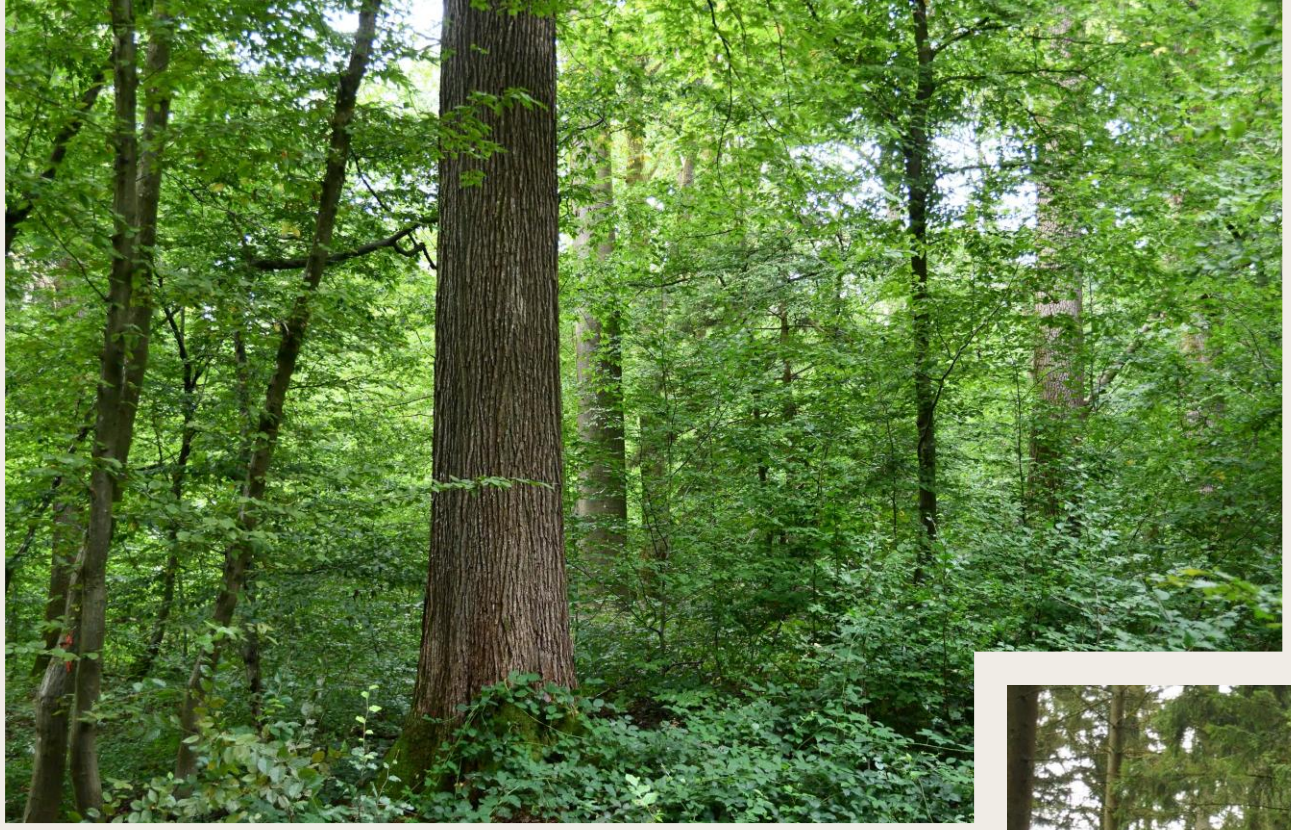
Effet de la densité des peuplements et de la pression des ongulés sur la régénération en situation de SMCC dans le contexte du changement climatique

Gauthier Ligot
Gembloux Agro-Bio Tech, University of Liege, Belgium

LIÈGE université
Gembloux
Agro-Bio Tech



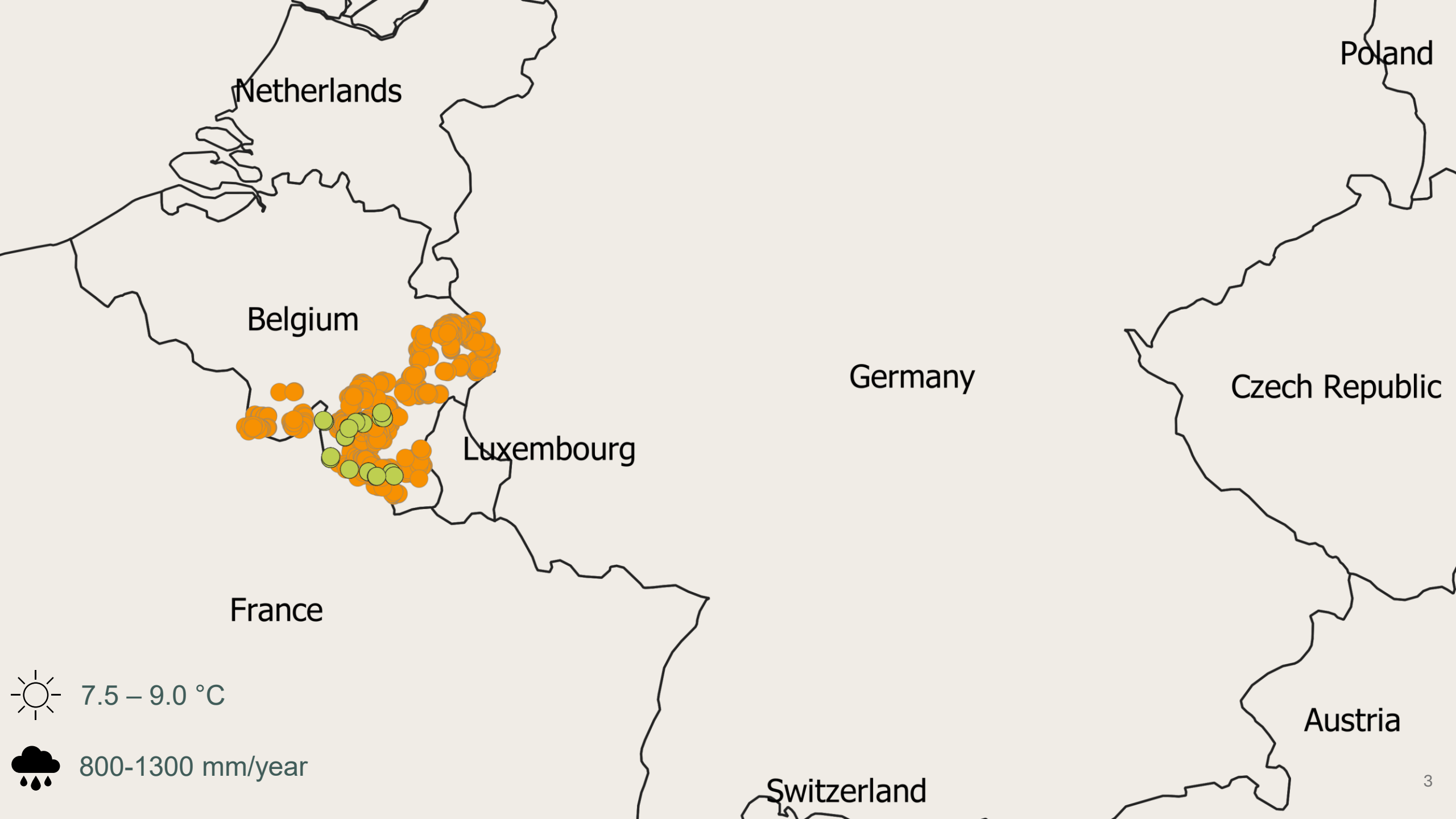
Continuous cover forestry

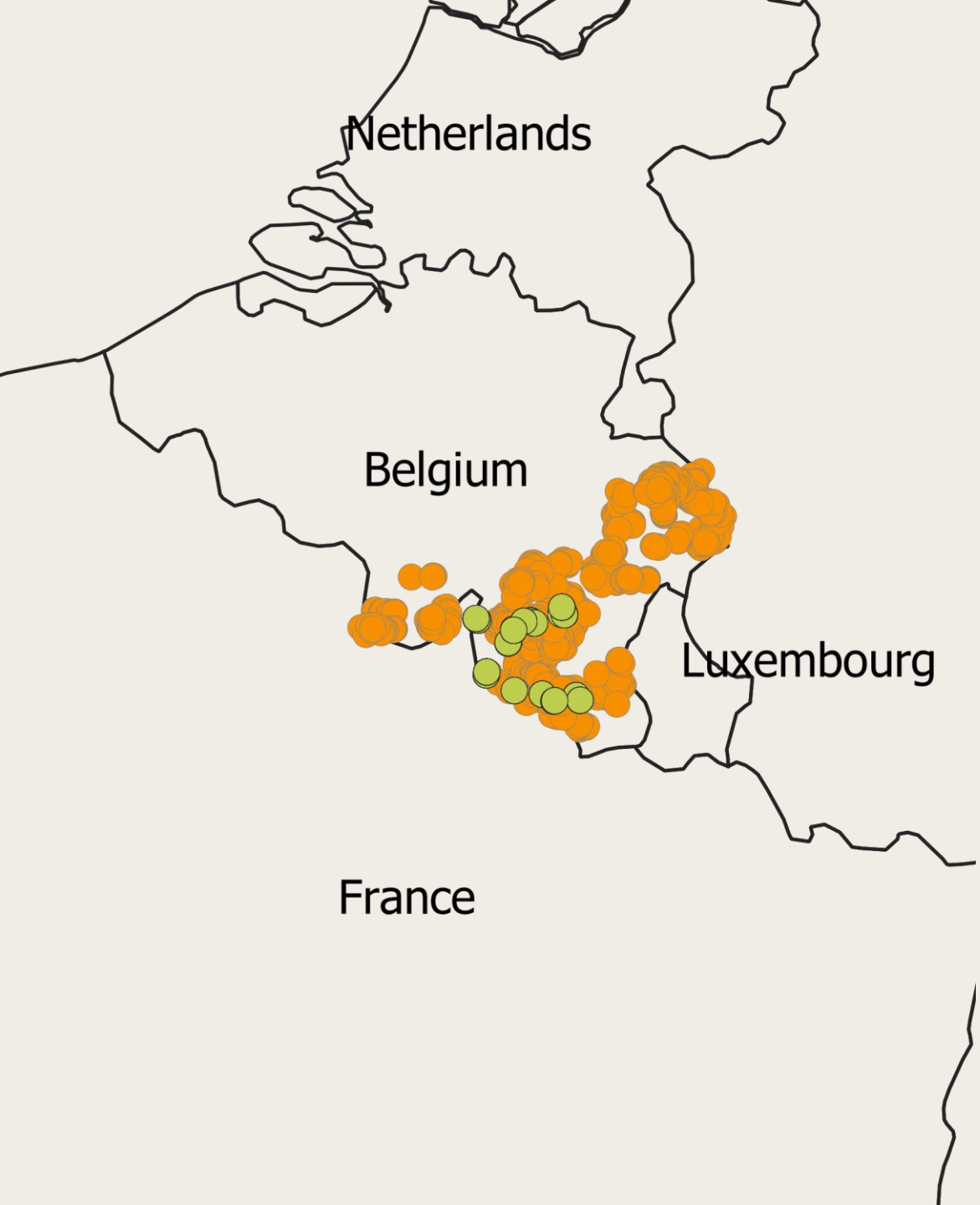
Natural regeneration

Global changes

Resilience

Diversification


Netherlands
Poland
Belgium
Germany
Czech Republic
Luxembourg
France
Austria
Switzerland
7.5 – 9.0 °C
800-1300 mm/year



Forests on **mesic acidophilous** sites dominated by broadleaved species and managed with **continuous cover forestry**.

Main species with different shade tolerance :

Fagus sylvatica (beech)
Picea abies (spruce)
Carpinus betulus (hornbeam)
Acer pseudoplatanus (sycomore mapple)
Quercus petraea (sessile oak)
Fraxinus excelsior (ash)
Quercus robur (pedonculate oak)
Betula pendula, *Betula pubescens* (birch)

4

Can we promote the natural regeneration of oak? What are the light conditions that best promote species diversity?

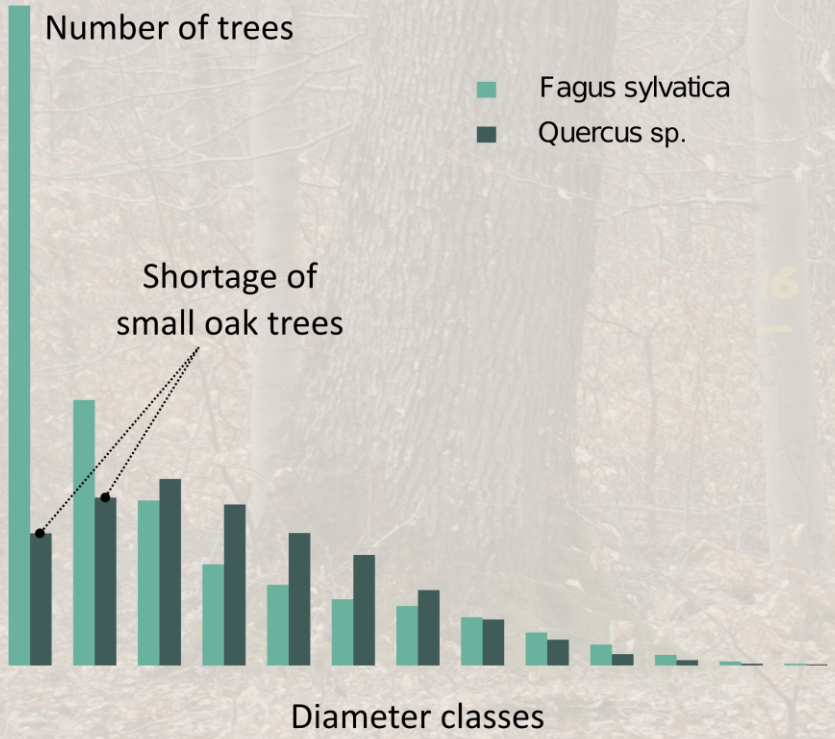
Sessile oak
Quercus petraea (Matt) Liebl.

Less shade-tolerant
Scarce in natural regeneration

European beech
Fagus sylvatica L.

Shade-tolerant
Invade the understory

Density of oak and beech by size class in southern Belgium (550 000 ha)



7.5 – 9.0 °C

800-1300 mm/year

Forests on **mesic acidophilous** sites with coniferous plantation species and managed with **continuous cover forestry** conversion into unevenaged stand

Main species with different shade tolerance :

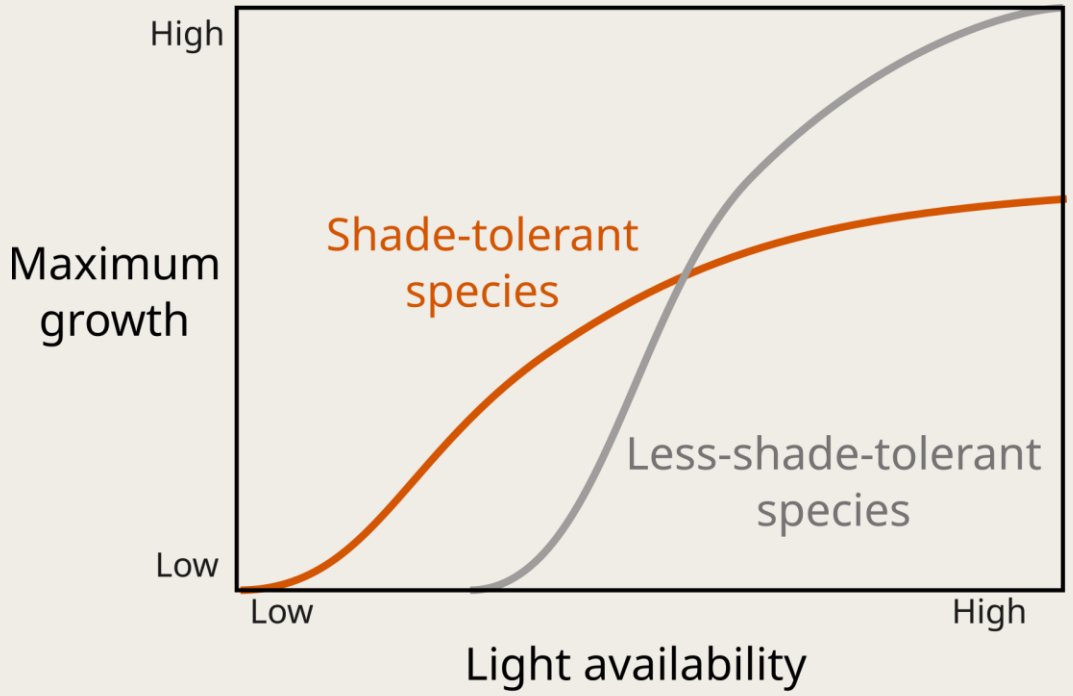
Fagus sylvatica (beech)
Picea abies (spruce)
Pseudotsuga menziesii (Douglas-fir)
Larix sp. (Larch)

6

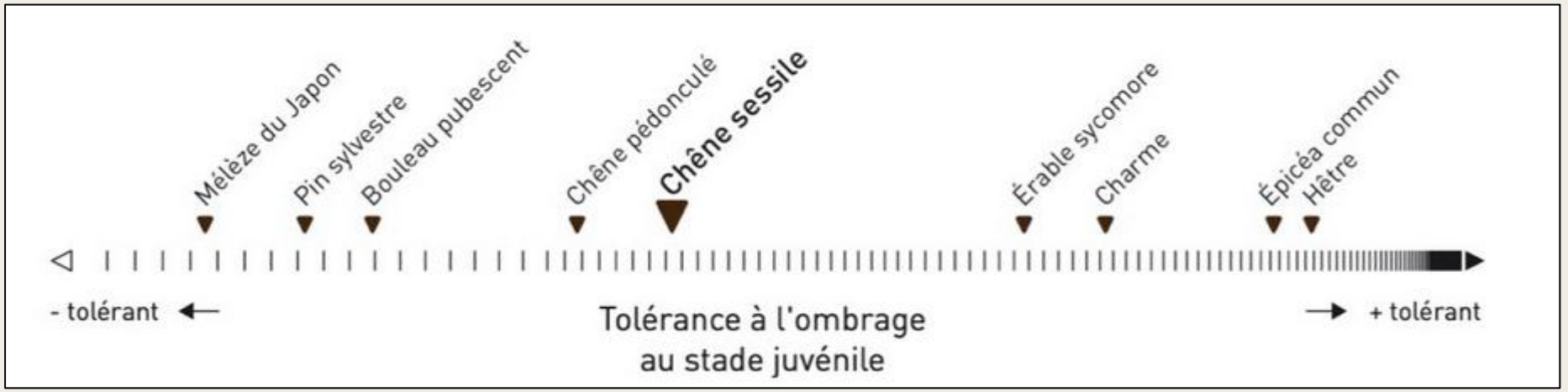
Can we expect that tree species diversity will increase in stands managed without clear-cut? Can we control it?

Controlling regeneration diversity by regulating canopy openness (in forests managed under CCF)

Assuming a trade-off between survival at low-light conditions and maximum growth at high-light conditions,
it should be possible to steer regeneration composition controlling understory light through targeted felling



adapted from Smith et Huston (1989) *Vegetatio 83:49-69*



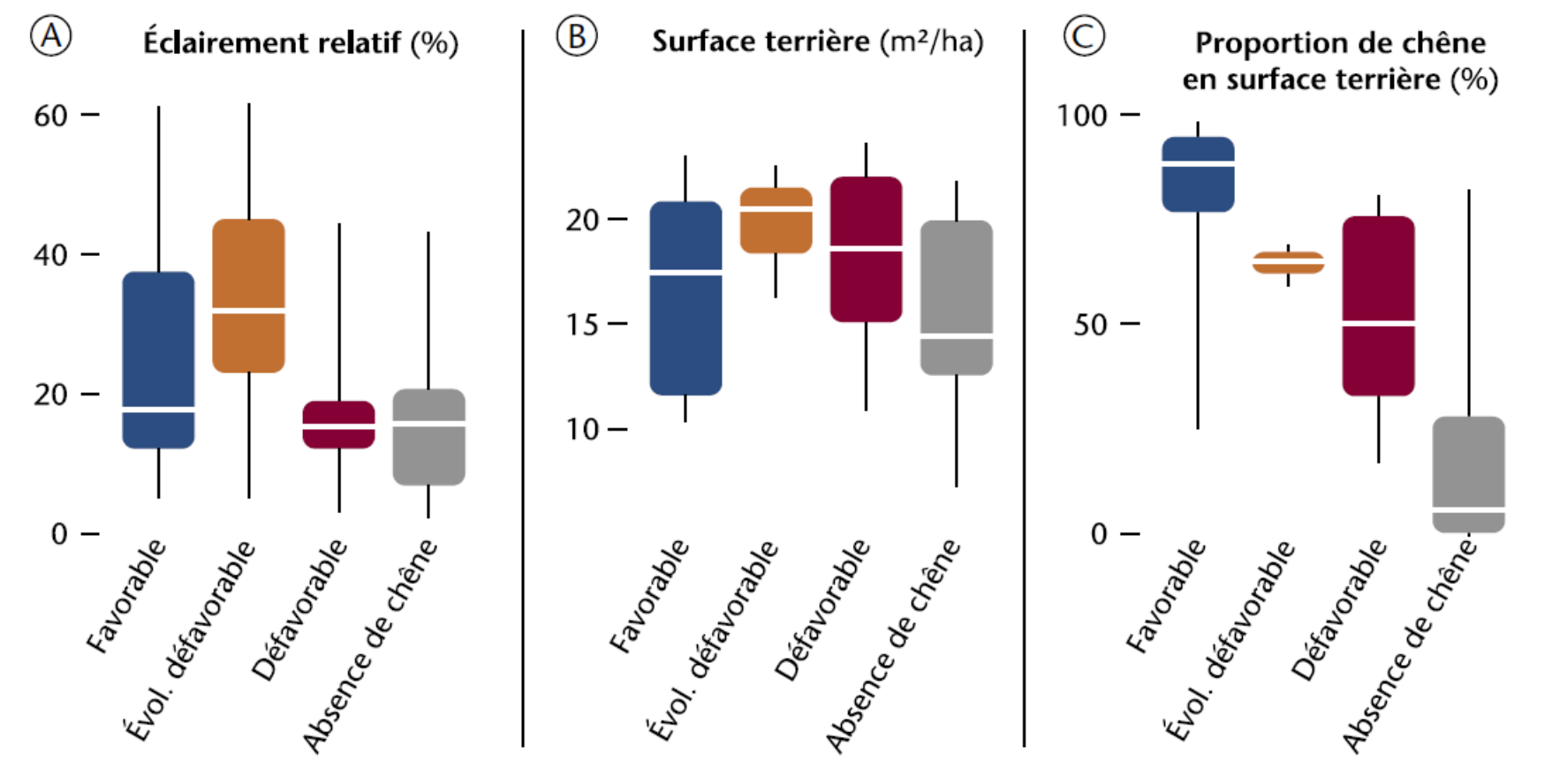
27 fenced sites

From early successional oak forests to late successional beech forests

Height of the 3 tallest saplings. Repeated measurements during 3 years.

Hemispherical photographs to estimate the percentage of above canopy light (PACL) transmitted to the understory.

Oak regeneration success depended primarily on the abundance of adult oak trees



LIGOT et al. 2014, Forêt Wallonne. 128
Also demonstrated by : Dietz et al. 2022 Forest Ecology and Management, 503; Petritan et al. 2012 Forest Ecology and Management, 280 ; Annighöfer et al (2015) Plos one

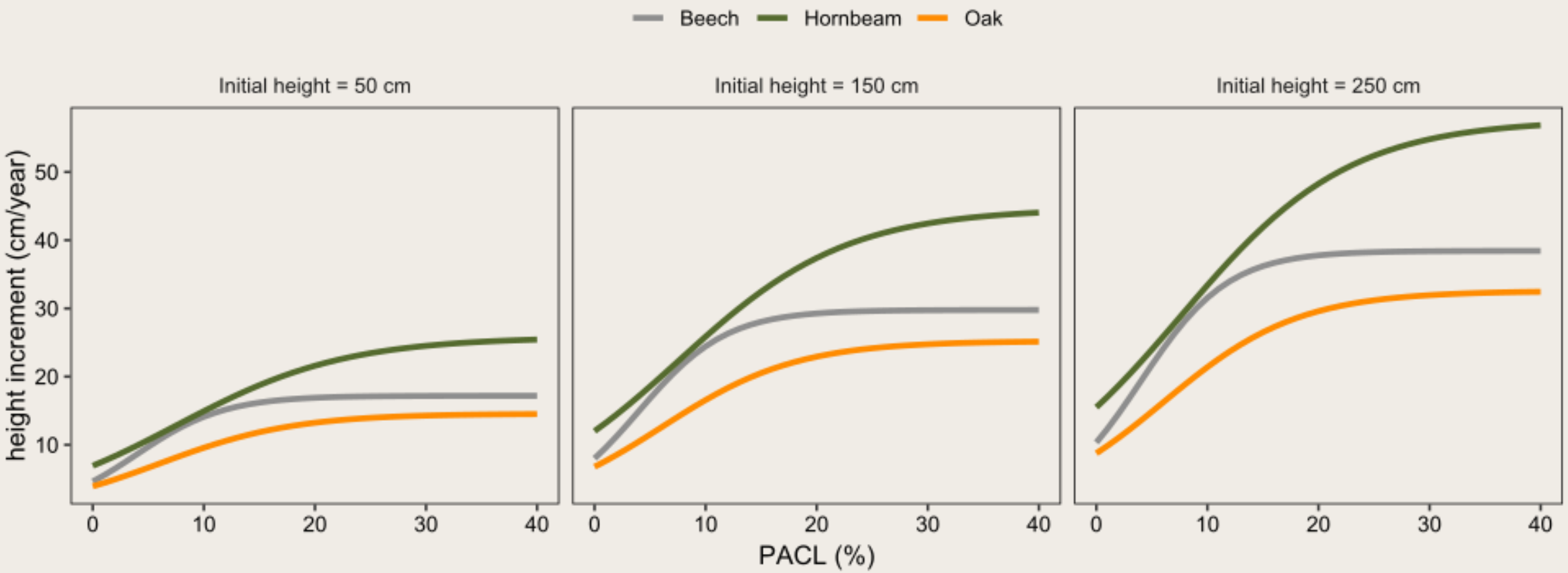
Beech regenerations grow faster than oak regenerations whatever the light conditions

- Importance of initial sapling height
- No tradeoff between survival in shade and growth in high-light condition
- Oak saplings needs twice as much light as beech saplings to reach their full growth potential
- Optimum light : 20 – 40% of above canopy light

LIGOT et al. 2013, For. Ecol. Manage. 304

Hornbeam might even grow faster than beech…

(with a small sample, though)



Model used and presented in : BARRERE et al. 2024, Ecological Modelling.489

Many similar observations in different forests

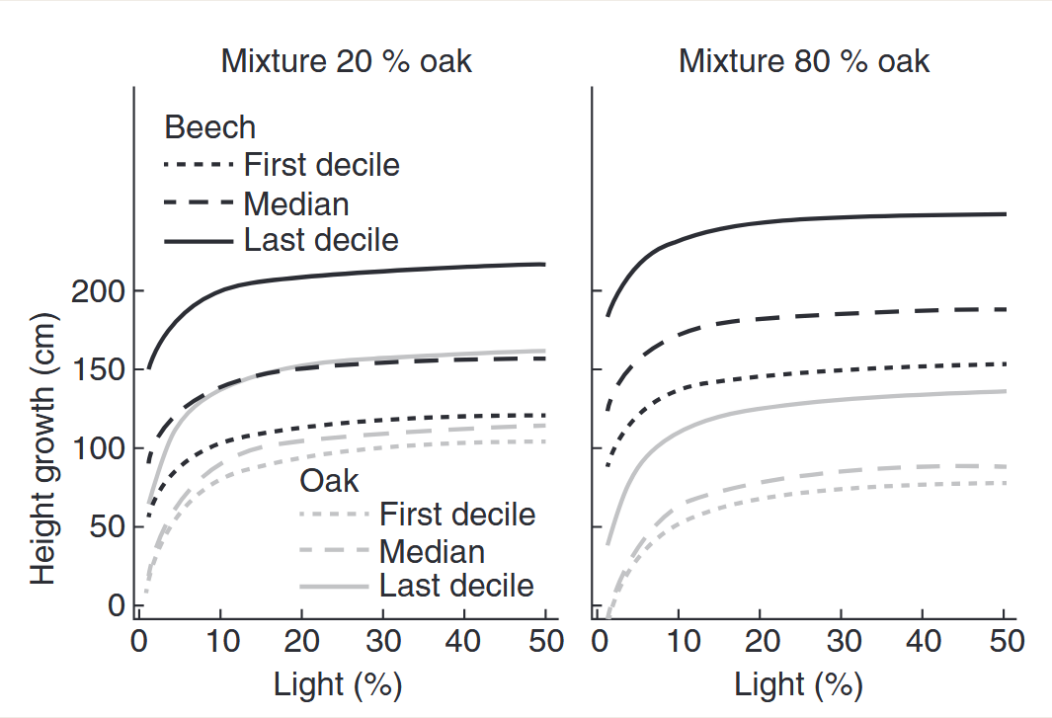
Annals of Botany **112**: 1421–1430, 2013
doi:10.1093/aob/mct200, available online at www.aob.oxfordjournals.org

ANNALS OF BOTANY Founded 1887

Light and competition gradients fail to explain the coexistence of shade-tolerant *Fagus sylvatica* and shade-intermediate *Quercus petraea* seedlings

Rosalinde Van Couwenberghe[1,2,*], Jean-Claude Gégout[1,2], Eric Lacombe[1,2] and Catherine Collet[1,2]

[1]*INRA, UMR1092, Laboratoire d'Etude des Ressources Forêt Bois, Centre de Nancy, 54280 Champenoux, France and*



Uneven-aged oak-beech stand in **France** (Lorraine)

- Storms opened the canopy
- Light gradient : 5-50%
- Initially, some beech seedlings were taller than oak seedlings

"No rank reversal occurs between the two species along the light gradient [...] spatial heterogeneity in canopy opening [does not explain] the coexistence of the two species studied"

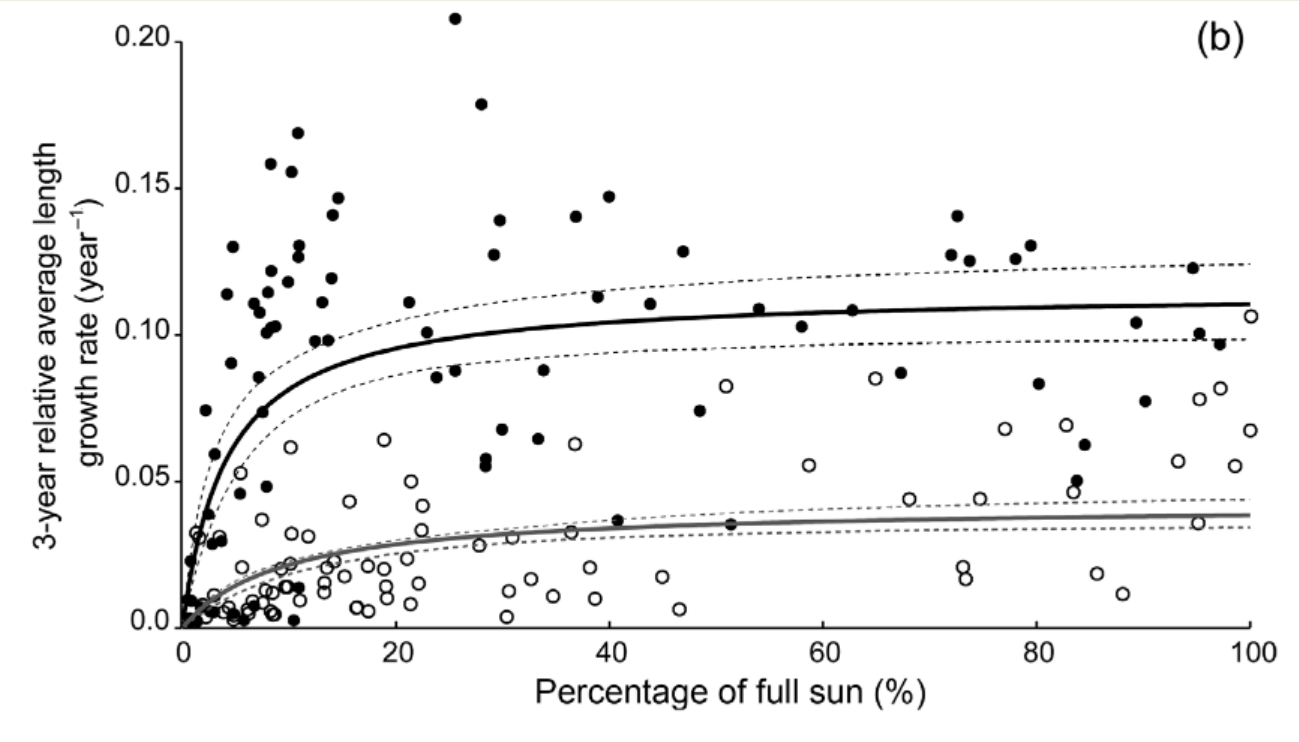
Many similar observations in different forests

Growth, mortality, and morphological response of European beech and downy oak along a light gradient in sub-Mediterranean forest

Georges Kunstler, Thomas Curt, Monique Bouchaud, and Jacques Lepart

Downy oak-beech-pine forest in **France** (Causse du Larzac)

“beech has a better growth and survival than oak at a high light regime. This is not in agreement with the mortality–growth trade-off”



Beech

Downy oak (*Q. pubescens*)

Kunstler et al (2005) Can. J. For. Res. 35

But also, some different observations

Forest Ecology and Management 503 (2022) 119758

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Beech and hornbeam dominate oak 20 years after the creation of storm-induced gaps

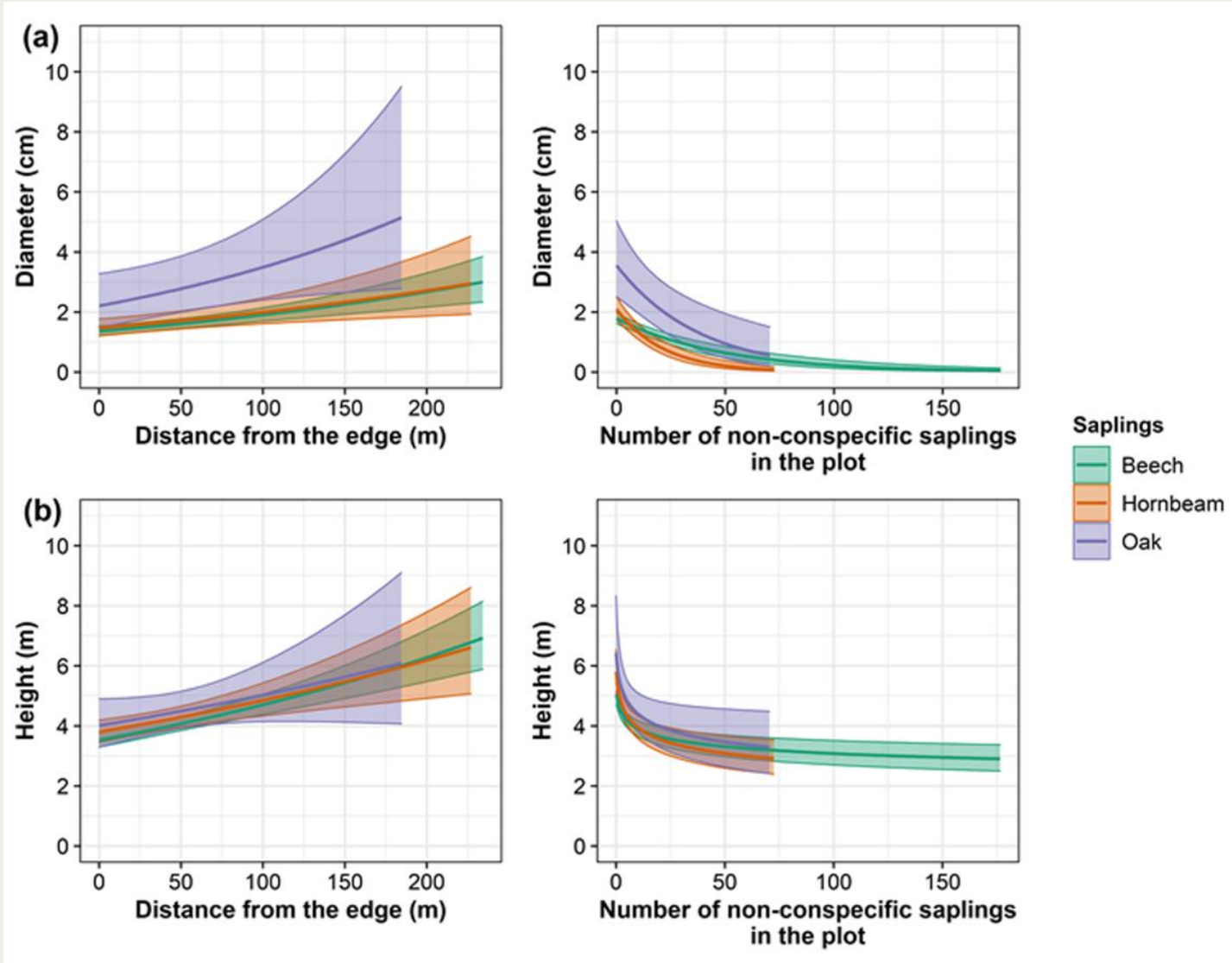
Lucie Dietz [a,b,*], Jean-Claude Gégout [a], Jean-Luc Dupouey [a], Eric Lacombe [a], Lisa Laurent [a], Catherine Collet [a]

[a] Université de Lorraine, AgroParisTech, INRAE, UMR Silva, 54000 Nancy, France
[b] Office National des Forêts, 54000 Nancy, France

Inventory in storm-induced gaps (20 years after the storm) in **France**

- 1153 plots, 108 gaps (with some gaps > 1 ha)
- Saplings of oak, beech, hornbeam
- No silvicultural treatment during 20 years

"Unlike Ligot et al., (2013), Van Couwenberghe et al. (2013) or Tinya et al. (2020), we did not observe a dominance of beech or hornbeam over oak DBH or height, showing that oak saplings were not overtopped 20 years after opening."



But also, some different observations

European Journal of Forest Research (2020) 139:41–52
https://doi.org/10.1007/s10342-019-01238-7

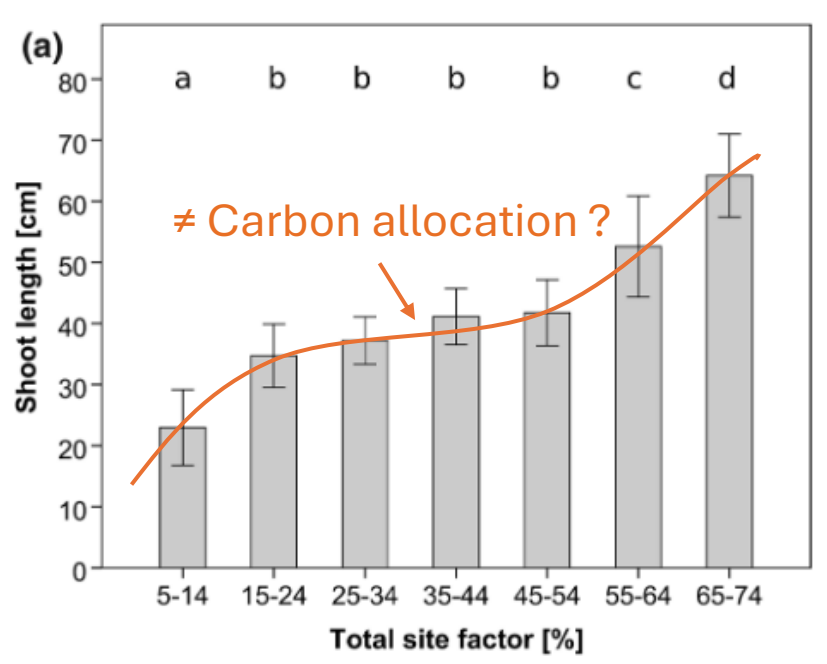
ORIGINAL PAPER

Photosynthetic performance, height growth, and dominance of naturally regenerated sessile oak (*Quercus petraea* [Mattuschka] Liebl.) seedlings in small-scale canopy openings of varying sizes

Tobias Modrow[1] · Christian Kuehne[3] · Somidh Saha[2] · Jürgen Bauhus[1] · Patrick L. Pyttel[1]

160 year-old oak stand with an under- and midstory of beech and hornbeam in **Germany** (Heilbronn).

- Managers opened gaps of varying size (0.05-0.2 ha)
- Light gradient : 5-75 %
- Oak and beech seedlings were initially of about the same size (20 cm).



“at relative radiation levels of close to 50% oak was able to compete with or even outgrow shade-tolerant species while shade-intolerant species were still not competitive enough to dominate the regeneration layer”

But also, some different observations

Einfluss unterschiedlicher Hiebsformen auf die Naturverjüngung eines Traubeneichen-Buchen-Mischbestandes

– Der Versuch „Mastlager“ der Forschungsanstalt für Waldökologie und Forstwirtschaft Rheinland-Pfalz im Forstamt Wasgau (früher Eppenbrunn) –

Burghard von Lüpke
Institut für Waldbau der Universität Göttingen

2008

Abstract

Title of the paper:

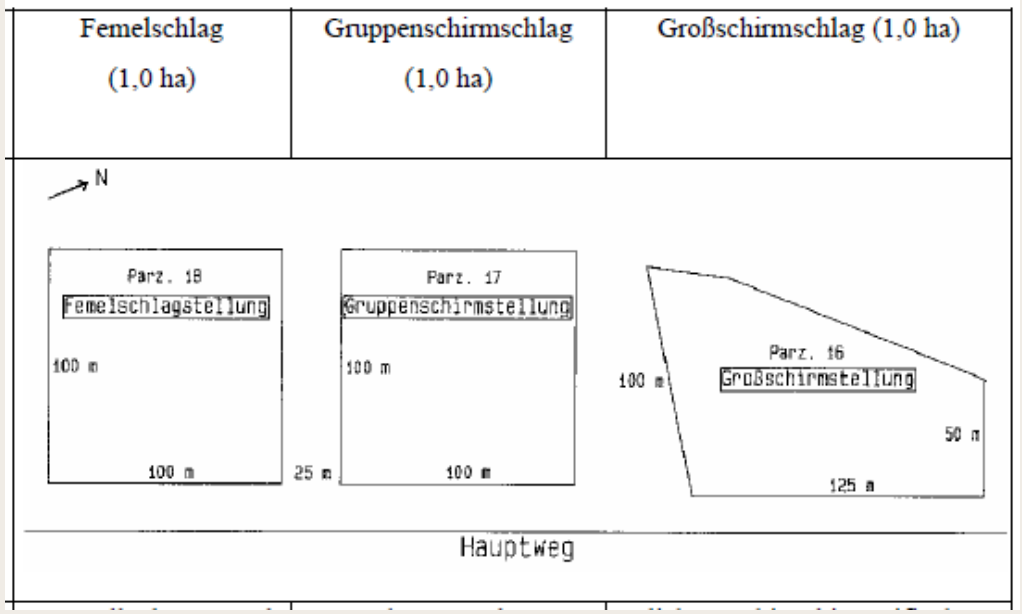
Influence of various cutting types on natural regeneration of a sessile oak – beech mixed stand. – The experiment “Mastlager” of the Research Institute for Forest Ecology and Forestry Rhineland-Palatinate in the district Wasgau (formerly Eppenbrunn) –

300 year-old oak-beech stand in **Germany** (Heilbronn).

Treatment : 3 cutting types to release oak regeneration after mast year 1989 (Irregular shelterwood, group shelterwood, uniform shelterwood)

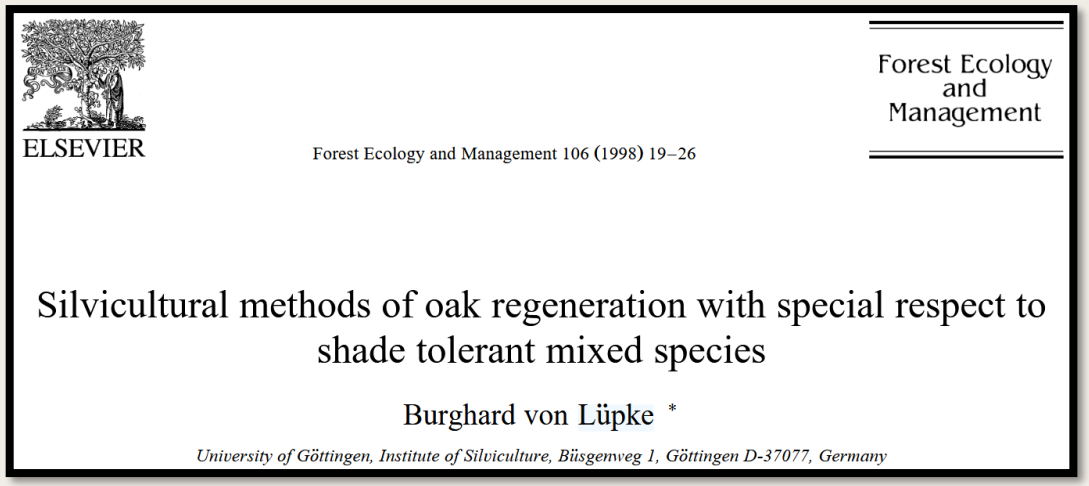
- Light gradient : 27-67%

Oak saplings grew faster than beech when PACL > 38% after 5 years and PACL > 50% after 8 years



Von Lüpke (2008) Forstarchiv, 2008, 79

Going back to the silvicultural recommendations of von Lüpke (1998)



ELSEVIER

Forest Ecology and Management 106 (1998) 19–26

Forest Ecology and Management

Silvicultural methods of oak regeneration with special respect to shade tolerant mixed species

Burghard von Lüpke *

University of Göttingen, Institute of Silviculture, Büsgenweg 1, Göttingen D-37077, Germany

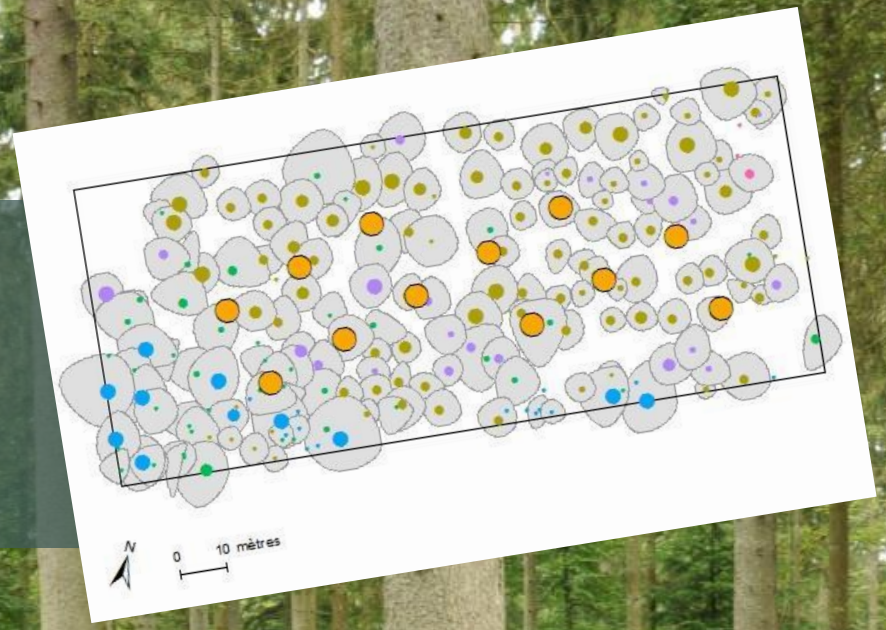
Silvicultural recommendations to maintain mixed oak-beech stands in forests naturally dominated by beech (sub-Atlantic region of **Germany**)

- ✓ "**Initial height** has proved to be very important to the height increment [...]: plants which were initially larger had a greater increment."
- ✓ "The oaks should have as great an age advantage as possible over the beeches; beeches should never originate from advanced growth."
- ✓ "canopy covers, which allow between **40% and 10% of full light** to penetrate, transfer the competitive relationship more and more away from the oaks **in favour of the beeches**."
- ✓ "Generally speaking, young oaks grow initially faster in clear **cut areas** than beech of the same age and achieve an advantage of 1–2 m within 30 years. [...] in Open area, beech saplings were affected by **late frost** whereas the oak were not affected."
- ✓ "The regulation of inter-specific competition during cleanings and thinnings often necessitates great effort to maintain such a high number of oaks"

9 coniferous stands in Belgium at 400-600 m a.s.l

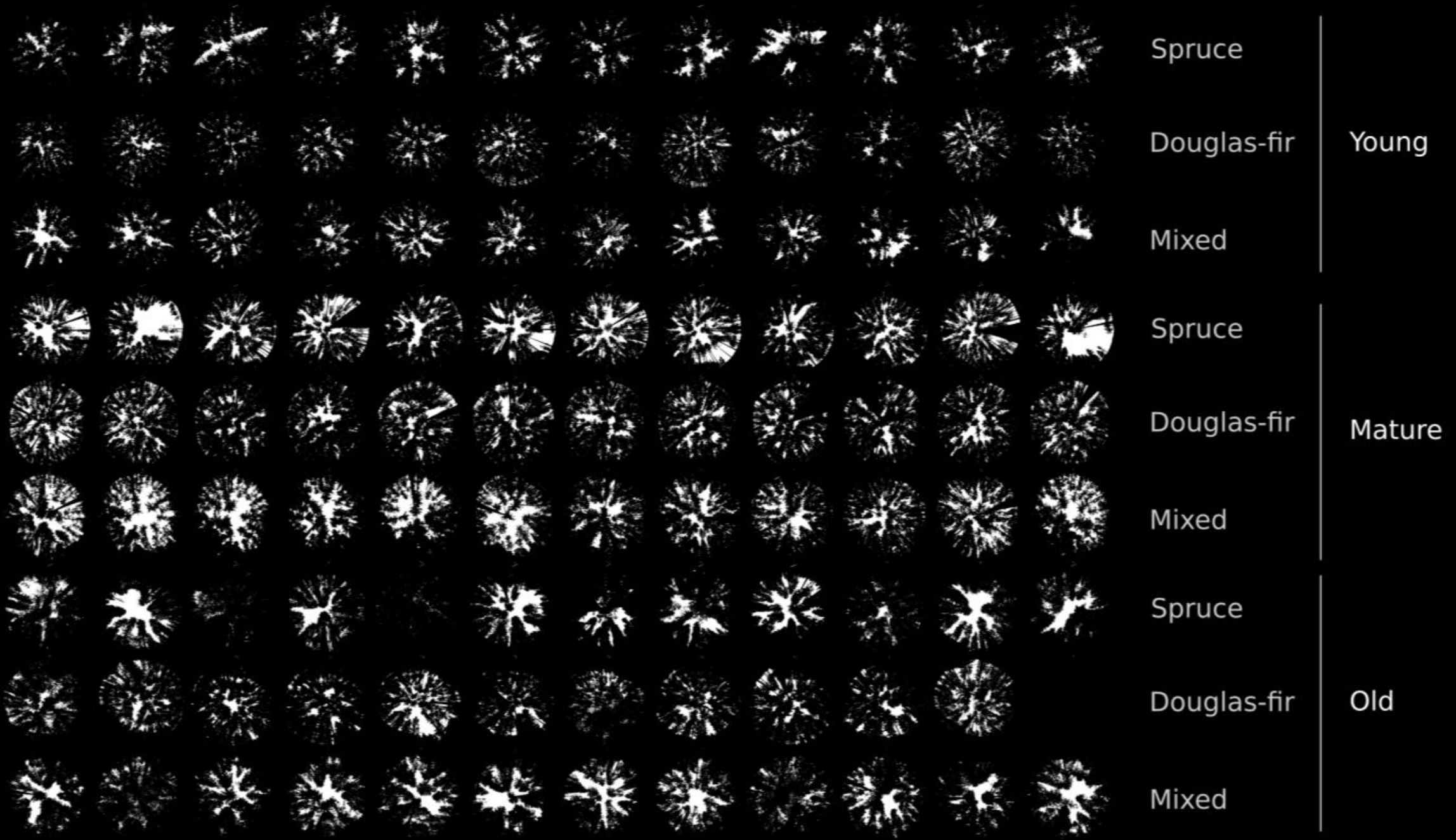
	Young 35 year old	Mature 60 year old	Old 80-150 year old
Spruce *Picea abies* (L.) Karst			
Douglas fir *Pseudotsugae menziesii* (Mirb.) Franco			
Mixed *Picea abies* (L.) Karst *Pseudotsugae menziesii* (Mirb.) Franco *Larix* sp. *Abies alba* Mill. *Tsuga heterophylla* (Raf.) sarg.			

- 1 ha plots in each site
- 12 circular subplots of 3-m radius



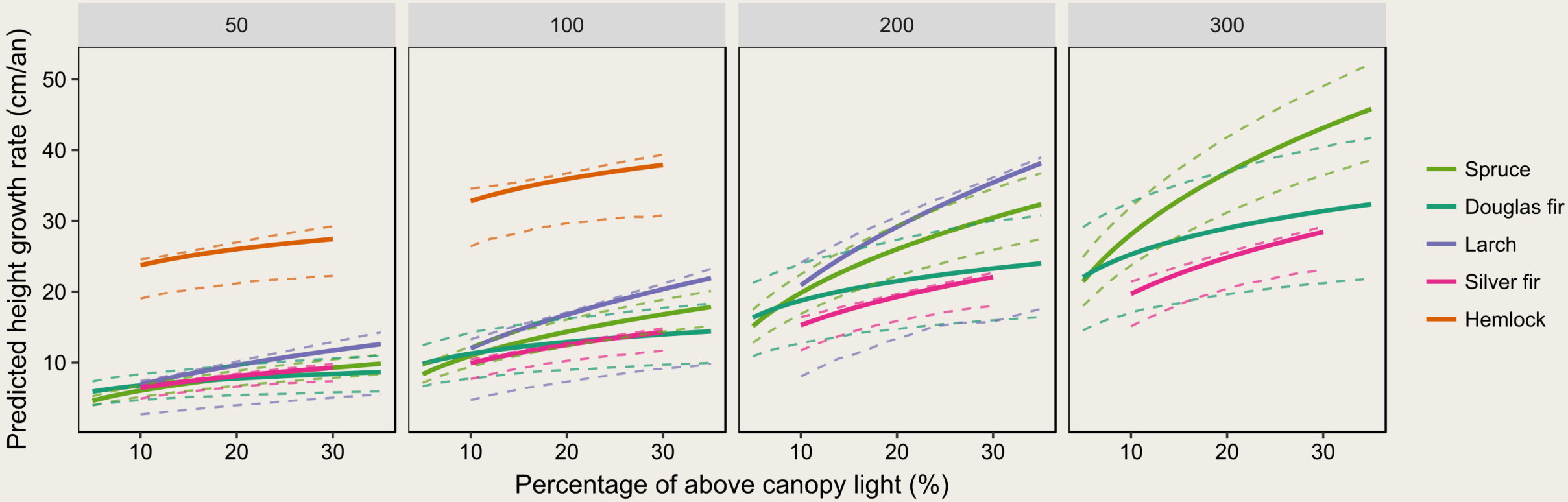
For the 3 tallest saplings of each species, we measured

- Sapling height
- Terminal shoots
- …


Spruce
Douglas-fir
Mixed
Young
Spruce
Douglas-fir
Mixed
Mature
Spruce
Douglas-fir
Mixed
Old

The ranking of species based on height growth was the same under all lighting conditions

- Height increment increased with sapling heigh
- Western hemlock grew three times faster than the other species

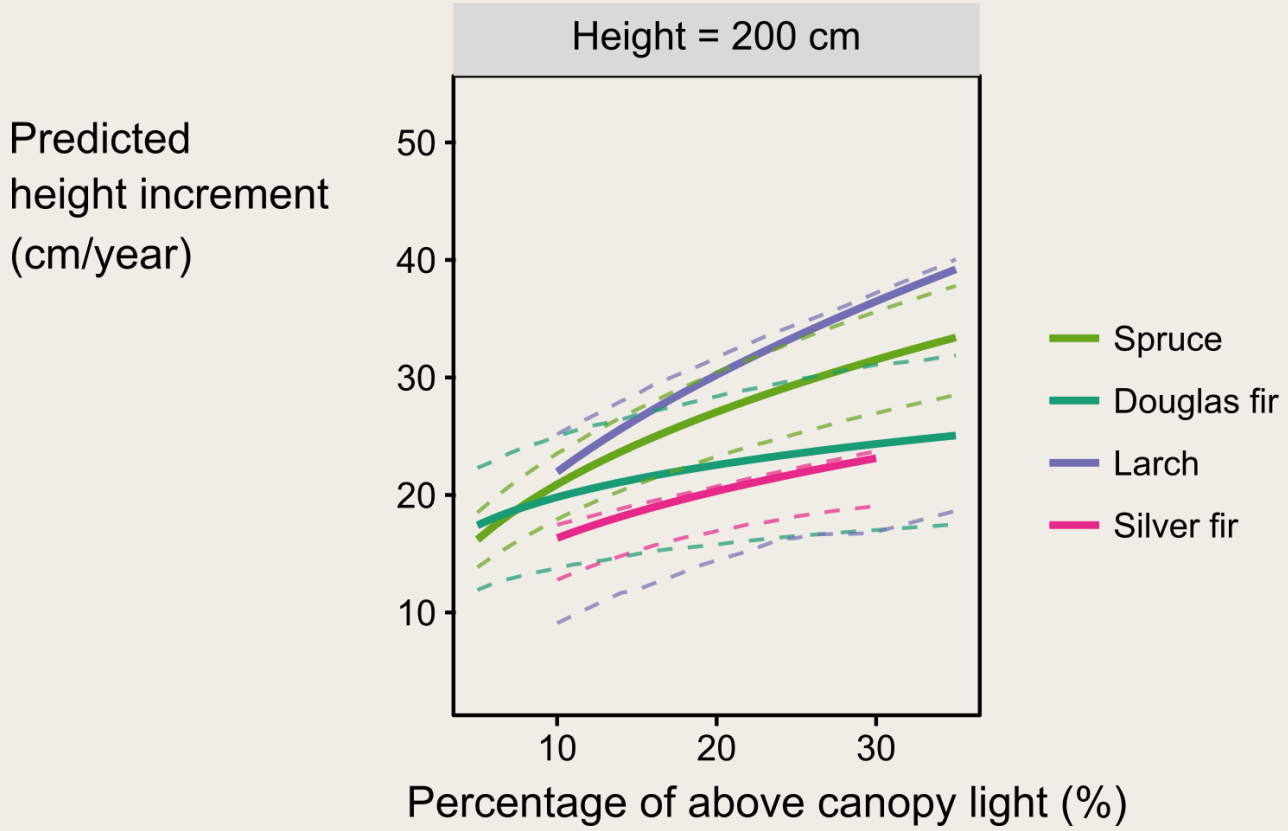


Ligot et al. (2020) Forestry, 93, 616–629

The ranking of species based on height growth was the same under all light conditions

By order of decreasing height increment:

1. Larch (shade intolerant)
2. Spruce (shade tolerant)
3. Douglas fir (less shade tolerant)
4. Silver fir (very shade tolerant)



Ligot et al. (2020) Forestry, 93, 616–629

Douglas fir

Spruce

Increased sensitivity to different pest and pathogens in the recent years (abundance of necroses and important defoliation):

- *Phaeocryptopus gaeumannii* (Swiss needle cast)
- *Sirococcus conigenus*
- *Contarinia pseudotsugae*
- …

Overall, weak niche partitioning over the studied light gradients

Similarly, gap size has been showed[1] to be a poor predictor of recruitment composition, especially to predict the regeneration success of less-shade tolerant species.

1. Busing and White (1997) Oikos 78 ; Coates (2002) For. Ecol. Manag. 155 ; De Römer et al. (2007) J. Veg. Sci. 18 ; Nagel et al. (2010) Plant Ecol. 208

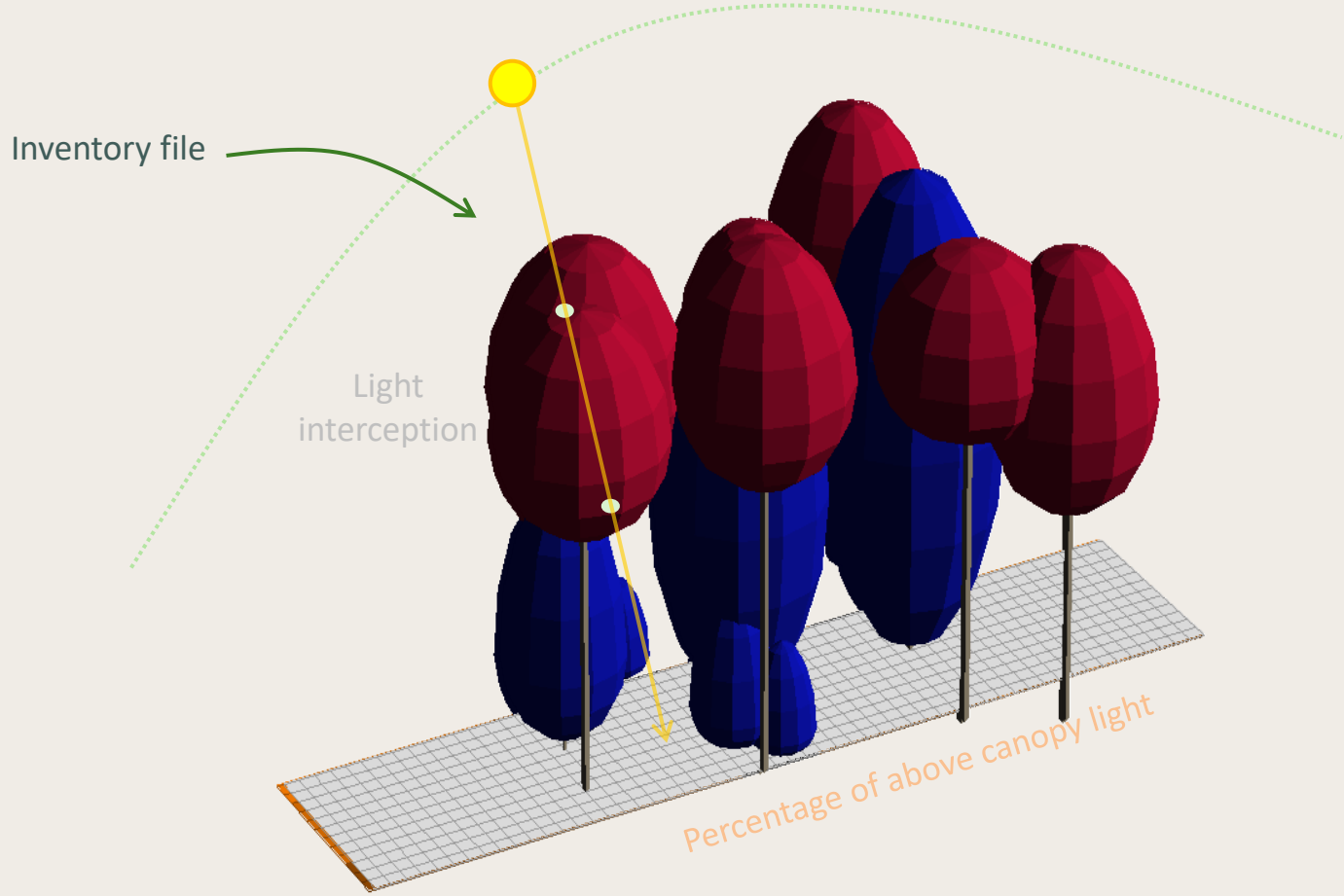
Interspecific competition depends on multiple factors

- Light is one abiotic factors among others (Temperature, water and nutrient availability….)

- Management history (stand composition)
- Difference in initial height (presence of advanced saplings)
- Herbivores (ungulates)
- Pest and pathogens
- …

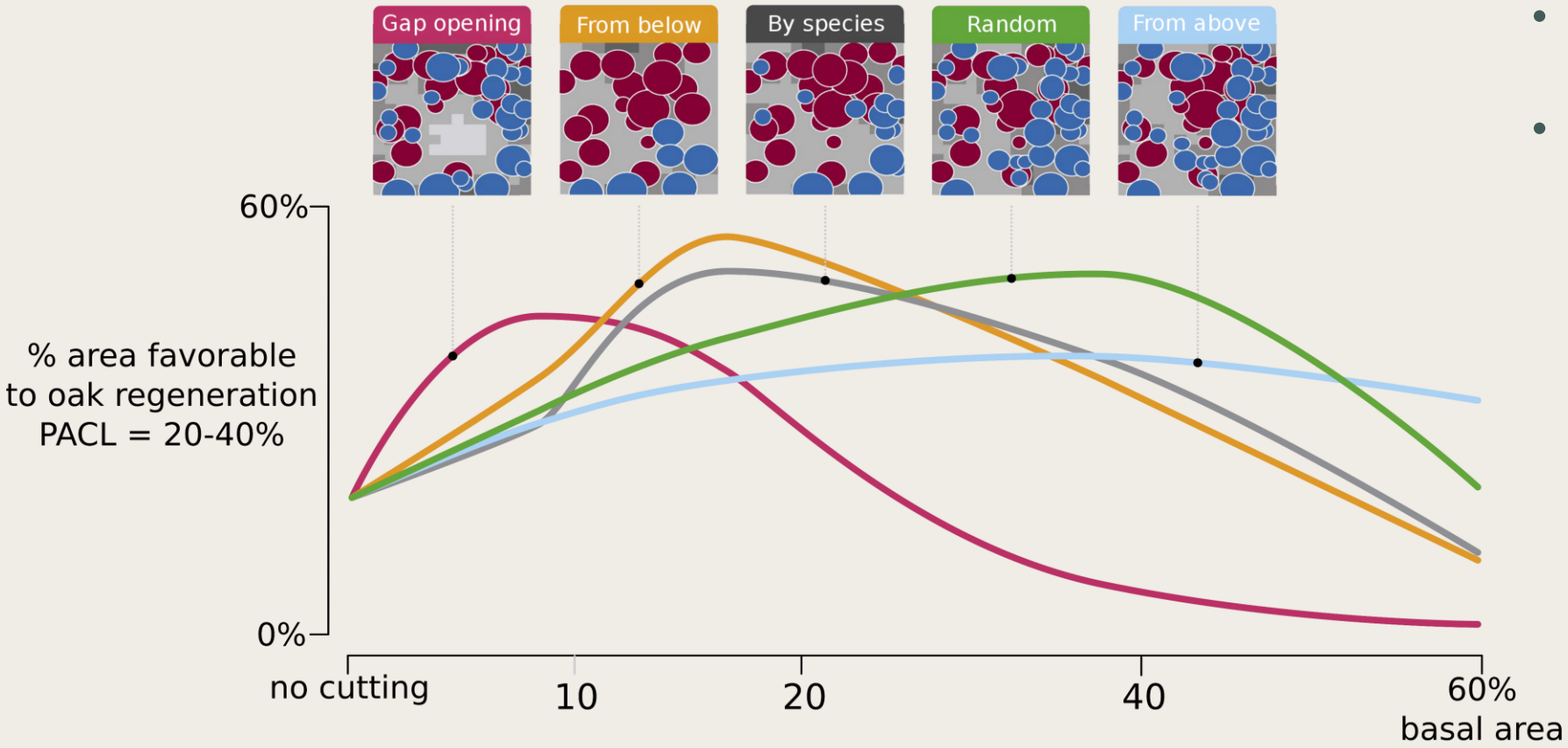
Under CCF, to control recruitment composition, forest manager must control canopy openness and implement silvicultural interventions

Modeling light interception



LIGOT et al. 2014, Can. J. For. Res. 44
natheob.github.io/SamsaRaLight/

Simulating different silvicultural options to promote oak regeneration



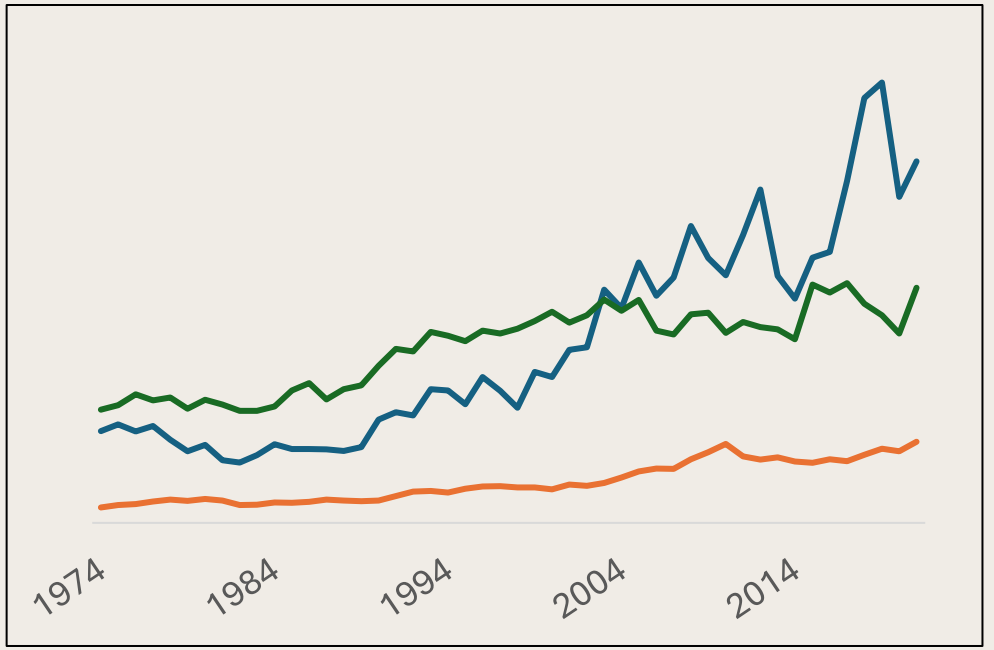
- Opening small gaps (<500 m²)
- Cutting preferentially small trees and trees of shade tolerant species maximized the area favorable to oak

LIGOT et al. 2014, For. Ecol. Manage. 327


How much ungulates reduce regeneration height growth ?
How much ungulates affect future stand diversity under CCF?

Isle of Man
Ireland
U.K. of Great Britain and Northern Ireland
Netherlands
Poland
Germany
Ukraine
Belgium
Luxembourg
Guernsey
Jersey
France

Ungulate populations have increased since the 80s threatening the development of natural regeneration.



Monitoring natural regeneration in pairs of fenced-unfenced plots

726 plot pairs (Systematic sampling) established where regeneration is not advanced but expected to be in good conditions (e.g. understory light) to thrive.

Annual monitoring (2016-2021) : Species identity and height of the 5 tallest seedlings ; Cover of woody/non-woody species.

Unfenced 1

1 m

Fenced

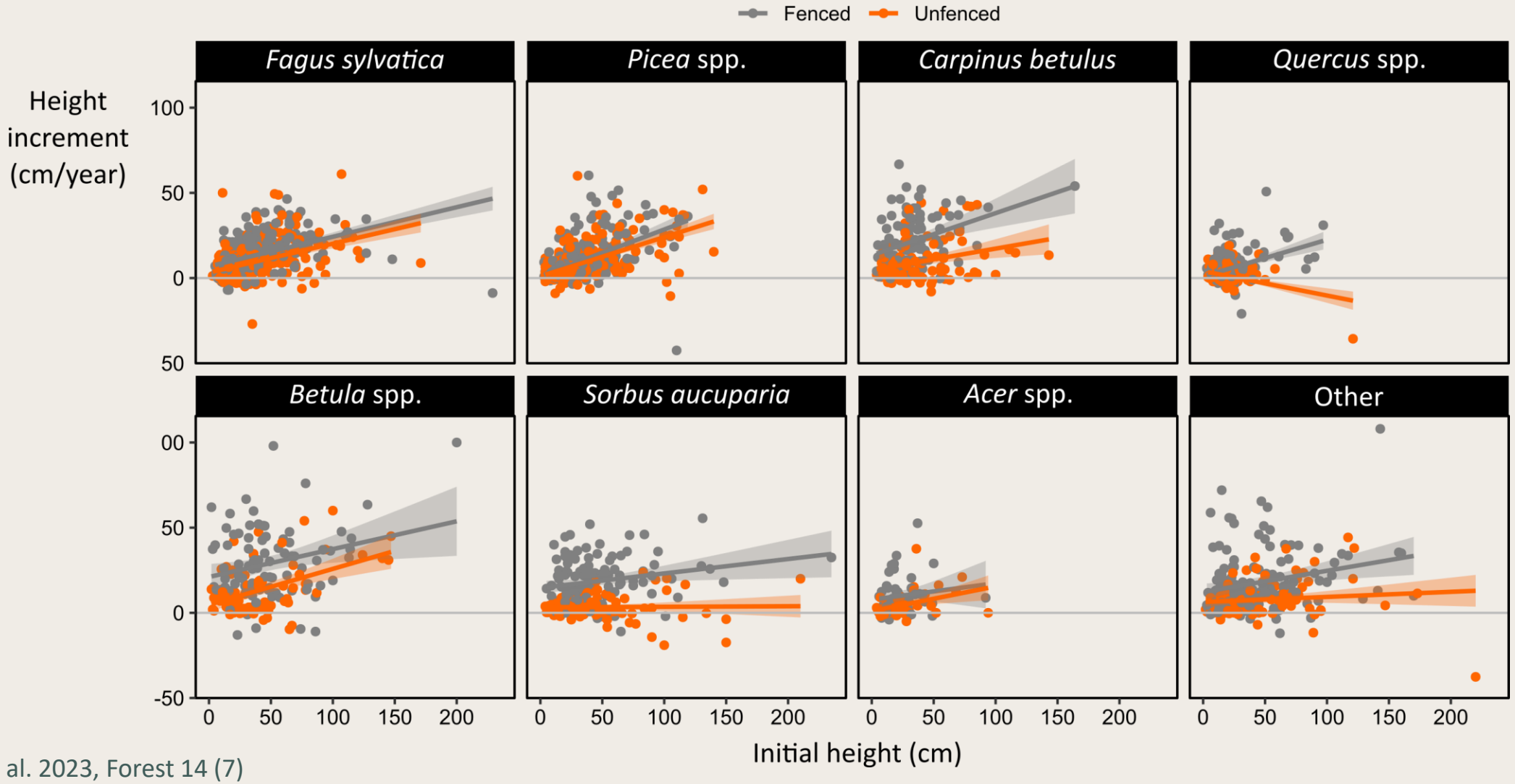
1 control plots with wooden lattice

1 m

Unfenced 2

(In case the 1st plot get damaged)

Considering only the tallest saplings, the height increment of all species but beech and spruce was significantly reduced by browsing.



CANDAELE et al. 2023, Forest 14 (7)

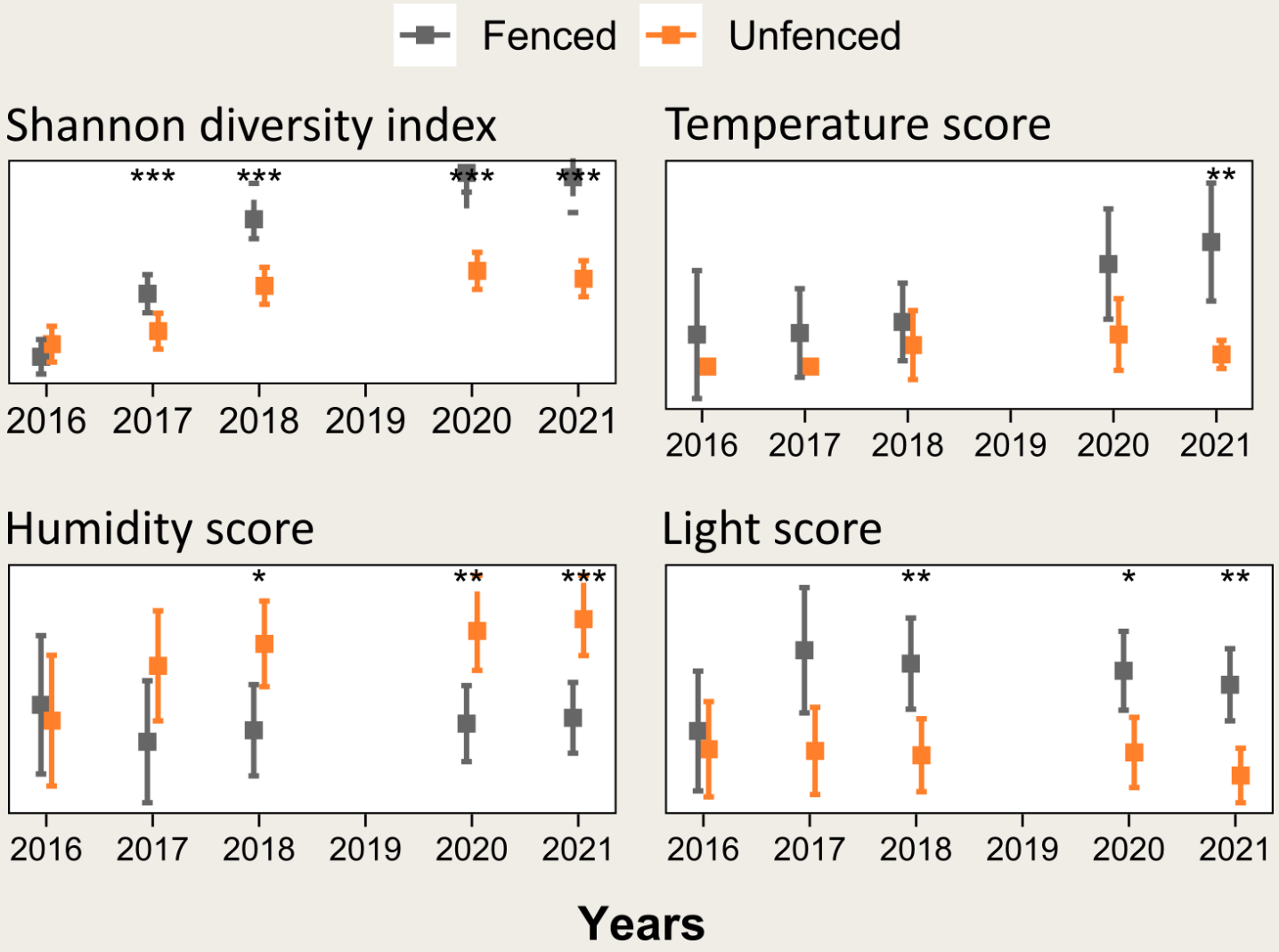
Species ranking in height increment was altered by browsing but oak was the slowest growing species in fenced and unfenced plots.

In fenced plots	
Species	**iH (cm/yr)**
Birch (Betula sp.)	25
Rowan (Sorbus aucuparia)	18
Hornbeam (Carpinus betulus)	17
Beech (Fagus sylvatica)	13
Maple (Acer pseudoplatanus)	11
Norway spruce (Picea abies)	10
Oak (Quercus sp.)	7

Unfenced plots			
Species	**iH (cm/yr)**	**Δ (cm/yr)**	**Δ (%)**
Birch	10	15	60
Spruce	10	n.s.	n.s.
Beech	9	4	30
Hornbeam	6	11	65
Maple	5	6	54
Rowan	3	15	83
Oak	3	4	57

strongly suppressed species

CANDAELE et al. 2023, Forest 14 (7)



Browsing reduced regeneration diversity, increased the share of shade tolerant species and species less-tolerant to warmer and drier conditions

CANDAELE et al. 2023, Forest 14 (7)

Broad

- Shade tolerance : ++
- Browsing resistant : ++
- Growth rate : +

Grow well in the understory, sit-and-wait strategy

High light

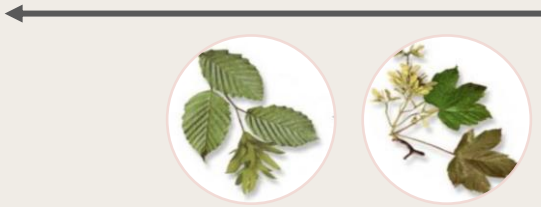
- Shade tolerance : -
- Browsing resistant : --
- Growth rate : ++

Grow well in large gaps and/or if ungulate pressure is low.

Nowhere

- Shade tolerance : -
- Browsing resistant : -
- Growth rate : --

Do not regenerate easily, could regenerate better outside forests.

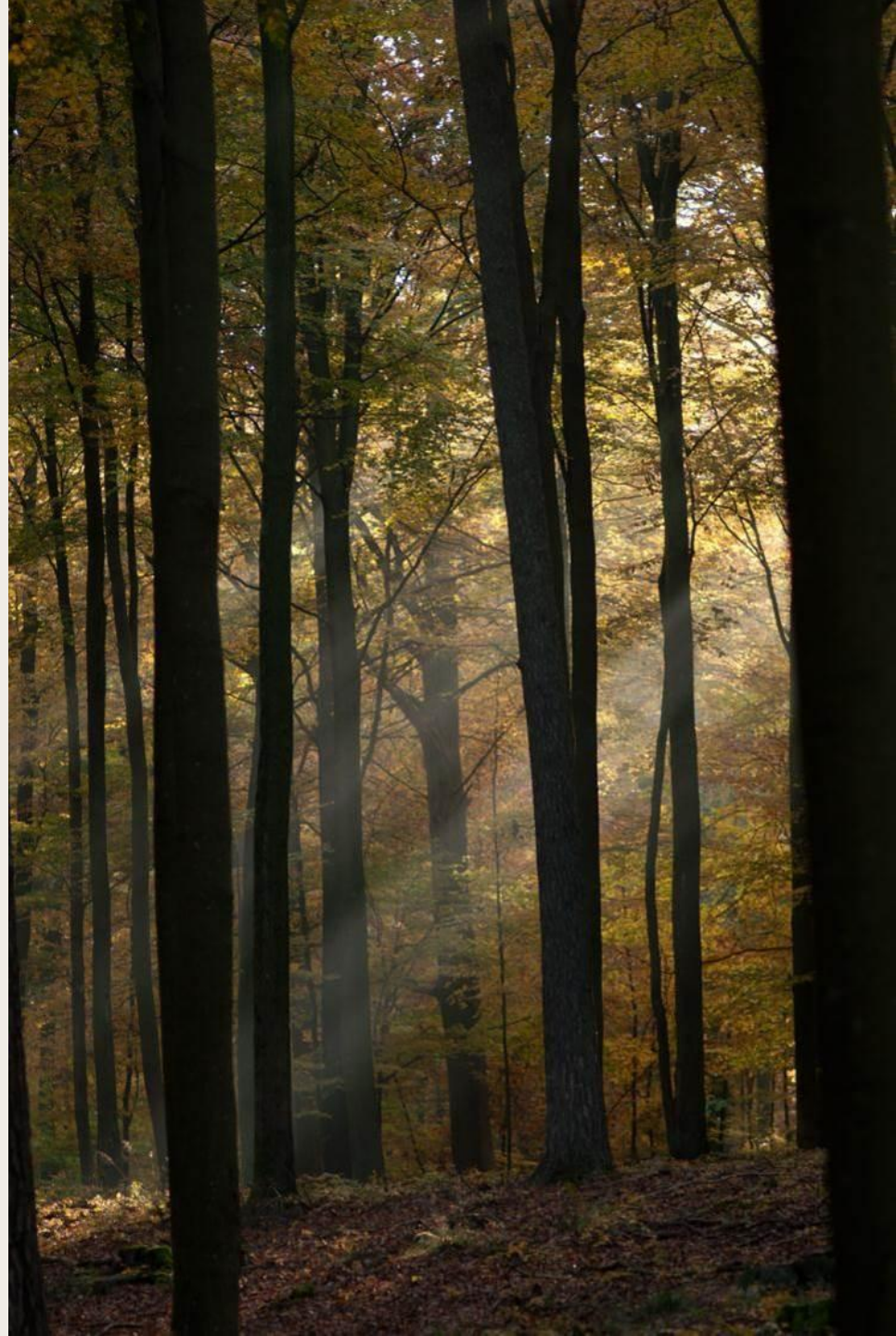


Walter et al. 2020 FORECO

Conclusions

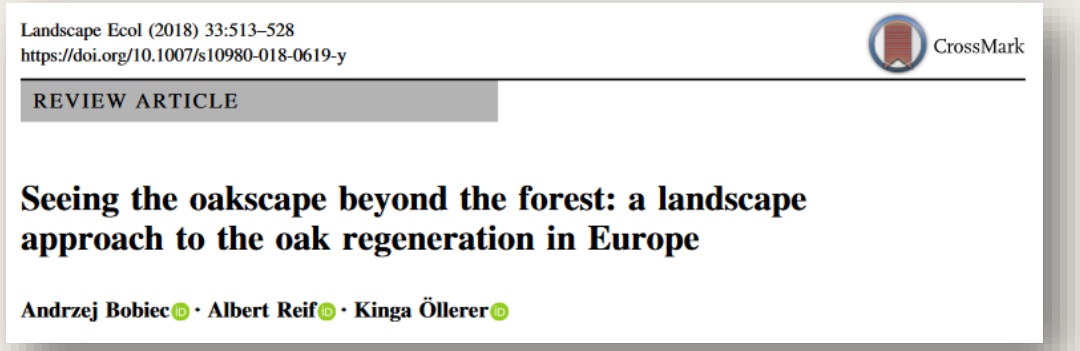
Increasing forest diversity and forest resilience requires more than managing stand density and understory light availability.

Ungulate pressure can lead to a reduction in forest resilience to climate change. In some conditions, ungulates favor the late-successional species that are also less tolerant to dry and warm conditions.



Call to action

- Compare **different silvicultural strategies** to promote regeneration diversity (with simulation tools and forest experiments).
- Investigate new solutions **at the landscape scale** as oak is known to regenerate profusely in transitional habitats (e.g., abandoned farmland) which requires allowing land use change.


Landscape Ecol (2018) 33:513–528
https://doi.org/10.1007/s10980-018-0619-y

CrossMark

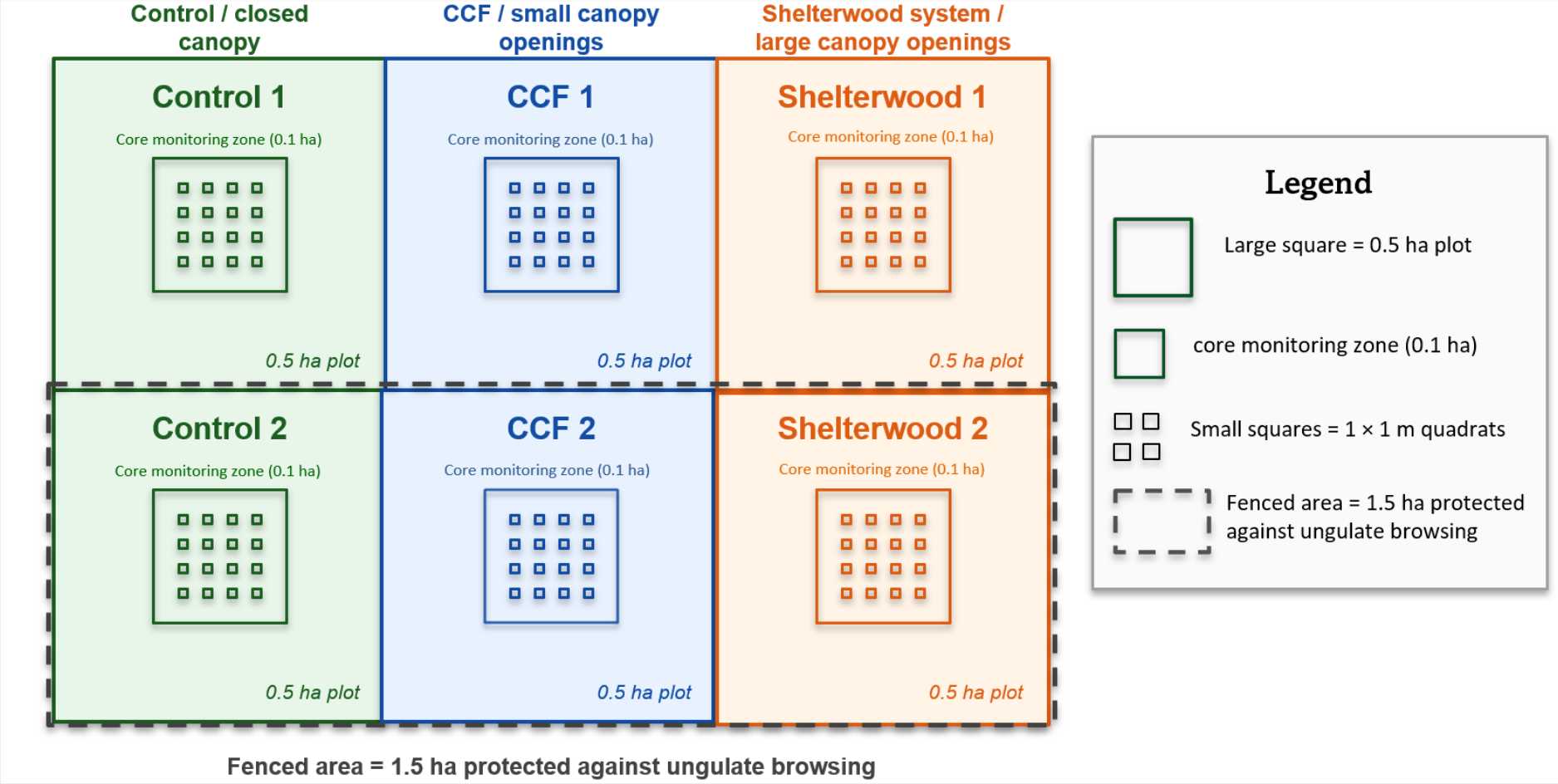
REVIEW ARTICLE

Seeing the oakscape beyond the forest: a landscape approach to the oak regeneration in Europe

Andrzej Bobiec · Albert Reif · Kinga Öllerer

CHENOSCOPE / OAKADAPT

- 3 sites (St Hubert, Florenville, Habay)




Thank you !
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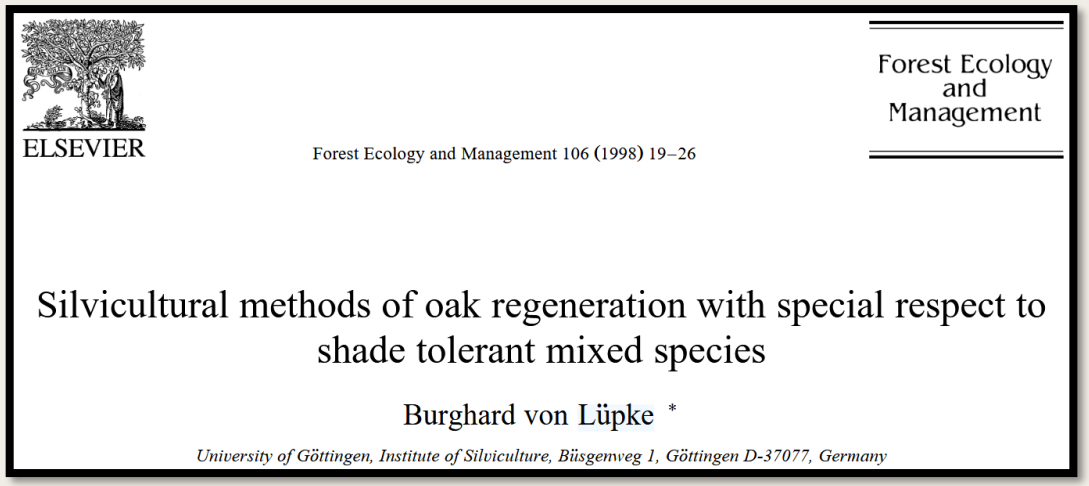
Gembloux
Agro-Bio Tech

Going back to the silvicultural recommendations of von Lüpke (1998)



ELSEVIER

Forest Ecology and Management 106 (1998) 19–26

Forest Ecology and Management

Silvicultural methods of oak regeneration with special respect to shade tolerant mixed species

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Silvicultural recommendations to maintain mixed oak-beech stands in forests naturally dominated by beech (sub-Atlantic region of **Germany**)

- ✓ "**Initial height** has proved to be very important to the height increment within a particular period: plants which were initially larger had a greater increment."
- ✓ "The oaks should have as great an age advantage as possible over the beeches; beeches should never originate from advanced growth."
- ✓ "canopy covers, which allow between **40% and 10% of full light** to penetrate, transfer the competitive relationship more and more away from the oaks **in favour of the beeches**."
- ✓ "Generally speaking, young oaks grow initially faster in clear cut areas than beech of the same age and achieve an advantage of 1–2 m within 30 years." in Open area, beech saplings were affected by late frost whereas the oak were not affected."
- ✓ "The regulation of inter-specific competition during cleanings and thinnings often necessitates great effort to maintain such a high number of oaks"