data compilation

AND

A

- forest*
- tree*
- stand*

B

- model*
- simul*
- process*
- mechan*

AND

C

- grow*
- producti*
- NPP

AND

D

- climat* chang*
- global change
- environmental change

→ dec 2011: 7,642 paper in WoS

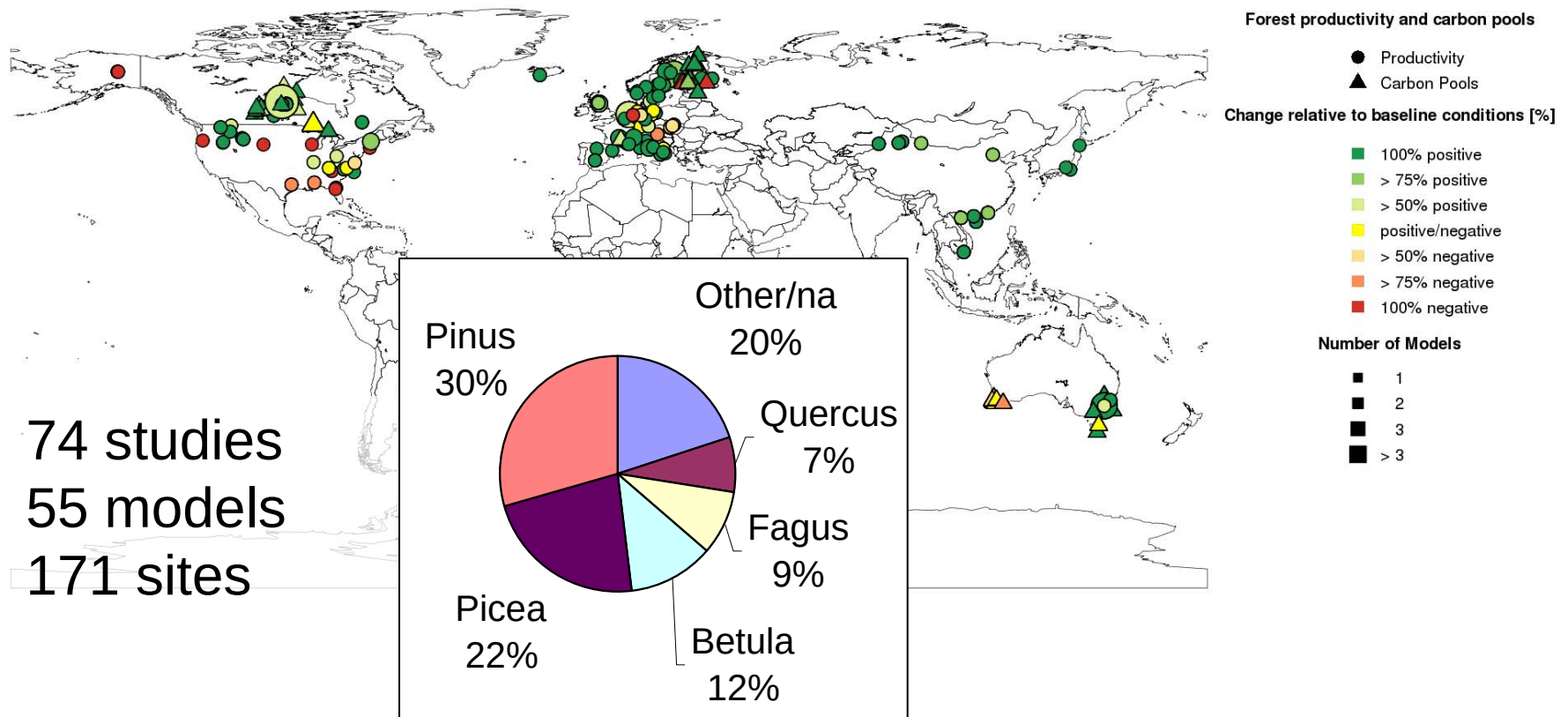
→ title & abstracts: simulate productivity under global change?

→ ~550 papers: process-based (tree, stand, grid), gap, hybrid or statistical models

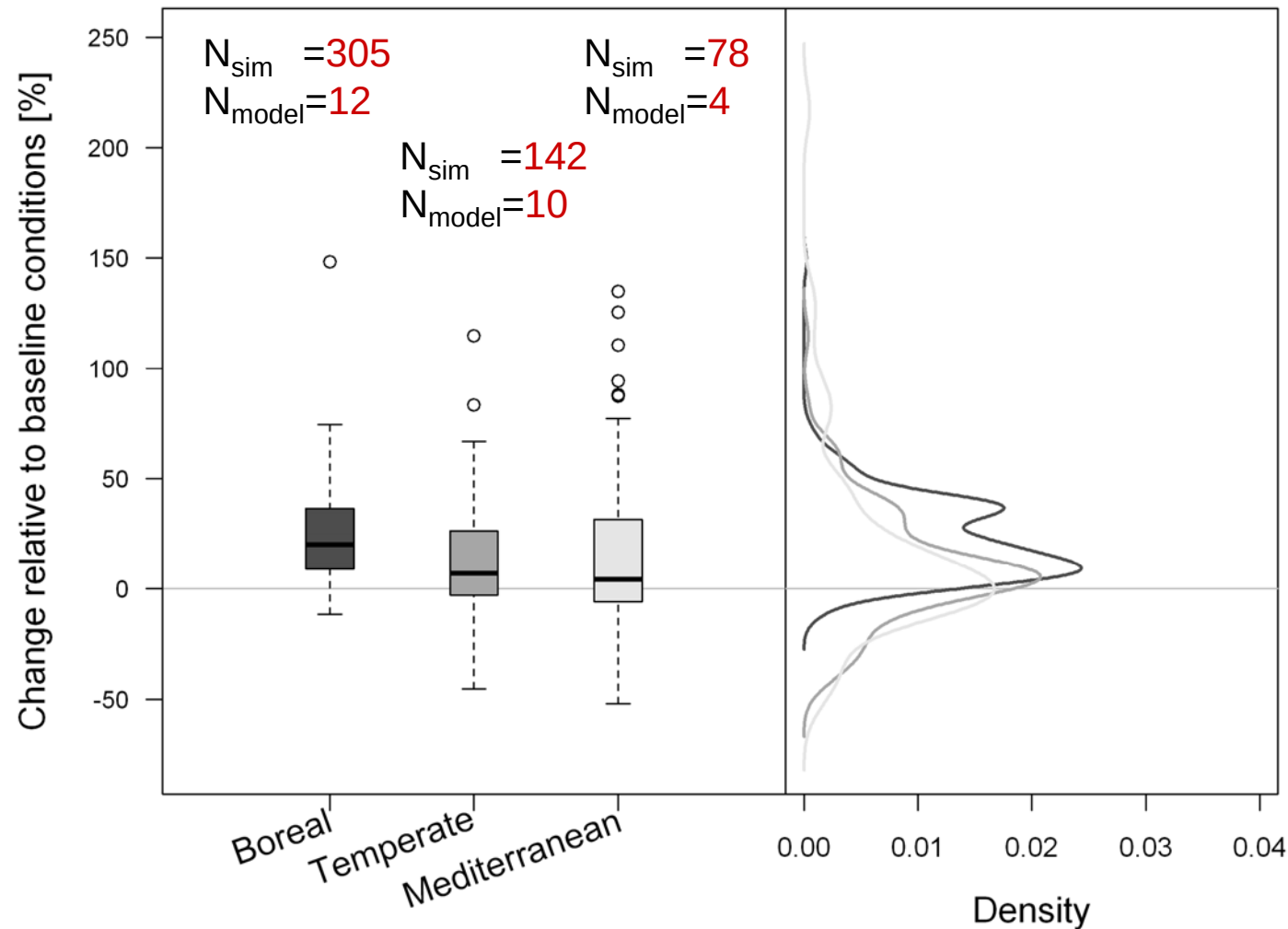
→ focus: **stand-level PBMs**

Qualitative changes

1209 simulations: 79% positive, 19% negative, 2% zero

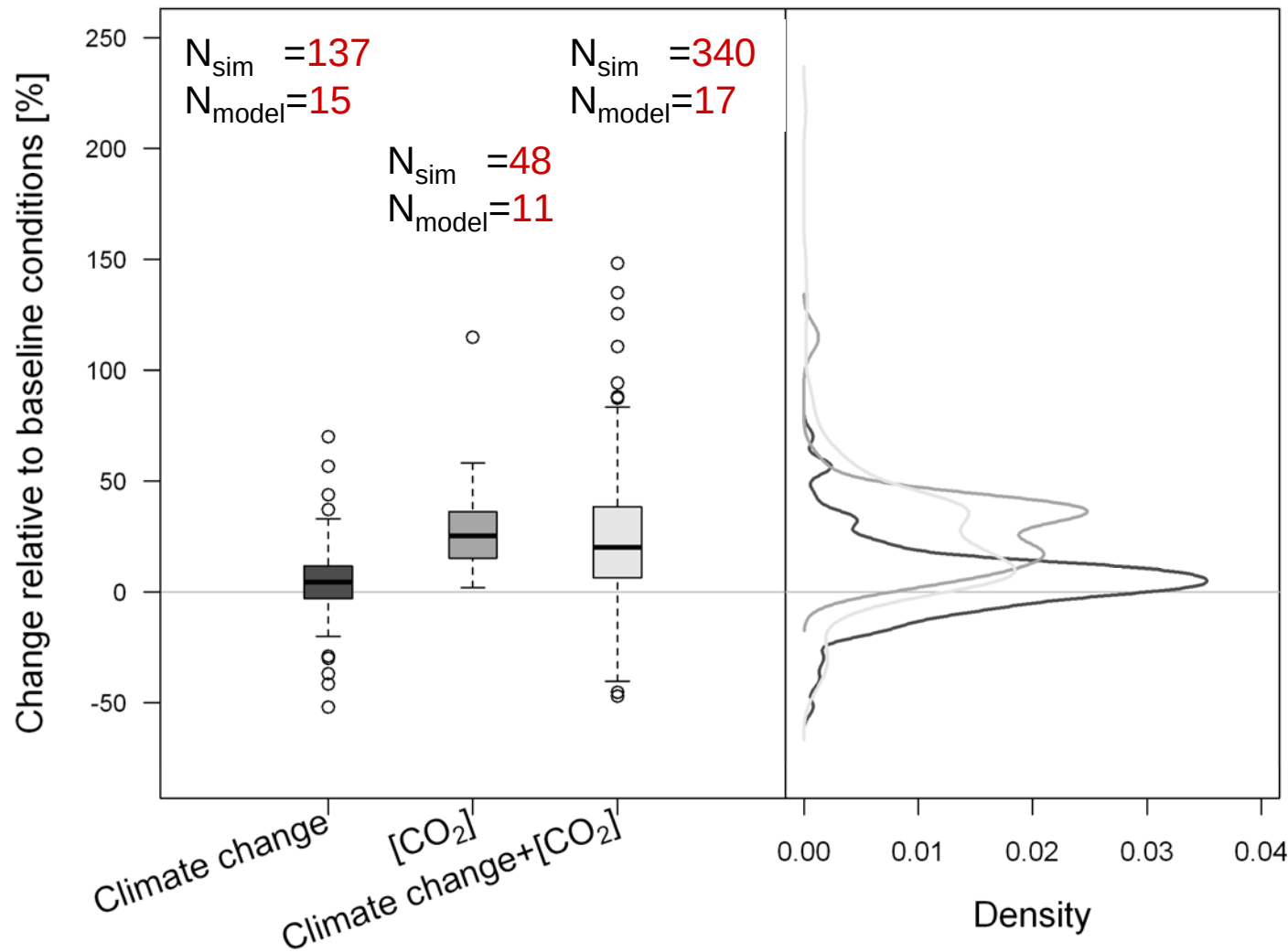


Transient simulations: Biomes



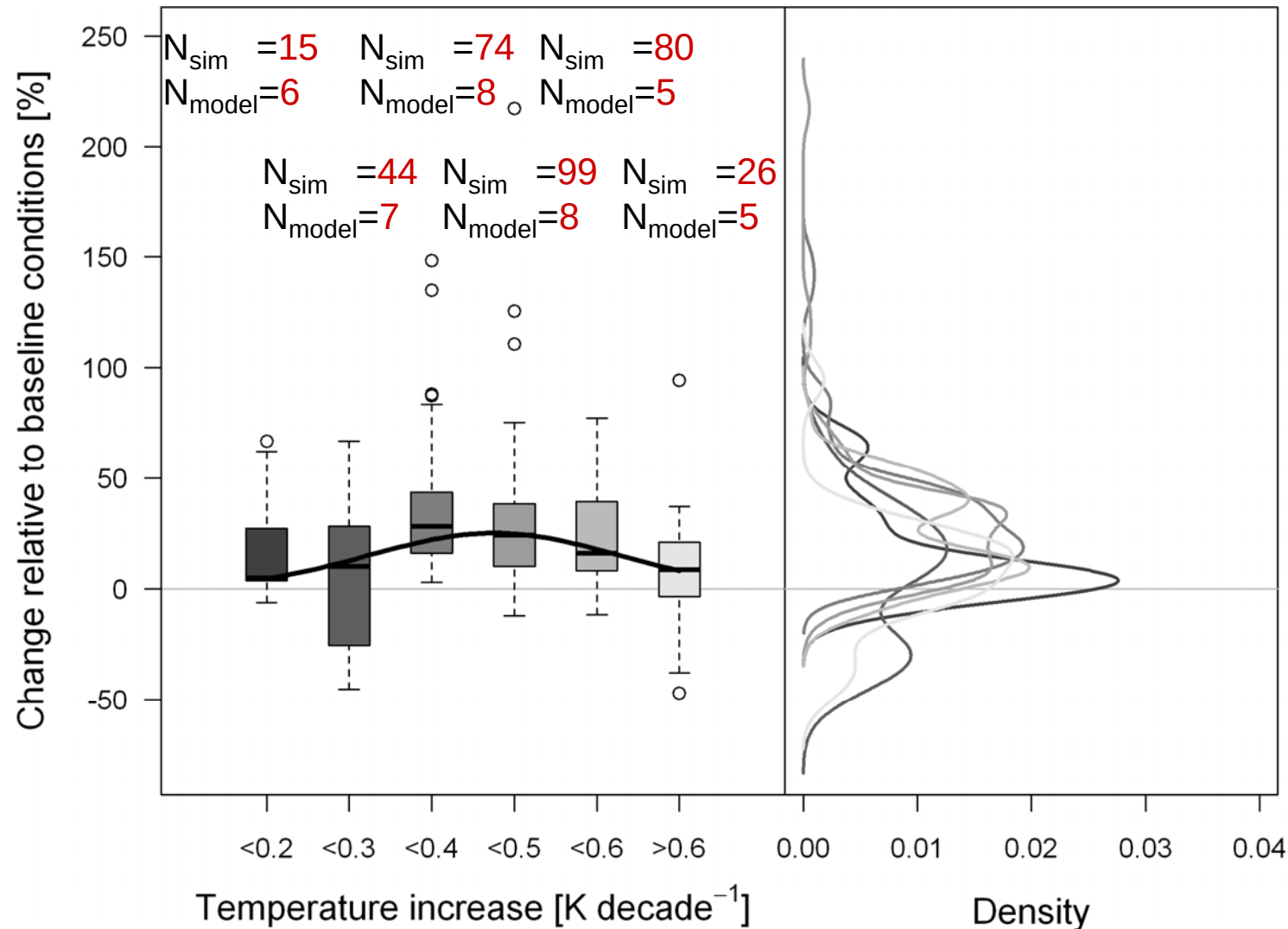
...strong
CO₂-effect
(Kirschbaum 2000;
Keenan et al. 2011)

Transient simulations: Global Change Driver



...but:
drought, N-
limitation and
acclimation
override CO₂-
effect? (Penuelas
et al. 2010; Norby et
al. 2010)

Combined simulations: Pace of temperature increase



Discussion & Conclusion: Model structural uncertainties

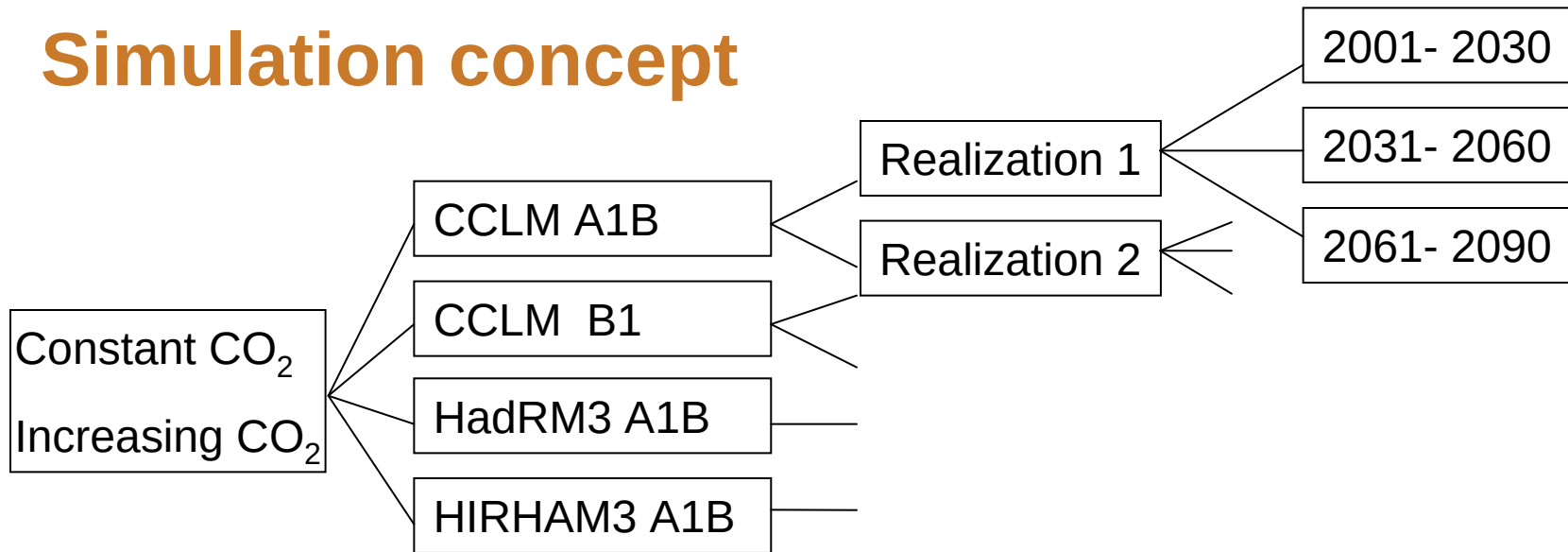
1. assumption: models equally good & independent (Tebaldi & Knutti 2007; Medlyn et al. 2011)
2. publication bias
3. strong model effects
4. tropics? (Laurance et al. 2004; Lewis et al. 2004 but Feeley et al. 2007)
5. boreal & temperate productivity increase
 - ➔ interactions, feedbacks & disturbances
 - ➔ full carbon cycle

Input uncertainty - Climate ensembles

to project forest productivity changes at a large number of sites in Europe with one PBM using several climate change scenarios from different climate models

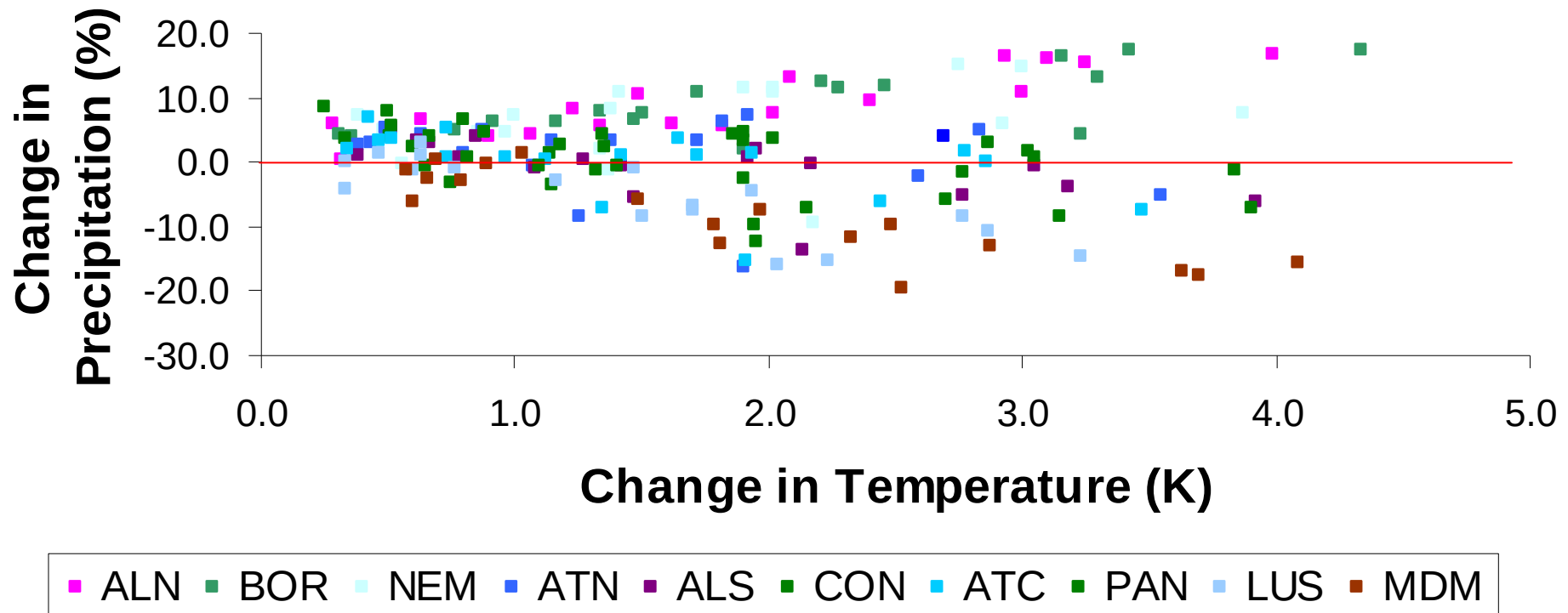
➔ Reyer C, P Lasch-Born, F Suckow, M Gutsch, A Murawski, T Pilz (under review) *Projecting regional changes in forest net primary productivity in Europe under climate change and carbon dioxide concentrations*. Annals of Forest Science

Simulation concept

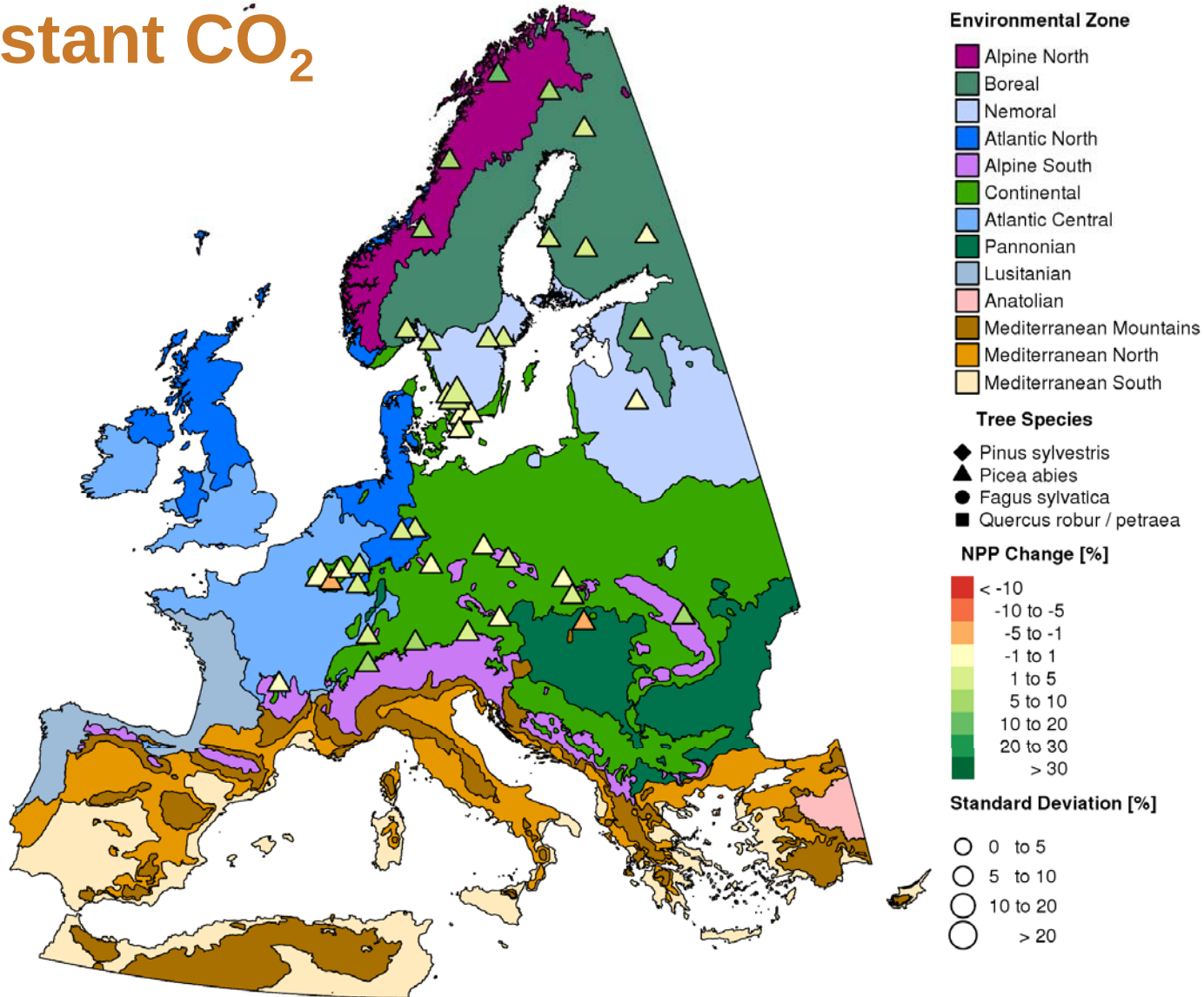


- ➔ 6 (realizations) * 3 (time slices) * 2 (CO₂ assumptions)
= 36 “climate change scenarios”
- ➔ relative change of NPP (base period 1971-2000)
- ➔ without disturbances
- ➔ environmental zones (Metzger et al. 2005)
- ➔ four main tree species

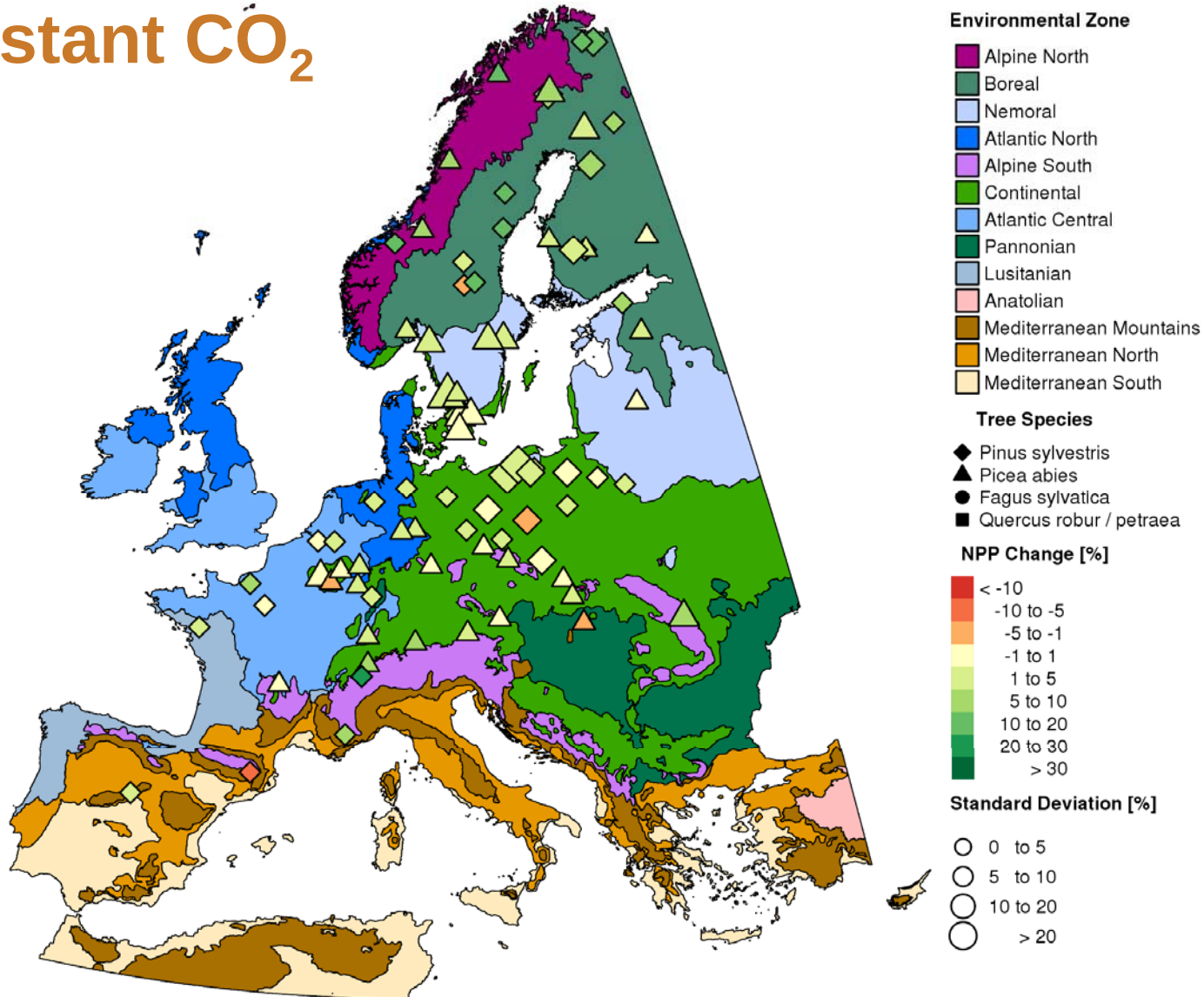
Regional Climate Change



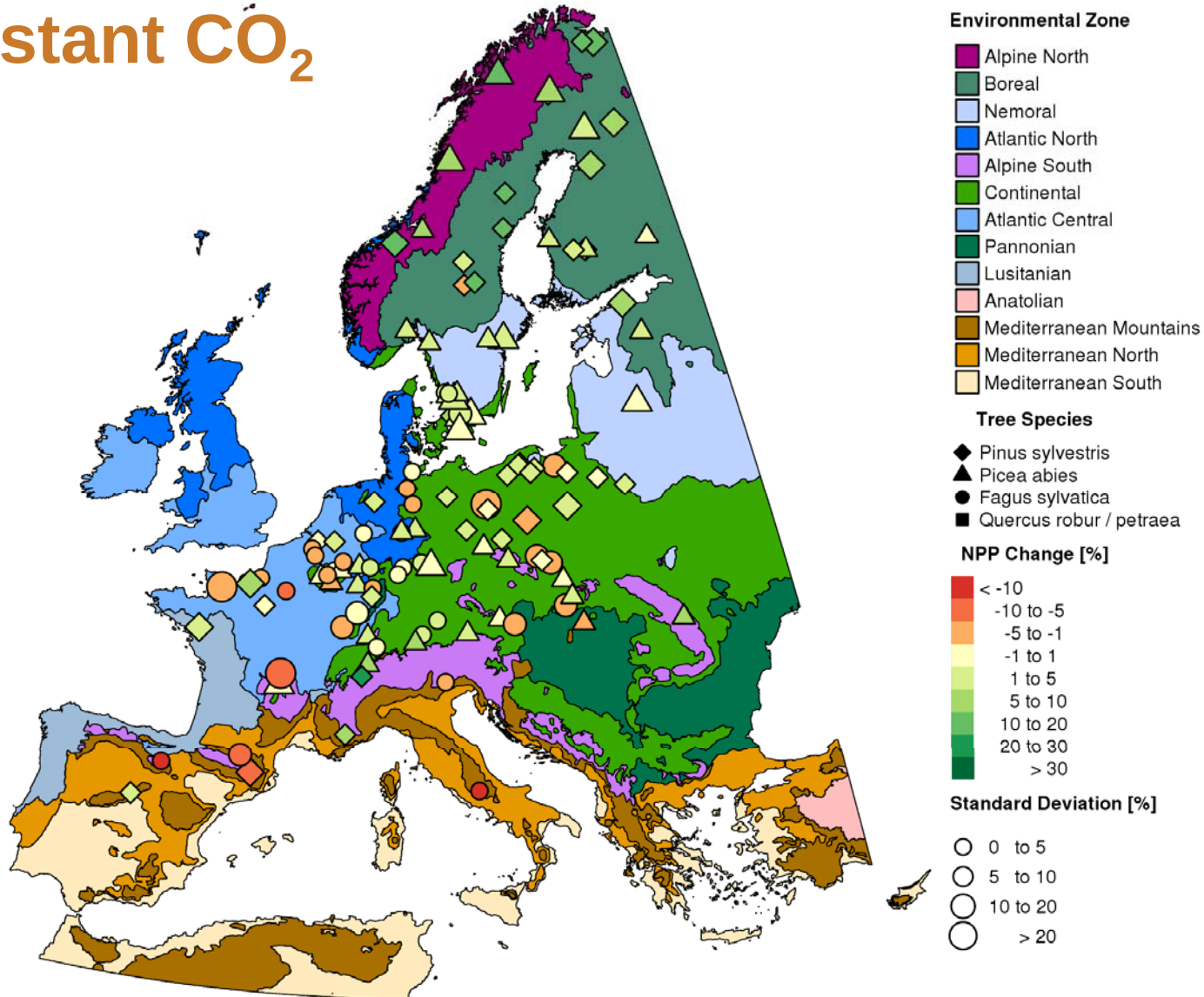
Constant CO₂



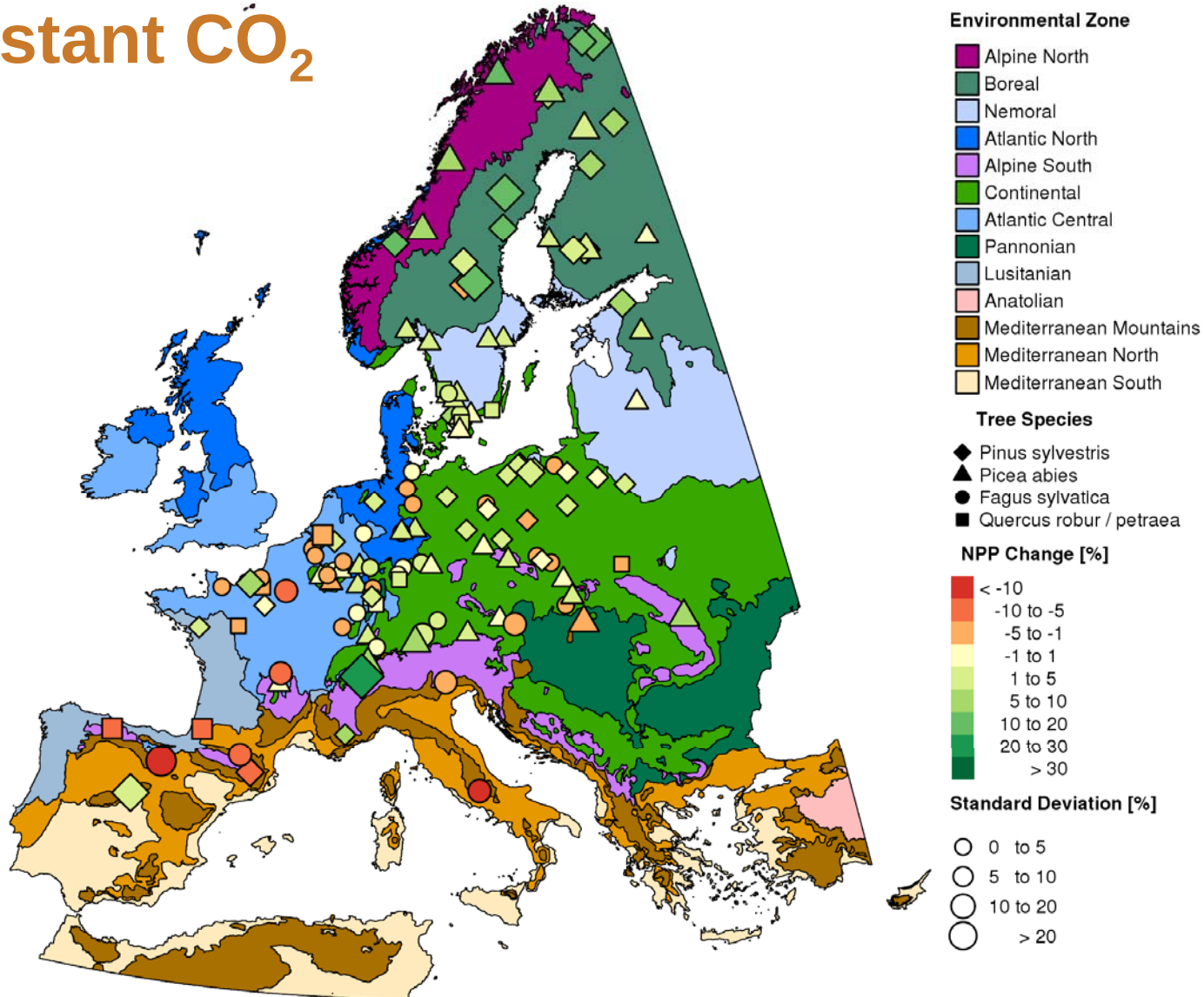
Constant CO₂



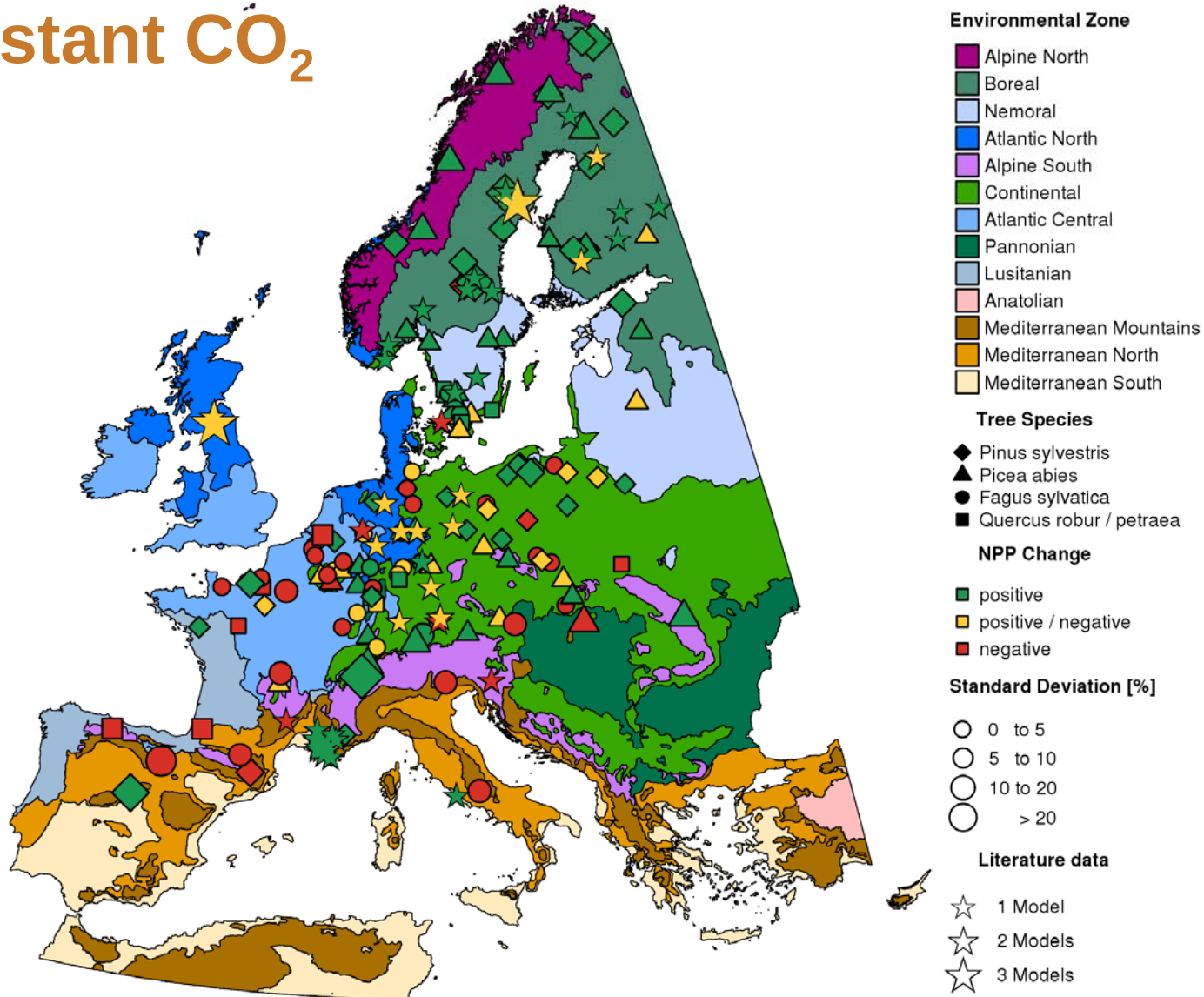
Constant CO₂



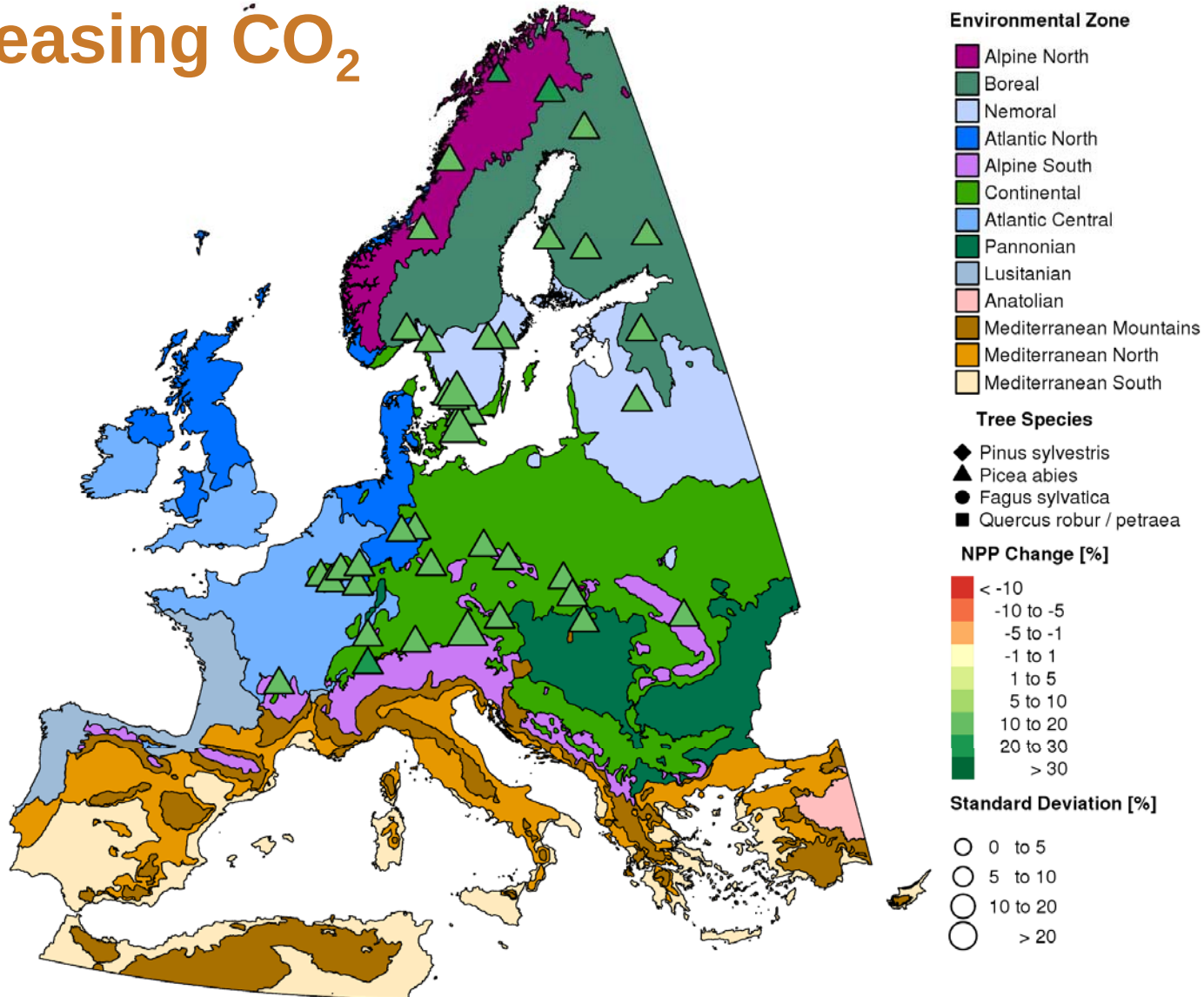
Constant CO₂



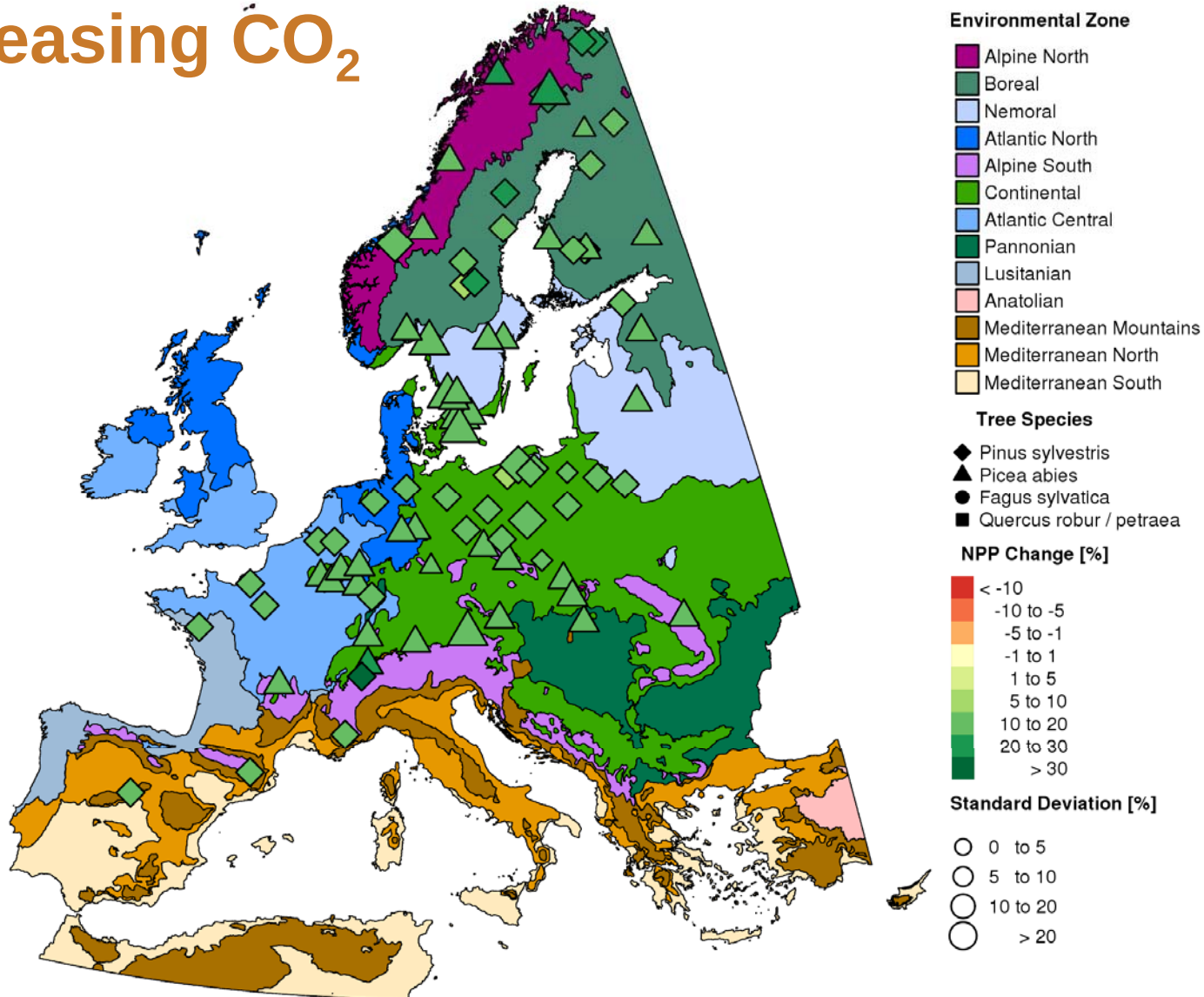
Constant CO₂



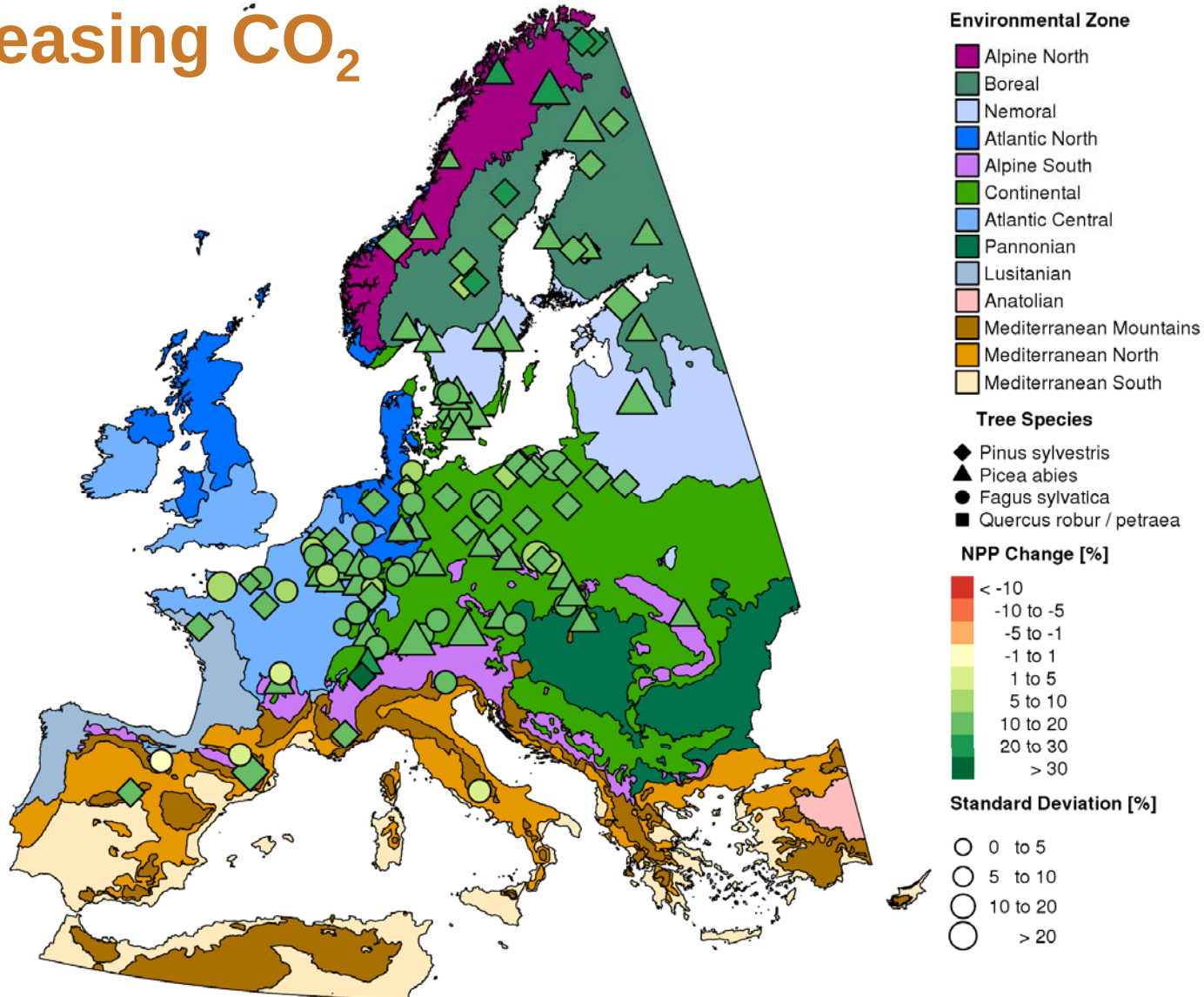
Increasing CO₂



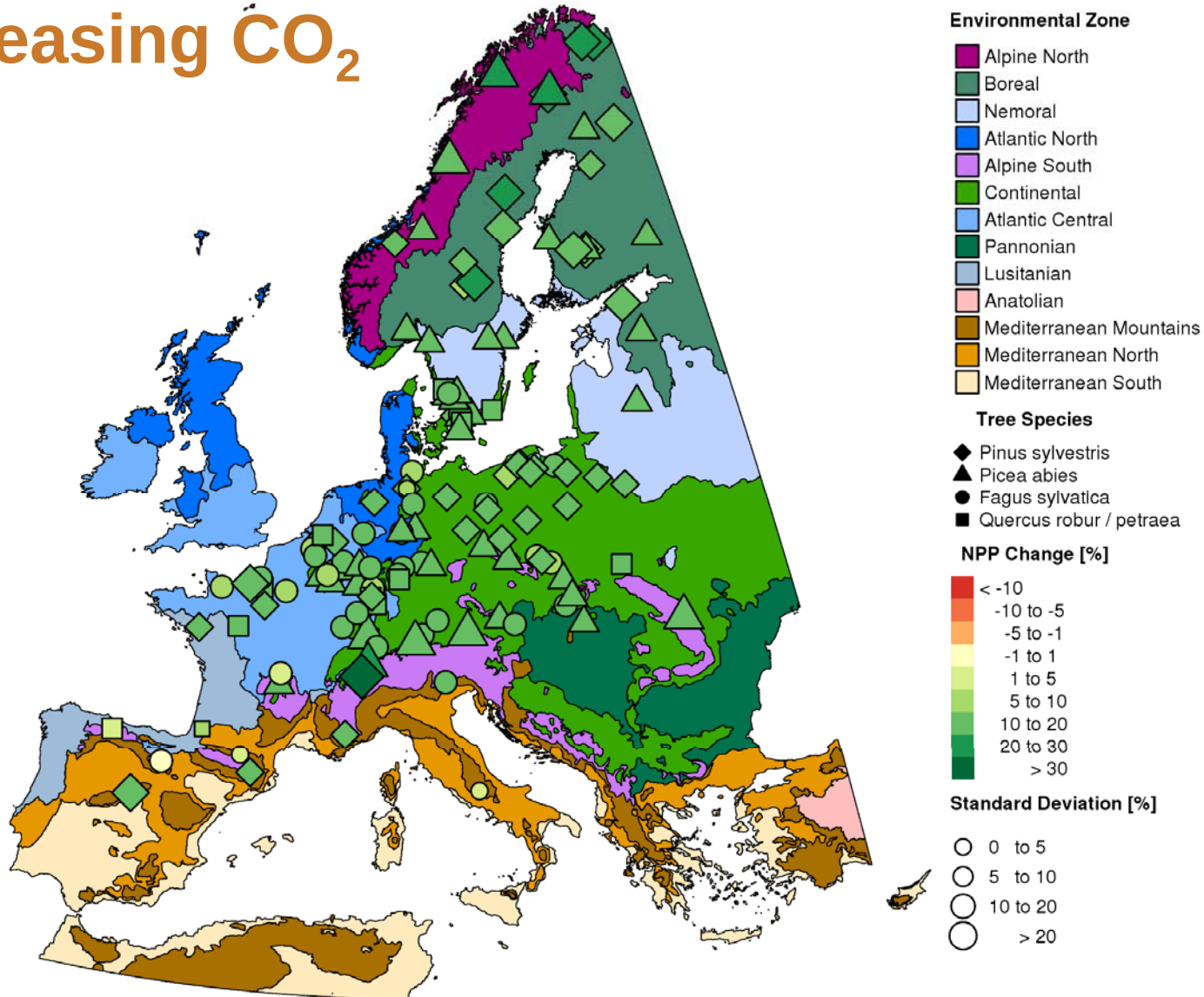
Increasing CO₂



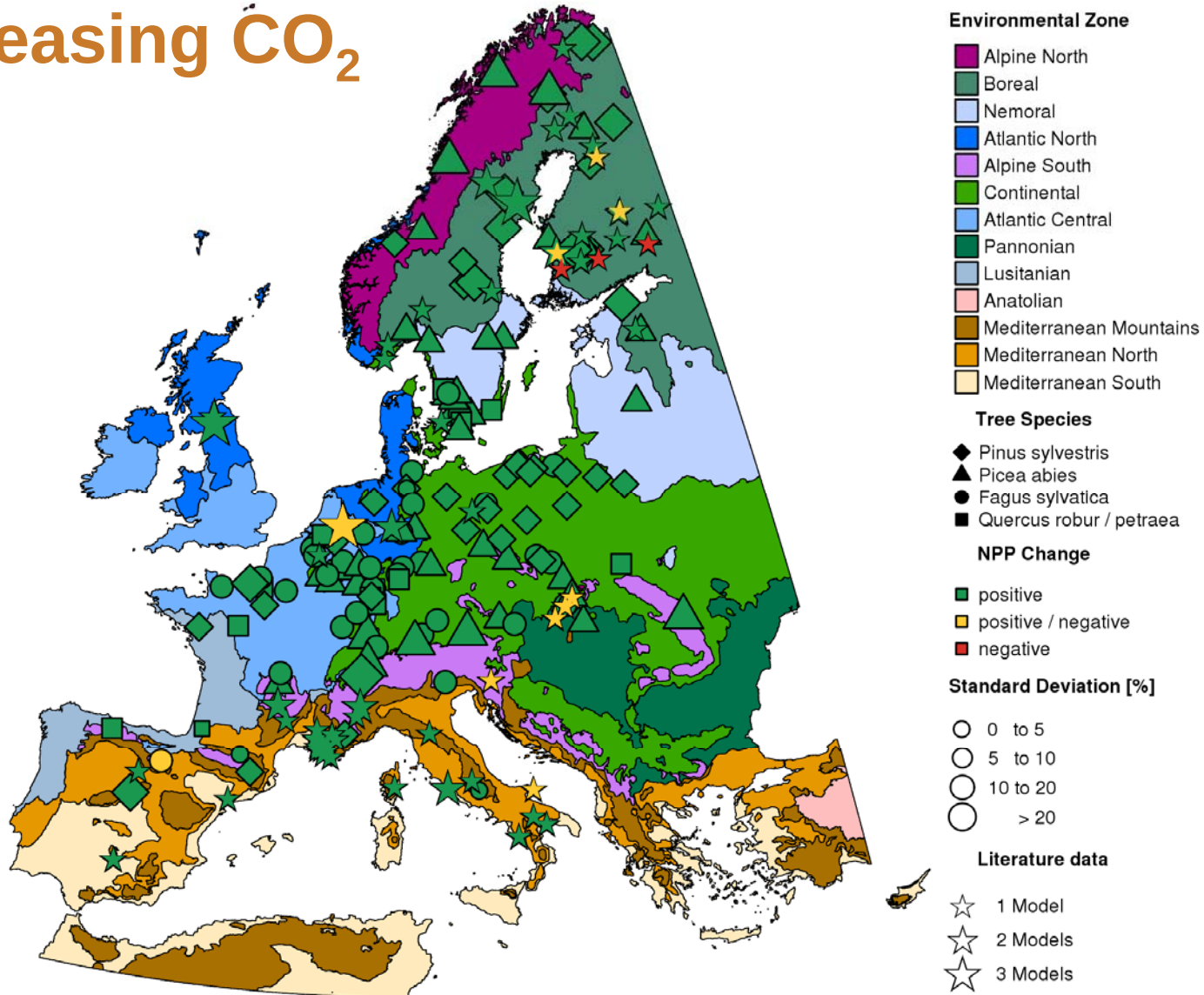
Increasing CO₂



Increasing CO₂



Increasing CO₂



Discussion & Conclusion: Input/scenario uncertainties

- Increasing NPP: northern and high altitude sites (sufficient nutrients and water)
- Decreasing NPP: southern sites with decreasing precipitation
In-between: many continental forests...
- CO₂-effect dominates temperature and precipitation impacts
- Conifers gain more than broadleaves in the northern and central regions (plot selection!)

Acknowledgements:

ICP Forests office and all country experts for providing data

Parameter uncertainty - Monte Carlo simulations

to combine analysis of parameter uncertainty (calibrated & uncalibrated) with simulation studies of climate change impacts on forest productivity

➔ Reyer C, M Flechsig, P Lasch-Born, M van Oijen (to be submitted) *Integrating parameter uncertainty of a process-based model in assessments of climate change effects on forest productivity*. Annals of Forest Science

Parameter uncertainty: allocation submodel

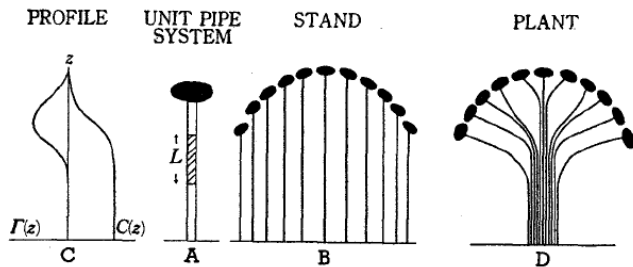


Fig. 5. Diagrammatic representation of the simple pipe model of plant form

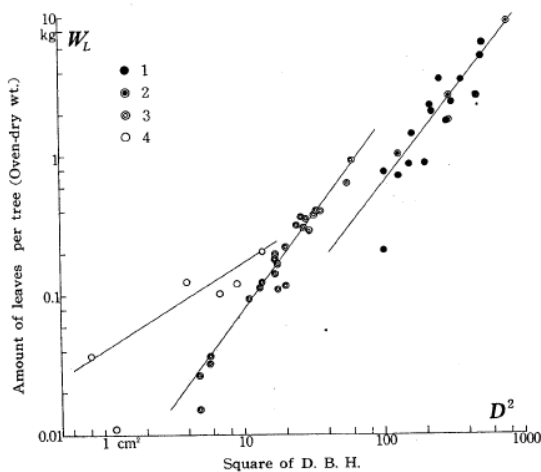
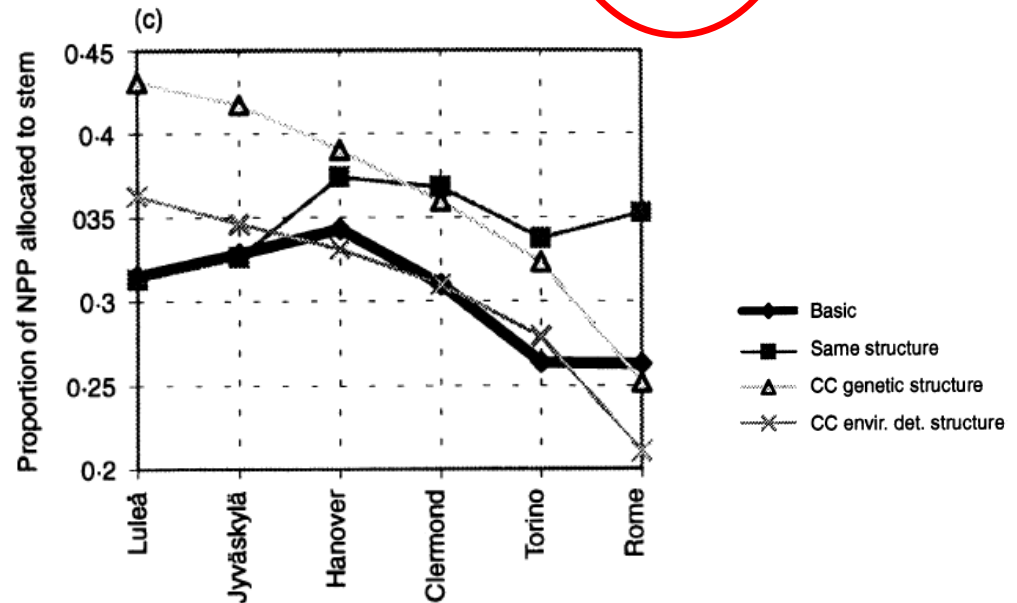


Fig. 5. Allometric relations between the amount of leaves per tree (W_L) and the trunk diameter at breast height (D), as shown by the linear regressions between $\log W_L$ and $\log D^2$, in birch stands of east-central Hokkaido

1) *Betula platyphylla japonica*, 45-years-old stand at Asyoro
2) *B. Maximowiczii*, 43-years-old stand at Niposotu 3) *B. Ermani*, 18-years-old stand at Simizu 4) *B. Maximowiczii*, 7-years-old stand.

Table 1. Site-specific parameter values of the changing parameters for the six sites on the gradient. All parameters but potential evapotranspiration are changing for each input year

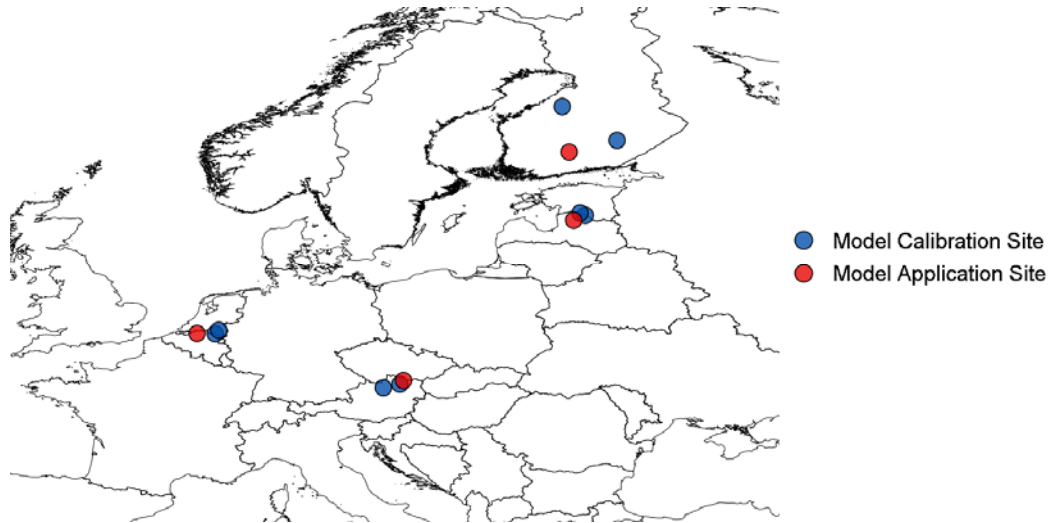
Location	Light extinction effect on photoproduction	Potential gross photoproduction (gCg unshaded needles year ⁻¹)	Foliage per unit stem sapwood (kg m ⁻²)	Relative respiration rate
Rome	-0.26	4.77	957	0.14
Torino	-0.24	4.14	841	0.75
Clermond Ferrand	-0.25	4.43	754	0.61
Hanover	-0.27	4.21	619	1.39
Jyväskylä	-0.29	2.99	485	1.00
Luleå	-0.32	2.73	487	0.96



Shinozaki et al. 1962a, b

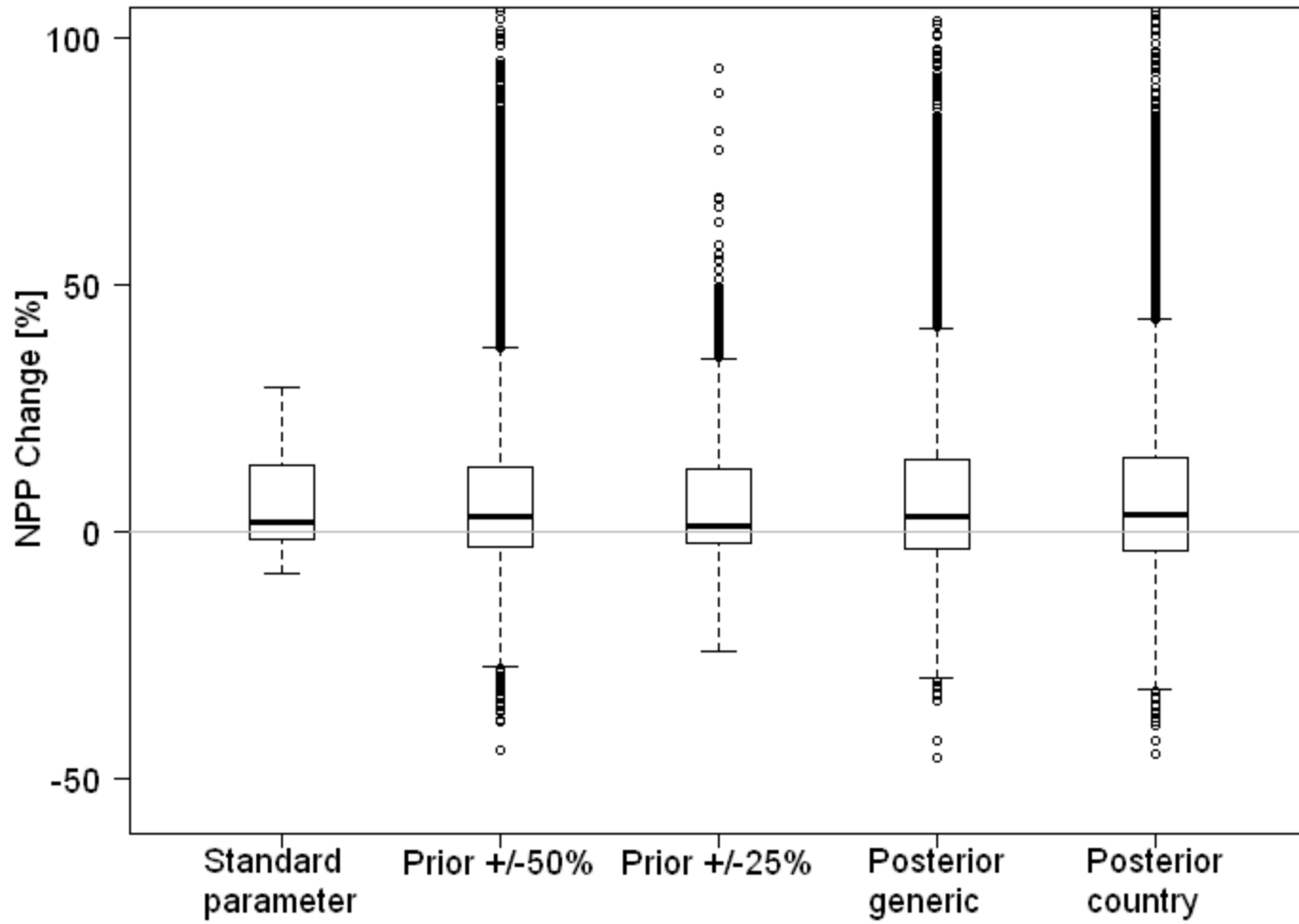
Berninger & Nikinmaa 1997

Parameter uncertainty: methods

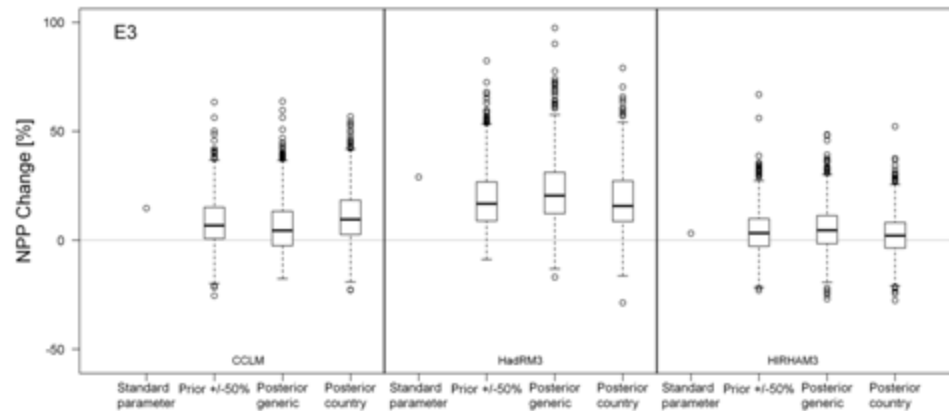


- **Climate Change:** 3 GCM/RCMs, A1B-scenario, 2061-2090 relative to 1971-2000
- **Monte Carlo simulations:** 43 parameters, priors: +/-25% and +/-50%, 1001 runs
- **Bayesian calibration:** posteriors: country-specific and generic
- **Total:** 3 GCM/RCMs * 2 time periods * 4 stands * 4 parameter distributions * 1001 MC runs = **96 096 simulations**

Parameter uncertainty vs. Standard parameters



Parameter uncertainty vs. Standard parameters



Discussion & Conclusion: Parameter uncertainties

- climate change and parameter uncertainty higher than climate change uncertainty alone
- even after calibration parameter uncertainty under climate change is high
- direction of change consistent between standard parameter settings and parameter uncertainty

Overall Conclusions

- CO₂-effect
- Include different types of uncertainties for robust impact projections:
- Model structural uncertainty:
 - ➔synchronized model intercomparisons
- Input uncertainty:
 - ➔ensemble runs from different GCM/RCMs and emission scenarios
- Parameter uncertainty:
 - ➔very important, especially in complex models with many parameters

Questions & Comments

Thank you!