LIÈGE université
Gembloux
Agro-Bio Tech

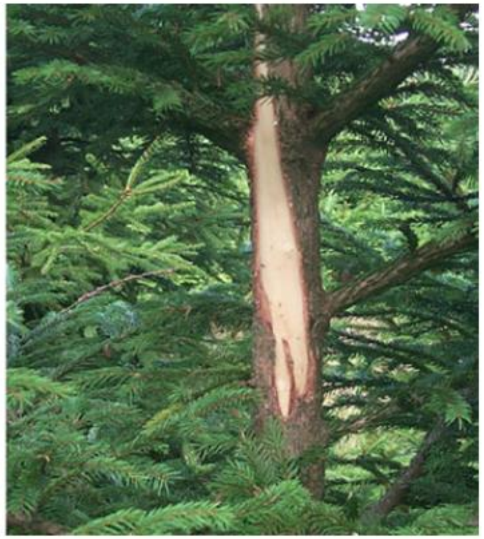
From the simulation of forest plantation dynamics to the quantification of bark-stripping damage by ungulates

Gauthier Ligot, Thibaut Gheysen, Jérôme Perin, Romain Candaele, François de Coligny, Alain Licoppe, Philippe Lejeune

FOREM 2023
Grenoble

Bark-stripping damage

- Excessive ungulate densities induce different damage
- Including bark-stripping damage
- Wounded tissues often get infected (*Stereum sanguinolentum*)
- Rot might develop in the stems
- Particularly for Norway spruce
- Timber production losses

Protections against bark-stripping damage

Plastic sleeves

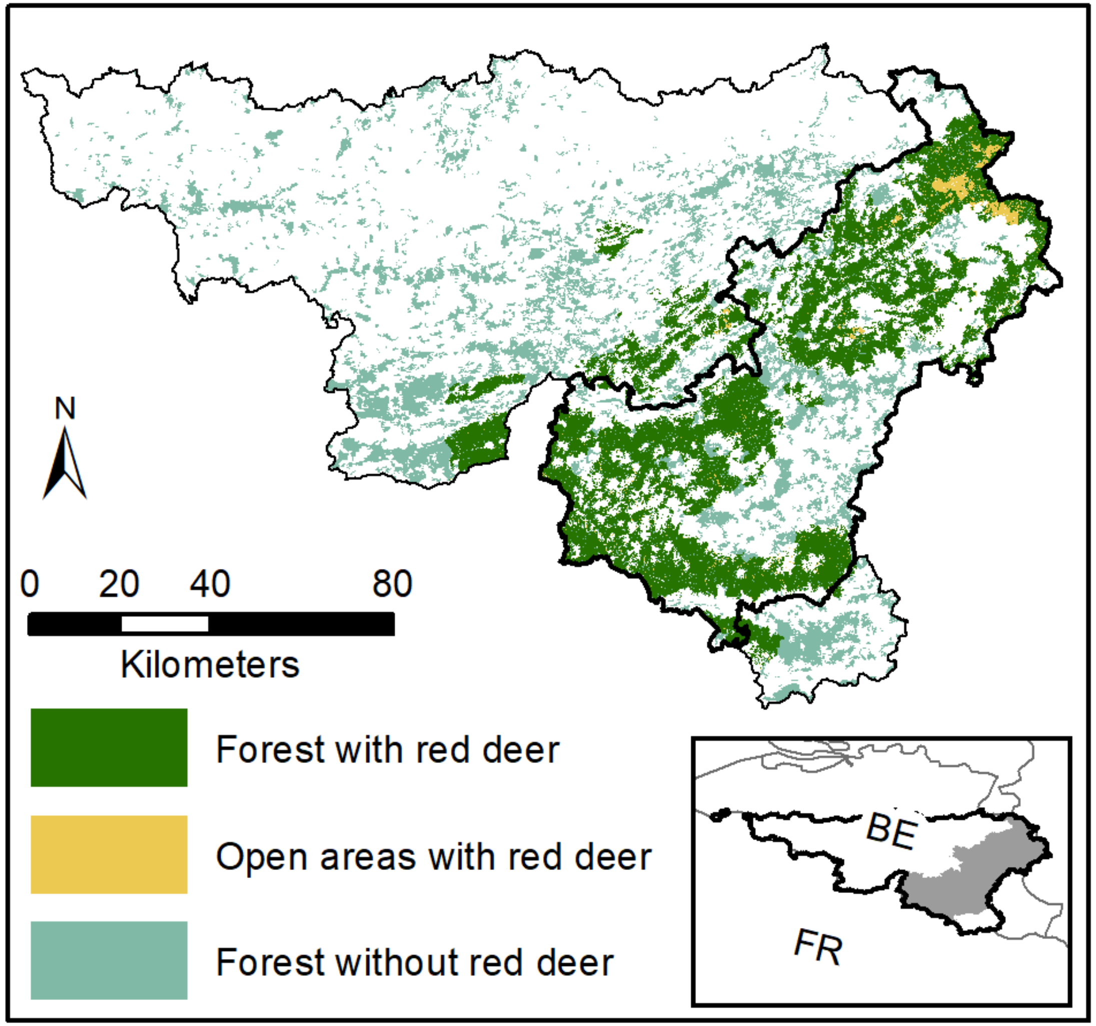
Gerstner plane

Fence

Research objectives

- Model stand dynamics and bark-stripping damage
- Virtual experiment
  - Assess the financial losses due to bark-stripping damages
  - Should rotation be shortened in highly impacted stands?
  - Is it cost-effective to protect the plantations with fences or individual protections?

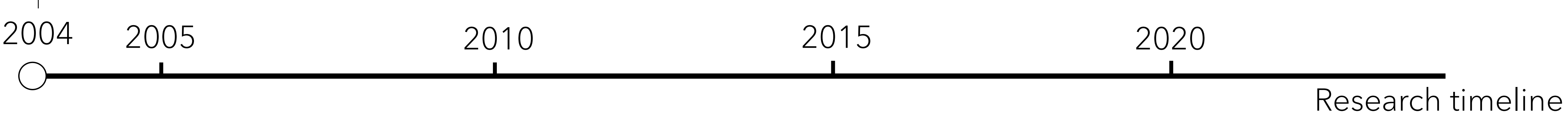
Study area

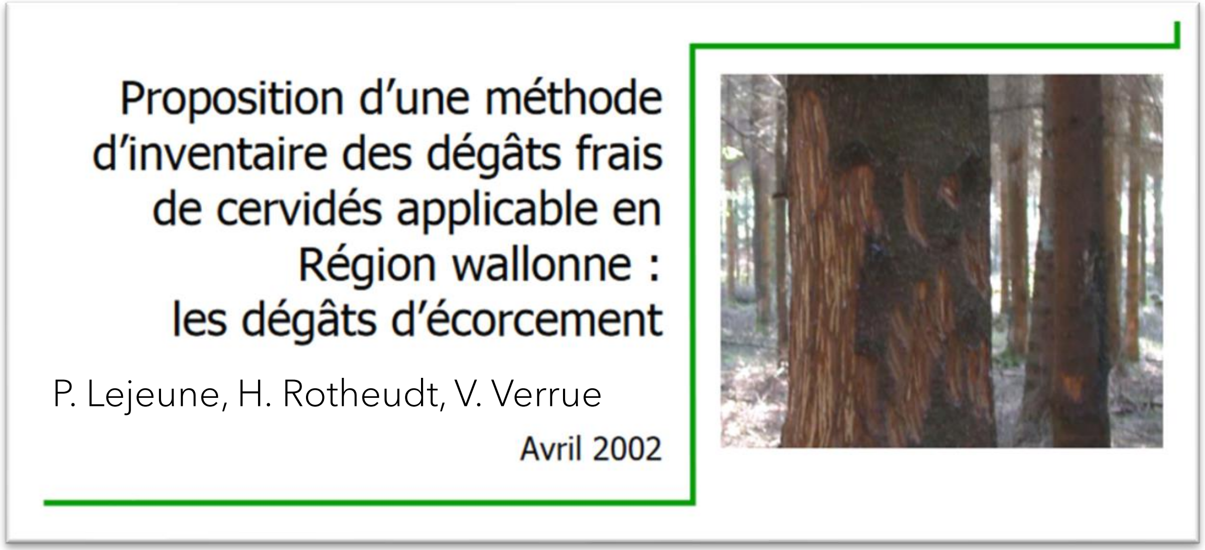


- Mostly in Ardenne
- 20 – 700 m a.s.l.
- 7.5 – 10.5 °C
- 800 – 1400 mm/year
- Norway spruce plantation =
  - 26% of forest area (92% in Ardenne)
  - 50% of the timber production in Wallonia
- Red deer : 0 - 16.5 deer/km^2
  0 - 6.7 shot deer/year/km^2

Bark-stripping inventory

Start of the permanent **monitoring** of bark-stripping damage in Wallonia

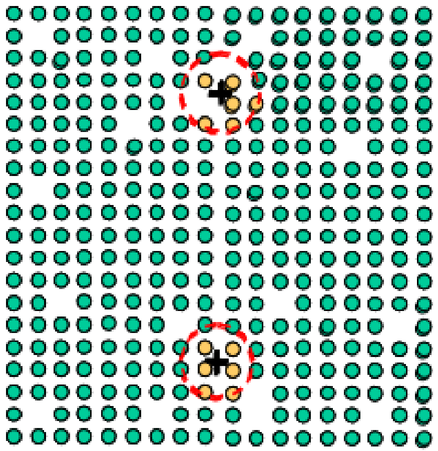




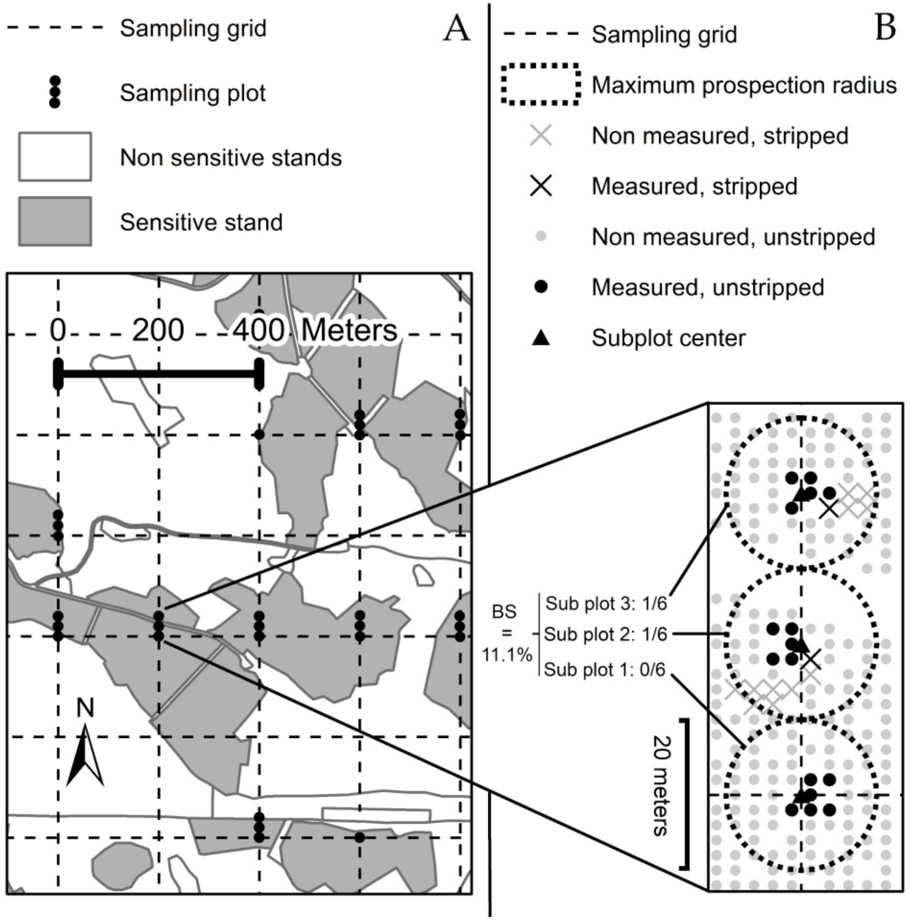
Proposition d'une méthode d'inventaire des dégâts frais de cervidés applicable en Région wallonne : les dégâts d'écorcement

P. Lejeune, H. Rotheudt, V. Verrue

Avril 2002

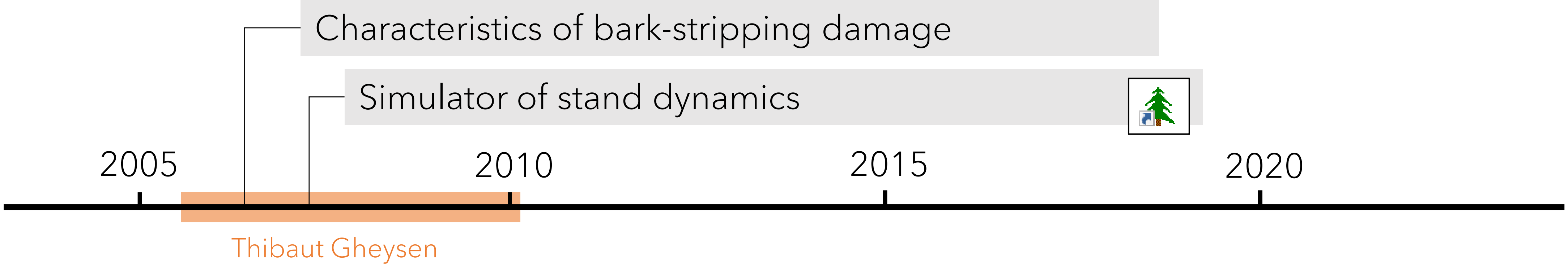


Bark-stripping inventory



- 200 x 200 sampling grid
- Random selection of grid nodes
- Stands 8-36 years old
- 3 circular subplots / node
- Measurements of the 6 closest trees
  - Dbh, bark-stripping damage, …

The factors driving bark-stripping damage



Environ Monit Assess
DOI 10.1007/s10661-010-1832-6

A regional inventory and monitoring setup to evaluate bark peeling damage by red deer (*Cervus elaphus*) in coniferous plantations in Southern Belgium

Thibaut Gheysen · Yves Brostaux · Jacques Hébert · Gauthier Ligot · Jacques Rondeux · Philippe Lejeune

2010

- Damage dimensions
- Bark-stripping rate variability

Annals of Forest Science
DOI 10.1007/s13595-012-0253-9

ORIGINAL PAPER

Modeling recent bark stripping by red deer (*Cervus elaphus*) in South Belgium coniferous stands

Gauthier Ligot · Thibaut Gheysen · François Lehaire · Jacques Hébert · Alain Licoppe · Philippe Lejeune · Yves Brostaux

2012

Variable
Intercept
Sqrt(DeerDensity)
Altitude
$SnowCover^2$
AgriProp
UrbanDist
1/SaplingDiversity

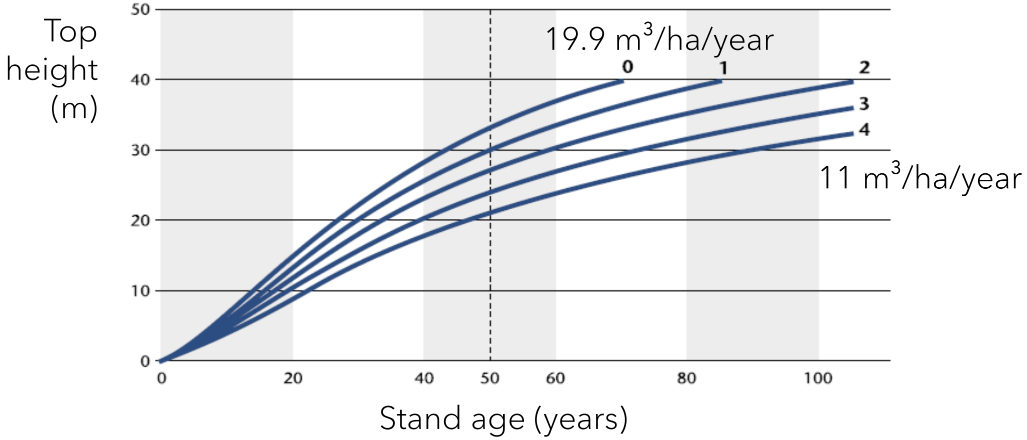
- Bark-stripping rate in response to environmental factors

Top-height growth

Modelling top-height growth (Spruce, Douglas-fir, larch)

2005 2010 2015 2020

Jérôme Perin



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journal homepage: www.elsevier.com/locate/foreco

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Modelling the top-height growth and site index of Norway spruce in Southern Belgium

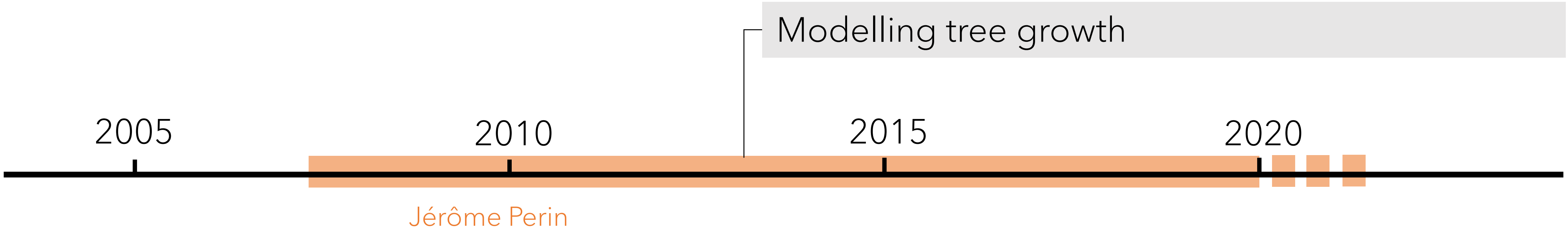
Jérôme Perin [a,*], Jacques Hébert [a], Yves Brostaux [b], Philippe Lejeune [a], Hugues Claessens [a]

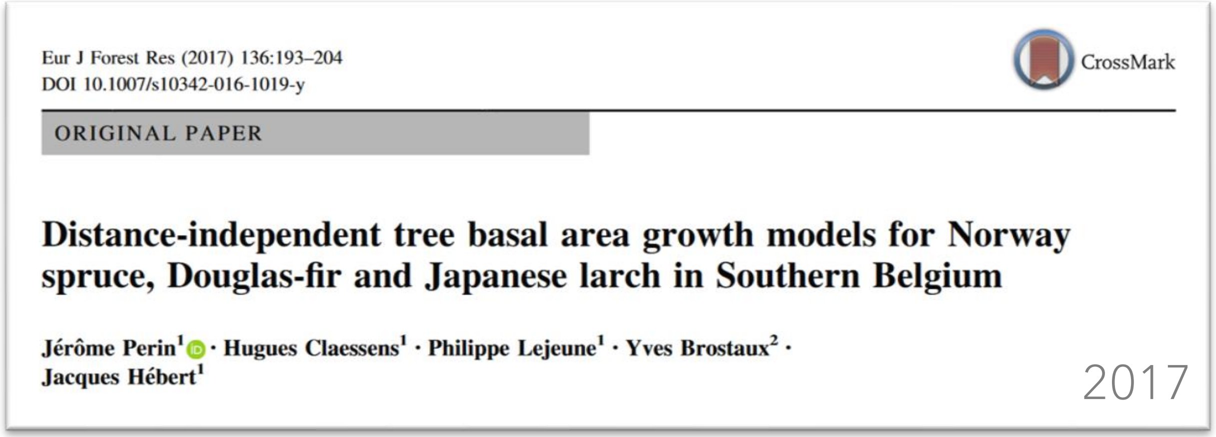
[a] Unit of Forest and Nature Management, Gembloux Agro-Bio Tech, University of Liege, 2 Passage des Déportés, 5030 Gembloux, Belgium

[b] Applied Statistics, Computer Science and Mathematics, Gembloux Agro-Bio Tech, University of Liege, 2 Passage des Déportés, 5030 Gembloux, Belgium

2013

Tree growth



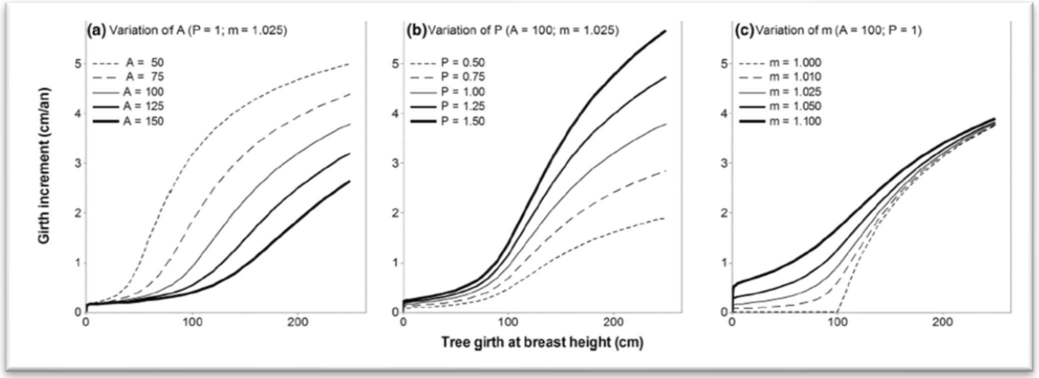

Eur J Forest Res (2017) 136:193–204
DOI 10.1007/s10342-016-1019-y
CrossMark

ORIGINAL PAPER

Distance-independent tree basal area growth models for Norway spruce, Douglas-fir and Japanese larch in Southern Belgium

Jérôme Perin[1] · Hugues Claessens[1] · Philippe Lejeune[1] · Yves Brostaux[2] · Jacques Hébert[1]

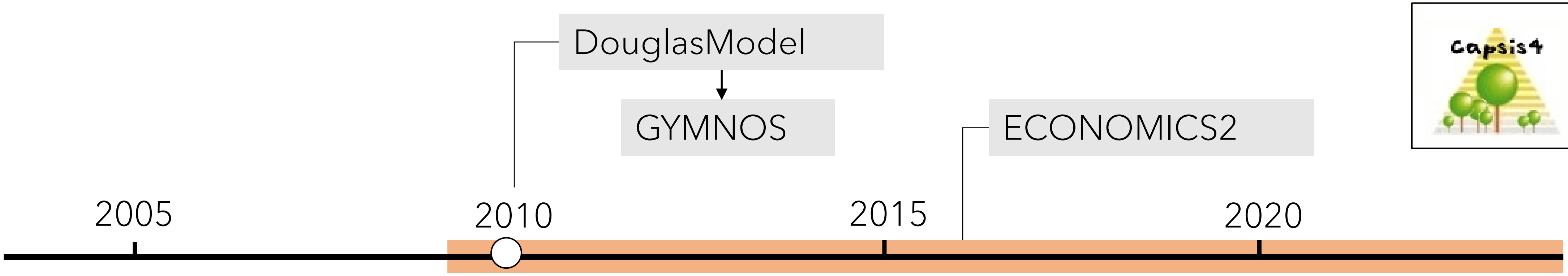
2017



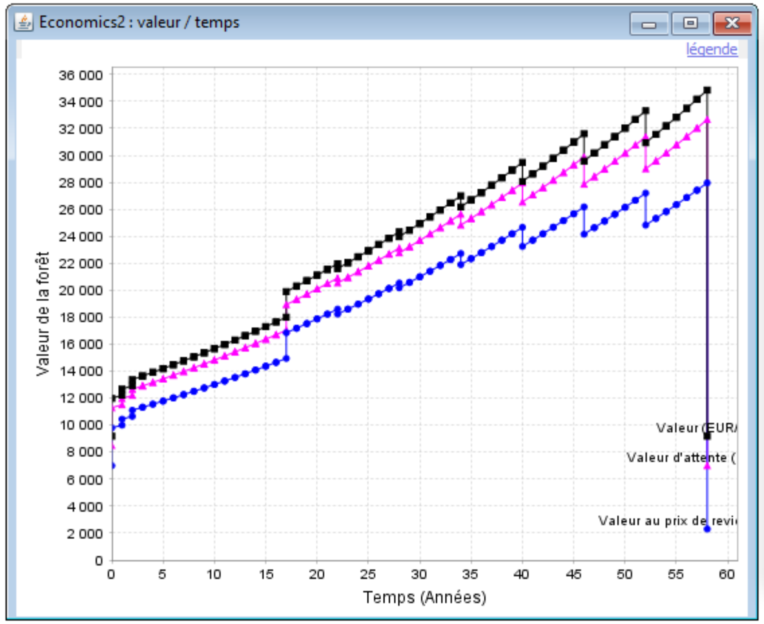
Tree basal area increment

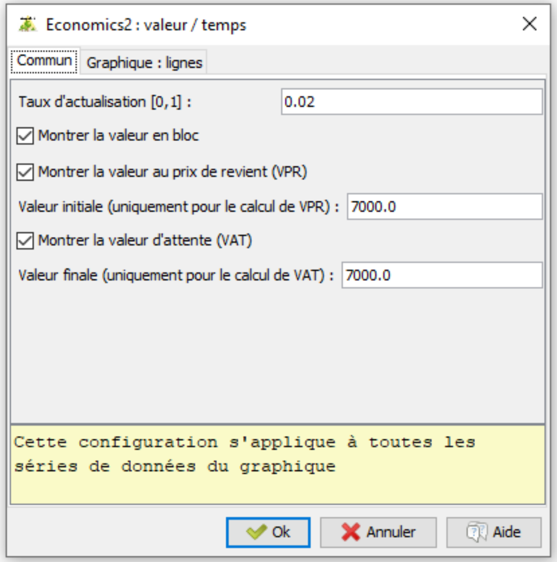
= f(top height, basal area, dbh)

Stand dynamics model



Gauthier Ligot, Jérome Perin, Samuel Quevauvillers





Stand dynamics model

- Distance-independant tree model
- Even-aged stands of Norway spruce, douglas fir, larch
- Yield tables

De nouvelles normes sylvicoles pour les futaies pures équiennes d'épicéa et de douglas en appui à la gestion de la forêt publique en Wallonie

Jérôme Perin | Jacques Hébert | Philippe Lejeune | Hugues Claessens
Unité de Gestion des Ressources forestières (ULg-GxABT)

Avec plus de 150 000 ha, l'épicéa et le douglas couvrent ensemble près du tiers de la forêt wallonne. Ces nouvelles normes sylvicoles, mises au point grâce à des outils de simulation, reflètent les orientations que le DNF souhaite insuffler dans les pessières et douglasaies qu'il gère en futaies pures équiennes.

RÉSUMÉ

L'importance de l'épicéa et du douglas pour notre filière bois n'est plus à démontrer. Les pessières et les douglasaies occupent en effet près du tiers de la surface productive de la forêt en Wallonie et représentent la moitié du volume sur pied. Néanmoins, les scénarios de gestion communément appliqués à ces deux essences ne font pas toujours l'unanimité auprès des acteurs de la filière-bois. Par ailleurs, les dernières études de productivité menées sur ces deux essences ont mis en évidence que leur potentiel de croissance était parfois sous-estimé. Il apparaissait dès lors utile de répercuter ces avancées scientifiques sous la forme d'outils d'aide à la décision (normes sylvicoles et tables de production) en faisant ressortir les spécificités de ces deux essences.

Stand dynamics model

Process	Equation	
Top height	$\mathrm{Hdom}_y = (0.130 \cdot \mathrm{age}_y + bi) \cdot \left(1 - \exp(-\frac{\mathrm{age}_y}{22.4})\right)^{2.05}$	(1)
	$bi = \frac{\mathrm{Hdom}_{50}}{(1-\exp(-(\frac{50}{22.4}))^{2.05}} - 0.130 \cdot 50$	
Stand initialization	$\mathrm{gbh}_i \sim Log\text{-}\mathcal{N}(\mu_i, \sigma^2); \quad \mu_i = 0.5 \cdot log(cg^2) - \sigma^2; \quad \sigma = 0.0245 \cdot N^{0.317}$	(2)
	$cg = \left(\frac{40000 \cdot \pi \cdot 13.3 \cdot \mathrm{rdi}}{N}\right)^{1/1.65}; \quad \mathrm{rdi} = 1 - \exp(-2.61 \cdot 10^{-6} \cdot N \cdot \mathrm{Hdom}^2)$	
H-D allometry	$h_i = 0.799 \cdot \mathrm{Hdom} \cdot \arctan\left(\tan(\frac{1}{0.799}) \cdot \frac{\mathrm{gbh}_i}{Gdom}\right)\left(\tan(\frac{1}{0.799}) \cdot \frac{\mathrm{gbh}_i}{Gdom}\right)$	(3)
Girth growth ($h_i \geq 10$)	$\Delta \mathrm{gbh}_i = (\mathrm{gbh}_{i,y-1}^2 + \Delta g_i \cdot 4 \cdot \pi)^{0.5} - \mathrm{gbh}_{i,y-1}$	(4)
	$\Delta g_i = \frac{P}{2} \cdot \left(\mathrm{gbh}_{i,y-1} - M \cdot A + ((M \cdot A + \mathrm{gbh}_{i,y-1})^2) - 4 \cdot A \cdot \mathrm{gbh}_{i,y-1})^{0.5}\right)$	
	$A = 3.98 \cdot \mathrm{Hdom}_y^{0.780}; \quad P = 0.216 + 0.801 \cdot (\mathrm{Hdom}_y - \mathrm{Hdom}_{y-1})$	
	$M = 1 + \exp(0.135 \cdot \mathrm{Hdom}_y - 0.185 \cdot BA_{y-1})$	
Girth growth ($h_i < 10$)	$\Delta \mathrm{gbh}_i = \exp(\log(\mathrm{gbh}_{i,y-1}) + \mu_{i,y} - \mu_{i,y-1}) + \mathrm{gbh}_{i,y-1}$	(5)
Height growth	$\Delta h_i = 0.799 \cdot (\mathrm{Hdom}_y - \mathrm{Hdom}_{y-1}) \cdot \arctan\left(\tan(\frac{1}{0.799}) \cdot \frac{\mathrm{gbh}_{i,y}}{Gdom_{y-1}}\right)$	(6)
Timber volume	$V_i = 0.0135 - 0.00128 \cdot \mathrm{gbh}_i + 0.0000457 \cdot \mathrm{gbh}_i^2 - 7.70 \cdot 10^{-8}.\mathrm{gbh}_i^3$	(7)
	$-0.00114 \cdot \mathrm{Hdom} + 2.58 \cdot 10^{-6} \cdot \mathrm{gbh}_i^2 \cdot \mathrm{Hdom}$	
Taper function	$g10_i = 5.36 + 1.07 \cdot \mathrm{gbh}_i - 0.00194 \cdot \mathrm{gbh}_i^2 + 7.47 \cdot 10^{-7} \cdot \mathrm{gbh}_i^3$	(8)
	$-0.416 \cdot h_i + 2.86 \cdot 10^{-5} \cdot \mathrm{gbh}_i^2 \cdot h_i$	
	$g_{h,i} = a_h + b_h \cdot g10_i + \frac{c_h}{g10_i^2}$	(9)
Tree mortality	$\mathrm{rdi} = \frac{N}{N_{\max}}; \quad N_{\max} = 40000 \cdot \pi \cdot 13.286 \cdot cg^{-1.65}$	(10)
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Thinning	$s_i = S \cdot u_i + (1 - S) \cdot \frac{\mathrm{gbh}_i - \mathrm{gbh}^*}{m}; \quad u_i \sim U[0,1]$	(13)
	$\mathrm{gbh}^* = T \cdot (\max(\mathrm{gbh}) - \min(\mathrm{gbh})) + \min(\mathrm{gbh})$	
	$m = \max(\mathrm{gbh}^* - \min(\mathrm{gbh}), \max(\mathrm{gbh}) - \mathrm{gbh}^*) + 1$	
	$\frac{\mathrm{cut}_{\mathrm{damaged}}/N_{\mathrm{damaged}}}{\mathrm{cut}_{\mathrm{healthy}}/N_{\mathrm{healthy}}} = 1.5$	(14)
Bark-stripping rate	$\tau_{\mathrm{summer},s} = f_{\mathrm{summer}}(\mathrm{age}_s; \mu = 3.08, \theta = 0.194) \cdot \frac{\mathrm{BSR} \cdot (36-8)}{0.854} \cdot 0.2$	(15)
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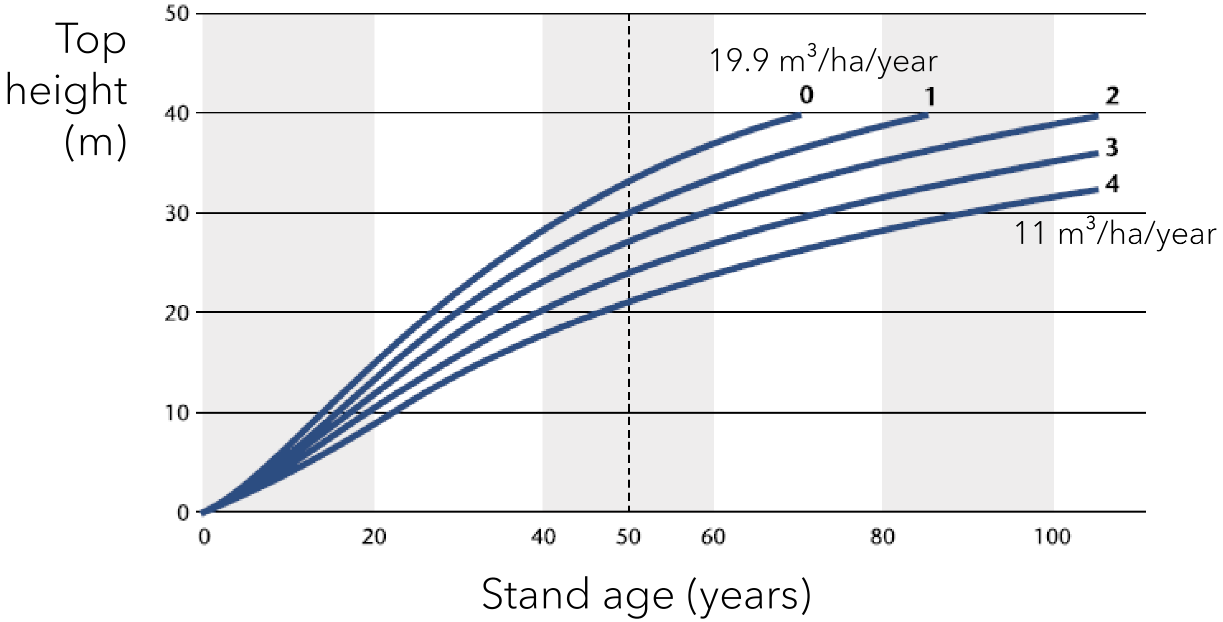
Decay spread	$dl = \exp(0.769 + 0.336 \cdot \log(Ks) + 0.150 \cdot \log(w) + 0.605 \cdot \log(l)$	(18)
	$+0.336 \cdot \log(p) + 0.545 \cdot \log(rw))$	

Stand dynamics model



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Stand dynamics model

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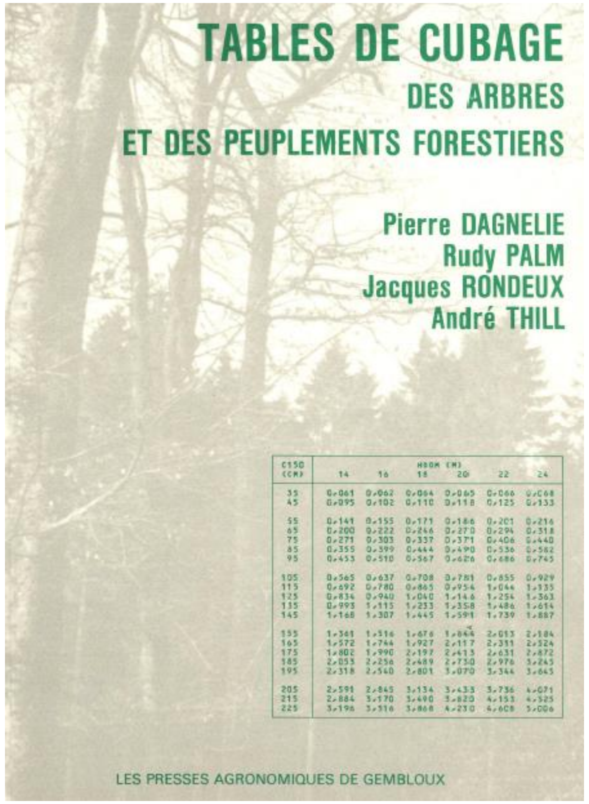
Stand dynamics model

- Relations allométriques



1985

2013

Process	Equation	
Top height	$\text{Hdom}_y = (0.130 \cdot \text{age}_y + bi) \cdot \left(1 - \exp(-\frac{\text{age}_y}{22.4})\right)^{2.05}$	(1)
	$bi = \frac{\text{Hdom}_{50}}{(1-\exp(-(\frac{50}{22.4}))^{2.05}} - 0.130 \cdot 50$	
Stand initialization	$\text{gbh}_i \sim Log\text{-}\mathcal{N}(\mu_i, \sigma^2); \quad \mu_i = 0.5 \cdot log(cg^2) - \sigma^2; \quad \sigma = 0.0245 \cdot N^{0.317}$	(2)
	$cg = \left(\frac{40000 \cdot \pi \cdot 13.3 \cdot \text{rdi}}{N}\right)^{1/1.65}; \quad \text{rdi} = 1 - \exp(-2.61 \cdot 10^{-6} \cdot N \cdot \text{Hdom}^2)$	
H-D allometry	$h_i = 0.799 \cdot \text{Hdom} \cdot \arctan\left(\tan(\frac{1}{0.799}) \cdot \frac{\text{gbh}_i}{\text{Gdom}}\right)\left(\tan(\frac{1}{0.799}) \cdot \frac{\text{gbh}_i}{\text{Gdom}}\right)$	(3)
Girth growth ($h_i \geq 10$)	$\Delta\text{gbh}_i = (\text{gbh}_{i,y-1}^2 + \Delta g_i \cdot 4 \cdot \pi)^{0.5} - \text{gbh}_{i,y-1}$	(4)
	$\Delta g_i = \frac{P}{2} \cdot \left(\text{gbh}_{i,y-1} - M \cdot A + ((M \cdot A + \text{gbh}_{i,y-1})^2) - 4 \cdot A \cdot \text{gbh}_{i,y-1})^{0.5}\right)$	
	$A = 3.98 \cdot \text{Hdom}_y^{0.780}; \quad P = 0.216 + 0.801 \cdot (\text{Hdom}_y - \text{Hdom}_{y-1})$	
	$M = 1 + \exp(0.135 \cdot \text{Hdom}_y - 0.185 \cdot BA_{y-1})$	
Girth growth ($h_i < 10$)	$\Delta\text{gbh}_i = \exp(\log(\text{gbh}_{i,y-1}) + \mu_{i,y} - \mu_{i,y-1}) + \text{gbh}_{i,y-1}$	(5)
Height growth	$\Delta h_i = 0.799 \cdot (\text{Hdom}_y - \text{Hdom}_{y-1}) \cdot \arctan\left(\tan(\frac{1}{0.799}) \cdot \frac{\text{gbh}_{i,y}}{\text{Gdom}_{y-1}}\right)$	(6)
Timber volume	$V_i = 0.0135 - 0.00128 \cdot \text{gbh}_i + 0.0000457 \cdot \text{gbh}_i^2 - 7.70 \cdot 10^{-8} . \text{gbh}_i^3$	(7)
	$-0.00114 \cdot \text{Hdom} + 2.58 \cdot 10^{-6} \cdot \text{gbh}_i^2 \cdot \text{Hdom}$	
Taper function	$g10_i = 5.36 + 1.07 \cdot \text{gbh}_i - 0.00194 \cdot \text{gbh}_i^2 + 7.47 \cdot 10^{-7} \cdot \text{gbh}_i^3$	(8)
	$-0.416 \cdot h_i + 2.86 \cdot 10^{-5} \cdot \text{gbh}_i^2 \cdot h_i$	
	$g_{h,i} = a_h + b_h \cdot g10_i + \frac{c_h}{g10_i^2}$	(9)
Tree mortality	$\text{rdi} = \frac{N}{N_{\max}}; \quad N_{\max} = 40000 \cdot \pi \cdot 13.286 \cdot cg^{-1.65}$	(10)
	$\text{rdi}_{\max} = \text{rdi}_{y-1} + (1 - \min(1, \text{rdi}_{y-1}^{8.5}))(\text{rdi} - \text{rdi}_{y-1}) - 0.5 \max(0, \text{rdi}_{y-1} - 1)$	(11)
	$s_i = u_i \cdot \frac{\text{gbh}_i - \min(\text{gbh})}{\max(\text{gbh}) - \min(\text{gbh})}; \quad u_i \sim U[0,1]$	(12)
Thinning	$s_i = S \cdot u_i + (1 - S) \cdot \frac{\text{gbh}_i - \text{gbh}^*}{m}; \quad u_i \sim U[0,1]$	(13)
	$\text{gbh}^* = T \cdot (\max(\text{gbh}) - \min(\text{gbh})) + \min(\text{gbh})$	
	$m = \max(\text{gbh}^* - \min(\text{gbh}), \max(\text{gbh}) - \text{gbh}^*) + 1$	
	$\frac{\text{cut}_{\text{damaged}}/N_{\text{damaged}}}{\text{cut}_{\text{healthy}}/N_{\text{healthy}}} = 1.5$	(14)
Bark-stripping rate	$\tau_{\text{summer},s} = f_{\text{summer}}(\text{age}_s; \mu = 3.08, \theta = 0.194) \cdot \frac{\text{BSR}\cdot(36-8)}{0.854} \cdot 0.2$	(15)
	$\tau_{\text{winter},s} = f_{\text{winter}}(\text{age}_s; \mu = 2.68, \theta = 0.440) \cdot \frac{\text{BSR}\cdot(36-8)}{0.950} \cdot 0.8$	(16)
Prob. of damage	$P(\text{being damaged}, i) = 0.0144 \cdot dbh_i \cdot \exp(-0.125 \cdot dbh_i) + \epsilon_i$	(17)
	$\epsilon_i \sim \mathcal{N}(0, 5.27 \cdot 10^{-3})$	
Decay spread	$dl = \exp(0.769 + 0.336 \cdot \log(Ks) + 0.150 \cdot \log(w) + 0.605 \cdot \log(l)$	(18)
	$+0.336 \cdot \log(p) + 0.545 \cdot \log(rw))$	

Bark-stripping models

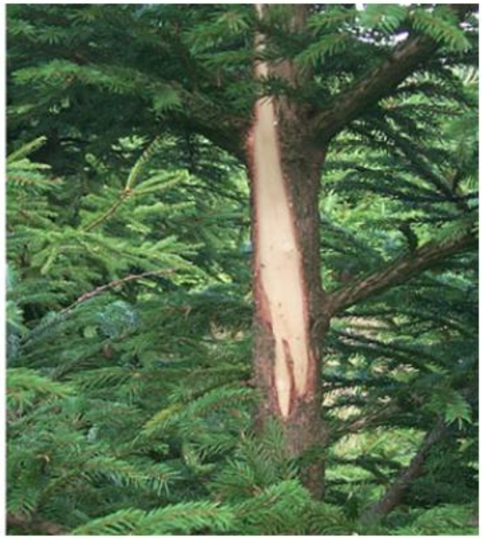
95% of the damage occurs on 8-36 year-old tree

Process	Equation	
Top height	$Hdom_y = (0.130 \cdot age_y + bi) \cdot \left(1 - \exp(-\frac{age_y}{22.4})\right)^{2.05}$	(1)
	$bi = \frac{Hdom_{50}}{(1-\exp(-(\frac{50}{22.4}))^{2.05}} - 0.130 \cdot 50$	
Stand initialization	$gbh_i \sim Log\text{-}\mathcal{N}(\mu_i, \sigma^2)$; $\mu_i = 0.5 \cdot log(cg^2) - \sigma^2$; $\sigma = 0.0245 \cdot N^{0.317}$	(2)
	$cg = \left(\frac{40000 \cdot \pi \cdot 13.3 \cdot rdi}{N}\right)^{1/1.65}$; $rdi = 1 - \exp(-2.61 \cdot 10^{-6} \cdot N \cdot Hdom^2)$	
H-D allometry	$h_i = 0.799 \cdot Hdom \cdot arctan\left(tan(\frac{1}{0.799}) \cdot \frac{gbh_i}{Gdom}\right)\left(tan(\frac{1}{0.799}) \cdot \frac{gbh_i}{Gdom}\right)$	(3)

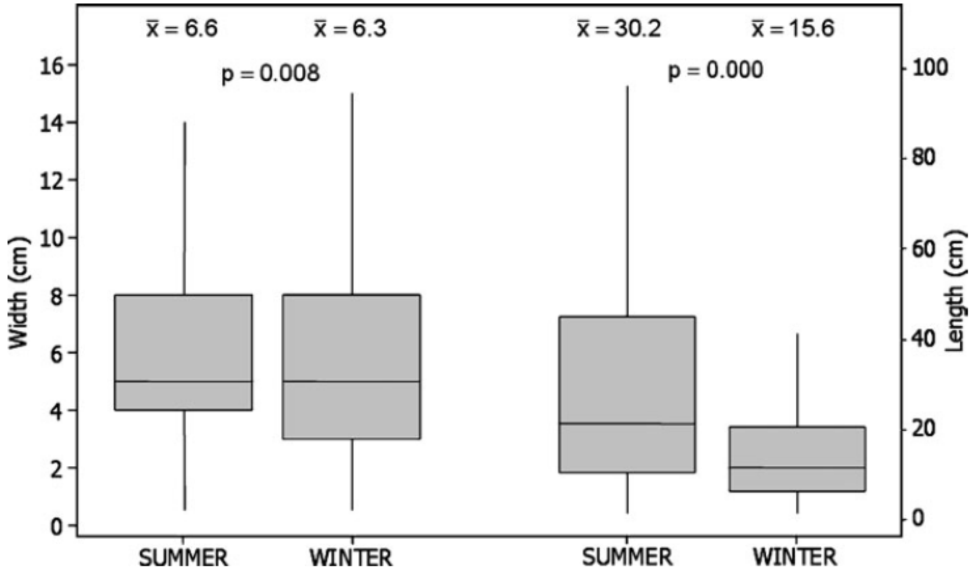
Winter damage
80%

Max. in 21-year-old plantations

Summer damage
20%



Max. in 12-year-old plantations



$gbh^* = T \cdot (\max(gbh) - \min(gbh)) + \min(gbh)$

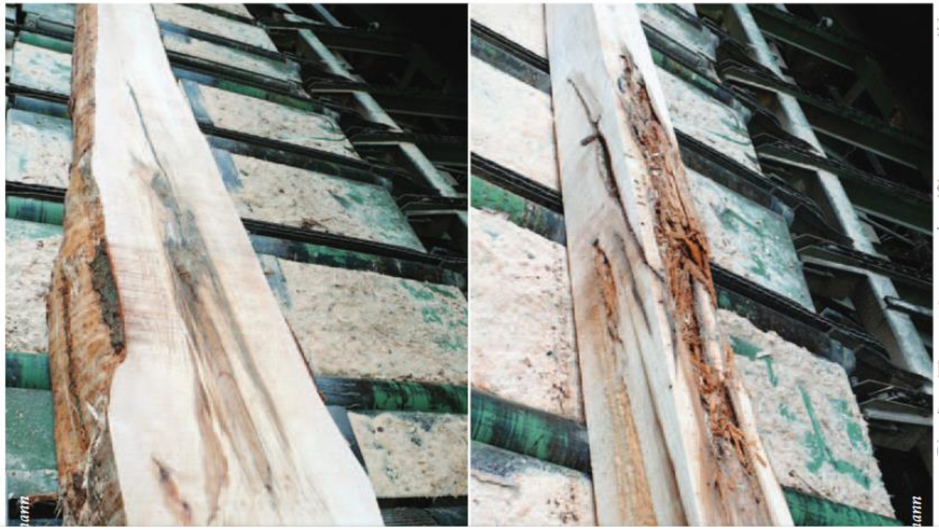
$m = \max(gbh^* - \min(gbh), \max(gbh) - gbh^*) + 1$

Variables	Season	Distribution	Parameter ± std. error	
Height (cm)	All	$Weibull(k, \delta)$	4.692 ± 0.034	112.421 ± 0.232
Width (cm)	All	$Log\text{-}\mathcal{N}(\mu, \theta^2)$	1.582 ± 0.006	0.634 ± 0.004
Length (cm)	Summer	$Log\text{-}\mathcal{N}(\mu, \theta^2)$	2.834 ± 0.022	0.922 ± 0.015
Length (cm)	Winter	$Log\text{-}\mathcal{N}(\mu, \theta^2)$	2.236 ± 0.007	0.704 ± 0.005

Decay spread

$+0.336 \cdot \log(p) + 0.545 \cdot \log(rw))$

Bark-stripping models



Zur Ausbreitung der Wundfäule in der Fichte

Von H. Löffler

Aus dem Institut für Forstliche Arbeitswissenschaft und Verfahrenstechnik der Forstlichen Forschungsanstalt München

Löffler 1975

Process	Equation	
Top height	$Hdom_y = (0.130 \cdot age_y + bi) \cdot \left(1 - \exp(-\frac{age_y}{22.4})\right)^{2.05}$	(1)
	$bi = \frac{Hdom_{50}}{(1-\exp(-(\frac{50}{22.4}))^{2.05}} - 0.130 \cdot 50$	
Stand initialization	$gbh_i \sim Log\text{-}\mathcal{N}(\mu_i, \sigma^2)$; $\mu_i = 0.5 \cdot log(cg^2) - \sigma^2$; $\sigma = 0.0245 \cdot N^{0.317}$	(2)
	$cg = \left(\frac{40000 \cdot \pi \cdot 13.3 \cdot rdi}{N}\right)^{1/1.65}$; $rdi = 1 - \exp(-2.61 \cdot 10^{-6} \cdot N \cdot Hdom^2)$	
	$\ldots 99 \cdot Hdom \cdot \arctan\left(\tan(\frac{1}{0.799}) \cdot \frac{gbh_i}{Gdom}\right)\left(\tan(\frac{1}{0.799}) \cdot \frac{gbh_i}{Gdom}\right)$	(3)
	$(gbh^2_{i,y-1} + \Delta g_i \cdot 4 \cdot \pi)^{0.5} - gbh_{i,y-1}$	(4)
	$\cdot \left(gbh_{i,y-1} - M \cdot A + ((M \cdot A + gbh_{i,y-1})^2) - 4 \cdot A \cdot gbh_{i,y-1})^{0.5}\right)$	
	$\ldots 3 \cdot Hdom_y^{0.780}$; $P = 0.216 + 0.801 \cdot (Hdom_y - Hdom_{y-1})$	
	$\cdot \exp(0.135 \cdot Hdom_y - 0.185 \cdot BA_{y-1})$	
	$\exp(\log(gbh_{i,y-1}) + \mu_{i,y} - \mu_{i,y-1}) + gbh_{i,y-1}$	(5)
	$\ldots 799 \cdot (Hdom_y - Hdom_{y-1}) \cdot \arctan\left(\tan(\frac{1}{0.799}) \cdot \frac{gbh_{i,y}}{Gdom_{y-1}}\right)$	(6)
	$\ldots 135 - 0.00128 \cdot gbh_i + 0.0000457 \cdot gbh_i^2 - 7.70 \cdot 10^{-8} . gbh_i^3$	(7)
	$\ldots 4 \cdot Hdom + 2.58 \cdot 10^{-6} \cdot gbh_i^2 \cdot Hdom$	
	$\ldots .36 + 1.07 \cdot gbh_i - 0.00194 \cdot gbh_i^2 + 7.47 \cdot 10^{-7} \cdot gbh_i^3$	(8)
	$h_i + 2.86 \cdot 10^{-5} \cdot gbh_i^2 \cdot h_i$	
		(9)
	$\ldots 13.286 \cdot cg^{-1.65}$	(10)
	$\ldots))(rdi - rdi_{y-1}) - 0.5 \max(0, rdi_{y-1} - 1)$	(11)
	$\ldots U[0,1]$	(12)
	$u_i \sim U[0,1]$	(13)
	$\ldots) + \min(gbh)$	
	$\ldots gbh) - gbh^*) + 1$	
		(14)
Bark-stripping rate	$\tau_{summer,s} = f_{summer}(age_s; \mu = 3.08, \theta = 0.194) \cdot \frac{BSR \cdot (36-8)}{0.854} \cdot 0.2$	(15)
	$\tau_{winter,s} = f_{winter}(age_s; \mu = 2.68, \theta = 0.440) \cdot \frac{BSR \cdot (36-8)}{0.950} \cdot 0.8$	(16)
Prob. of damage	$P(\text{being damaged}, i) = 0.0144 \cdot dbh_i \cdot \exp(-0.125 \cdot dbh_i) + \epsilon_i$	(17)
	$\epsilon_i \sim \mathcal{N}(0, 5.27 \cdot 10^{-3})$	
Decay spread	$dl = \exp(0.769 + 0.336 \cdot \log(Ks) + 0.150 \cdot \log(w) + 0.605 \cdot \log(l)$	(18)
	$+ 0.336 \cdot \log(p) + 0.545 \cdot \log(rw))$	

- Decay spread = f(wound dimensions, growth rate, time elapsed since damage, social status)
- Decay column reaches < 3 m in most cases (rarely up to 4 m)

Simulation plan

- 11 values of annual bark-stripping rates from 0 to 10%
- 5 site indexes : 21, 24, 27, 30, 33 m
- Thinnings as defined in the yield tables
- 4 protective treatments
  - No protection
  - Bark-scrapping 400 crop trees/ha
  - Bark-scrapping all trees
  - Fencing
- 5 répétitions

→ 1,100 simulations

Financial assessment

Timber price
estimated from 499 public sales in 2021 (0.4 Mm^3).

Decayed timber : 5 €/m^3

Girth class (cm)	Price (€/m^3)
< 40	0.0
[40 – 50[	3.3
[50 – 60[	14.9
[60 – 70[	25.4
[70 – 80[	35.0
[80 – 90[	43.6
[90 – 100[	51.2
[100 – 110[	57.8
[110 – 120[	63.4
[120 – 130[	68.0
[130 – 140[	71.6
[140 – 150[	74.2
[150 – 160[	75.8
[160 – 170[	76.4
[170 – 180[	76.0
[180 – 190[	74.6
[190 – 200[	72.2
> 200	68.8

Costs
Market price list of FNEF (2022)
Fence = 6000 €/ha

Cost	Year	Price (€/ha)
Plantation	0	2400
Weeding	1	640
Weeding	3	640
Weeding	5	640
Pruning	17	1219

- Net present value

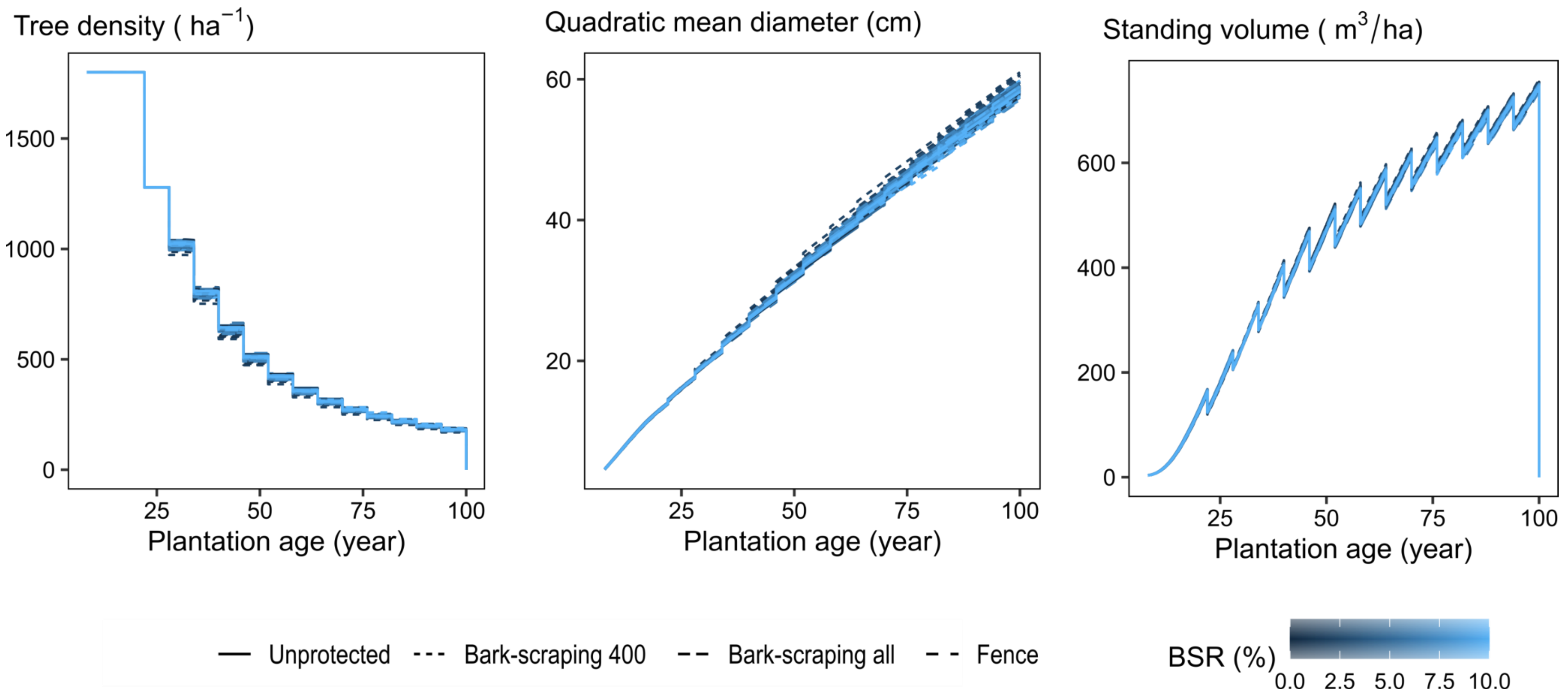
$$NPV = \frac{\sum_{i=0}^{n} R_{(i)} - C_{(i)}}{(1+r)^i}$$

$$NPV_{\infty} = NPV.\frac{(1+r)^n}{(1+r)^n - 1}$$

- Optimum rotation length (max. 100 years)

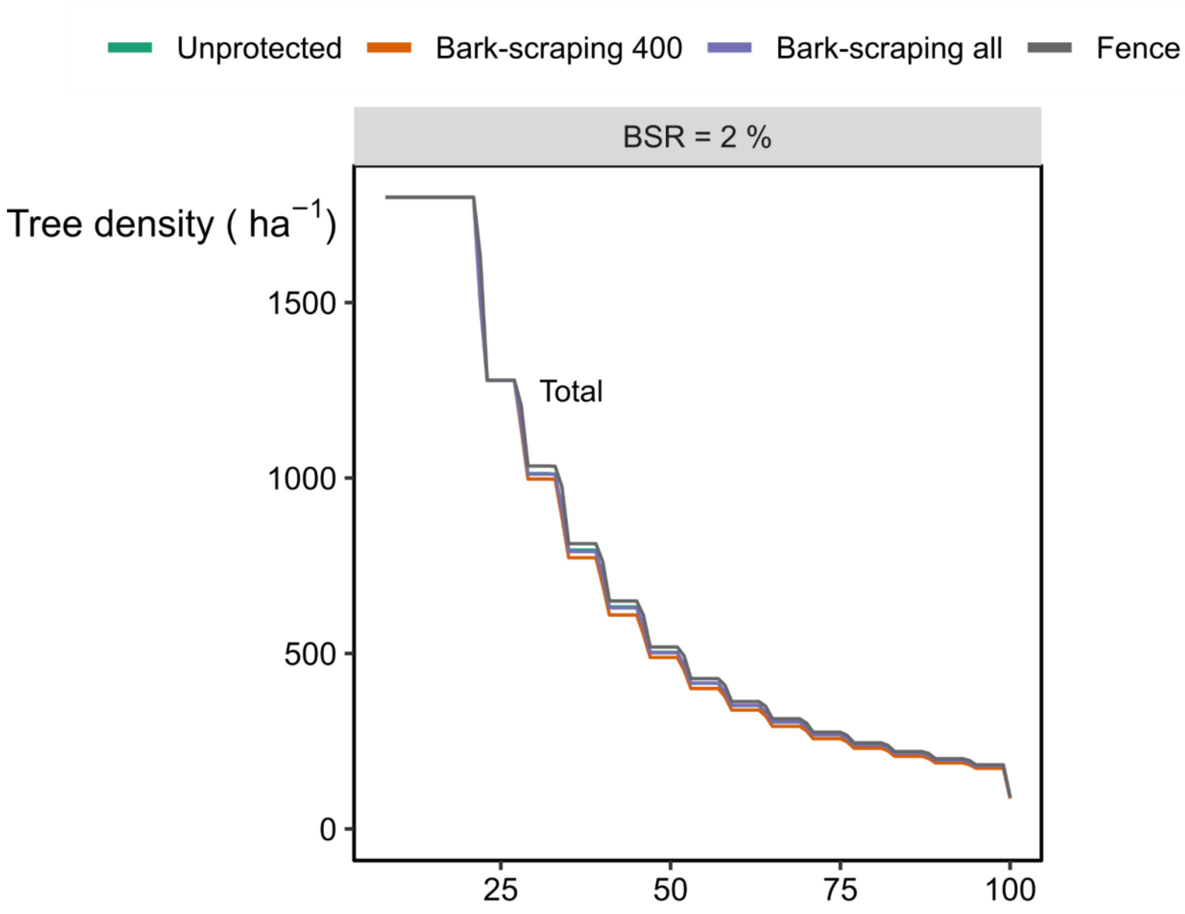
- r = 1%, 2%, 3%, 4%

Stand characteristics over time



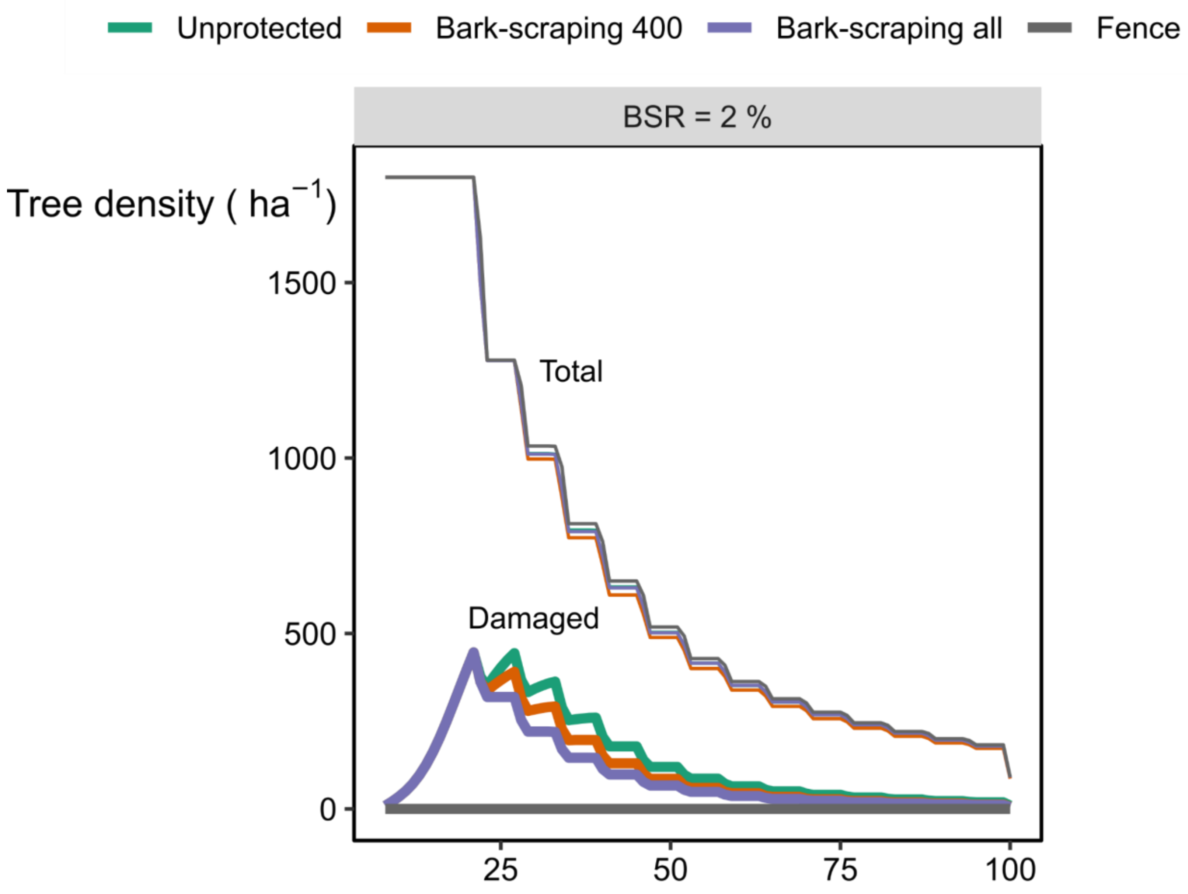
Site index = 27 m

Damage instances over time



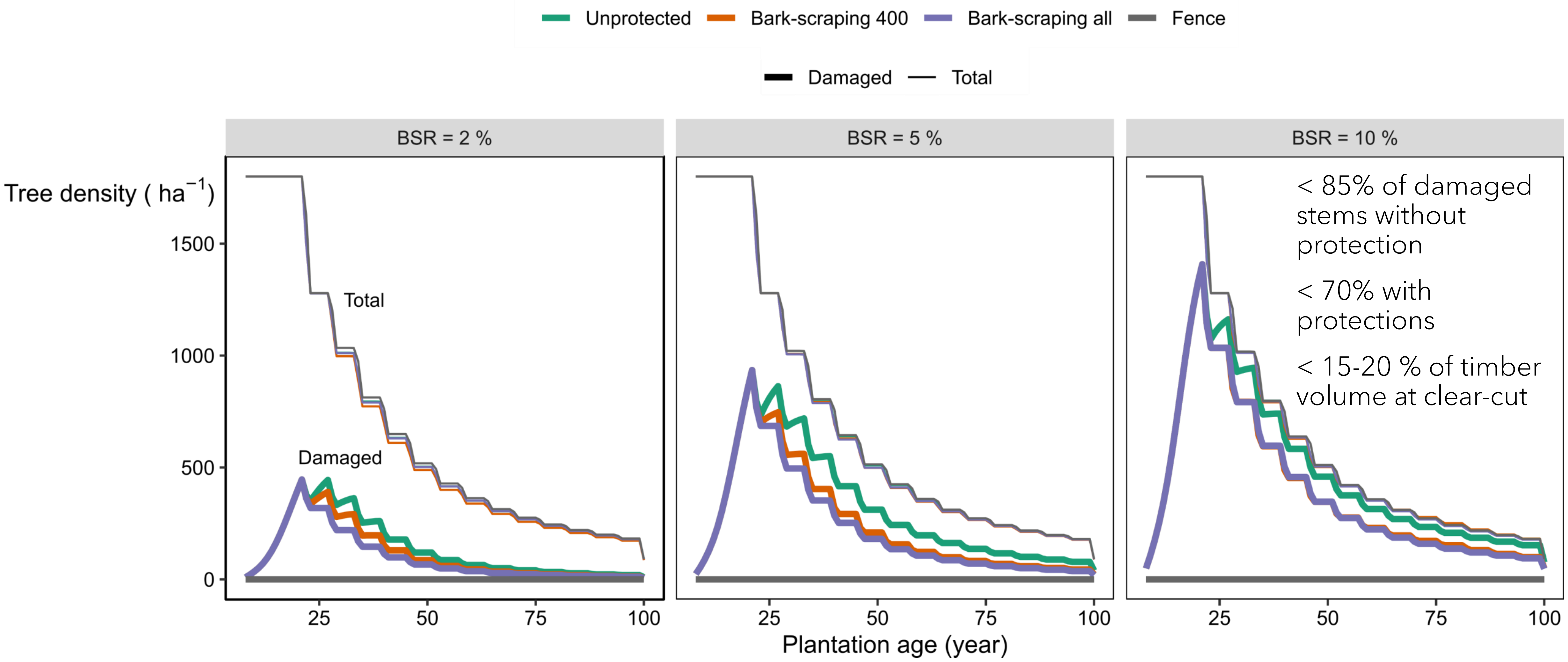
Site index = 27 m

Damage instances over time



Site index = 27 m

Damage instances over time



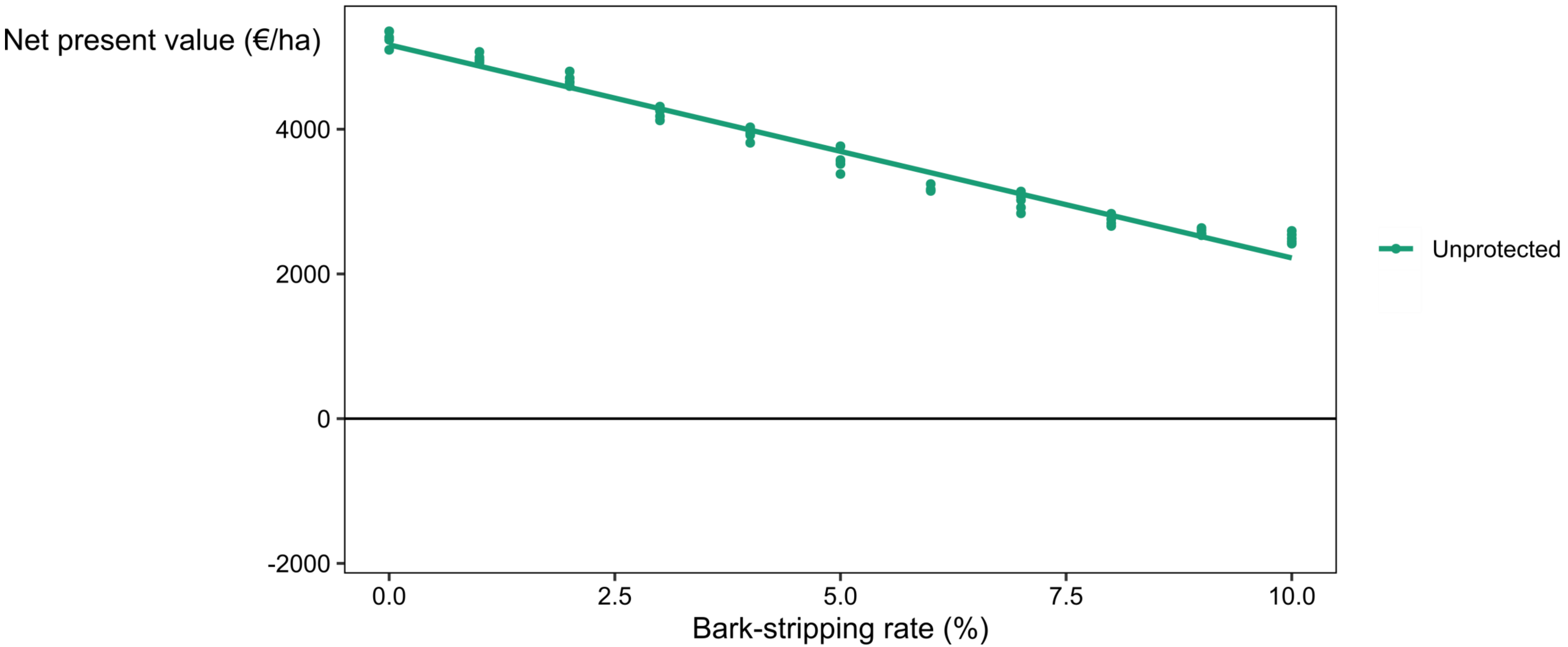
< 85% of damaged stems without protection

< 70% with protections

< 15-20 % of timber volume at clear-cut

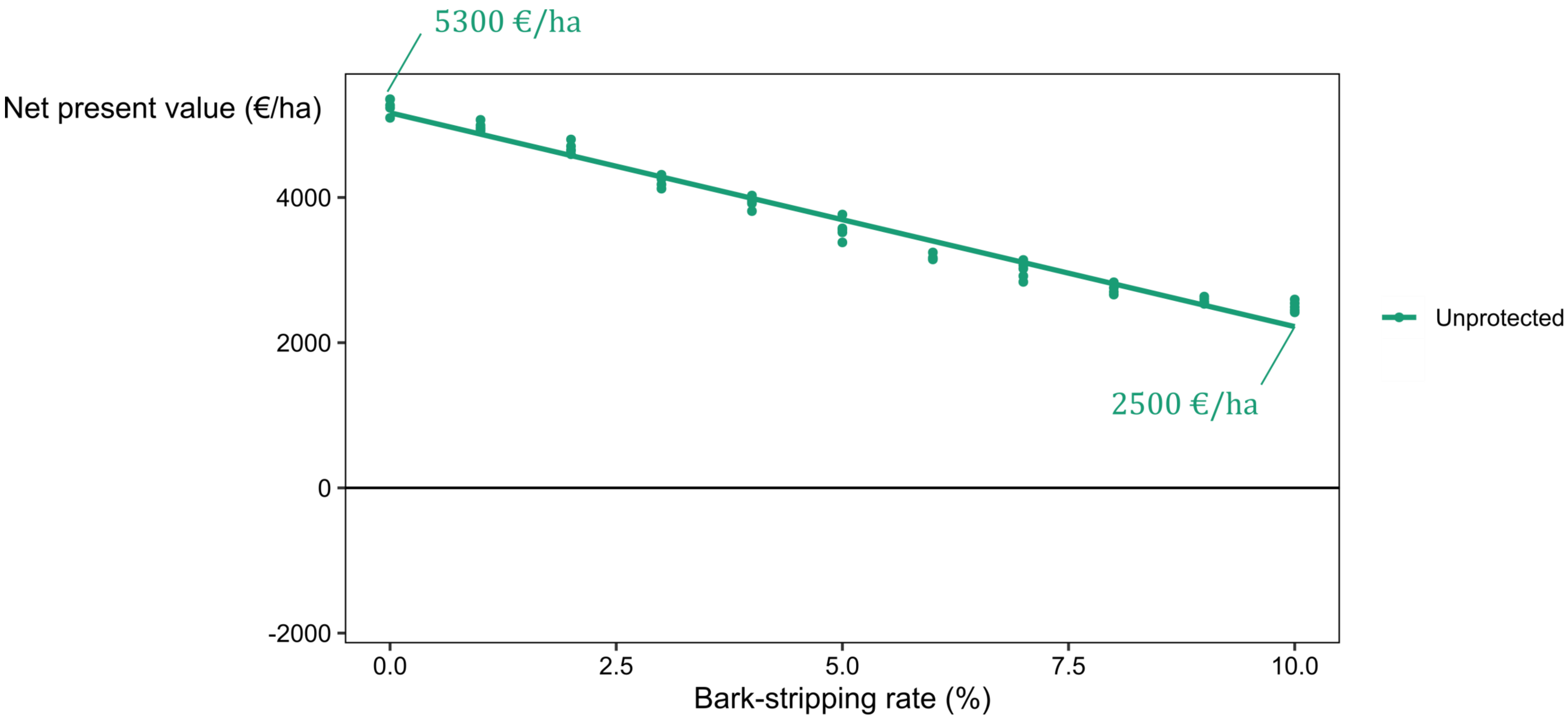
Site index = 27 m

Net present value



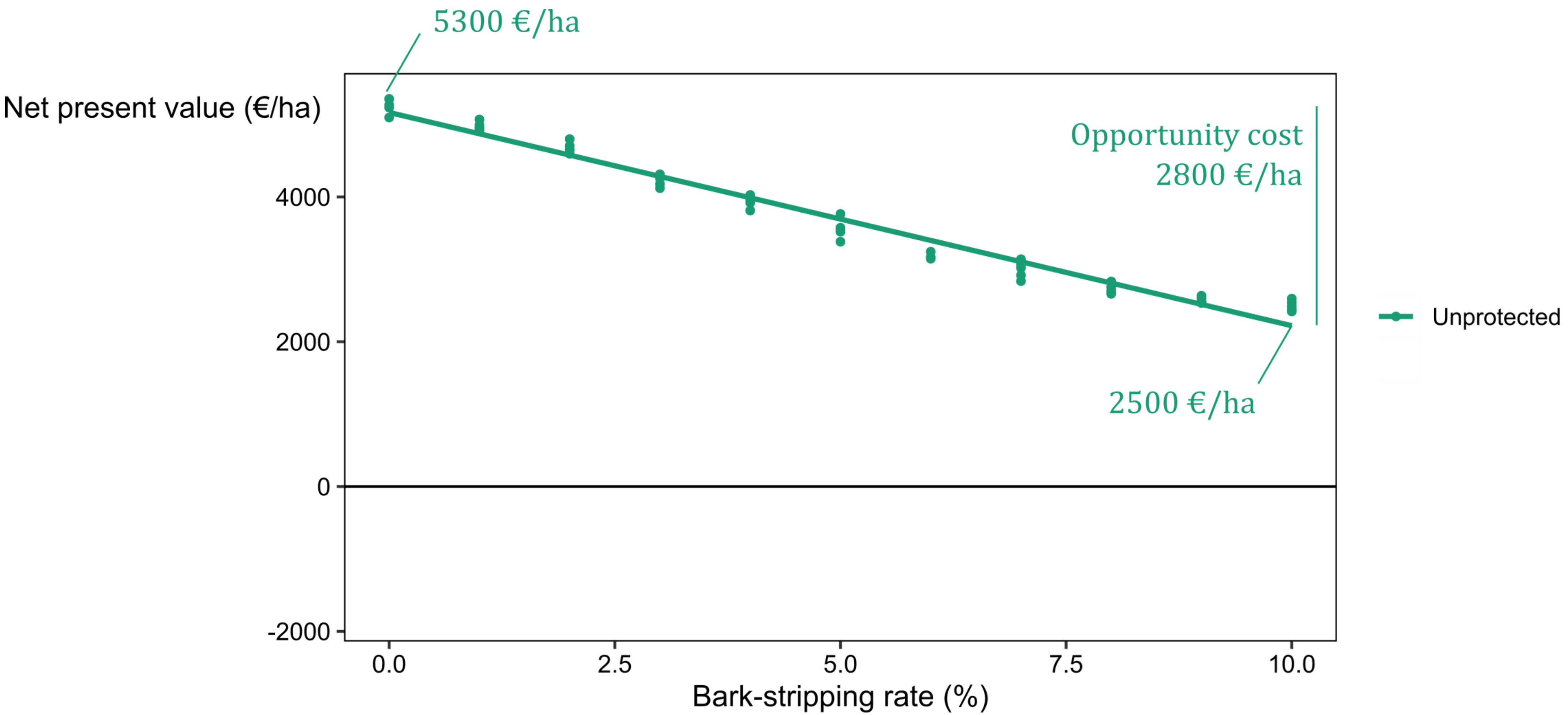
Site index = 27 m and r = 3%

Net present value



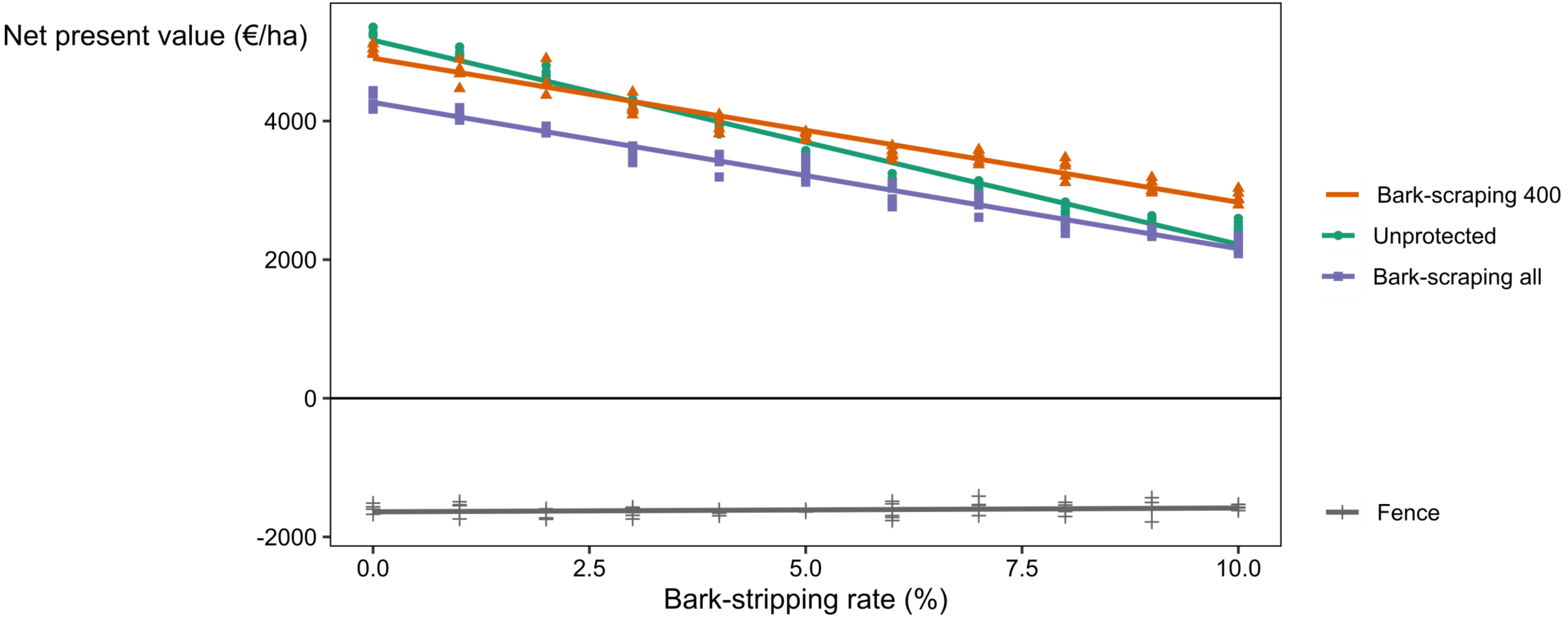
Site index = 27 m and r = 3%

Net present value



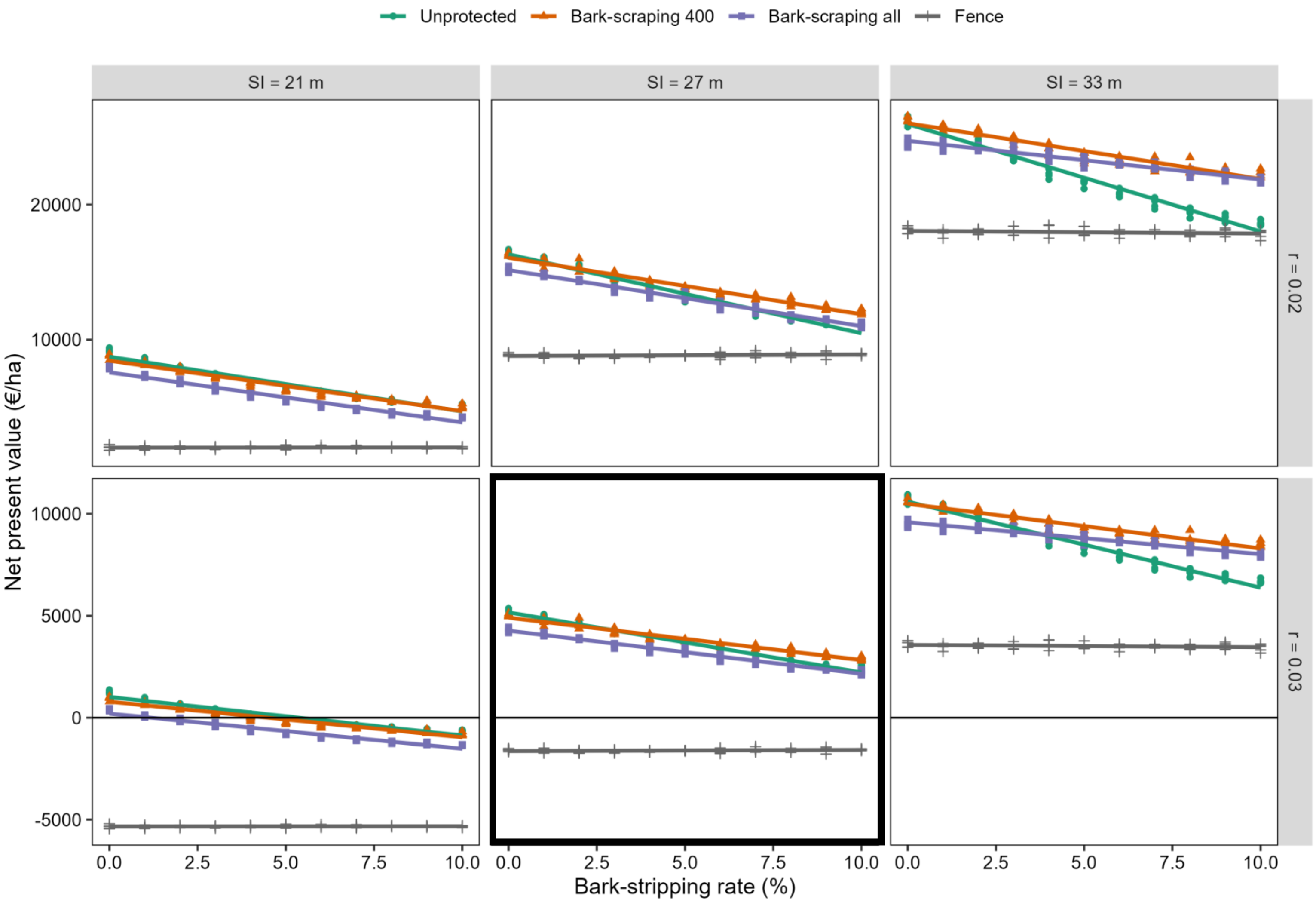
Site index = 27 m and r = 3%

Net present value



Site index = 27 m and r = 3%

Net present value

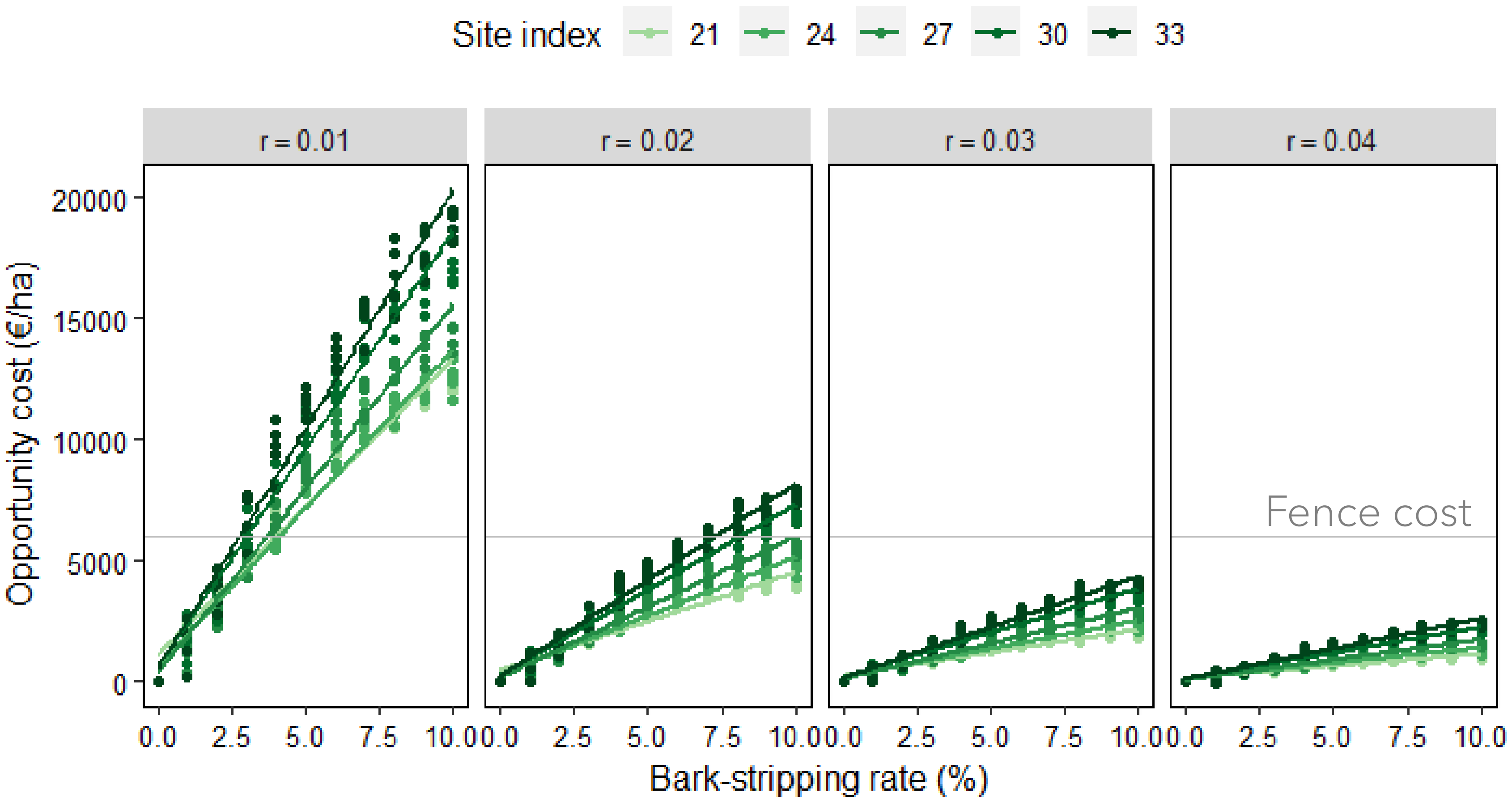


Bark-scraping 400 crop trees/ha seemed more efficient than Bark-scraping all trees

Bark-scraping 400 crop trees/ha seemed efficient particularly in the most productive stands

Fencing was mostly not profitable (NPV < 0)

Opportunity cost



0 - 19,445 €/ha

Opportunity cost increased linearly with bark-stripping rate.

The slope increased with SI and depended on r.

How badly does bark-stripping harm timber production ?

Bark-stripping cost can be substantial : 0 – 100 % of NPV

With BSR = 10%, 85% of the trees are damaged at clear-cut (15 % of timber volume). A few studies predicted even greater proportion of damaged timber.

In averaged conditions (BSR = 4%, SI = 27 m, r = 2%) :

- loss of net revenue of 19%
- Bark-stripping cost = 2,647 €/ha
- 53 €/ha/year (~ hunting rent)

The cost is higher in the most fertile sites

How should forest management be adapted ?

- Rotation should be kept unchanged or slightly lengthened
- Fencing is unlikely to be cost-effective (except with high BSR, low r and required protections against browsing)
- Cheap individual protections can be cost-effective
    - Particularly on crop trees
    - particularly in the most productive sites
    - or if installed years before the first thinning

Study limitations

Models were calibrated for :

- healthy trees (2000-2020)
- even-aged stands

And rely on assumptions

- Damage, decay and sensitivity to drought, wind damages, insects, …

LIÈGE université Gembloux Agro-Bio Tech

Wallonie service public SPW

Regen

Capsis4

Capsis

Computer-aided projection of strategies in silviculture

INRAE cirad AGRICULTURAL RESEARCH FOR DEVELOPMENT cnrs IRD Institut de Recherche pour le Développement FRANCE

2005 — 2010 — 2015 — 2020

"Levels of wild ungulate populations have usually been adjusted to the damage levels, with limited regard to the actual cost of such damage.
The model we propose in this study can be used to assess the cost of bark-stripping damage balancing long-term revenues against short-term costs of protection measures and long-term costs of bark-stripping damage."

European Journal of Forest Research
https://doi.org/10.1007/s10342-023-01565-w

ORIGINAL PAPER

Check for updates

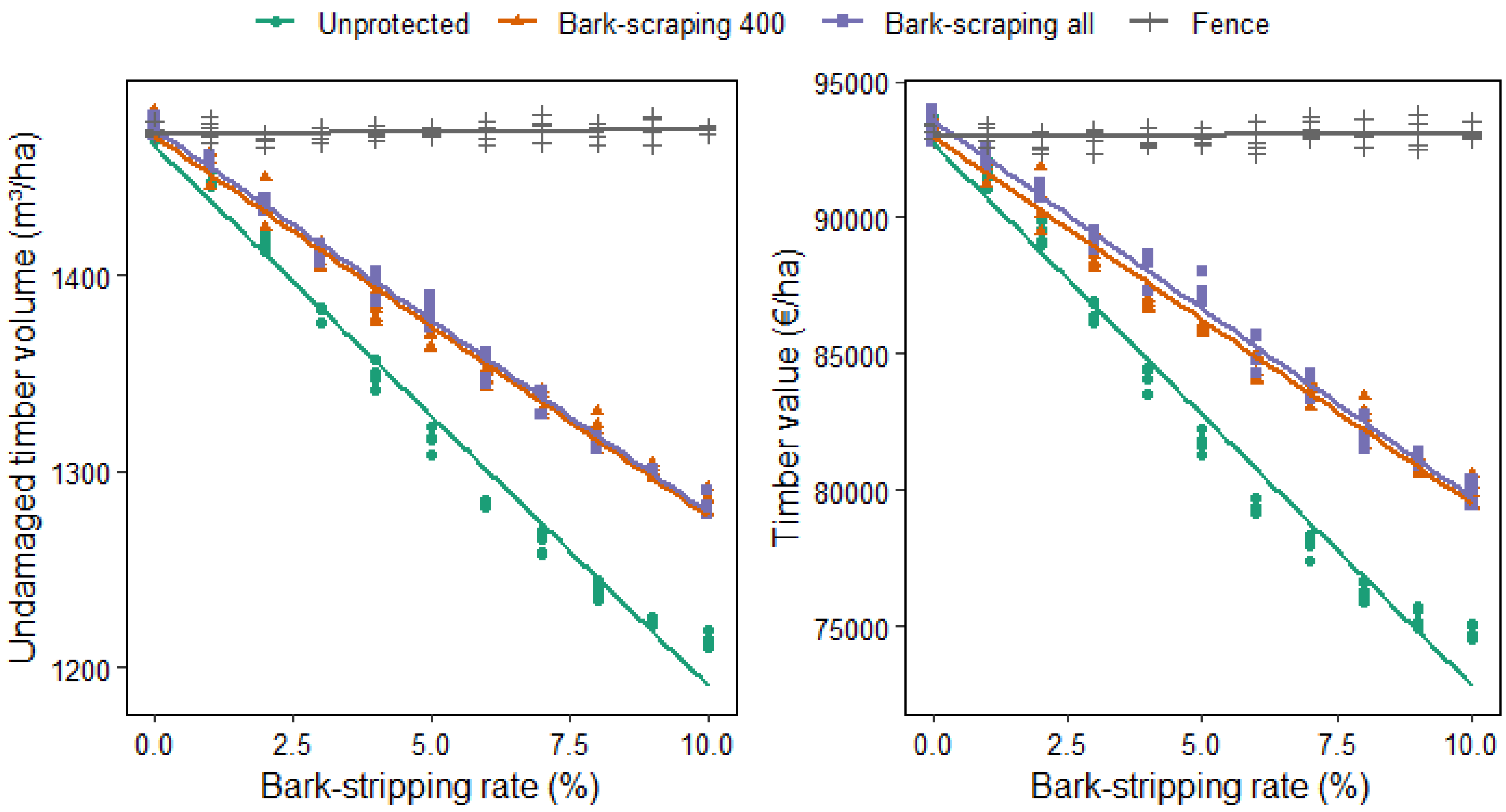
From the simulation of forest plantation dynamics to the quantification of bark-stripping damage by ungulates

Gauthier Ligot[1] · Thibaut Gheysen[2] · Jérôme Perin[1] · Romain Candaele[1] · François de Coligny[4] · Alain Licoppe[3] · Philippe Lejeune[1]

Received: 19 January 2023 / Revised: 7 March 2023 / Accepted: 29 March 2023

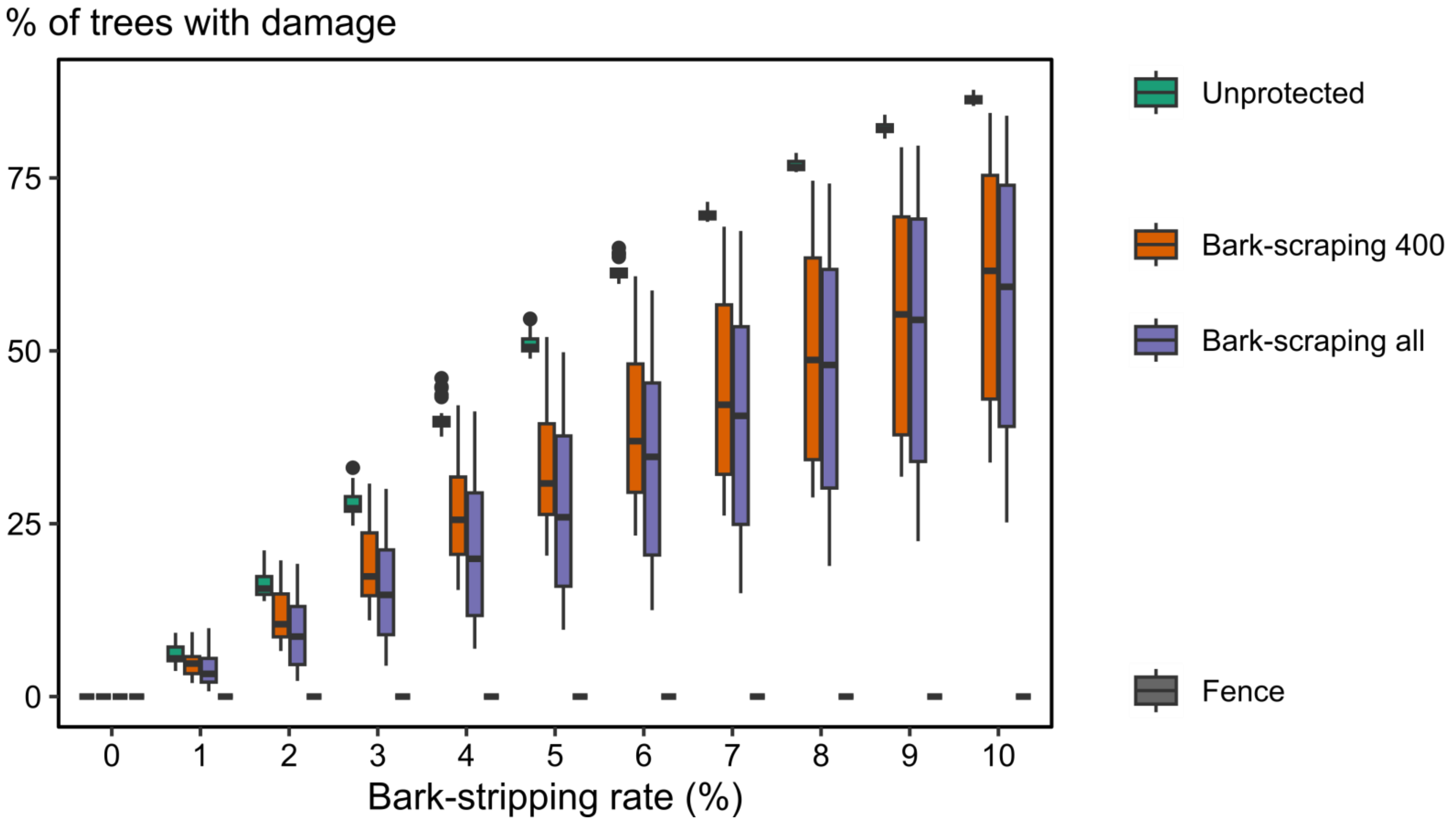

Merci pour votre attention

Decayed timber across all thinnings



Site index = 27 m

Decayed timber at clear-cut



- 0 – 85% of damaged stems at clear-cut without protection
- < 70% with protections

Decayed timber at clear-cut