Predicting the adaptive responses of biodiverse plant communities using functional trait evolution

Jaideep Joshi, Florian Hofhansl, Shipra Singh, Benjamin D. Stocker, Toyo Vignal, Åke Brännström, Oskar Franklin, Carolina C. Blanco, Izabela F. Aleixo, David Lapola, Iain Colin Prentice, and Ulf Dieckmann

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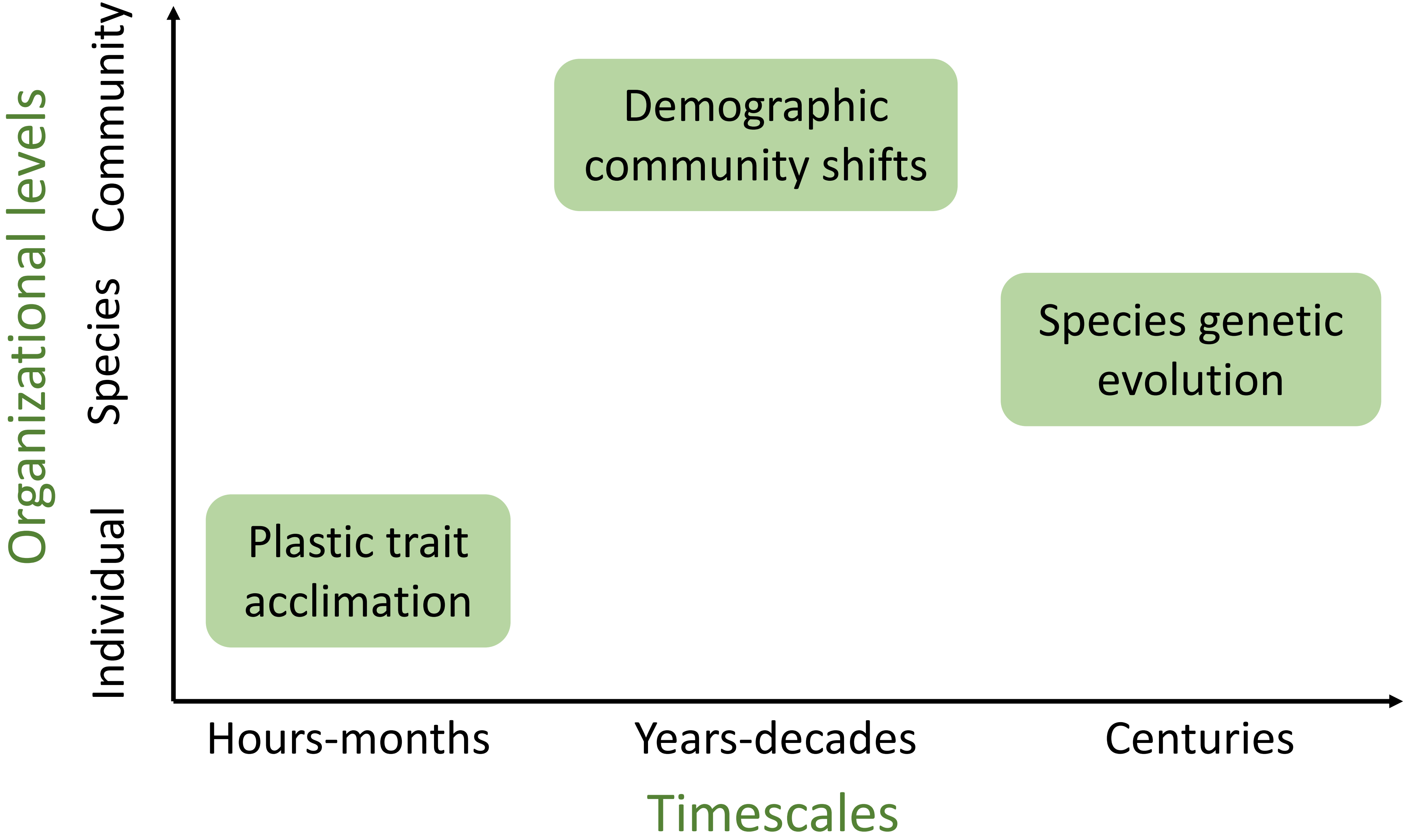
How does a biodiverse ecosystem respond to climate change?



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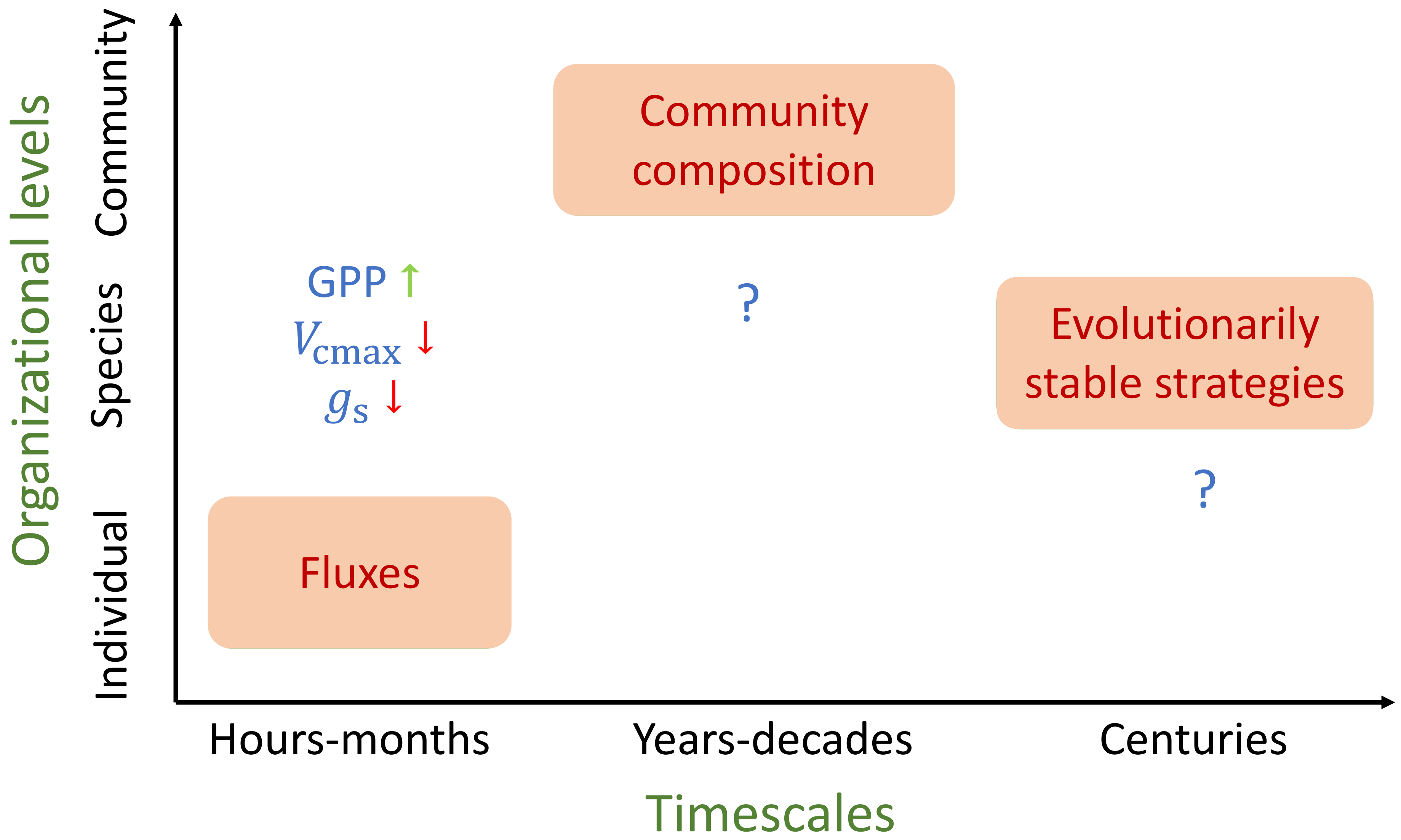


Plant-FATE: Our eco-evolutionary vegetation model

Physiological acclimation
Optimality principles

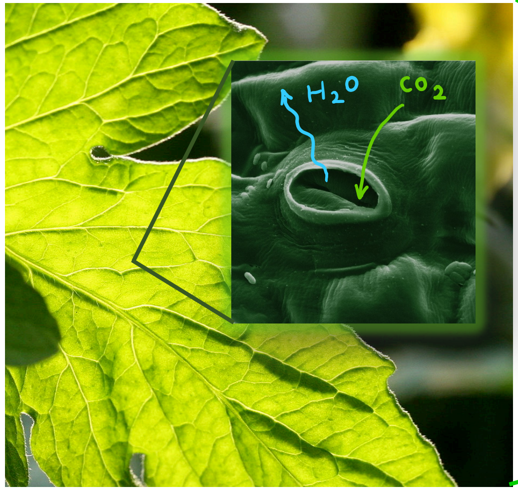
Optimal photosynthesis, hydraulics, allocation

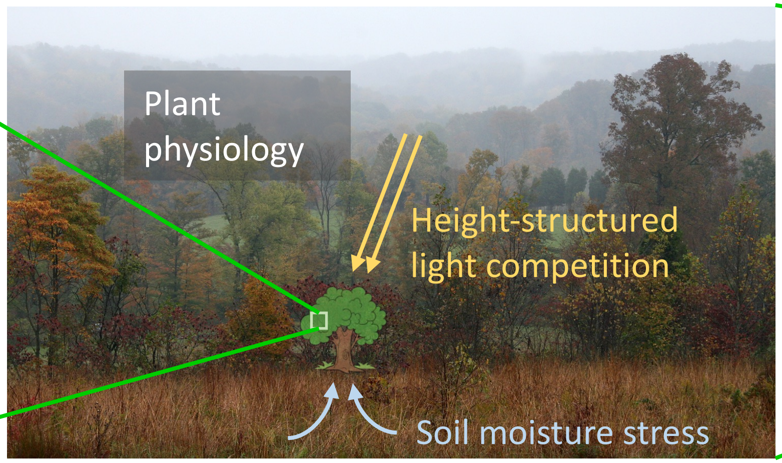
Vegetation demographics
Size-structured population modelling

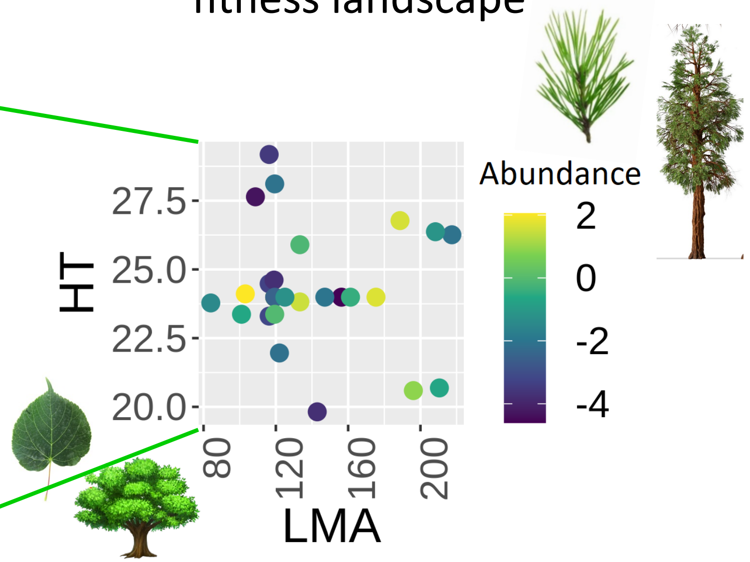
Competition for light and water, optimal crown placement

Species evolution
Evolutionary dynamics

Gradual ascension of the fitness landscape







Days - Months

Years - Decades

Centuries

Image Credits: Muffet, Huw Williams

We address four key Questions

1. What are the changes in fluxes (GPP, transpiration) under elevated CO_2 (eCO_2) compared to ambient CO_2 (aCO_2)?
2. What are the timescales of responses at the three organizational levels?
3. Are there potential species shifts under eCO_2?
4. How do allocation shifts occurring in response to nutrient limitation affect ecosystem responses to eCO2?

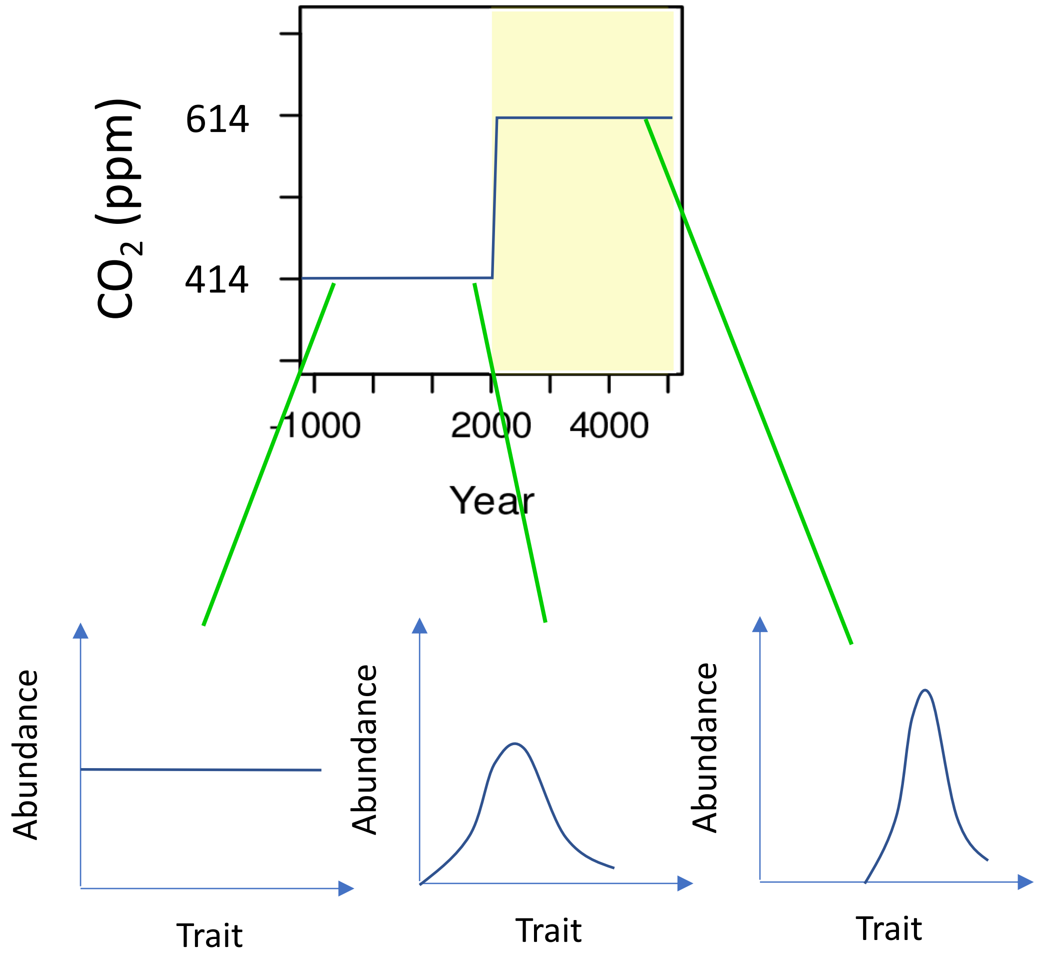
We apply the model to a hyperdiverse Amazonian forest

1. Forced with periodic extension of observed meteorological data from 2000-2015

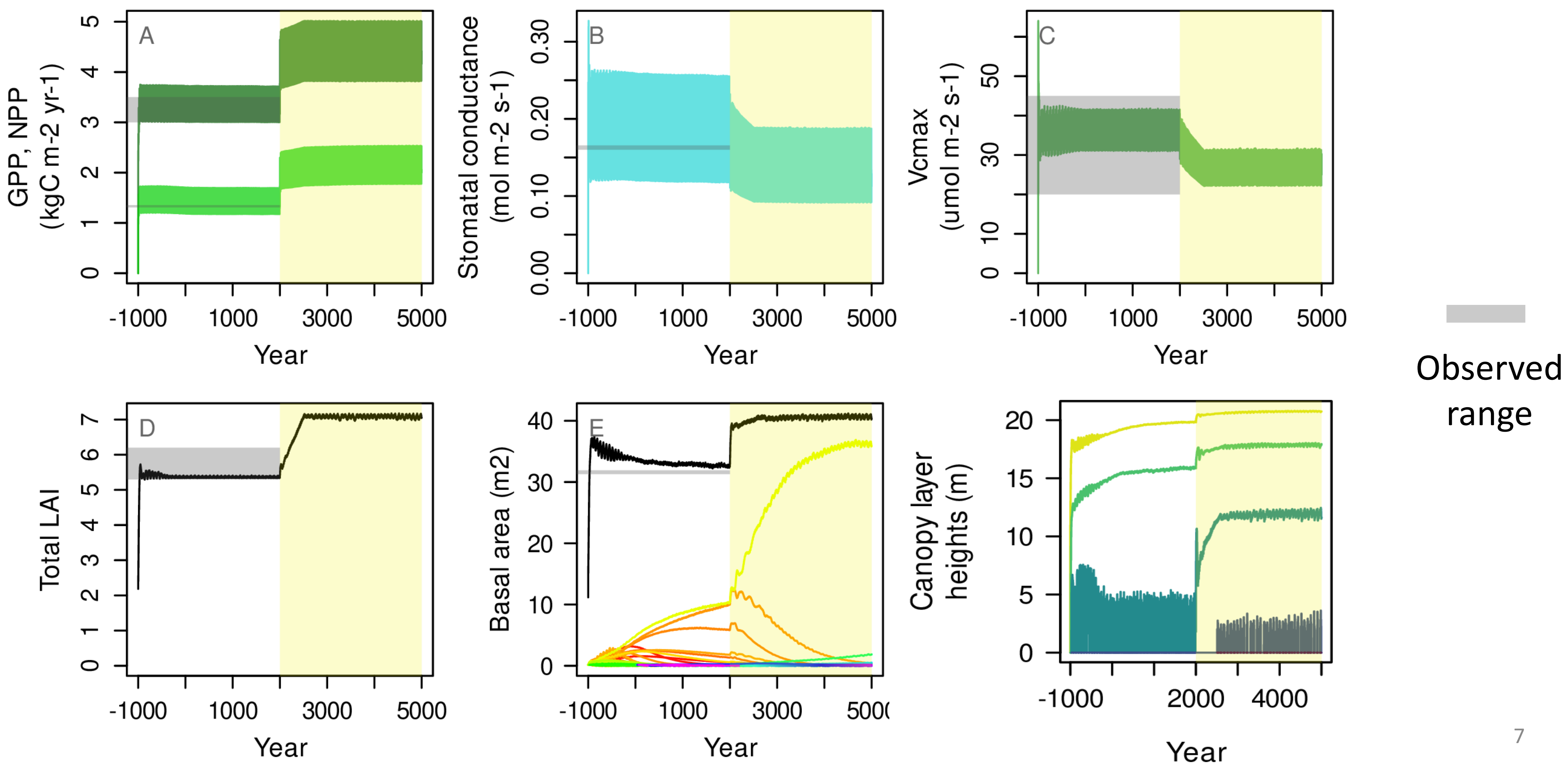
2. Species defined as unique combinations of 4 traits: LMA, max. height, wood density, xylem ψ_{50}

3. Start with 100 species with random trait values with equal abundance

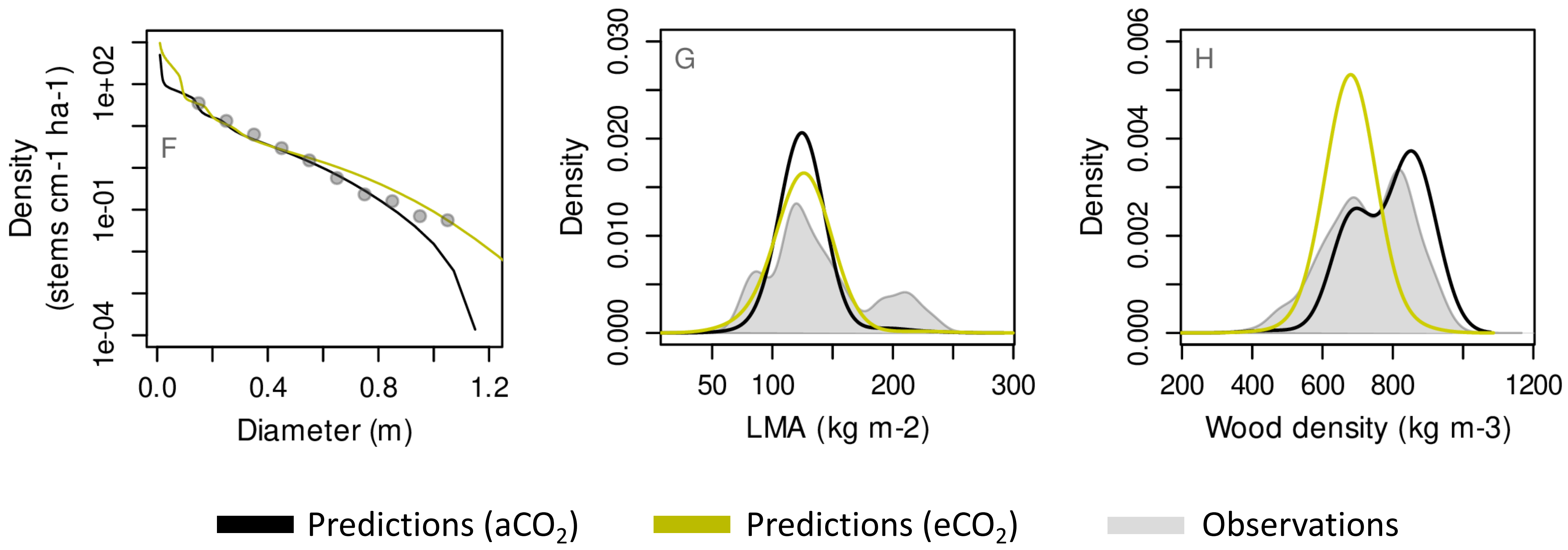
4. Let community composition evolve via competitive exclusion



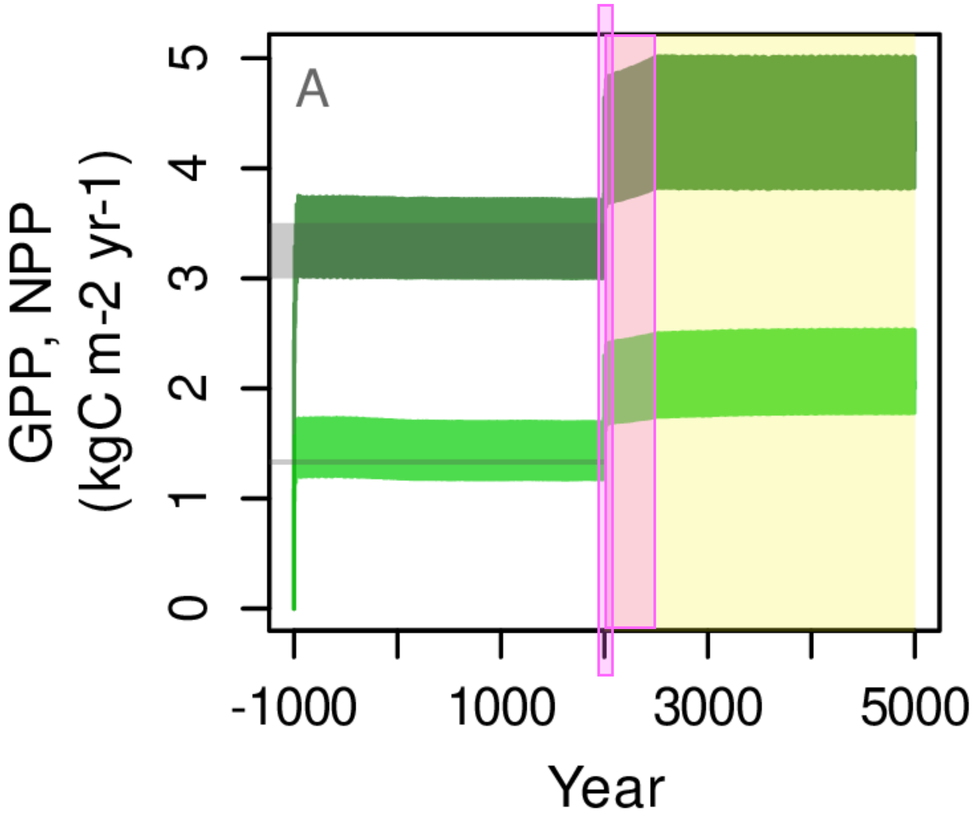
GPP increases, transpiration decreases under eCO_2

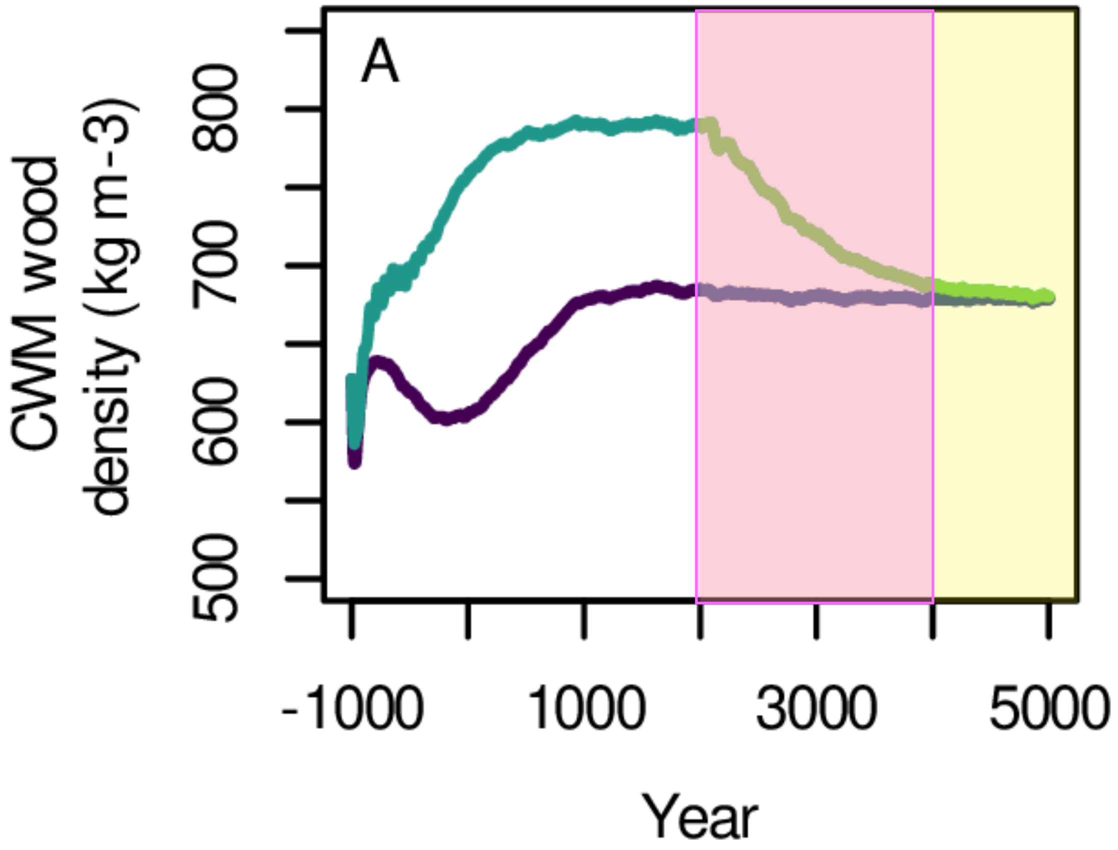


Community shifts to larger trees and species with lower wood density under eCO_2



Community responds on three timescales





1. Physiological response in increased leaf-level photosynthesis ~1 year

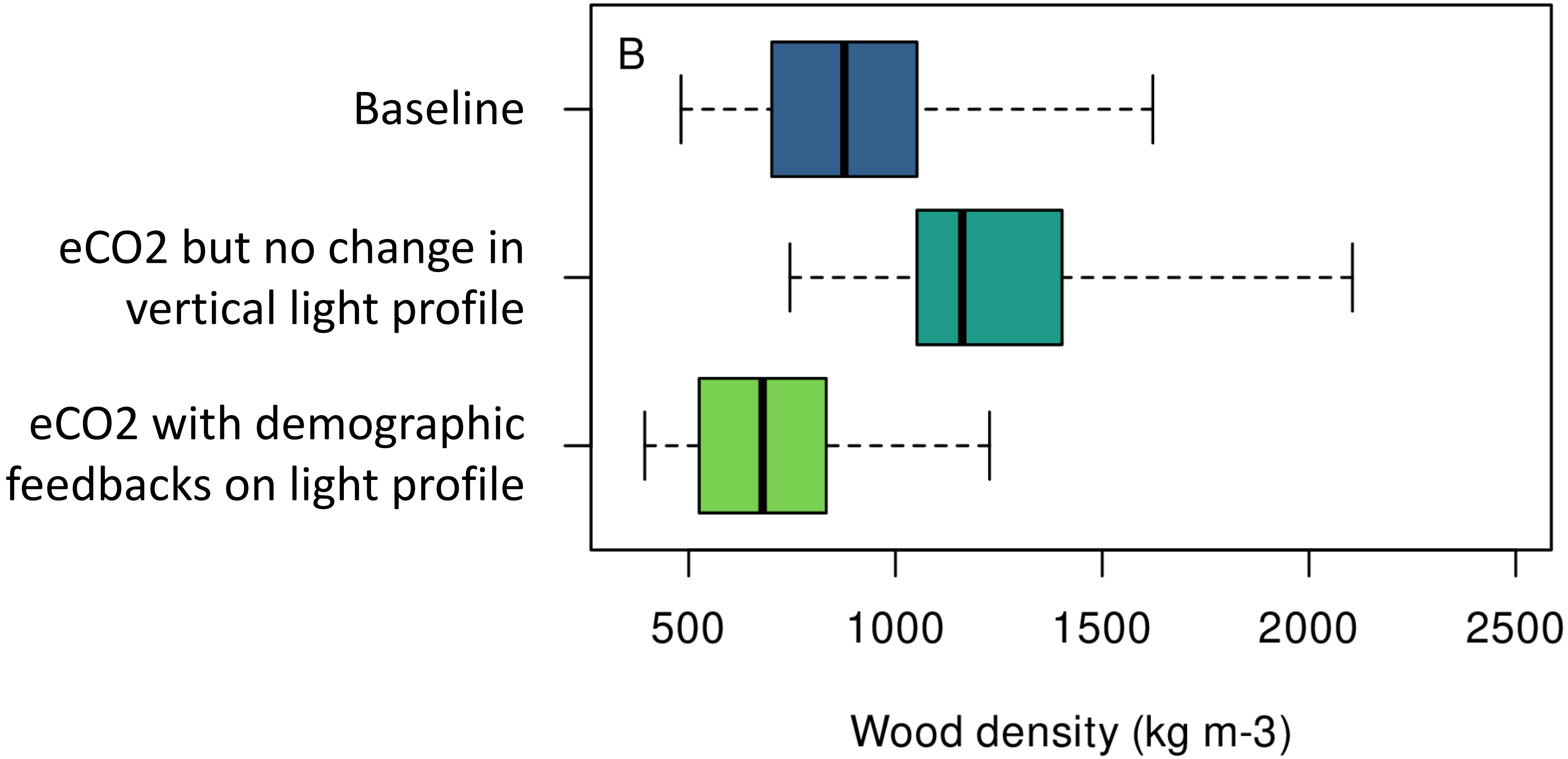
2. Demographic change due to changing light environment ~500 years

3. Evolutionary change due to changing species composition ~2000 years

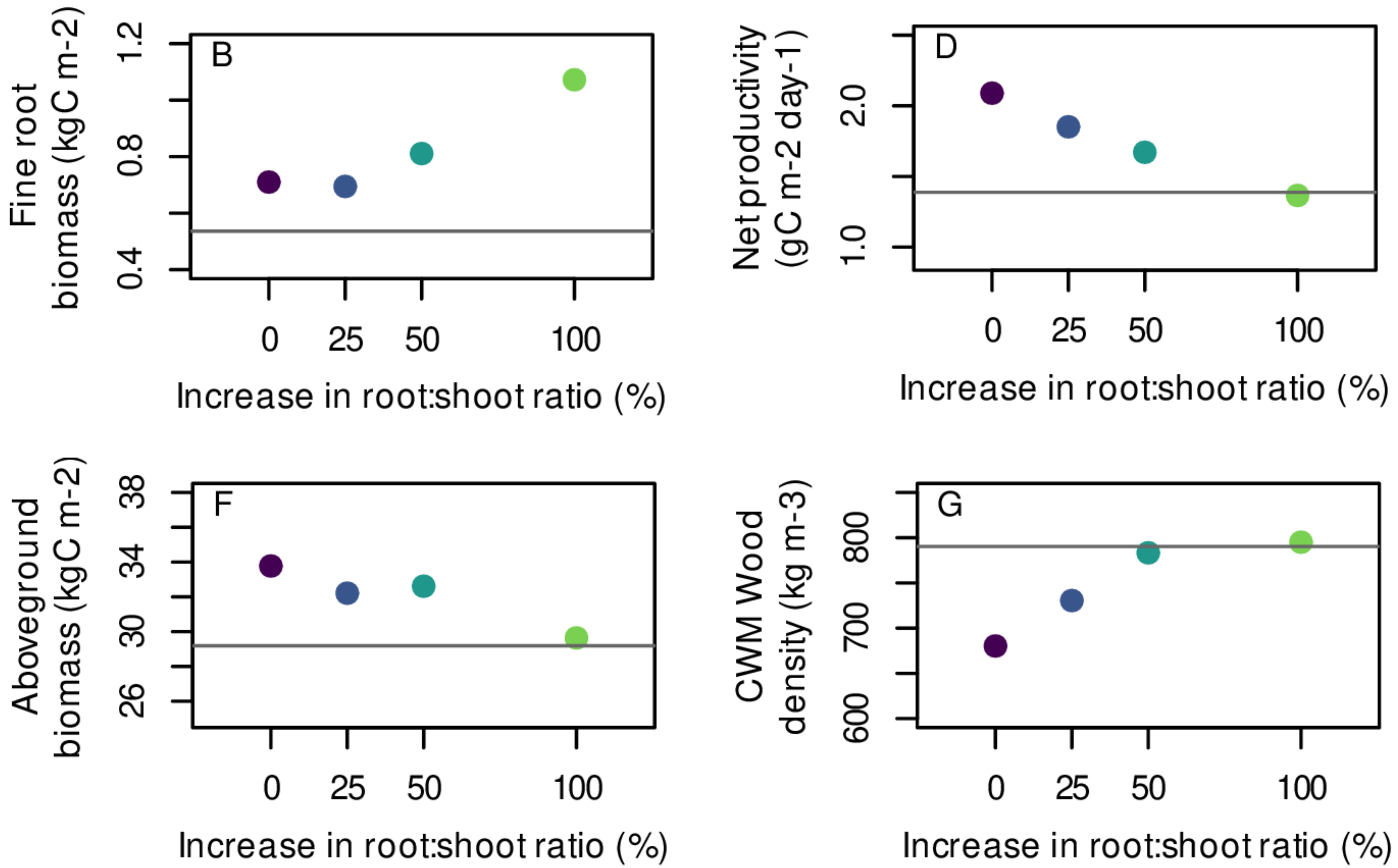
Population-environment feedbacks alter the direction of the community shift

Predicted optimal wood density

(for different combinations of LMA, Max Height, and P50)



Nutrient limitation diminishes the said response



Take home messages

1. The Plant-FATE model correctly predicts ecosystem fluxes, forest structure, and species composition under ambient CO_2
2. Under elevated CO_2, productivity increases but community shifts to lower wood density
3. The direction of the shift is determined by feedbacks between forest structure and the environment: not accounting for environmental feedbacks can predict opposite outcomes
4. Increased root-zone allocation dampens the increase in productivity but also prevents community shift

Thank you

Questions?

jaideep.joshi@giub.unibe.ch