EGU General Assembly BG3.24 | EGU24-15114

DYNAMICS IN CO_2 UPTAKE, GROWTH, AND MORTALITY OF AN OLD-GROWTH TEMPERATE FOREST UNDER DROUGHT STRESS

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Nationalpark Hainich
ICOS Integrated Carbon Observation System
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Introduction

- Improved understanding of **drought stress responses** and **adaptation mechanisms** in forest ecosystems → Assessment of adaptive capacities and development of supportive management measures

- Comprehensive and long-term data set of a protected mixed-beech forest in Central Germany

- Investigation of stress effects and transformation processes caused by the 2018 and 2019 summer droughts on tree and stand scale

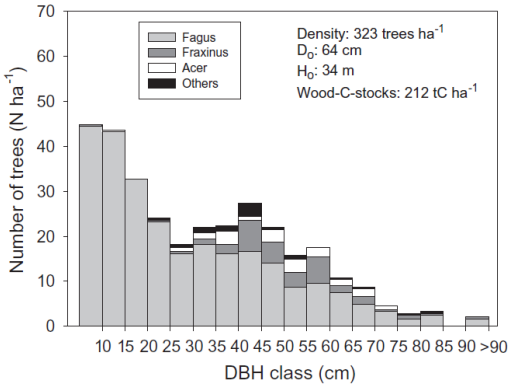
→ **How stable is the CO_2-uptake?**
→ **What was the impact of the recent droughts?**

Study Site Hainich

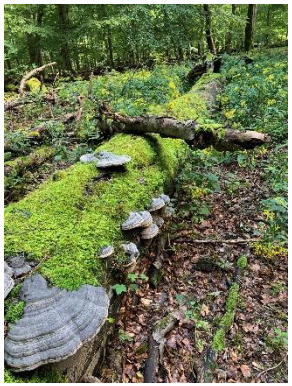
Nationalpark Hainich

WORLD NATURAL HERITAGE BEECH FORESTS

- National Park since 1997
- UNESCO World Heritage since 2011
- mixed-beech forest with near-natural and diverse structures in Central Germany



- main species:
  - *Fagus sylvatica*
  - *Fraxinus excelsior*
  - *Acer pseudoplatanus*



Herbst et al. 2015, doi:10.1016/j.foreco.2015.05.034

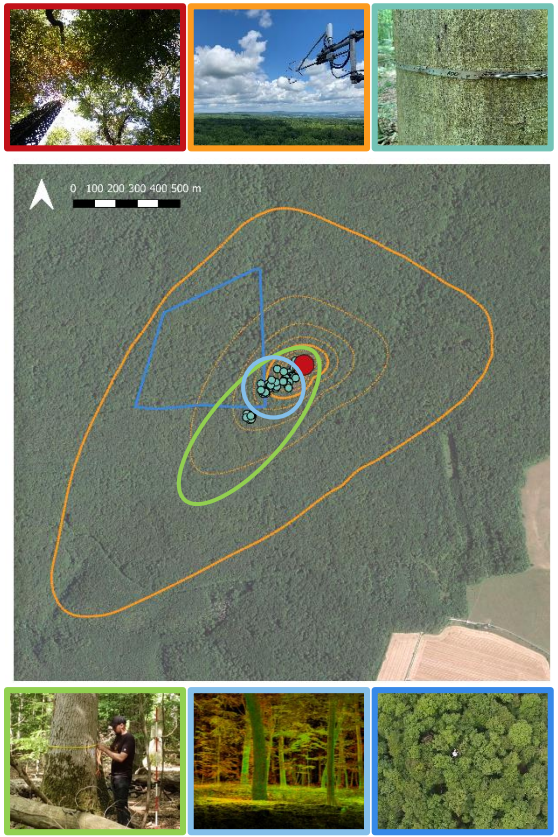
Data Set

- continuous measurements since autumn 1999
  - meteorology and soil climate
  - CO_2 and H_2O flux exchange via eddy covariance method
  - annual tree growth via dendrometer bands, of 80 trees
- further measurements in recent years
  - comprehensive inventory in 2017 of main footprint, of 788 trees
  - structural indices via terrestrial laser scans
  - drone imagery (structure from motion) and aerial laser scans

among others…

stand scale

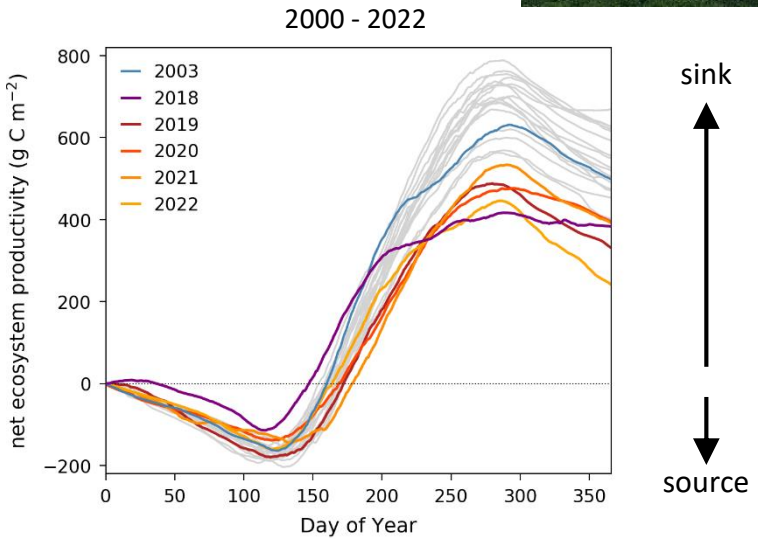
tree scale



Results - CO_2 Fluxes on Stand Level

Eddy Covariance Method

- long stability since 2000
- Decrease in CO_2 uptake by 29% and 38% in 2018 and 2019, but still strong sink
- lower CO_2 uptake also after drought

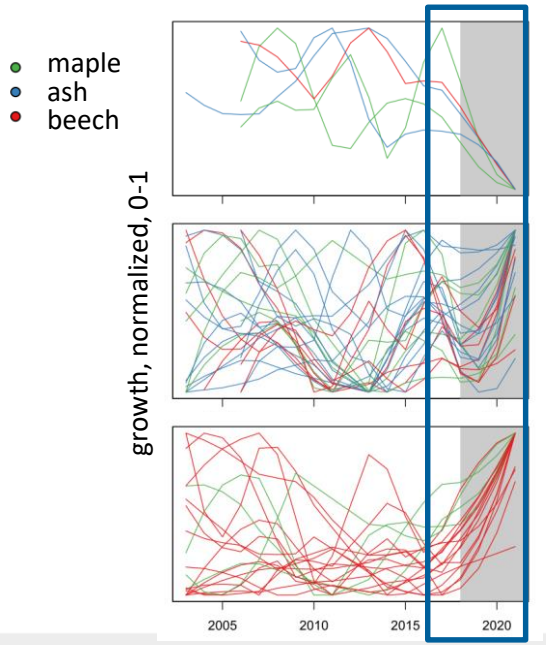


→ transformation processes

Results - Growing Patterns on Tree Level

Dendrometer Bands of 80 Trees

- surviving trees, ring increments



- **8%** of investigated trees: long-term impairment
  - applies to all species, DBH > 46 cm
  - Controls cannot be described statistically.
- **37%** of investigated trees: growth reduction in 2018/2019, but recovery thereafter
  - applies to all species and DBH classes
  - proportionally high ash percentage (48% | 18%)

→ Most surviving trees were not restricted in their growth.

- **56%** of investigated trees: continuation of positive growth trend without any impairment
  - exclusively beech and maple
  - Vitality: 2.1 | 2.8 ($p<0.01$)
  - Height: 29 m | 32 m ($p=0.1$)

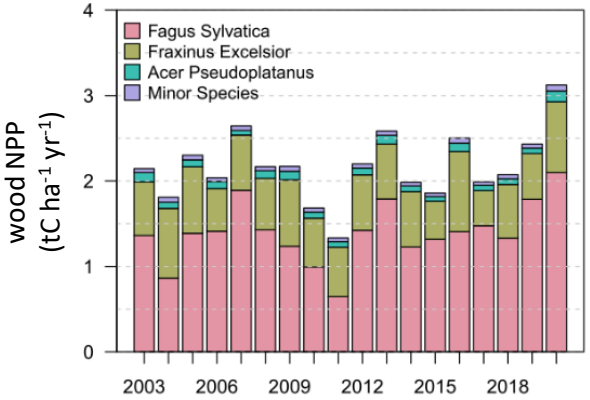
Structural complexity: 1.95 | 1.88 ($p<0.05$)
Light competition: 12 | 23 ($p<0.01$)

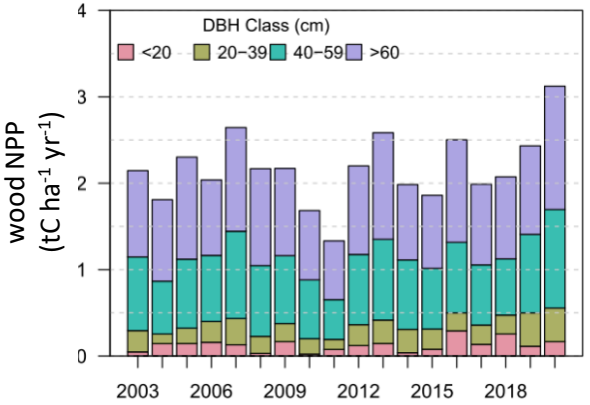
Koebsch et al. unpubl.

Results - Growing Patterns on Stand Level

Inventory of 788 Trees

- estimation of standing biomass of surviving trees using growth models and allometric functions (for each species and year)





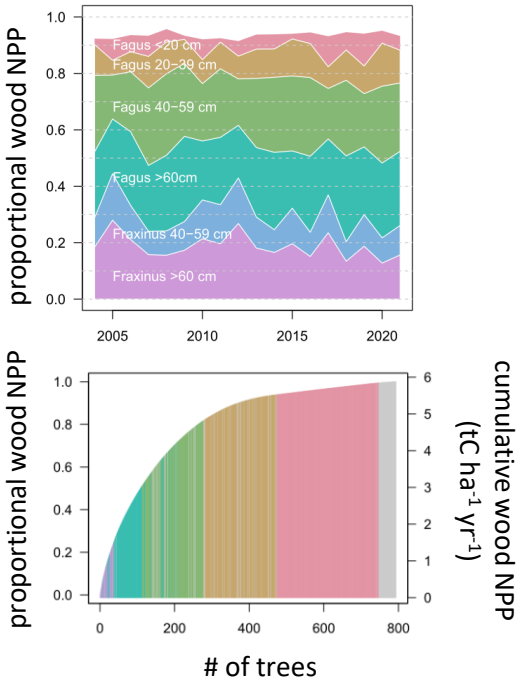
→ increase in wood NPP

- Net primary productivity (NPP) of wood shows no collapse (without mortality).
- wood NPP is dominated by large and medium trees (DBH > 20 cm)

Koebsch et al. unpubl.

Results - Growing Patterns on Stand Level

Inventory of 788 Trees



- Relative contribution of larger DBH classes is disproportionately important.
  → 15% of trees account for almost 45% of NPP
- Relative contribution of larger DBH classes (> 60 cm) decreases slightly.
- High number (approx. 40%) of small trees (< 20 cm) has only a small share of NPP (5-10%).

→ Few, large trees contribute most to wood NPP.

Koebsch et al. unpubl.

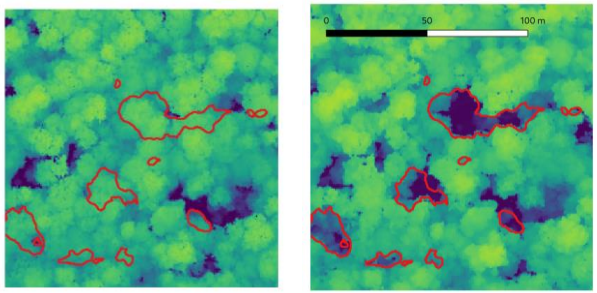
Results - Gap Dynamic and Mortality

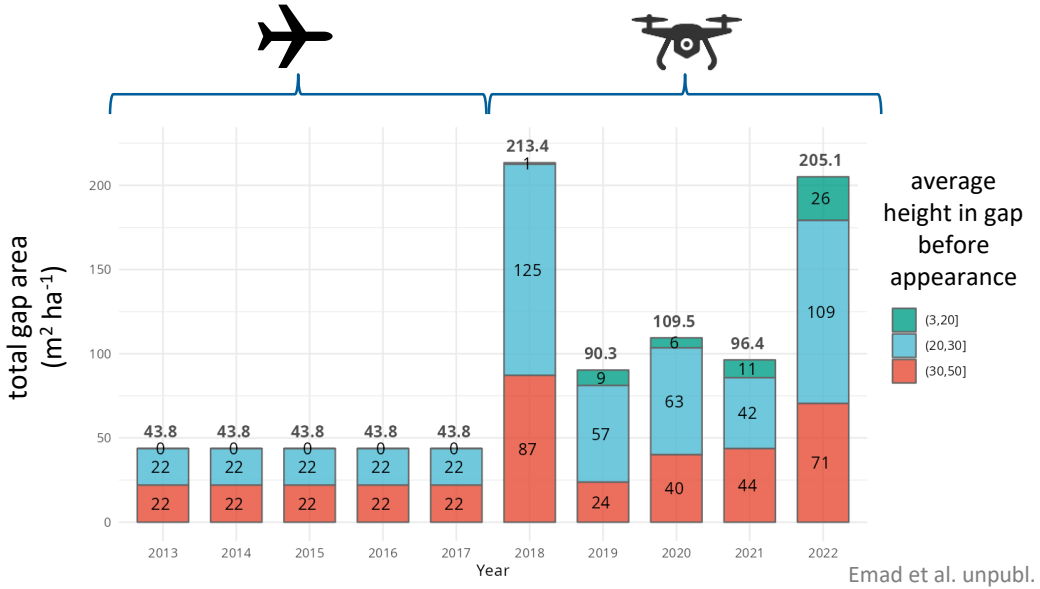
Drone Imagery and Aerial Laser Scans

change in mortality

- detection of gaps based on change in canopy height

new gaps since 2018

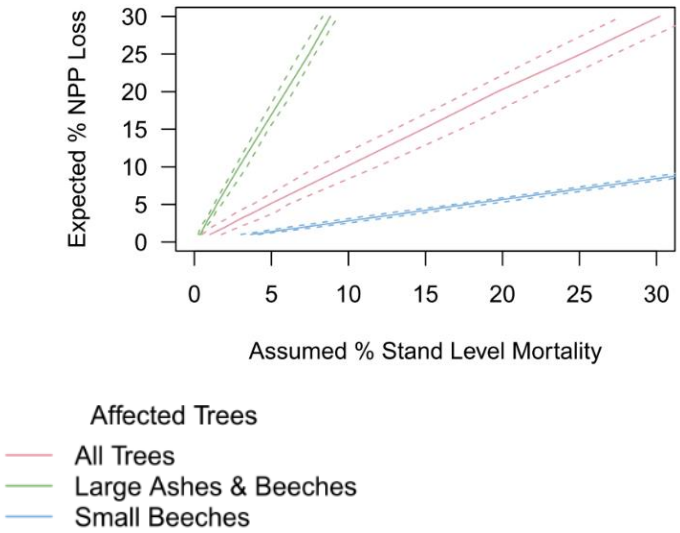




- increase in gaps since 2018
- method covers primarily overstory trees, as indicator for stand mortality

Emad et al. unpubl.

Results - Wood NPP and Mortality



- sensitivity of NPP for mortality of different tree groups:
  - for large ash trees (DBH > 40 cm) and beech trees (DBH > 60 cm)
    → ≈ 3% loss in NPP per 1% mortality
  - for small beech trees (DBH < 40cm)
    → ≈ 0.3% loss in NPP per 1% mortality

→ The loss of large trees significantly reduces stand growth.

Koebsch et al. unpubl.

Conclusions

- sustained reduction in net CO_2 uptake after long-term stability
- mortality increased by a factor of 2-5 (based on overstory trees)
- at the same time increased growth of surviving trees

→ observation of substantial transformation dynamics

→ Increased growth of surviving trees cannot compensate the loss in CO_2 uptake of dead trees.

→ Disturbance effects - such as drought - accelerate major forest dynamics processes with a temporal reduction of the net CO_2 sink.

→ Structural diversity can buffer disturbance-related outage.

→ Consistent long-term monitoring is needed to further investigate the initiated transformation processes, the stand and tree resilience, and the impact of legacy effects.

Thank you for your attention!

GEFÖRDERT VON

And great thanks to…
the Bioclimatology Group and former colleagues,
students assistances, BSc and MSc students,
all members of the Digital Forest project,
the National Park Hainich,
the team of MPI-BGC!

Nationalpark Hainich

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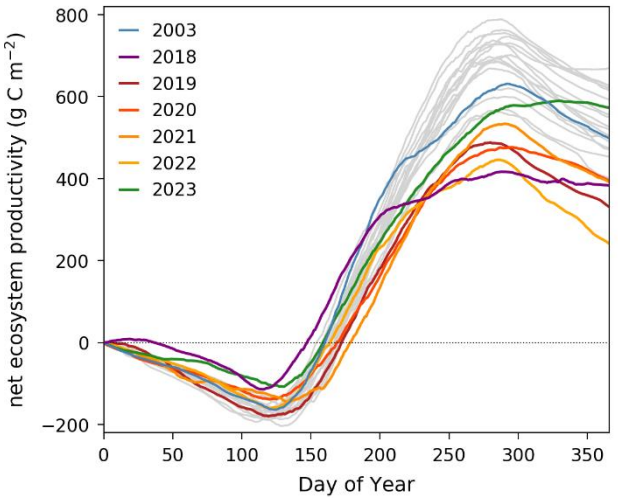


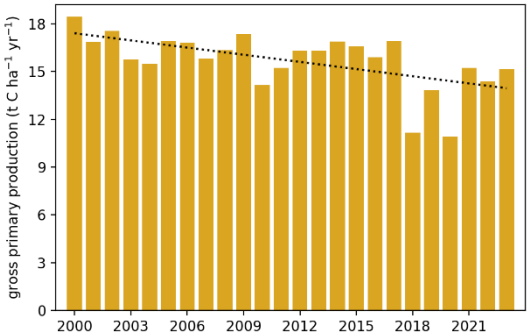
→ transformation processes

Results - CO_2 Fluxes on Stand Level

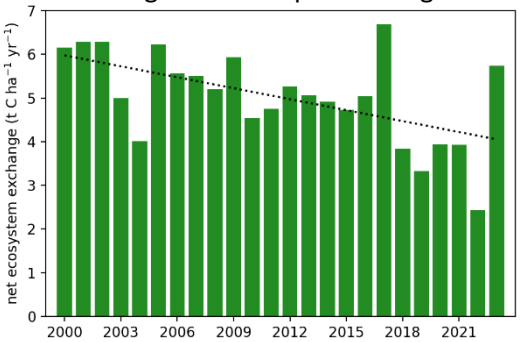
Eddy Covariance Method

- annual sums

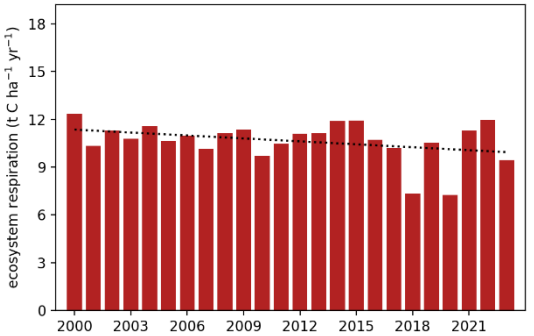
GPP
nighttime flux partitioning



NEP
nighttime flux partitioning



R_{eco}
nighttime flux partitioning

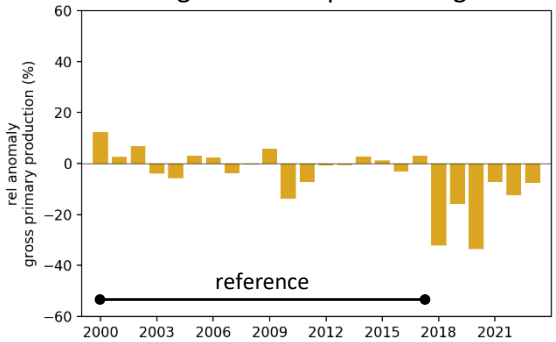


Results - CO_2 Fluxes on Stand Level

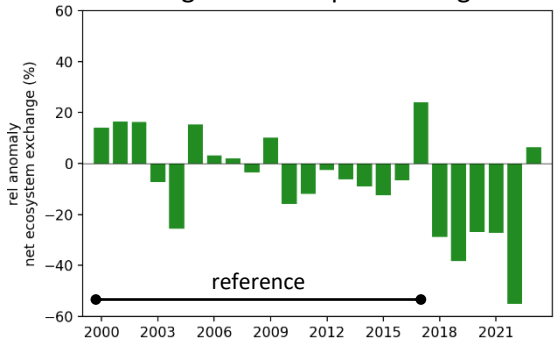
Eddy Covariance Method

- relative anomalies

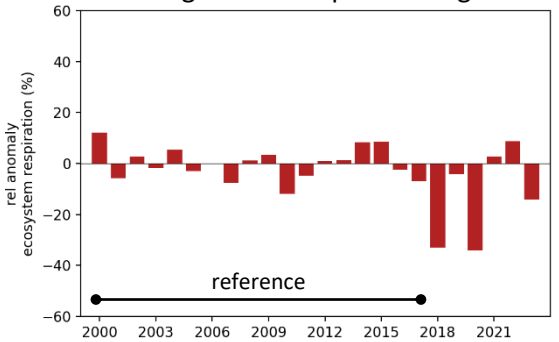
GPP
nighttime flux partitioning



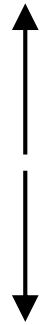
NEP
nighttime flux partitioning



R_{eco}
nighttime flux partitioning



larger sink
or source



smaller sink
or source