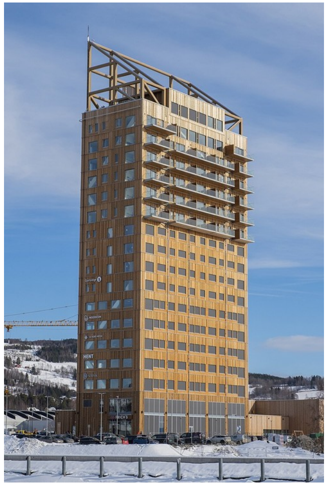
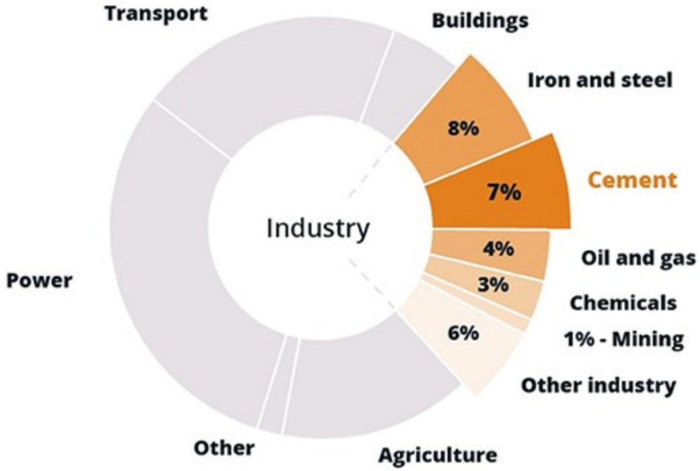
Strategies for climate-smart forestry in European forests under uncertain future climate

Carbon Mitigation Potential of Forests





- Mitigation = Forest sink + Product sink + Substitution effects

  Europe: 315 + 40 + 410 $MtCO_{2e}$ / yr

Grassi et al. (2021)

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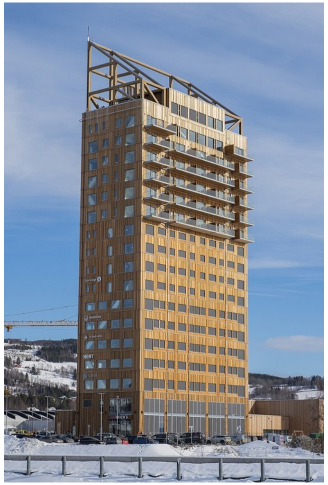

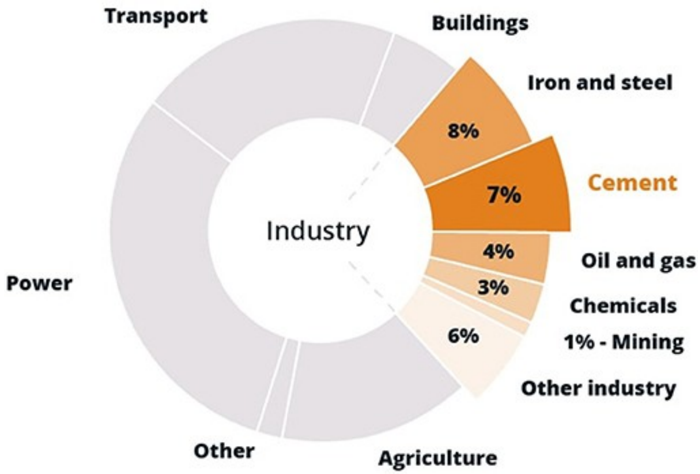

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  Europe: 315 + 40 + 410 $MtCO_{2e}$ / yr

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

Grassi et al. (2021)

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: 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%

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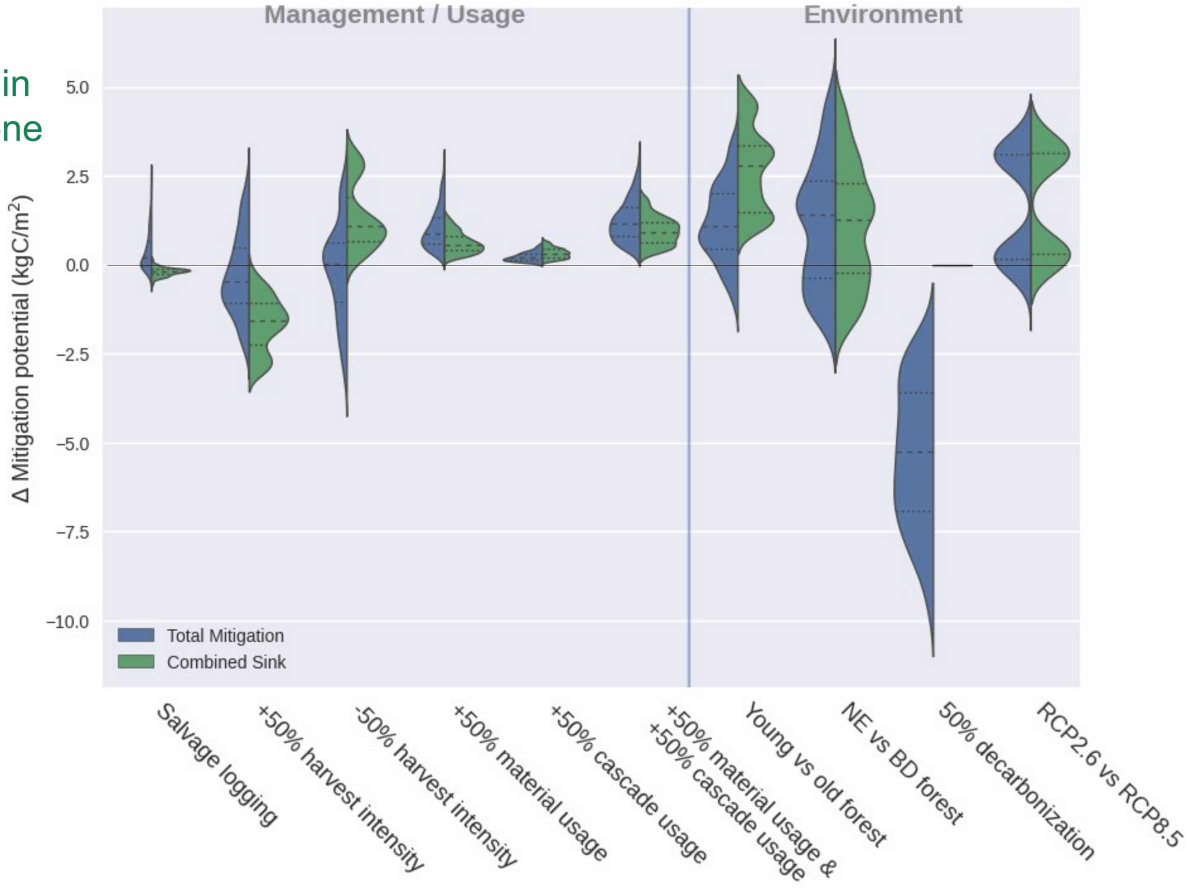
includes temperature-related disturbance increases

100% referring to currently observed values

See Suvanto et al. (in prep.)

0%: current emission levels
100%: zero emissions

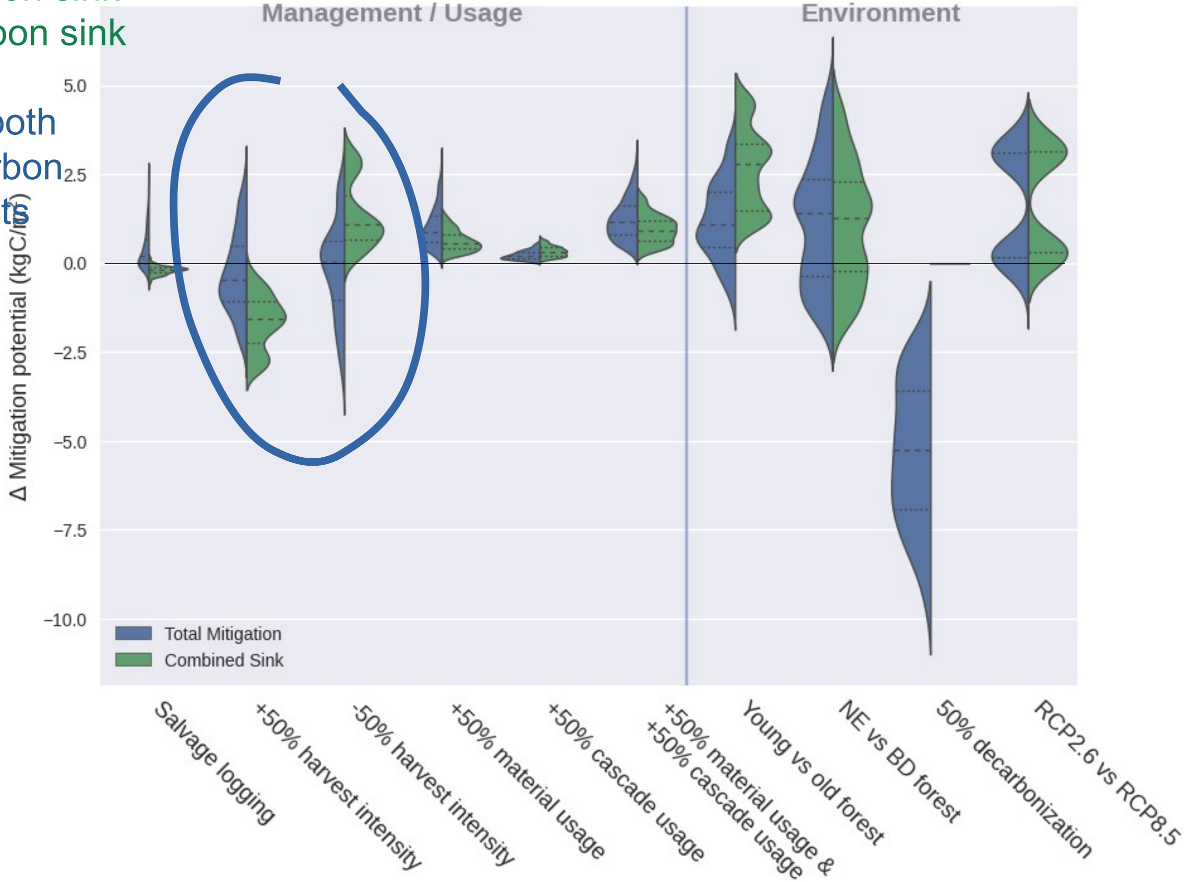
Here we show the change in mitigation potential when one driver is changed



Gregor et al. (in review)

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



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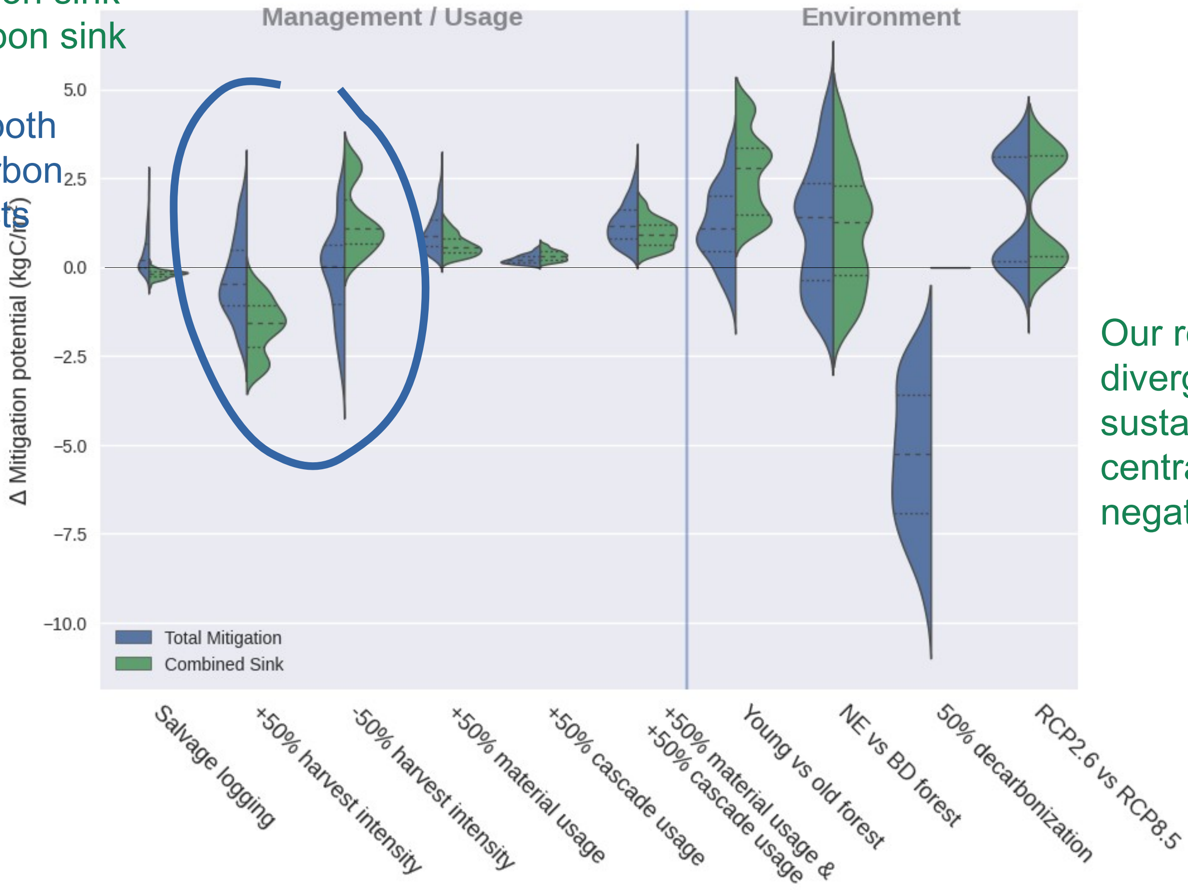

Our results indicate that diverging from currently sustainable harvest levels in central Europe will likely have negative effects on mitigation!

Gregor et al. (in review)

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)

This however changes with assumptions about future disturbance rates!

Gregor et al. (in review)

Increase of material wood usage instead of fuel wood has a clear benefit!

Gregor et al. (in review)

Forests are more than carbon!

- Forests offer **numerous other ecosystem services**
- It is crucial to consider all ecosystem services!

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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
- The mitigation potential of forests strongly relies on substitution effects which depend on the carbon-intensity of the alternative products

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

Konstantin Gregor[1], Thomas Knoke[1], Andreas Krause[1], Christopher P. O. Reyer[2], Mats Lindeskog[3], Phillip Papastefanou[1,3], Benjamin Smith[3,4], Anne-Sofie Lansø[5,6], and Anja Rammig[1]

[1]TUM School of Life Sciences, Technical University of Munich, Freising, Germany, [2]Potsdam Institute for Climate Impact Research, Member of the Leibniz Association, Potsdam, Germany, [3]Department of Physical Geography and Ecosystem Science, Lund University, Lund, Sweden, [4]Hawkesbury Institute for the Environment, Western Sydney University, Penrith, NSW, Australia, [5]Department of Environmental Science, Aarhus University, Aarhus, Denmark, [6]Laboratoire des Sciences du Climat et de l'Environnement (LSCE/IPSL) CEA-CNRS-UVSQ, Université Paris-Saclay, Gif-sur-Yvette, France

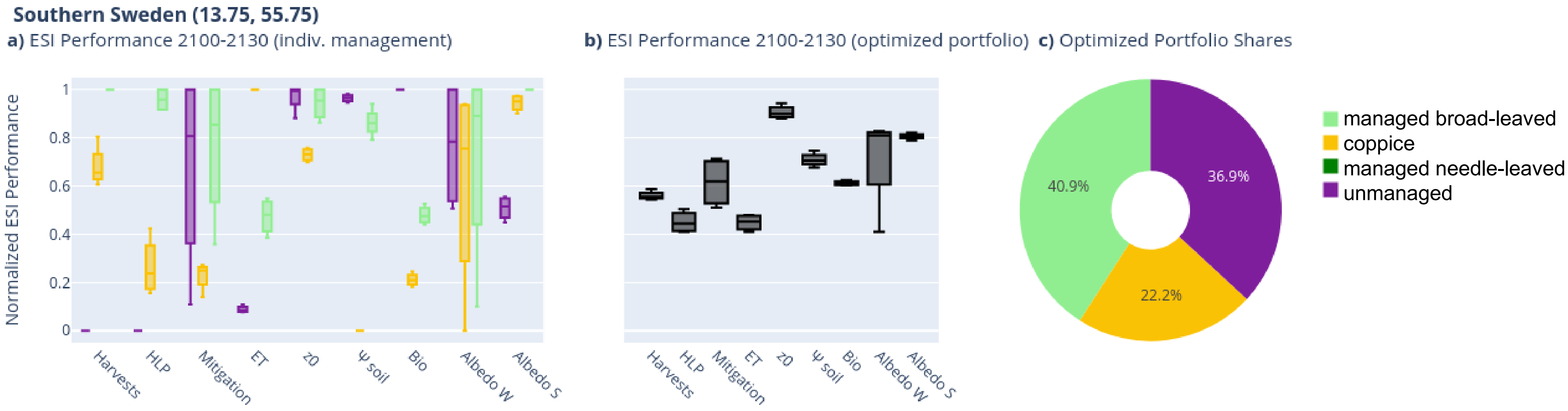
Abstract Forests mitigate climate change by storing carbon and reducing emissions via substitution effects of wood products. Additionally, they provide many other important ecosystem services (ESs), but are

TUM

Managing forests for mitigation **and** other ecosystem services

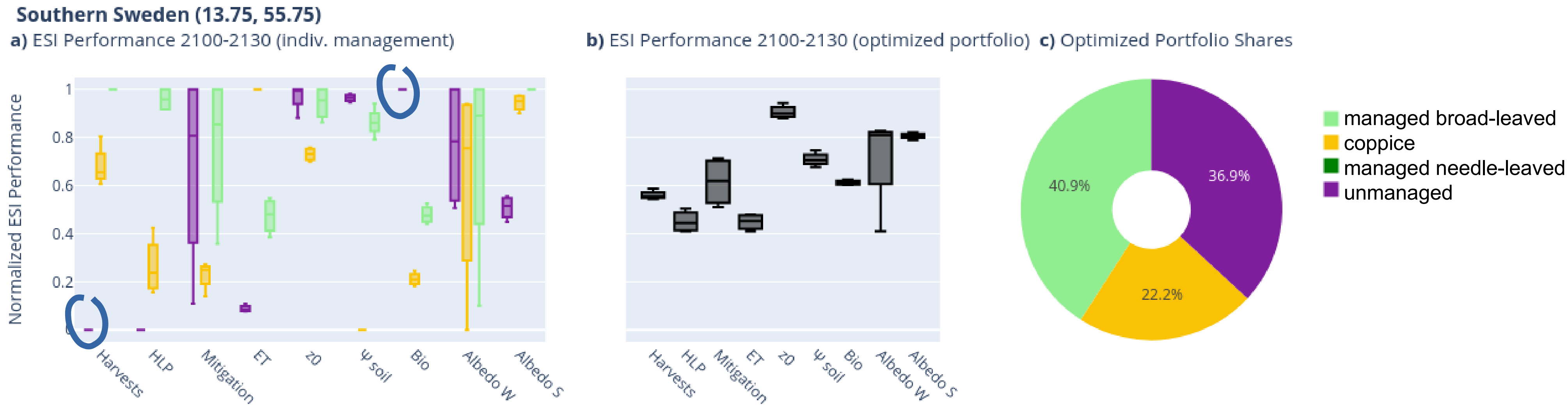
- Idea: create management portfolios that
- 1. offer multiple ecosystem services
  2. regardless of the climate scenario
- How to do that?
- → **Robust multi-criteria optimization**

Robust Multi-Criteria Optimization



Gregor et al. (2022)

Robust Multi-Criteria Optimization

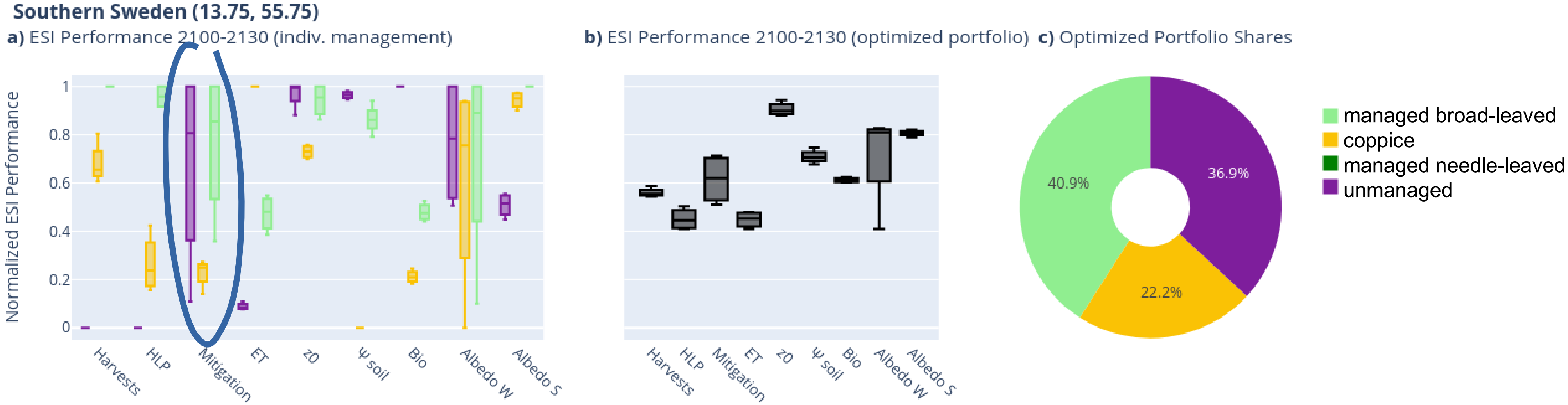


Some management forms are **good for some ecosystem services, but bad for others**

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

Gregor et al. (2022)

Robust Multi-Criteria Optimization

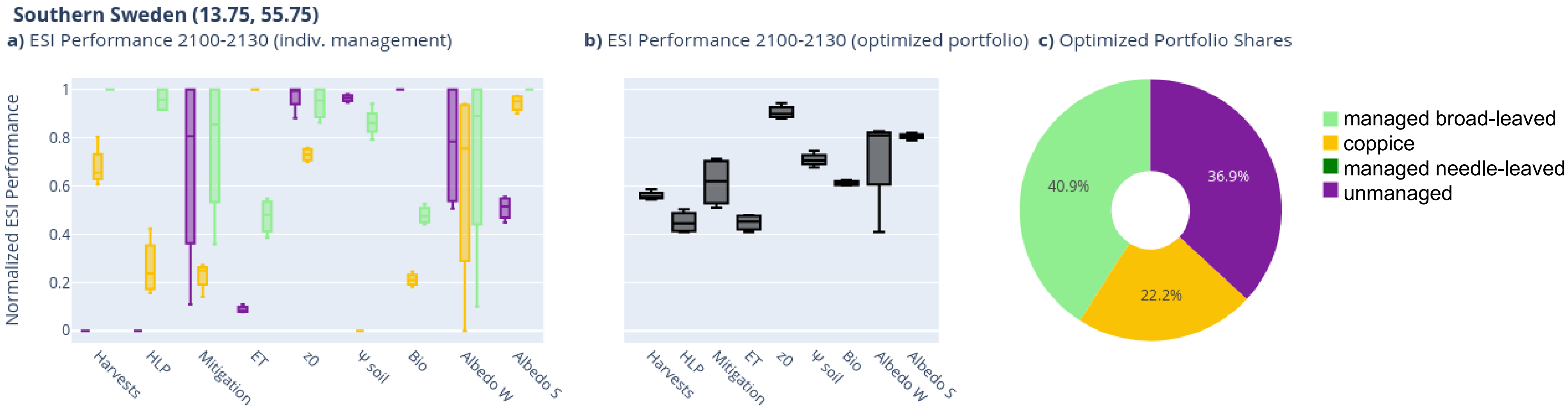


The spread shows: **a management form might be both good or bad for an ecosystem service, depending on the RCP!**

Example: unmanaged forests: low mitigation in high-emissions scenario (no wood products),
high mitigation in low emissions scenario (forest carbon sink is more important)

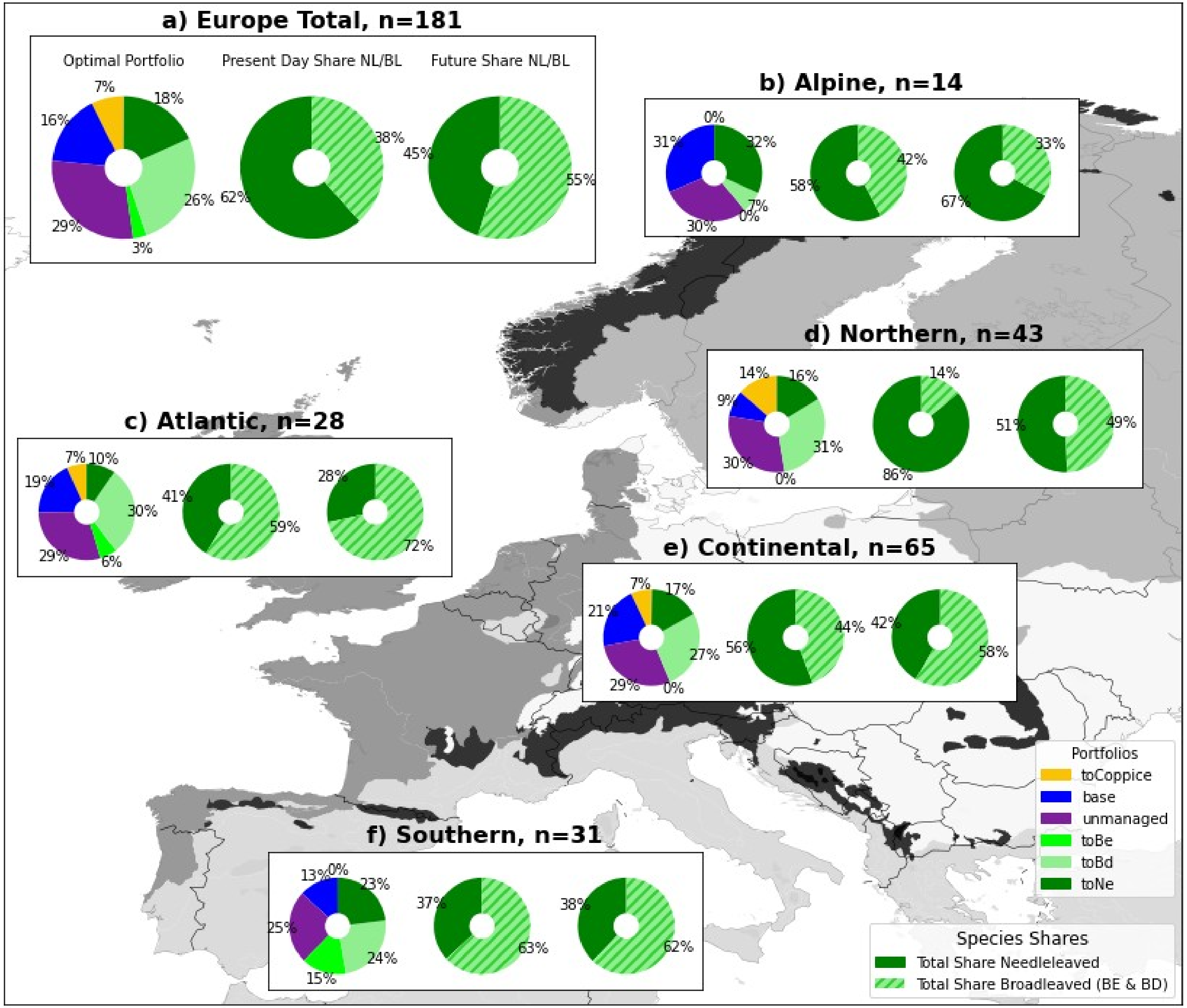
Gregor et al. (2022)

Robust Multi-Criteria Optimization



Our methodology creates management portfolios,
that provide best possible balance of **all ecosystem services under all RCPs**

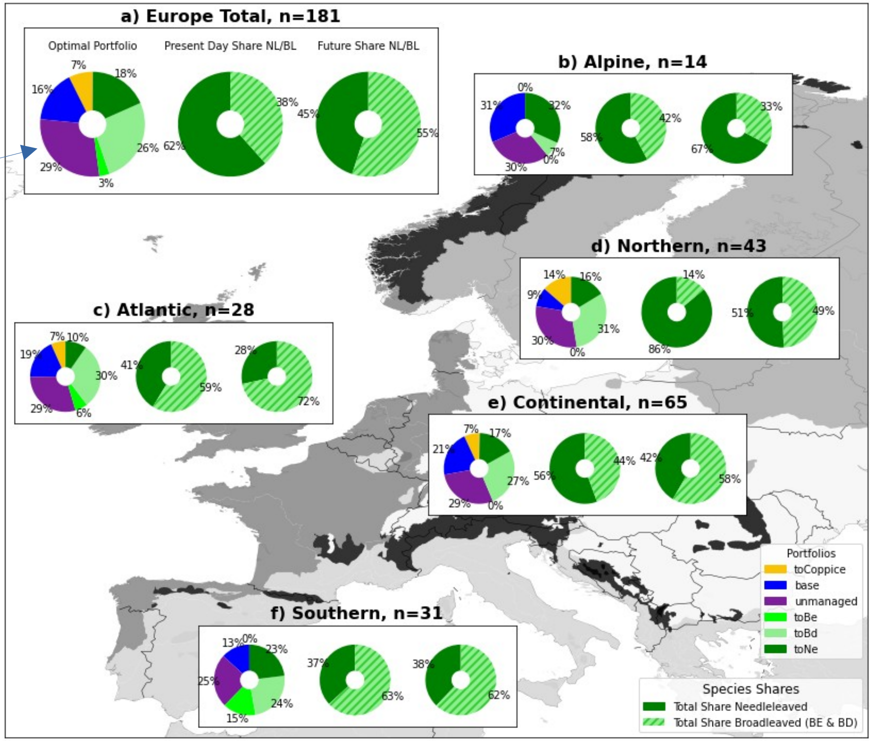
Gregor et al. (2022)



Gregor et al.
(2022)

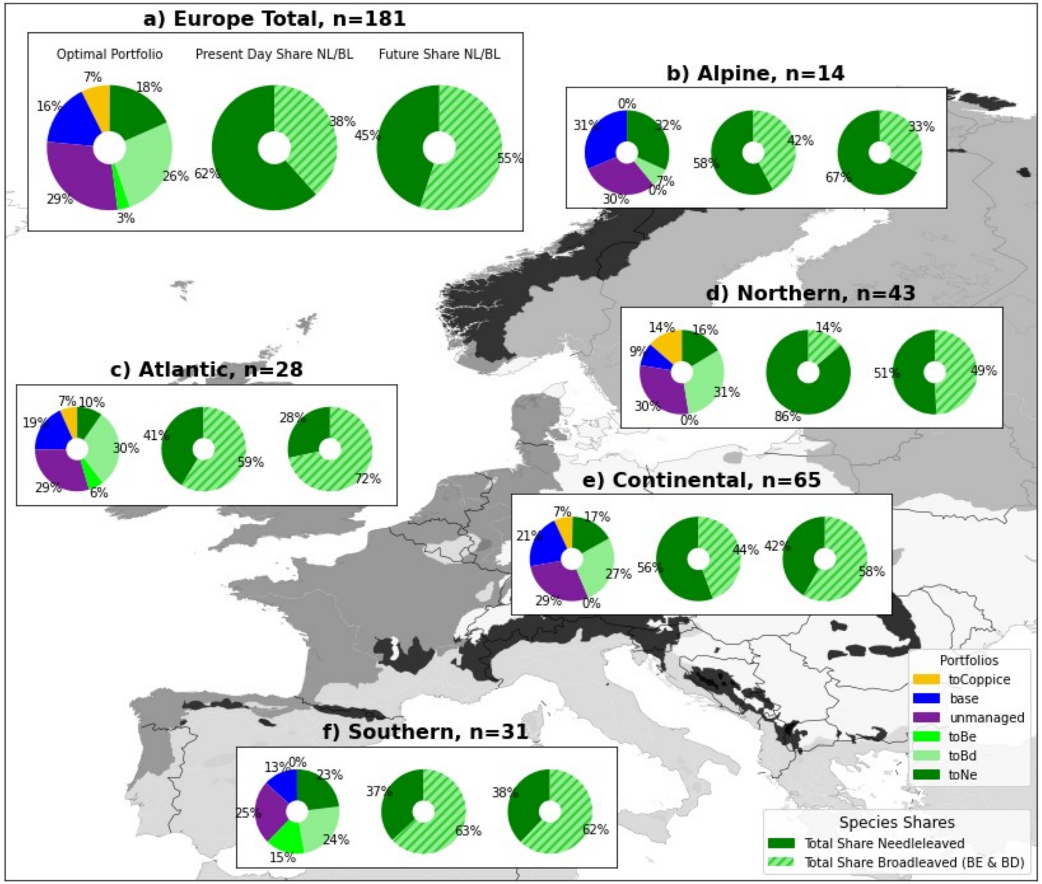
Obvious question: How can we reconcile this large fraction of unmanaged forests with the idea that material wood usage is beneficial for climate change mitigation?

→ allow pan-European constraints on harvest levels



Gregor et al. (in prep.)

Keeping harvests at present day levels



Gregor et al. (in prep.)

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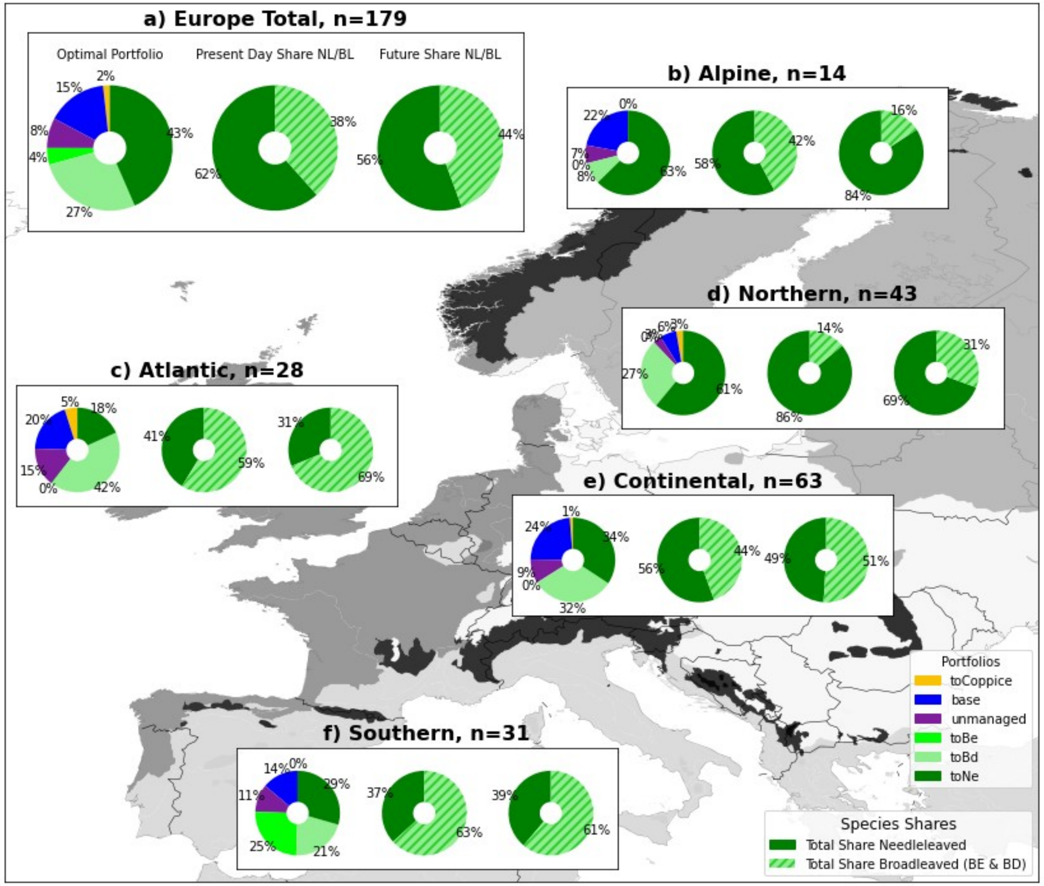
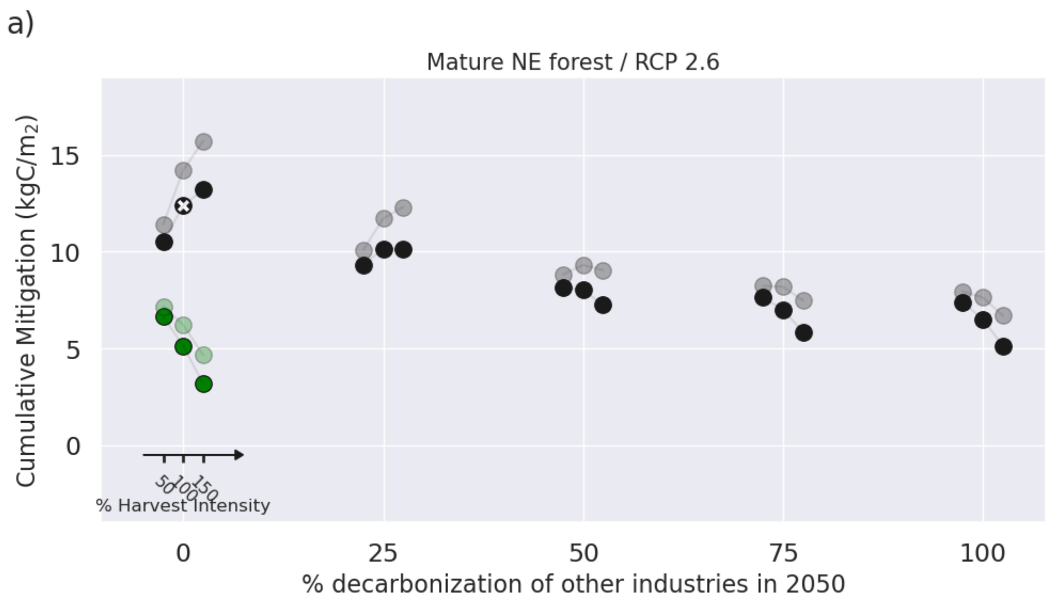


Gregor et al. (in prep.)

References

- Grassi, G., Fiorese, G., Pilli, R., Jonsson, K., Blujdea, V., Korosuo, A., & Vizzarri, M. (2021). Brief on the role of the forest-based bioeconomy in mitigating climate change through carbon storage and material substitution, 1–16.
- Gregor, K., Knoke, T., Krause, A., Reyer, C. P. O., Lindeskog, M., Papastefanou, P., Smith, B., Lansø, A.-S., & Rammig, A. (2022). Trade-Offs for Climate-Smart Forestry in Europe Under Uncertain Future Climate. Earth's Future, 10 (9), 1–25.
- Krause, A., Knoke, T., & Rammig, A. (2020). A regional assessment of land-based carbon mitigation potentials: Bioenergy, BECCS, reforesta- tion, and forest management. GCB Bioenergy, 12(5), 346–360. https://doi.org/10.1111/gcbb.12675
- Lindeskog, M., Smith, B., Lagergren, F., Sycheva, E., Ficko, A., Pretzsch, H., & Rammig, A. (2021). Accounting for forest management in the estimation of forest carbon balance using the dynamic vegetation model LPJ-GUESS (v4.0, r9710): implementation and evaluation of simulations for Europe. Geoscientific Model Development, 14 (10), 6071–6112.
- Smith, B., Wårlind, D., Arneth, A., Hickler, T., Leadley, P., Siltberg, J., & Zaehle, S. (2014). Implications of incorporating N cycling and N limitations on primary production in an individual-based dynamic vegetation model. Biogeosciences, 11 (7), 2027–2054.

Impact of harvest and wood usage



Gregor et al. (in review)

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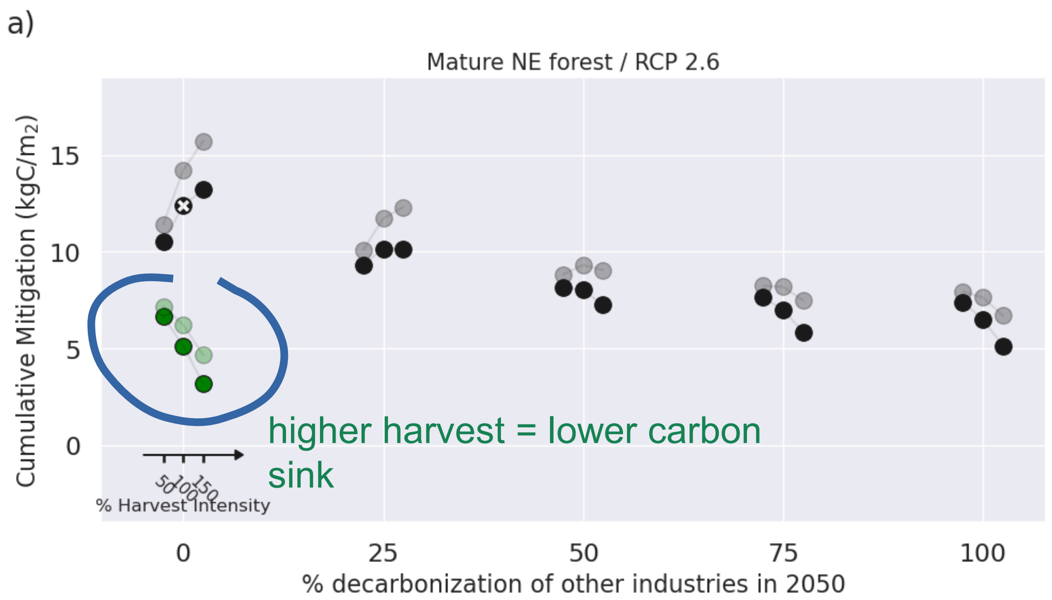

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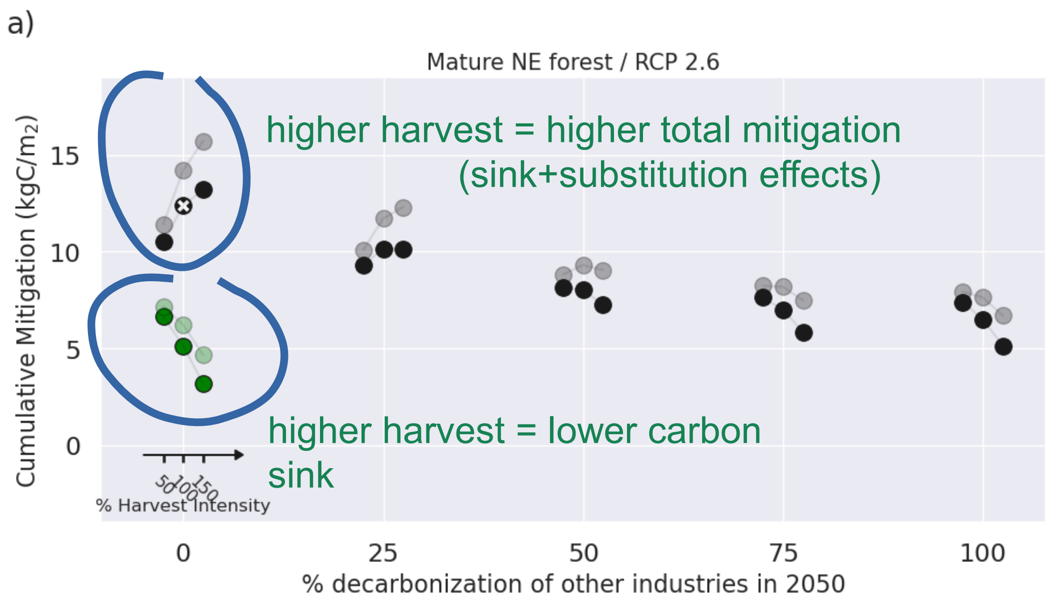

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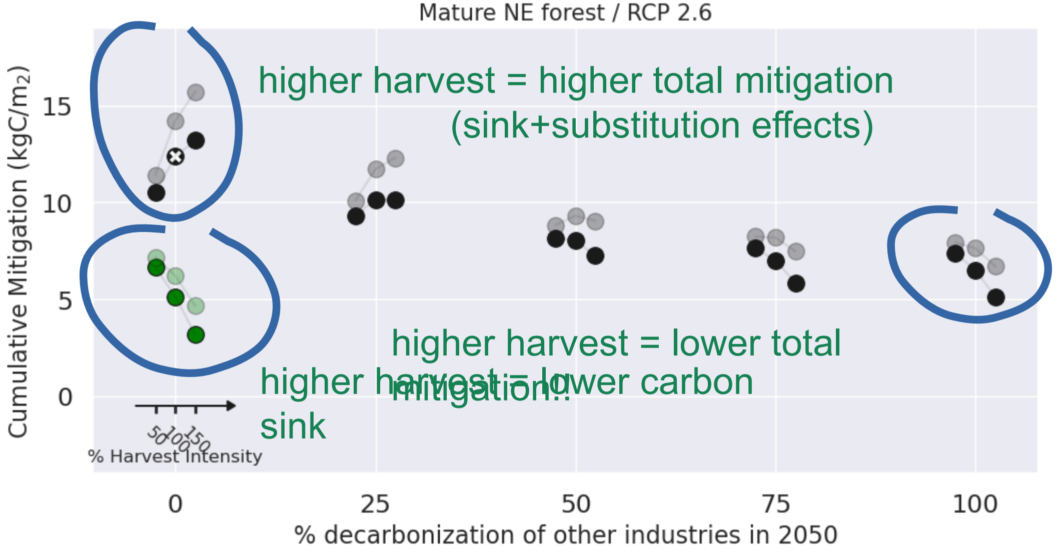
Impact of harvest and wood usage

a)



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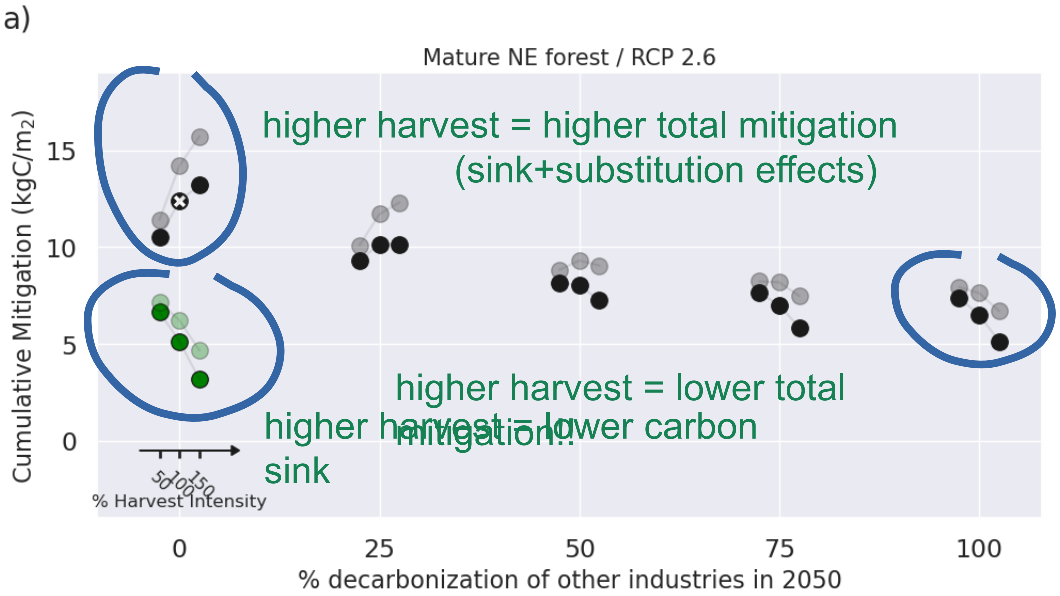
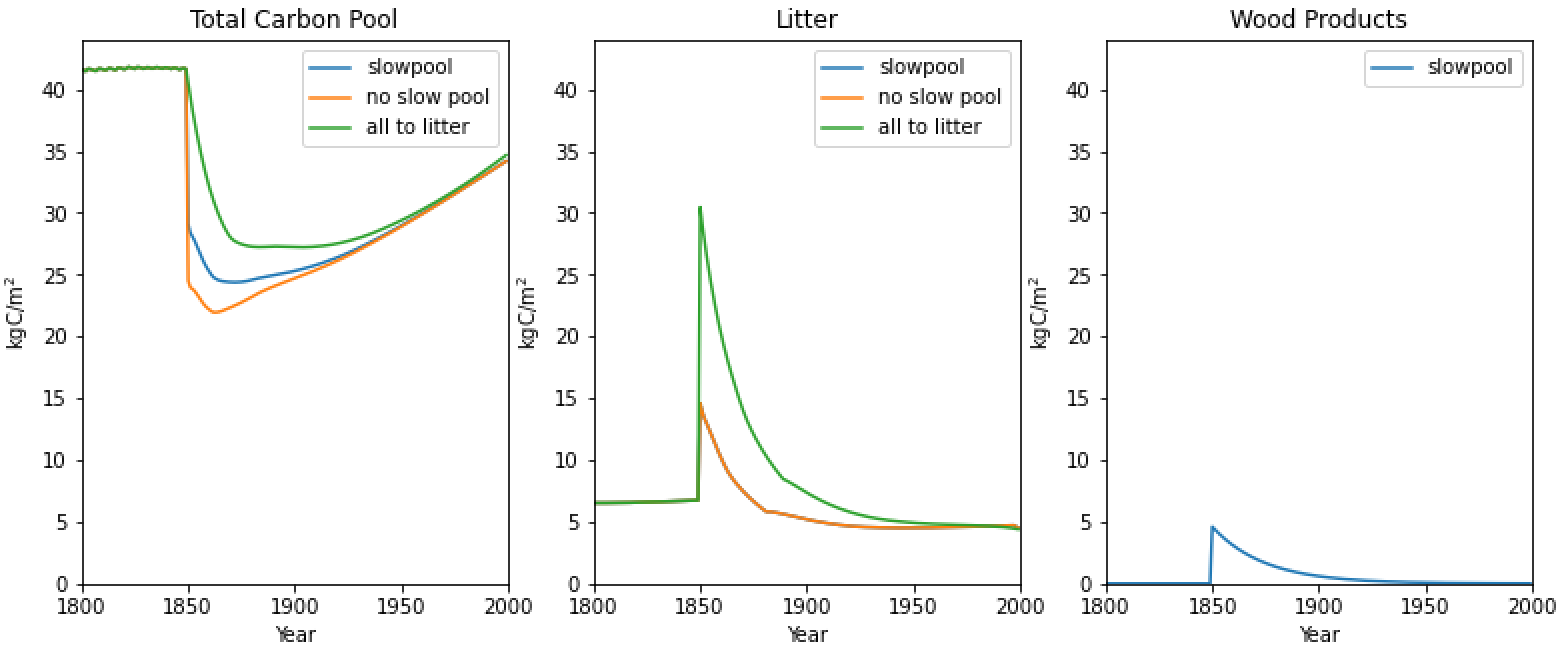


Conclusion: higher harvest leads to lower sink. But whether it leads to higher mitigation depends on the substitution effects. When substitution effects are still high (other products are still very carbon-intensive), decreasing **sustainable** harvests probably has a negative impact for carbon mitigation,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

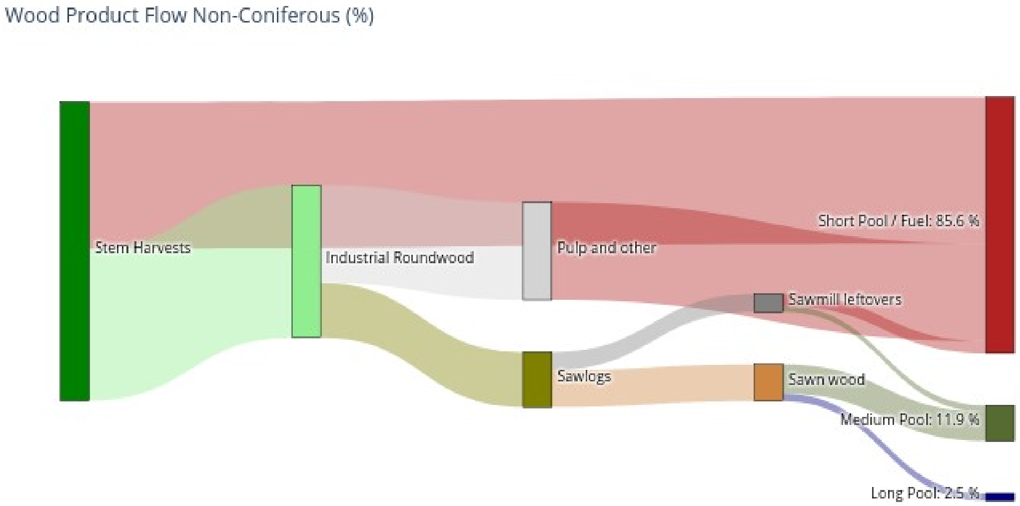
Gregor et al. (in review)

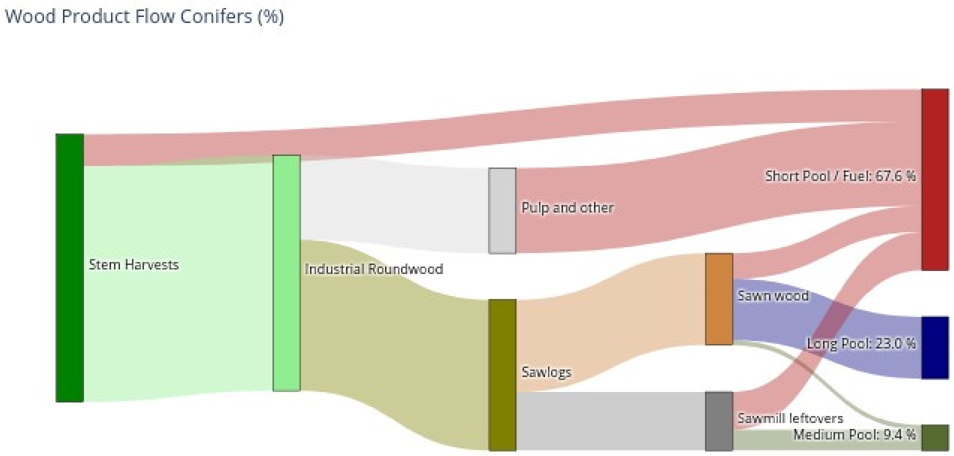
Default LPJ-GUESS wood usage / decay



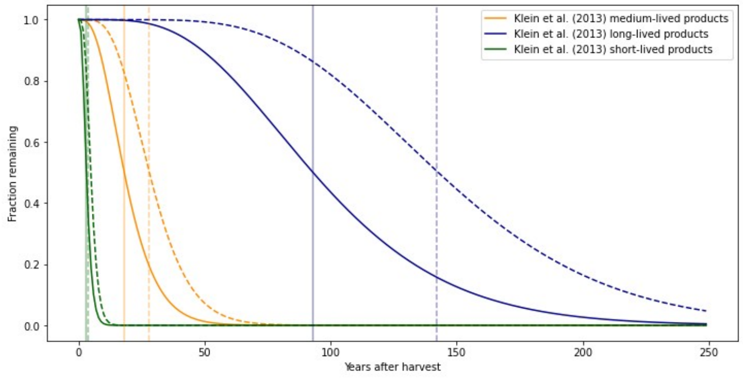
33% of stem harvests to product pool, 4% of the pool decays each year

Wood Usage in Europe





We implemented 3 product pools (short-, medium-, long-lived) and time-dependent decay rates ("Krausepools")



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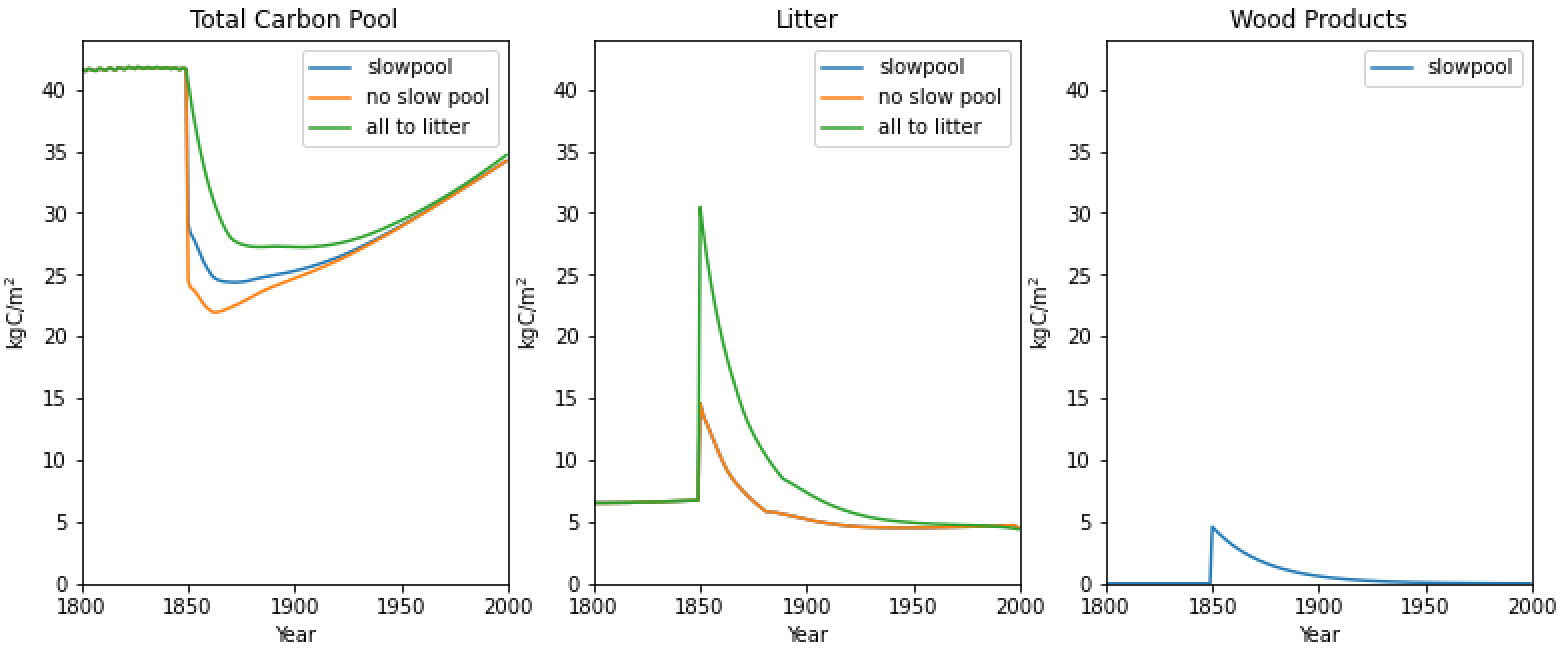

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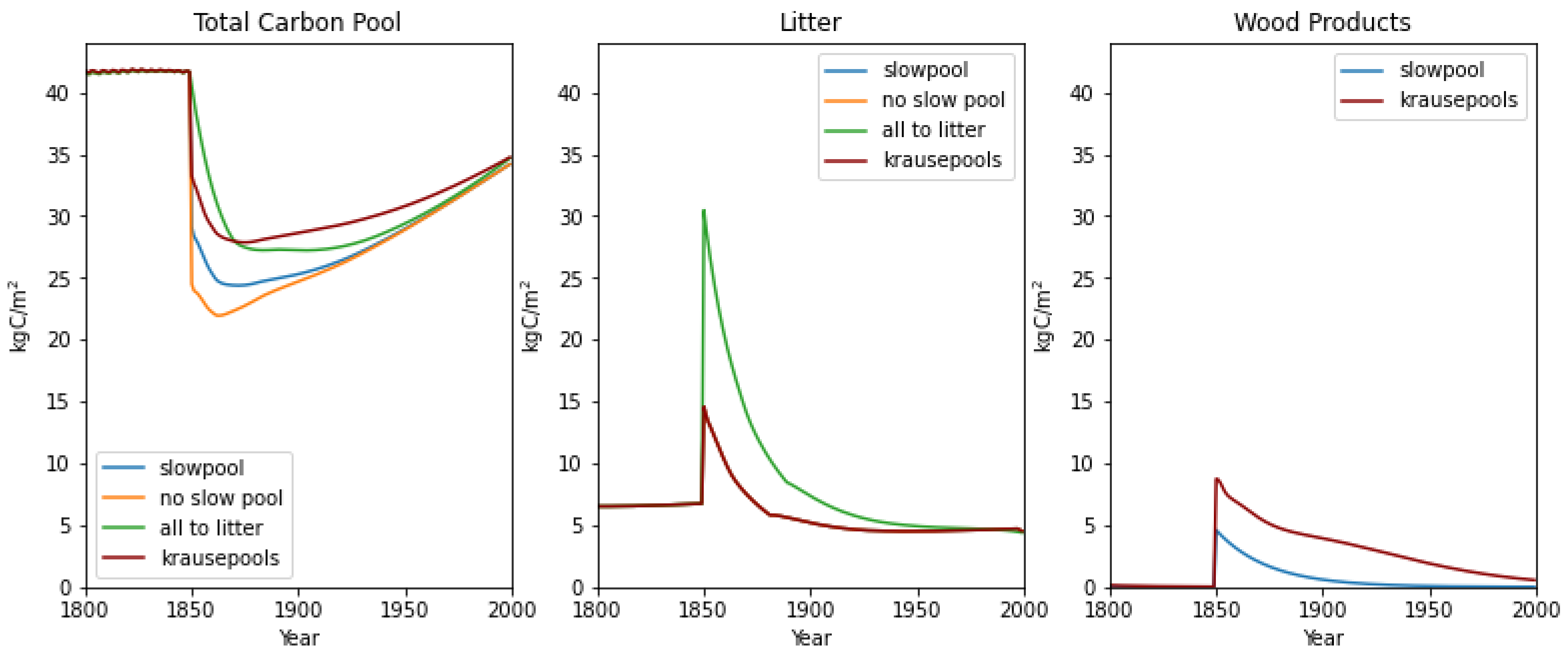
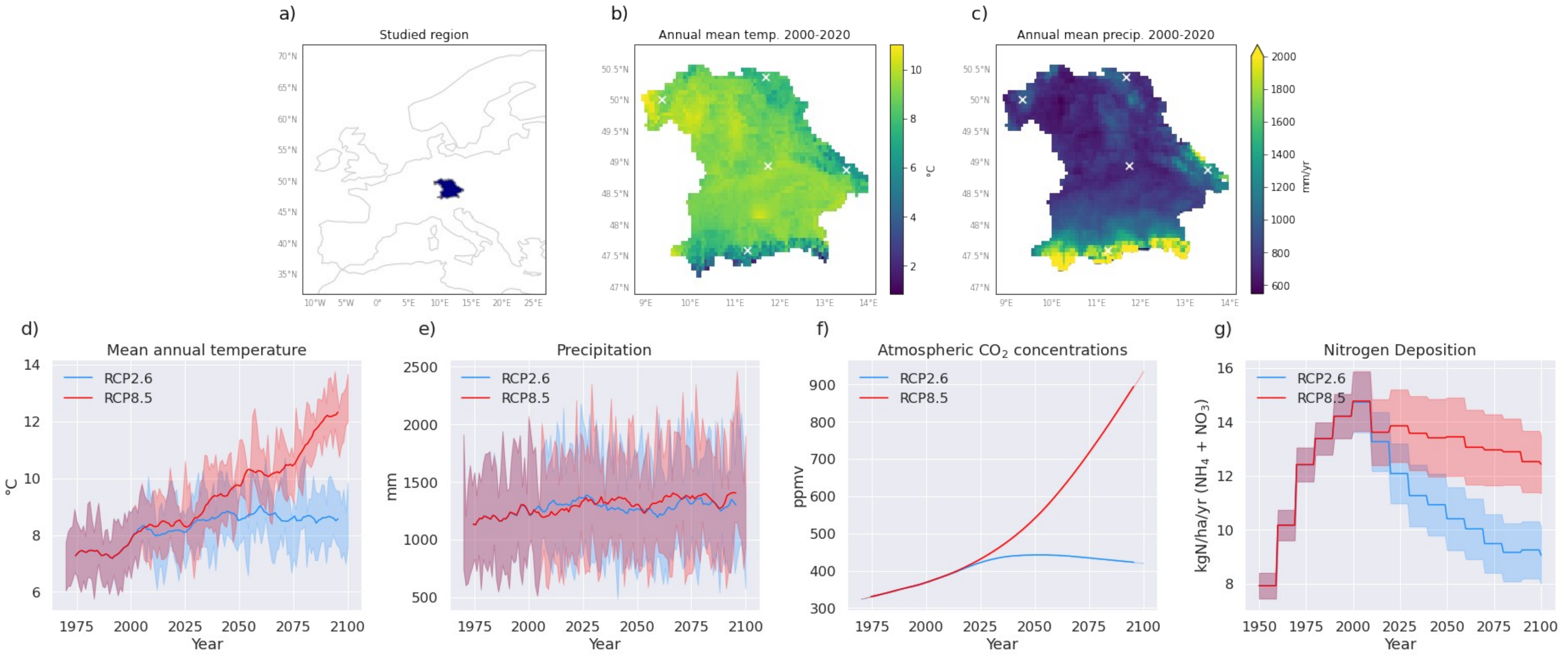
New LPJ-GUESS wood usage / decay



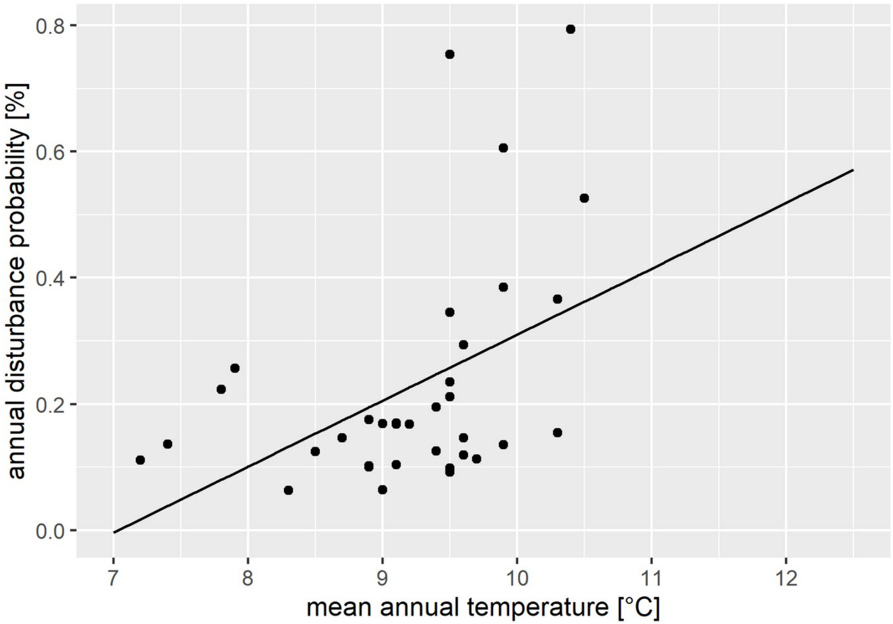
Krause et al. (2020), Gregor et al. (2022)

Study Region: Bavaria



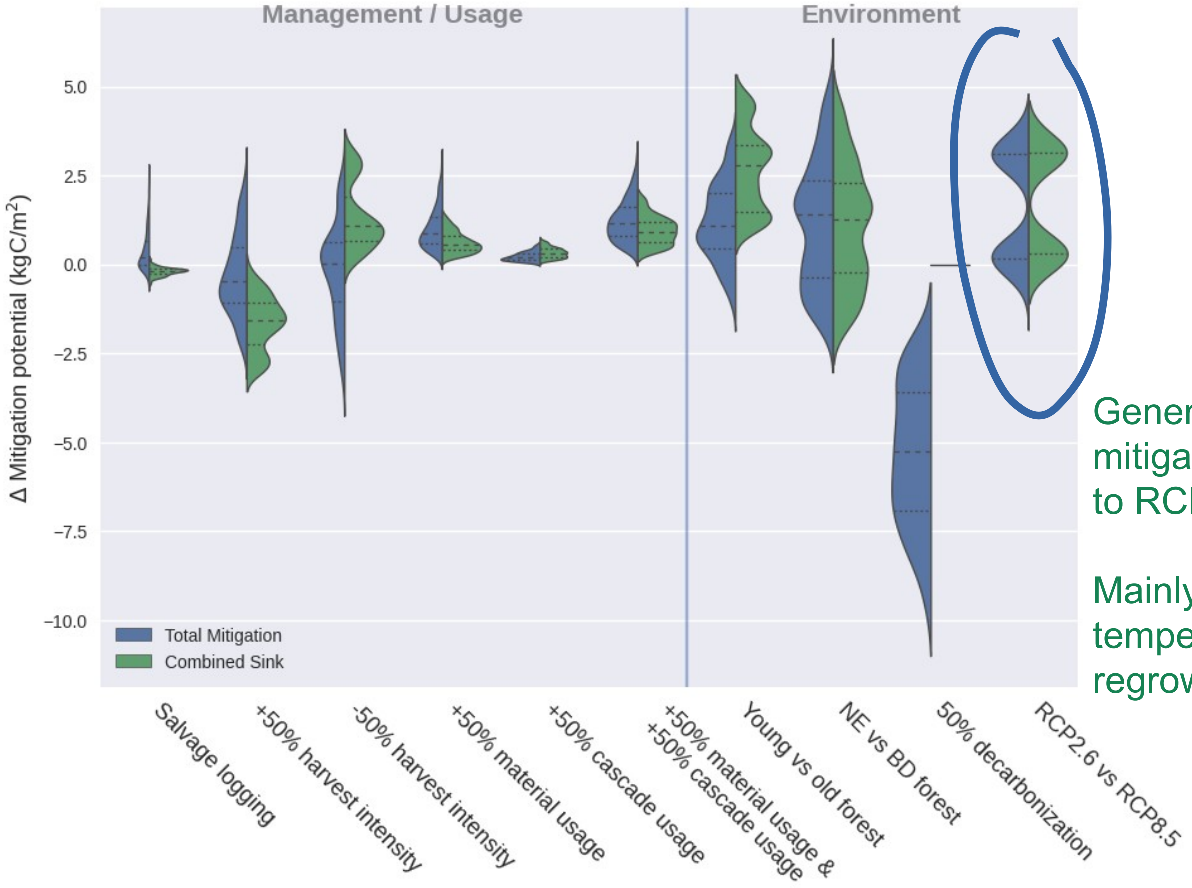
Konstantin Gregor - konstantin.gregor@tum.de - @konni_gregor

Disturbances



Temperature-dependent and species-dependent disturbance intervals

Senf & Seidl (2021), Pugh et al. (2019)



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

Mainly because of high temperatures impairing forest regrowth, and disturbances

Gregor et al. (in review)

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