

Ecosystem services and alternative silvicultural approaches in Norwegian forest

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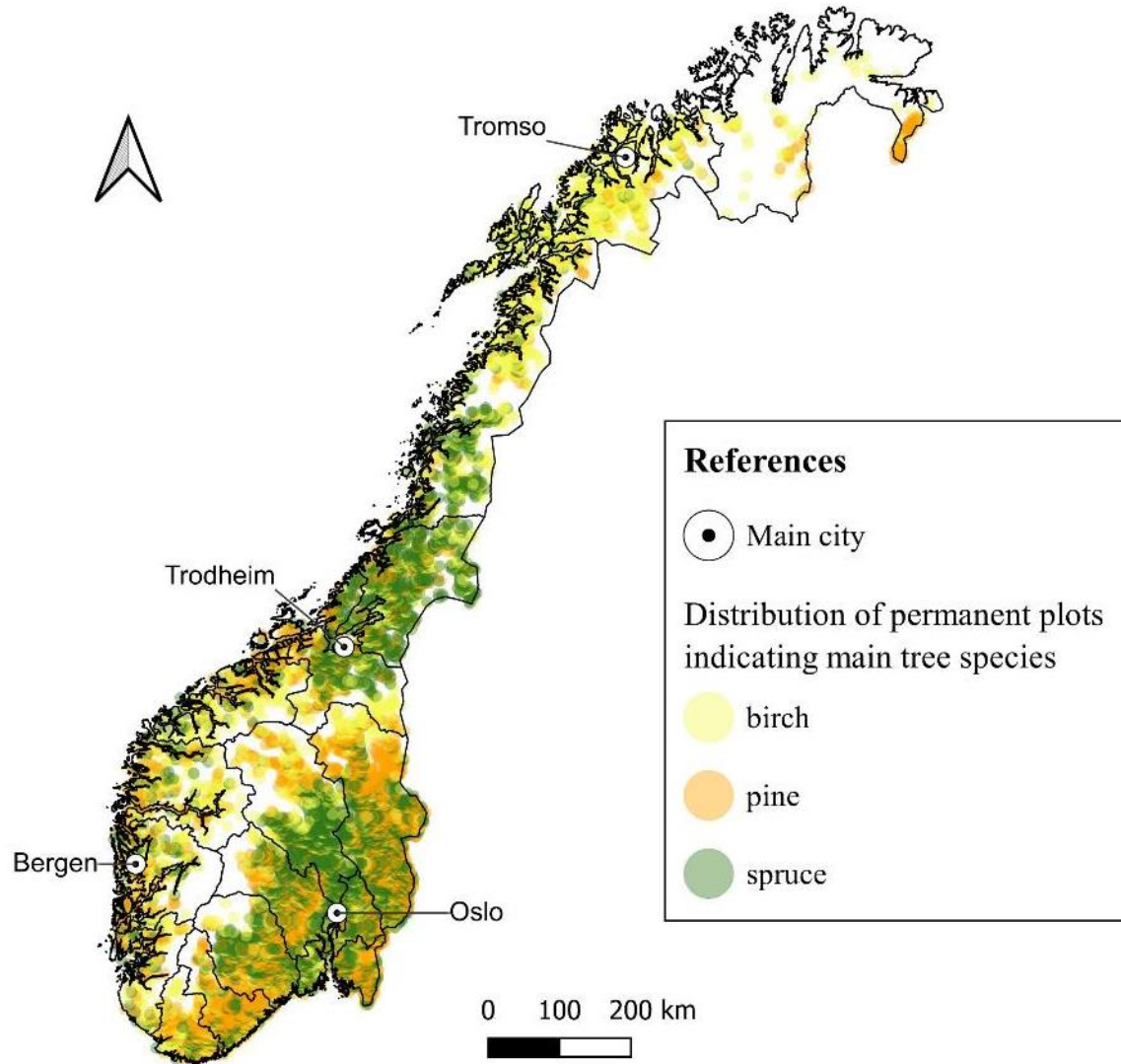
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³International Institute for Applied Systems Analysis

Dominant Tree Species in Norway



Productive forest area:

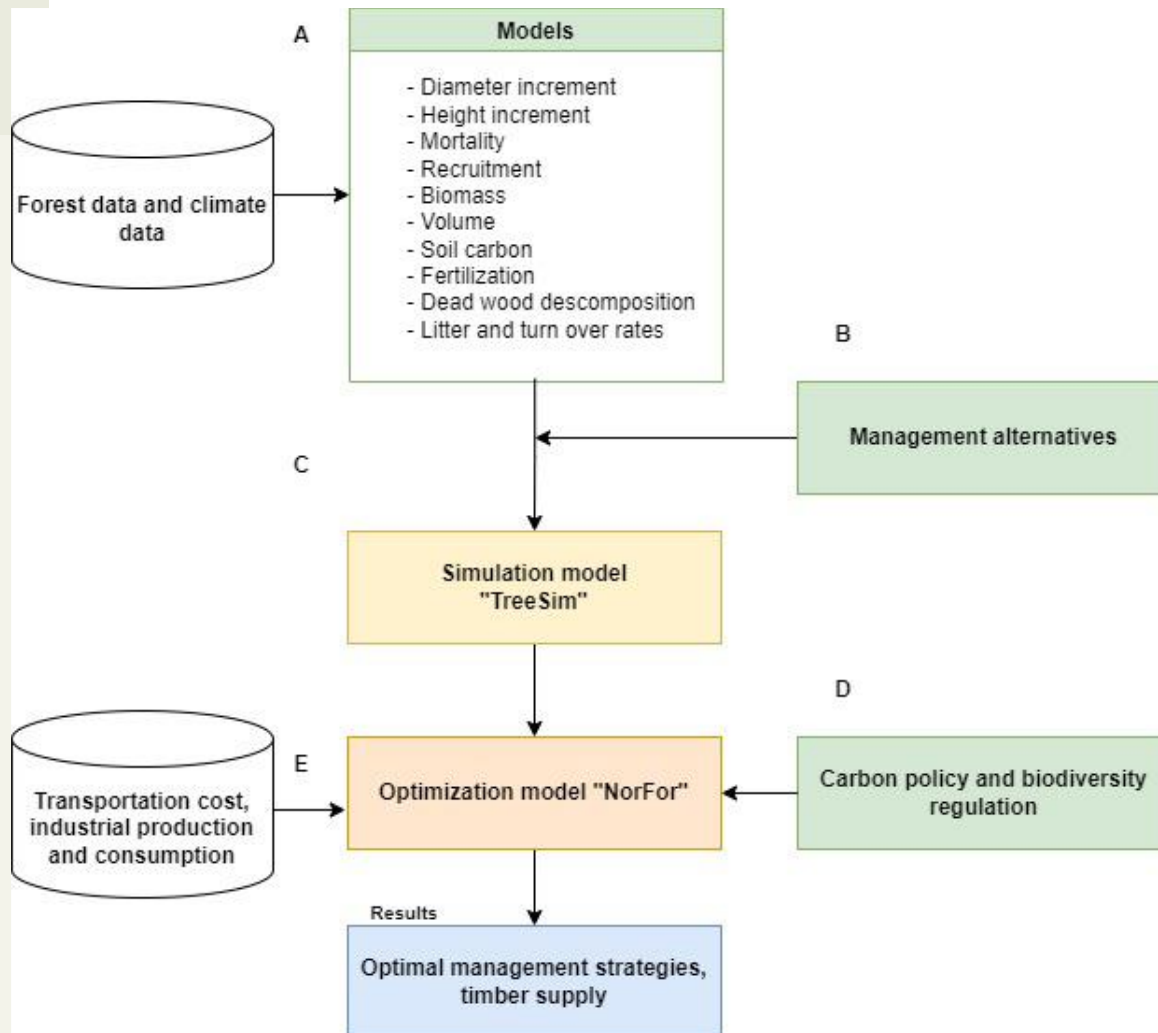
- 81,167 km² (25% of total mainland area)
- 4 % under protected scheme
- Timber harvested (2024)
~ 12 million m³

A photograph of a forest scene. In the background, a yellow logging machine is visible, partially obscured by trees. The foreground shows a mix of green and brown vegetation, with several tall, thin trees. The sky is blue with some clouds.

Paper I: policy impacts

Impacts of biodiversity and carbon policies on the management of Norwegian forest and its ecosystem services.

Base year 2020; 5-year periods; 30 periods total; focus on year 2140 (Period 24)



Two policies:

- **Carb:** Carbon pricing (100€ tCO₂⁻¹)
- **Bio:** Biodiversity regulation (harvest constraints)

Four scenarios:

Business As Usual (**BAU**), **Bio**, **Carb**, **BioCarb**

Impacts of biodiversity and carbon policies on forest management across site productivity classes in Norway



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INTRODUCTION

Even-aged management is the dominant silvicultural regime in many Nordic countries including Norway. Alongside timber and forest industry production, increasing carbon sequestration and preserving habitats are forest objectives high on the policy agenda. However, few studies have analyzed how forest management can be adapted to better support carbon and biodiversity aims alongside timber production. We aim to fill part of this void by employing a simulation-optimization framework including such policies, using Norway as a case study.

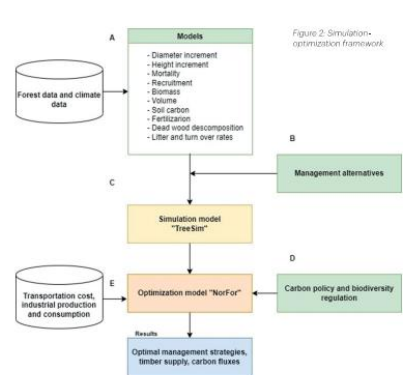


Figure 2: Simulation-optimization framework

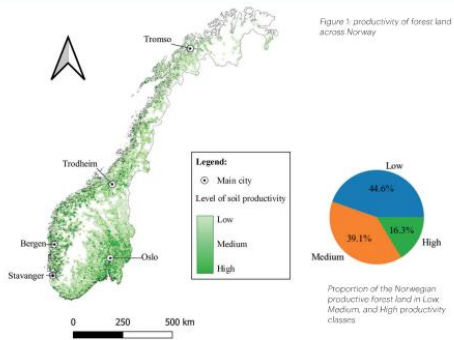


Figure 1: productivity of forest land across Norway

METHODS AND MATERIALS

We applied the tree-level simulator TreeSim¹ and the Norwegian National Forest Inventory data to simulate yields, biodiversity and carbon sequestration for a set of management intensity classes (MIC). Next, we fed the simulated yields into the optimization model Norfor² of the Norwegian forest sector that projects management, harvests and industrial output based on observed behavior of forest owners, industry and consumers to compare impacts of policies³ (Figure 2). The MIC minor common management practices in Norwegian forests and included sets of methods for regeneration, other silvicultural measures and harvests, including sets of harvest timings. No management was an option for all plots.

We included the policies Carb and Bio, and a combined policy, BioCarb. These were contrasted to a business-as-usual (BAU) scenario with no policy. The Carb policy was a tax/subsidy scheme where forest owners were credited if sequestration were above BAU levels and were in the opposite case subject to taxes. The carbon price was 100 €/tCO₂e. The Bio scenario included three policy-relevant constraints: no harvest of warm deciduous trees, no harvest of areas older than 160 years and halve the harvest volume of forage species for deer from its current level. The BioCarb policy included both Carb and Bio policies. Scenarios were run for 5-year periods until year 2170 and outcomes compared for year 2140.

RESULTS

The results show that:

- Harvests of all species are reduced with the carbon policies on low-productive and high-productive forest land (Figure 3)
- Harvest levels are maintained with the biodiversity policy with harvest of spruce and pine replacing deciduous on low and medium-productive sites (Figure 3)
- The combined carbon and biodiversity policy have additive effects on harvest on medium- and high-productive forest land (Figure 3)
- Biodiversity policy leads to more set-aside on high-productive sites (Figure 4)
- Carbon policy leads to more set-aside on low-productive sites (Figure 4)
- Old-growth forest area increases considerably across site productivity classes from year 2020 to 2140 in BAU (Figure 5)
- Biodiversity policy has minor changes on old-growth area while carbon policy have substantial effects on the old-growth forest area on low-productive sites (Figure 5)

IMPLICATIONS AND CONCLUSIONS

- The synergic effects between carbon and biodiversity policies vary with site productivity
- With a high carbon price, large low-productive areas are taken out of production
- The biodiversity policy constrains management and harvest mostly on high-productive sites
- BAU mimics carbon policy management on medium and high-productive sites, and biodiversity policy management on low-productive sites
- Most forest land in Norway is of low and medium productivity. Policy outcomes vary with productivity. The effects of combined carbon and biodiversity policy may be closer to carbon policy or biodiversity policy depending on site productivity.
- With notable geographical gradients in site productivity, policies may have significant regional distributional impacts which warrant closer inspection before implementation

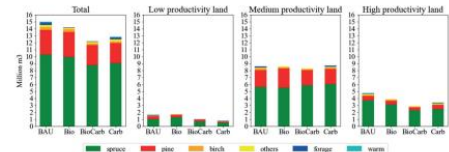


Figure 3: Timber harvest in million cubic meter (m³) by tree species group and productivity class in year 2140

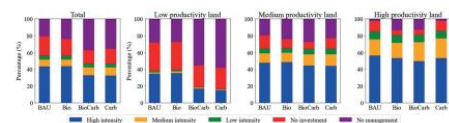


Figure 4: Areas allocated to management intensity classes (%) by productivity class in year 2140

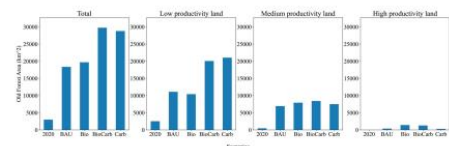


Figure 5: Old forest area (km²) by productivity class in year 2140

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Impacts of biodiversity and carbon policies on the management of Norwegian forest and its ecosystem services

López L.N., Sjølie H.K., Nabhani A., Aguilar F.X. (2024). Impacts of biodiversity and carbon policies on the management of Norwegian forest and its ecosystem services. Silva Fennica vol. 58 no. 4 article id 23067. 28 p. <https://doi.org/10.14214/sf.23067>

Highlights

- National-level biodiversity and carbon forest sector policies modelled in a simulation-optimization framework.
- Impacts of policies on management along site productivity gradients estimated.
- Policies vary in impact across productivity gradients with regional implications.

¹ Nabhani, A., López, L.N., & Sjølie, H.K. (2024). TreeSim: An environmental individual tree simulator and its application to forest management. *Forest Ecology and Management*, 581, 119021.
² López, L.N., López, L.N., & Sjølie, H.K. (2024). Combining biodiversity and forest sector production models to provide policy advice on the forest management. *Scandinavian Journal of Forest Research*, 39(5), 2024018.



Paper II: wildlife impact

*Consequences of moose browsing on timber production and
management*

(ongoing manuscript)

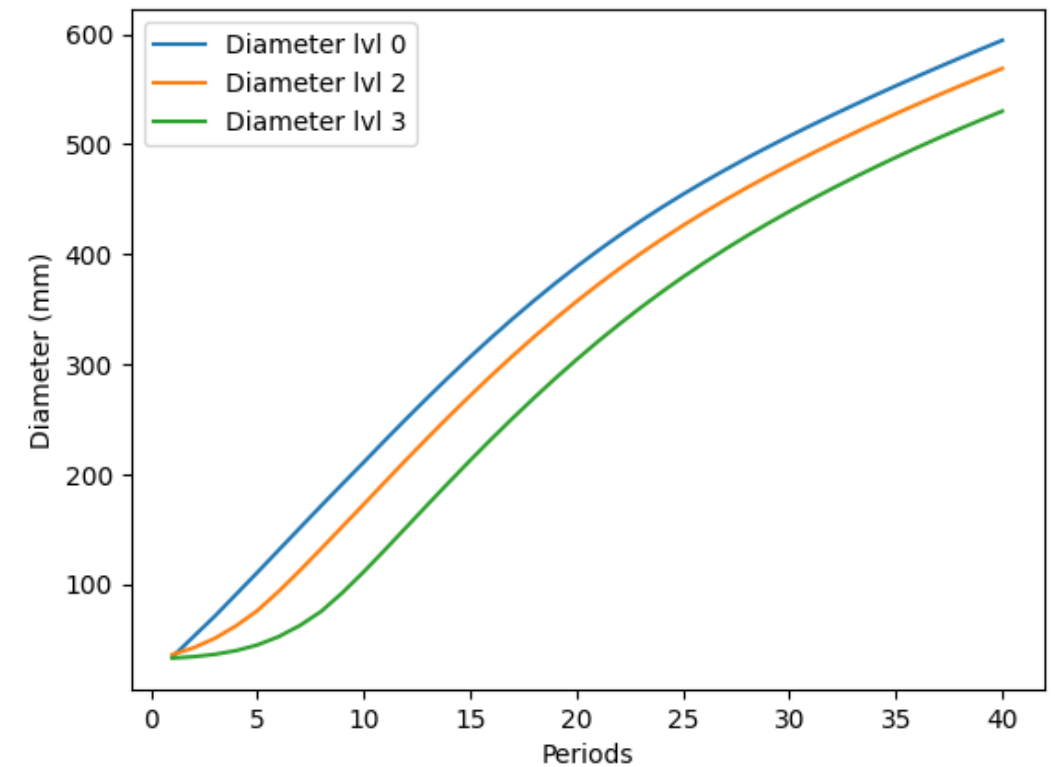
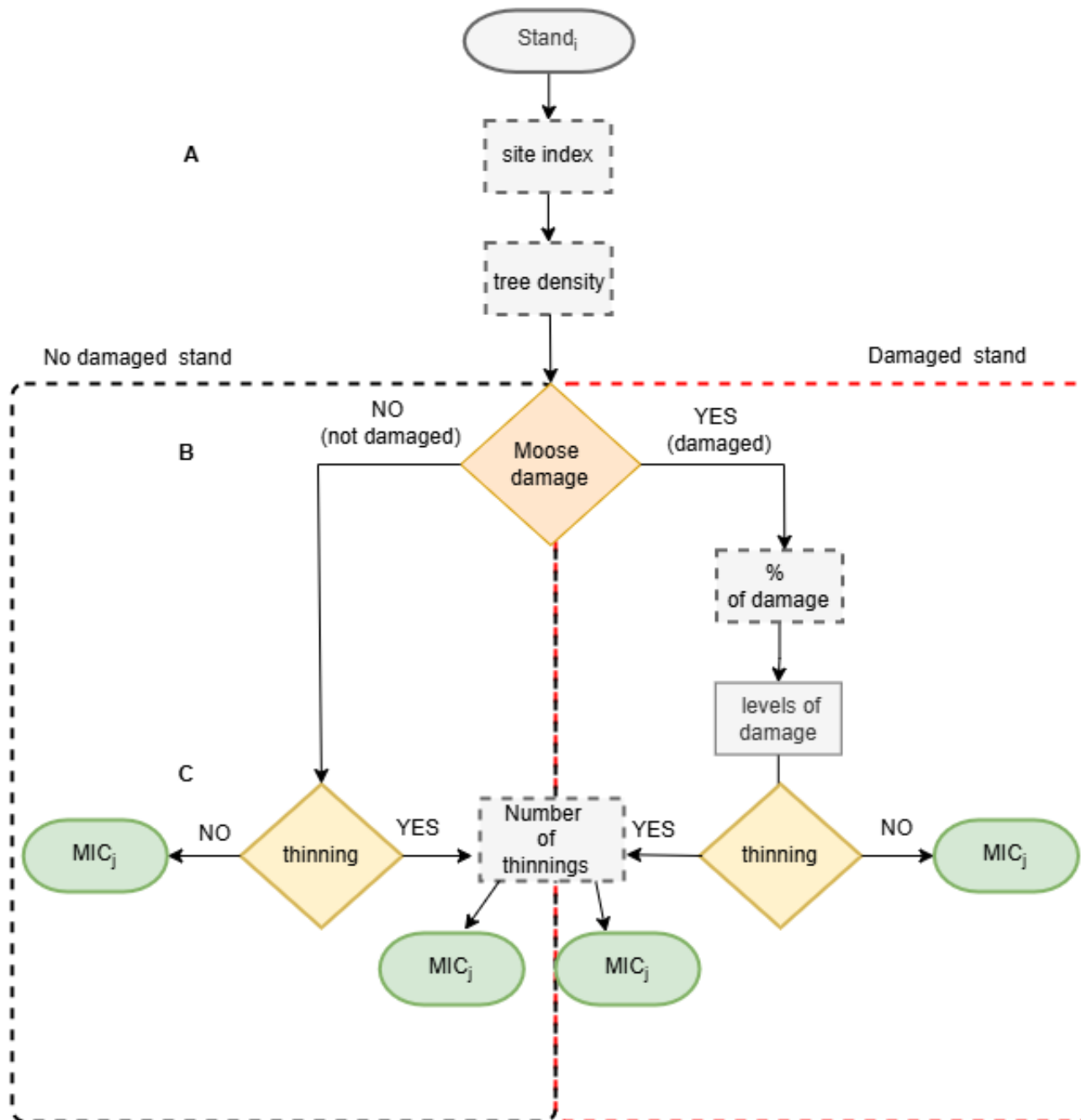
Objectives of our study

- Estimate damage functions for pine based on pine and moose densities.
- Simulate long-term consequences of browsing on growth and yield.
- Indicate changes in optimal management and consequences on timber production and economic surplus.



Drawing from: [Moose Illustration - loosen-studio](#)

Forest Moose Simulator

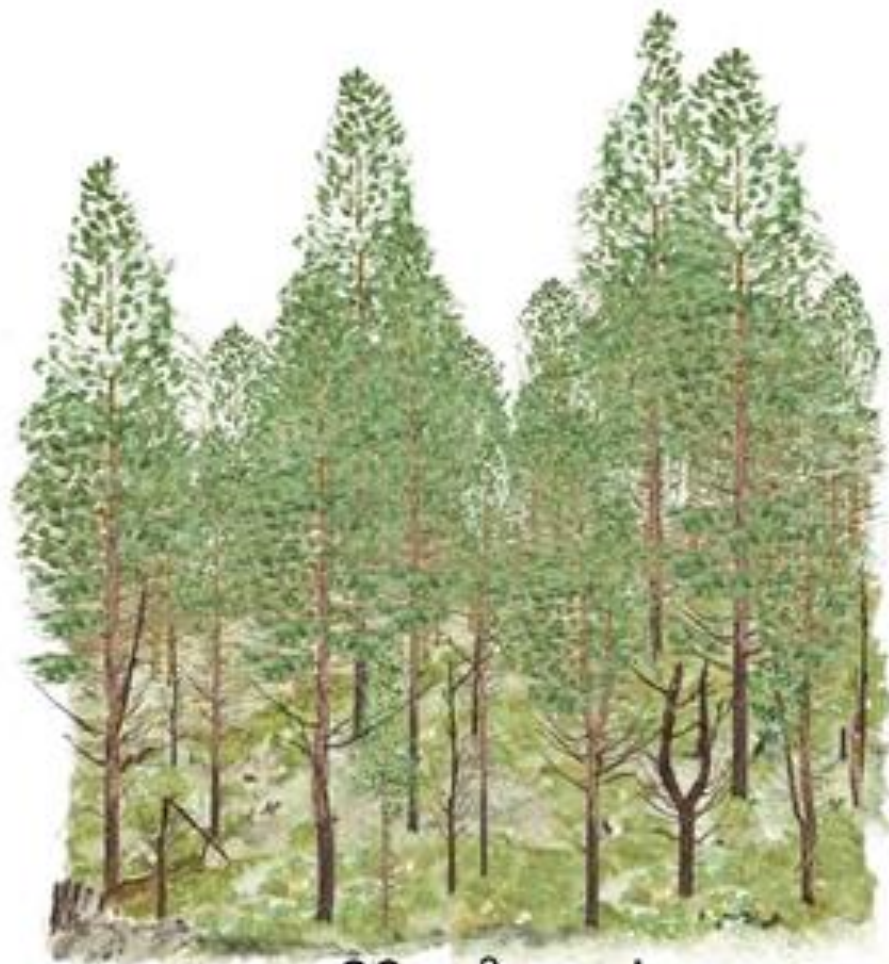


Permanenta skador på bestånd

(Permanent damage to the stand)



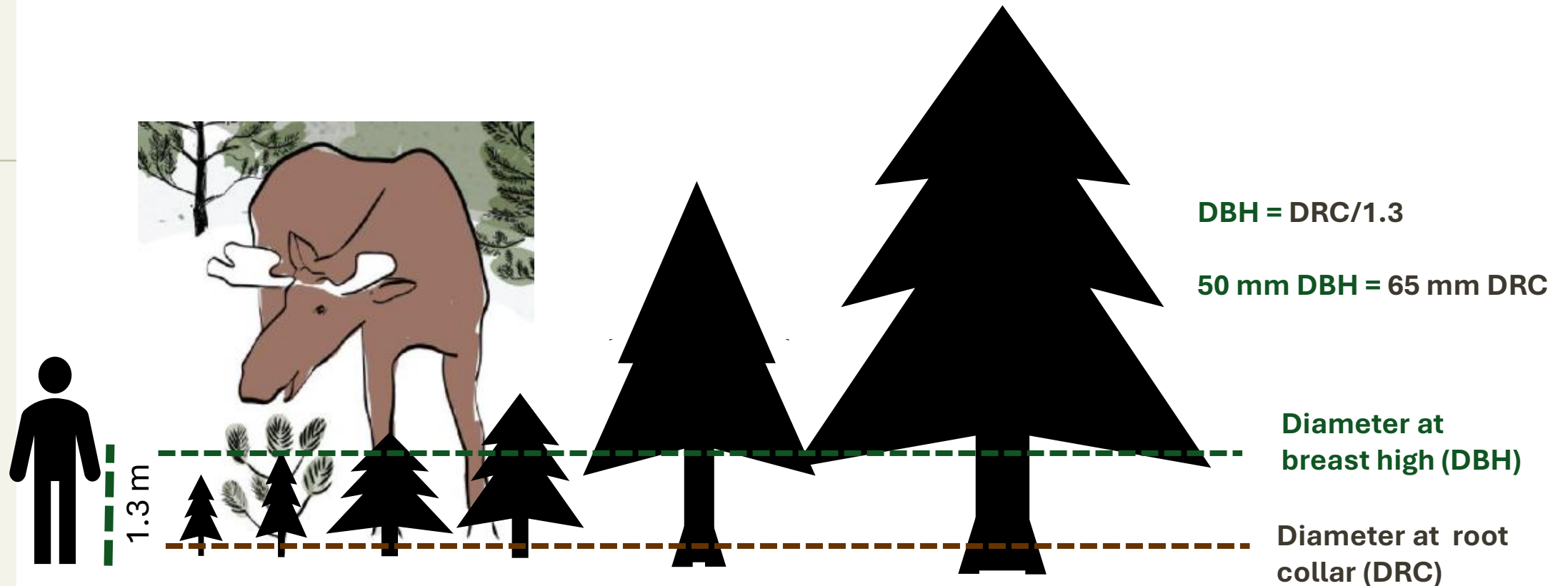
180 m³ per ha



60 m³ per ha

Challenges with current Models

- Equations based on National Forest Inventory (NFI) data, which includes only trees with a **DBH ≥ 50 mm (5 cm)** and total height ≥ 4 m.





Spatial analyses

Inland Forest Model: integrating forest data
at county level.

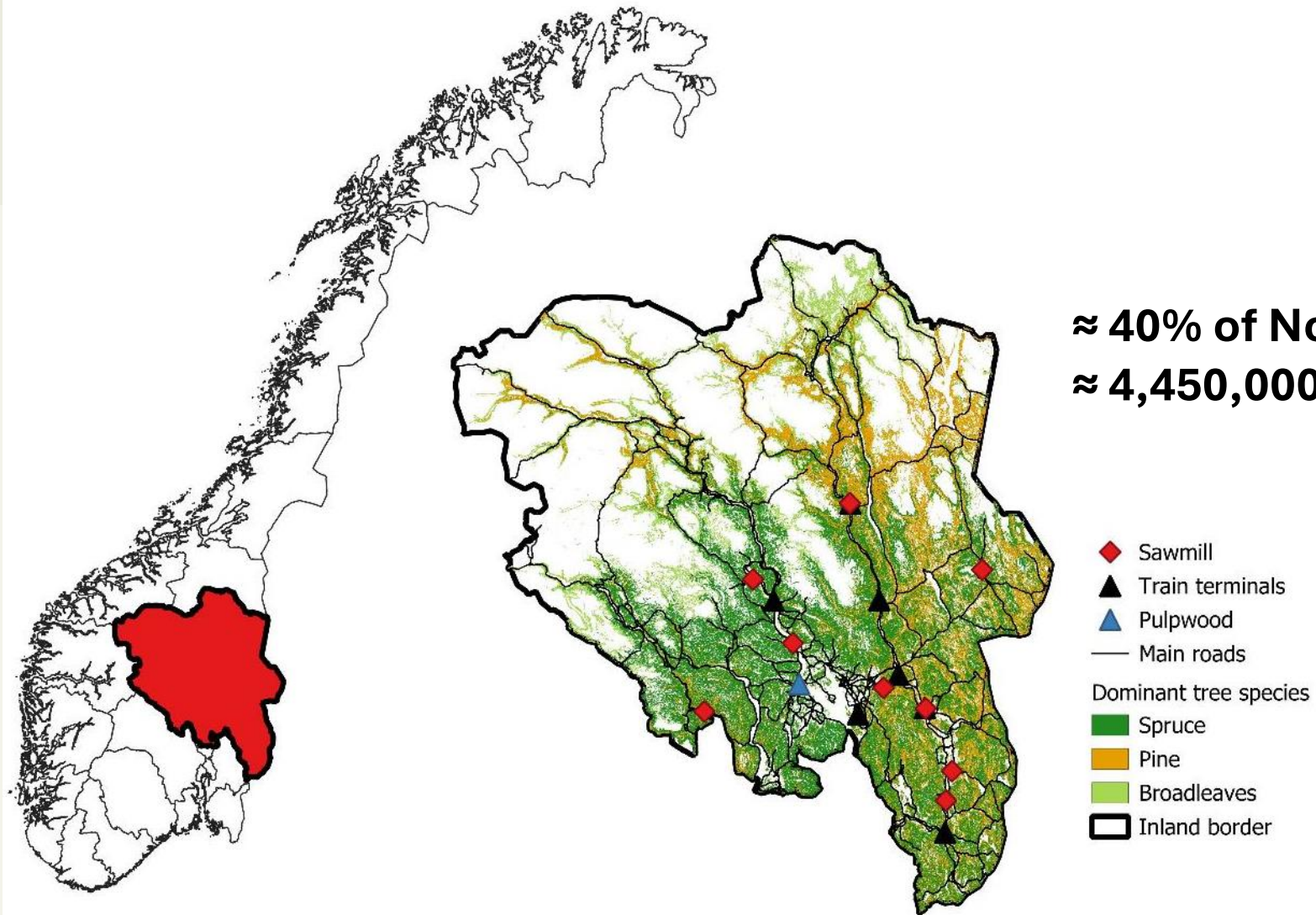
Selection cutting in mixed forests on sloped areas



Clearcutting practices in sloped pine forest



Forest Industry Infrastructure and Dominant Tree Species Distribution in Inland



**≈ 40% of Norway's total timber harvest.
≈ 4,450,000 million m³ (2023)**

PLOT



Ground: measure of forest
attributes

PIXEL



Digital map: Wall-to-wall
modeled forest attributes

NFI

Simulation and optimization

pixel

grid
cell

Optimization
Model

Management
alternatives

Grid cell_{id1}

Aggregate pixels

cat₃₃₃₃

cat₁₁₁₁

run simulation

NFI plot

plot_id₁ cat₁₁₁₁

plot_id₂ cat₁₁₁₁

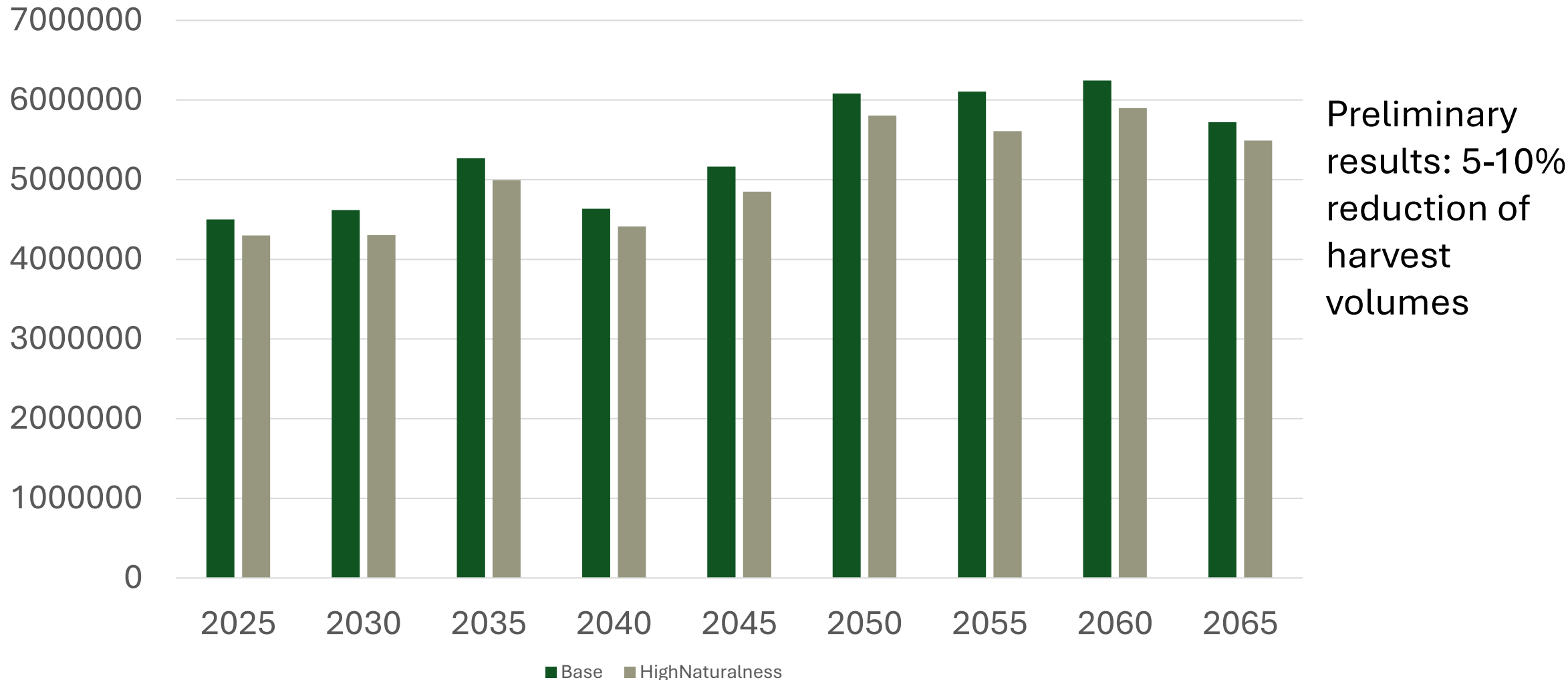
plot_id₃ cat₁₁₁₁

plot_id₄ cat₁₁₁₁

...

- average results

Total volume harvested (m3)





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