DEVELOPING THE SCOTS PINE RESOURCE

Northern Periphery Programme 2007–2013

Euroopan unioni
Euroopan aluekehitysrahasto

Pine timber with respect to structural glued products

***Erkki Verkasalo*, Mika Grekin, Håkan Lindström, Thibaut Surini, Binod Gyawali**

NPP-DSP GlueLam Conference and Excursion

Trondheim, Norway

12.-14.4.2010

Outline

- **Production of structural glulam in Finland**
- **Critical properties of solid wood in glued structural products**
- **Results: density, strength and stiffness**
- **Results: stability and moisture resistance**

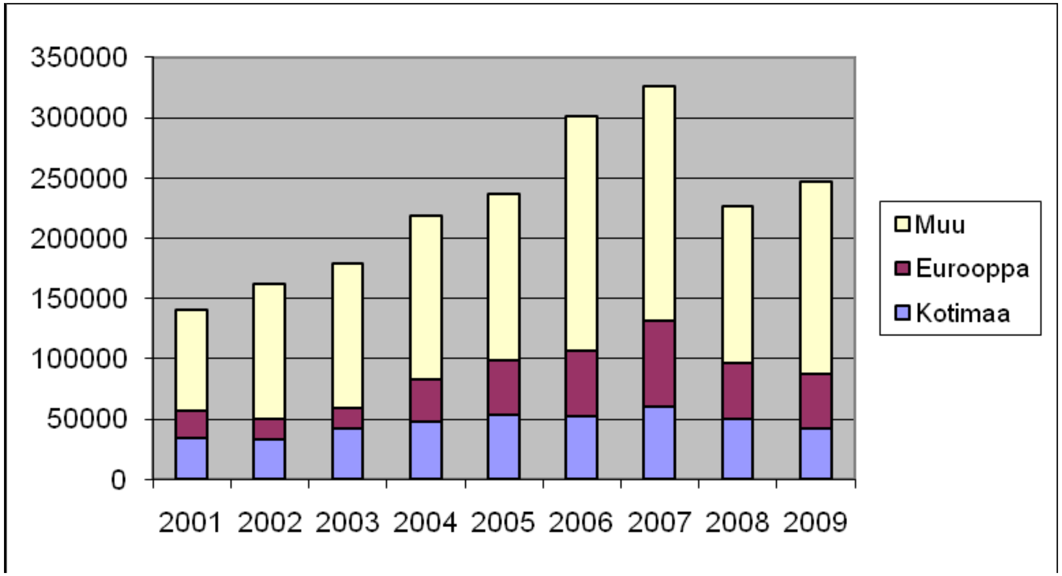
Production of structural glulam in Finland

- **Growth until 2007**
- **250 000 m3 in 2009**

  - Domestic 18 %

  - Europe 18 %

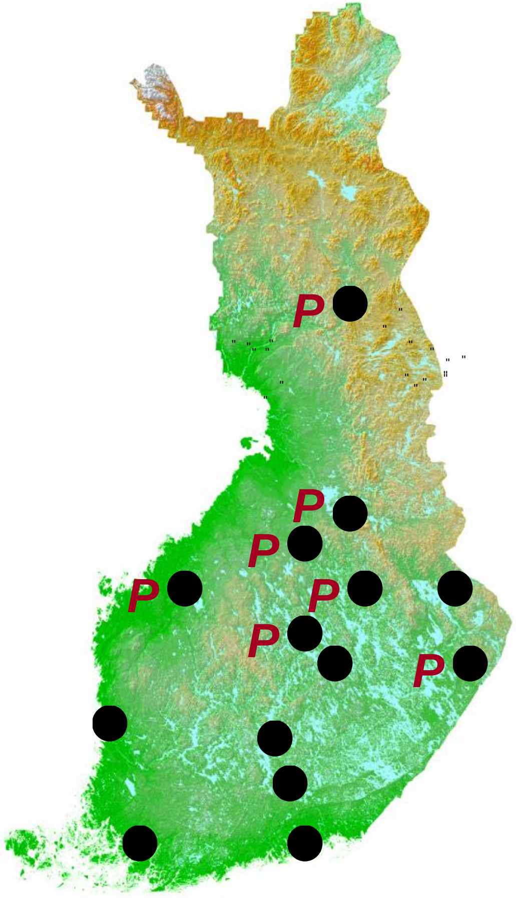
  - Others (mainly Japan) 64 %



- **One of the biggest producing countries in Europe**
- **Along with Austria, the biggest exporting country to Japan**
- **Spruce** *(Picea abies)* **is the main material (80%)**
- **Pine** *(Pinus sylvestris)* **is the second but growing material (20%)**

Glulam industries in Finland

- ***Manufacturers:*** ***Anaika Components Oy Ltd., Arktos Group Oy Ltd., Finland Laminated Timber Oy Ltd., Havesa Components Oy, Keitele Engineering Wood Oy, Kestopalkki LPJ Oy, Late-Rakenteet Oy, Metsäliitto Co-op., PRT-Lami Oy, Versowood Oy***
- **In addition, laminated log house timber is manufactured, by two component manufacturers (Hasetec Oy, LAMECO LHT Oy) and several log house factories**
- ***Finnish association of glulam industries is the collaboration organ at the national and international level: statistics, standardisation, market promotion, research and development***
- ***More information: www.liimapuu.fi***



P = regular pine production

Critical properties of solid wood

- **Density, strength and stiffness**
- **Stability: shrinkage anisotropy, deformations, EMC**
- **Moisture resistance: adsorption – desorption, EMC**
- **Checking tendency: shear strength, tensile strength perpendicular to grain**
- **Surface roughness / smoothness, clustering of molecules of liquid (drop test)**
- **Wood – glueline contact and interaction (overall)**

Note! In general, gluing can be controlled (if done properly),

and wood material is the cause of failure in gluing

Scots pine - literature study

Working Papers of the Finnish Forest Research Institute 36
http://www.metla.fi/julkaisut/workingpapers/2006/mwp036.htm
ISBN-13: 978-951-40-2019-3 (PDF)
ISBN-10: 951-40-2019-7 (PDF)
ISSN 1795-150X

Nordic Scots Pine vs. Selected Competing Species and Non-Wood Substitute Materials in Mechanical Wood Products

Literature Survey

Mika Grekin

Wood Material Science Research Programme

METLA www.metla.fi

http://www.metla.fi/julkaisut/workingpapers/2006/mwp036.htm

Contents

4

Scots pine vs. other softwoods

	Pinus contorta	Picea abies	Pseudotsuga menziesii
Density			
Basic	0	–	+
Air-dry	–	–	0
Pith-bark variation	0 / +	–	–
Base-top variation	–	–	
Shrinkage			
Axial	–	+	–
Radial	+	–	+
Tangential	–	0	–
Volumetric	0	+	0

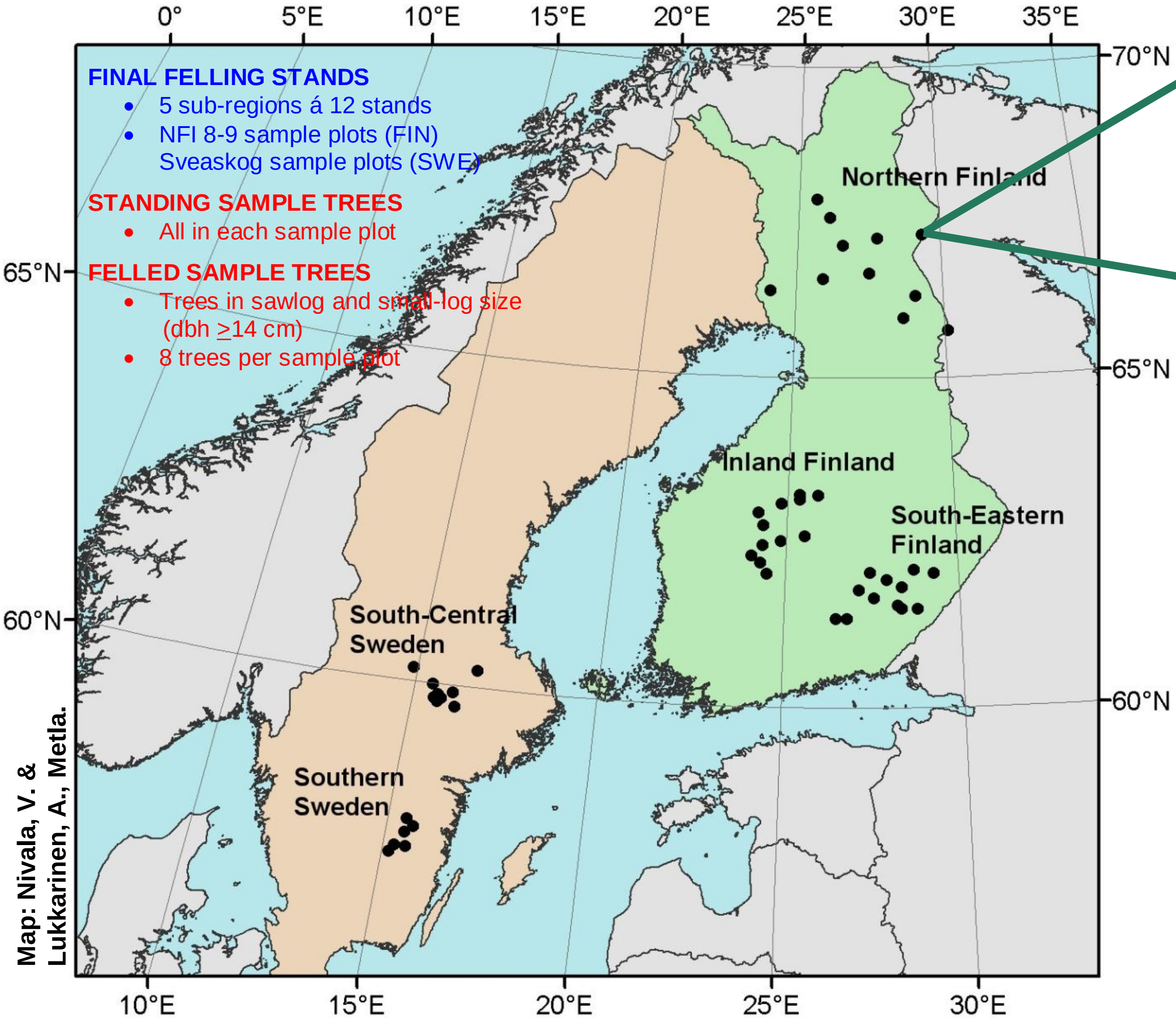
0 = no difference, + = >5 % larger than in pine, – = <5 % than in pine

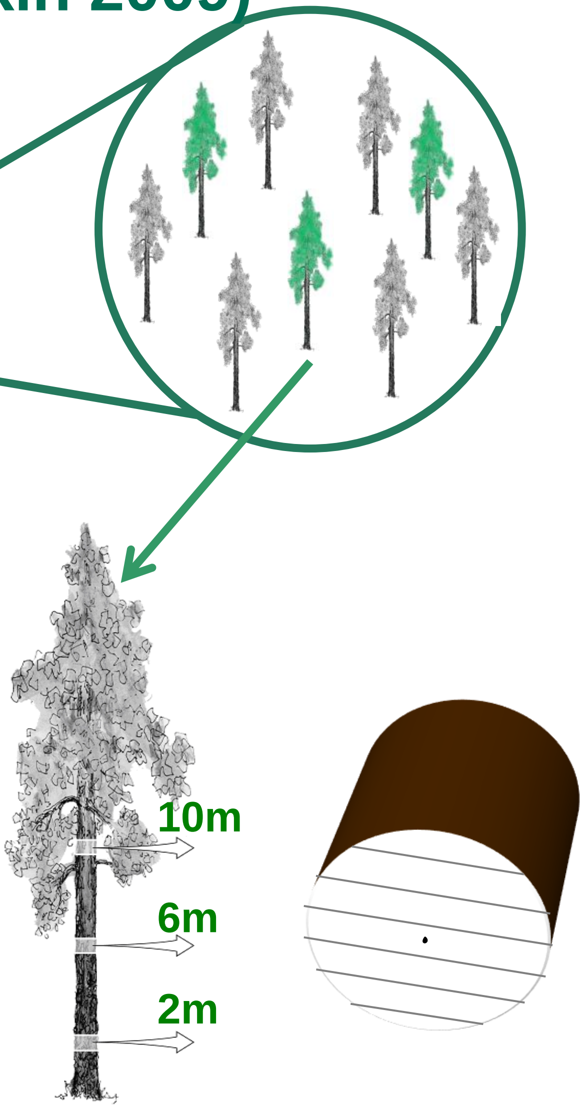
Scots pine vs. other softwoods

	Pinus contorta	Picea abies	Pseudotsuga menziesii
Mechanical properties			
Bending strength ||	–	–	–
Modulus of elasticity ||	–	0	+
Compresssion strength ||	–	–	0
Compression strength ⊥	–	–	–
Tensile strength ||		–	+
Tensile strength ⊥	–	–	–
Shear strength||	–	–	–
Brinell-kovuus ⊥	–	–	+

0 = no difference, + = >5 % larger than in pine, – = <5 % than in pine

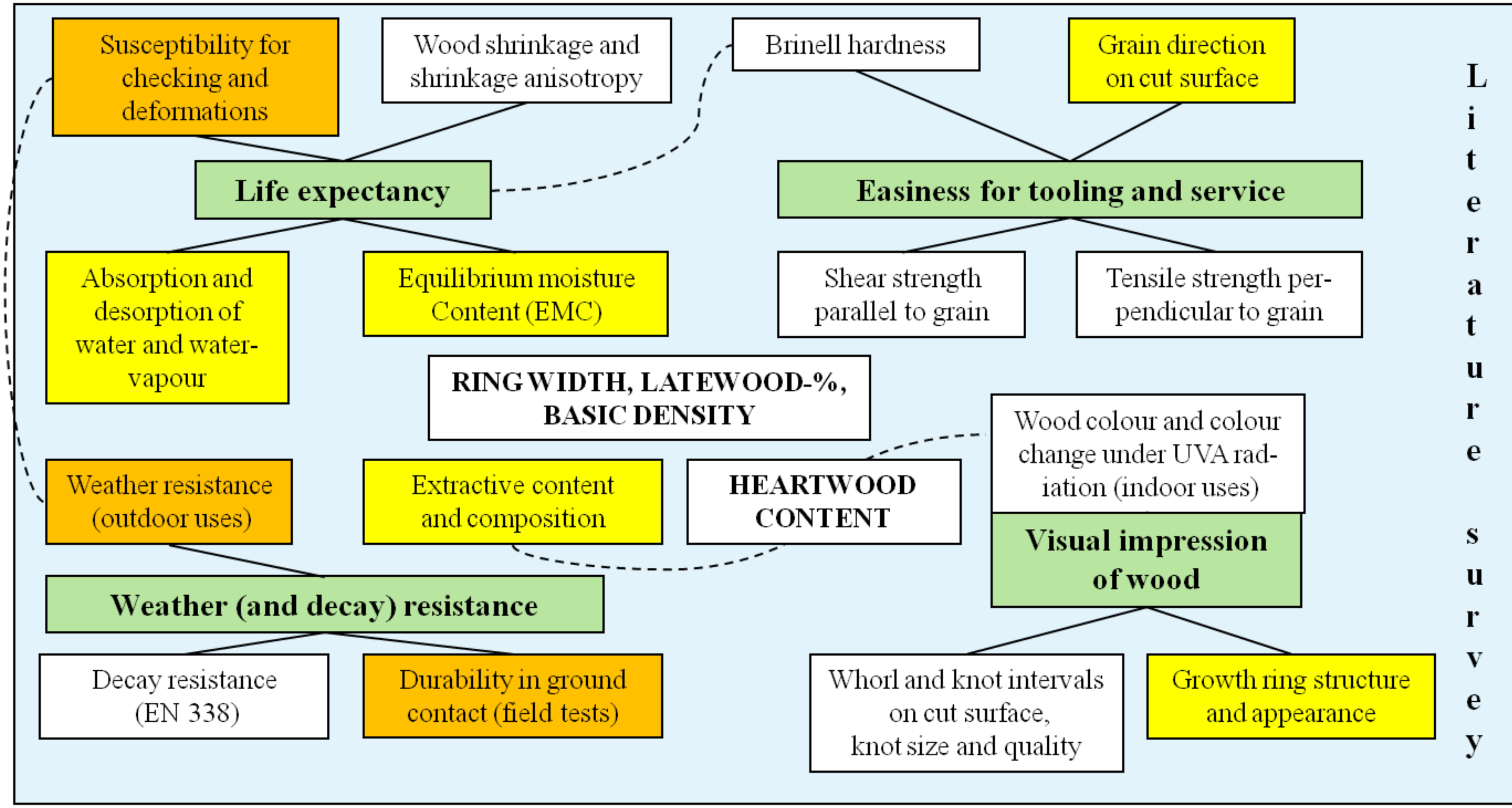
Properties of Scots pine wood from five regions in Finland and Sweden (Verkasalo & Grekin 2009)





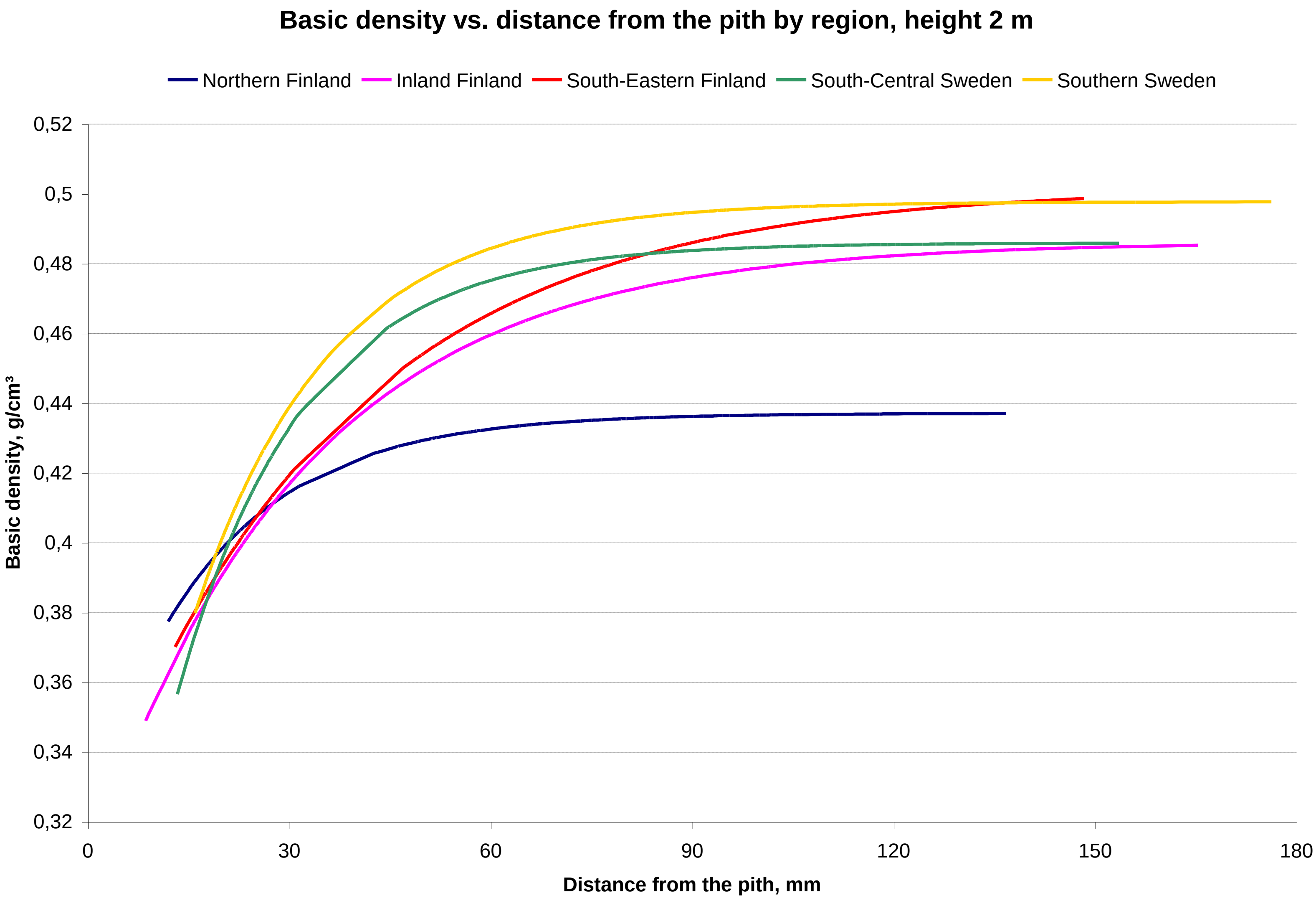
Outline of project 1

Groups of key features | Results published | Under reporting | Under analysis or testing

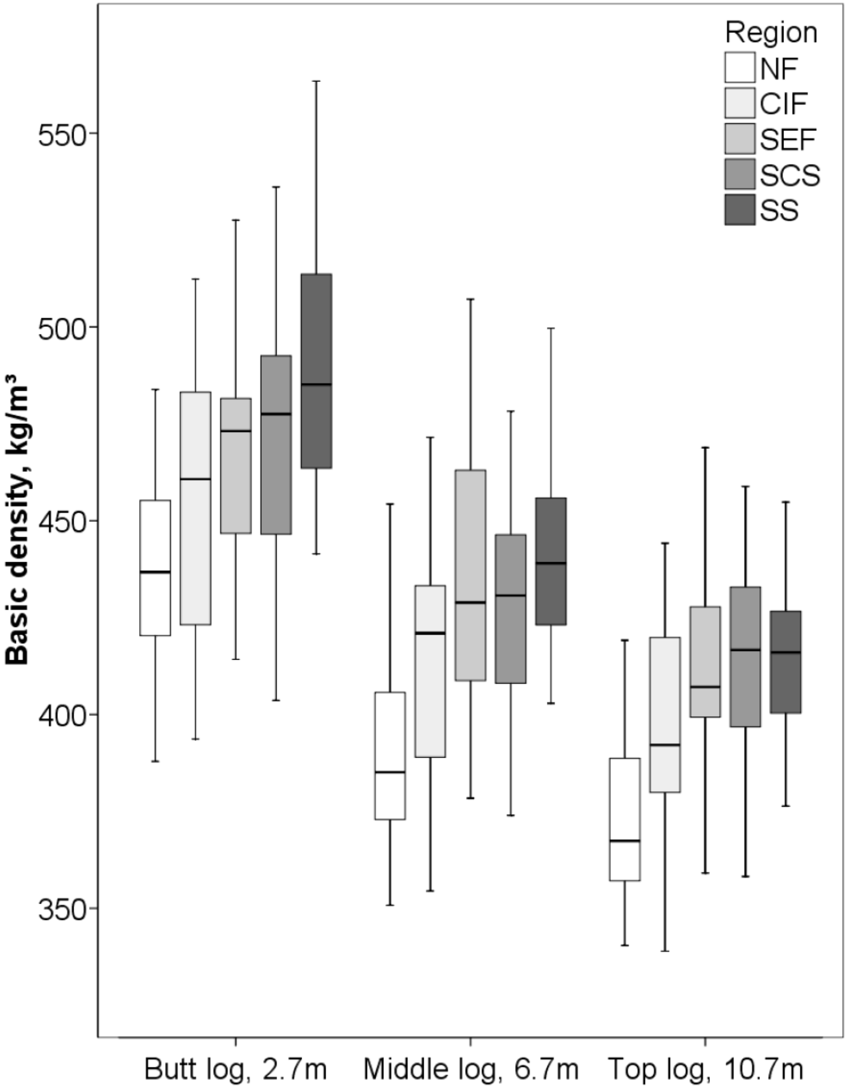


*** Project 2 / SLU Forest Products - Building product properties of sawn timber billets: MOE, MOR, drying deformations**

Basic density; by distance from the pith



Basic density; by height position in tree



Basic density, causes of variation

- Case 1: significant predictors
  - + region
  - – height position
  - R^2=52 %
- Random variation

- Case 2: significant predictors
  - + effective thermal s
  - – height position
  - – relative height
  - – ring width
  - + latewood percenta
  - R^2=64 %
- Random variation

Basic density, comp. with pulpwood density of south-north regions in Finland (Hakkila 1968)

Latitude, degree north	Scots pine	Norway spruce
60-62	399	380
62-64	410	396
64-66	387	387
66-68	375	387

Air-dry density, typical values of some softwoods

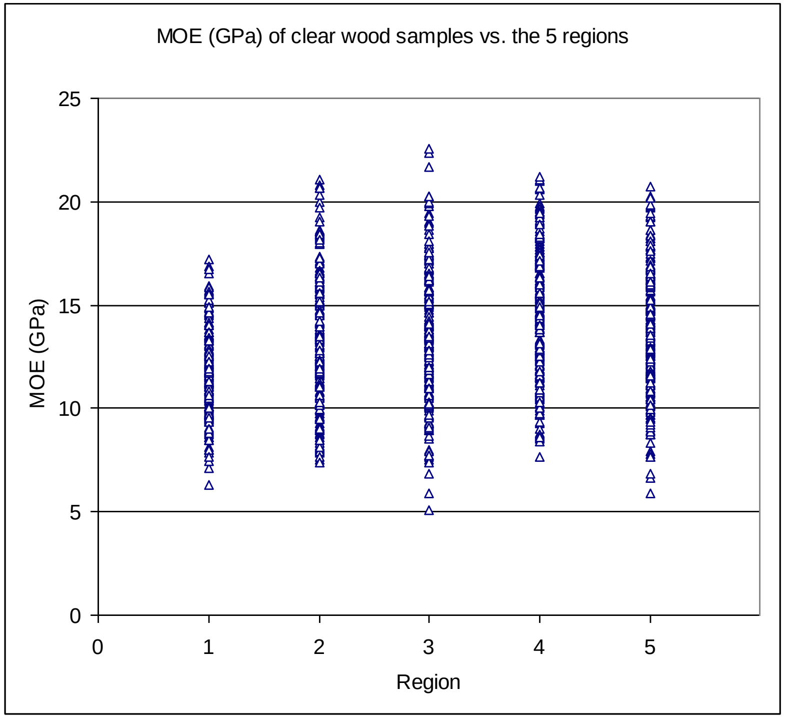
Species	Latin name	Air-dry density, kg/m3 (MC 12%)
Western red cedar	Thuja plicata	330
Radiata pine	Pinus radiata	380
Norway spruce	Picea abies	380
Lodgepole pine	Pinus contorta	420
Scots pine	Pinus sylvestris	430
Douglas fir	Pseudotsuga menziesii	490
Loblolly pine	Pinus taeda	520

Modulus of elasticity – clear wood (Dr. Håkan Lindström, SLU Uppsala)

Table. Modulus elasticity measured with knots included in the specimen (MOE 1) and after elimination of the knots (MOE 2). 1120 wood samples, at 12 % MC, distributed on radial positions of the log: 'pith' (position 1), 'medium' (position 2), and 'mature' (position 3). Samples from 180 Swedish and Finnish sample trees.

MOE (GPa)	Finland & Sweden			
	Min	*Max*	*Avg*	*stddev*
MOE 1, pith	5.0	22.9	11.1	2.5
MOE 1, medium	6.4	21.8	14.0	2.9
MOE 1, mature	6.8	22.6	15.2	3.1
MOE 2, pith	5.1	22.6	11.7	2.5
MOE 2, medium	8.5	21.7	14.7	2.7
MOE 2, mature	7.5	22.3	15.6	2.6

Modulus of elasticity – clear wood (Dr. Håkan Lindström, SLU Uppsala)



It may be that region 1 has slightly lower variability in MOE when compared with material from regions 2-5.

However, this is inconclusive evidence as there is limited amount of samples in this explorative study.

Modulus of elasticity – clear wood (Dr. Håkan Lindström, SLU Uppsala)

Statistical modelling

- MOE assessed on c. 1120 wood samples with knot/defects (Mode
- MOE assessed on c. 1120 wood samples without knot/defects (Mo

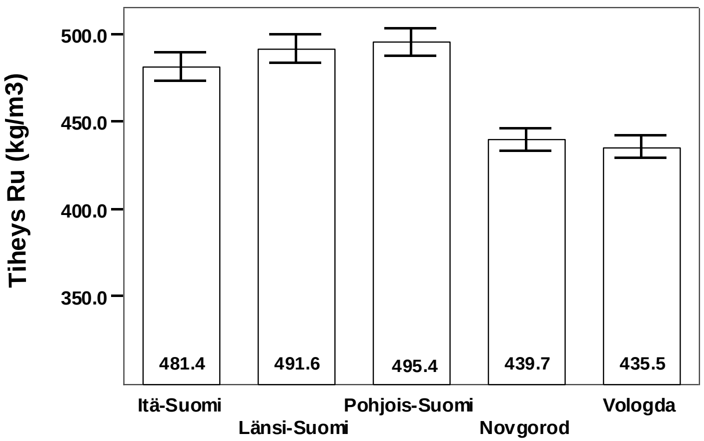
Best model based on 5 variables			
Model	R^2Adj	RMSE	Significant variables in model(p<
1	0.43	6.3 GPa	Site type, 2nd Highest, LowestDkn Height in tree, Dist from pith
2	0.52	5.2 GPa	Tempsum, LowDknot, HighDkno

Comparison of centre yield sawn timber of Scots pine from Finnish and Russian logs (Hautamäki et al. 2010)

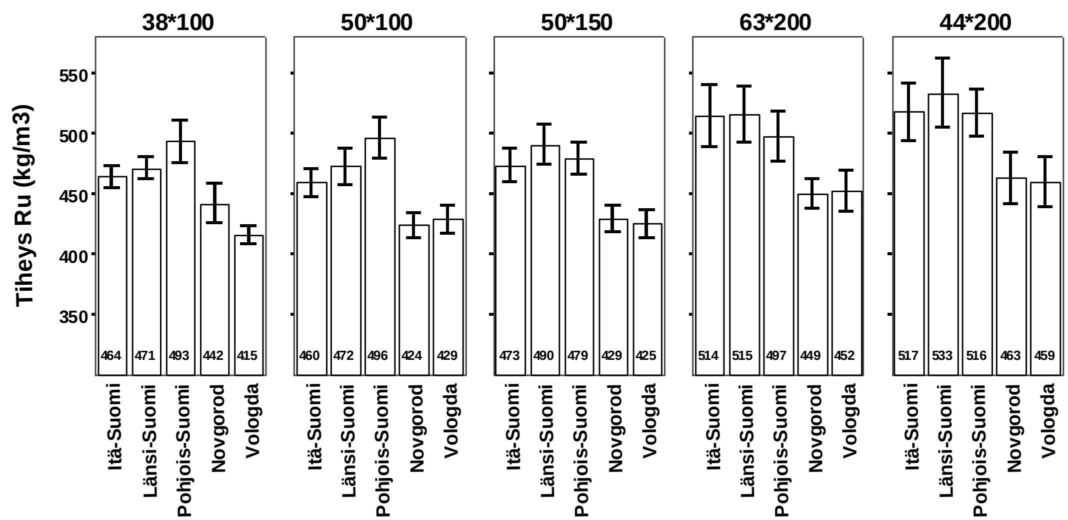
Figure 1. Approximate sampling areas in Finland and in Russia, W-F representing western Finland, N-F for northern Finland and S-E F for south-eastern Finland (Hautamäki et al. 2010).

Density (MC 12%)

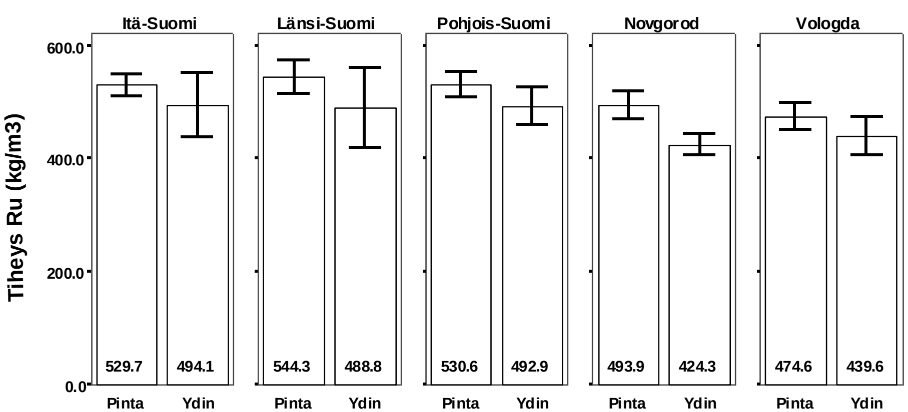
Tiheys alueittain (keskiarvot ja niiden keskivirheet)



Tiheys sahedimensioittain ja alueittain (keskiarvot ja niiden keskivirheet)

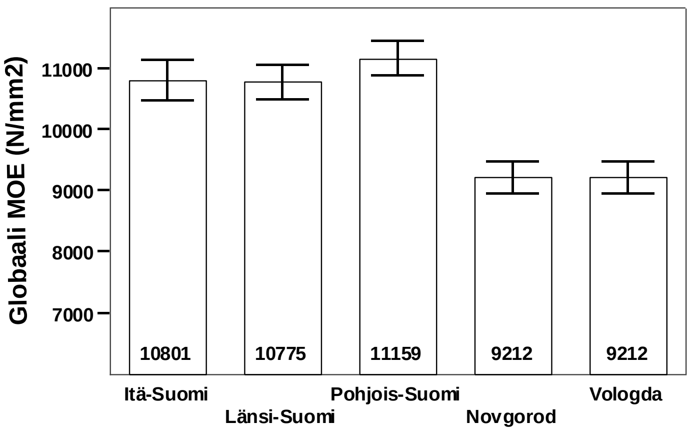


Tiheys sahedimensiossa 44x200mm alueittain (keskiarvot ja niiden keskivirheet)

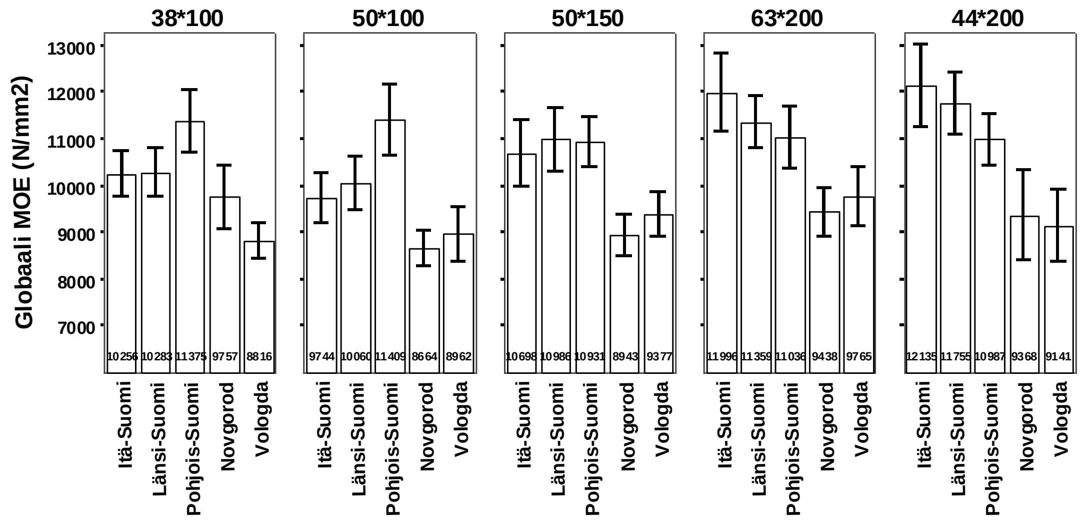


MOE (global)

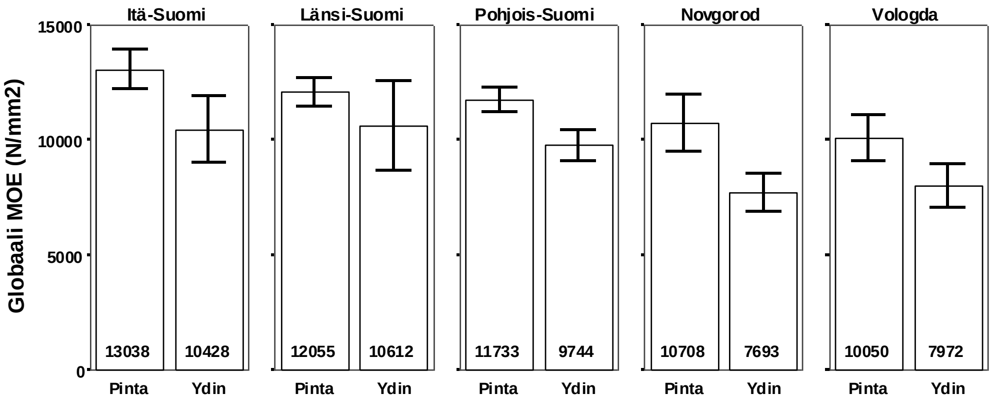
Kimmomoduuli alueittain (keskiarvot ja niiden keskivirheet)



Kimmomoduuli sahedimensioittain ja alueittain (keskiarvot ja niiden keskivirheet)

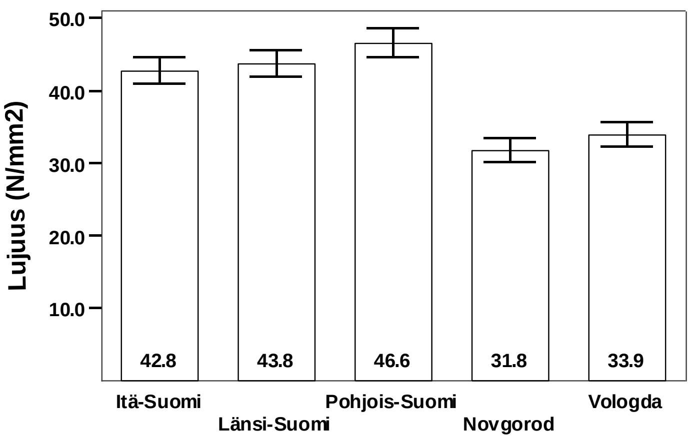


Kimmomoduuli sahedimensiossa 44x200mm alueittain (keskiarvot ja niiden keskivirheet)

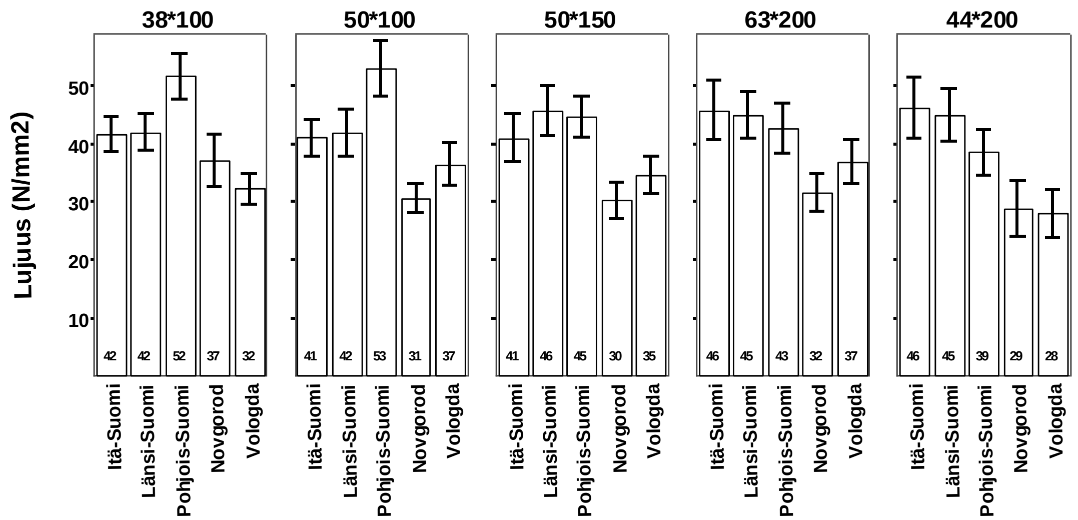


MOR (bending)

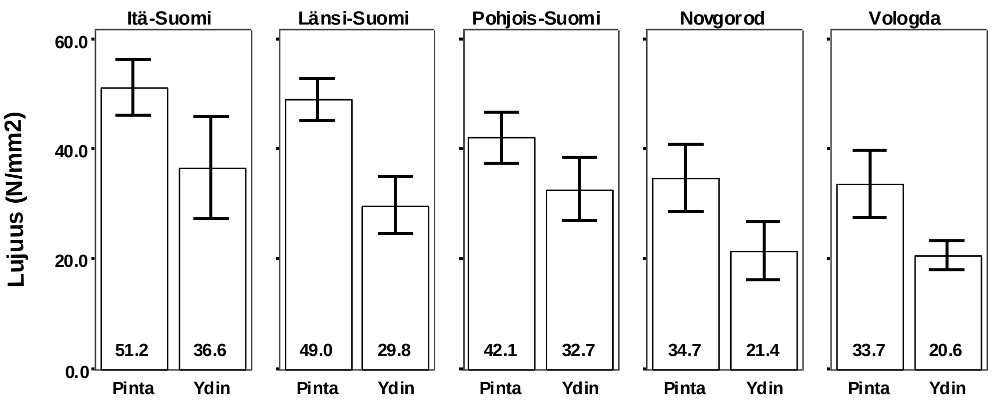
Lujuus alueittain (keskiarvot ja niiden keskivirheet)



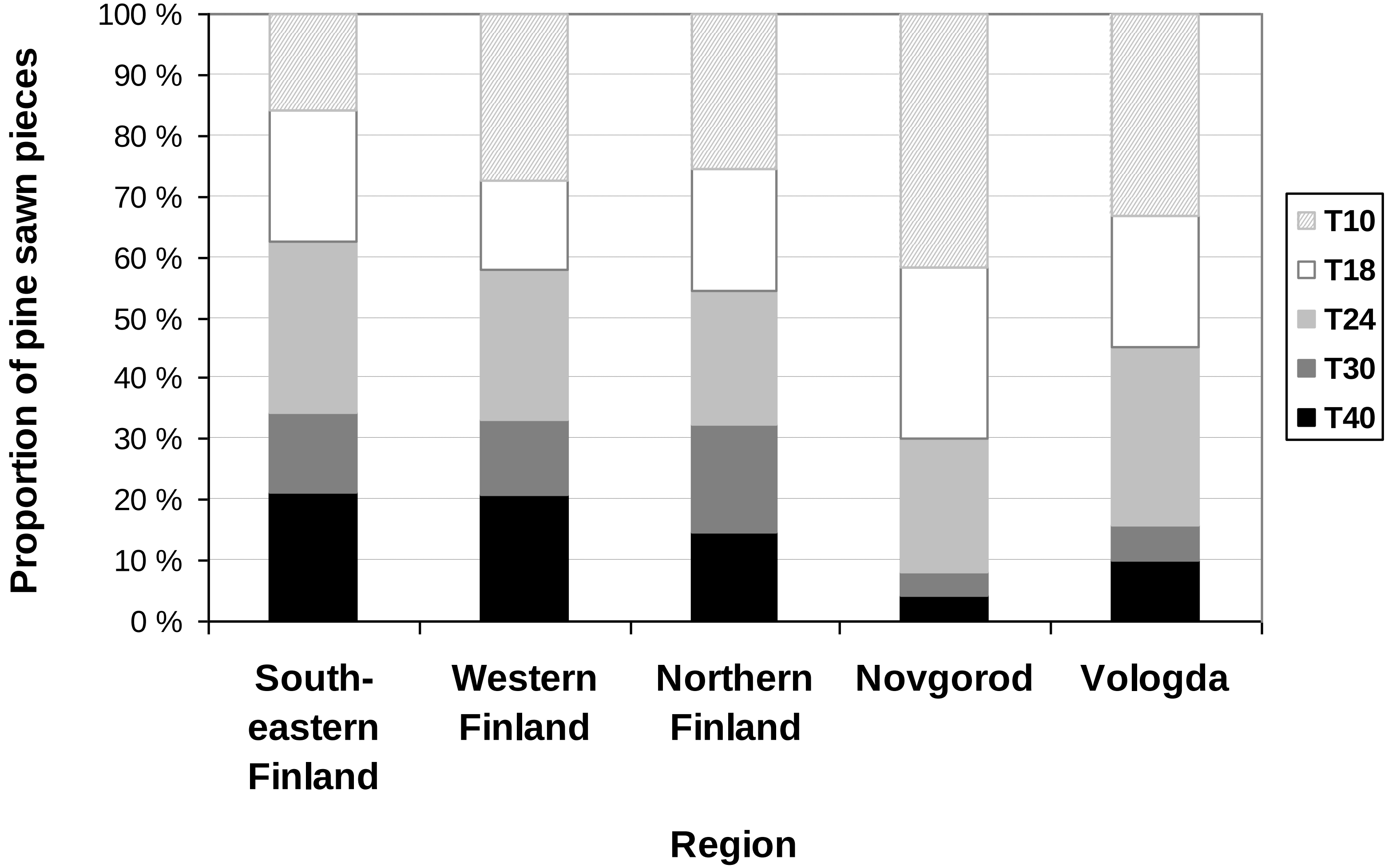
Lujuus sahedimensioittain ja alueittain (keskiarvot ja niiden keskivirheet)



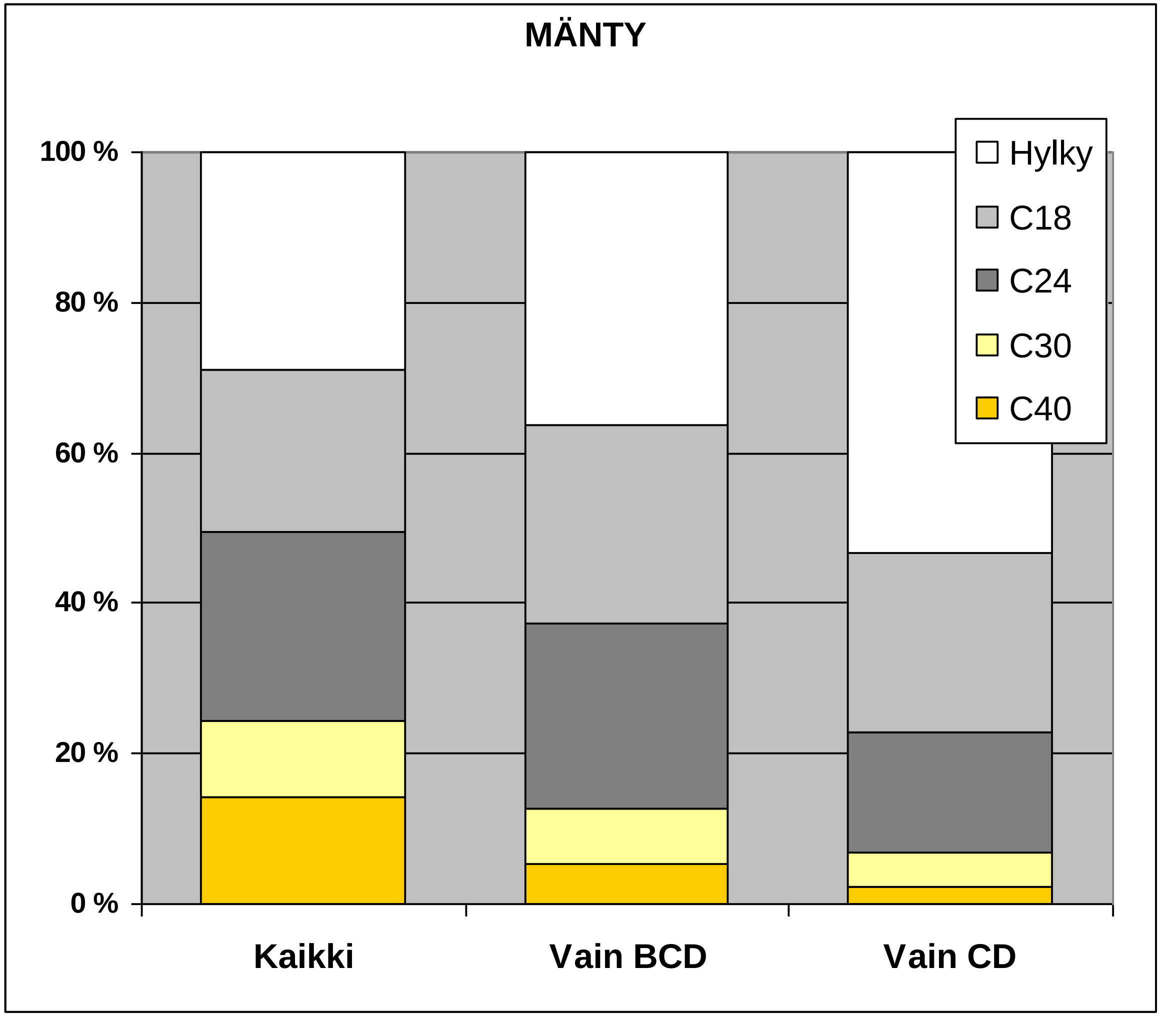
Lujuus sahedimensiossa 44x200mm alueittain (keskiarvot ja niiden keskivirheet)



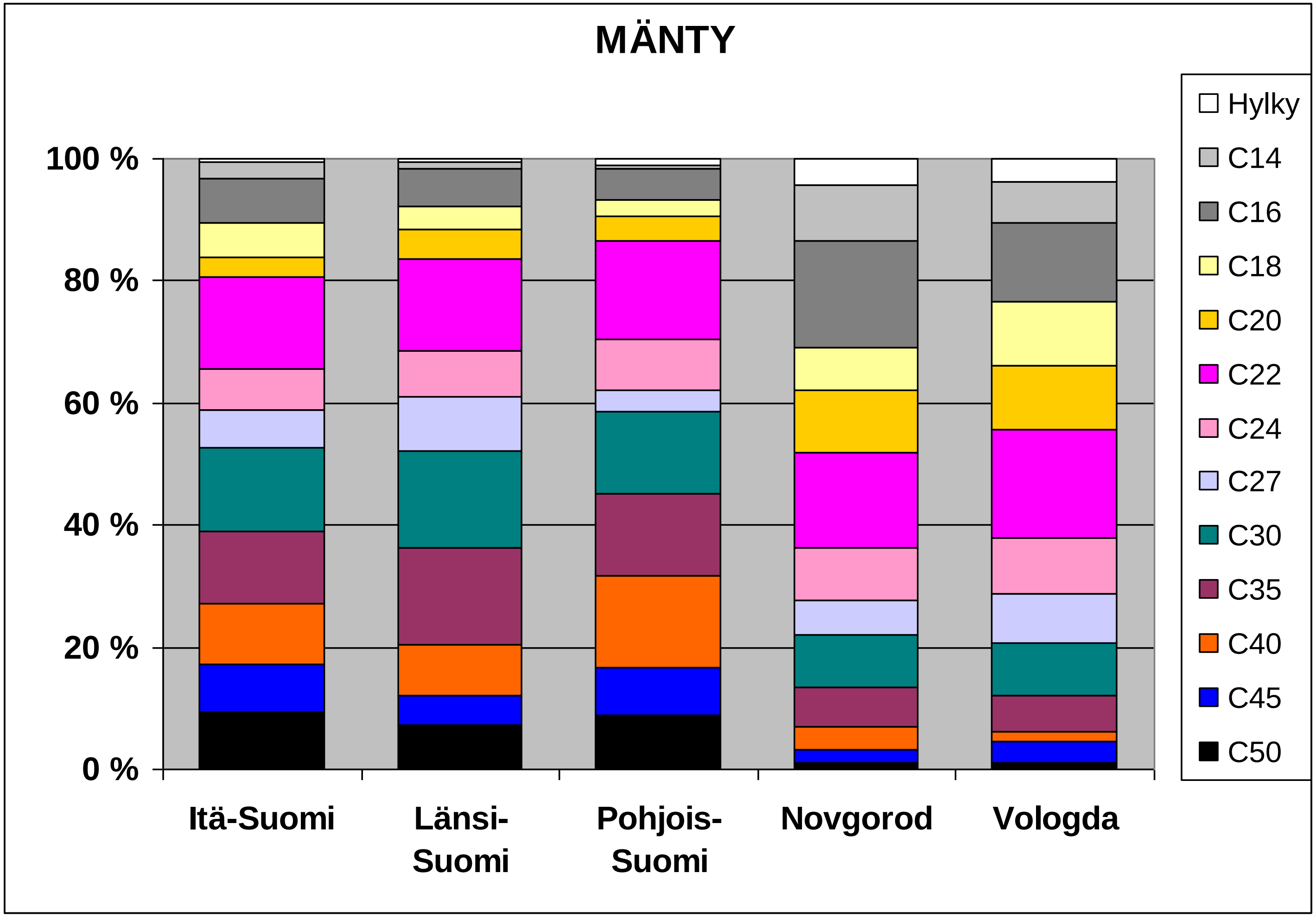
Visual strength grade distributions (T grading)



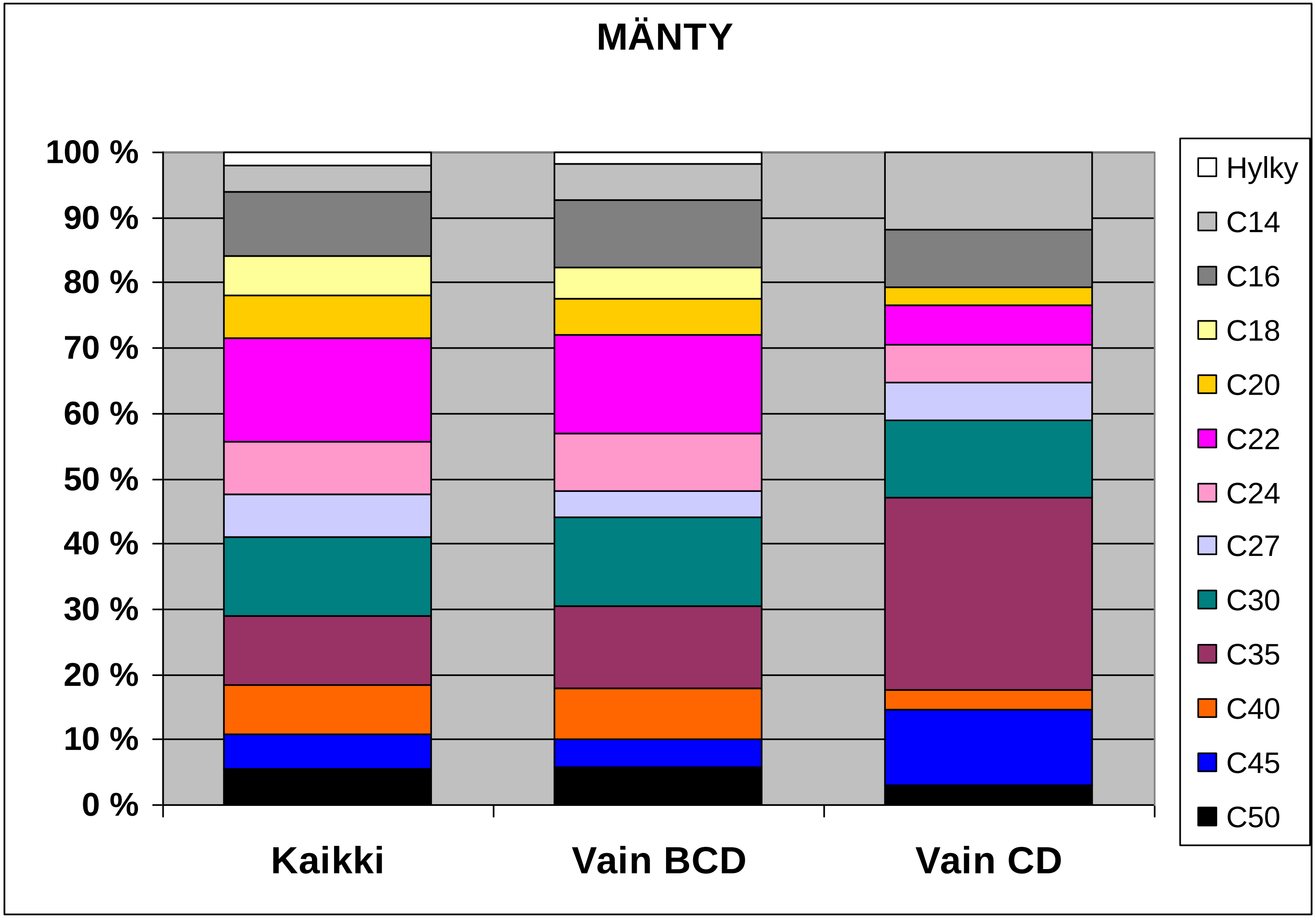
Effect of off-sorting sawn pieces by NT criteria to visual strength grade distributions (T grading)



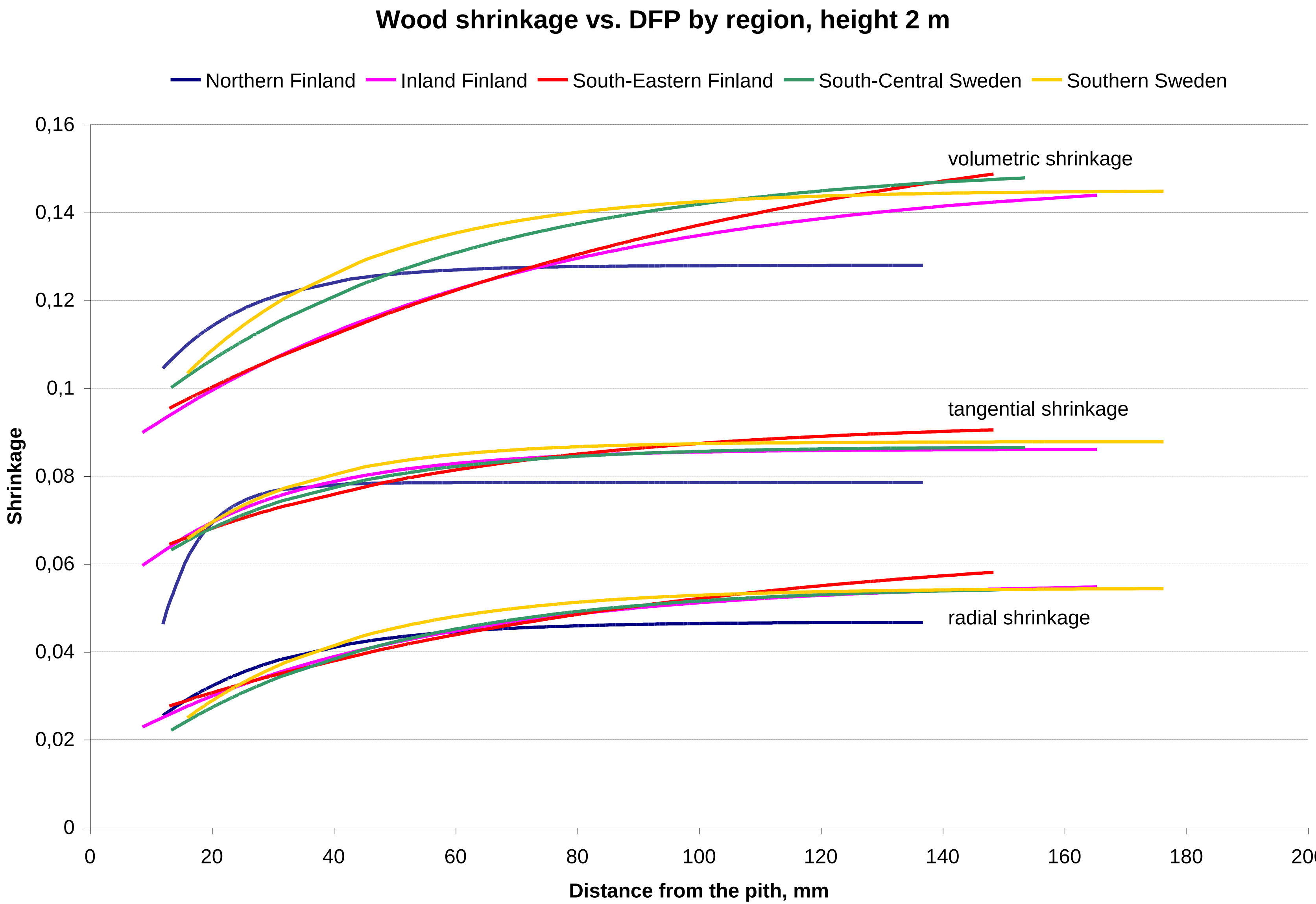
Strength grade distributions (simulated), EN 338



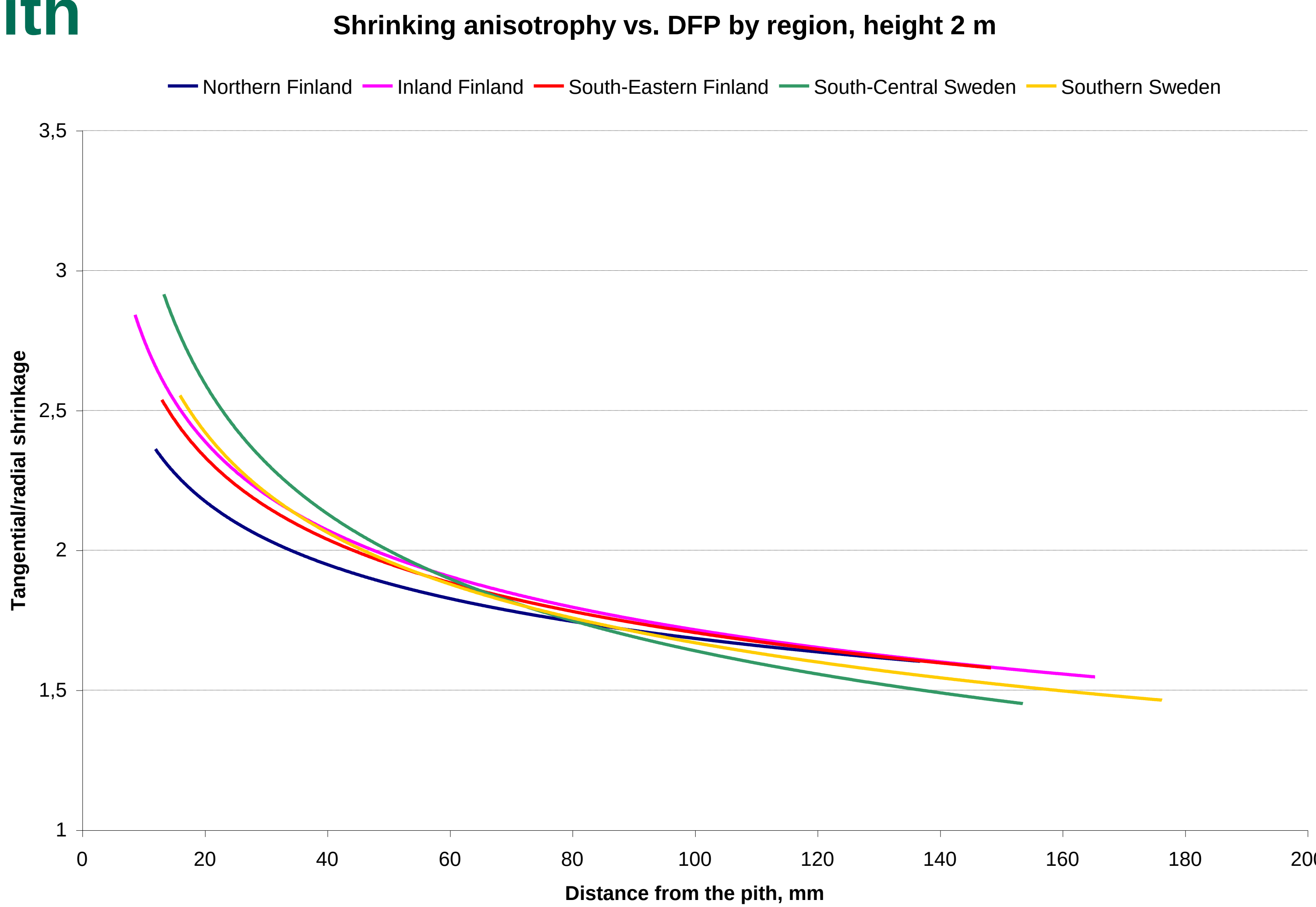
Effect of visual off-sorting by NT criteria to simulated strength grade distributions (EN 338)



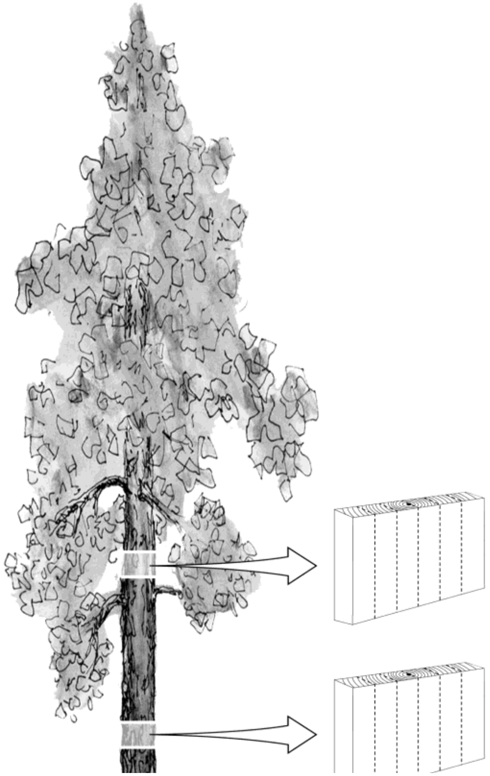
Wood shrinkage, by distance from pith



Shrinkage anisotropy, by distance from the pith

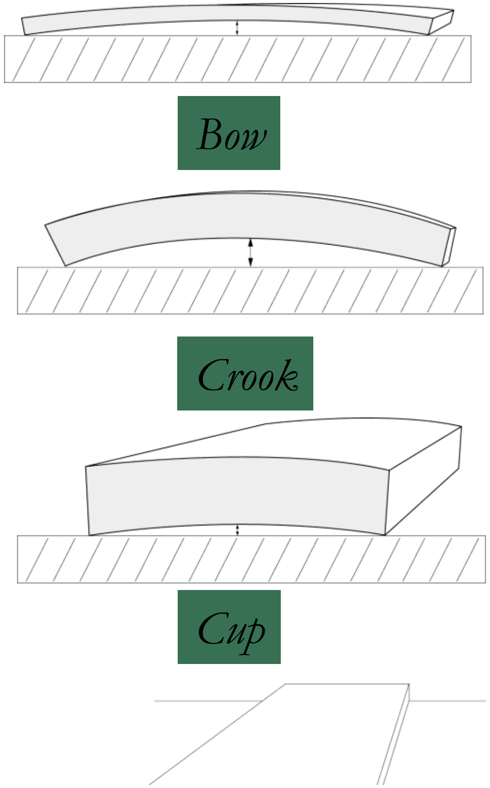


Form stability (Dr. Håkan Lindström, SLU Uppsala)

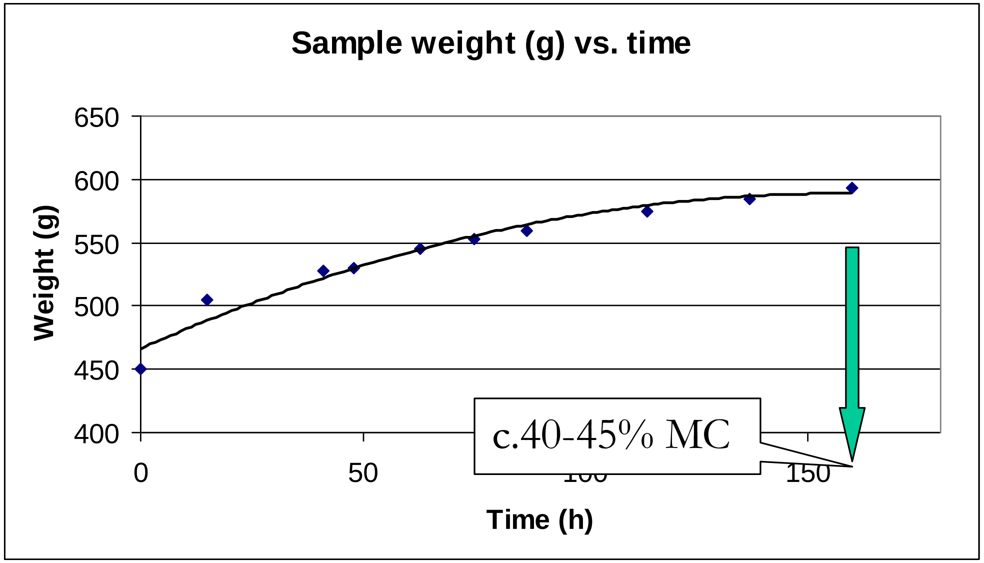


Short boards were cut from the centre of the stem bolts sampled at 2 m height from the 180 Finnish & Swedish sample trees.

The intention was to study



Form stability (Dr. Håkan Lindström, SLU Uppsala)



The dimensional change, as a measurement of form stability, was calculated as the difference between dimensional board measurements at:

a) Original moisture content (c. 12 % MC)

b) A moisture content beyond fibre saturation point (c. 40-45 % MC)

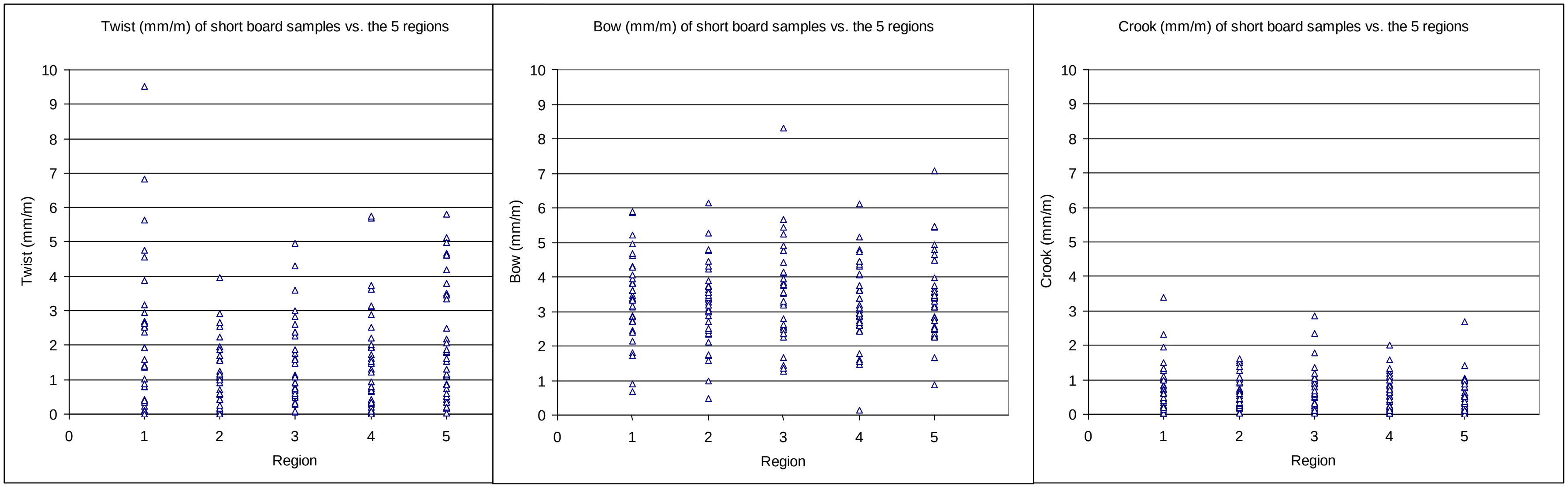
To compensate for the variation in board length (100*20*330-600mm), the form change was calculated as mm/m for twist, bow, & crook, whereas cup being non-dependent of

Form stability (Dr. Håkan Lindström, SLU Uppsala)

Shape distortion of the Swedish and Finnish sample trees.

Distortion variable (n=175)	Finland & Sweden			
	Min	*Max*	*Avg*	*Stdev*
Twist (mm/m)	0.0	9.5	1.7	1.6
Bow (mm/m)	0.1	8.3	3.4	1.2
Crook (mm/m)	0.0	3.3	0.4	0.4
Cup (mm)	0.7	3.2	1.8	0.4

Form stability (Dr. Håkan Lindström, SLU Uppsala)



No obvious difference in measured form stability was seen with region or tree class. There is a set of factors that makes it difficult to extract information:

a) Board size

b) Random variation in wood structure (compression wood, local grain deviation, etc.)

c) Sawing pattern misrepresentative (cover whole cross-section of small diameter trees,

Moisture resistance (Mr. Binod Gyawali)

Calculation

The following calculations were performed before analysis.

Relative Mass Increment: (Initial Mass-Mass at x time)/Initial Mass

Relative Air Dry Density= Mass at 12%MC/volume 12%MC

Initial Moisture Content= (Initial Mass-Final Mass at 0%MC)/Final Mass

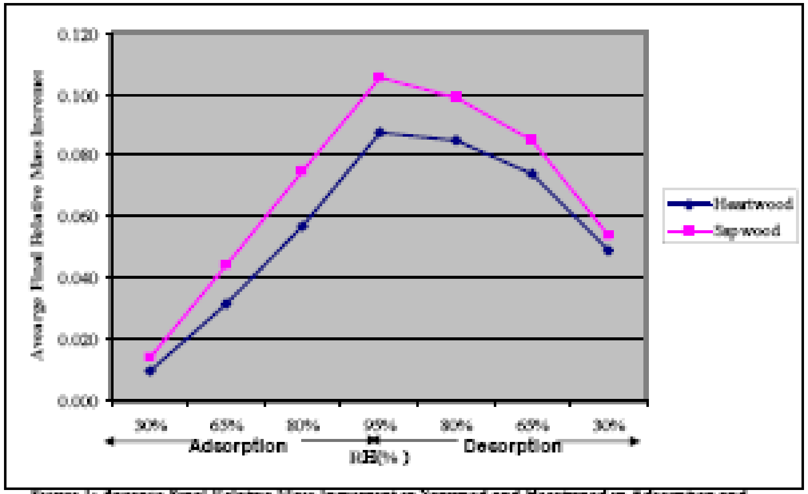


Figure 1: Average Final Relative Mass Increment in Sapwood and Heartwood in Adsorption and Desorption

Figure 1 showed that, during adsorption process, the final average mass increment in heart wood and sapwood was found increasing with increasing RH. While, the average mass increment in heart wood and sapwood was found decreasing with decreasing RH during desorption process

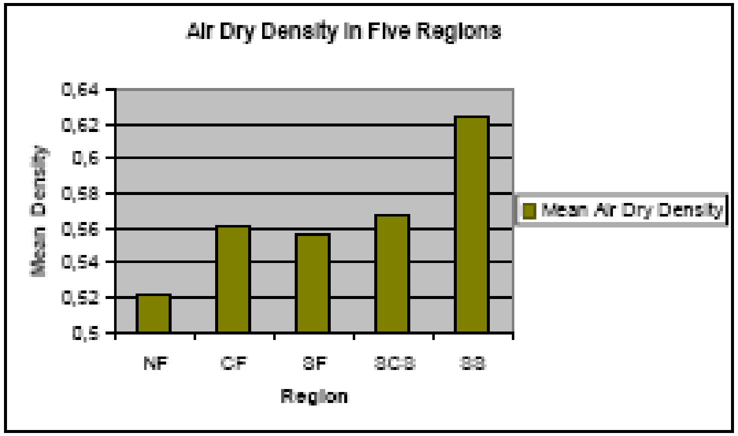


Figure 2: Relative Mean Air Dry Density at Five Regions

Fig.2 showed that the Mean Air dry density increased from Northern Finland (0.52094gm/cm³) to Southern Sweden (0.623785 gm/cm³).

Moisture resistance (Mr. Binod Gyawali)

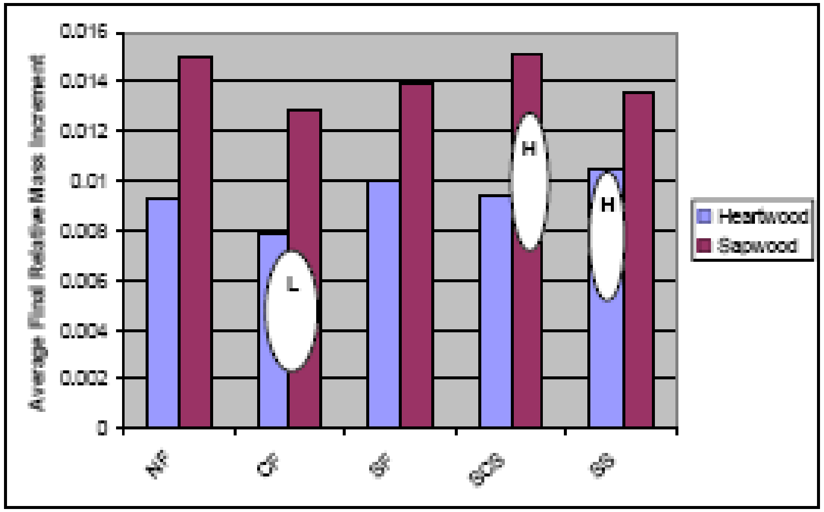


Figure 10: Comparison of average relative moisture increment in Heartwood and Sapwood by Region at Adsorption 30% RH

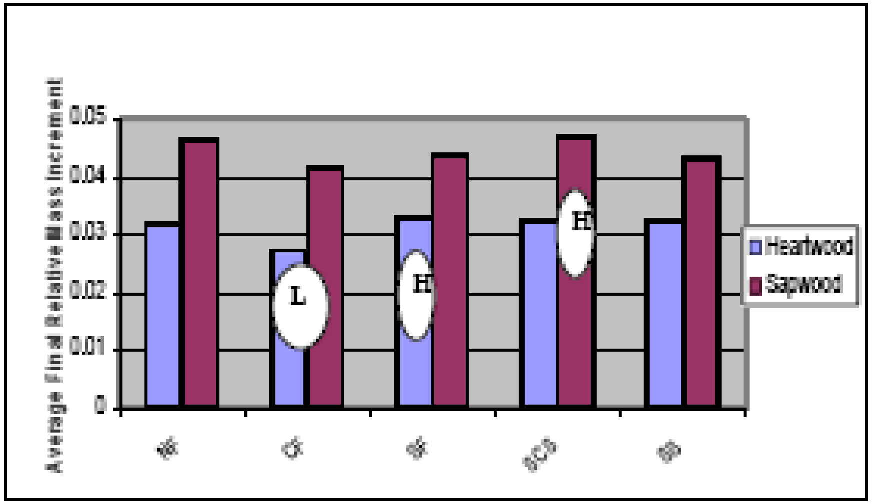


Figure 11: Comparison of average relative moisture increment in Heartwood and Sapwood by Region at Adsorption 65% RH

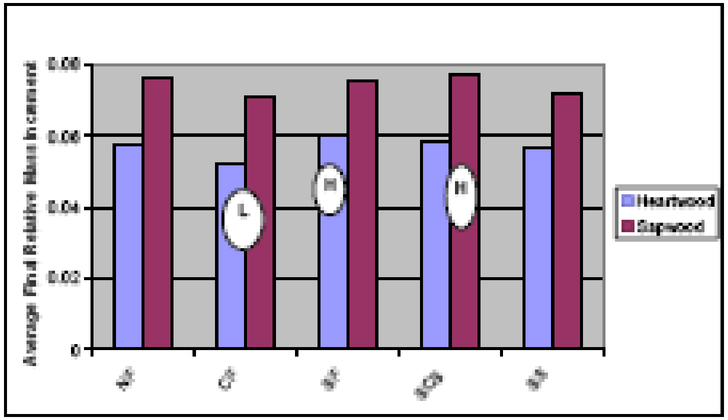


Figure 12: Comparison of average relative moisture increment in Heartwood and Sapwood by Region at Adsorption 80% RH

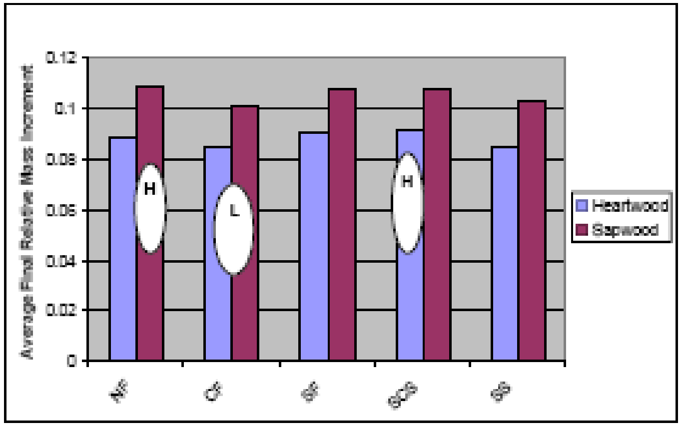


Figure 13: Comparison of average relative moisture increment in Heartwood and Sapwood by Region at Adsorption 95% RH

Moisture resistance (Mr. Binod Gyawali)

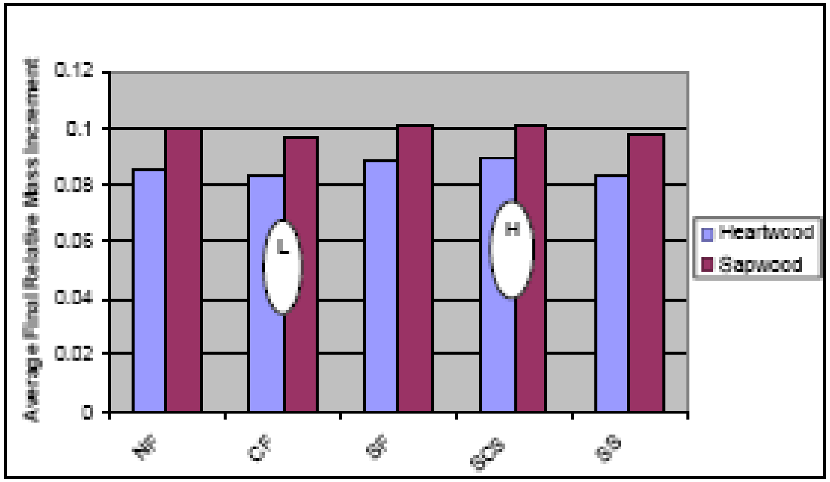


Figure 14: Comparison of average relative moisture increment in Heartwood and Sapwood by Region at Desorption 80% RH

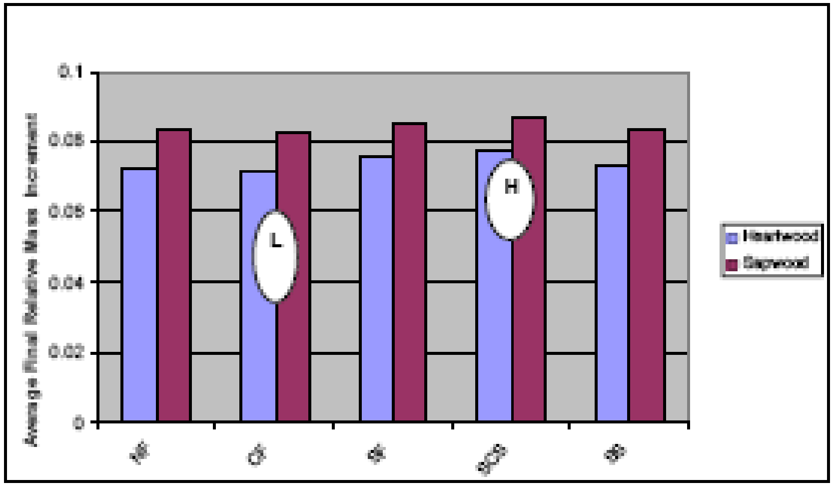


Figure 14: Comparison of average relative moisture increment in Heartwood and Sapwood by Region at Desorption 65% RH

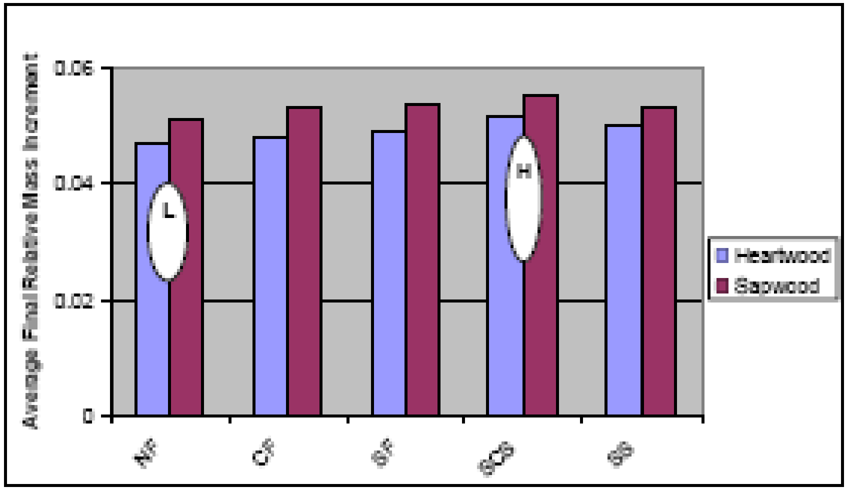


Figure 15: Comparison of average relative moisture increment in Heartwood and Sapwood by Region at Desorption 30% RH

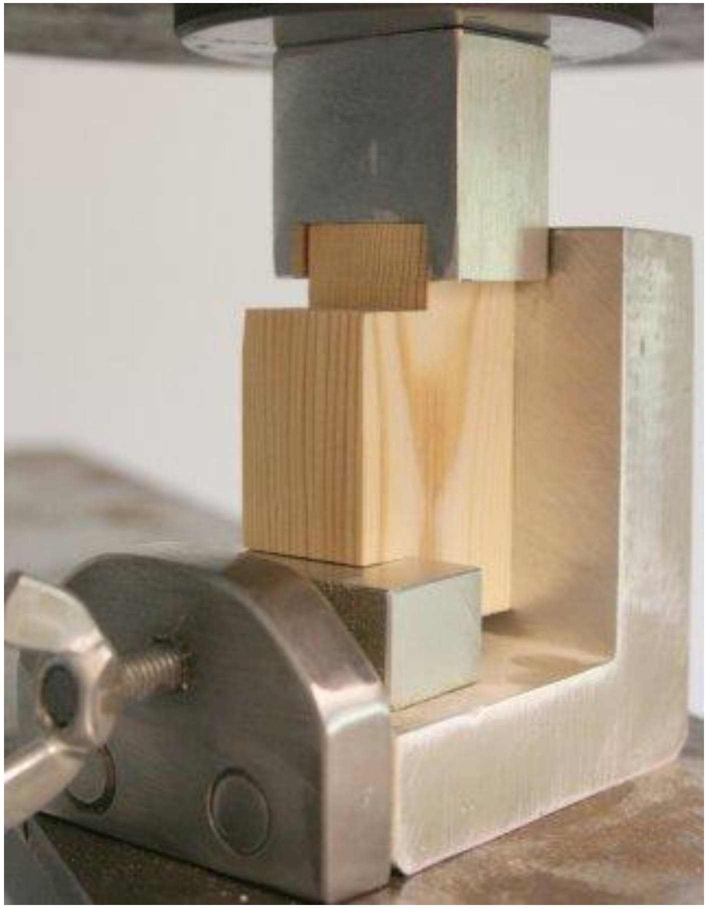
Moisture resistance (Mr. Binod Gyawali)

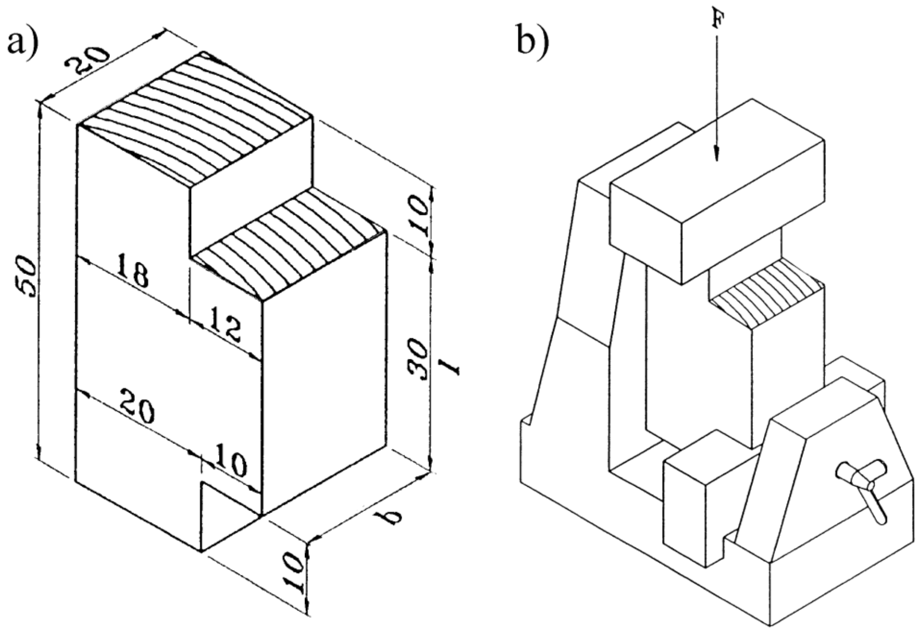
Conclusion

- Mean Air Dry Density of wood specimen after adsorption and desorption process were found higher in sapwood (0.568gm/cm3) than heartwood (0.558 gm/cm3).
- Air Dry Density was found higher in sapwood and lower in heartwood and found increased from North to South. Southern Sweden was found with higher mean air dry density among all regions.
- Air Dry Density had negative correlation with relative mass increment in both sapwood and heartwood.
- Sapwood had a higher moisture uptake and a higher mass loss increment than heartwood compared with heartwood.
- Moisture uptake and moisture loss in both sapwood and heartwood during adsorption and desorption found lower and slower in Central Finland than other region while south central Sweden region showed higher moisture uptake by Sapwood during adsorption and higher moisture loss during desorption by both sapwood and heartwood.
- Mean initial moisture content was found higher in Heartwood than in Sapwood and decreased towards south from North. Heartwood of Central Finland and South Central Sweden was found with higher mean initial moisture content while sapwood had higher mean initial moisture content in other regions.
- Sapwood had more susceptible to cracks than heartwood and found higher in Northern region.

Shear strength – describes resistance to checking

- Shear strength was measured from small clear specimens at 12% moisture ratio





Shear strength – describes resistance to checking

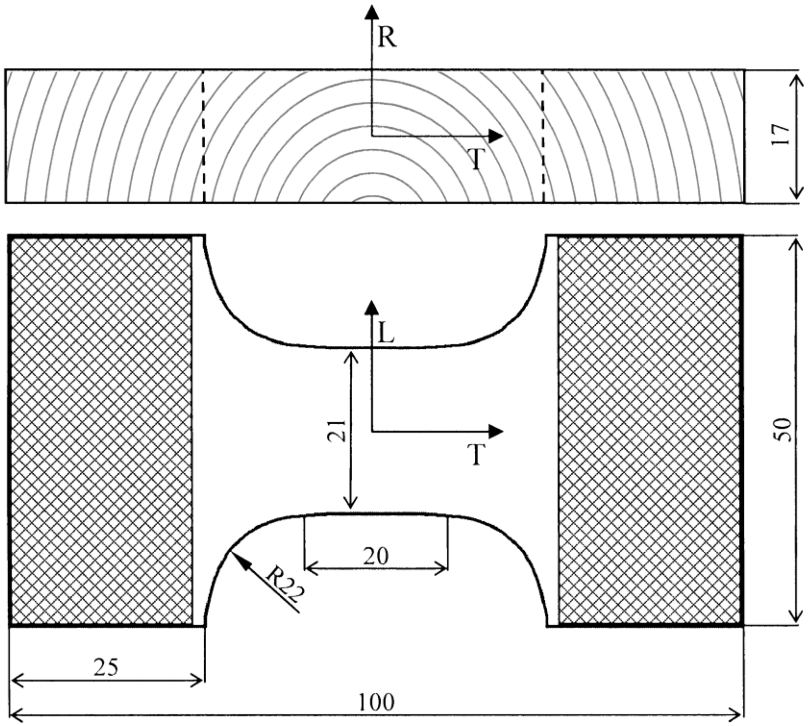
		Shear strength, N/mm²	Basic density, kg/m³	Average ring width, mm	N
2m height	***Northern Finland***	8.6 (1.17)	415 (43)	1.17 (0.87)	69
	Inland Finland	8.8 (1.18)	432 (53)	1.64 (1.06)	70
	S-E Finland	8.8 (1.28)	432 (53)	2.12 (1.41)	88
	S-C Sweden	9.1 (1.20)	447 (54)	1.85 (1.32)	85
	Southern sweden	9.6 (1.24)	462 (49)	1.62 (1.04)	85
6m height	***Northern Finland***	7.8 (0.84)	378 (27)	1.30 (0.94)	64
	Inland Finland	8.0 (0.85)	393 (37)	2.03 (1.38)	73
	S-E Finland	8.4 (1.01)	405 (41)	2.40 (1.42)	79

Shear strength – describes resistance to checking

- Case 1: shear strength was affected by
  - + Region
  - – Height in the tree
  - + DFP
  - – DBH
  - ✓ R^2=34.5%
- Case 2: shear strength was affected by
  - + Basic density
  - + Region
  - + DFP
  - – DBH
  - ✓ R^2=64.0%

- Covariance parameters
  - ✓ Tree 22%
  - ✓ Stand 4%
  - ✓ Residual 75%
- Covariance parameters
  - ✓ Tree 4%
  - ✓ Stand 4%
  - ✓ Residual 92%

Tensile strength perpendicular to grain – describes resistance to checking



Tensile strength perpendicular to grain – describes resistance to checking

Table 3. Number of specimens, means, and standard deviations (in parentheses) of tensile strength perpendicular to grain (σ_T, N/mm²) and basic density ($\rho_{0,g}$, kg/m³) in different regions and boards.

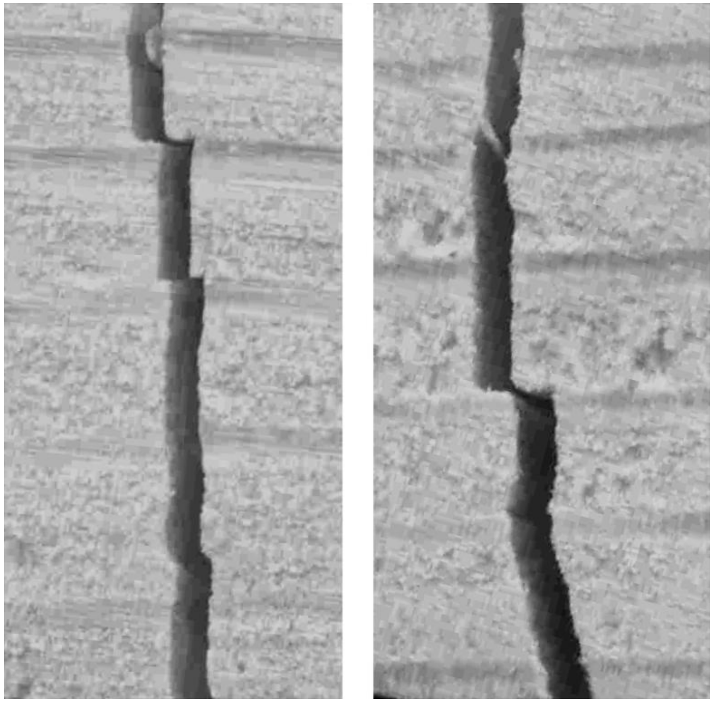
	Board, number	- **counted from the pith outwards**							
	1			2			3		
Region	σ_T	$\rho_{0,g}$	N	σ_T	$\rho_{0,g}$	N	σ_T	$\rho_{0,g}$	N
1	4.4 (0.79)	373 (20)	17	3.7 (0.97)	401 (42)	23	3.5 (0.61)	413 (36)	9
2	3.8 (1.21)	402 (40)	25	3.2 (0.81)	437 (49)	28	3.1 (0.83)	430 (51)	10
3	3.7 (0.82)	407 (34)	31	3.1 (0.68)	439 (38)	27	2.9 (0.79)	442 (34)	11
4	4.1 (0.83)	411 (29)	20	3.2 (0.75)	437 (41)	28	2.8 (0.69)	440 (39)	15
5	3.8 (0.81)	412 (34)	20	3.1 (0.79)	454 (52)	29	2.7 (0.68)	446 (39)	21

Tensile strength perpendicular to grain

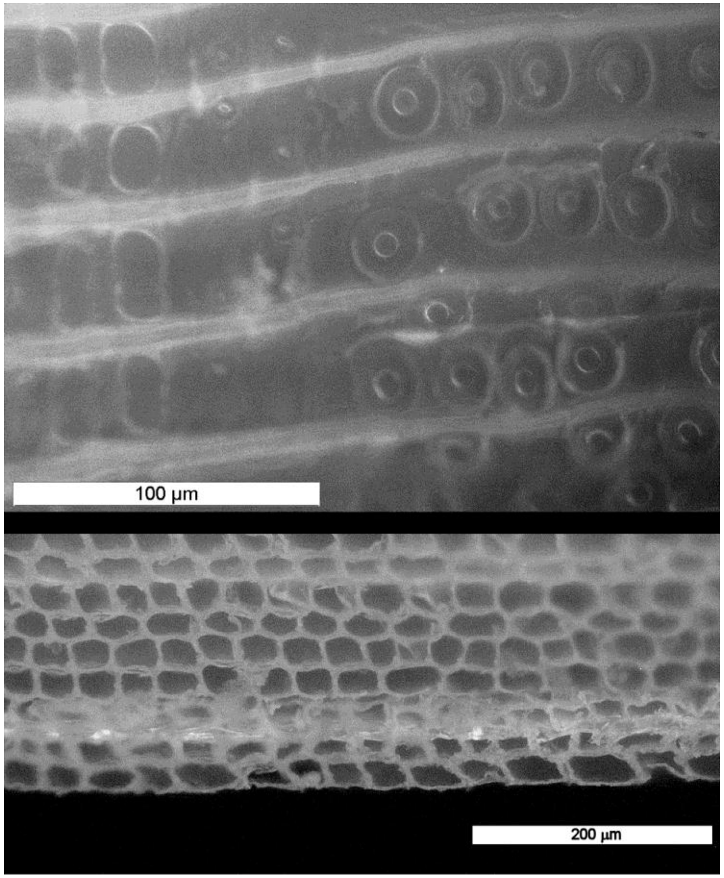
- Case 1: tensile strength was affected by
  - Region
  - Board number
  - DBH of tree
  - ✓ R^2=24.7%
- Covariance parameters
  - ✓ Tree 3%
  - ✓ Stand N/A
  - ✓ Residual 97%

- Case 2: tensile strength was affected by
  - Region
  - Board number
  - Ring width
  - R^2=26.1%
- Covariance parameters
  - Tree 1%
  - Stand N/A
  - Residual 99%

Tensile strength perpendicular to grain



Typical crack path found in perpendicular-to-grain tensile strength specimens. Tortuous, stepwise crack path indicates *TR* crack propagation.



Fluorescence microscope images of the typical fracture surfaces of perpendicular-to-grain tensile strength specimens in this study; the fracture occurred in *LR* plane. The fracture path indicates intercell (IC) failure

More information

Erkki Verkasalo, professor, wood science and technology

Finnish Forest Research Institute

P.O. Box 68 (Yliopistokatu 6)

FI-80101 Joensuu

Finland

erkki.verkasalo@metla.fi