Analysis of the effect of the parameter: `param_type` in Forceeps

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```r
library(tidyverse)
library(fs)
library(gridExtra)
library(grid)
library(knitr)
library(patchwork)
opts_chunk$set(echo=FALSE)
```

Abstract

This report presents an in-depth analysis of the effect of the `param_type` parameter on the probability of being cut and on the cutting score in the Forceps model. The study combines a theoretical approach based on the model's equations and a practical application on simulated data. The results provide a better understanding of how this parameter influences stand structure and cutting dynamics.

Introduction

Forest management relies on cutting decisions influenced by parameters such as tree diameter and selection indices. The Forceps model formalizes the probability of cutting as a function of a cutting type parameter (`param_type`), which modulates randomness and selectivity in harvesting. This report details the effect of this parameter through a theoretical study and a practical simulation.

Theoretical study: Effect of the `param_type` parameter

In the Forceps model, the probability that a tree is cut depends on its diameter (or circumference, denoted c_i) and the cutting type parameter p (`param_type` in the code). The following equations govern the calculation:

Definition of variables: - c_{Min}: minimum circumference (here 0) - c_{Max}: maximum circumference (here 200) - c_i: circumference of tree i - p: cutting type parameter, between 0 and 1

Calculation of randomness:

$$\text{randomness} = \begin{cases} 2p & \text{if } p \leq 0.5 \\ 2 - 2p & \text{if } p > 0.5 \end{cases}$$

Calculation of the circumference of maximum probability:

$$c_{\text{maxProba}} = p \times (c_{\text{Max}} - c_{\text{Min}}) + c_{\text{Min}}$$

Calculation of the range (rangeMax):

$$\text{rangeMax}_1 = c_{\text{maxProba}} - c_{\text{Min}} + 1$$

$$\text{rangeMax}_2 = -c_{\text{maxProba}} + c_{\text{Max}} + 1$$

$$\text{rangeMax} = \max(\text{rangeMax}_1, \text{rangeMax}_2)$$

Probability of being cut:

$$\text{probaOfBeingCut} = 1 - \frac{|c_i - c_{\text{maxProba}}|}{\text{rangeMax}}$$

Cutting score (weighting between randomness and selectivity):

$$\text{score} = \text{randomness} \times \text{uniformProba} + (1 - \text{randomness}) \times \text{probaOfBeingCut}$$

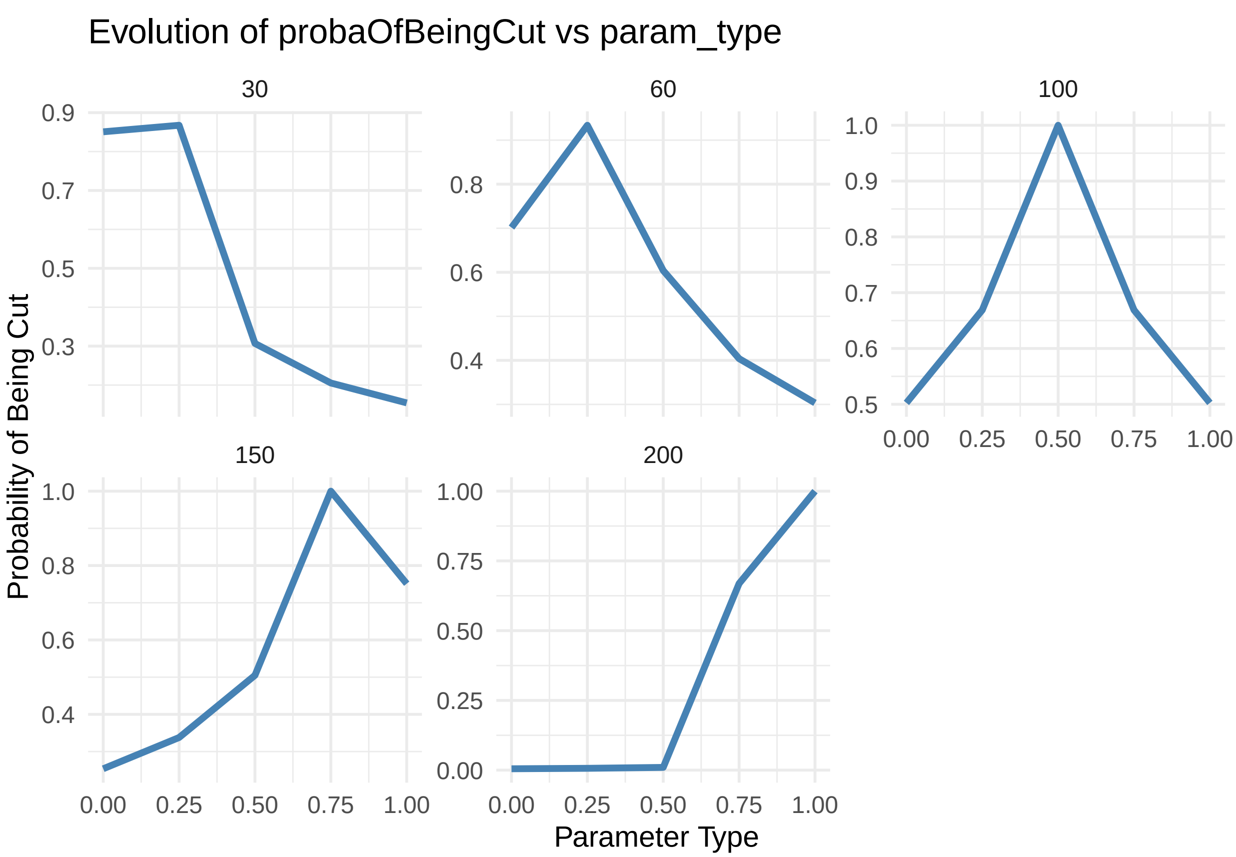
where uniformProba is set to 0.5 for visualization.

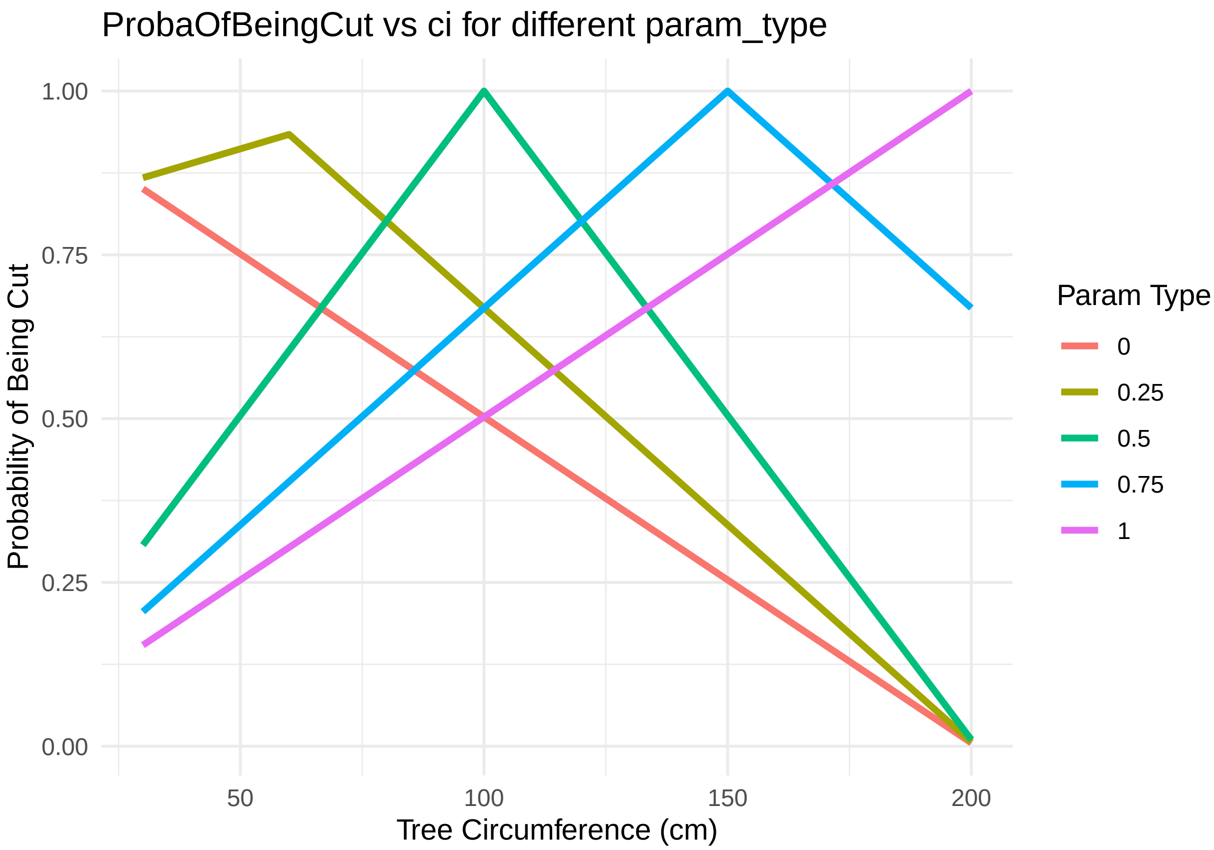
These equations express the trade-off between random cutting (high `randomness` value) and selective cutting centered on a diameter class (low `randomness` value). The parameter p modulates this trade-off.

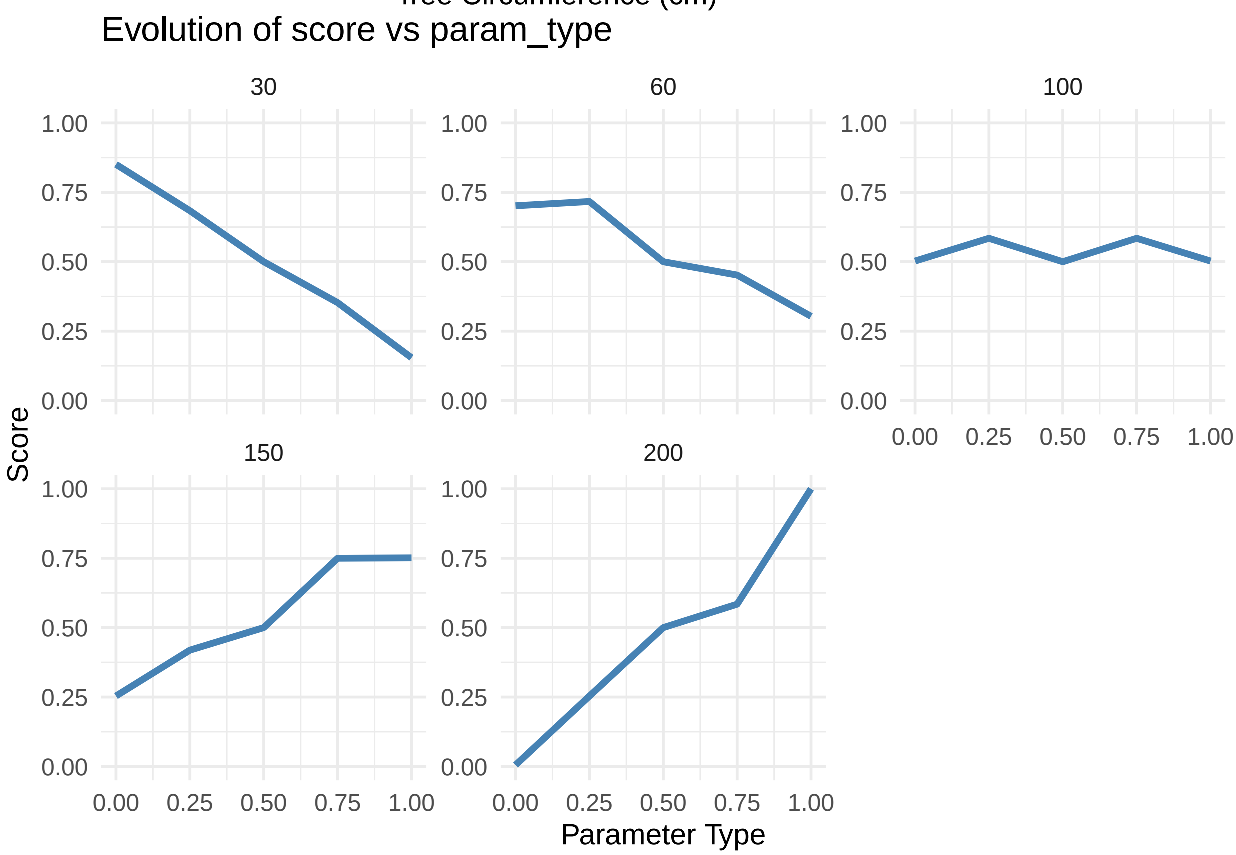
Visualisation of effects

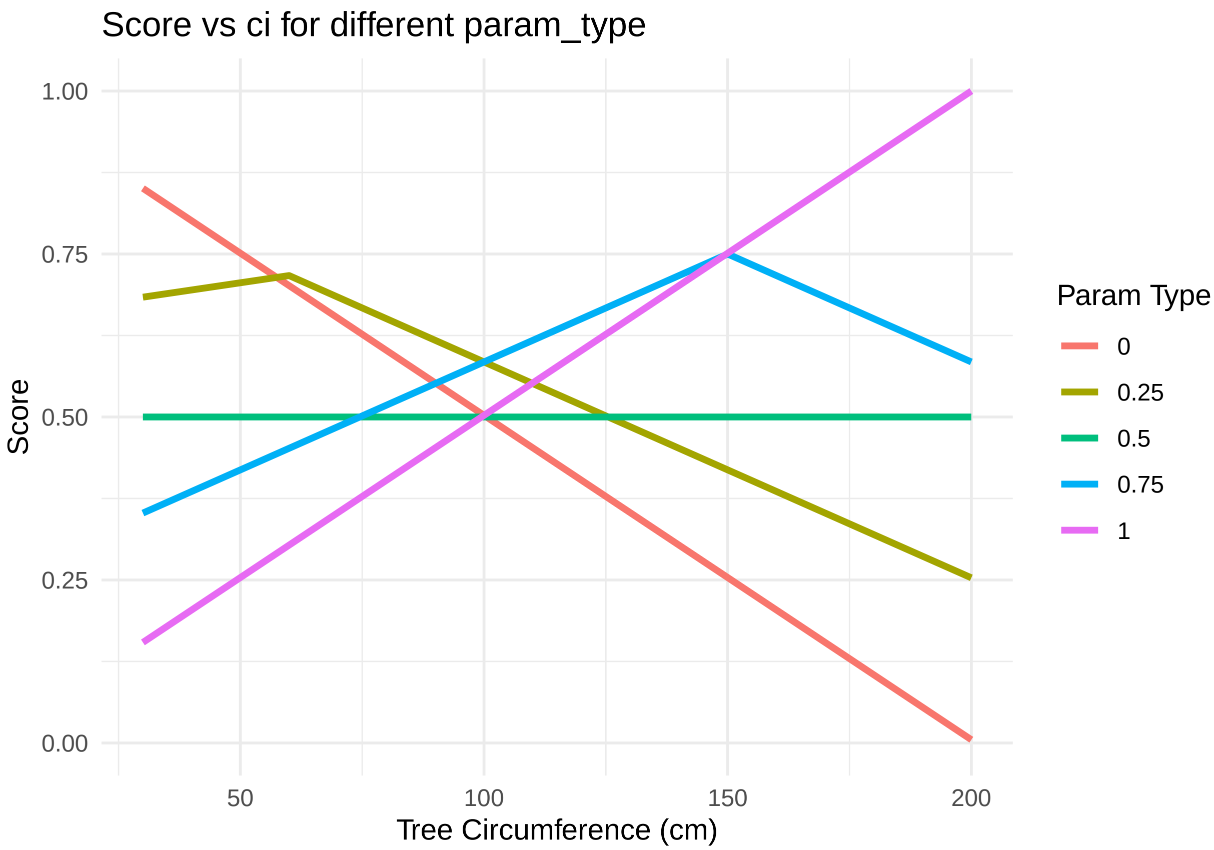
The following plots illustrate the evolution of the probability of being cut and the score as a function of p and tree diameter.

```
## Warning: Using `size` aesthetic for lines was deprecated in ggplot2 3.4.0.
## i Please use `linewidth` instead.
## This warning is displayed once every 8 hours.
## Call `lifecycle::last_lifecycle_warnings()` to see where this warning was
## generated.
```




ProbaOfBeingCut vs ci for different param_type
Probability of Being Cut
1.00
0.75
0.50
0.25
0.00
50
100
150
200
Tree Circumference (cm)
Param Type
0
0.25
0.5
0.75
1


Evolution of score vs param_type
30
60
100
150
200
Score
1.00
0.75
0.50
0.25
0.00
0.00 0.25 0.50 0.75 1.00
Parameter Type

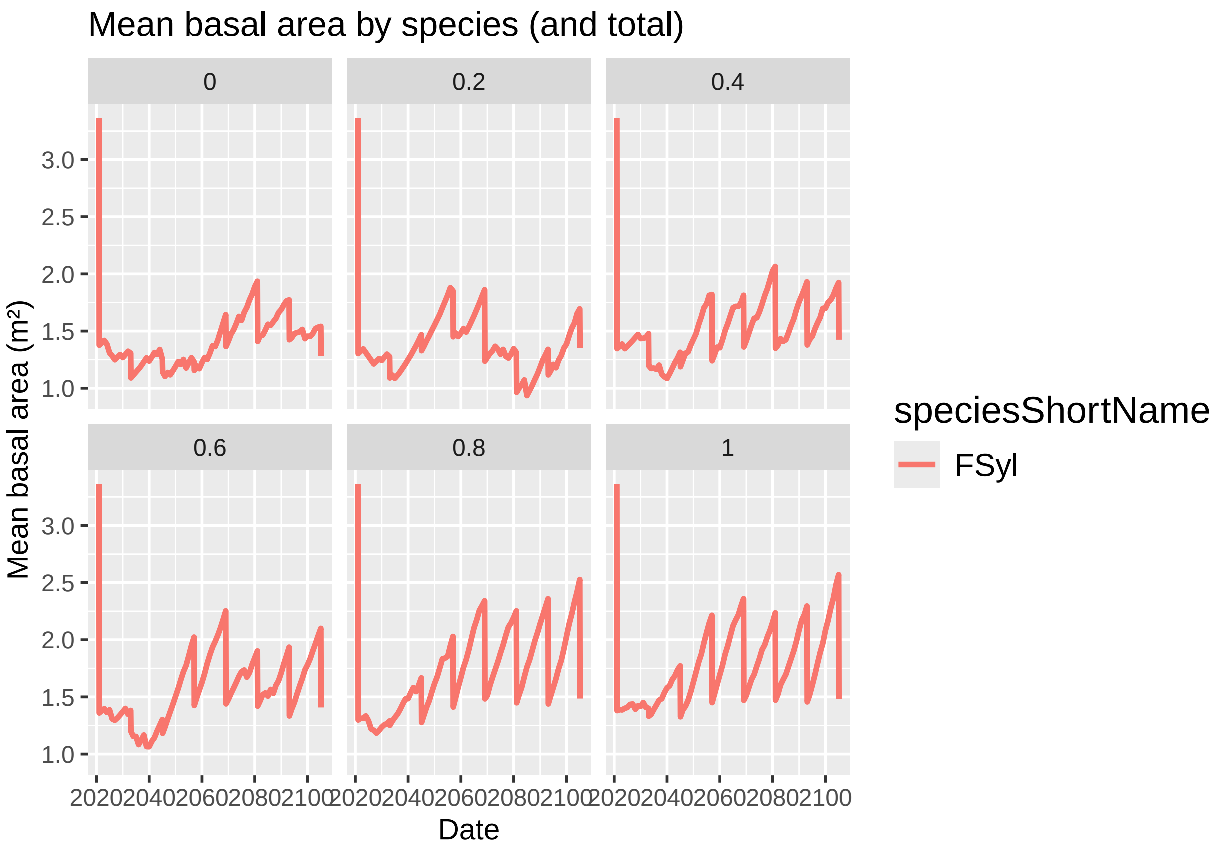


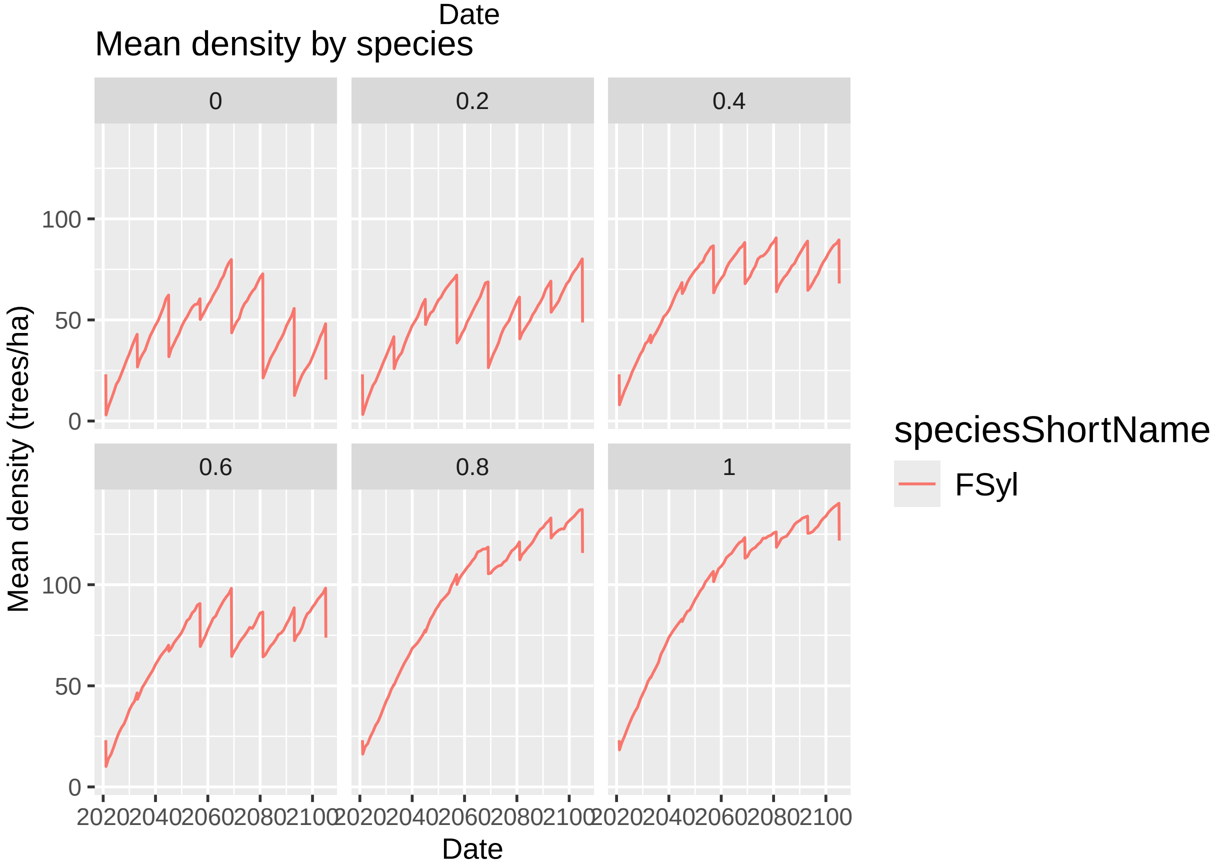
Practical application: Simulation on a Fagus sylvatica forest

A simulation is performed on a beech forest (FSyl), with a 12-year rotation, target basal area of 15 m²/ha, initial basal area of 34 m²/ha, and 20 trees uniformly distributed between 0 and 80 cm in diameter. For each trajectory we use one and the same `param_type` value (0 to 1) for every cutting action during the 80 years of simulation.

Analysis of results

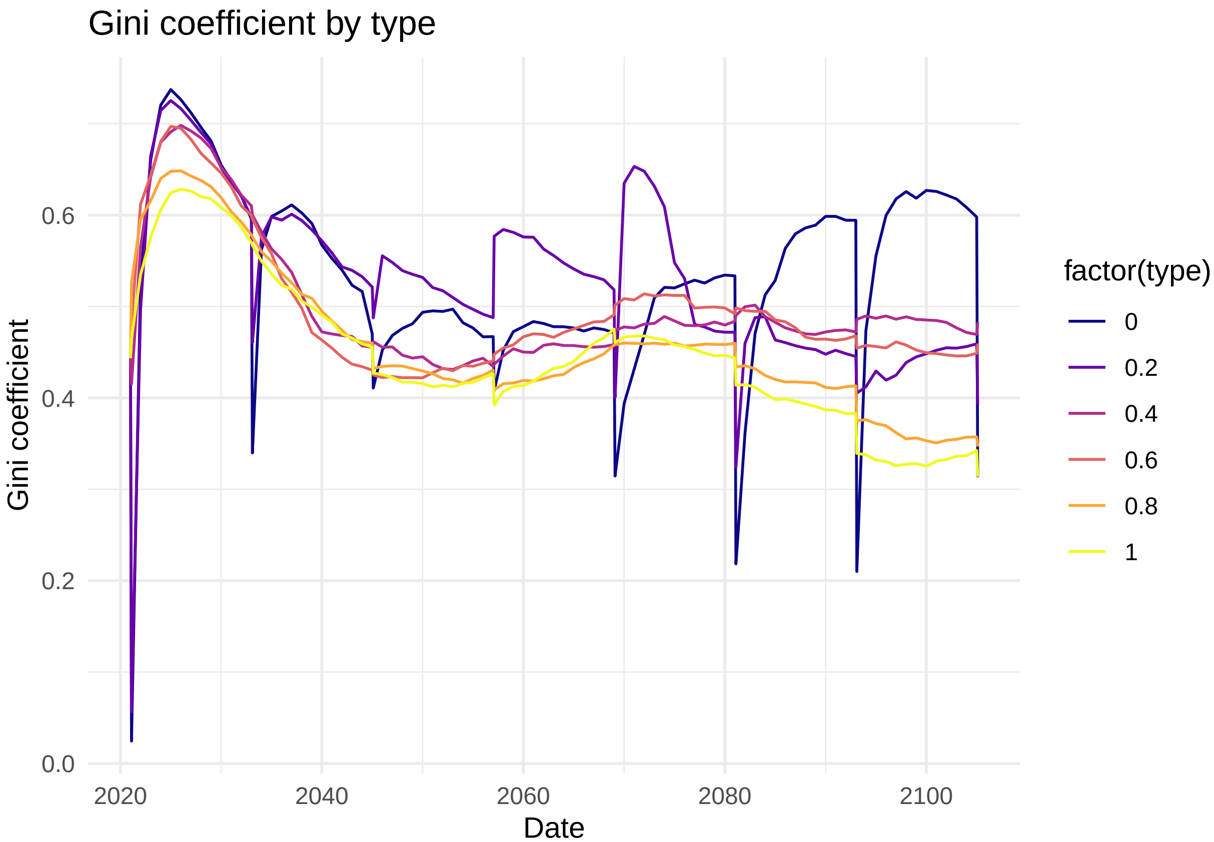
The results are analyzed according to several indicators: - Mean basal area and stem density in each trajectory - Gini coefficient (diameter structure) - Distribution of diameter classes before and after cutting



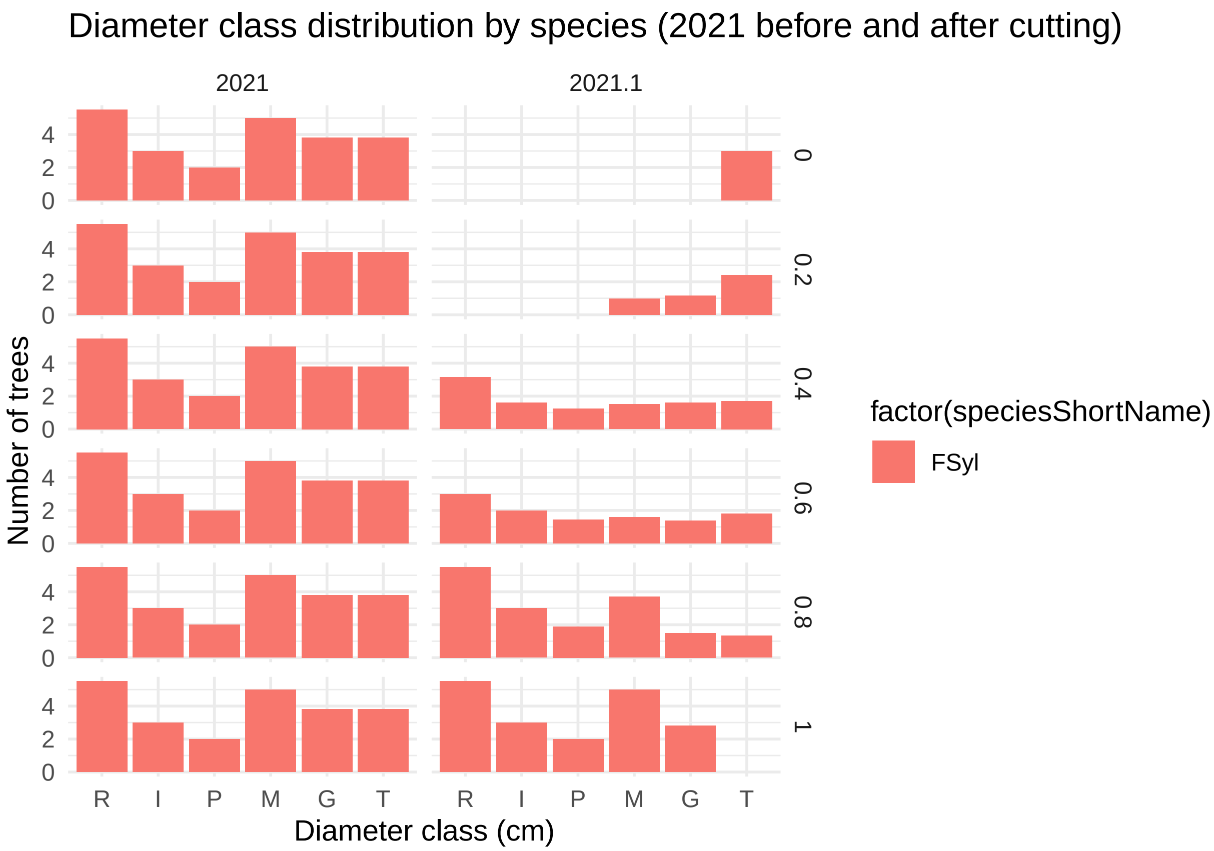



```
## `summarise()` has grouped output by 'date'. You can override using the
```

```
## `.groups` argument.
```



Diameter class distribution in 2021 and just after cutting



Conclusion

The study shows that the `param_type` parameter plays a key role in modulating cutting selectivity. A low value (close to 0) favors cutting the smallest trees with strong selectivity. As `param_type` approaches 0.5, both the average diameter of cut trees increases and the randomness of selection rises, resulting in less precise targeting. At `param_type = 0.5`, cutting is totally random. A high value (close to 1) targets the largest trees.

References

- Forceps model code