Reconciling climate-smart forestry in Europe with constraints on forest protection and timber demand

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Background: numerous demands

- Timber provision
- Carbon sink
- Local climate regulation
- Water cycling
- Provision of habitat for biodiversity
- Non-wood products

Background: climate-smart forestry

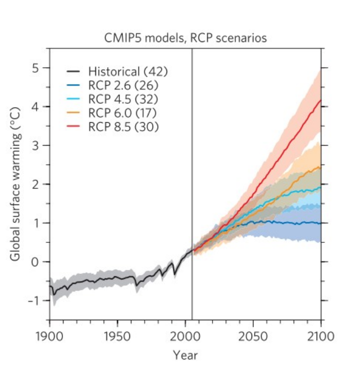
- Numerous definitions
- Mathys et al. (2021):

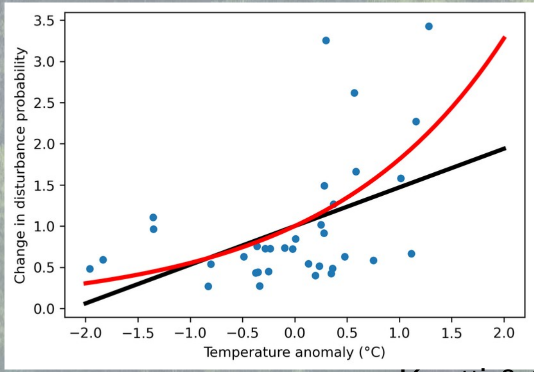
set by the pan-European indicators for sustainable forest management (SFM, Bowditch et al., 2020; Santopuoli et al., 2021). CSF is composed of three main pillars: 1) increasing the mitigation potential of forests, 2) adapting forests to climate change and 3) ensuring the sustainable provision of ES (Nabuurs et al., 2018).

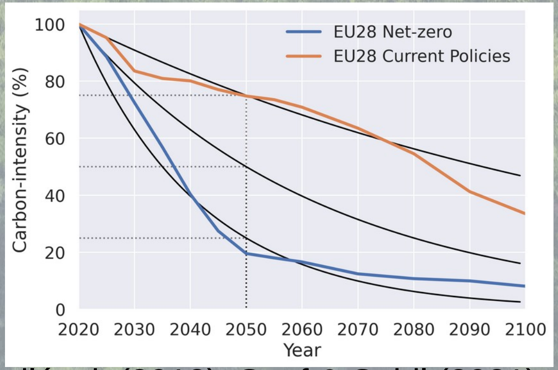
CSF is increasingly recognized as an effective forest management

Background: uncertainty

- Climate uncertainty
  - Affects forest growth/health
- Disturbance uncertainty
- Decarbonization uncertainty
  - Affects climate impact of wood products







Knutti & Sedlácek (2013), Senf & Seidl (2021), Schreyer et al. (2020)

Methods: Factorial simulation experiment to quantify the drivers of forest-based mitigation

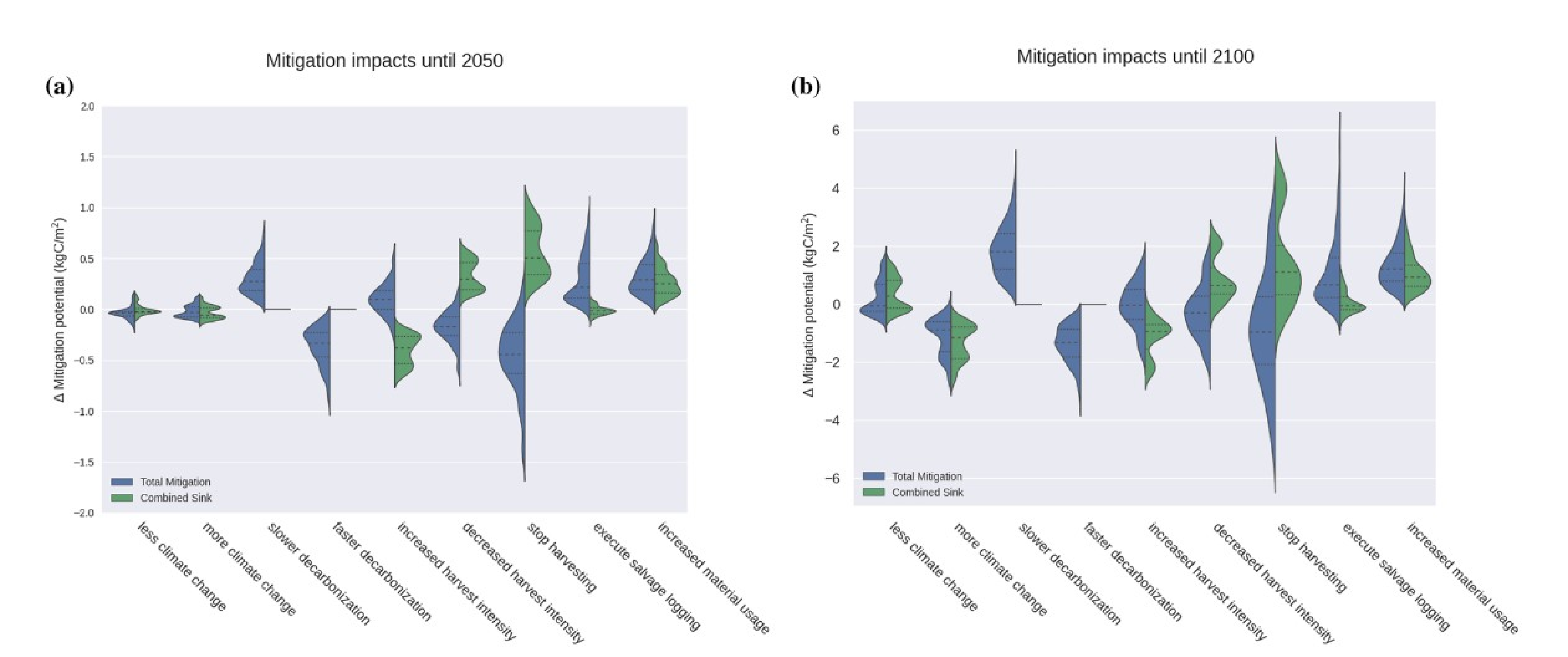
Table 1 The considered values of the factors used in this study

Factor	Values	Comment
Climate change and N deposition	RCP2.6, RCP4.5, RCP8.5	See Fig. 1
Disturbance probability change (*)	Constant, linear, exponential	Changes in disturbance frequency based on temperature anomaly (Additional file 1: Fig. S1)
Forest age	Mature, young	Planted between 1921 and 1940, or between 1981 and 2000, respectively (Additional file 1: Fig. S2)
Forest type	BD, NE	Broad-leaved deciduous, needle-leaved evergreen forests
Harvest intensity	0%, 50%, 100%, 150%	Direct change in harvest intensity starting after 2020 compared to current values
Salvage logging	Yes, no	After every disturbance after 2020
Material wood usage	100%, 150%	The increase to 150% was implemented as a linear change from 2020 until 2050 at the expense of short-lived products and firewood
Cascade usage	100%, 150%	The change to 150% was implemented as a direct change of the lifetime of products created after 2020
Decarbonization in 2050	25%, 50%, 75%	Exponential decrease based on [44], reaching the given percentage value in 2050 (Additional file 1: Fig. S5)

All possible combinations were simulated, leading to $3 \times 3 \times 2 \times 2 \times 4 \times 2 \times 2 \times 2 \times 3 = 3456$ simulations

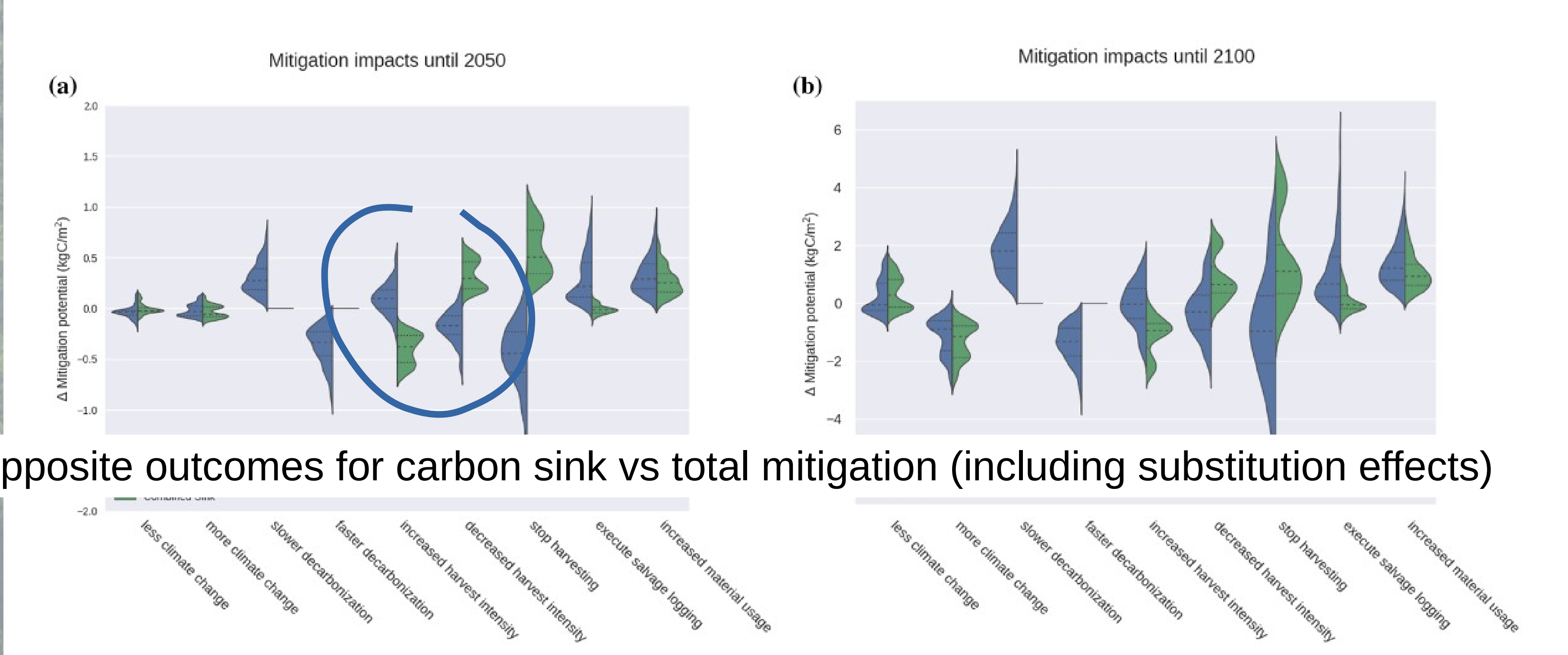
(*) Note that we used the exponential increase as the default in our analyses unless stated otherwise

Results: Factorial simulation experiment to quantify the drivers of forest-based mitigation



Gregor et al. (2024)

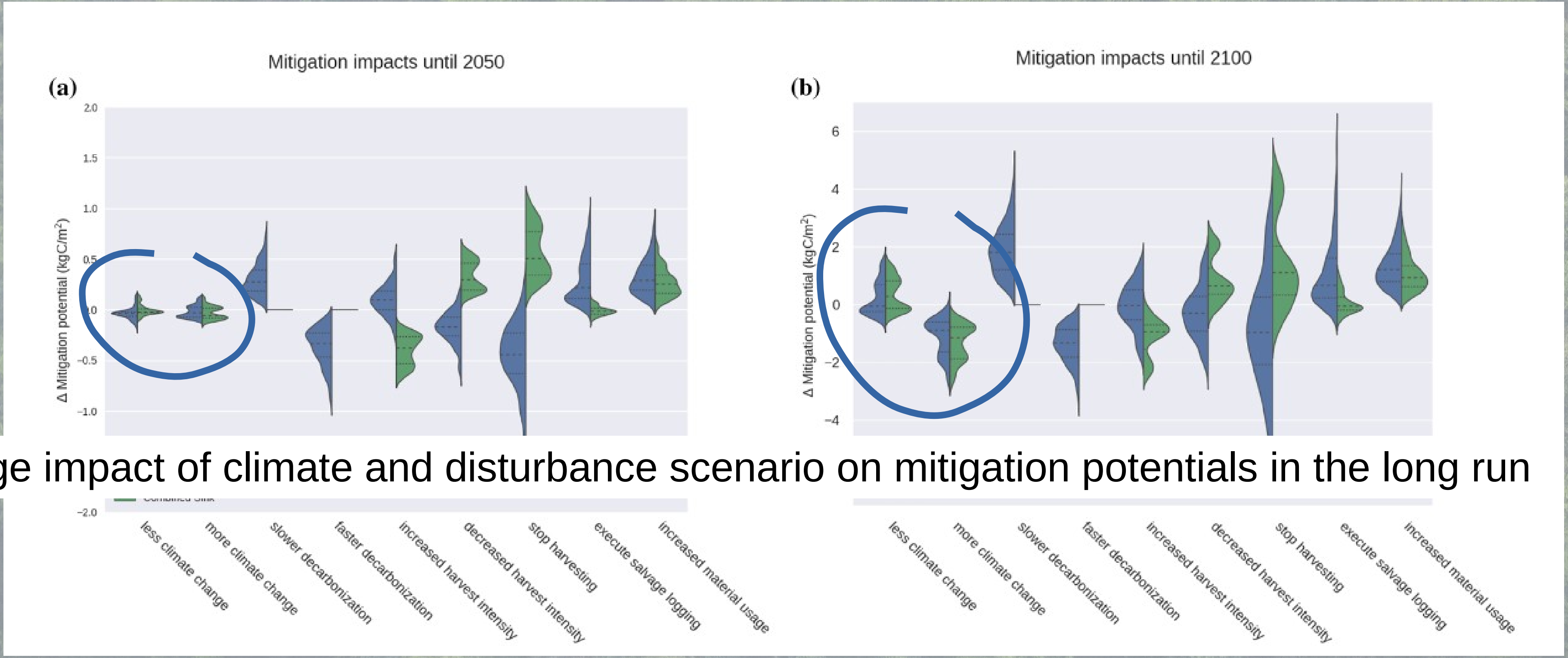
Results: Factorial simulation experiment to quantify the drivers of forest-based mitigation



Opposite outcomes for carbon sink vs total mitigation (including substitution effects)

Gregor et al. (2024)

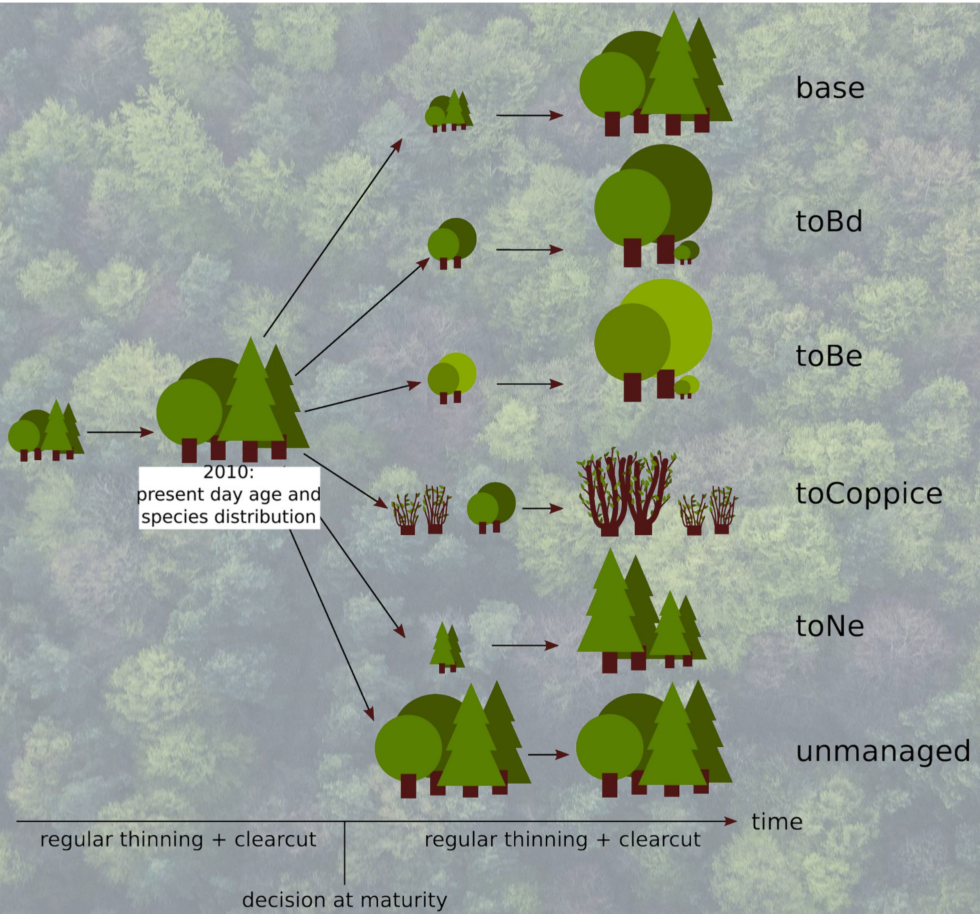
Results: Factorial simulation experiment to quantify the drivers of forest-based mitigation



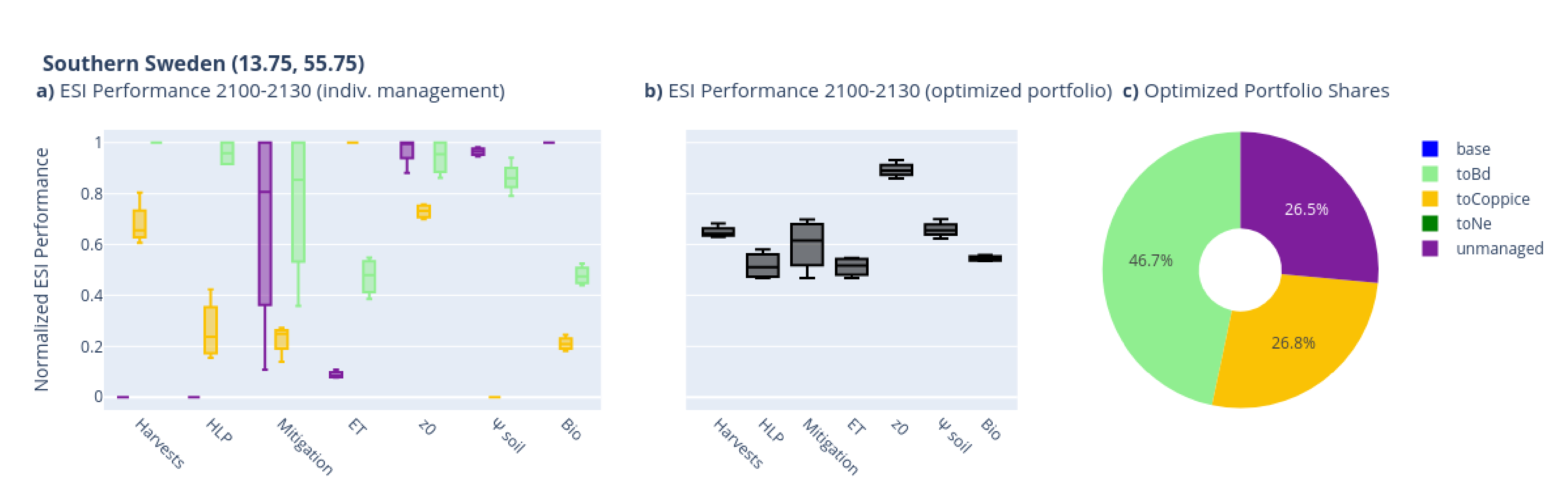
Large impact of climate and disturbance scenario on mitigation potentials in the long run

Gregor et al. (2024)

Methods: robust multi-criteria optimization for climate-smart forestry under uncertainty

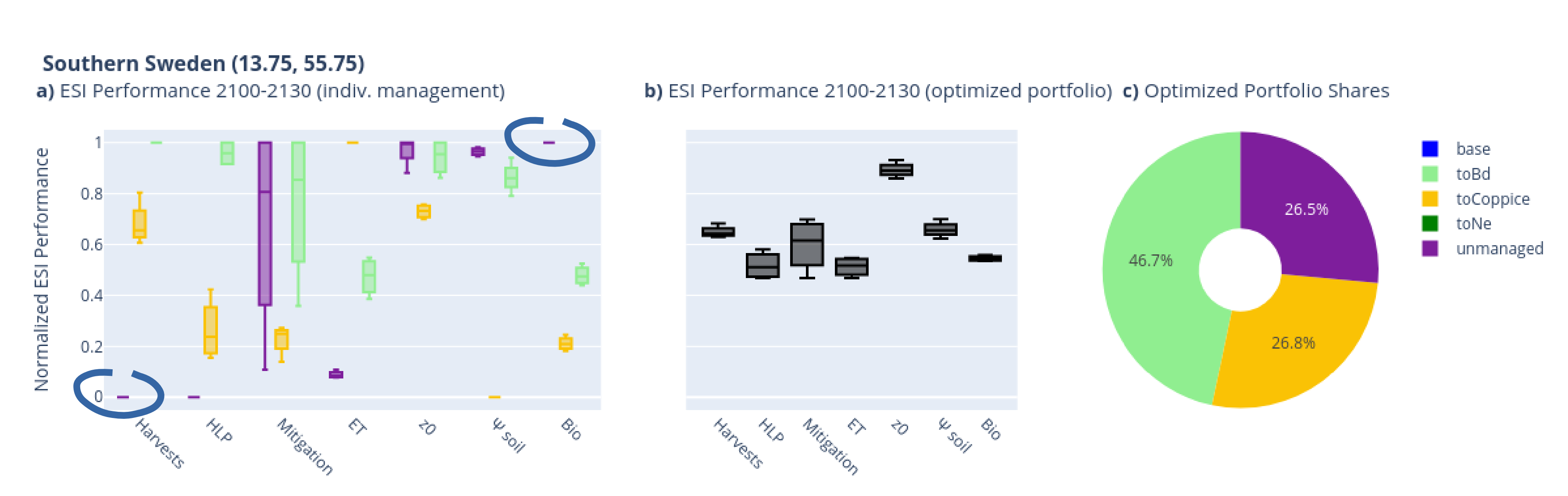


Results: robust multi-criteria optimization for climate-smart forestry under uncertainty



Gregor et al. (2022)

Results: robust multi-criteria optimization for climate-smart forestry under uncertainty



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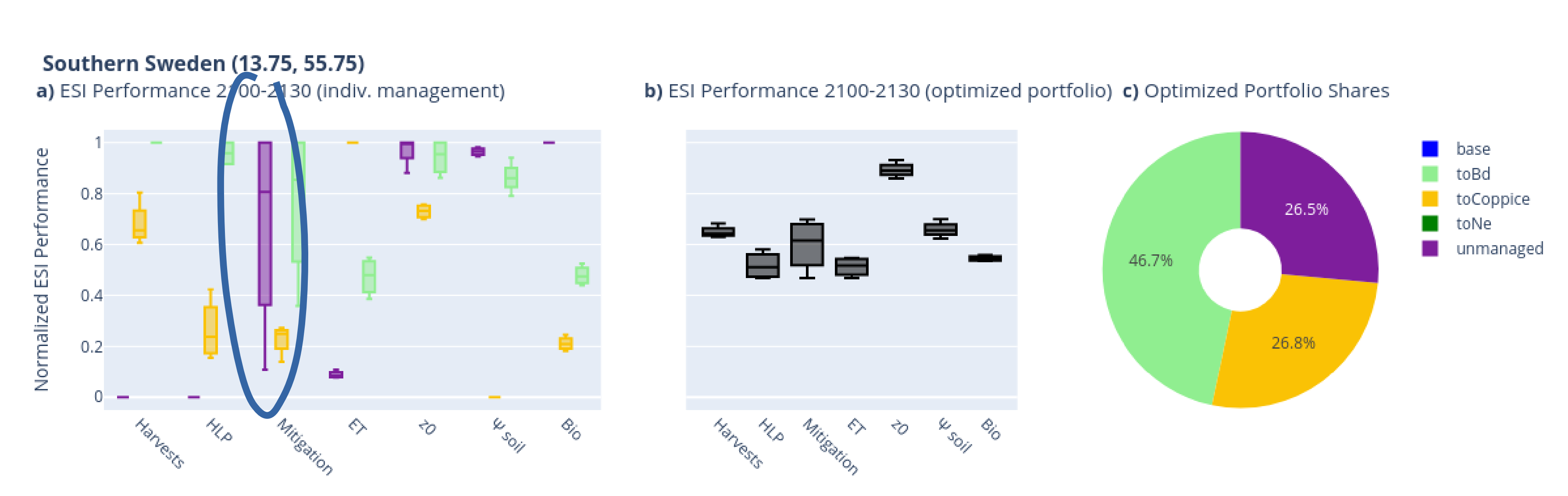
Results: robust multi-criteria optimization for climate-smart forestry under uncertainty



Gregor et al. (2022)

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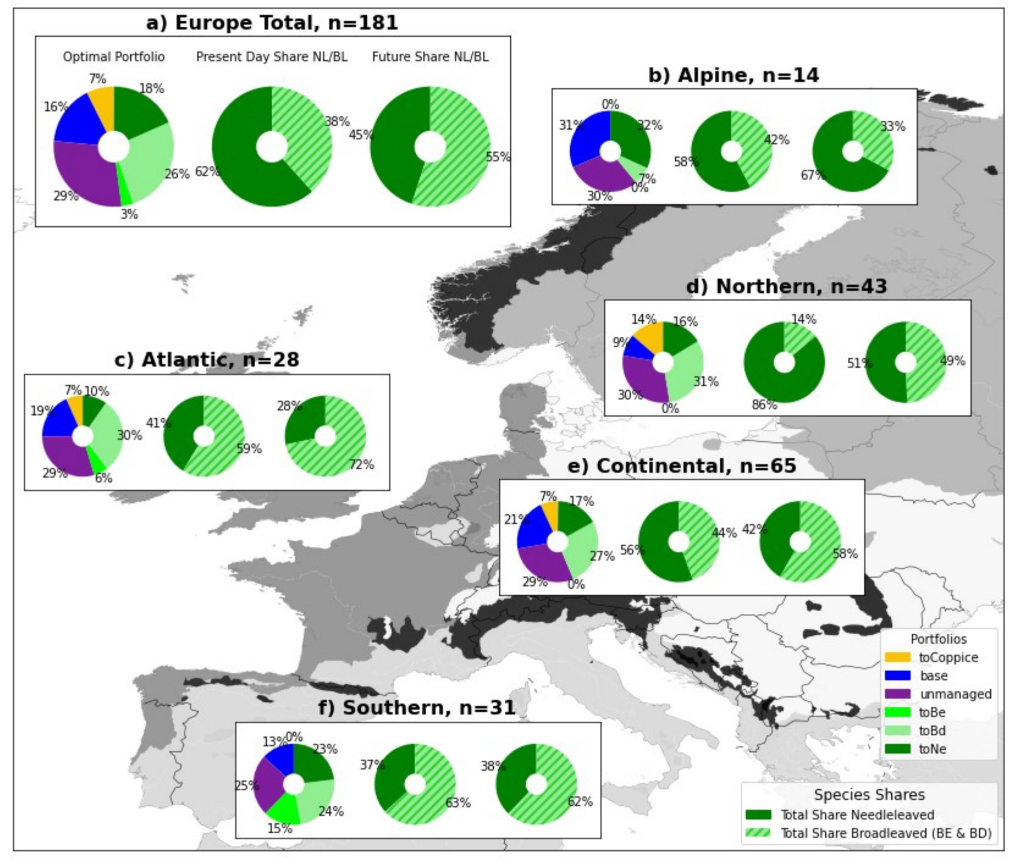


Gregor et al. (2022)

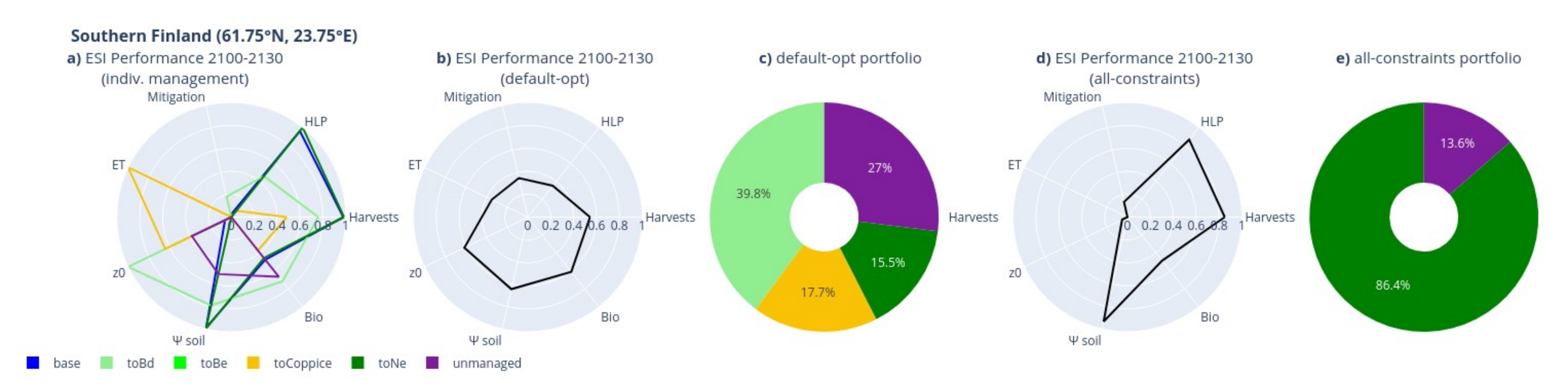
Background: constraints

- EU LULUCF targets
  - EU forests shall be a sink of 310 $MtCO_2$/yr
- EU Biodiversity Strategy
  - Protect 30% of EU land area
  - Strictly protect 10% of EU land area
- EU Forest Strategy
  - Enhance usage of wood for long-term purposes
- Wood demands are increasing

Methods: robust multi-criteria optimization for climate-smart forestry under uncertainty *and constraints*

- Enforce stable harvest levels
- Enforce strict protection on 10% of land area
- “Hard constraints”: must be met under all scenarios

Results: robust multi-criteria optimization for climate-smart forestry under uncertainty *and constraints*

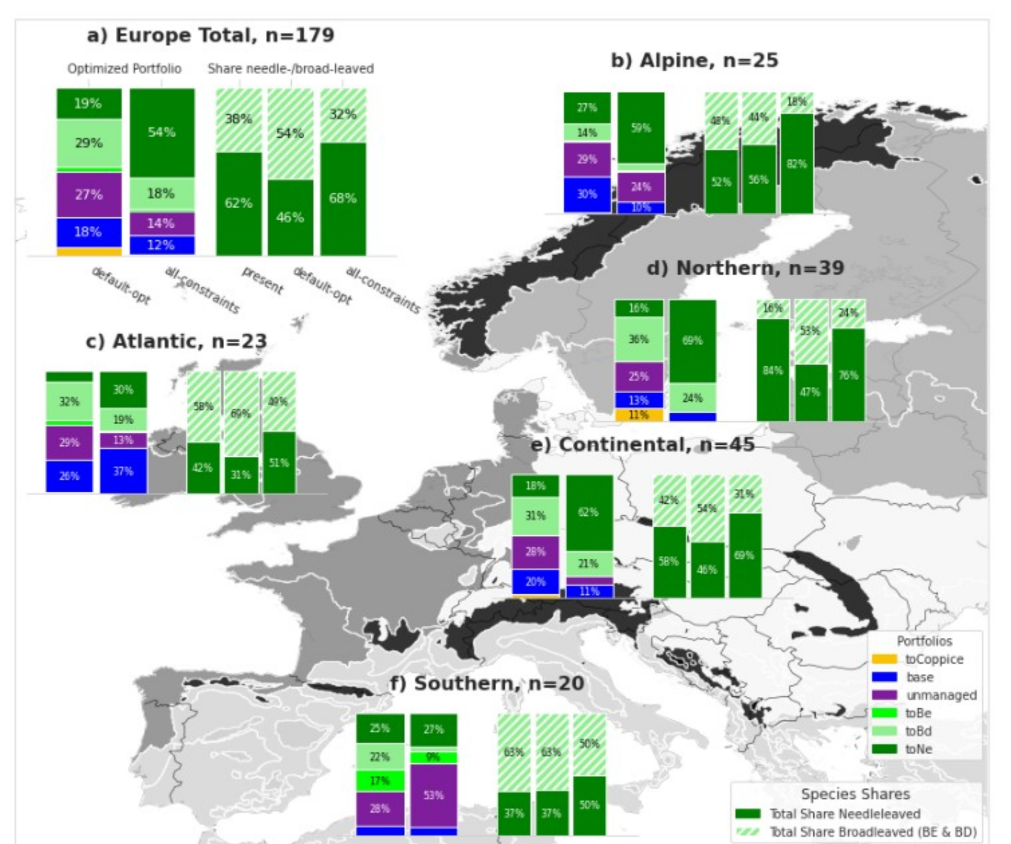


- Constraints heavily restrict the balanced provision of ecosystem services
- Much less diversification

Gregor et al. (in revision)

Results: robust multi-criteria optimization for climate-smart forestry under uncertainty *and constraints*

- A focus on timber provision is required in productive regions to maintain present-day harvest levels while also strictly protecting 10% of land area
- “unfair” distribution of protection areas
- Productive areas rarely selected for protection (although some species require productive sites)



Gregor et al. (in revision)

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