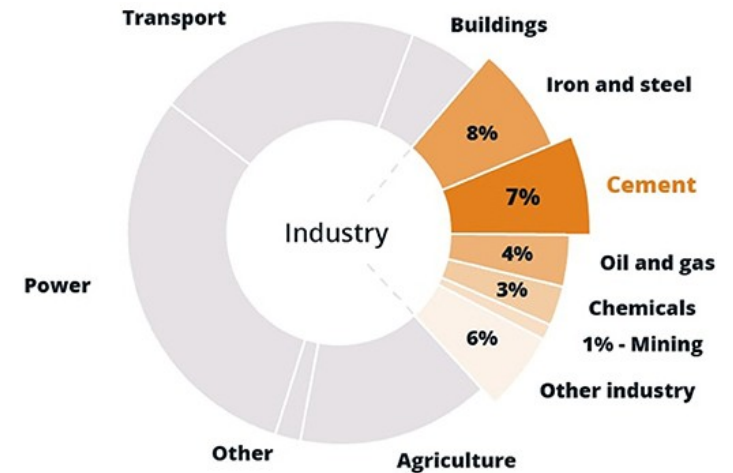


Quantifying 7 drivers of forest-based carbon mitigation

Number 4 will surprise you!



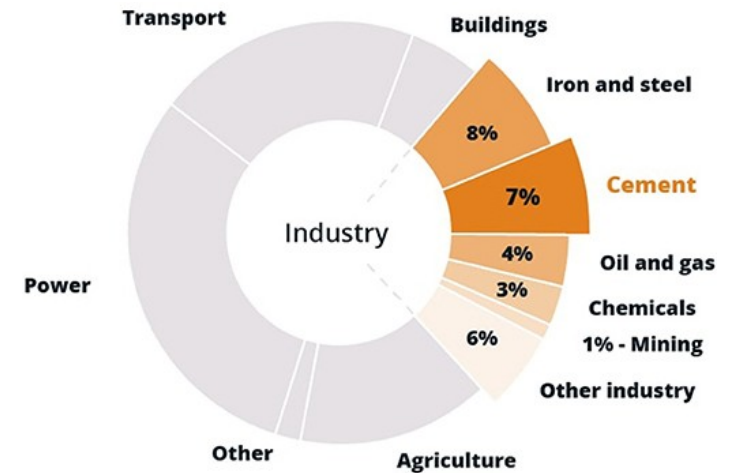
Carbon Mitigation Potential of Forests



Mitigation = Forest sink + Product sink + Substitution effects

Europe (Grassi et al., 2021): 315 + 40 + 410 MtCO_{2e} / yr

Carbon Mitigation Potential of Forests



Mitigation = Forest sink + Product sink + Substitution effects

Europe (Grassi et al., 2021): 315 + 40 + 410 MtCO_{2e} / yr

Note: **theoretical** value, assuming substitution effect for every created wood product

Drivers of the carbon mitigation potential

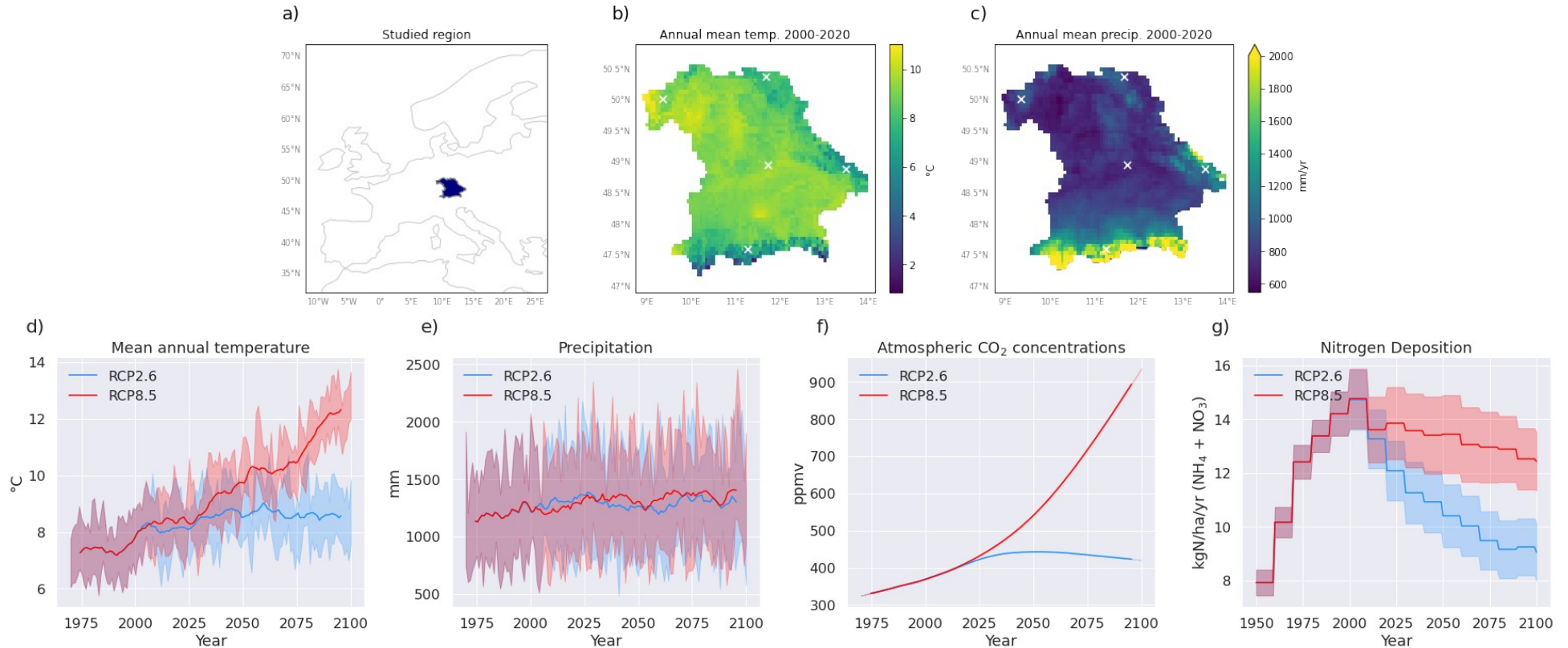
What is the impact of each of them?

- 1) Forest age
- 2) Forest type
- 3) Climate change scenarios and associated disturbances
- 4) Harvest intensity
- 5) Wood usage
- 6) Salvage logging
- 7) Carbon intensity of replaced products

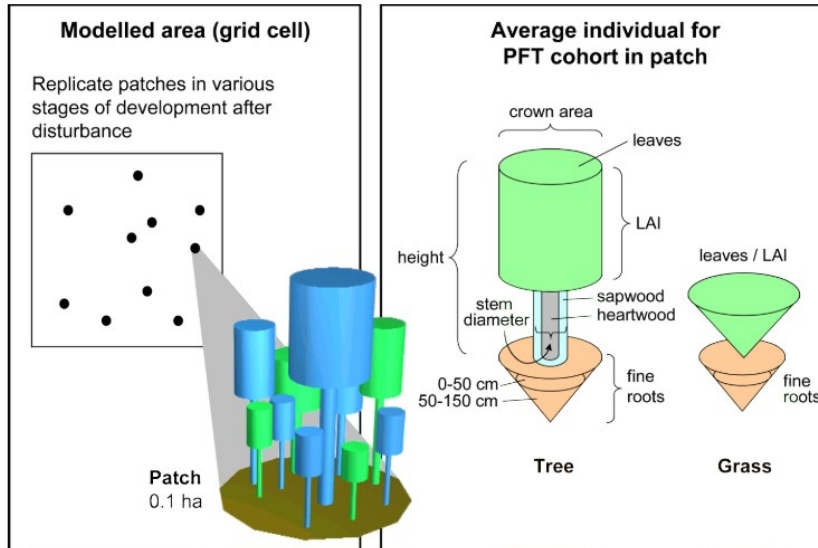
And: what about other ecosystem services?

Idea: use modeling to quantify the impact of each of the drivers.

Study Region: Bavaria

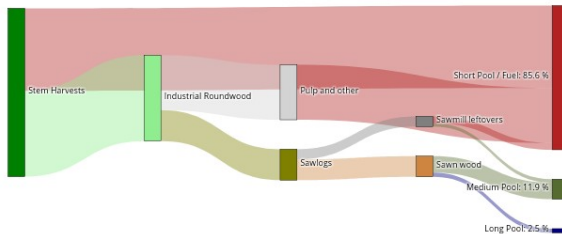


Vegetation model LPJ-GUESS



- Dynamic Global Vegetation Model (Smith et al., 2014)
 - used, e.g., in the Global Carbon Project
- Photosynthesis, allocation, growth, competition, water and nutrient limitation
- Establishment and mortality
- Age cohorts
- Litter and soil dynamics
- Forest management (Lindeskog et al., 2021)
- Fuelwood, short-, medium-, and long-lived wood product pools

Wood Product Flow Non-Coniferous (%)



er P.O. Reyer, Thomas Knoke, Benjamin F. Meyer, Susanne Suvanto, and Anja Rammig

stantin.gregor@tum.de please reach out :)

Factorial simulation experiment

Table 1 The considered values of the various factors used in this study. All possible combinations were simulated, leading to $2 \times 2 \times 2 \times 3 \times 2 \times 2 \times 2 \times 5 = 960$ simulations.

Factor	Values
Climate / Disturbances	RCP2.6, RCP8.5
Forest age	young, mature
Forest type	BD, NE
Harvest intensity	50%, 100%, 150%
Salvage logging	yes, no
Material wood usage	100%, 150%
Cascade usage	100%, 150%
Decarbonization by 2050	0%, 25%, 50%, 75%, 100%

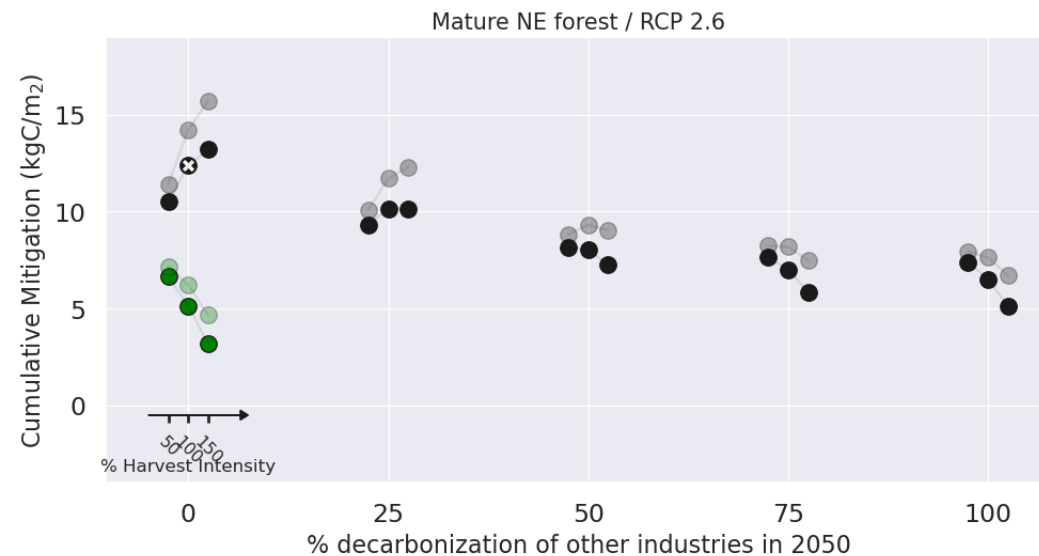
includes temperature-related disturbance increases

100% referring to currently observed values

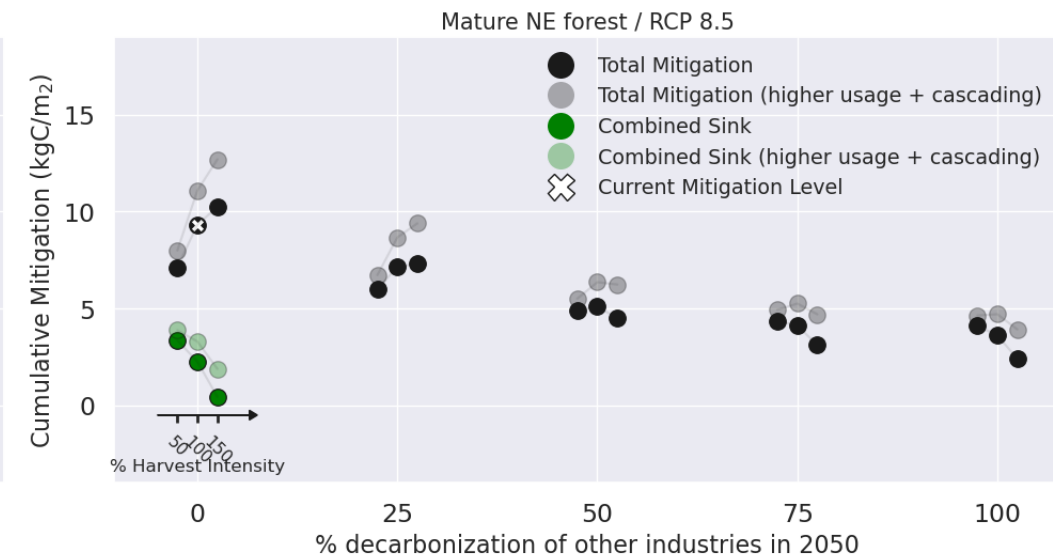
0%: current emission levels
100%: zero emissions

Impact of harvest and wood usage

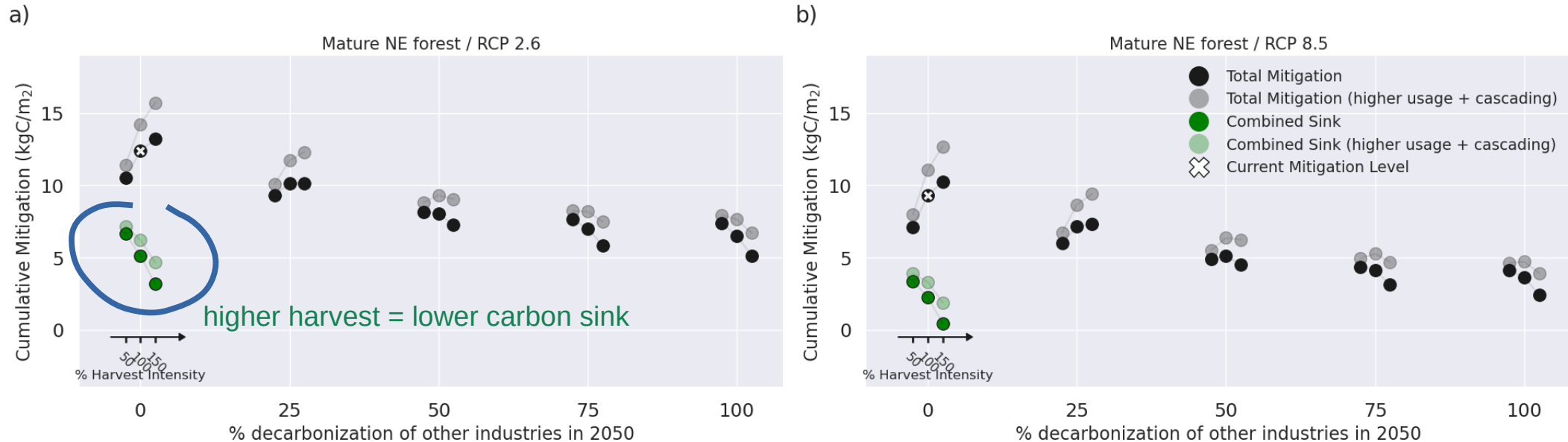
a)



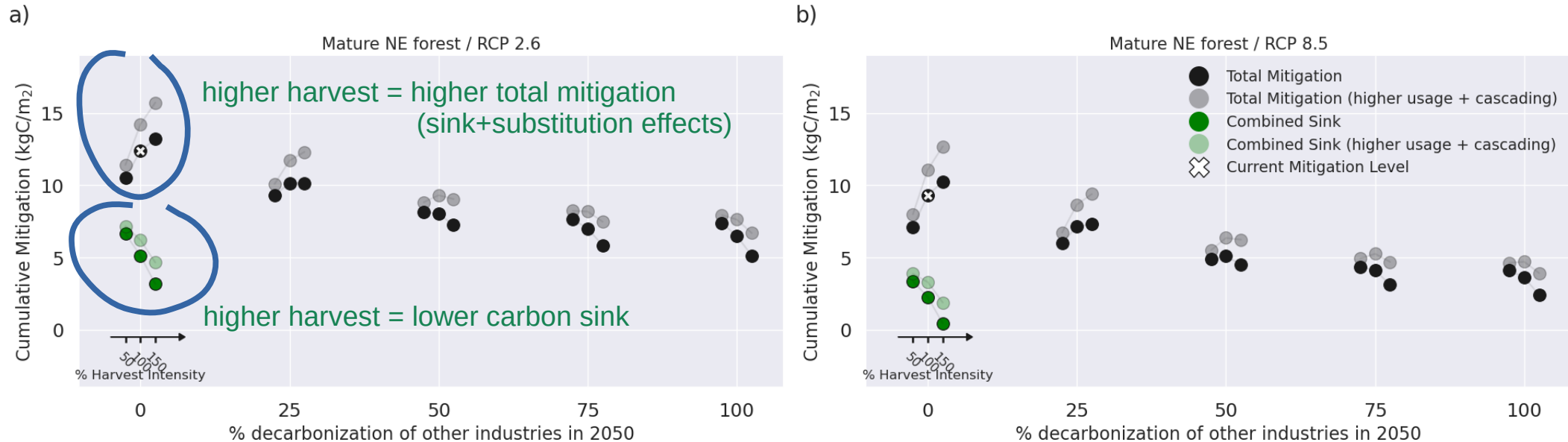
b)



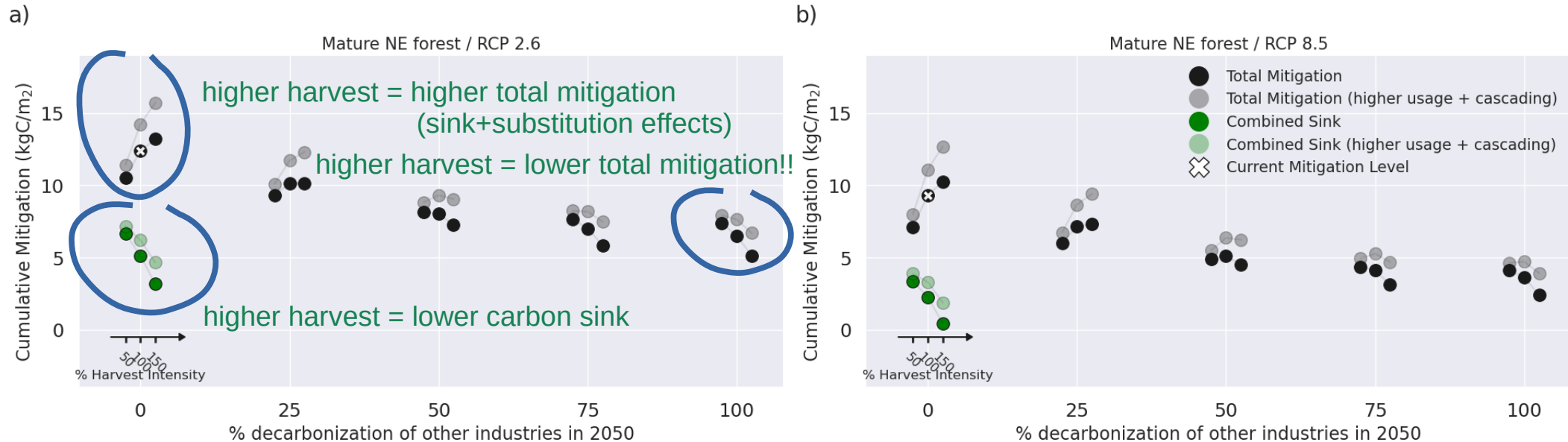
Impact of harvest and wood usage



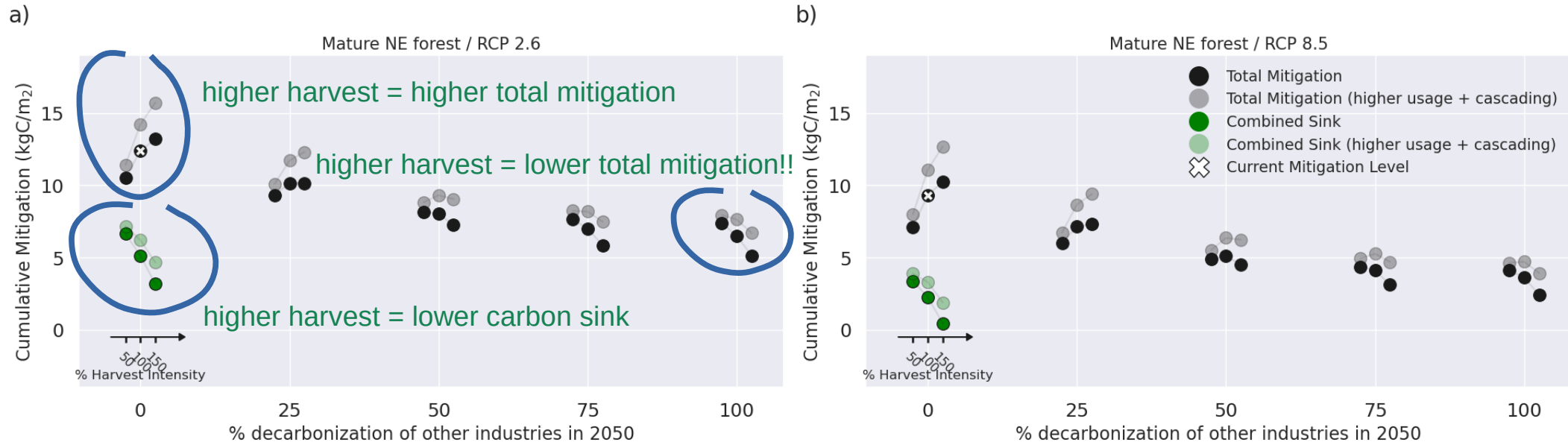
Impact of harvest and wood usage



Impact of harvest and wood usage



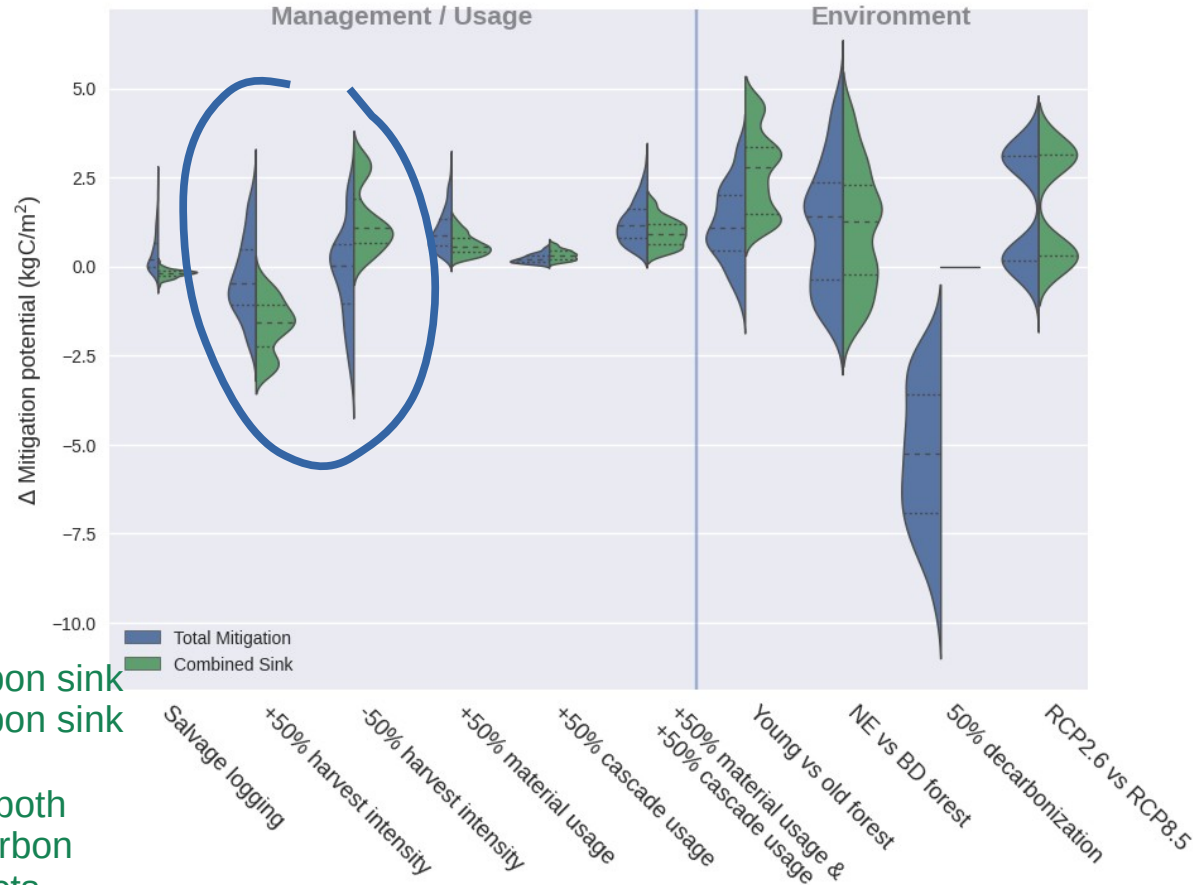
Impact of harvest and wood usage



Conclusion: higher harvest leads to lower sink. But whether it leads to higher mitigation depends on the substitution effects. When substitution effects are still high (other products are still very carbon-intensive), decreasing **sustainable** harvests probably has a negative impact for carbon mitigation, at least in the next decade

Here we show the change in mitigation potential when one driver is changed

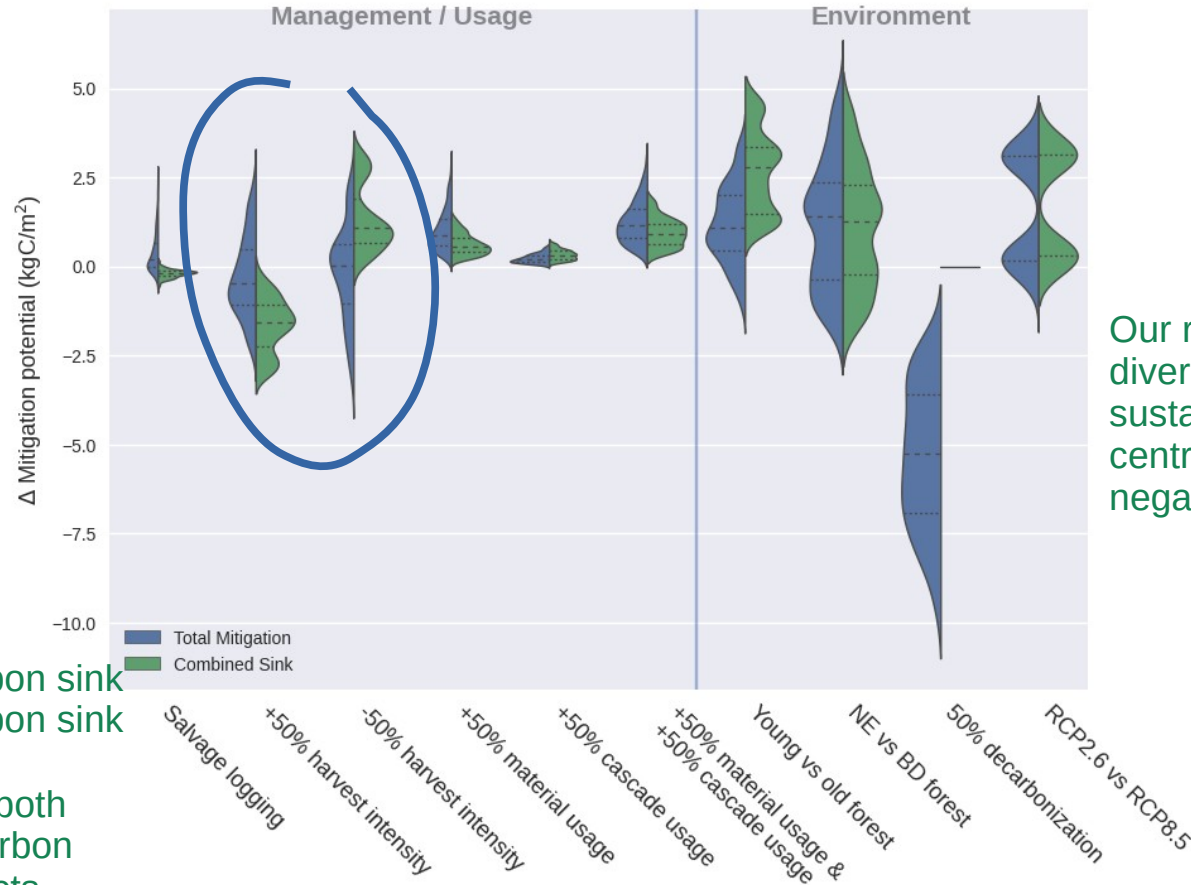




As shown before:

higher harvest = lower carbon sink
 lower harvest = higher carbon sink

But total mitigation can go both ways! It depends on the carbon intensity of replaced products



Our results indicate that diverging from currently sustainable harvest levels in central Europe will likely have negative effects on mitigation!

As shown before:

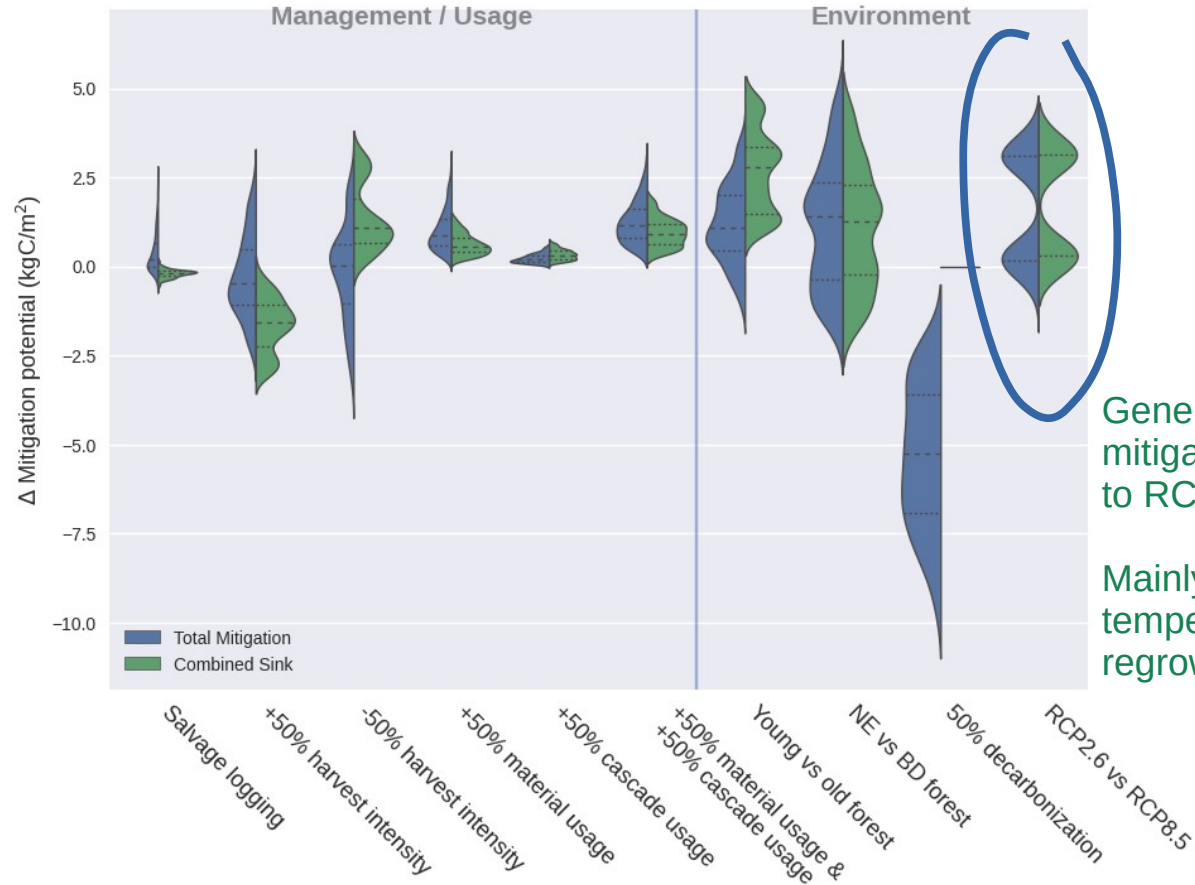
higher harvest = lower carbon sink
lower harvest = higher carbon sink

But total mitigation can go both ways! It depends on the carbon intensity of replaced products



Needle-leaved forests generally have a higher mitigation impact!

Mainly because their wood is used more for long-lived products, not because of stronger growth (in terms of kgC/ha)



Generally lower potential for mitigation in RCP8.5 compared to RCP2.6.

Mainly because of high temperatures impairing forest regrowth, and disturbances

Findings

- Much lower potential for mitigation in higher RCPs
- Much higher C sink in young forests
 - Somewhat offset when including substitution effects
- Higher mitigation for needle-leaved forests
- Time aspect: substitution is important in next few decades
- No clear benefit of both decreasing and increasing harvests
 - Considering both carbon sink and substitution effects
- Salvage logging plays minor role for carbon mitigation

Forests are more than carbon!

- Forests offer **numerous other ecosystem services**
- It is crucial to consider all ecosystem services!
- Please refer to our recent paper

<https://doi.org/10.1029/2022EF002796>



Earth's Future

RESEARCH ARTICLE

10.1029/2022EF002796

Key Points:

- Strategies for climate-smart forestry under a range of climate scenarios always lead to trade-offs between different ecosystem services (ESs)
- Higher shares of unmanaged and broad-leaved forests are beneficial for numerous ESs, but lead to decreased timber provision

Trade-Offs for Climate-Smart Forestry in Europe Under Uncertain Future Climate

Konstantin Gregor¹ , Thomas Knoke¹, Andreas Krause¹ , Christopher P. O. Reyer² , Mats Lindeskog³, Phillip Papastefanou^{1,3} , Benjamin Smith^{3,4}, Anne-Sofie Lansø^{5,6}, and Anja Rammig¹ 

¹TUM School of Life Sciences, Technical University of Munich, Freising, Germany, ²Potsdam Institute for Climate Impact Research, Member of the Leibniz Association, Potsdam, Germany, ³Department of Physical Geography and Ecosystem Science, Lund University, Lund, Sweden, ⁴Hawkesbury Institute for the Environment, Western Sydney University, Penrith, NSW, Australia, ⁵Department of Environment and Science, Aachen University, Aachen, Germany, ⁶Department of Science and Technology, Aachen University, Aachen, Germany



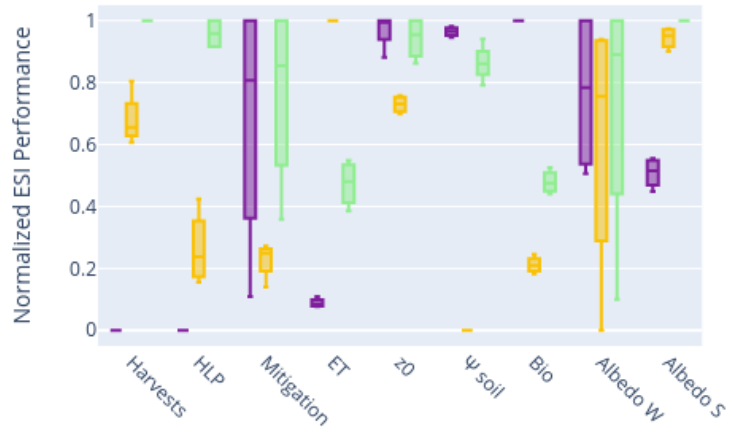
Managing forests for mitigation and other ecosystem services

- Idea: create management portfolios that
 1. offer multiple ecosystem services
 2. regardless of the climate scenario
- How to do that?
 - Robust multi-criteria optimization

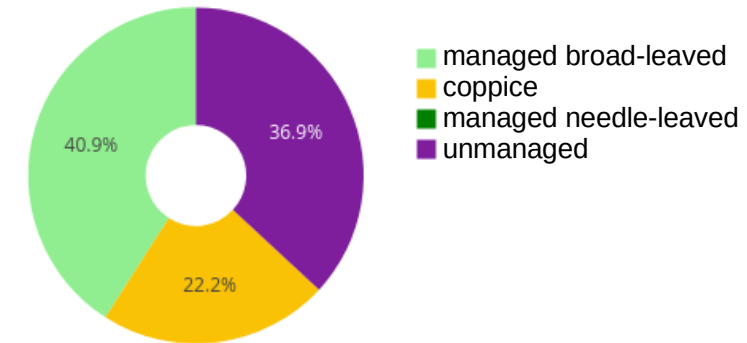
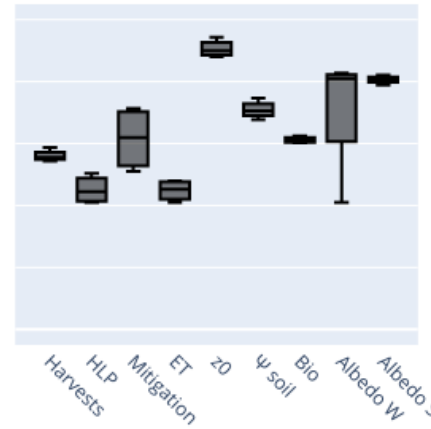
Example

Southern Sweden (13.75, 55.75)

a) ESI Performance 2100-2130 (indiv. management)

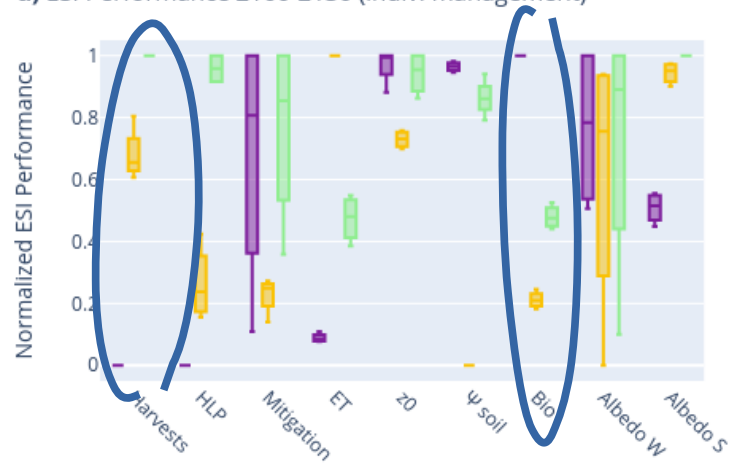


b) ESI Performance 2100-2130 (optimized portfolio) c) Optimized Portfolio Shares

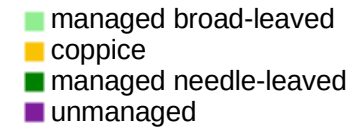
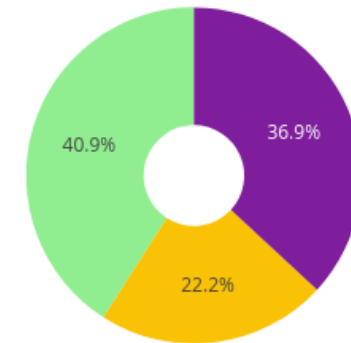
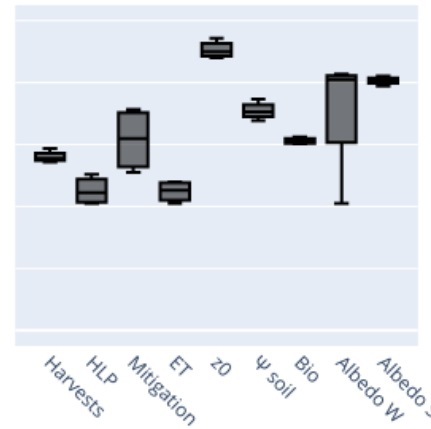


Southern Sweden (13.75, 55.75)

a) ESI Performance 2100-2130 (Indiv. management)



b) ESI Performance 2100-2130 (optimized portfolio) c) Optimized Portfolio Shares

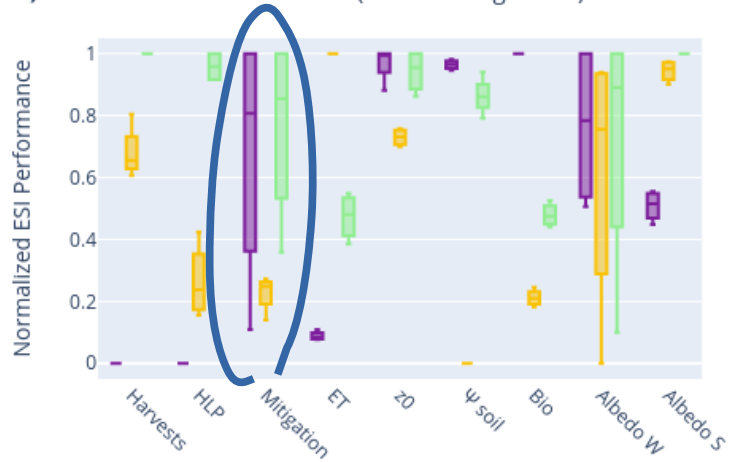


Some management forms are **good for some ecosystem services, but bad for others**

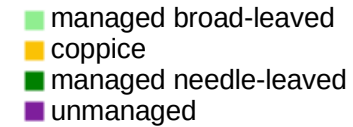
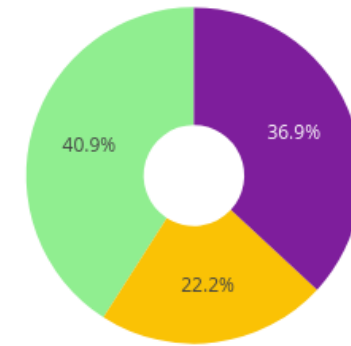
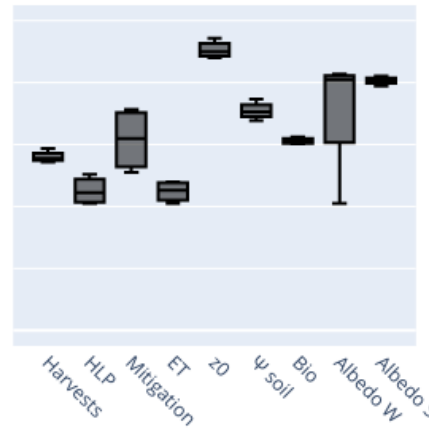
Example: unmanaged forest: good for biodiversity, bad for harvests

Southern Sweden (13.75, 55.75)

a) ESI Performance 2100-2130 (indiv. management)



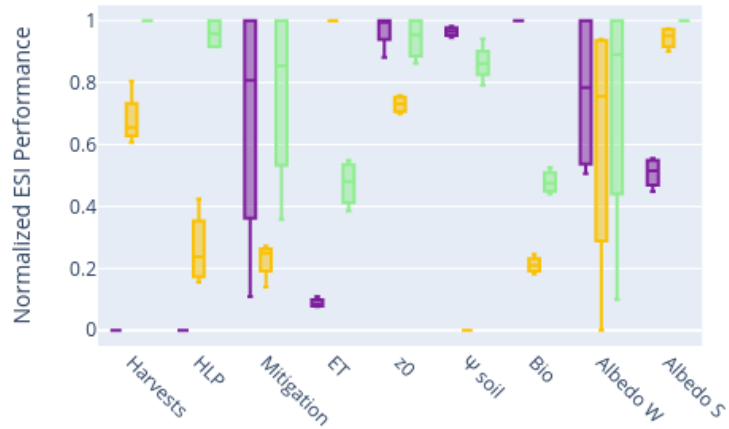
b) ESI Performance 2100-2130 (optimized portfolio) c) Optimized Portfolio Shares



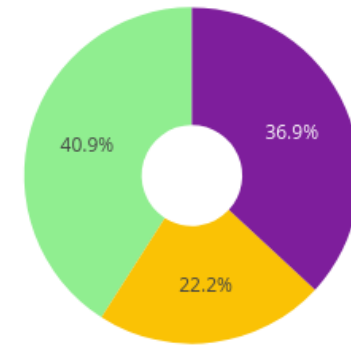
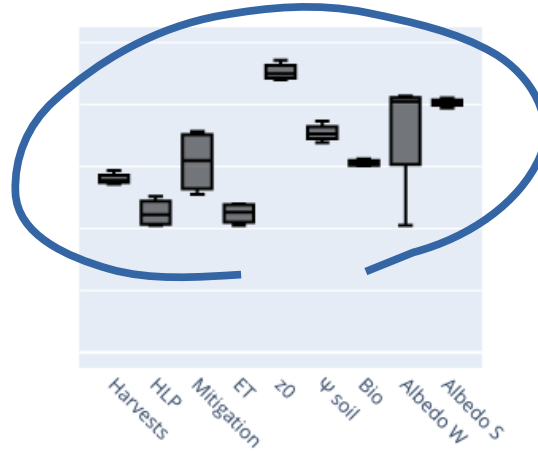
The spread shows: **a management form might be both good or bad for an ecosystem service, depending on the RCP!**
 Example: unmanaged forests: low mitigation in high-emissions scenario (no wood products), high mitigation in low emissions scenario (forest carbon sink is more important)

Southern Sweden (13.75, 55.75)

a) ESI Performance 2100-2130 (Indiv. management)



b) ESI Performance 2100-2130 (optimized portfolio) c) Optimized Portfolio Shares



■ managed broad-leaved
■ coppice
■ managed needle-leaved
■ unmanaged



Our methodology creates management portfolios, that provide **all ecosystem services under all RCPs**

What does that mean for European forests?
Find out here:

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