SIRT

Strategic Integrated Research in Timber

Edinburgh Napier UNIVERSITY

Making the Grade & Maximising the Opportunities

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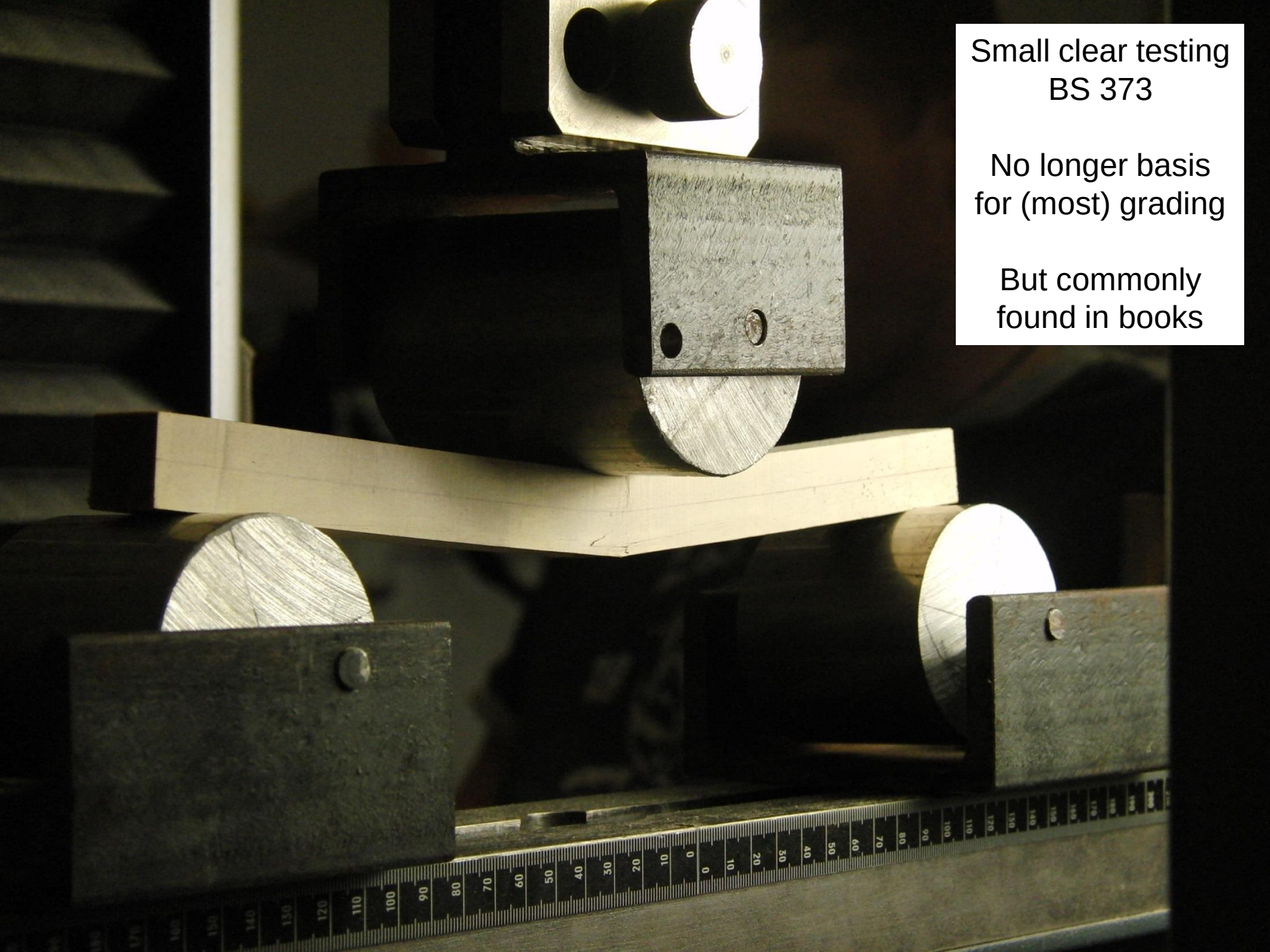
The Queen's Anniversary Prizes
For Higher and Further Education
2015

Issues - wood in construction

- Water
- “Figure” and “Defects”
- Anisotropy
- Inhomogeneity
- **Variation and uncertainty**
  - All materials have some variation and uncertainty
  - Main difference is we don’t manufacture the wood
  - …Trees do
  - Well…actually…trees and foresters do

Construction timber

- Structural design is about buildings
  - Staying safe
  - Staying fit for use
- More specifically
  - Safety of the people and the structure
    - Problem e.g. collapse due to lack of strength
  - The structure remaining functional
    - Problem e.g. too much movement due to lack of stiffness
  - In part, handled by grading – provides the numbers for engineers to use in their design calculations



Small clear testing
BS 373

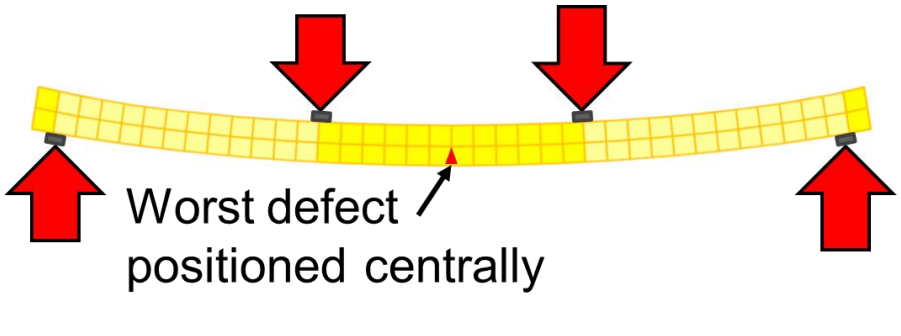
No longer basis
for (most) grading

But commonly
found in books

Full-size testing
EN 408

Current basis for (most) grading

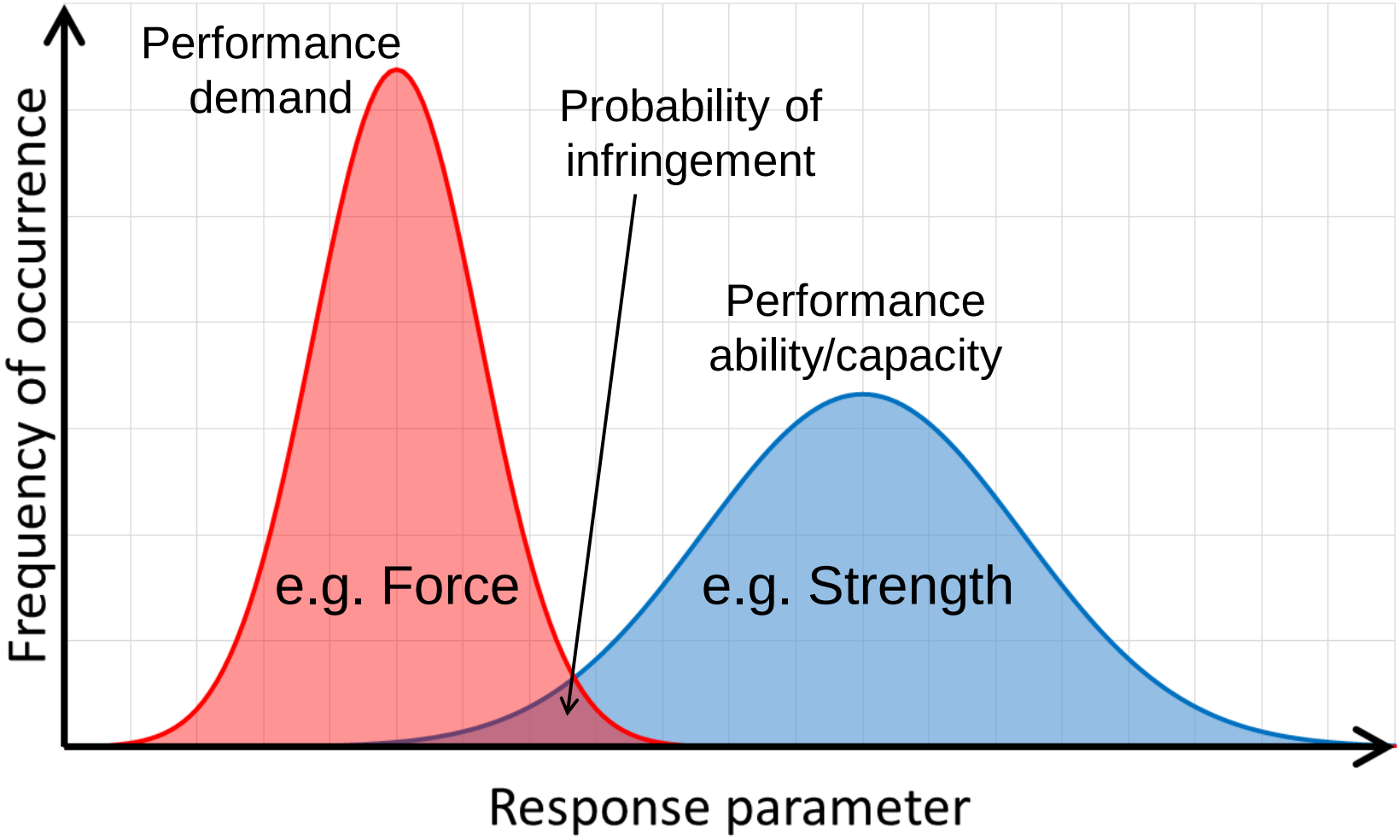
Very different from small clears – mostly due to the ‘defects’



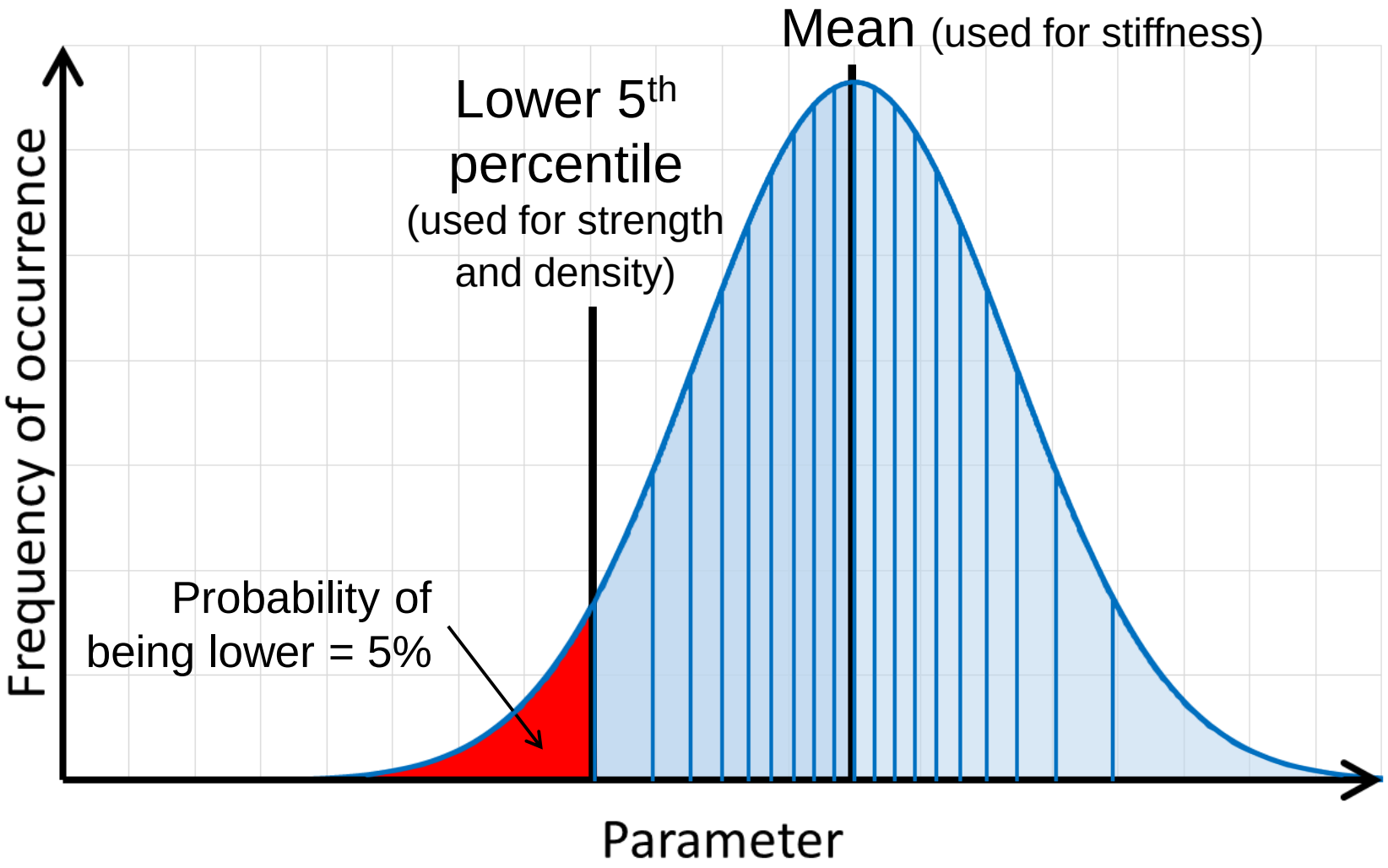
Grade-determining properties

- Strength
  - Usually major axis bending (aka Modulus of Rupture, MoR)
- Stiffness
  - Usually major axis bending (aka Modulus of Elasticity, MoE)
- Density (at 12% moisture content)
  - Also an indirect measure of strength in some elements of timber design
- All the other strength class properties are derived from these 3 main properties
  (By conservative relationships. Equations are in EN 384)

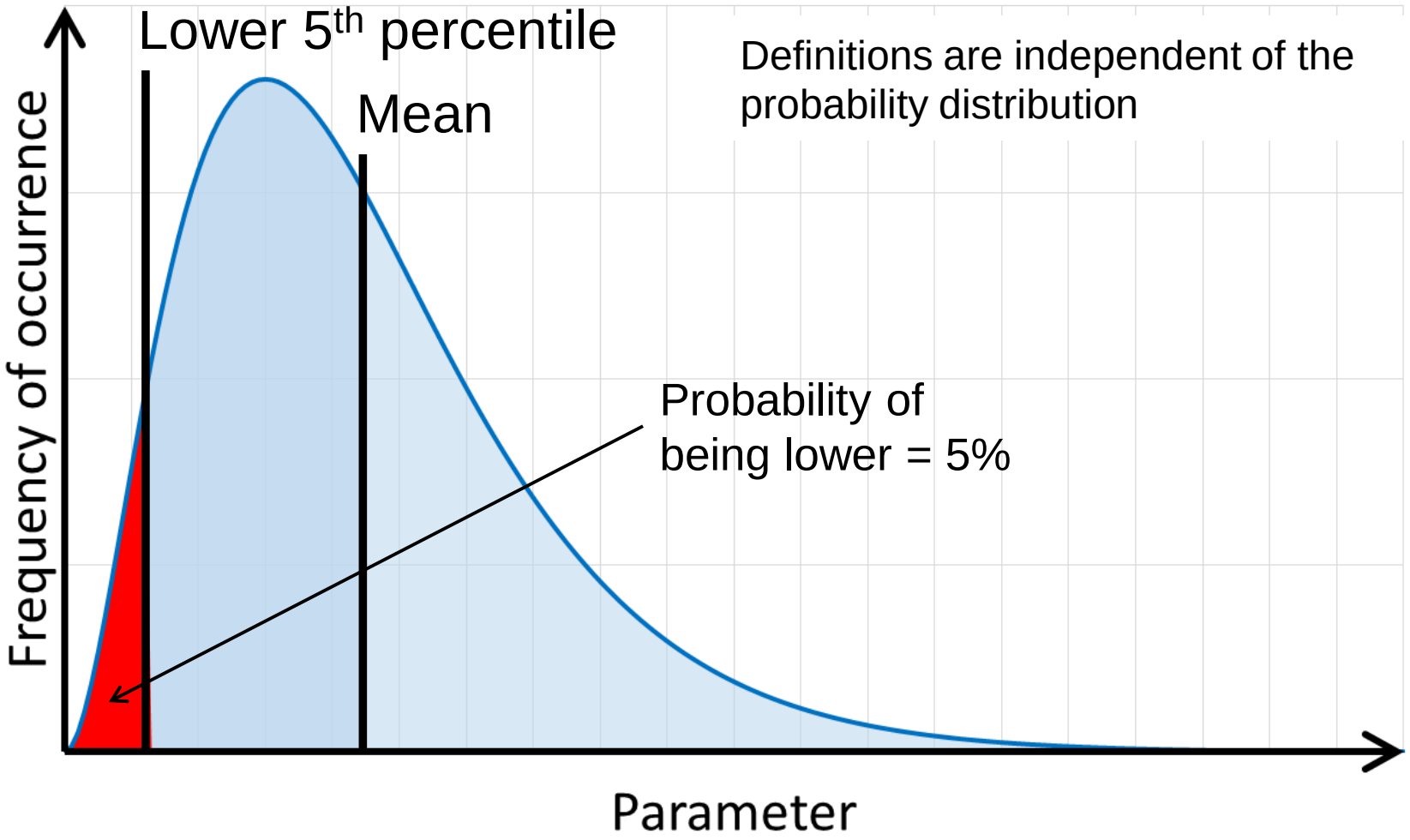
Dealing with uncertainty



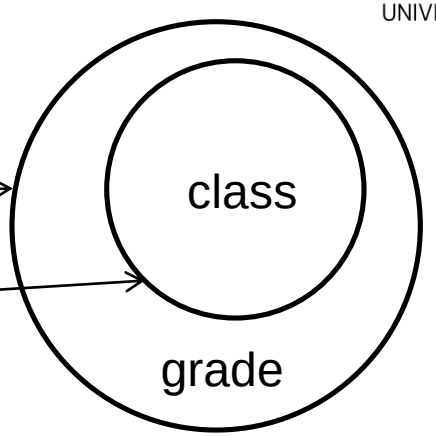
Characteristic values



Characteristic values



Grades and classes



- Strength grade
- Strength class
  - Has numerical properties
- Timber grades are assigned to a class
- EN 338 lists strength classes
- C classes for softwoods (/hardwoods)
- D classes for hardwoods
- These are not the only strength classes

New for 2016!

EN338:2016

	C14	**C16**	**C18**	C20	C22	**C24**
Strength properties in N/mm²						
Bending	14	**16**	**18**	20	22	**24**
Tension parallel	7,2	**8,5**	**10**	11,5	13	**14,5**
Tension perpendicular	0,4	**0,4**	**0,4**	0,4	0,4	**0,4**
Compression parallel	16					
Compression perpendicular	2,0					
Shear	3,0	**3,2**	**3,4**	3,6	3,8	**4,0**
Stiffness properties in kN/mm²						
Mean modulus of elasticity parallel bending	7,0	**8,0**	**9,0**	9,5	10,0	**11,0**
5 percentile modulus of elasticity parallel bending	4,7	**5,4**	**6,0**	6,4	6,7	**7,4**
Mean modulus of elasticity perpendicular	0,23	**0,27**	**0,30**	0,32	0,33	**0,37**
Mean shear modulus	0,44	**0,50**	**0,56**	0,59	0,63	**0,69**
Density in kg/m³						
5 percentile c density	290	**310**	**320**	330	340	**350**
Mean density	350	**370**	**380**	400	410	**420**

5th percentile values of full-size ….very different to mean values from small clear testing

Critical property

- To comply with the grade, characteristic values must be met (at least*)
- For a species and grade combination usually one property is limiting
  - Strength
  - Stiffness
  - Density
- So strength grading isn't *always* about predicting strength

* subject to adjustments

Critical property for spruce

British spruce: Sitka spruce and Norway spruce combined from UK and Ireland (WPCS)

SIRT benchmarking validation, 957 pieces

British spruce			C14	**C16**	C18	C20	C22
Strength	20.9	N/mm^2	14	16	18	20	22
Stiffness	8.2	kN/mm^2	7	8	9	9.5	10
Density	338	kg/m^3	290	310	320	330	340

It isn't density (or strength) that is limiting – it is stiffness

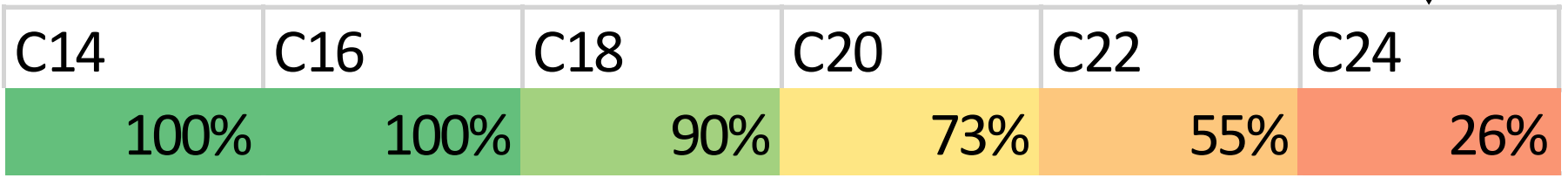
Grading trades yield for class

(with perfect grading – knowing the actual properties of each piece)

British spruce: Sitka spruce and Norway spruce combined from UK and Ireland (WPCS)

The other 74% is C16

(Single grade / reject)



For higher grades, density becomes critical. Yield of C27 ~ 9%

Grading methods for timber

- Visual strength grading
  - (not the same as appearance grading)
  - Knots, grain, species, origin…
- Machine strength grading
  - Machine control (pre-determined settings)
  - Output control (continuous testing)
- Additional overrides
  - Distortion, cracks, rot, insect damage, etc

See “strength grading of timber explained”

Visual strength grading

- Overarching requirements in EN 14081-1
- But done according to national standards
  - BS 4978 (softwoods)
  - BS 5756 (hardwoods)
  - Also German, Canadian, French, Italian, Dutch, Nordic, Spanish...
  - Need not be a formal standard – can make your own
- Assignments to classes in EN 1912
- According to testing to EN 384
- Can also be assignments elsewhere

Machine strength grading

- Machine 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 cheaper and more portable**

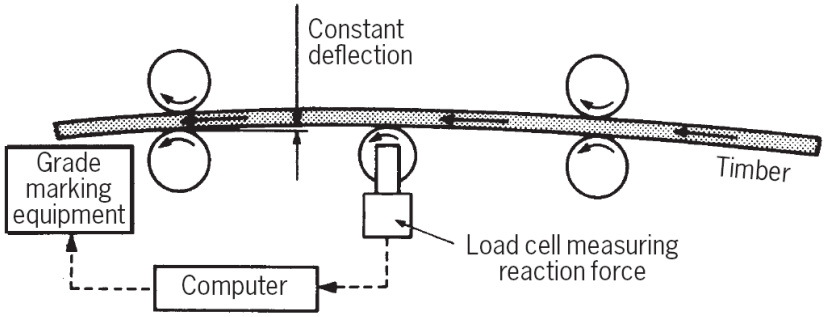
Important to realise

- Timber grading does not operate on a piece by piece basis
- Pieces are individually assigned to grades
- …but it is the population of timber in that grade that matters
- And how an individual piece is sorted into the grade depends on the machine operation / visual grading standard
- Collectively, the grade should meet the strength class characteristic values

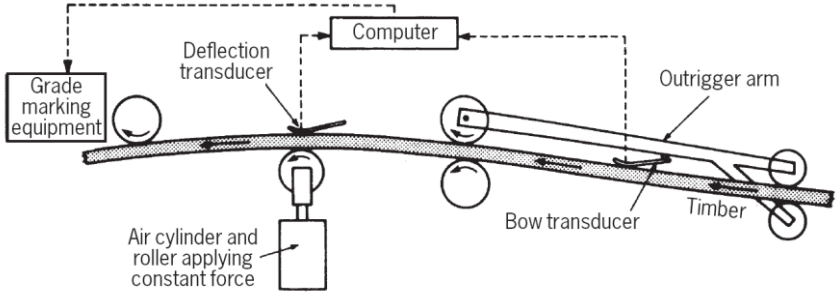
Bending graders

Minor axis bending stiffness

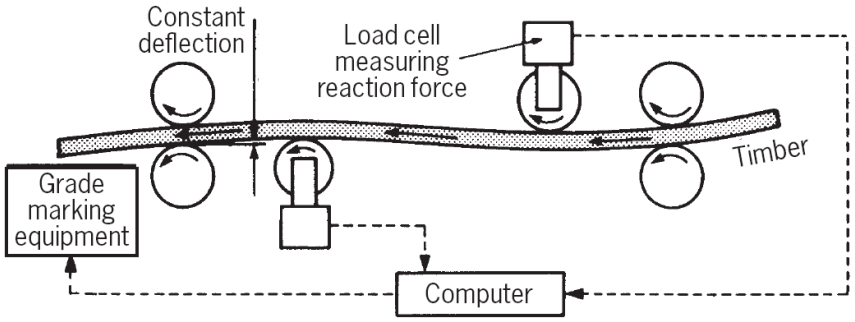
Cook-Bolinder

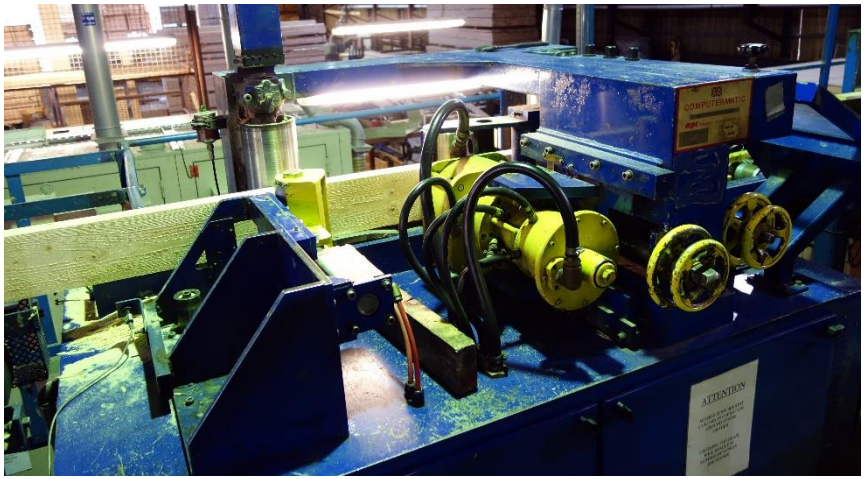


Computermatic



Timgrader





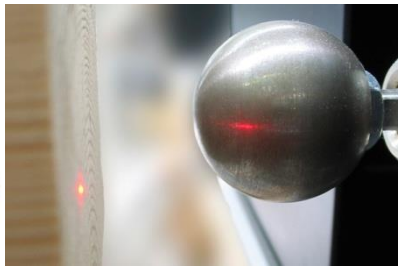
Figures from BRE Digest 476 “Guide to machine strength grading of timber”

Acoustic graders

Acoustic velocity, maybe density - effectively stiffness

Work well on British spruce because stiffness is the critical property

ViSCAN (MiCROTEC)



MTG (Brookhuis)

Precigrader (Dynalyse AB)

Triomatic (CBS-CBT)

Acoustic graders

Same principle as tools for forestry (either resonance or time of flight)

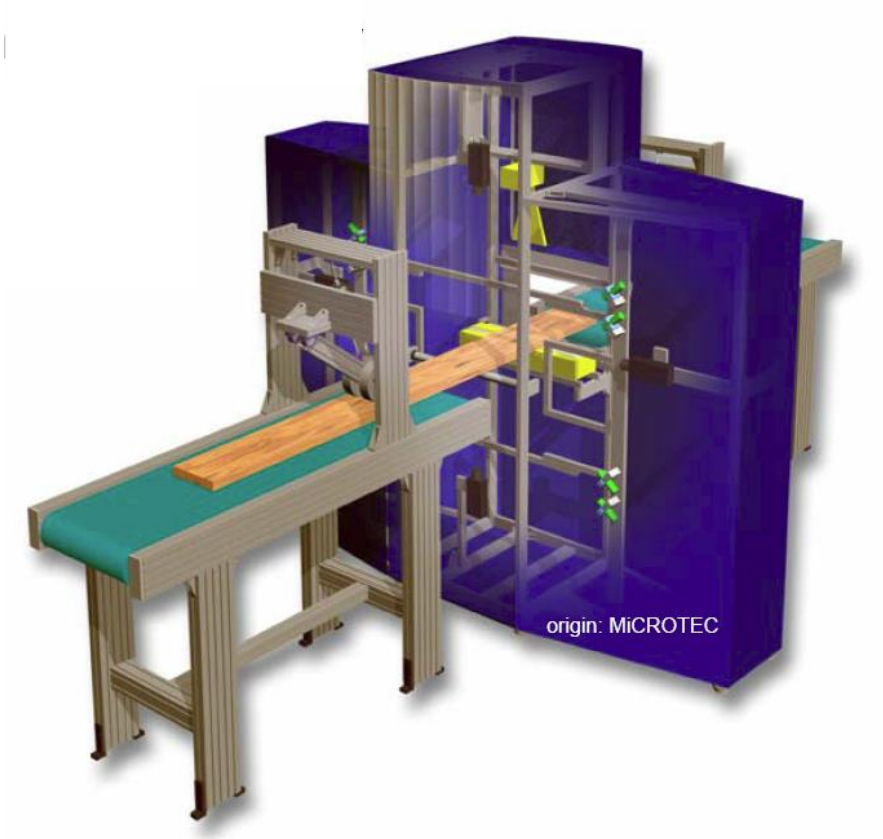
Not “grading” … but big potential for segregation or pre-grading

X-ray graders

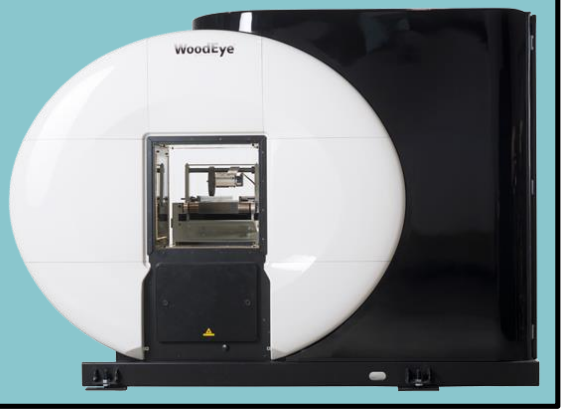
Clear wood and average density, knot size and location

Main machine for UK…because very fast

e.g. GOLDENEYE 702 (MiCROTEC)

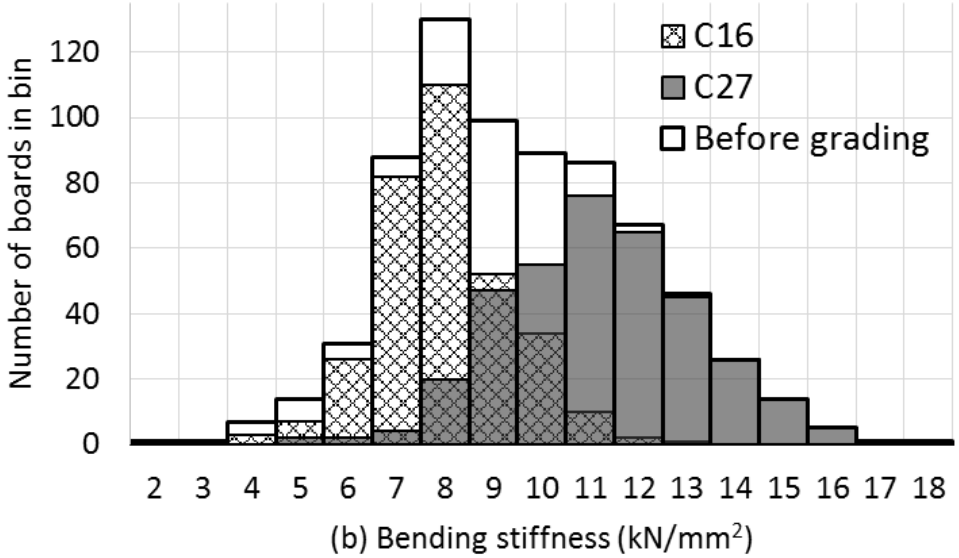


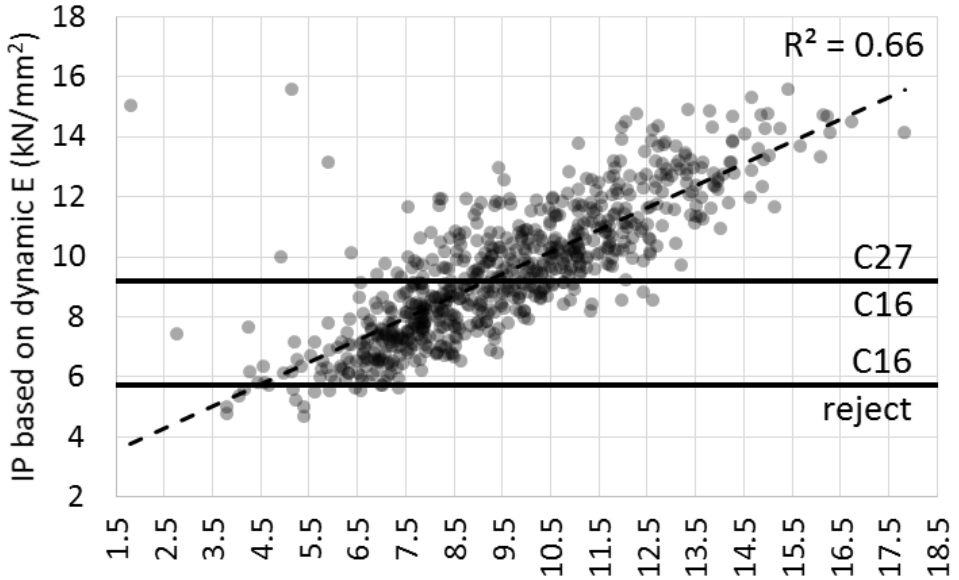
Lately also machines based on grain angle e.g. WoodEye



UK larch with mtgBATCH 962

(in-line version of hand-held MTG with balance)





	% of required		
	Bending strength	Bending stiffness	Density
Class	%	%	%
C16	143% ✓	105% ✓	129% ✓
C27	100% ✓	103% ✓	122% ✓

Example,
grading with stiffness
UK larch (WLAD)

The Queen's Anniversary Prizes
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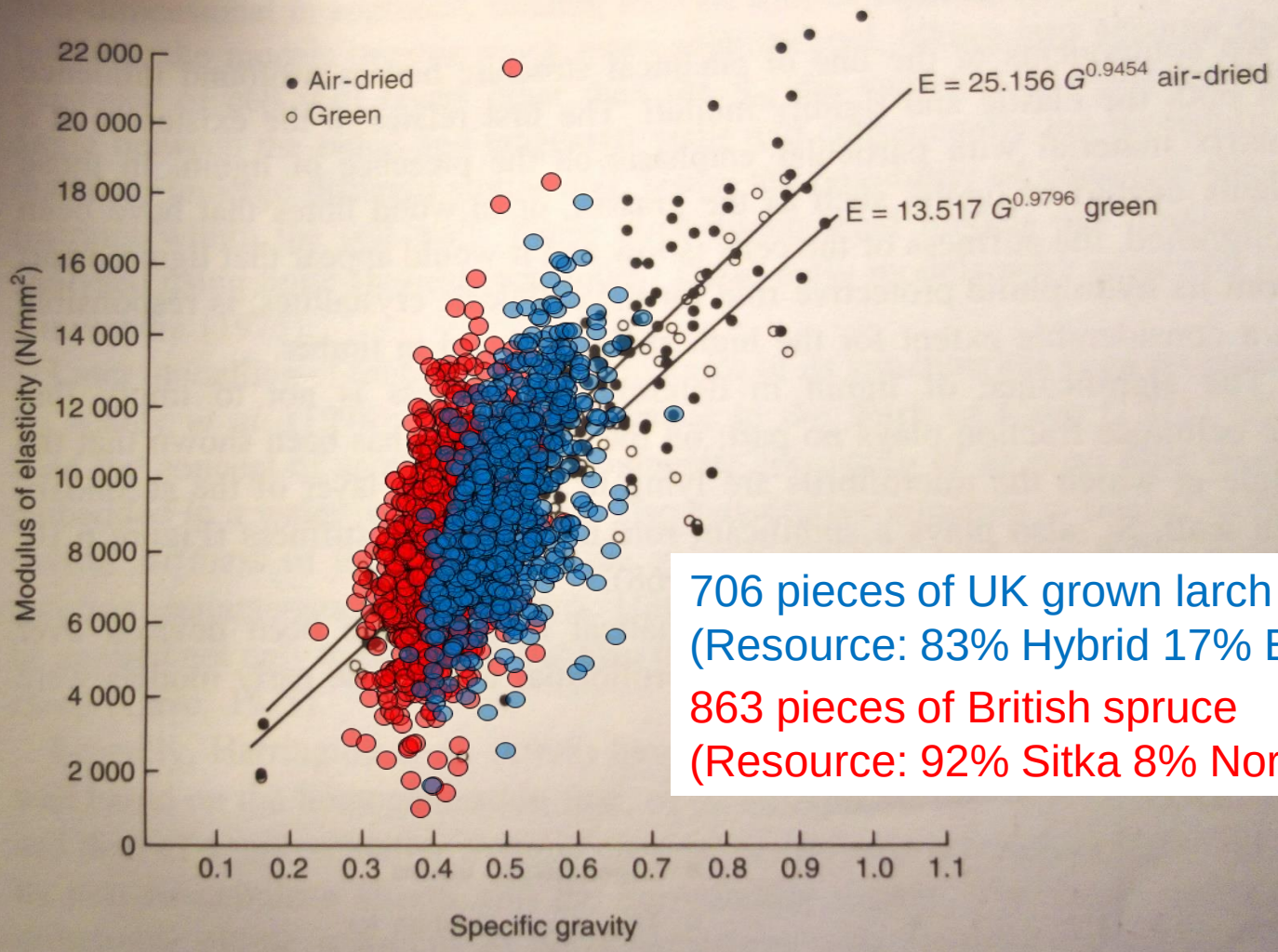


706 pieces of UK grown larch
(Resource: 83% Hybrid 17% European)

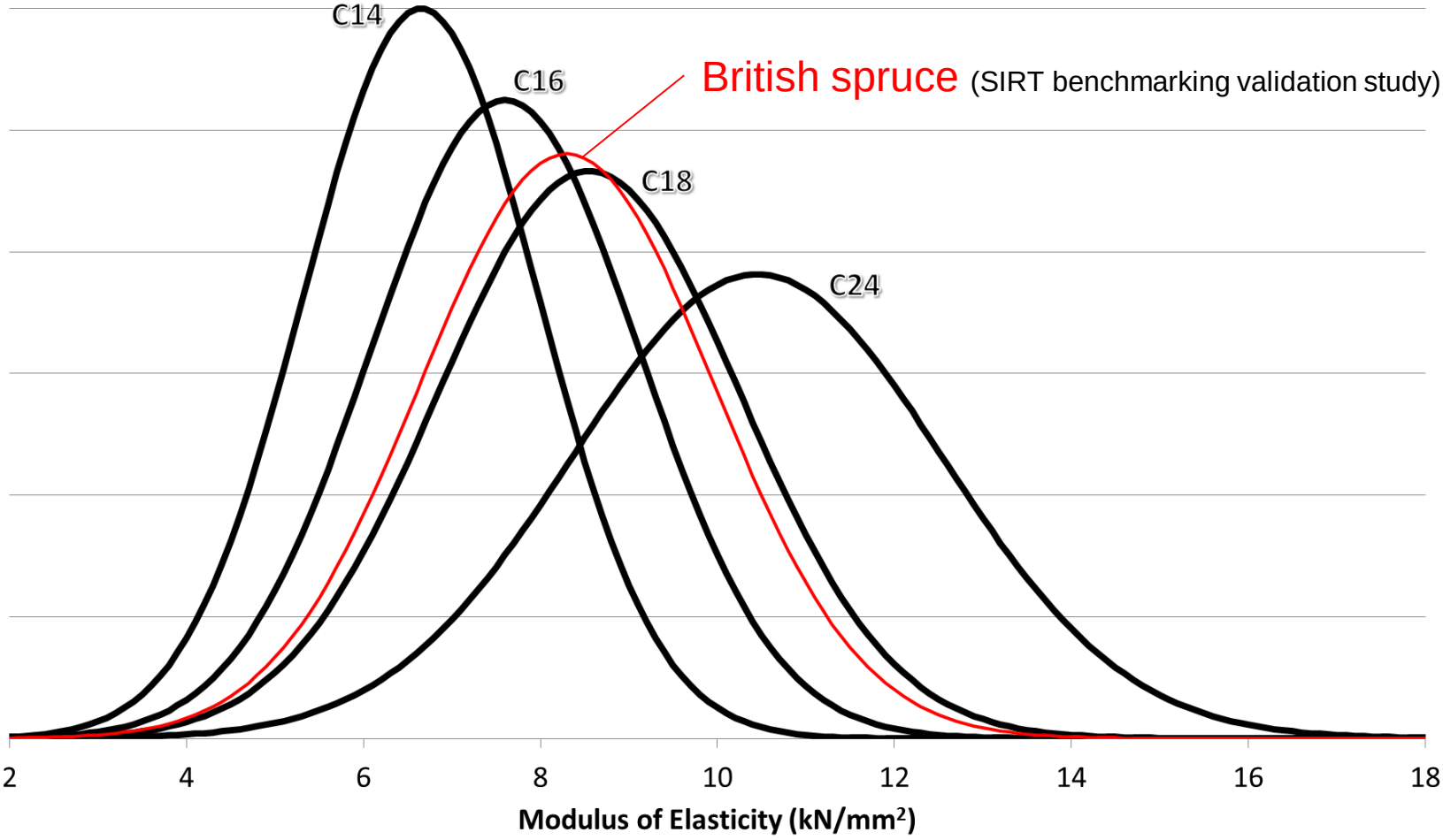
863 pieces of British spruce
(Resource: 92% Sitka 8% Norway)

Figure 6.9 Effect of specific gravity on the longitudinal modulus of elasticity for over

Variation in the resource

e.g. British spruce (mixture of Sitka spruce & Norway spruce)

Strength class definitions themselves overlap
(because they describe a population with certain variation)



Variation in the resource

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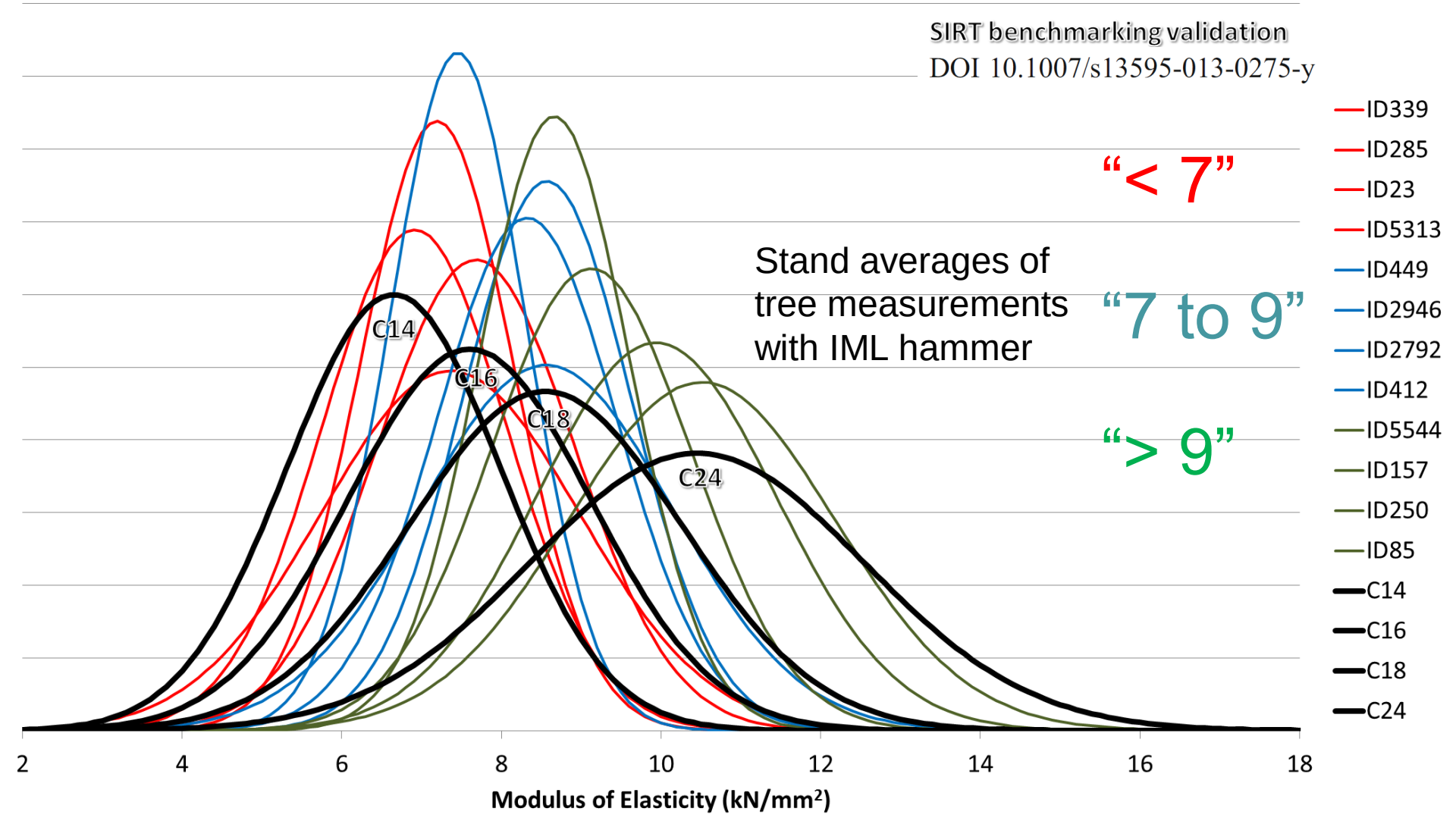
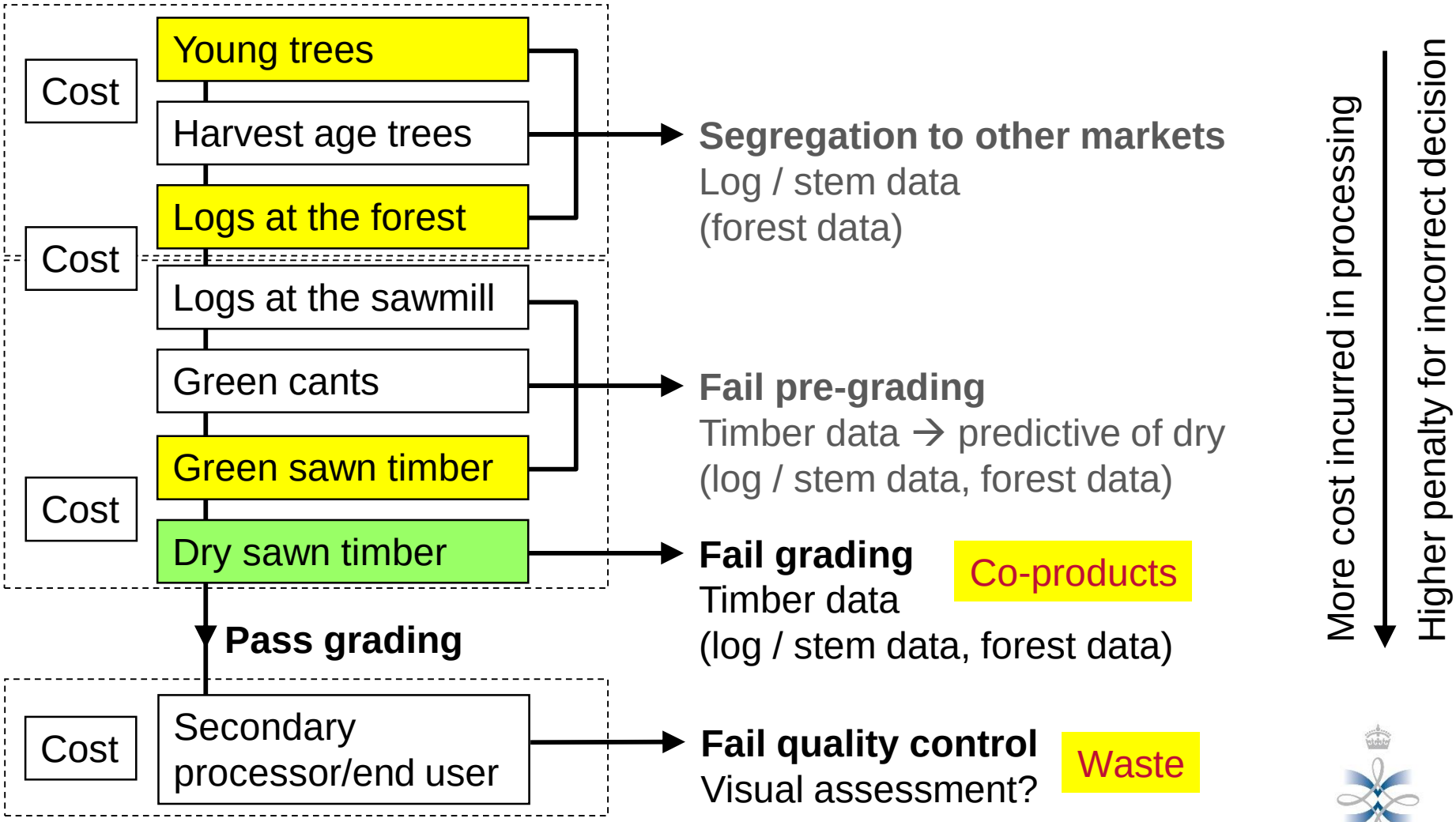


Sources of the variation

Source	Density	Strength	Stiffness
Between sites	23%	18%	26%
Between trees on a site	51%	25%	36%
Between logs in a tree	2%	5%	2%
Within log	25%	52%	35%

Moore, J. R., Lyon, A. J., Searles, G. J., Lehneke, S. A., Ridley-Ellis, D. J. Within- and between-stand variation in selected properties of Sitka spruce sawn timber in the United Kingdom: implications for segregation and grade recovery. Annals of Forest Science (February 2013) DOI 10.1007/s13595-013-0275-y

Reducing wastage



SIRT

Since 2003

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	Region
km	Forest
	Stand
	Tree
m	Log
	Sawn timber
cm	Clear wood
mm	Growth layer
	Wood anatomy
	Cell
µm	Cell wall
	Cell wall layers
	Microfibril clusters
nm	Molecular

Forest Research.
Forestry Commission.
Aberdeen University.
Growers.

Edinburgh Napier University.
Processors.

	Building
m	Assembly
	Sawn timber
cm	Details

The University of Glasgow.

The Queen's Anniversary Prizes For Higher and Further Education 2015

Conifer species researched

- **Sitka spruce (*Picea sitchensis*) (PCST)**
- Norway spruce (*Picea abies*) (PCAB)
- Hybrid larch (aka Dunkeld larch) (*Larix x eurolepis*) (LAER)
- Japanese larch (*Larix kaempferi*) (LAKM)
- European larch (*Larix decidua*) (LADC)
- Douglas fir (*Pseudotsuga menziesii*) (PSMN)
- Scots pine (*Pinus sylvestris*) (PNSY)
- Noble fir (*Abies procera*) (ABPR)
- Western hemlock (*Tsuga heterophylla*) (TSHT)
- Western red cedar (*Thuja plicata*) (THPL)
- Serbian spruce (*Picea omorika*)
- Pacific silver fir (*Abies amabilis*) (ABAM)
- Japanese red cedar (*Cryptomeria Japonica*) (CYJP)
- Grand fir (*Abies grandis*) (ABGR)
- European silver fir (*Abies alba*) (ABAL)

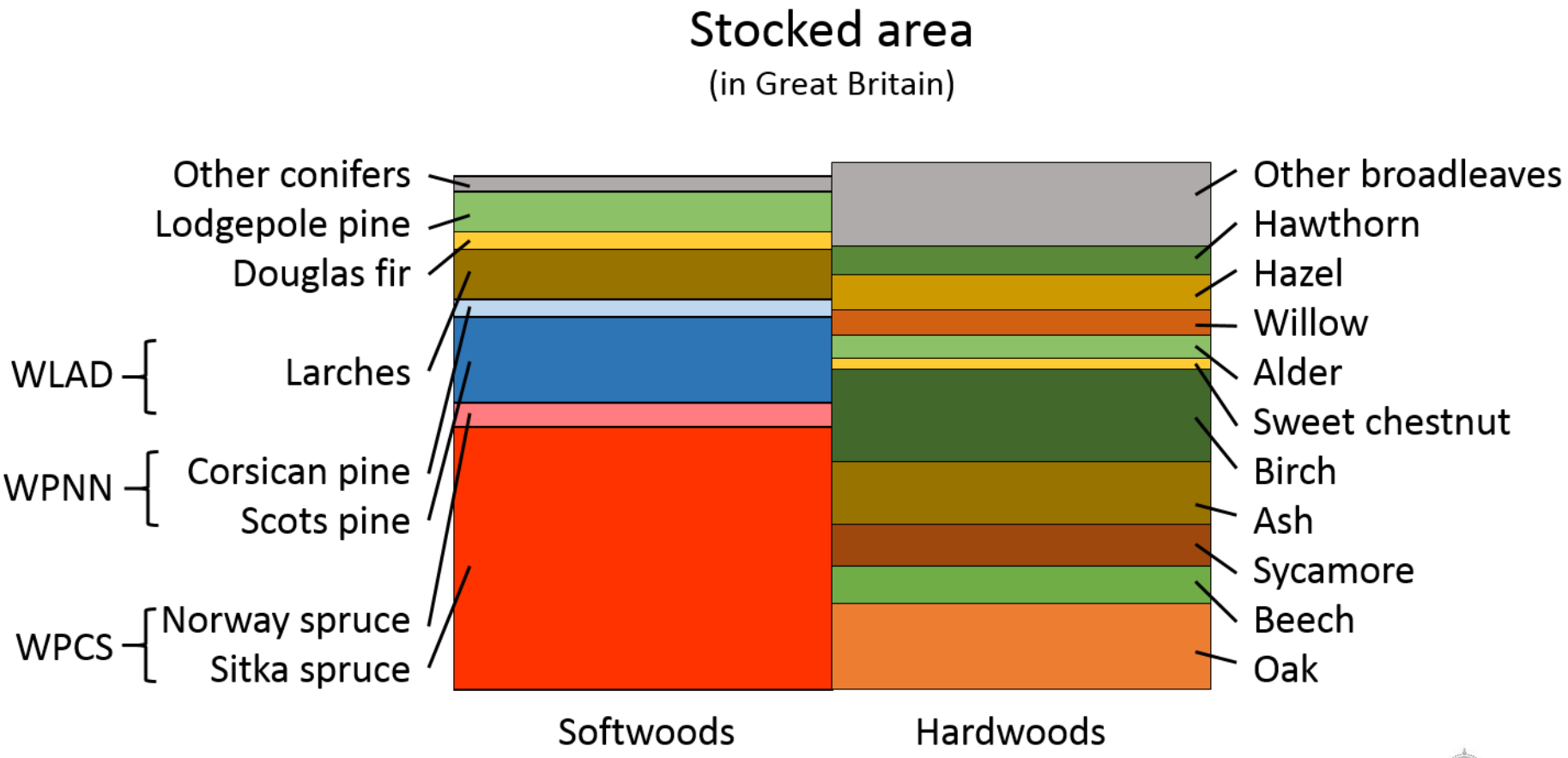
Hardwoods

Sycamore (ACPS)
(*Acer pseudoplatanus*)

Birch (BTXX)
(*Betula pendula/pubescens*)

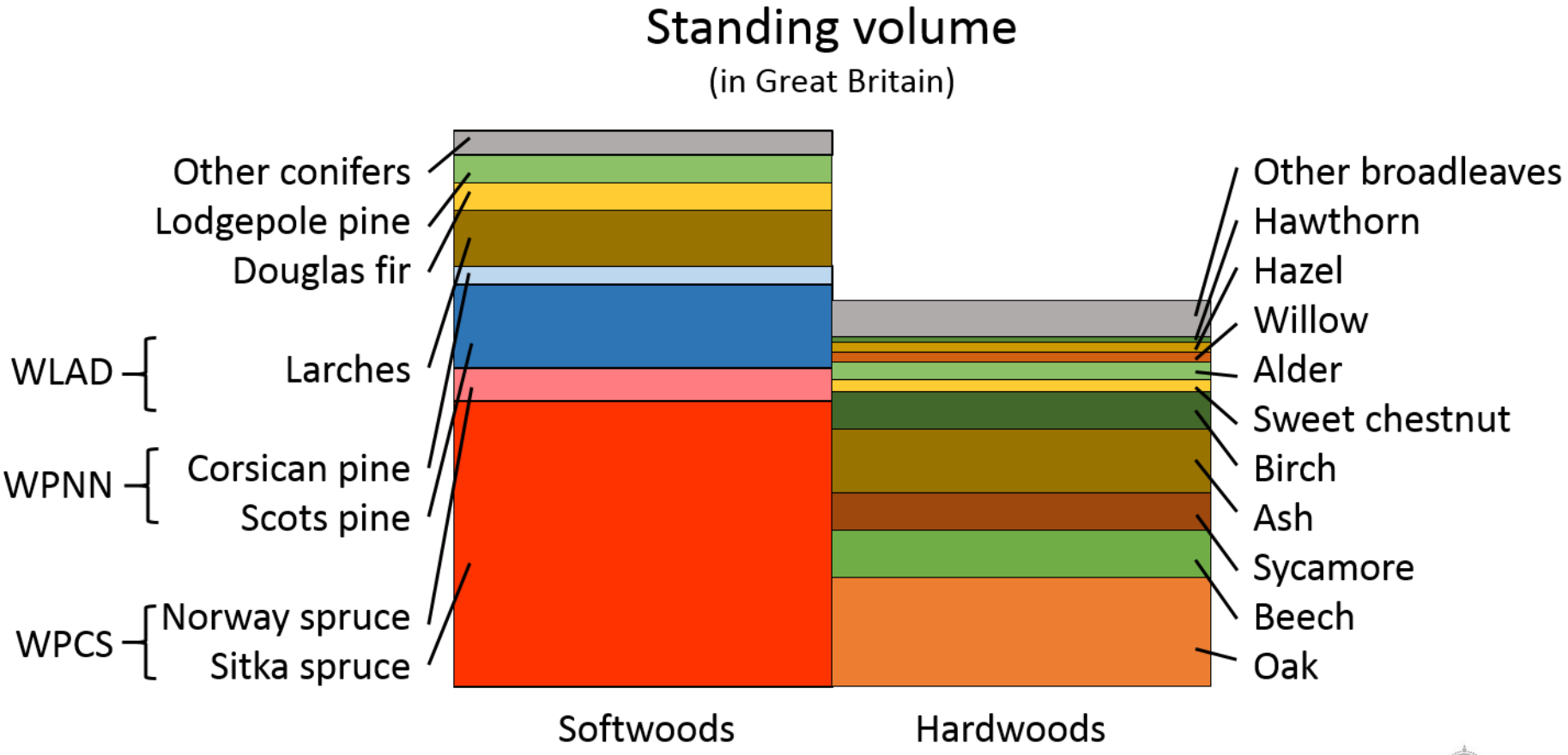
Research beginning
'Resilience'

Range of species

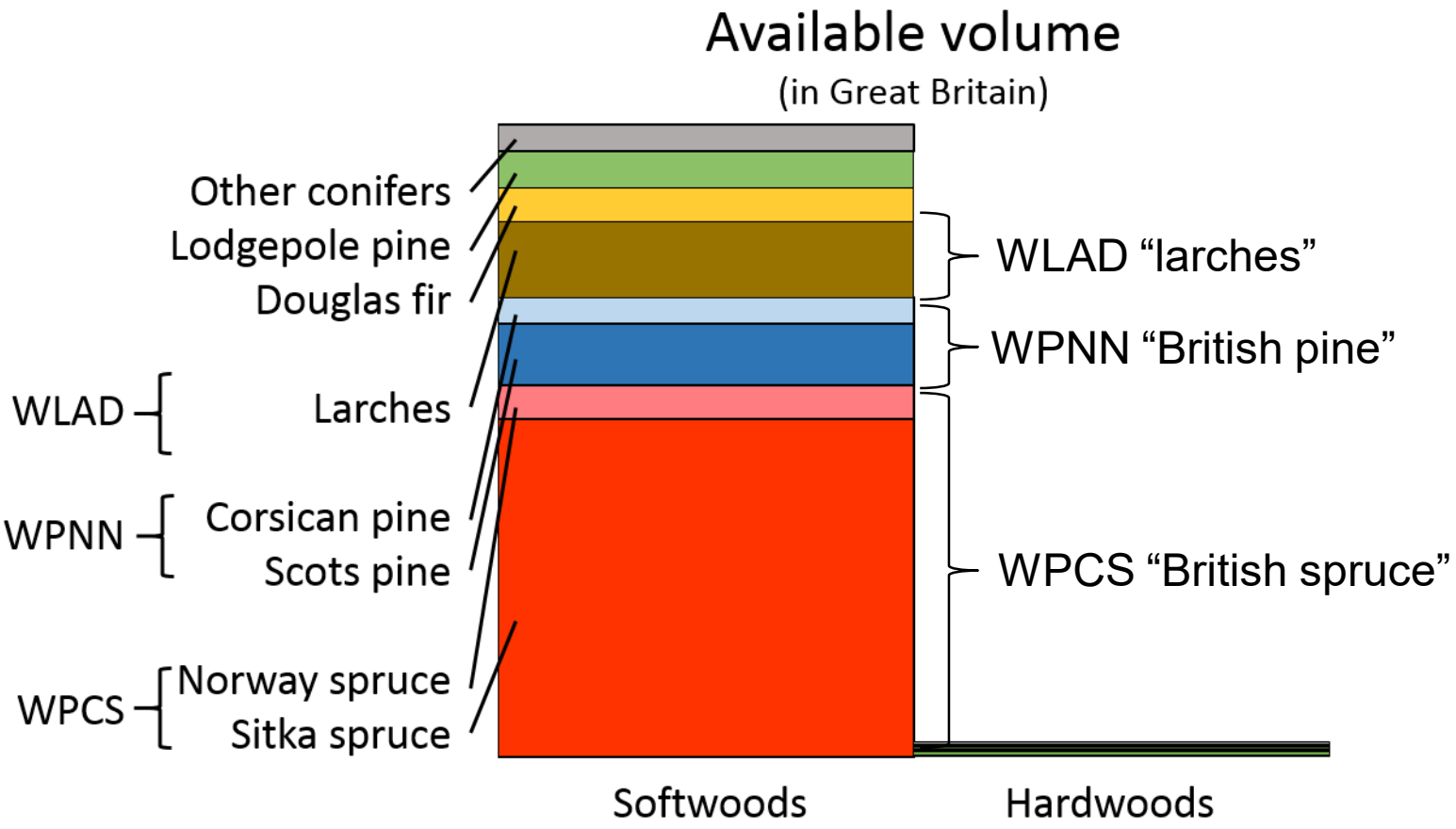


National Forest Inventory: 50-year forecast of softwood availability (Forestry Commission, April 2014)
National Forest Inventory: 50-year forecast of hardwood availability (Forestry Commission, April 2014)

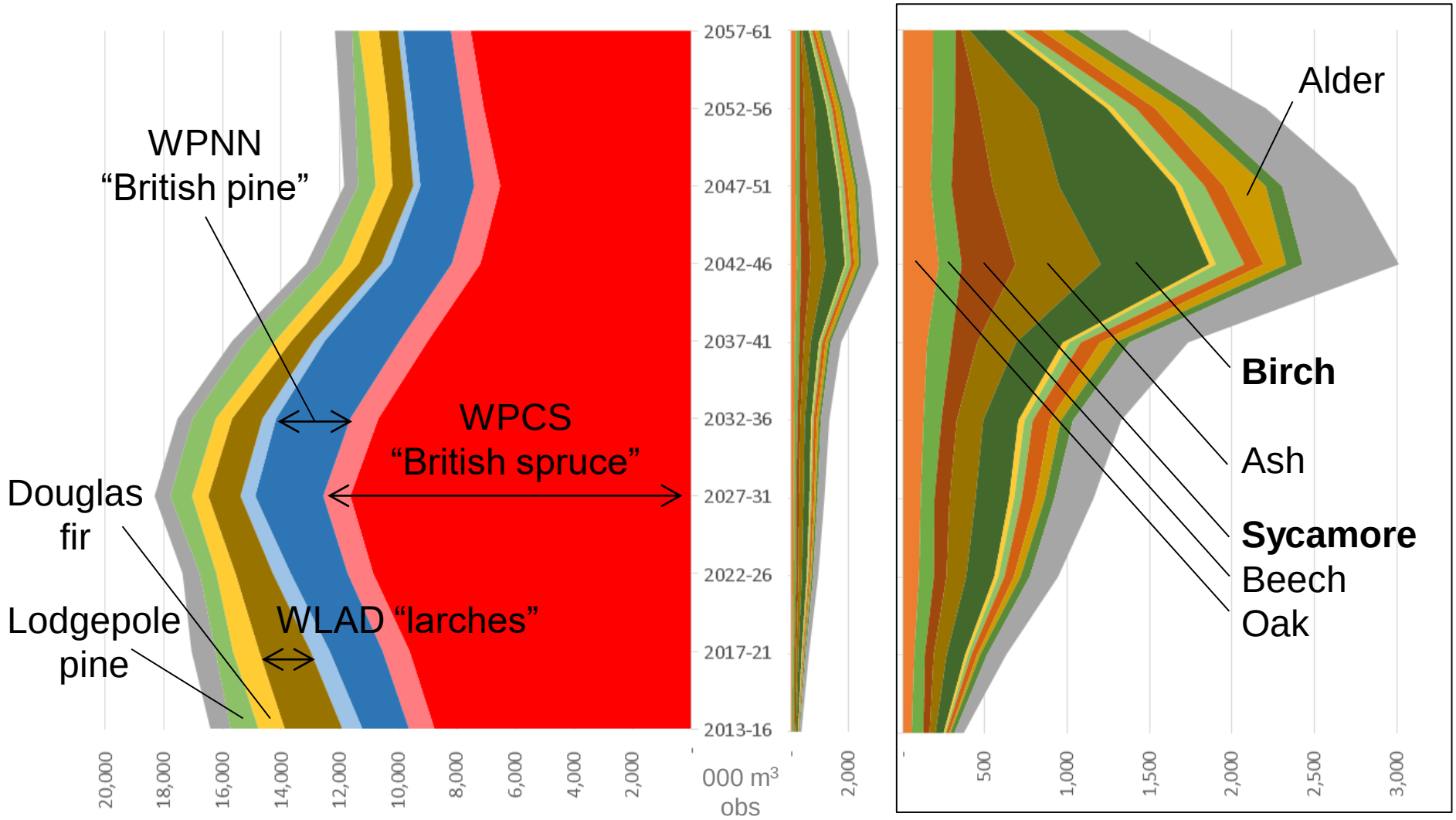
Range of species



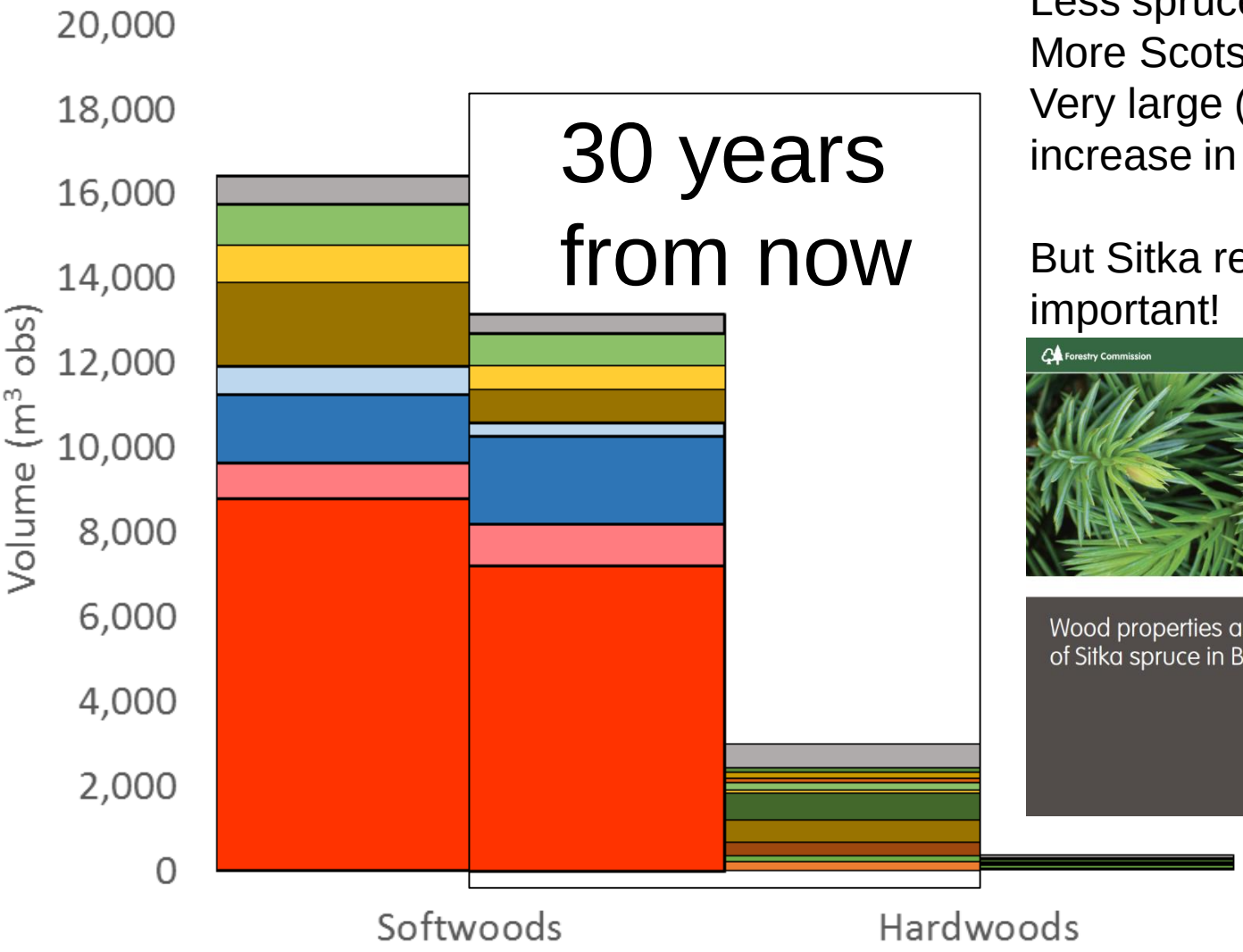
Range of species



GB volume forecast



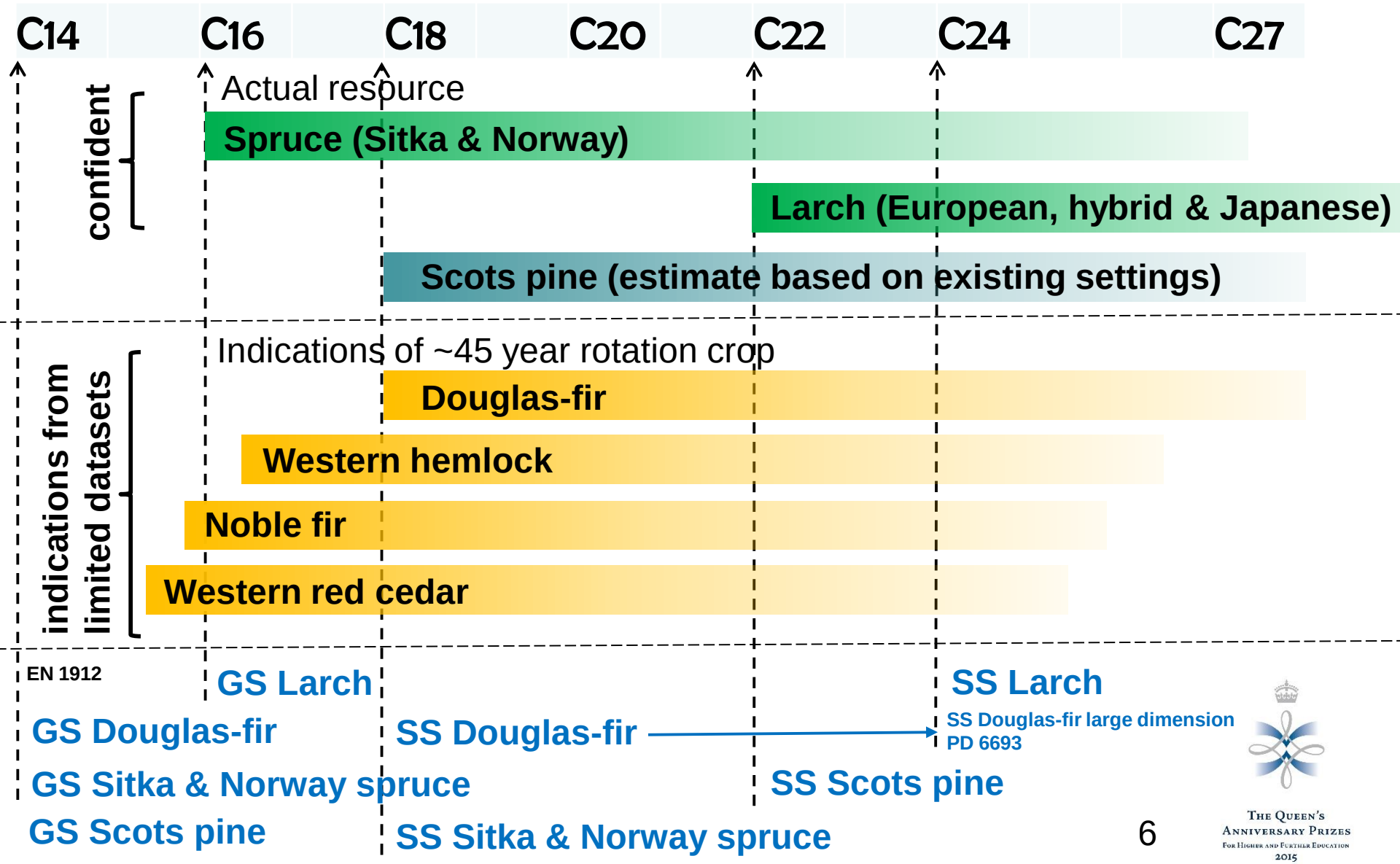
Species mix change…



Less spruce
More Scots pine
Very large (proportional) increase in hardwoods

But Sitka remains important!

UK-grown timber - potential

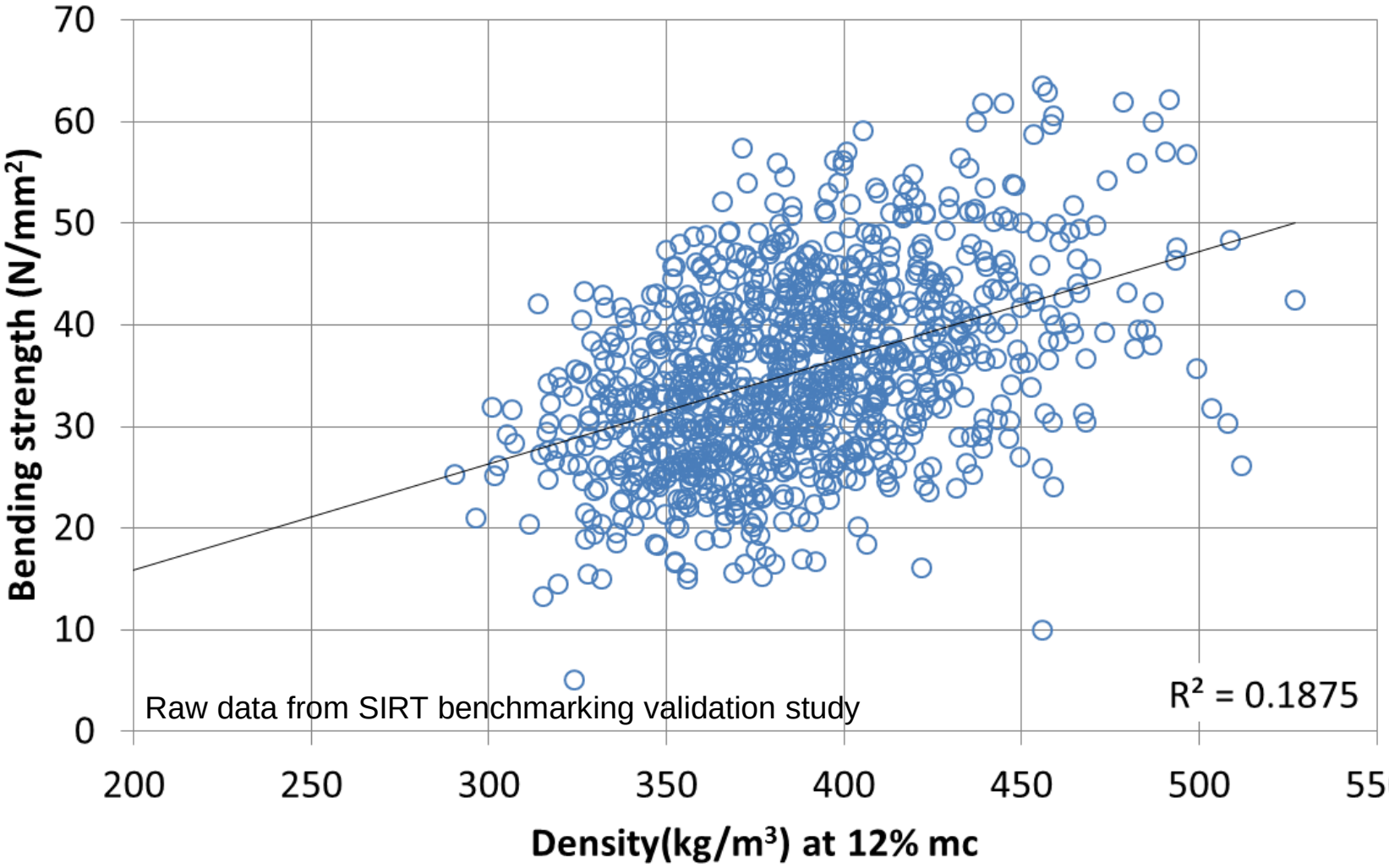


British timber myths

- “No good for construction”
- “Because it grows too quickly”
- “Means low density and low strength”

See “rate of growth” & “grade in Britain”

Density and bending strength



Mechanical properties

- Amount of cell wall material
  - Wood density
- How that cell wall material is arranged
  - Grain, earlywood, latewood
- How that cell wall material is made up
  - Cellulose : lignin
  - Microfibril angle

Juvenile core (softwoods)

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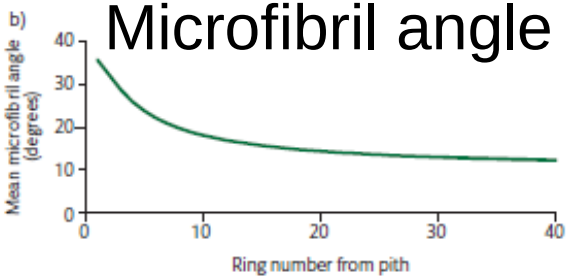
Microfibril angle



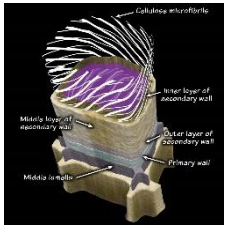
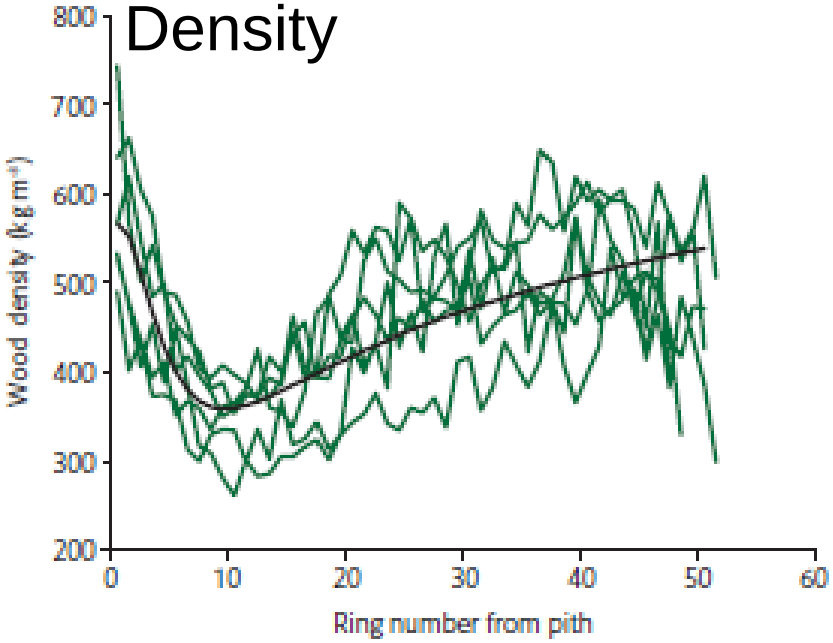


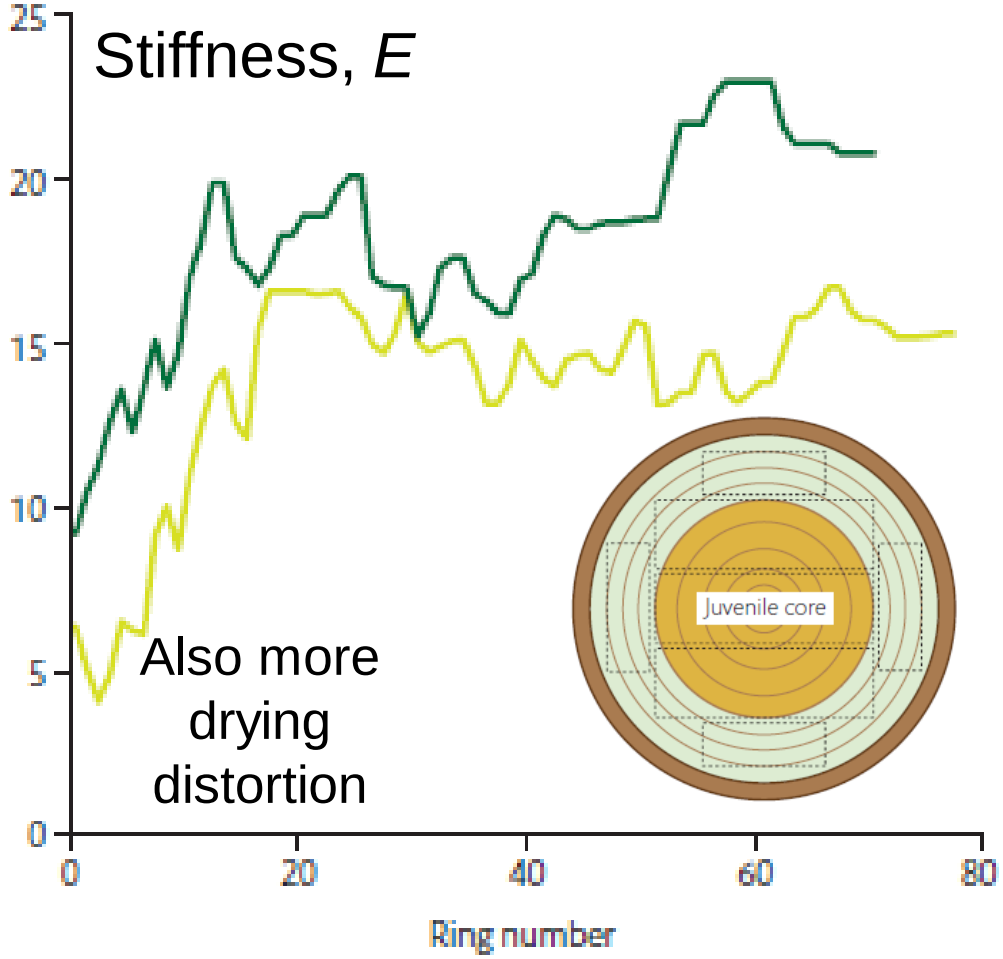
Figure 2.20 Example of the radial variation in modulus of elasticity for two specimens of Sitka spruce wood. Modulus of elasticity was estimated from data on density and microfibril angle obtained from SilviScan-3.

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.

Density

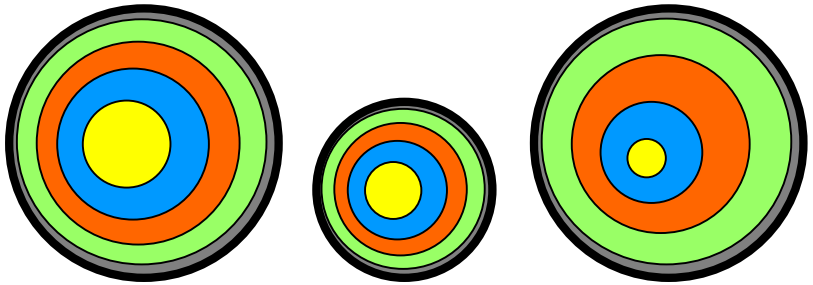


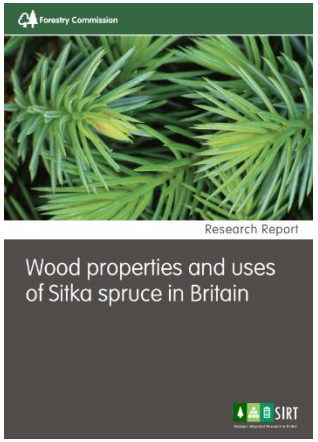
Stiffness, *E*



Factors → softwood quality

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





So what's next? (1/2)

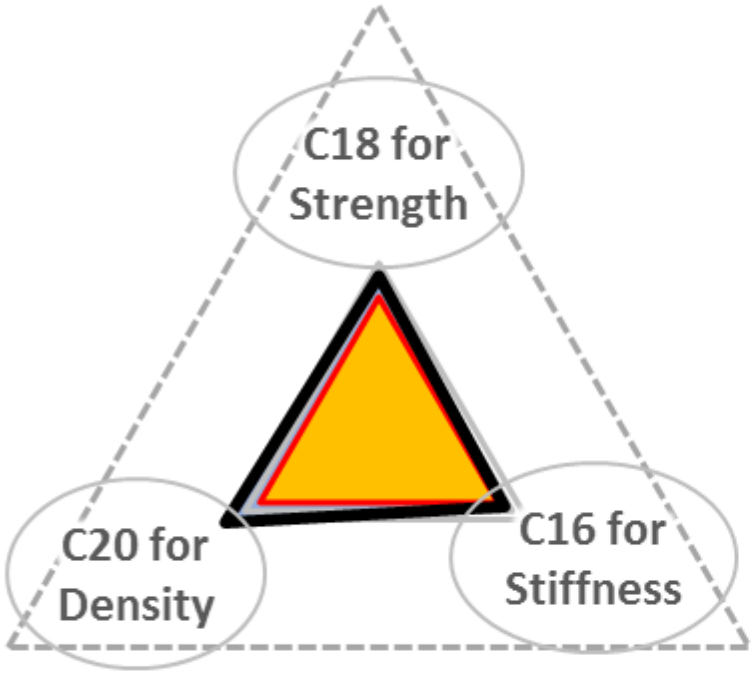
- Growth areas – and variability
  - Machine grading and visual grading
- Quality shifts
  - During production
  - Since settings were approved
  - Output control is too slow to adjust
  - Also better grading of "good" stands of timber?
- A better way to establish grading?
  - Better for species diversity

So what's next? (2/2)

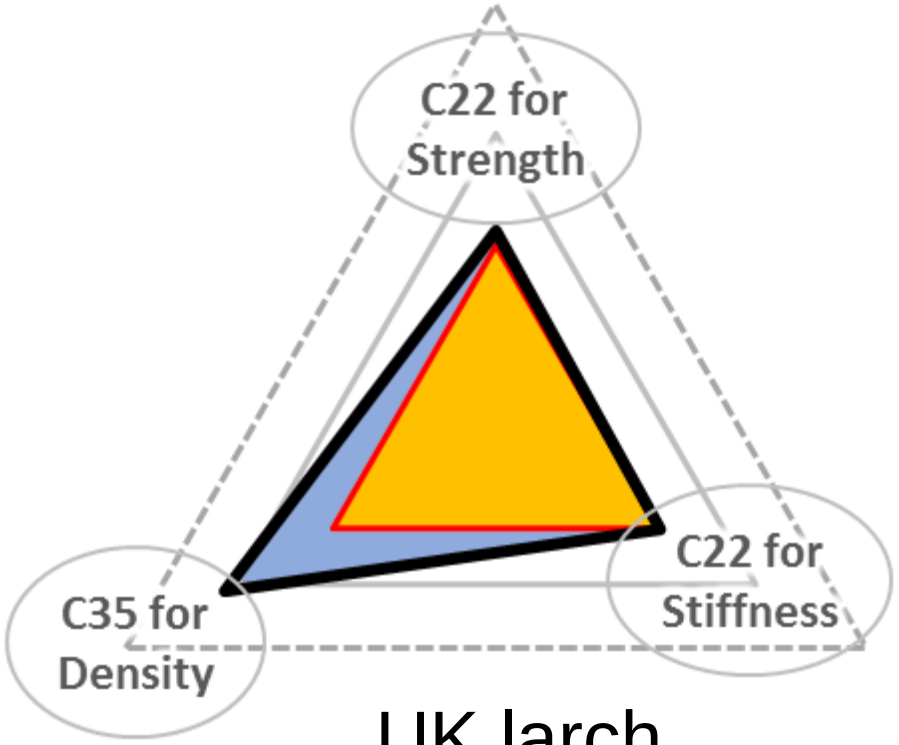
- Resource segregation
  - Standing trees, felled logs
  - Opportunities for making it work better
  - Figuring out the consequences for grading
- Tree breeding for better properties?

- Cheaper and more portable grading machines…could mean grading is done by the fabricator…no longer need to use 'commodity' strength classes…

Does not necessarily make sense to grade British spruce to C16 and then use it as studs, where bending stiffness is not as important as the strength that is reduced by the C16 strength class definition



British spruce (WPCS)



UK larch (WLAD)

C16+

C16+ is a user defined UK grade for studs. Its primary characteristic values are:

$f_{m,k}$ = 18,5 N/mm², $E_{0,mean}$ = 8000 N/mm², ρ_k = 330 kg/m³

Other characteristic values can be calculated from the equations given in EN 384.

(Strength > C18, and density of C20)

Secondary properties

- The secondary properties in EN338/EN384 are rather conservative
- You are permitted to specify your own values, established by testing

Visual grading

- For large cross-sections, visual grading will result in good yields since the knots are comparatively small
- There is good scope for improving visual grading assignments for home grown timber
- (Although that would require testing work)

Some current projects

- “Alternative” species
  - Including sawmill survey to gather information
- Drought crack in spruce
- Extractives content of UK trees
- British and European grading standards
- Improving resource segregation
- …And early information
- Education and knowledge transfer