Wood properties & strength grading

Dan Ridley-Ellis

James Jones open day for architects & engineers

Edinburgh Napier UNIVERSITY

School of Computing, Engineering & the Built Environment

d.ridleyellis@napier.ac.uk | @FlyingQuercus | 01.12.2022

SIRT Strategic Integrated Research in Timber

Health & Wellbeing

Environment & Sustainability

Culture and Communities

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Control

Standards | Policy | Training, education & skills

SIRT

Wood properties

Resource

Tree breeding
Forestry
Harvesting
Processing
Recovered wood
New species

Implications

Environment
Economy
Social and culture

Products

Manufacturing
Grading & NDT
Performance
Innovation
Use
Reuse & recycling

Scales

Molecular – Growth layer – Clear wood – Sawn timber – Log – Tree – Forest - Country



System design

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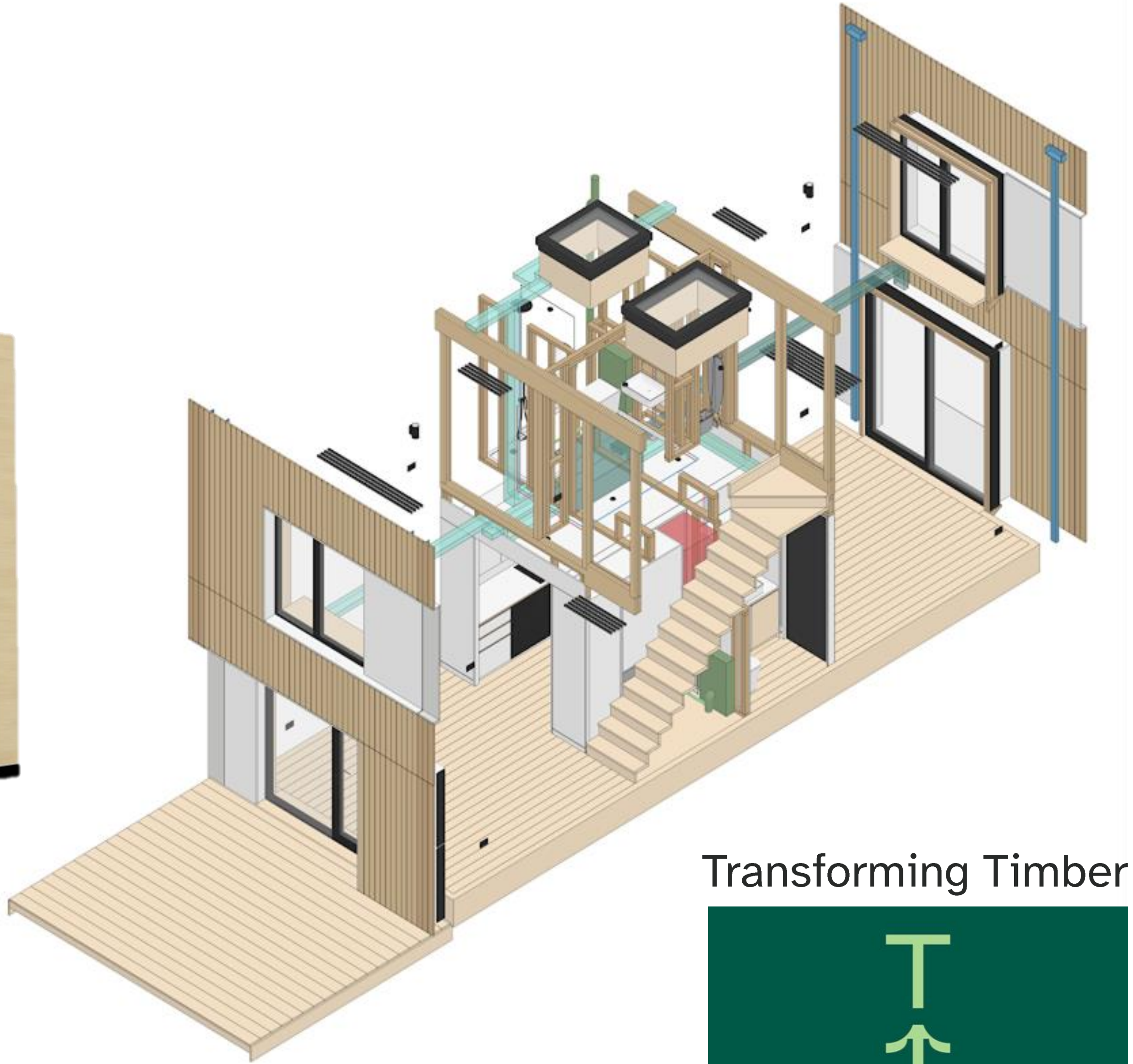
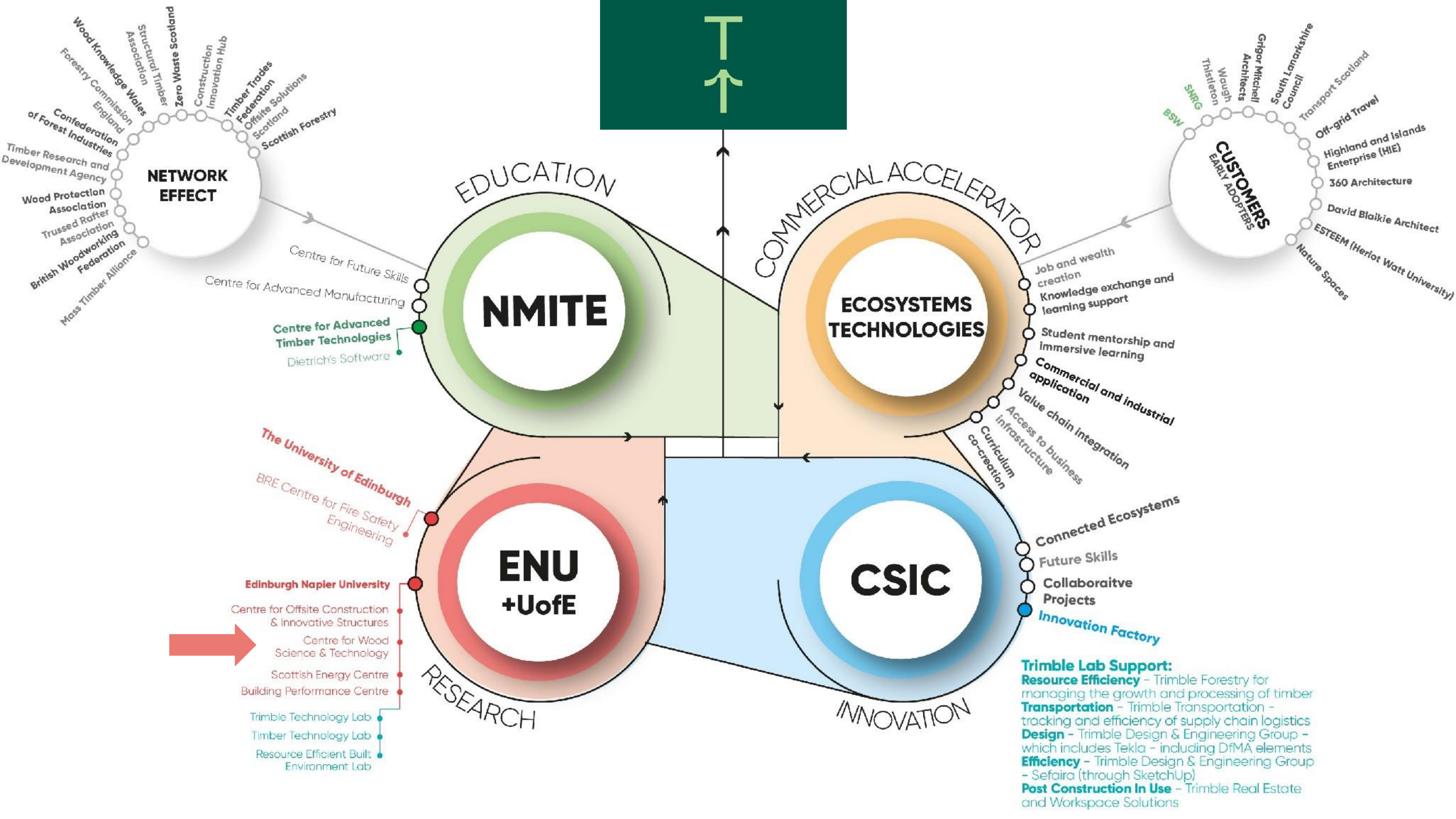


Transforming Timber



NETWORK EFFECT
Wood Knowledge Wales
Forestry Commission England
Confederation of Forest Industries
Timber Research and Development Agency
Wood Protection Association
Trussed Rafter Association
British Woodworking Federation
Mass Timber Alliance
Structural Timber Association
Zero Waste Scotland
Construction Innovation Hub
Timber Trades Federation
Offsite Solutions Scotland
Scottish Forestry
Centre for Future Skills
Centre for Advanced Manufacturing
Centre for Advanced Timber Technologies
Dietrich's Software
EDUCATION
NMITE
COMMERCIAL ACCELERATOR
ECOSYSTEMS TECHNOLOGIES
CUSTOMERS
EARLY ADOPTERS
BSW
SNRG
Thistleton
Waugh
Grigor Mitchell Architects
South Lanarkshire Council
Transport Scotland
Off-grid Travel
Highland and Islands Enterprise (HIE)
360 Architecture
David Blaikie Architect
ESTEEM (Heriot Watt University)
Nature Spaces
Job and wealth creation
Knowledge exchange and learning support
Student mentorship and immersive learning
Commercial and industrial application
Value chain integration
Access to business infrastructure
Curriculum co-creation
The University of Edinburgh
BRE Centre for Fire Safety Engineering
Edinburgh Napier University
Centre for Offsite Construction & Innovative Structures
Centre for Wood Science & Technology
Scottish Energy Centre
Building Performance Centre
Trimble Technology Lab
Timber Technology Lab
Resource Efficient Built Environment Lab
ENU +UofE
RESEARCH
CSIC
INNOVATION
Connected Ecosystems
Future Skills
Collaboraitve Projects
Innovation Factory
Trimble Lab Support:
Resource Efficiency – Trimble Forestry for managing the growth and processing of timber
Transportation – Trimble Transportation – tracking and efficiency of supply chain logistics
Design – Trimble Design & Engineering Group – which includes Tekla – including DfMA elements
Efficiency – Trimble Design & Engineering Group – Sefaira (through SketchUp)
Post Construction In Use – Trimble Real Estate and Workspace Solutions


What is wood?
What are trees?

Issues using wood

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- Water
- “Figure” and “Defects”
- Anisotropy (not the same in all directions)
- Inhomogeneity (not the same in all locations)
- **Variation and uncertainty**

What makes a tree (really)?

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- Does it have to be a plant?
  - Does it have to be a seed plant?
  - Does it have to be a land plant?
- Does it have to be tall? (how tall?)
  - Does what is underground matter?
- Does it have to have a trunk with branches?
  - Does it have to be woody?
  - Does it have to contain wood from secondary growth
- Does it have to live more than a year?
  - Above ground more than a year?

What makes a tree (really)?

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- Are all examples of the same species trees?
- Is a tree a tree it's whole life?
- Is it enough that people call it a tree?
- Does it have to be something people describe using the word tree?
- If it has an ancestor that was a tree does that make it a tree irrespective?

Does this look like a tree?

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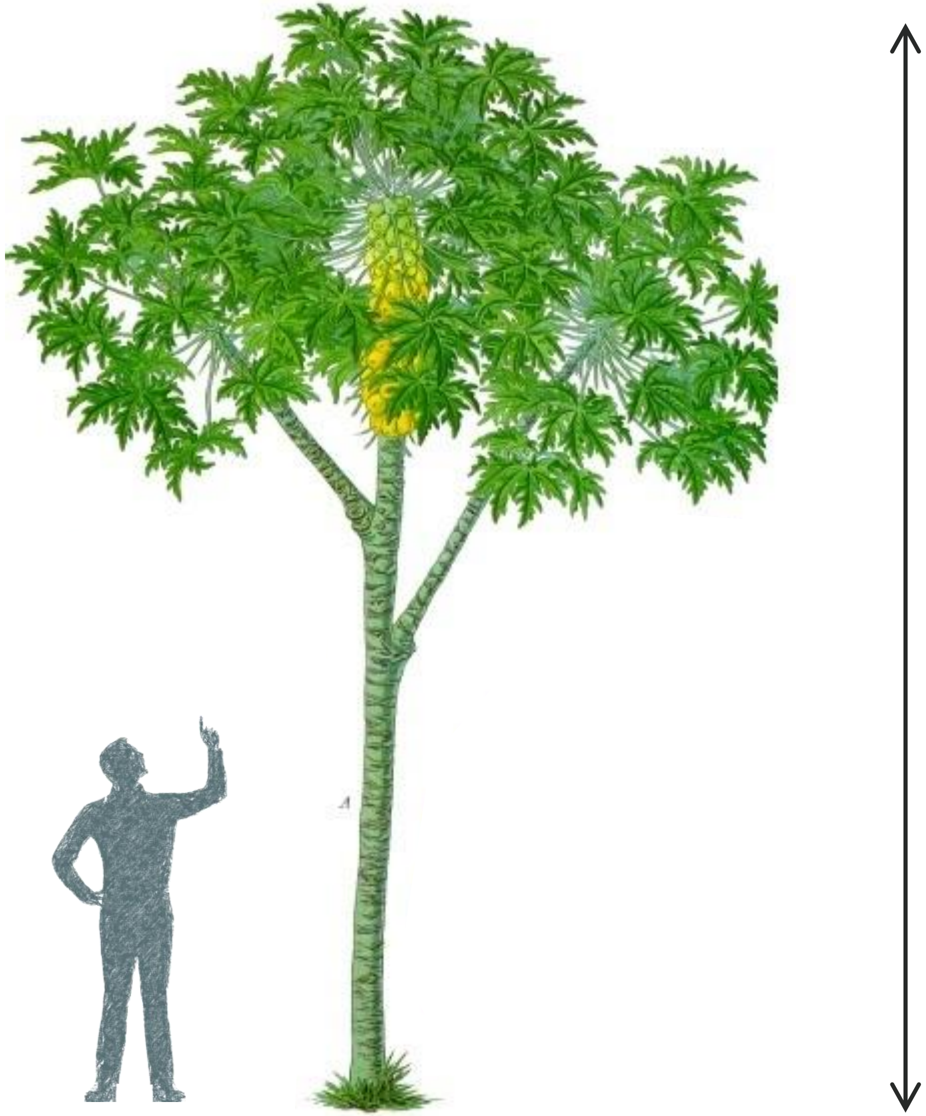

5 to 10 metres
(taller than a giraffe)

Can live up to 20 years

Is a flowering plant
(angiosperm)

Does this look like a tree?

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By Opioła Jerzy

1 to 6 cm tall

Has wood with growth rings

Can live 100+ years

Is a flowering plant (angiosperm)


sapwood
heartwood
(might be more durable)
bark
growth is outwards
cambium
pith
AB16-N
AB16-S

Trees and wood

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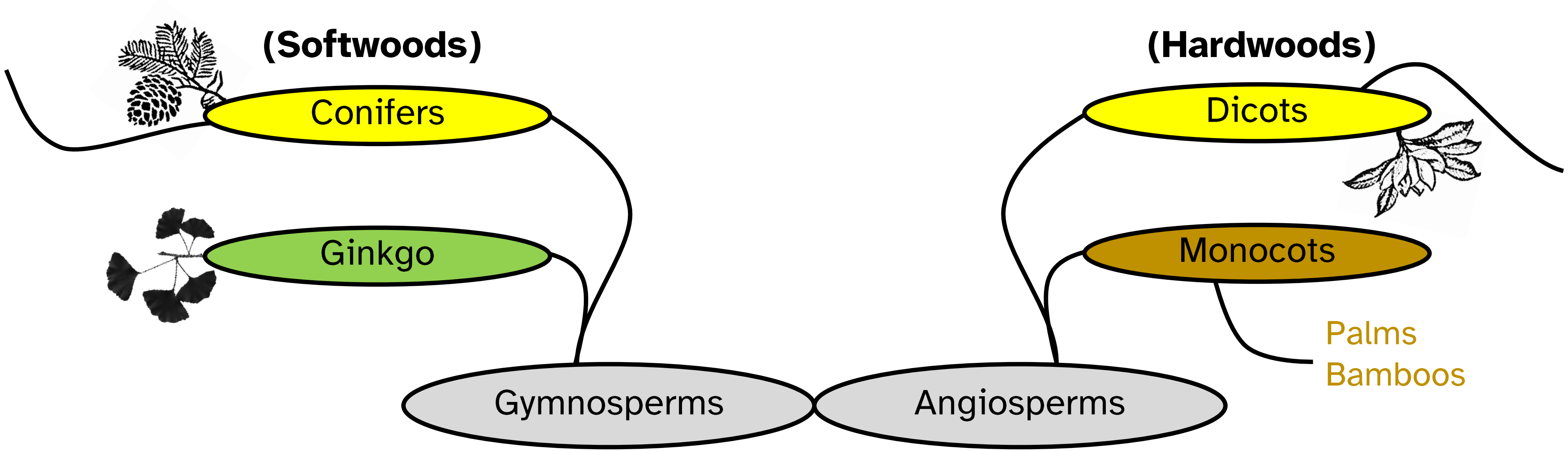

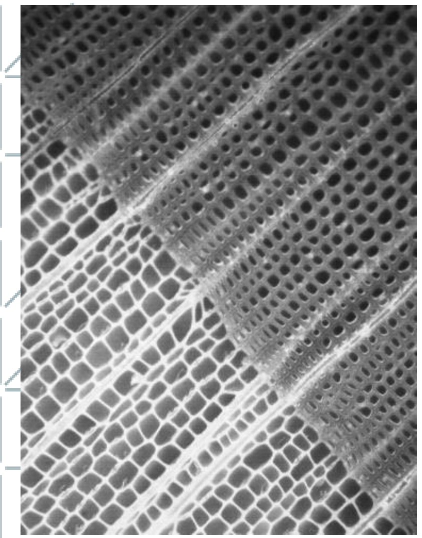

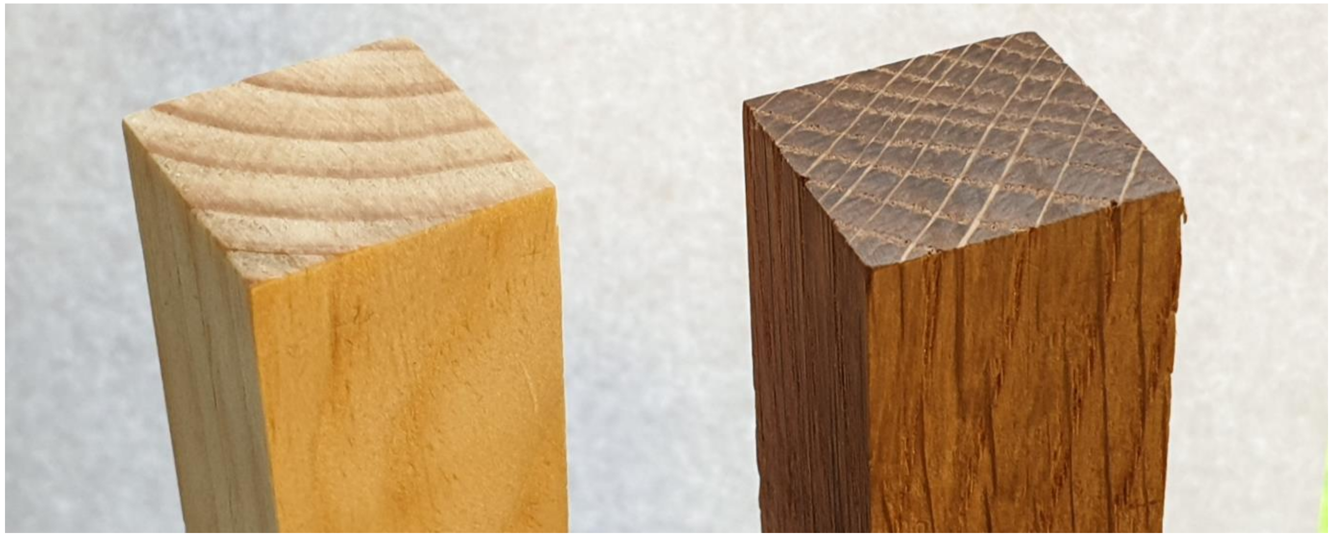

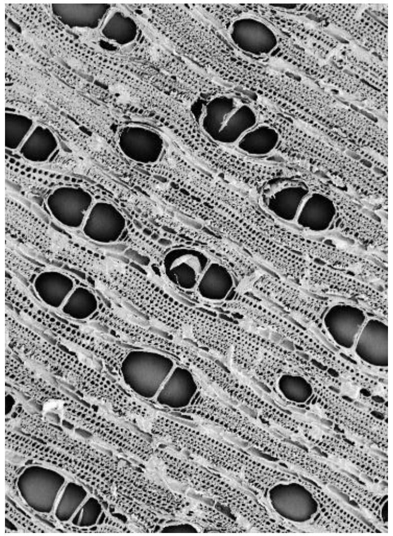

Trees and wood

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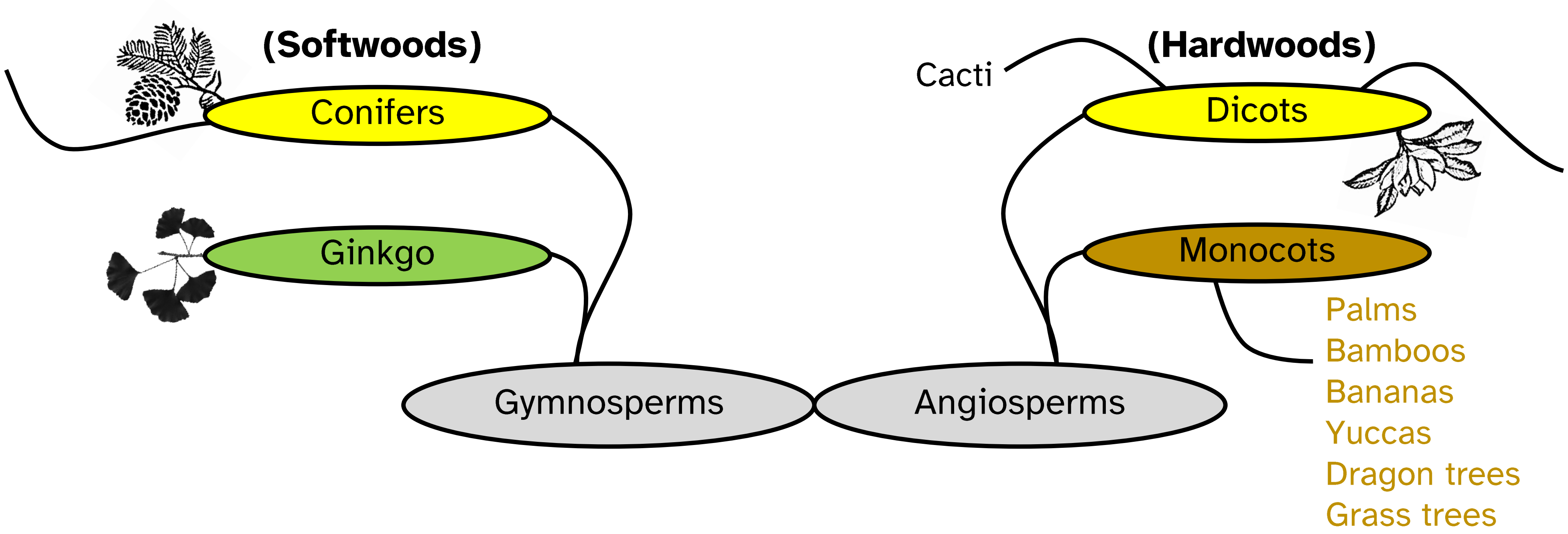

Trees...?

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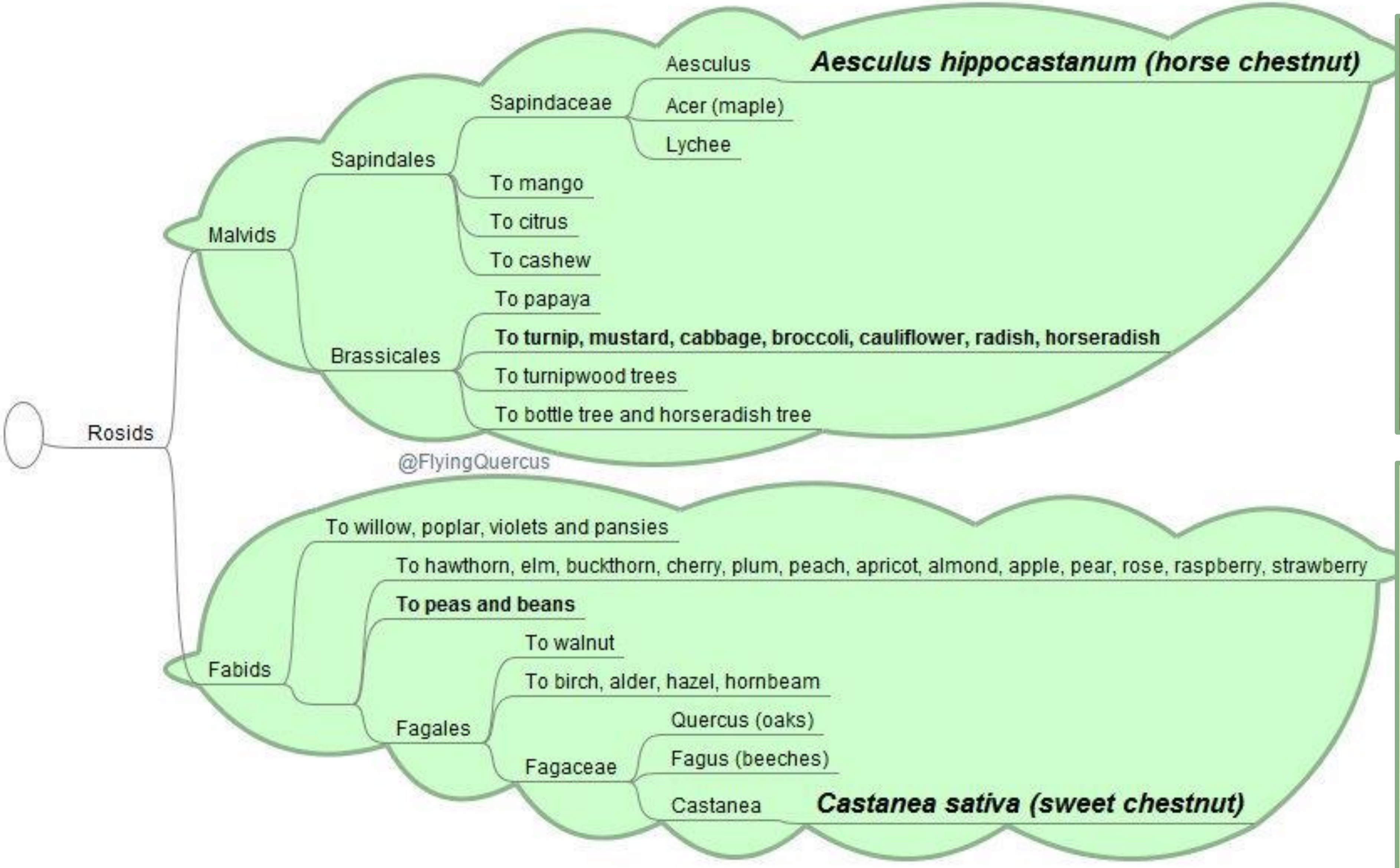
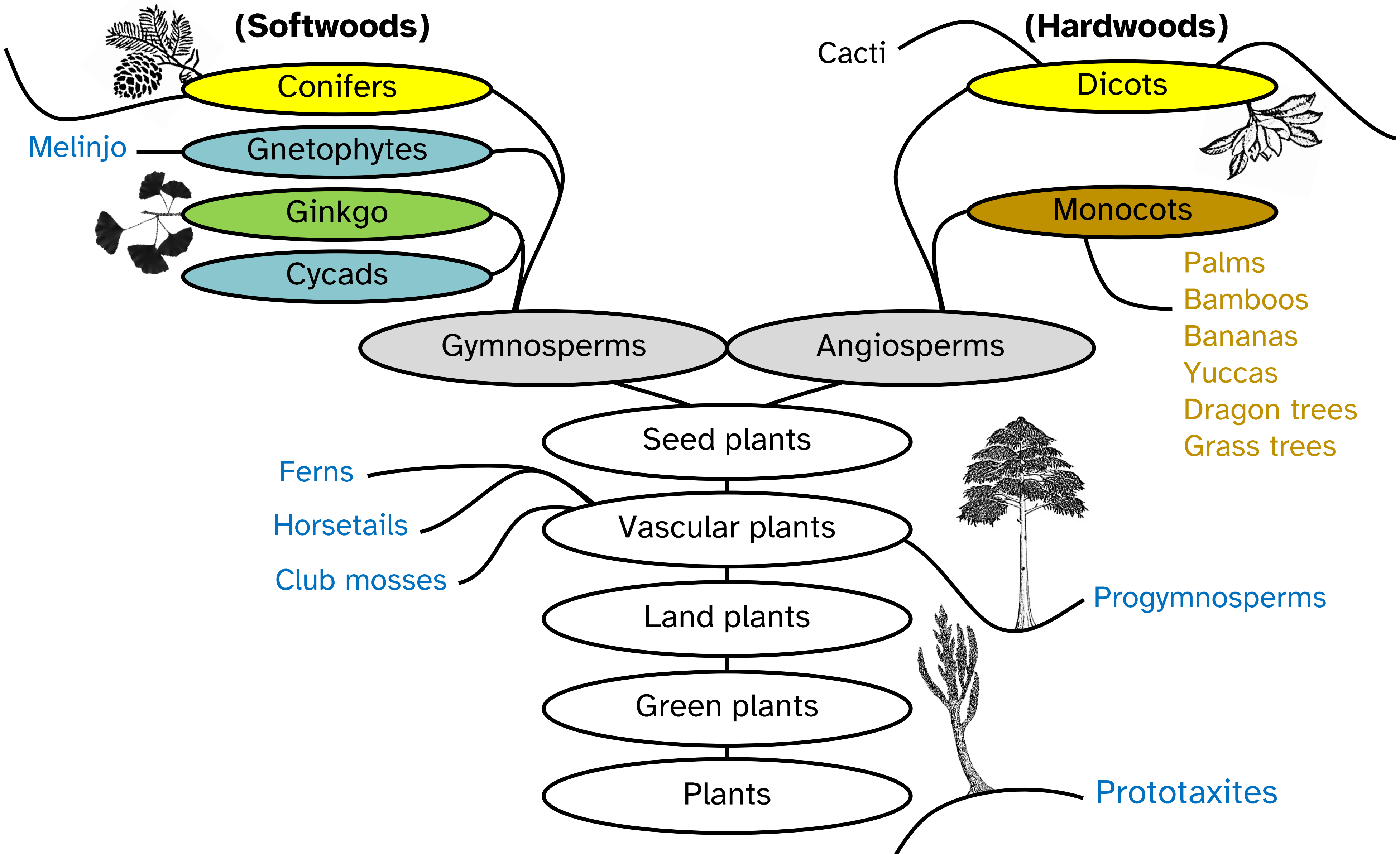


Trees and wood



How wood is made

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- Elements are
  - Carbon (C), Hydrogen (H) and Oxygen (O)
- Photosynthesis

Wood is about 90-95% made from the air

$$nCO_2 + 2nH_2O + \text{photons} \rightarrow (CH_2O)_n + nO_2 + nH_2O$$

carbon dioxide + water + light energy → carbohydrate + oxygen + water

Complicated stuff in the tree

wood

Cellulose
Lignin
Hemicellulose

The circle of life

Some properties that matter

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- Strength (bending, tension, shear, perp to grain, fracture etc...)
- Stiffness
- Density (fasteners, charring rate, self-weight, calorific value...)
- Hardness, toughness, tendency to split
- Dimensional stability / distortion
- Natural durability / difficulty to treat
- Appearance, colour and colour change
- Creep
- Cutting, finishing, gluing, painting etc

Durability

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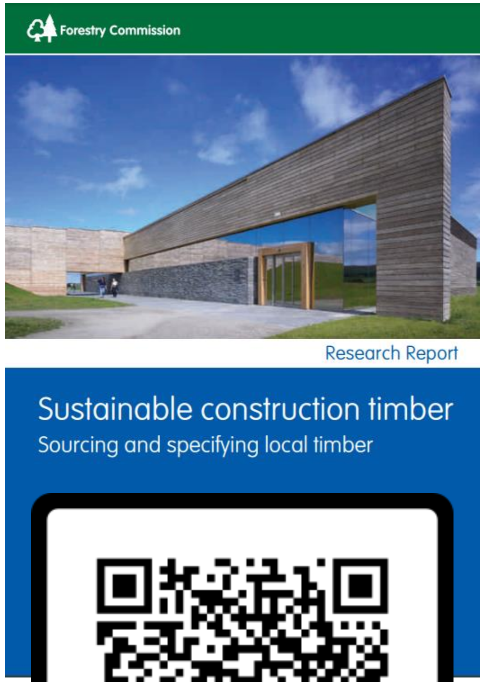
- Natural durability (heartwood only) (EN350)
- Via treatment
- Through design and detailing

- Use classes (EN335)

1. Internal, will not get wet
2. Internal, but might get wet occasionally
3. Outdoors, above the ground
4. Outdoors, in ground contact or fresh water
5. In seawater



SCAN ME

Moisture content

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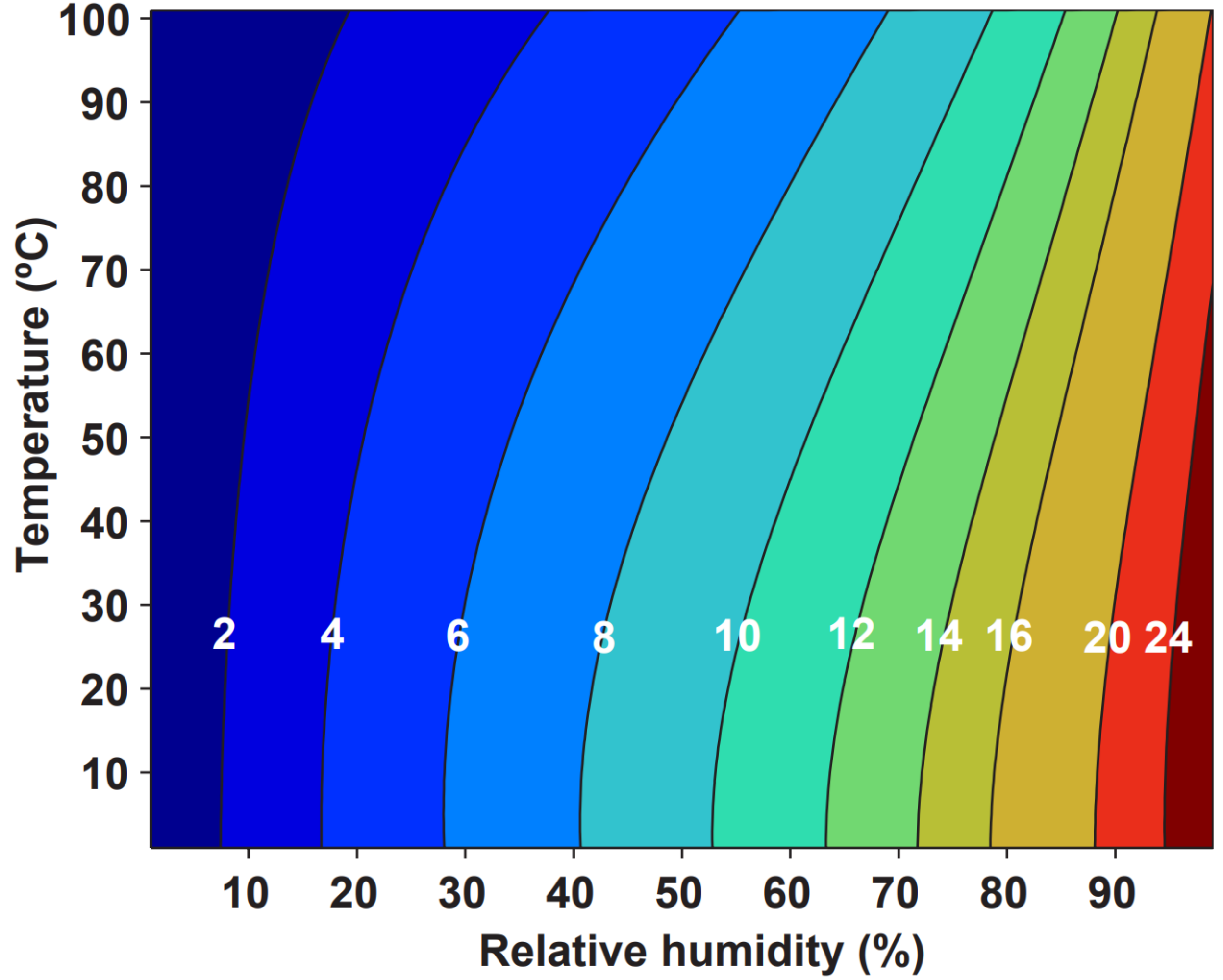

Wood Handbook, Wood as an Engineering Material (FPL USDA), March 2021
https://www.fpl.fs.usda.gov/documnts/fplgtr/fplgtr282/fpl_gtr282.pdf

$$\text{Moisture content} = \frac{\text{mass of water}}{\text{Mass of dry wood}}$$

Fibre saturation ≈ 30%
"Dry" < 20%
In service (indoors) ≈ 12% (or lower)

Method of *determination*

- Oven dry method EN13183-1

Methods of *estimation* (7% to 30%)

- Electrical resistance EN13183-2
- Capacitance EN13813-3

Structural engineering design

- About buildings
  - Staying safe
  - Staying fit for use
- Dealing with uncertainty
  - Of material
  - Of the actions on a structure
  - Of analysis and construction
- <u>True irrespective of the material</u>

(There is always some uncertainty)

Dealing with uncertainty

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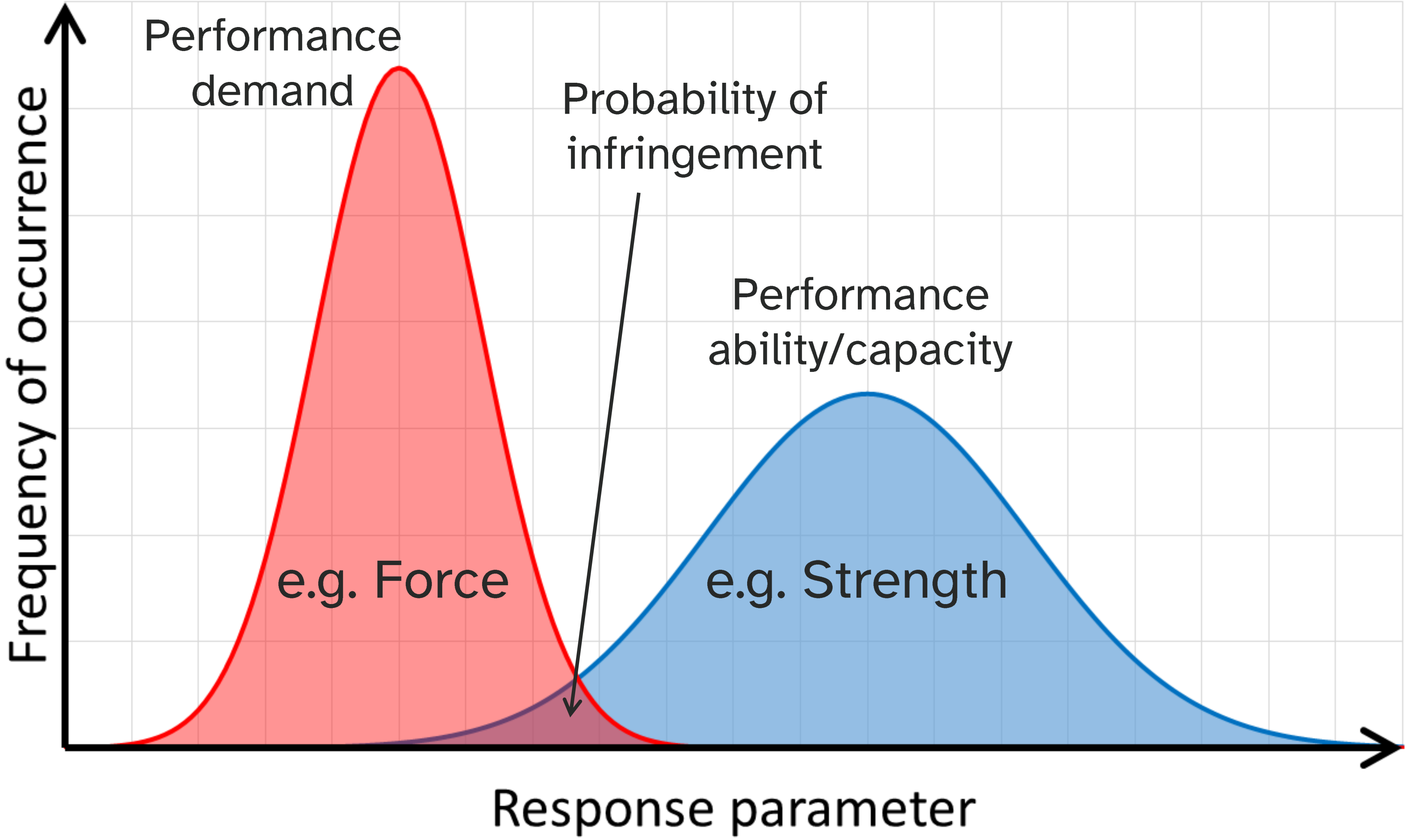

Statistics (as engineers see them)

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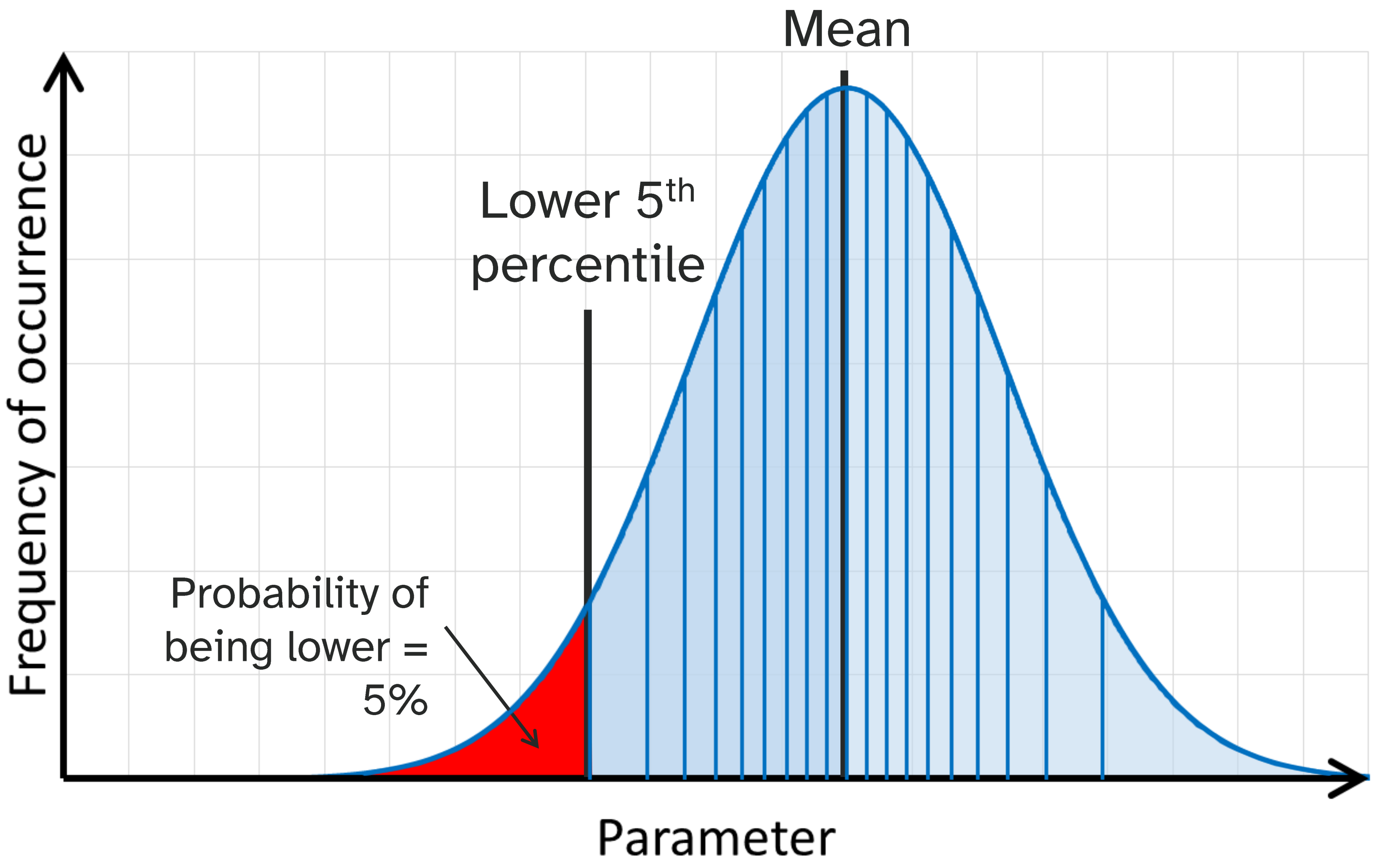

Grade determining properties

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- **Strength**
  - Bending or tension strength
  - Characteristic is the **5th percentile**
- **Stiffness**
  - Bending or tension stiffness
  - Characteristic is the **mean**
- **Density**
  - Used for indirect measure of strength / fire resistance (this is not density for dead weight)
  - Characteristic is the **5th percentile**


LEE

Secondary properties

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- Based on bending strength
  - Tension strength parallel to grain
  - Compression strength parallel to grain
  - Shear strength (or fixed)
- Based on bending stiffness
  - 5th percentile stiffness parallel to grain
  - Stiffness perpendicular to grain
  - Shear modulus
- Based on density
  - Compression strength perpendicular to grain
  - Mean density
- Fixed value (applies to all strength classes)
  - Tension strength perpendicular to grain

See EN384 table 2

For tension grades, the primary property is tension strength (the type of testing, and bending strength is a secondary property)

EN338

	Class	C14	**C16**	**C18**	C20	C22	**C24**	C2
Strength properties in N/mm²								
Bending	$f_{m,,k}$	14	**16**	**18**	20	22	**24**	2
Tension parallel	$f_{t,0,k}$	7,2	**8,5**	**10**	11,5	13	**14,5**	[illegible]
Tension perpendicular	$f_{t,90,k}$	0,4	**0,4**	**0,4**	0,4	0,4	**0,4**	[illegible]
Compression parallel	$f_{c,0,k}$	16	**17**	**18**	19	20	**21**	22
Compression perpendicular	$f_{c,90,k}$	2,0	**2,2**	**2,2**	2,3	2,4	**2,5**	2,5
Shear	$f_{v,k}$	3,0	**3,2**	**3,4**	3,6	3,8	**4,0**	4,0
Stiffness properties in kN/mm²								
Mean modulus of elasticity parallel bending	$E_{m,0,mean}$	7,0	**8,0**	**9,0**	9,5	10,0	**11,0**	11
5 percentile modulus of elasticity parallel bending	$E_{m,0,k}$	4,7	**5,4**	**6,0**	6,4	6,7	**7,4**	[illegible]
Mean modulus of elasticity perpendicular	$E_{m,90,mean}$	0,23	**0,27**	**0,30**	0,32	0,33	**0,37**	[illegible]
Mean shear modulus	G_{mean}	0,44	**0,50**	**0,56**	0,59	0,63	**0,69**	0,
Density in kg/m³								
5 percentile density	ρ_k	290	**310**	**320**	330	340	**350**	360
Mean density	ρ_{mean}	350	**370**	**380**	400	410	**420**	43

EN338	Class	D18	**D24**	D27	**D30**	D35	**D40**	D45	**D50**	D55	**D6**
Strength properties in N/mm²											
Bending	$f_{m,,k}$	18	**24**	27	**30**	35	**40**	45	**50**	55	**60**
Tension parallel	$f_{t,0,k}$	11	**14**	16	**18**	21	**24**	27	**30**	33	
Tension perpendicular	$f_{t,90,k}$	0,6	**0,6**	0,6	**0,6**	0,6	**0,6**	0,6	**0,6**	0,6	
Compression parallel	$f_{c,0,k}$	18	**21**	22	**24**	25	**27**	29	**30**	32	**33**
Compression perpendicular	$f_{c,90,k}$	4,8	**4,9**	5,1	**5,3**	5,4	**5,5**	5,8	**6,2**	6,6	**10,5**
Shear	$f_{v,k}$	3,5	**3,7**	3,8	**3,9**	4,1	**4,2**	4,4	**4,5**	4,7	**4,8**
Stiffness properties in kN/mm²											
Mean modulus of elasticity parallel bending	$E_{m,0,mean}$	9,5	**10,0**	10,5	**11,0**	12,0	**13,0**	13,5	**14,0**	15,5	**17,**
5 percentile modulus of elasticity parallel bending	$E_{m,0,k}$	8,0	**8,4**	8,8	**9,2**	10,1	**10,9**	11,3	**11,8**	13,0	**14**
Mean modulus of elasticity perpendicular	$E_{m,90,mean}$	0,63	**0,67**	0,70	**0,73**	0,80	**0,87**	0,90	**0,93**	1,03	**1,**
Mean shear modulus	G_{mean}	0,59	**0,63**	0,66	**0,69**	0,75	**0,81**	0,84	**0,88**	0,97	**1,06**
Density in kg/m³											
5 percentile density	ρ_k	475	**485**	510	**530**	540	**550**	580	**620**	660	**700**
Mean density	ρ_{mean}	570	**580**	610	**640**	650	**660**	700	**740**	790	**840**

EN338

	Class	T 8	T 9	T 10	**T 11**	T 12	T 13	**T 14**	T 14,5	T 15	T 16	**T 18**	**T 21**	**T 22**	T 24	T 26	T 27
Strength properties in N/mm²																	
Bending	$f_{m,,k}$	13,5	14,5	16	**17**	18	19,5	**20,5**	21	22	23	**25,5**	**29**	**30,5**	33	35	36,[illegible]
Tension parallel	$f_{t,0,k}$	8	9	10	**11**	12	13	**14**	14,5	15	16	**18**	**21**	**22**	24	26	[illegible]
Tension perpendicular	$f_{t,90,k}$	0,4	0,4	0,4	**0,4**	0,4	0,4	**0,4**	0,4	0,4	0,4	**0,4**	**0,4**	**0,4**	0,4	0,4	[illegible]
Compression parallel	$f_{c,0,k}$	16	17	17	**18**	19	20	**21**	21	21	22	**23**	**25**	**26**	27	28	29
Compression perpendicular	$f_{c,90,k}$	2,0	2,1	2,2	**2,2**	2,3	2,4	**2,5**	2,5	2,5	2,6	**2,7**	**2,7**	**2,7**	2,8	2,9	2,9
Shear	$f_{v,k}$	2,8	3,0	3,2	**3,4**	3,6	3,8	**4,0**	4,0	4,0	4,0	**4,0**	**4,0**	**4,0**	4,0	4,0	4,0
Stiffness properties in kN/mm²																	
Mean modulus of elasticity parallel tension	$E_{t,0,mean}$	7,0	7,5	8,0	**9,0**	9,5	10,0	**11,0**	11,0	11,5	11,5	**12,0**	**13,0**	**13,0**	13,5	14,0	15,0
5 percentile modulus of elasticity parallel tension	$E_{t,0,k}$	4,7	5,0	5,4	**6,0**	6,4	6,7	**7,4**	7,4	7,7	7,7	**8,0**	**8,7**	**8,7**	9,0	9,4	10,
Mean modulus of elasticity perpendicular	$E_{t,90,mean}$	0,23	0,25	0,27	**0,30**	0,32	0,33	**0,37**	0,37	0,38	0,38	**0,40**	**0,43**	**0,43**	0,45	0,47	0,5
Mean shear modulus	G_{mean}	0,44	0,47	0,50	**0,56**	0,59	0,63	**0,69**	0,69	0,72	0,72	**0,75**	**0,81**	**0,81**	0,84	0,88	0,94
Density in kg/m³																	
5 percentile density	ρ_k	290	300	310	**320**	330	340	**350**	350	360	370	**380**	**390**	**390**	400	410	410
Mean density	ρ_{mean}	350	360	370	**380**	400	410	**420**	420	430	440	**460**	**470**	**470**	480	490	490

“Grades” and “classes”

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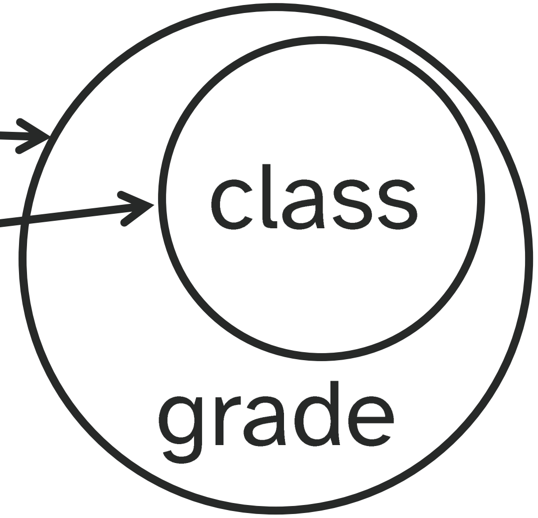
- Strength grade
- Strength class
  - Has numerical properties
- Timber grades are assigned to a class
- EN 338 lists strength classes
  - C bending classes for softwoods (now also hardwoods)
  - D bending classes for hardwoods
  - T tension classes for softwoods
- These are not the only strength classes (e.g. TR26)
- & just convenience – Declaration of Performance what matters



UK softwood summary

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	Species	Research*	Data	Ungraded Strength	Ungraded Stiffness	Ungraded Density	Grading (From 95% machine yield)	Durability (Fungi, EN350)
Grading options	Spruce (UK & IE) (Sitka & Norway)	ENU, FR, NUIG	😎	C16	C16	C20	C16 to C27	5-4
	Larch (UK & IE) (European, Japanese, hybrid)	ENU, FR, NUIG	😊	C20	C20	C40	C20 to C35	4-3 🙂
	Douglas-fir (UK & IE)	ENU, FR, NUIG	😊	C14	C22	C35	C16 to C40	4-3 🙂
	Pine (UK & IE) (Scots & Corsican)	ENU, FR, NUIG	🙂	C20	C18	C40	*C16 to C24*	4-3 🙂
No grading options	Noble fir	ENU, FR	🙂	C14	C16	C18	C16? to ?	4
	Western red cedar	ENU, FR	🙂	C16	C14	C16	C16? to ?	3 😊
	Western hemlock	ENU, FR	🙂	C18	C16	C30	C16? to ?	4
	Silver fir	ENU, FR	🤔	C20	C16	C27	C16? to ?	4
	Grand fir	ENU, FR	🤔	C16	C14	C18	C16? to ?	4
	Pacific silver fir	ENU, FR	🤔	C18	C18	C16	C16? to ?	?
	Serbian spruce	ENU, FR	🤔	C16	C18	C40	C16? to ?	?
	Japanese red cedar	ENU, FR	🤔	C14	<C14	<C14	C14? to ?	5
	Nordmann fir	ENU, FR	😌	<C14	C18	C30	C14? to ?	?

blogs.napier.ac.uk/cwst/

Durability is for heartwood against fungi. 5 = 'not durable'; 4 = 'slightly durable', 3 = 'moderately durable'
Pine grading options are limited and probably not optimal
* ENU = Edinburgh Napier University; FR = Forest Research; NUIG = National University of Ireland, Galway

SIRT
Strategic Integrated Research in Timber

Properties are influenced by

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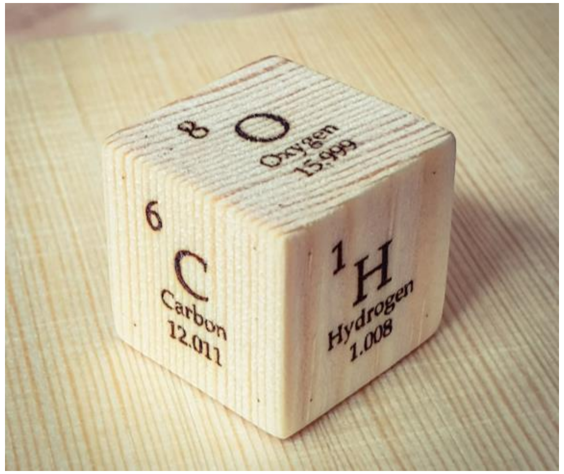
SIRT

Strategic Integrated Research in Timber



- **Species**
- **Growth area**
- Forest type, & management
- Tree selection & breeding
- Processing
- Handing after processing

“Quality” indicators

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- Species?
- Origin?
- Knots?
- Slope of grain?
- Ring width?
- Density?
- …

"Quality" indicators

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1. Things that determine quality directly
2. Things that correlate with quality somehow

A key thing about indicators

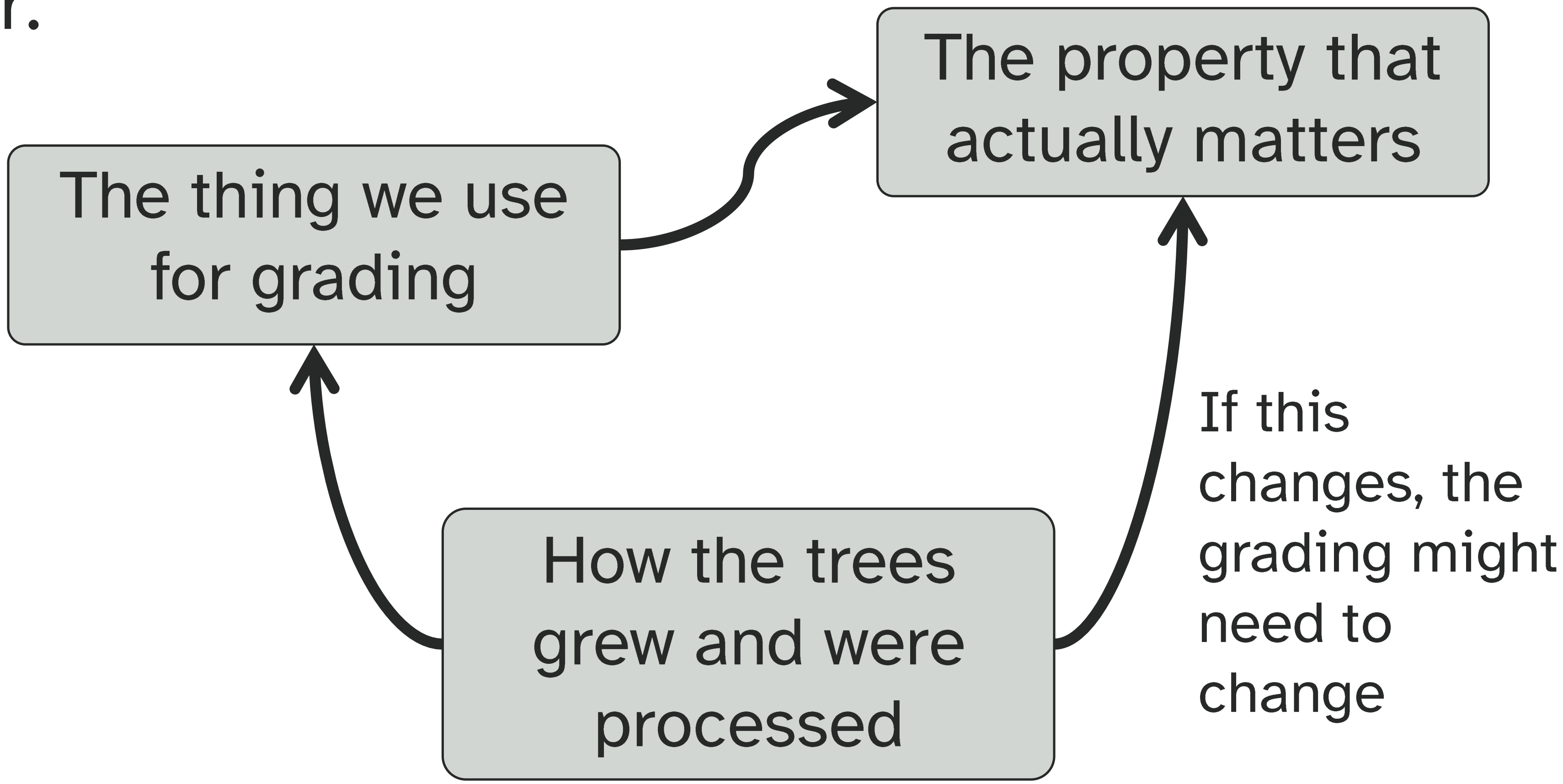
They can be useful for grading, but are often not deterministic

Especially for:

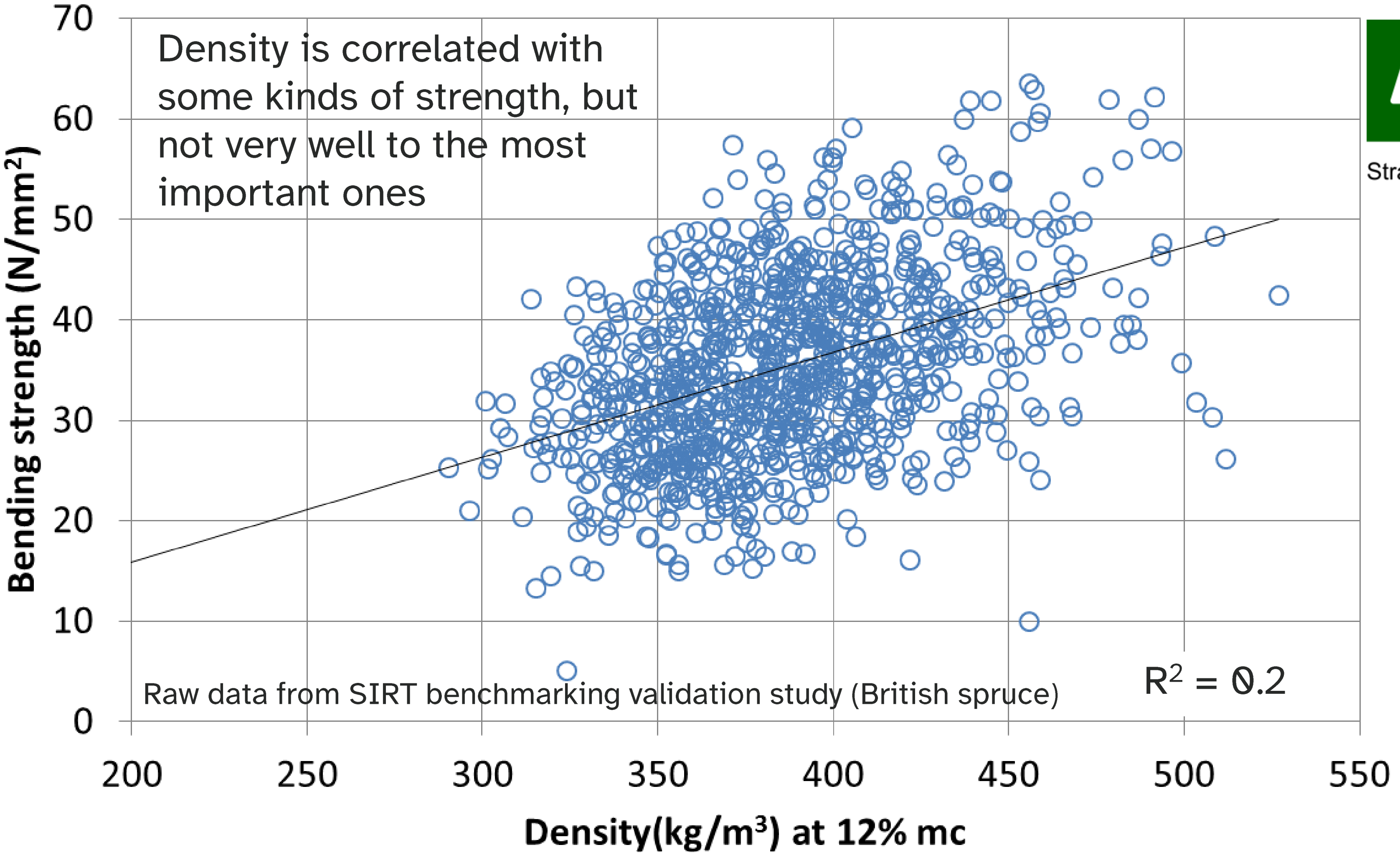
Knots

Ring width

Density



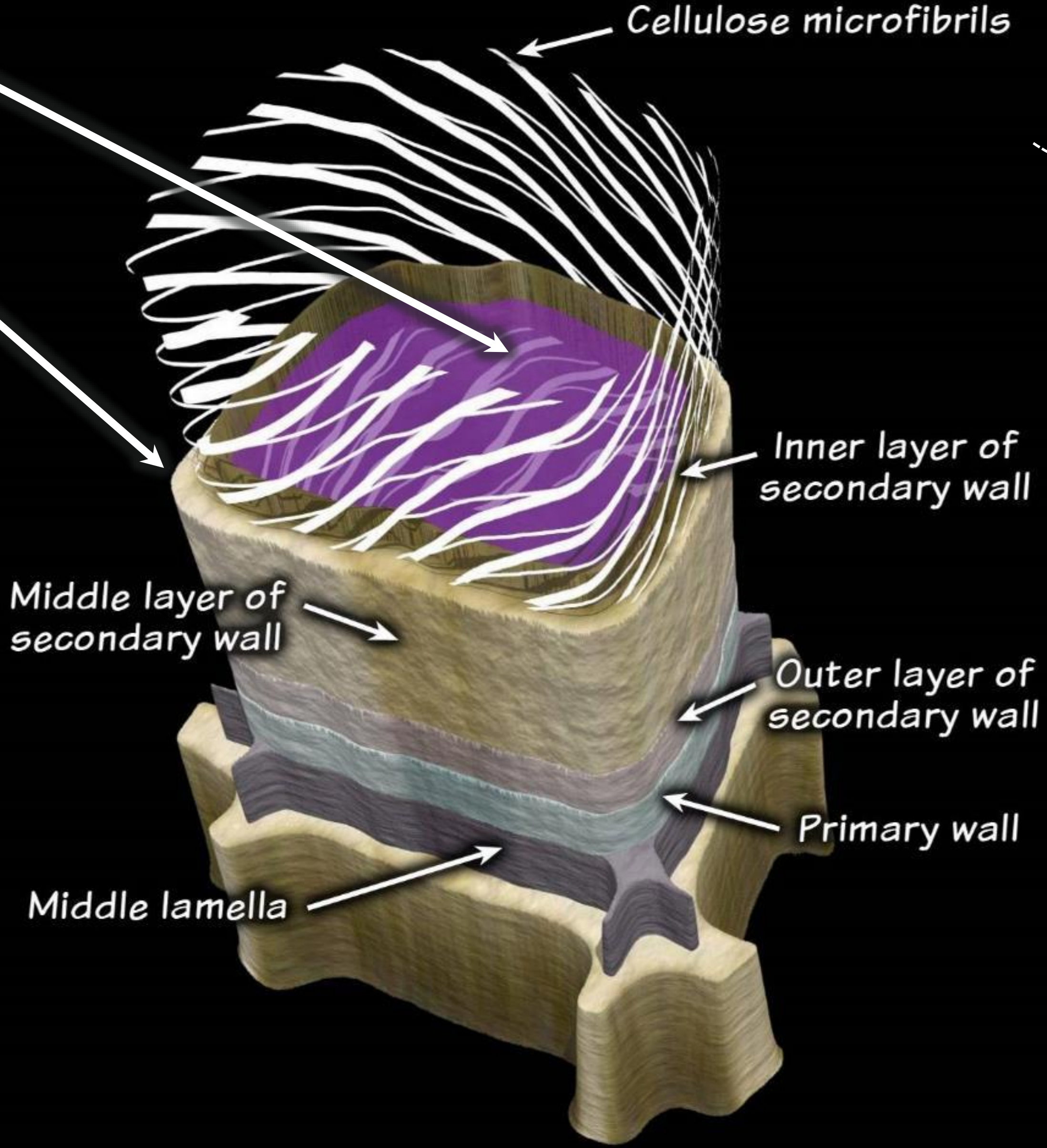
Density & bending strength

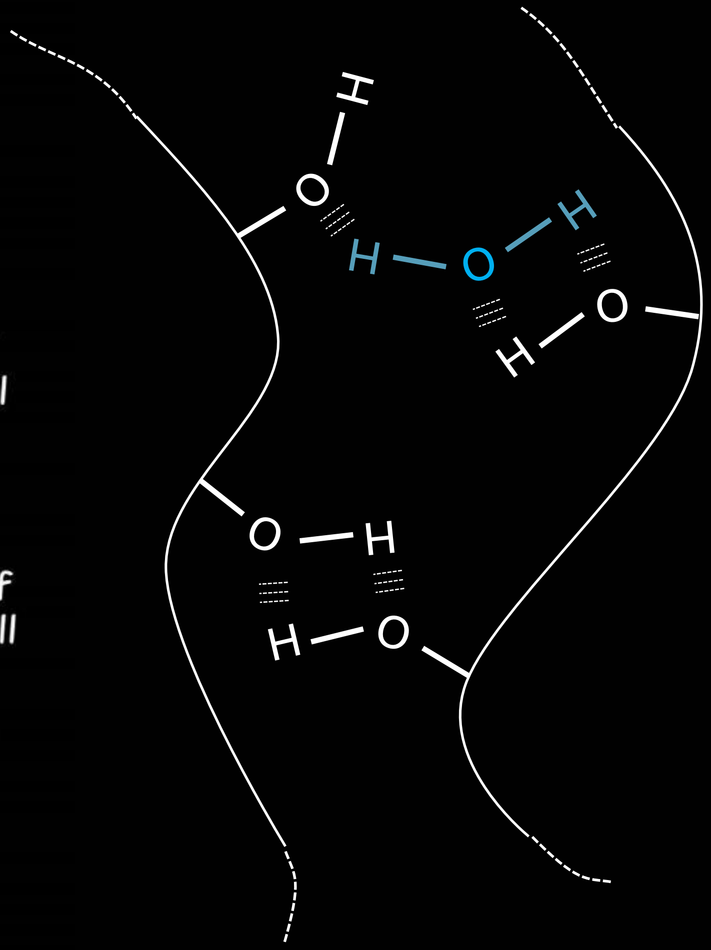


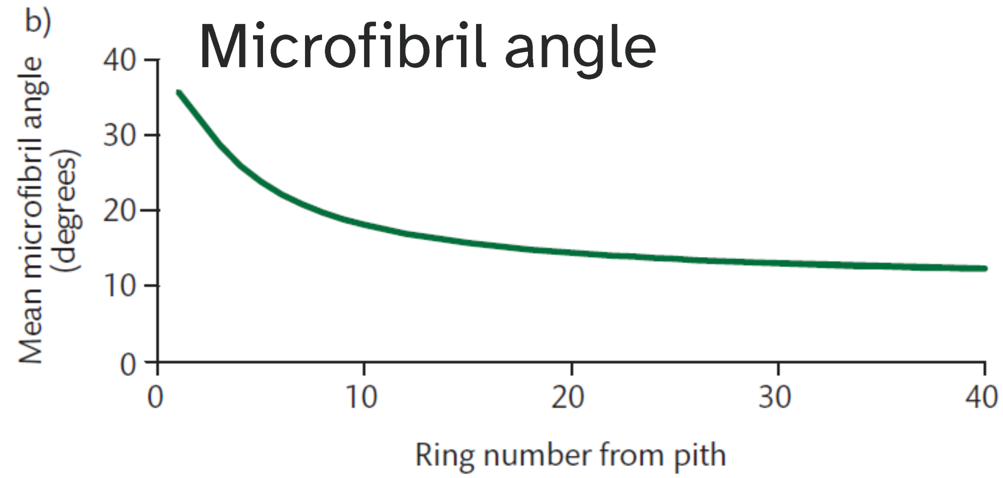
Strategic Integrated Research in Timber

“Free water”
When mc > ~30%

“Bound water”
Water molecules
in the cell wall







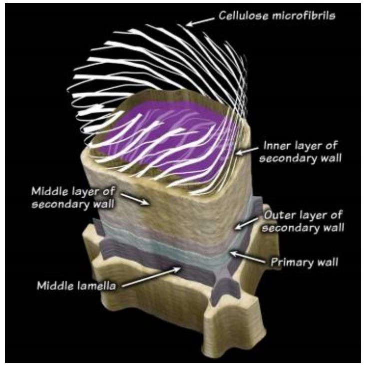


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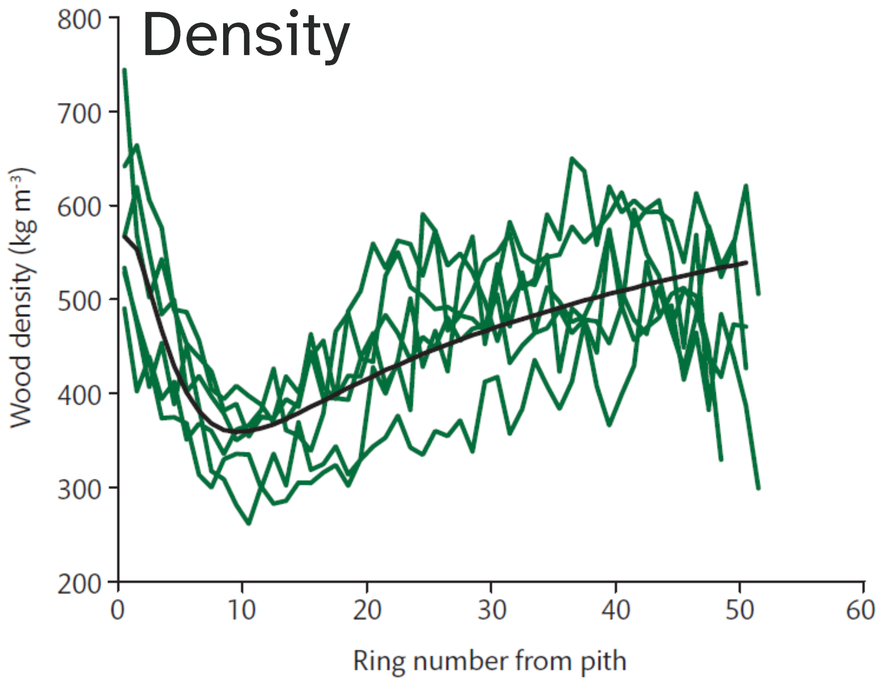
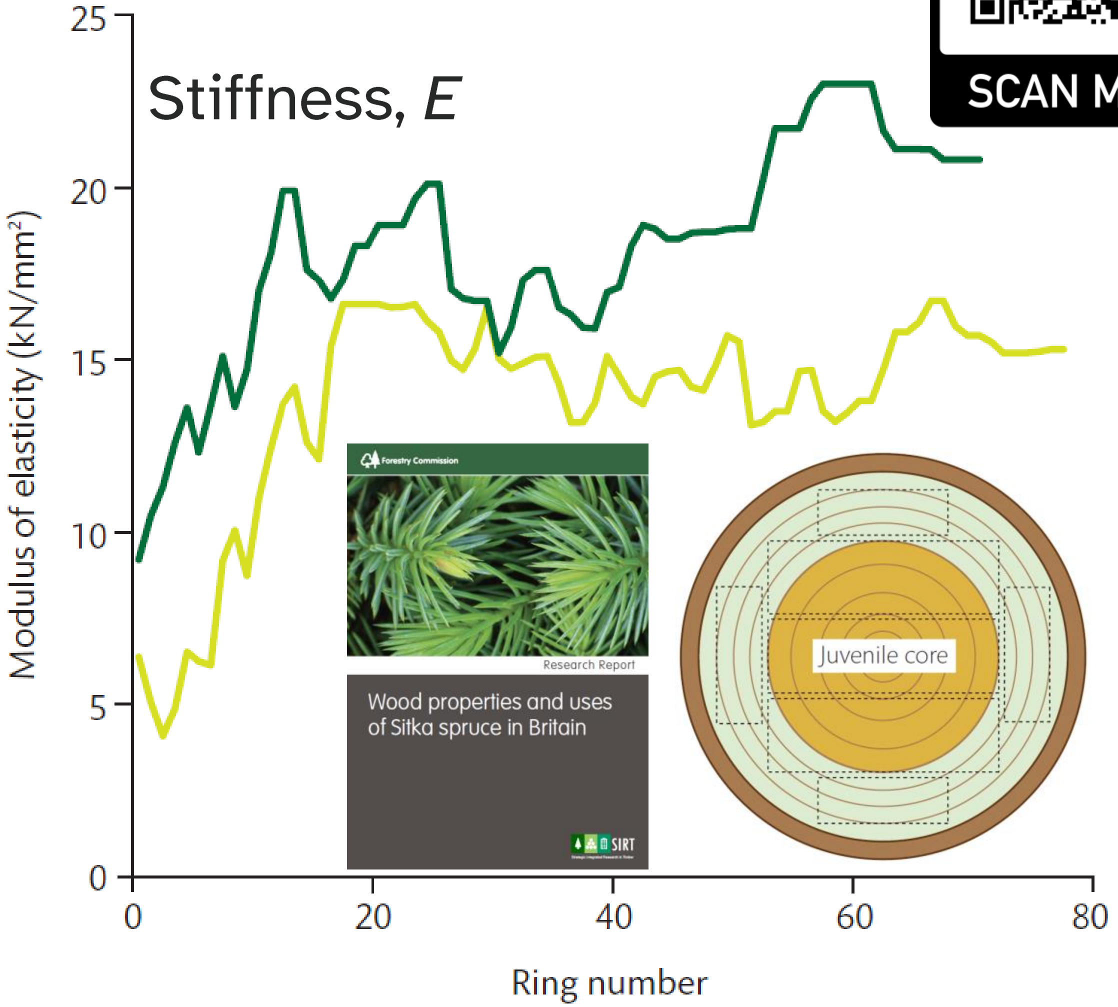
Figure 2.15 Radial profile of Sitka spruce wood density. The green lines show profiles for five individual trees sampled at Baronscourt in Northern Ireland, while the black line represents a model fitted to these data.





Influence via

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- Position within the tree
  - Radially & vertically
- Silviculture
  - Spacing, thinning, rotation length etc
- Site
  - Exposure, temperature, rainfall, soil type etc
- Genetics
  - Species, variety and individual

“Rate of growth”

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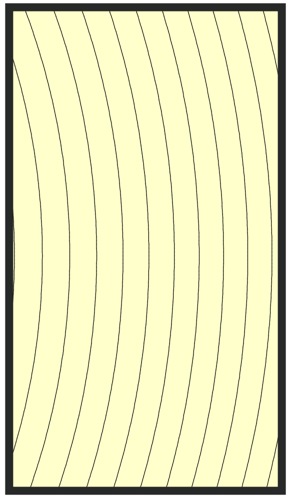
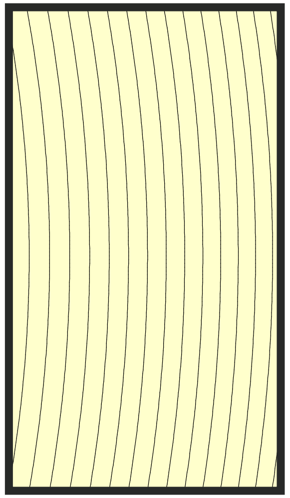
Grew in ~11 years



Grew in ~15 years



“Rate of growth”

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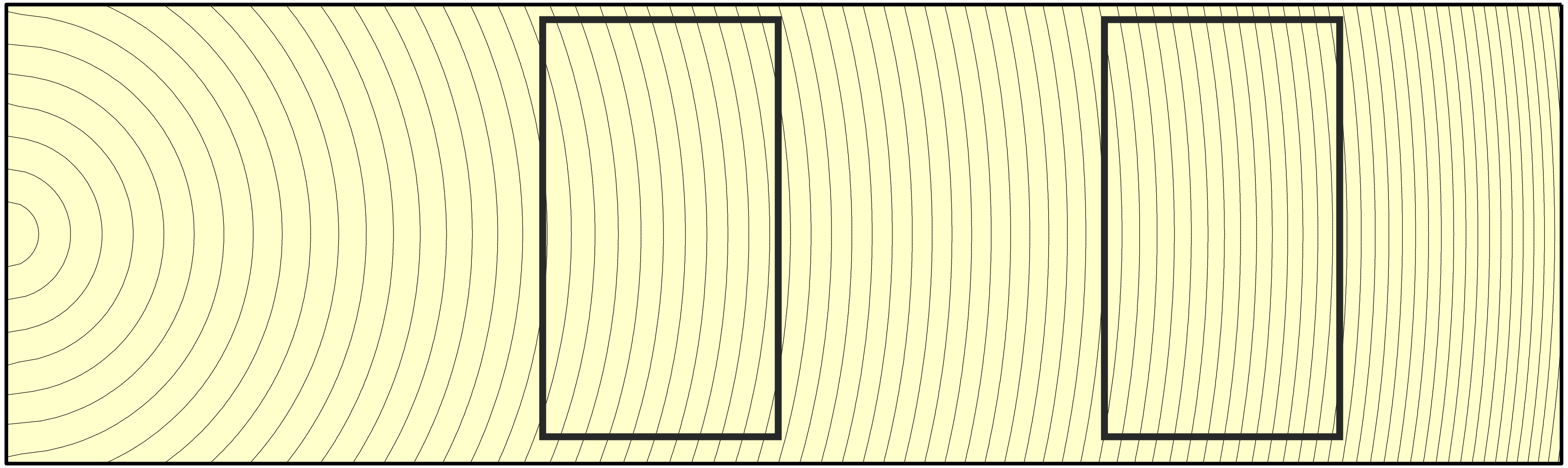
Bigger tree – actually growing faster (more wood) at this point



Density & ring width (softwood)

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- No visible growth rings
  - No correlation between growth rate and wood density.
- Gradual transition from earlywood to latewood
  - e.g. the spruces and the firs
  - Density might decrease with increasing growth rate, but for timber of mixed origins, ring width alone is not an accurate predictor of wood density
- Abrupt transition from earlywood to latewood
  - e.g. the larches and the hard pines
  - No correlation between growth rate and wood density.

Density & ring width (spruce)

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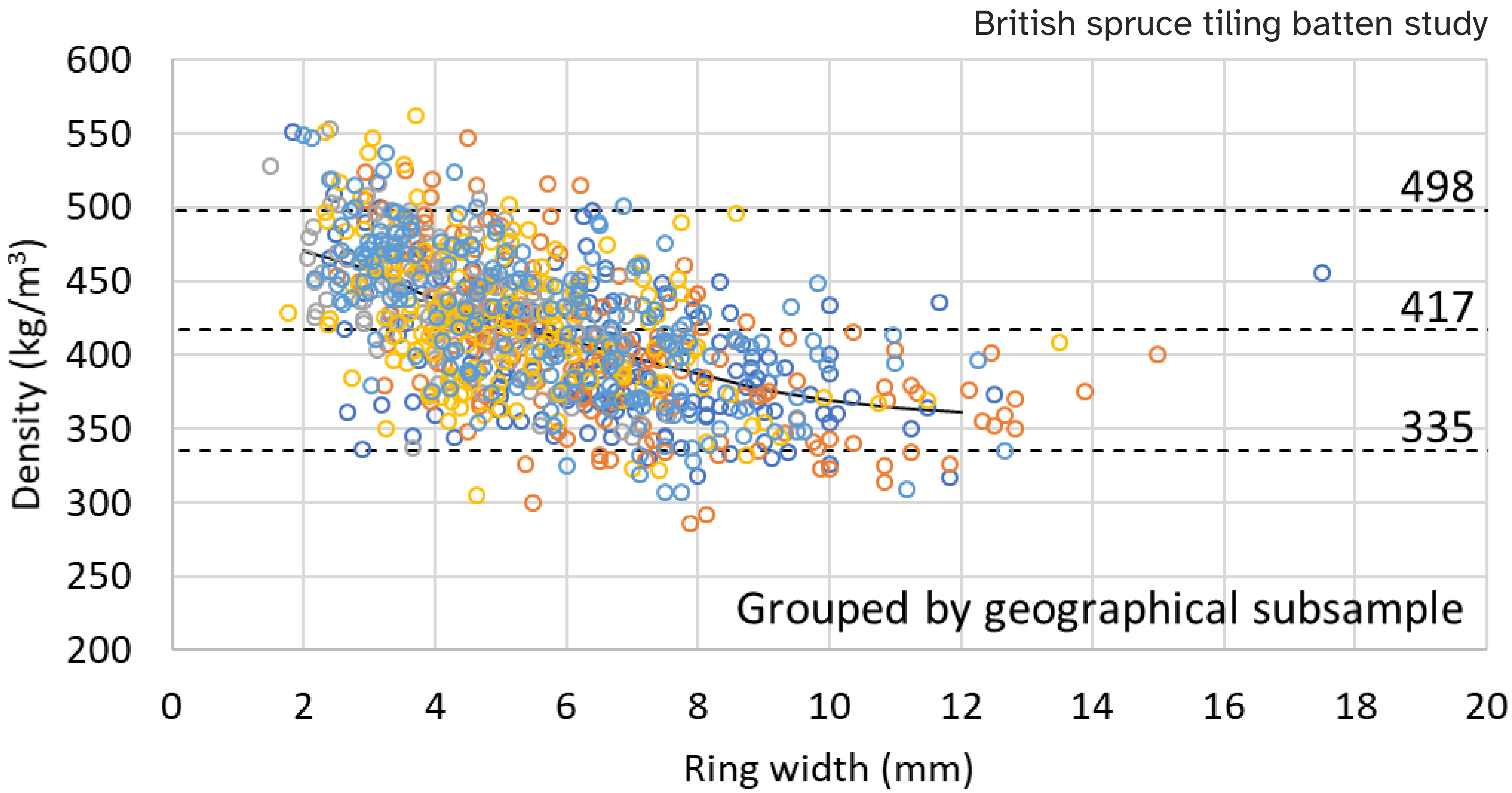

Density & ring width (spruce)

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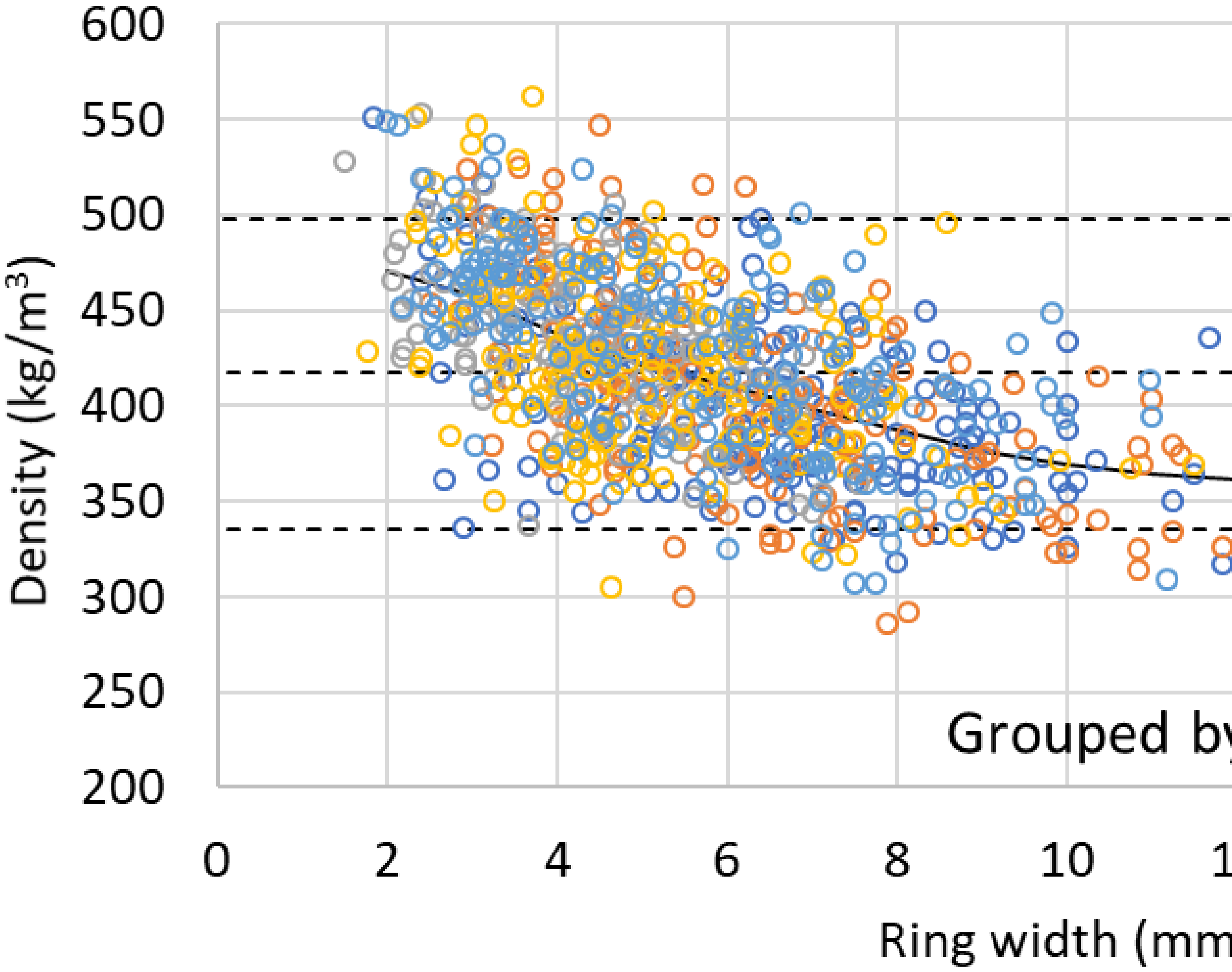
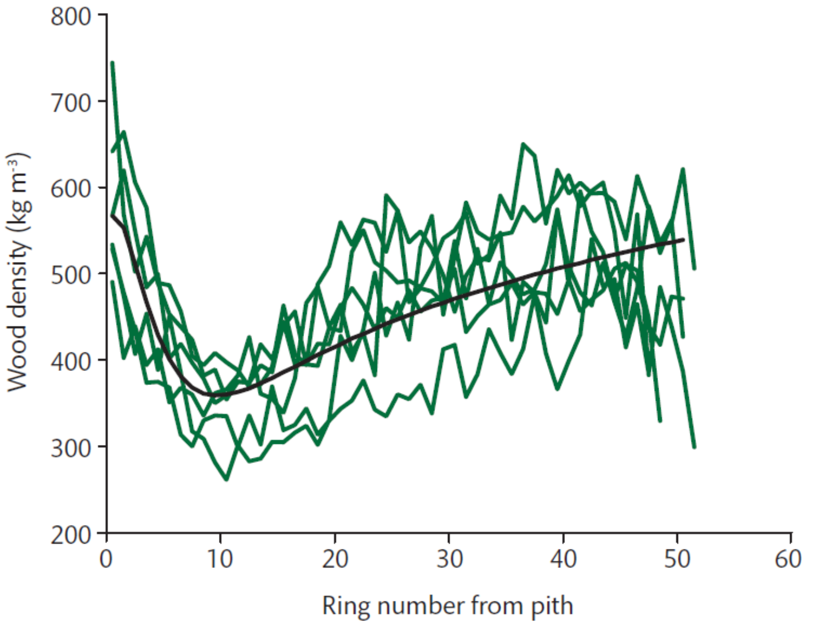


Figure 2.15 Radial profile of Sitka spruce wood density. The green lines show profiles for five individual trees sampled at Baronscourt in Northern Ireland, while the black line represents a model fitted to these data.



Grouped by geographical subsample

Grading methods for timber

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- **Visual** strength grading
  - (not the same as appearance grading)
- **Machine** strength grading
  - Machine control
  - Output control

- Those are the methods in Europe, other methods do exist around the world, such as proof testing

Visual override

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- To remove pieces with defects like rot and insect damage
- Things the customer wouldn't like
- ...and also drying defects

- "Dry-graded" timber
  - Means, specifically, checked for fissures and distortion at a moisture content of no more than 20%
  - The rest of the grading might have been done green

Home grown timber grading

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https://doi.org/10.1080/20426445.2022.2050549

INTERNATIONAL WOOD PRODUCTS JOURNAL
2022, VOL. 13, NO. 2, 127–136
https://doi.org/10.1080/20426445.2022.2050549

IOM3 Institute of Materials, Minerals & Mining | Taylor & Francis Taylor & Francis Group

RESEARCH ARTICLE

OPEN ACCESS | Check for updates

Strength grading of timber in the UK and Ireland in 2021

Dan Ridley-Ellis [a]†, David Gil-Moreno [b]‡ and Annette M. Harte [b]

[a]Centre for Wood Science & Technology, Edinburgh Napier University, Edinburgh, UK; [b]School of Engineering & the Ryan Institute, National University of Ireland Galway, Galway, Ireland

ABSTRACT

This paper summarises the state of the art for strength grading of construction timber grown in the United Kingdom and the Republic of Ireland. It includes the latest approvals based on recent research on spruce, larch and Douglas-fir. It lists the following information along with the primary references: visual grading grades and strength class assignments; grading machines with approved settings for machine control grading; the species, size ranges and strength class combinations covered; and grade determining properties of specific strength classes for the UK and Irish markets. This paper is useful for those grading timber, and those specifying UK and Irish grown timber.

ARTICLE HISTORY
Received 7 September 2021
Revised 29 November 2021
Accepted 1 March 2022

KEYWORDS
Grades; classes; machine strength grading; visual strength grading; structural timber; EN14081

Introduction

In Europe, structural timber is graded under the system set out by the European standard EN14081-1 and its supporting standards (e.g. Lycken et al. 2020). It sorts rectangular cross-section timber into categories based on required characteristic values exchange timber market with logs crossing the border. This is one of the reasons that modern grading rules usually treat both countries as a single growth area, particularly for Sitka spruce but also more recently for Douglas-fir (Gil-Moreno et al. 2019b) and larch. Collaborative research between Edin-

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view the pdf to be sure the information displays correctly

Grading is about populations

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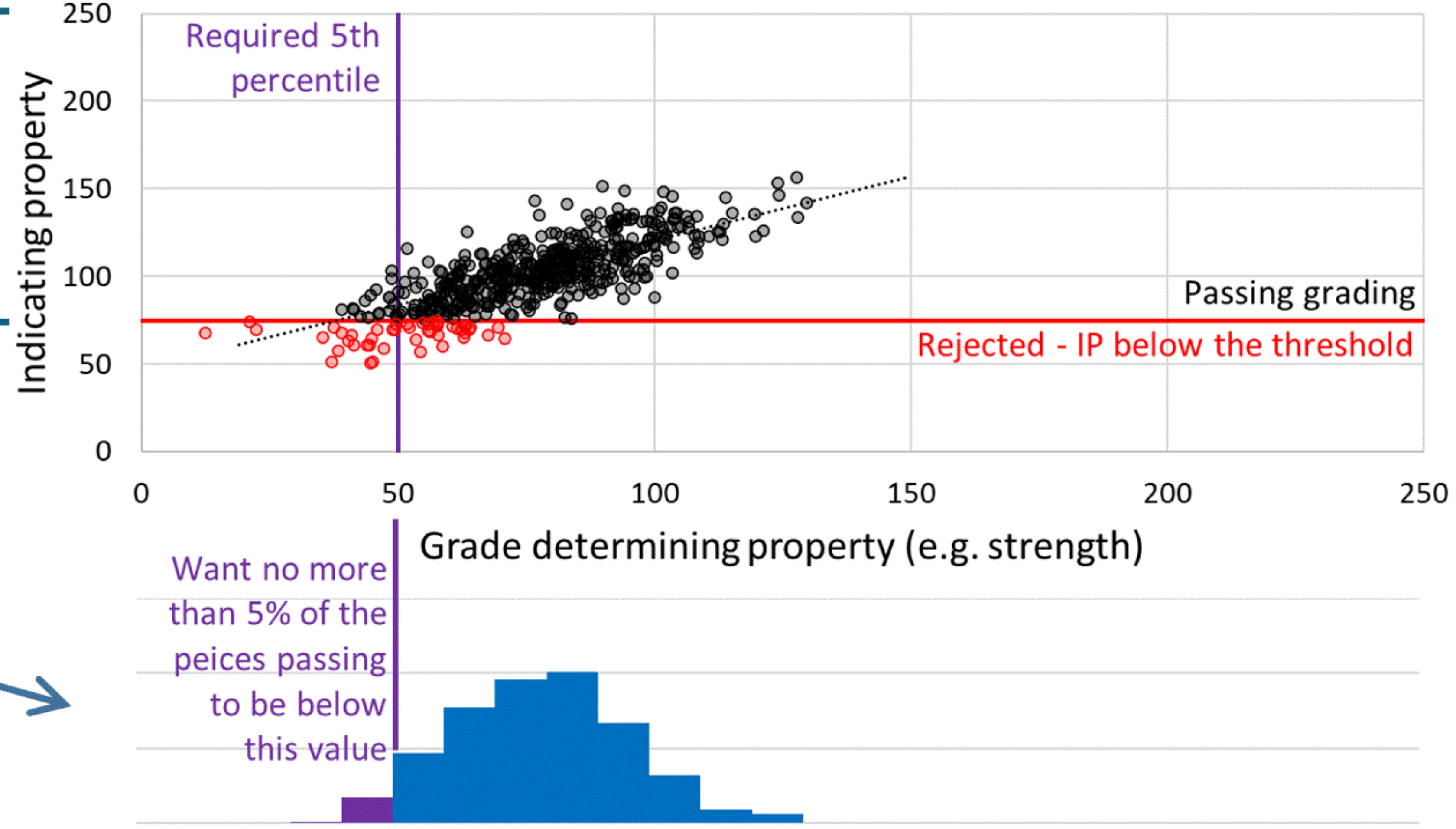
The histogram is for the timber passing the grade



Visual strength grading

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- Visually grade to a visual grading standard
  - e.g. SS, GS (softwoods to BS 4978)
- Assign to strength class based on grading standard, species and origin (all three must match)
  - EN 1912
    - e.g. British spruce SS → C18
    - e.g. British spruce GS → C14
  - Somewhere else (not in conflict with EN 1912)
- New assignments based on testing & analysis to EN 384

Table 3: Visual grading assignments when grading with BS 4978

Species	Source	Visual grade	Strength class	Reference
British spruce	UK	GS	C14	EN1912:2012 (§6)
		SS	C18	EN1912:2012 (§6)
British pine	UK	GS	C14	EN1912:2012 (§6)
		SS	C22	EN1912:2012 (§6)
Larch	UK	GS	C16	EN1912:2012 (§6)
		SS	C24	EN1912:2012 (§6)
Douglas-fir	UK	GS	C14	EN1912:2012 (§6)
		SS	C18	EN1912:2012 (§6)
		SS*	C24	PD6693-1:2012 (§6.2)

* cross-section area >20,000 mm^2, width and thickness ≥ 100 mm

Table 4: Visual grading assignments when grading with BS 5756

Species	Source	Visual grade	Strength class	Reference
Oak	UK	TH2	D24	PD6693-1:2012 (§6.1)
		TH1	D30	PD6693-1:2012 (§6.1)
		THB*	D30	PD6693-1:2012 (§6.1)
		THA*	D40	PD6693-1:2012 (§6.1)
Sweet chestnut	UK	TH1	D24	PD6693-1:2012 (§6.1)

* cross-section area >20,000 mm^2, width and thickness ≥ 100 mm

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Strength grading of timber in the UK and Ireland in 2021

Dan Ridley-Ellis, David Gil-Moreno and Annette M. Harte

Introduction

Knots & strength & stiffness

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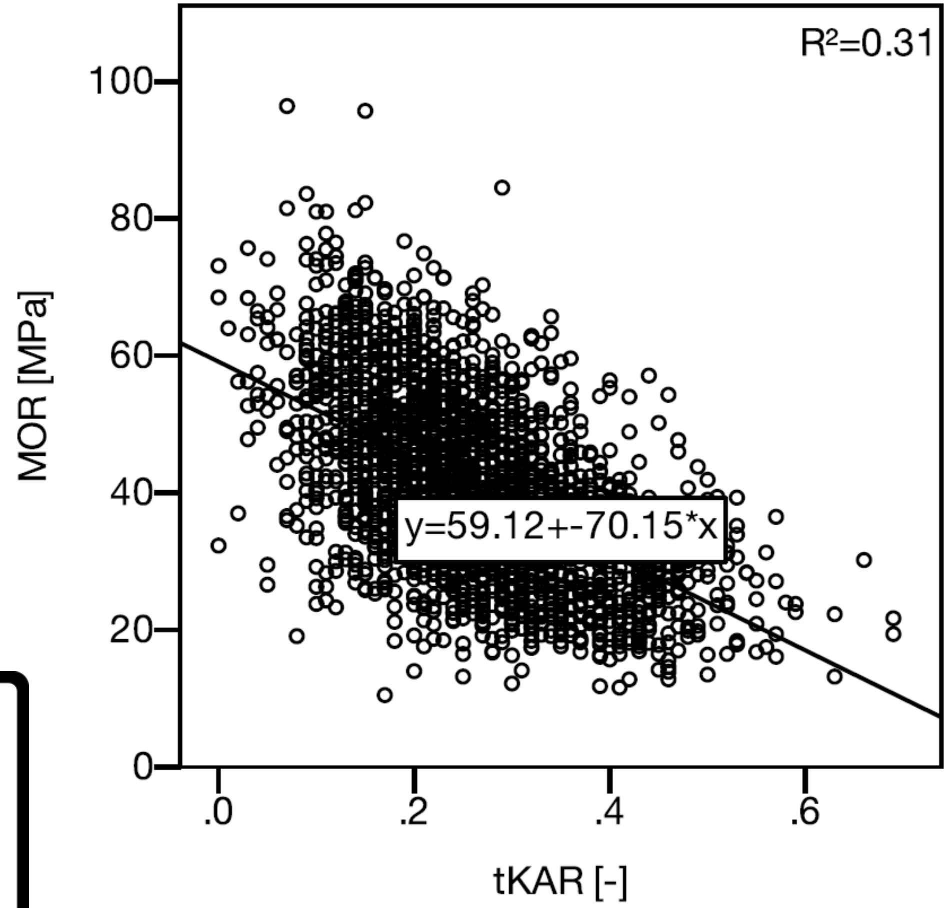

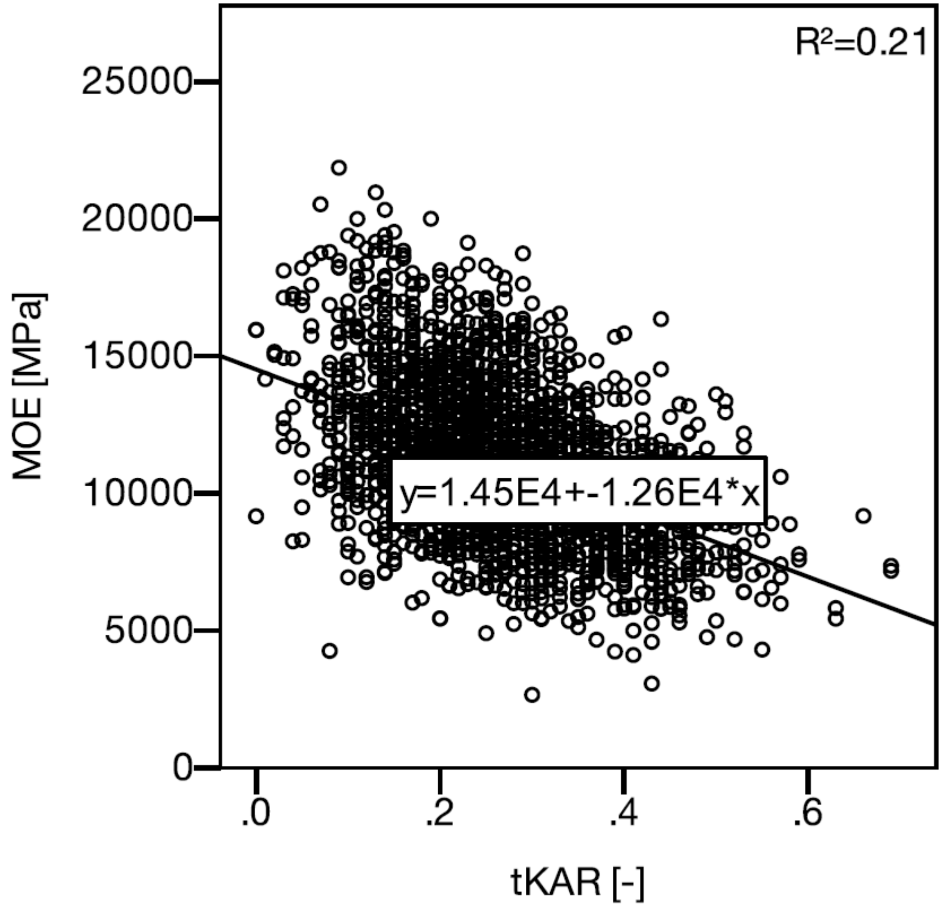

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PhD thesis by Peter Stapel, TU Munich. https://d-nb.info/1055039805/34

Machine strength grading

- Relates an 'indicating parameter' to the critical grade-determining parameter(s)
- Better accuracy than visual grading…
  …due to the parameters being measured
  …and the automation
  …so assignment to grade is less conservative
- Fast but expensive equipment
  (but getting some cheaper options)

Machine types

- Bending stiffness
  - Bending about the minor axis
- Dynamic (acoustic/vibration)
  - Essentially a measure of stiffness
  - May or may not include density
- X-rays
  - A combination of knots and density
  - Perhaps with optical camera
- Assessment of slope of grain
  - Using laser tracheid effect
- Mixtures of the above

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Microtec Goldeneye

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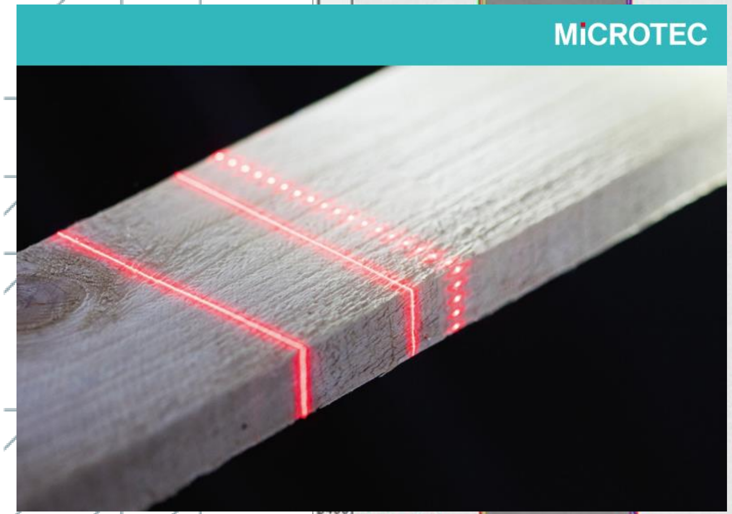
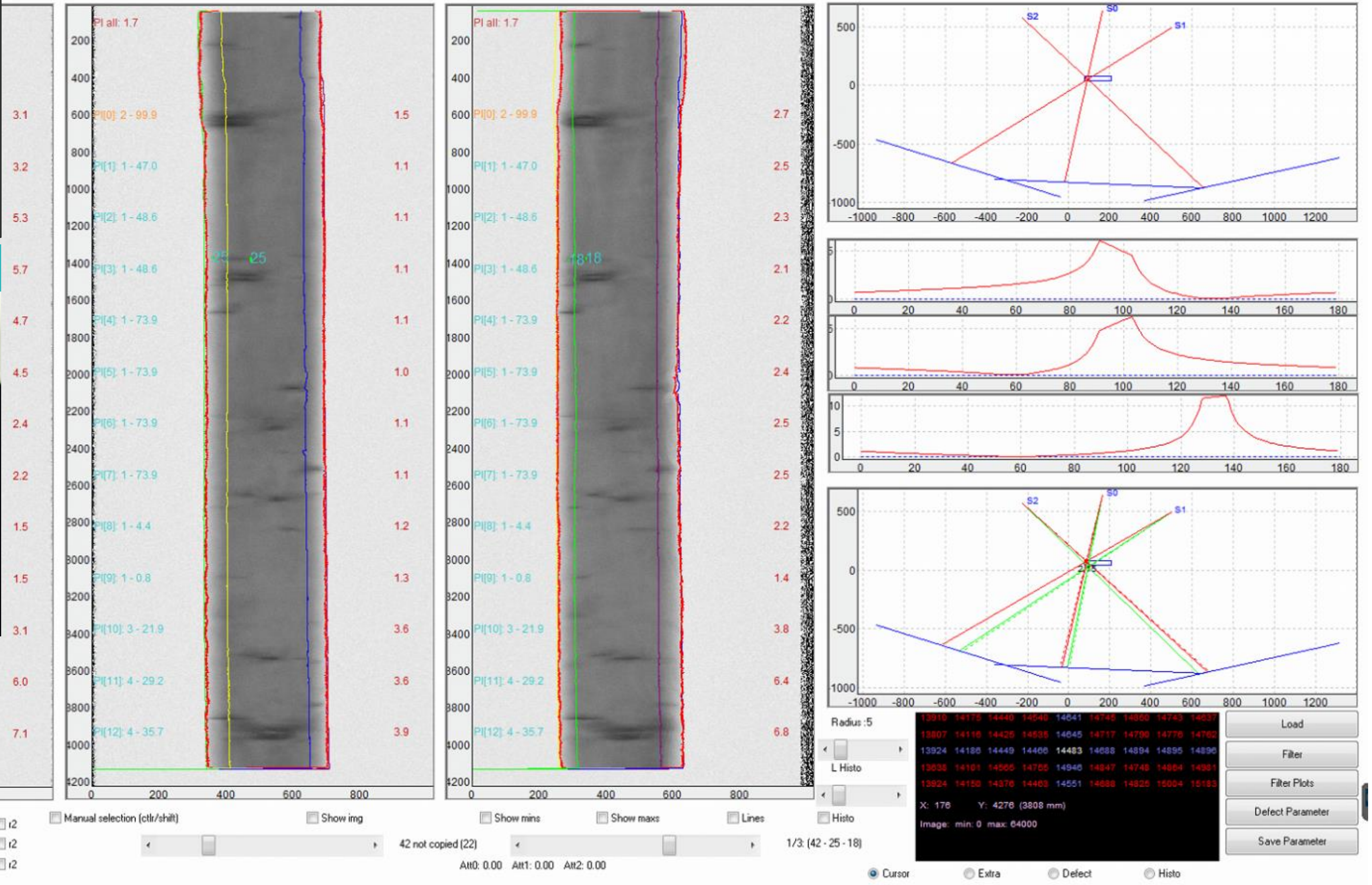
Goldeneye 802
Through board 2D x-ray
At up to 32 mph
Board splitting function





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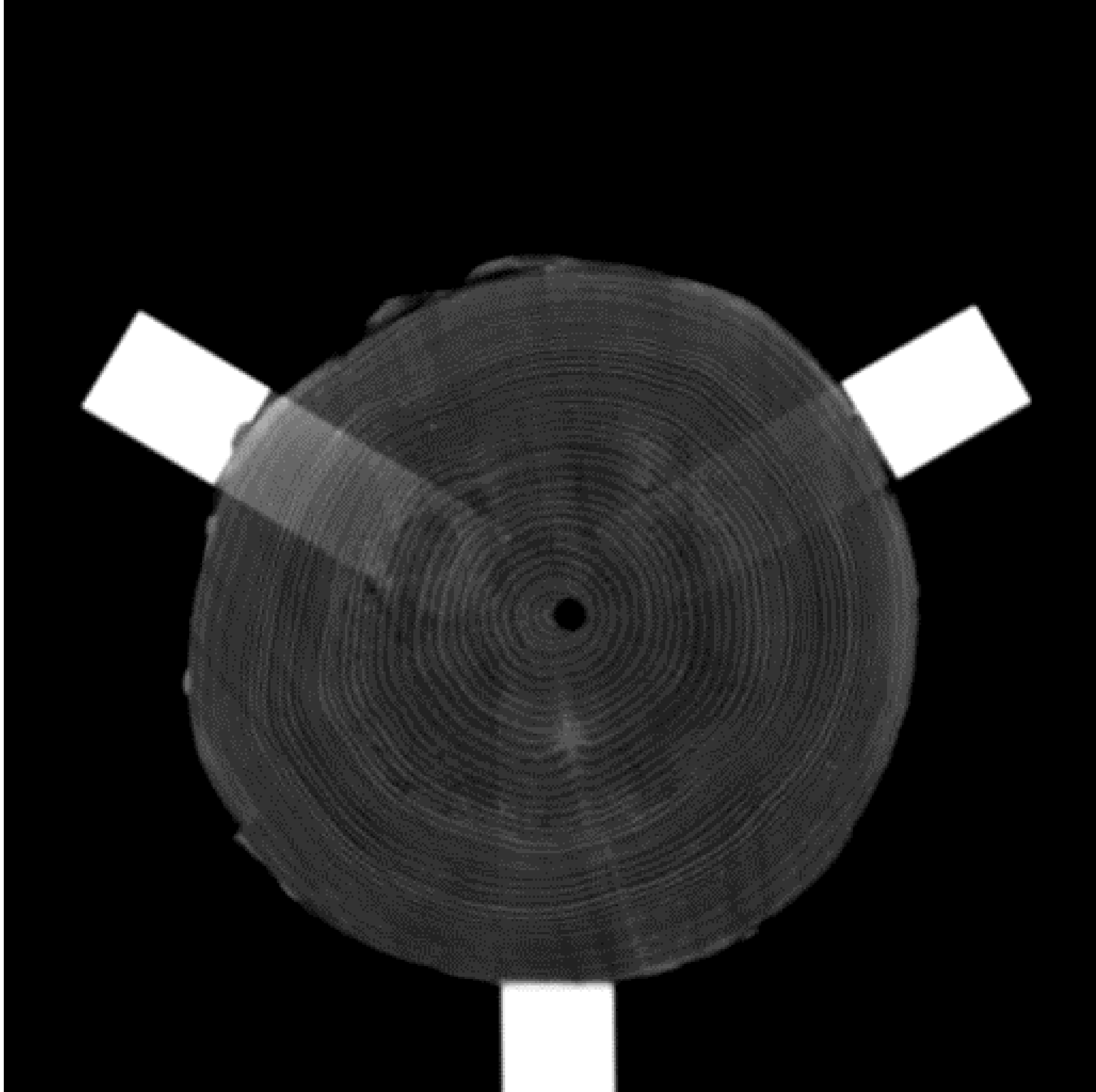
Goldeneye 802
Through board 2D x-ray

This →
3D x-ray (CT) of a log



Data from
Johannes A. J. Huber

Luleå University of Technology
Wood Science and Engineering,
Skellefteå, Sweden

Goldeneye 802
Through board 2D x-ray

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Grading – IP boundaries

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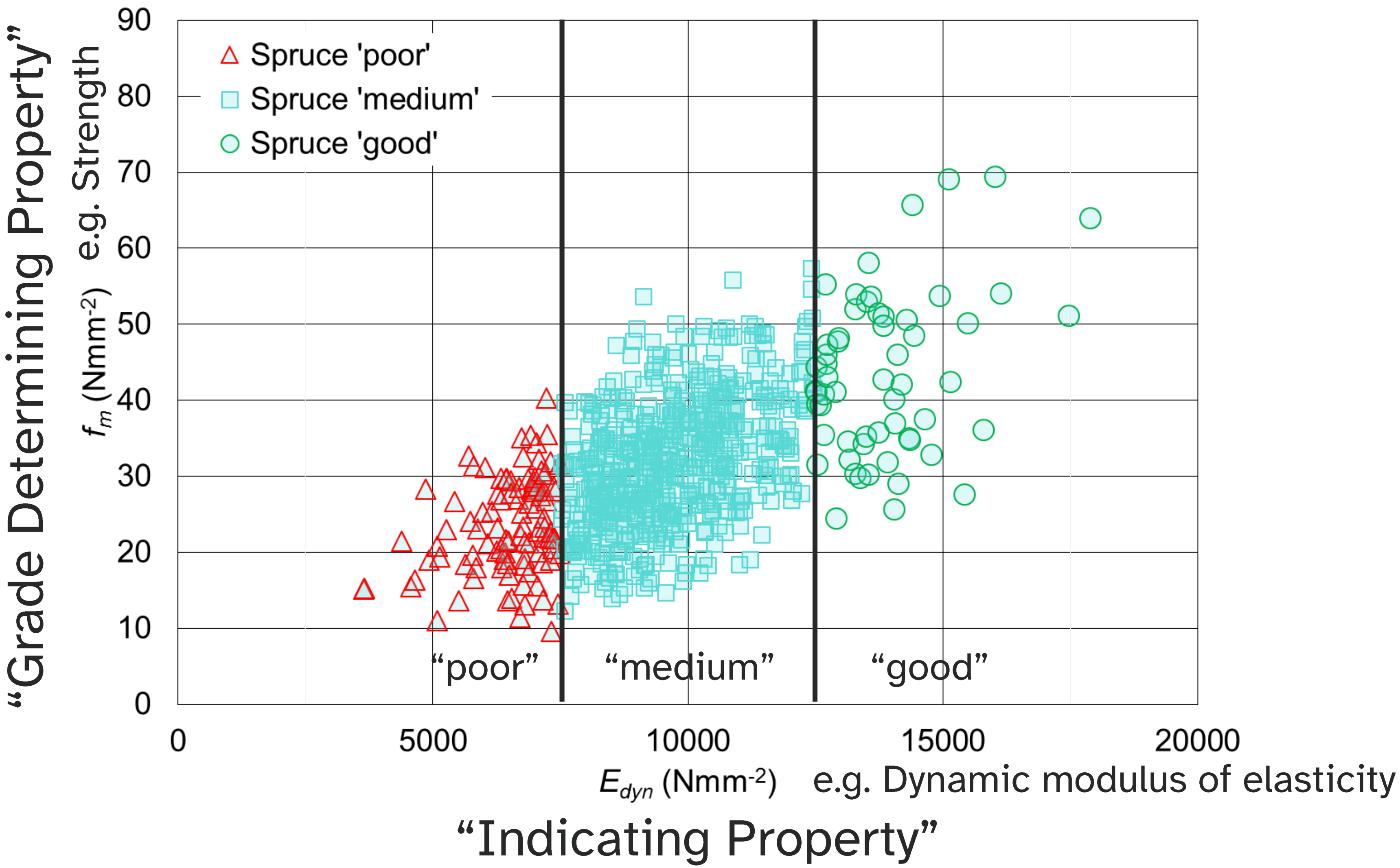

Grading – IP boundaries

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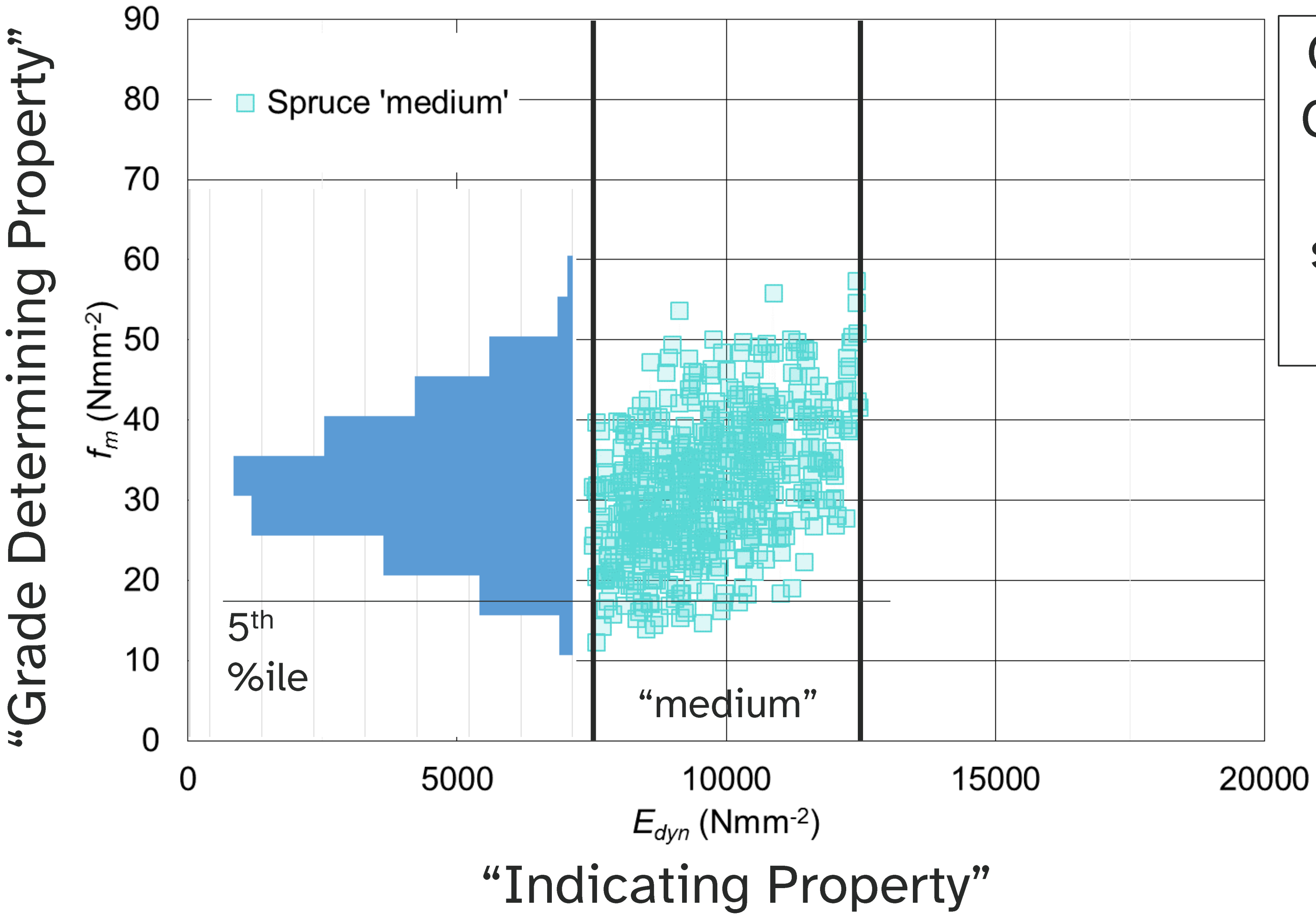
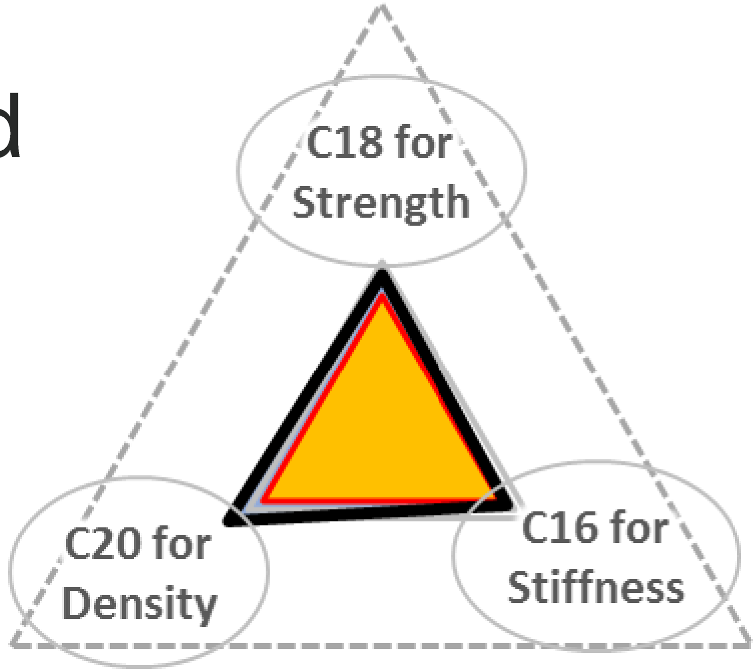


Grading aims that GDP requirements are met (at least) subject to various adjustments

British spruce

- Mostly Sitka spruce with some Norway spruce
- Usually want near 100% yield
- ∴ Grading C16/reject

- The resource is pretty close to being C16 even before grading



C16, C24 & British spruce

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- Example, with a good, realistic, grading machine
- Testing of ~2000 timbers from UK and IE
- This sampling covers a wide size range – from 22×47 mm to 75×250 mm
- Yield of 99% C16, 1% Reject, or
- Yield of 23% C24, 66% C16, 11% Reject
- If not including the small sizes, it is possible to get about 25% C24 and 75% C16 (with minimal rejects)

C16, C24 & British spruce

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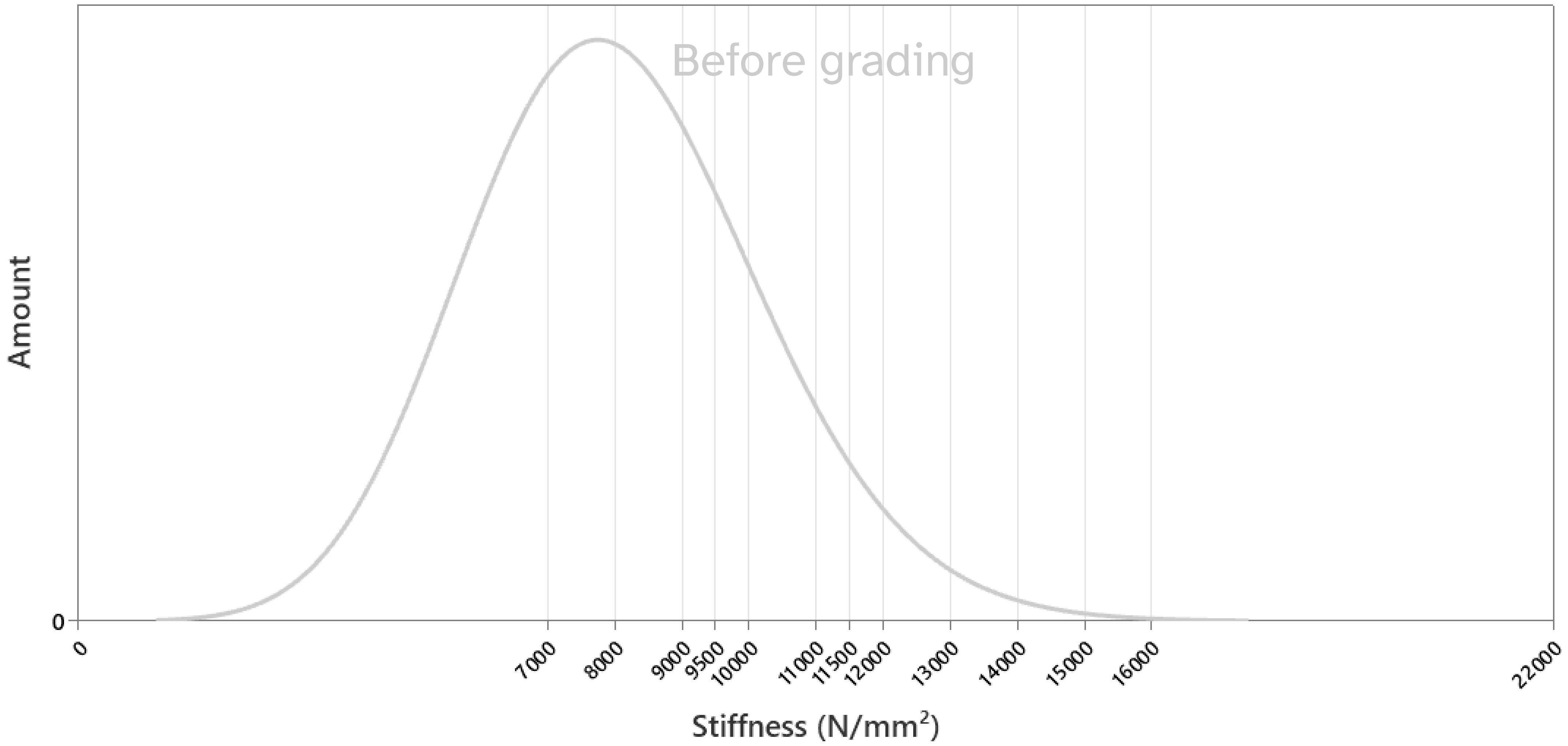

C16, C24 & British spruce

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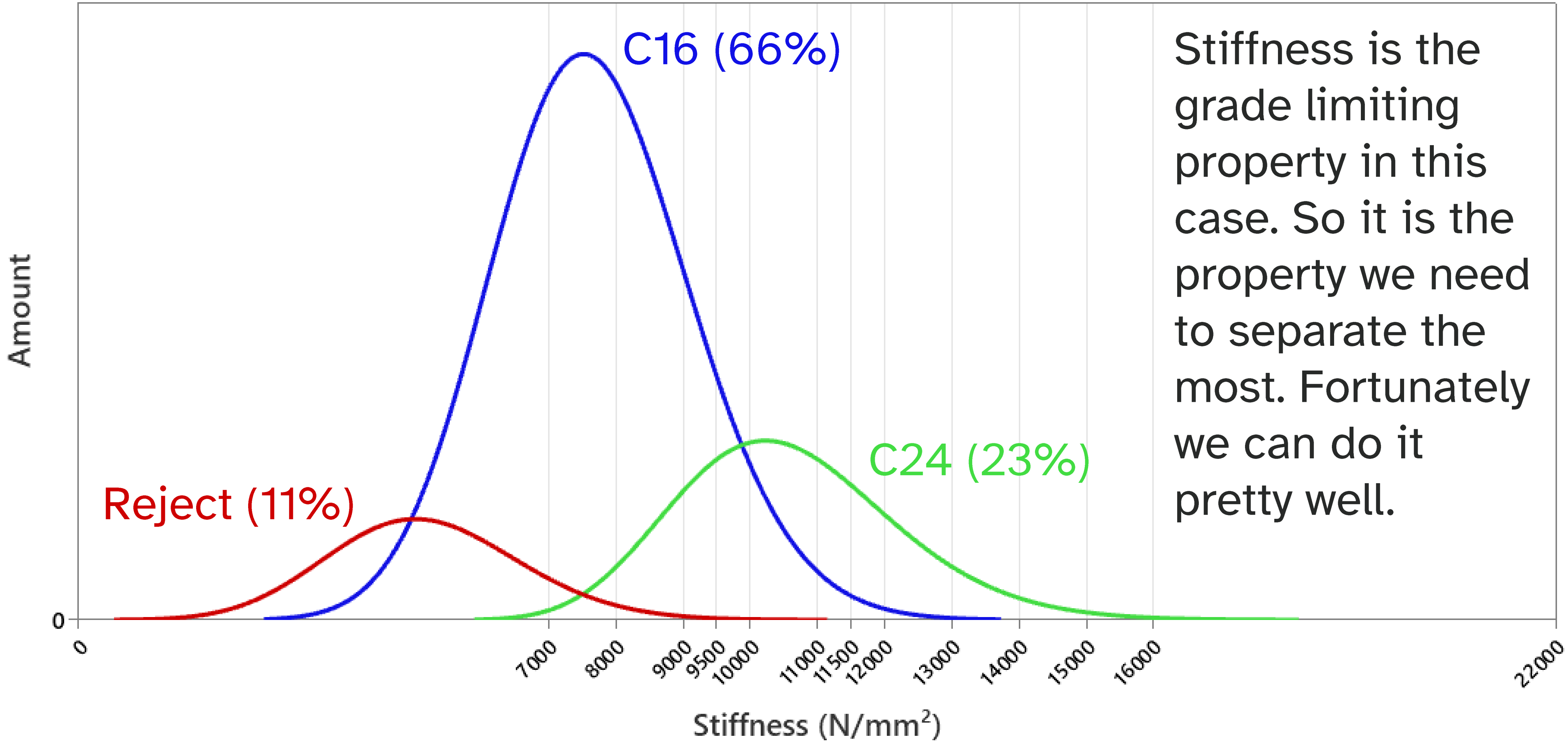

Stiffness is the grade limiting property in this case. So it is the property we need to separate the most. Fortunately we can do it pretty well.

C16, C24 & British spruce

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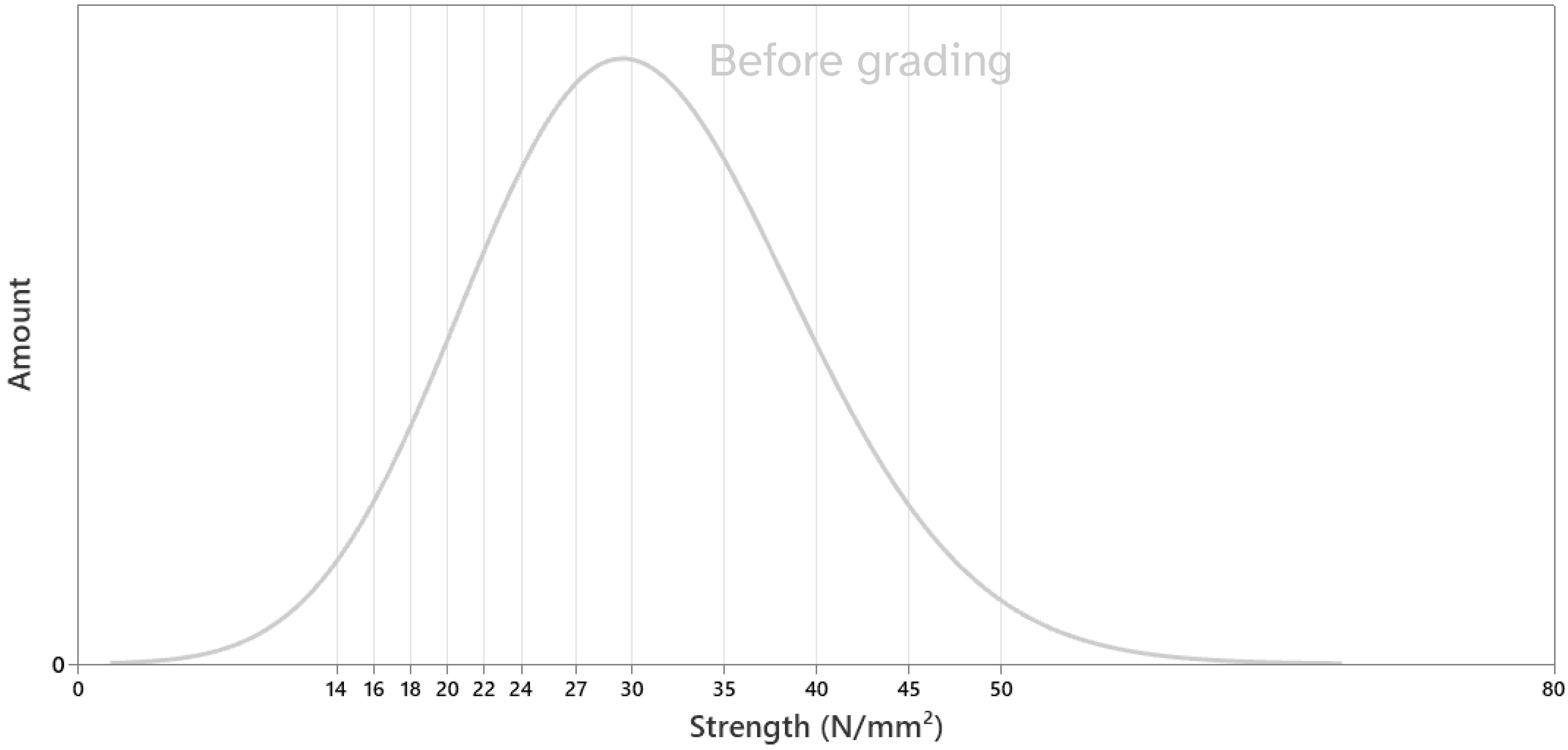

C16, C24 & British spruce

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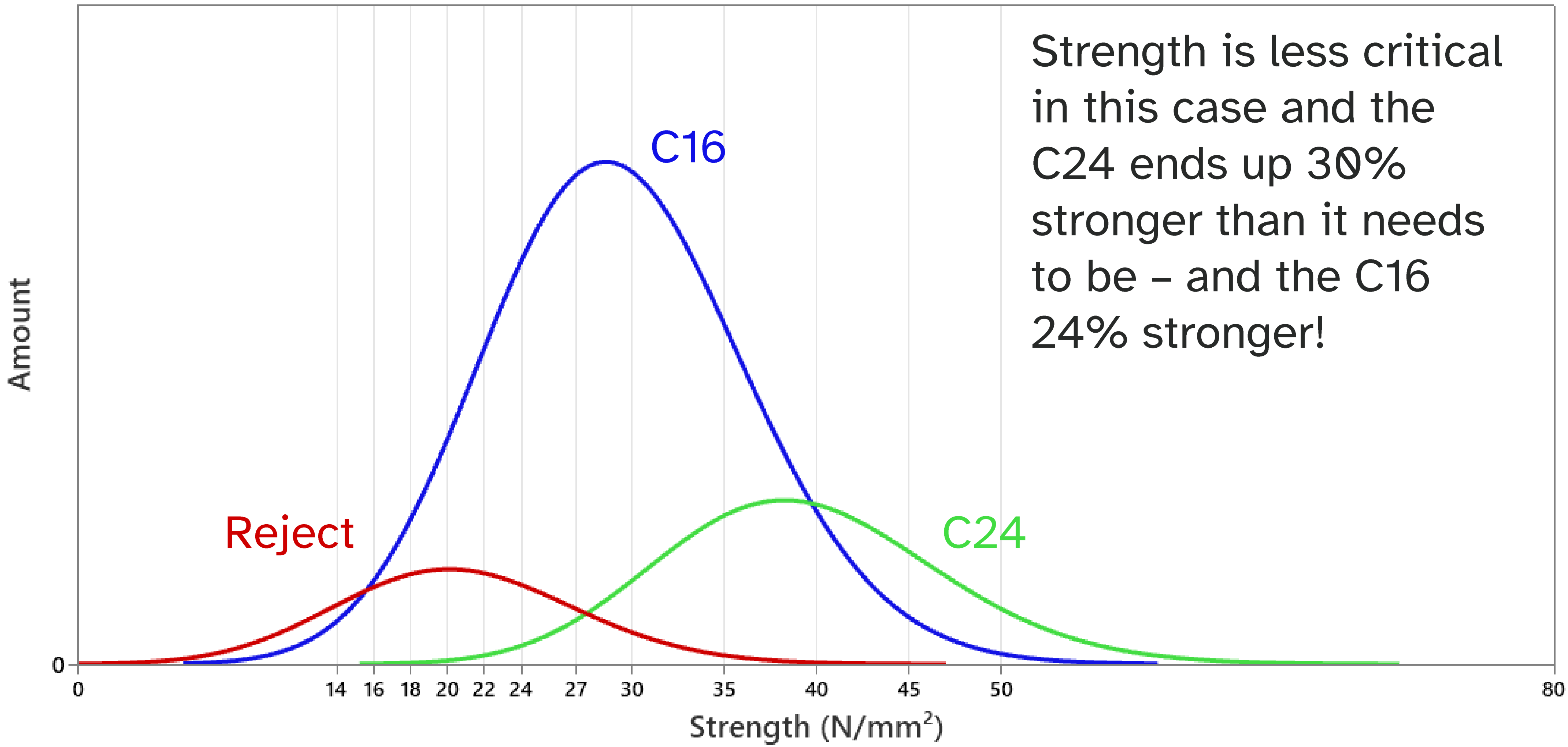

Strength is less critical in this case and the C24 ends up 30% stronger than it needs to be – and the C16 24% stronger!

C16, C24 & British spruce

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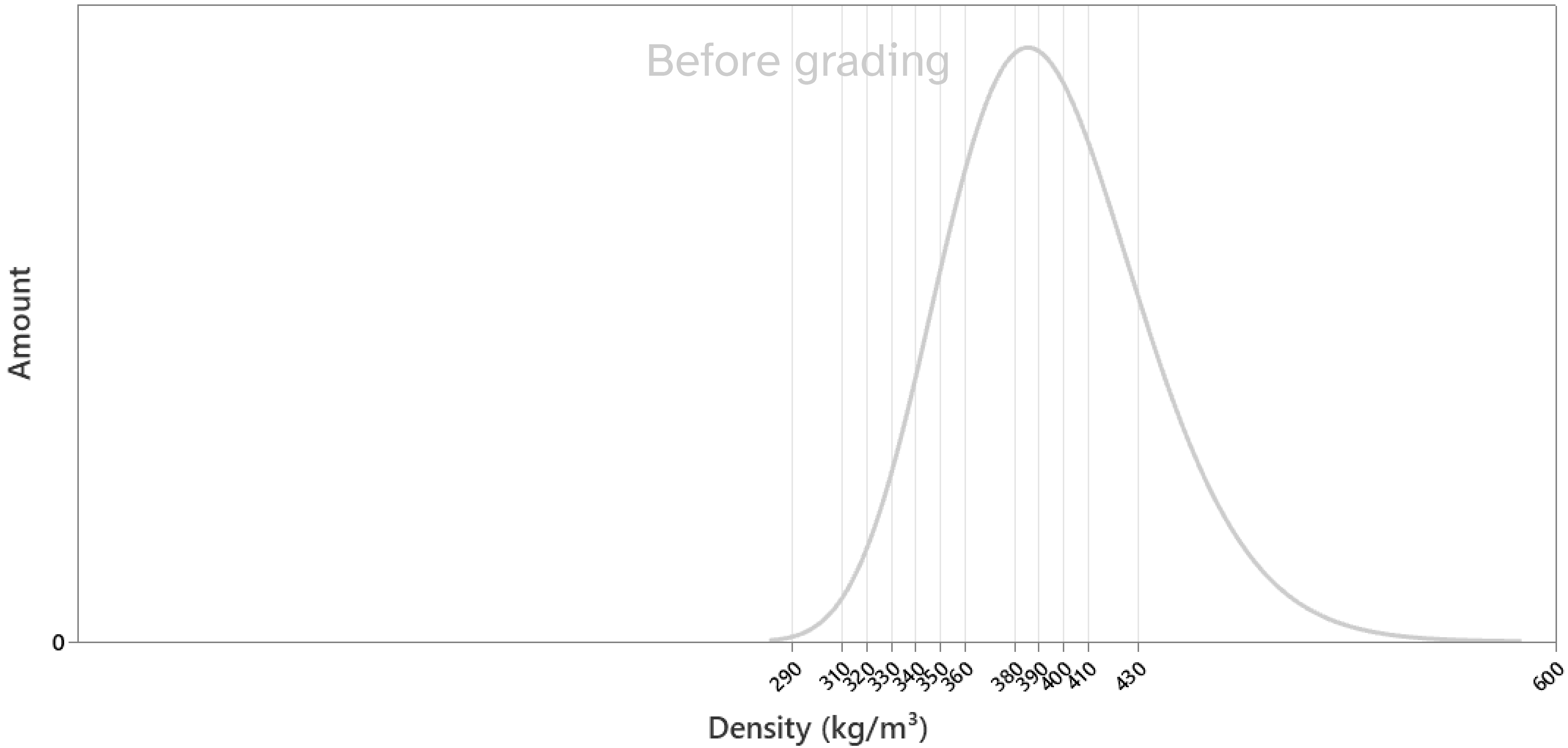

C16, C24 & British spruce

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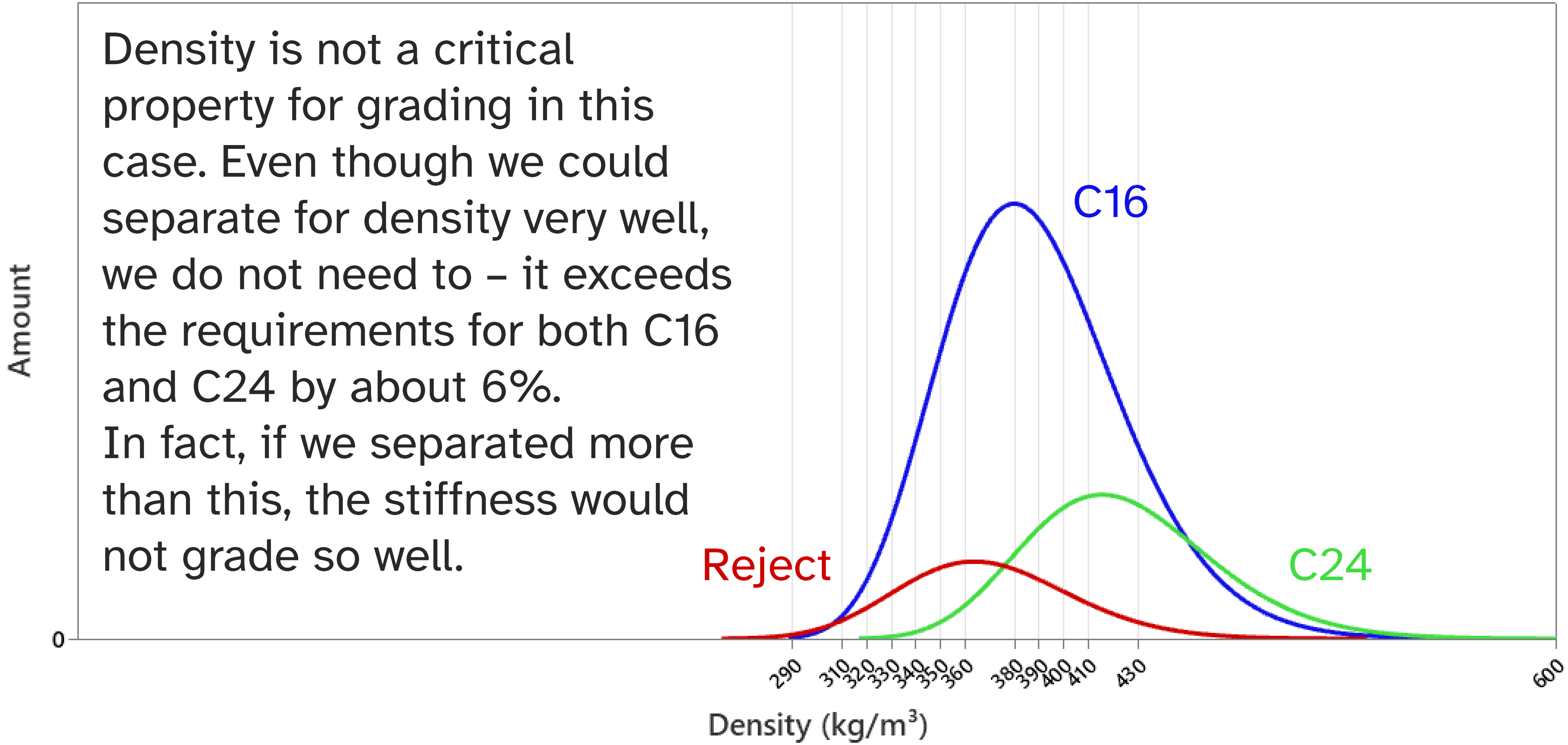
Density is not a critical property for grading in this case. Even though we could separate for density very well, we do not need to – it exceeds the requirements for both C16 and C24 by about 6%.
In fact, if we separated more than this, the stiffness would not grade so well.



Some quick points

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- C16 is sufficient for many things
- There is no need to over specify
- It is a waste of money, a waste of wood and limits options

- If C16 is not sufficient for the design, often the design can be adjusted to make it work with C16

Summary

Wood is a material of the future

The wood of the future is already growing

Strength grading is the process by which properties are ensured

Renewable does not mean infinite

Try not to over-specify

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If you want more

For a fuller description of strength grading in Europe see:

Ridley-Ellis, D., Stapel, P., and Baño, V.: Strength grading of sawn timber in Europe: an explanation for engineers and researchers. European Journal of Wood and Wood Products, 74(3): 291-306, 2016.

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Building from England's Woodlands

- WP1 Project management
- **WP2 Wood properties categorisation**
- WP3 Optimised engineered timber products
- WP4 Pilot manufacture and prototype testing
- **WP5 Outreach and education**

Funded by the
Timber in Construction Innovation Fund
Woods into Management Forestry Innovation Funds

Forestry Commission

Preliminary target species

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- Beech
- Oak
- Birch / poplar
- Sycamore
- Ash
- Willow
- Sweet chestnut
- Alder

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Thank you!

blogs.napier.ac.uk/cwst/

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