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Results from a case study at Södra Cell

Dag Molteberg, Södra Cell R&D

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Why case study

- How to make practical use of fibre property and paper property models for a pulp mill?
- Ideas:
  - Learn more about the effect of wood and fibre properties on pulp and paper properties
  - Can raw materials from different origin cause differences within the same product produced at different mills?
  - Investigate possibilities for increasing production volumes within special grades

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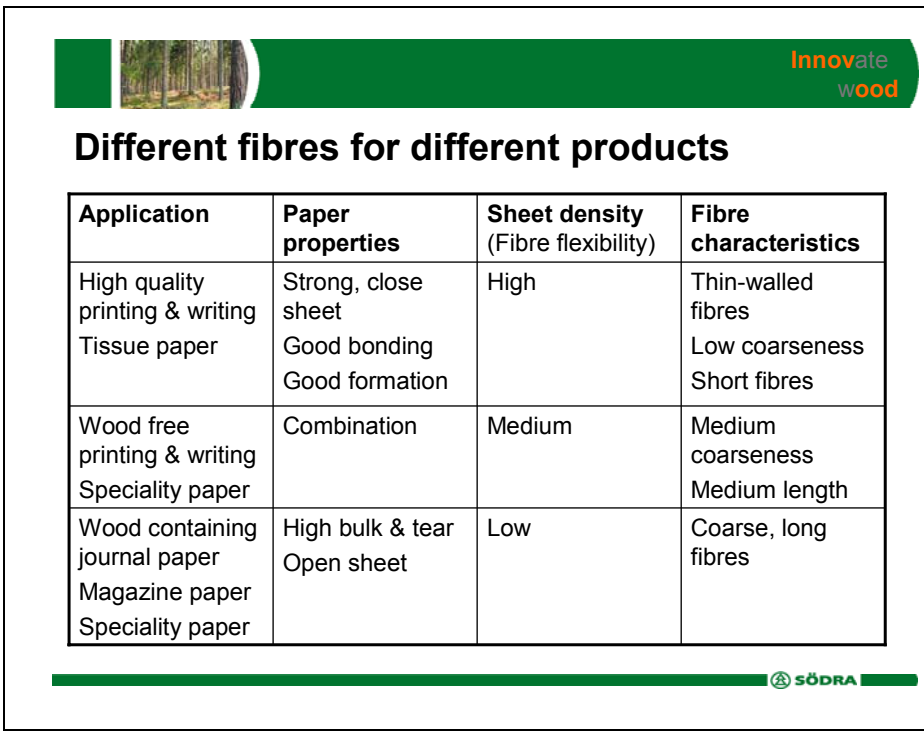

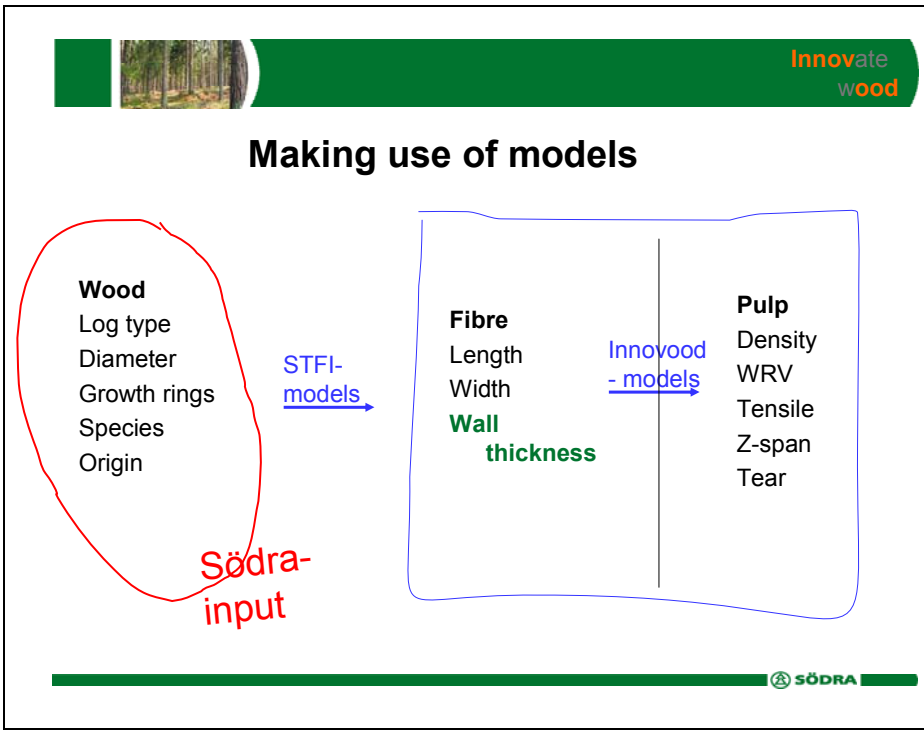

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Data from pulp mills

- 3 mills located in Norway and Sweden
- Wood raw material:
  - Scots pine and Norway spruce roundwood
  - Saw mill chips (softwood) and imported softwood and hardwood not included in this study

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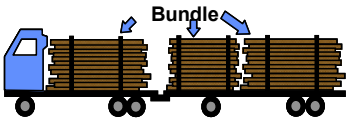
Pulp log properties



- Today: only volume, felling type (thinning / final cut) and species are normally registered.
- Needed extra information. From extraordinary measurements:
  - Average log diameter, mix of species, geographical origin, felling type of each bundle
  - Diameter, # rings, ring width, and species measured for 10-20 logs in each bundle
- Registration of pulp log properties
  - 543 bundles from 3 mills -> 6721 logs measured
  - Time consuming!

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Models for fibre and pulp & paper properties

- Fibre dimensions (from log properties)
  - Length, width, wall thickness
- Paper properties (from fibre dimensions)
  - WRV (water retention value)
  - Sheet density
  - Tensile index
  - Z-span (fibre strength)
  - Tear index

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Models for fibre dimensions

- Models developed by STFI *
  - N. spruce and S. pine in Sweden
- Describes variation in trees, not single logs.
  - Assumptions made about origin in tree and tree properties for each log to compensate for this
  - Log diameter, age and annual ring width are real and of (much) higher significance for fibre dimensions than variables with assumed figures.
- Same models used for logs from Norway
  - Models not validated directly, but internal Södra models for Norway give approximately same results

* Lundqvist S.-O., Grahn T., Hedenberg Ö. (2005): Models for fibre dimensions in different softwood species. Simulations and comparison of within and between tree variations for Norway and Sitka spruce, Scots and Loblolly pine. IUFRO fifth workshop "Wood quality modelling" Auckland, New Zealand, Nov 22-27, 2005. 14 pp.

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Models for pulp and paper properties

- Developed as part of the case study
  - Based on Innovood material
  - Unbleached, never-dried laboratory pulps
- Few samples (12), but very large range. Suitable for modelling
- Input variables
  - Fibre dimensions:
    - FL (fibre length)
    - FW (fibre width)
    - FWT (fibre wall thickness)
  - Species (pine and spruce)
  - PFI (refining revolutions in PFI mill)
- Modelling method: Multiple regression

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Models for pulp and paper properties

Unbleached, unrefined, never-dried laboratory pulp

Modelled Property	Species	Intercept	FL Fibre length	FW Fibre width	FWT Fibre wall thickness	R^2	RMSE
WRV	Common	2,31	-0,135		-0,101	0,91	0,039
Sheet density	Common	1276		-6,09	-148	0,95	22,8
Tensile index	Pine	169,3			-35,3	0,83	10,4
	Spruce	180,4			-35,3		
Z-span	Pine	20,2		3,21	23,7	0,45	18,0
	Spruce	37,6		3,21	23,7		
Tear index	Common	-12,2	8,08		3,04	0,90	1,80

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Ranking of effects with stepwise regression

Modelled Property	Ranking of effects by stepwise regression. Effect on R^2 1)					
	Rank 1	Rank 2	Rank 3	Rank 4	Total R^2	RMSE
WRV	**FL** 0,62	**PFI** 0,77	**FWT** 0,91		0,91	0,039
Sheet density	**FWT** 0,68	**PFI** 0,93	**FW** 0,95		0,95	22,8
Tensile index	**FWT** 0,68	**PFI** 0,79	**Species** 0,83		0,83	10,4
Z-span	**FW** 0,29	**FWT** 0,36	**Species** 0,45		0,45	18,0
Tear index	**FWT** 0,75	**FL** 0,85	**FWT*PFI** 0,90	**FL*PFI** 0,91	0,91	1,8

1) The R^2 value is calculated from the first effect alone for rank 1, for the first and second effect for rank 2 and so on.

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Results

- Variation of
  - Log properties
  - Modelled fibre properties
  - Modelled pulp and paper properties
- Scenarios:
  - Current wood segregation
  - Additional ways of wood segregation

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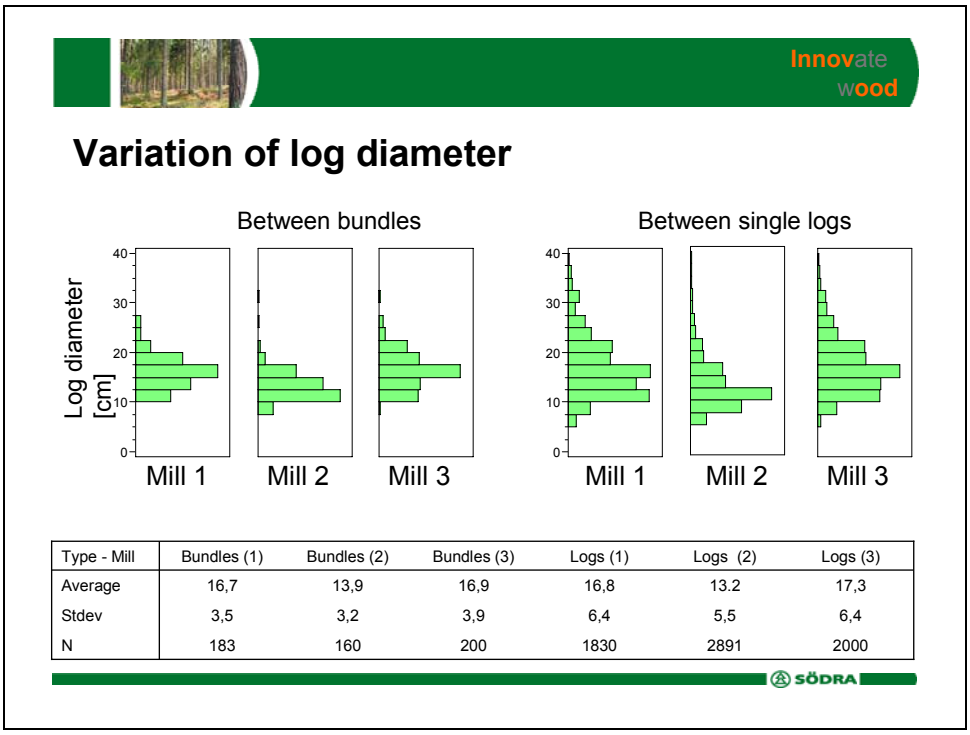
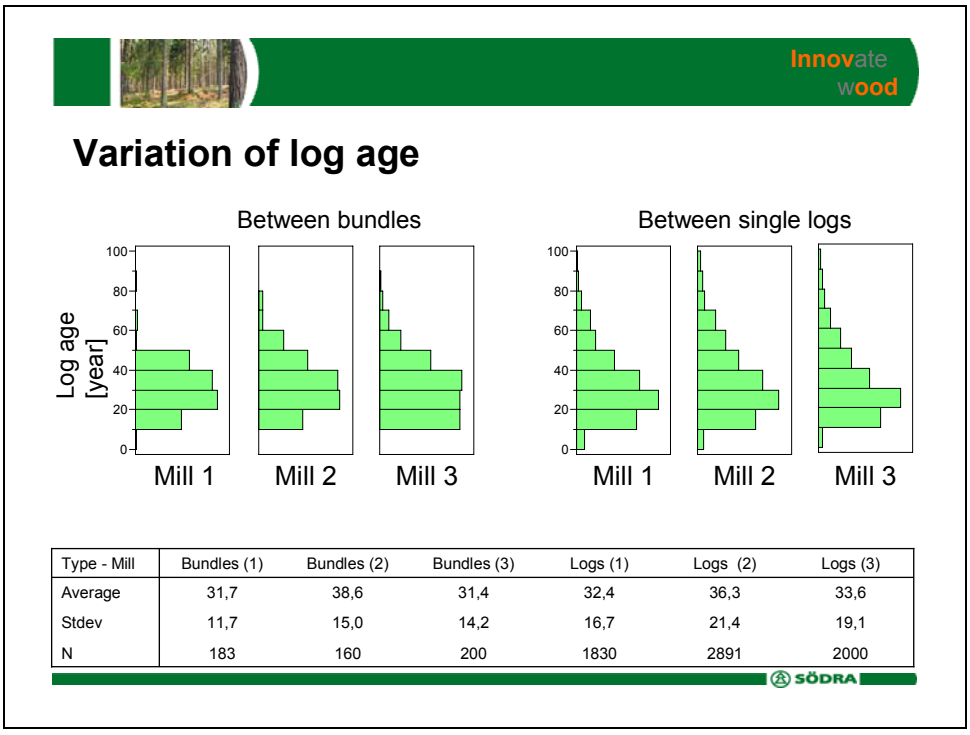


Type - Mill	Bundles (1)	Bundles (2)	Bundles (3)	Logs (1)	Logs (2)	Logs (3)
Average	16,7	13,9	16,9	16,8	13.2	17,3
Stdev	3,5	3,2	3,9	6,4	5,5	6,4
N	183	160	200	1830	2891	2000



Type - Mill	Bundles (1)	Bundles (2)	Bundles (3)	Logs (1)	Logs (2)	Logs (3)
Average	31,7	38,6	31,4	32,4	36,3	33,6
Stdev	11,7	15,0	14,2	16,7	21,4	19,1
N	183	160	200	1830	2891	2000

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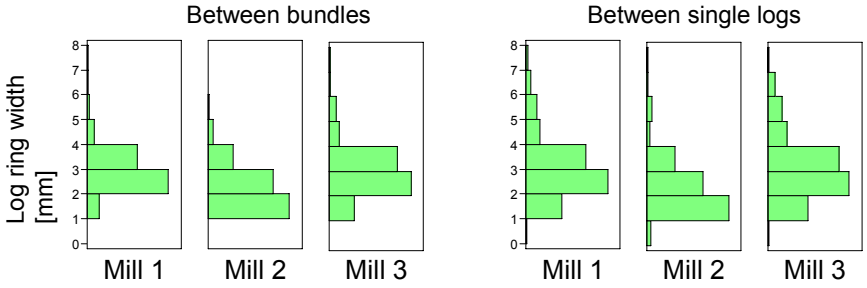
Variation of log ring width



Type - Mill	Bundles (1)	Bundles (2)	Bundles (3)	Logs (1)	Logs (2)	Logs (3)
Average	3,05	2,15	3,15	3,00	2,17	3,01
Stdev	1,10	0,76	0,94	1,37	1,01	1,18
N	183	160	200	1830	2891	2000

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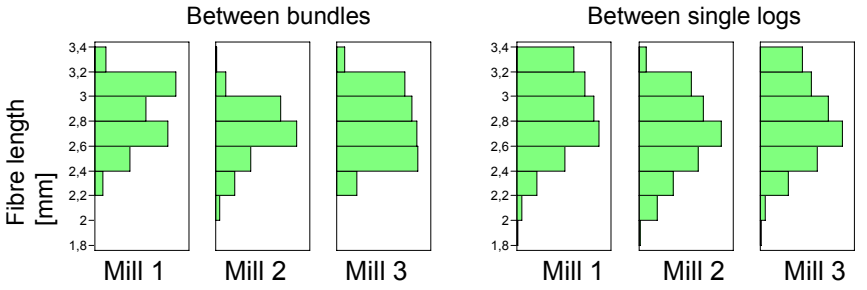
Variation of modelled fibre length



Type - Mill	Bundles (1)	Bundles (2)	Bundles (3)	Logs (1)	Logs (2)	Logs (3)
Average	2,85	2,71	2,77	2,86	2,70	2,80
Stdev	0,24	0,21	0,25	0,30	0,30	0,30
N	183	160	200	1830	2891	2000

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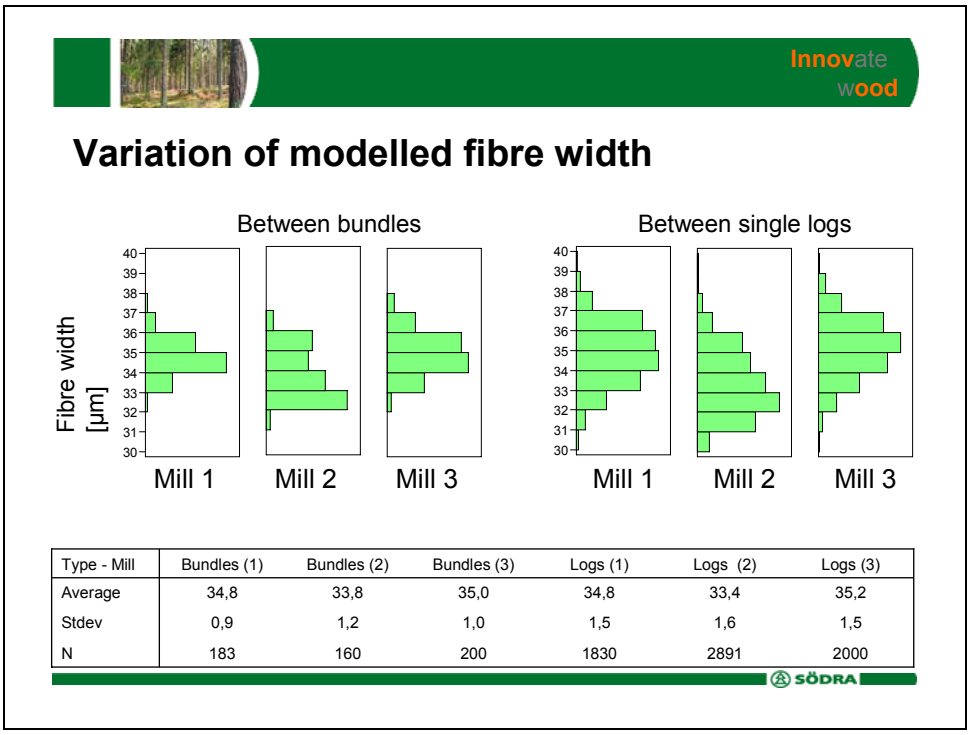
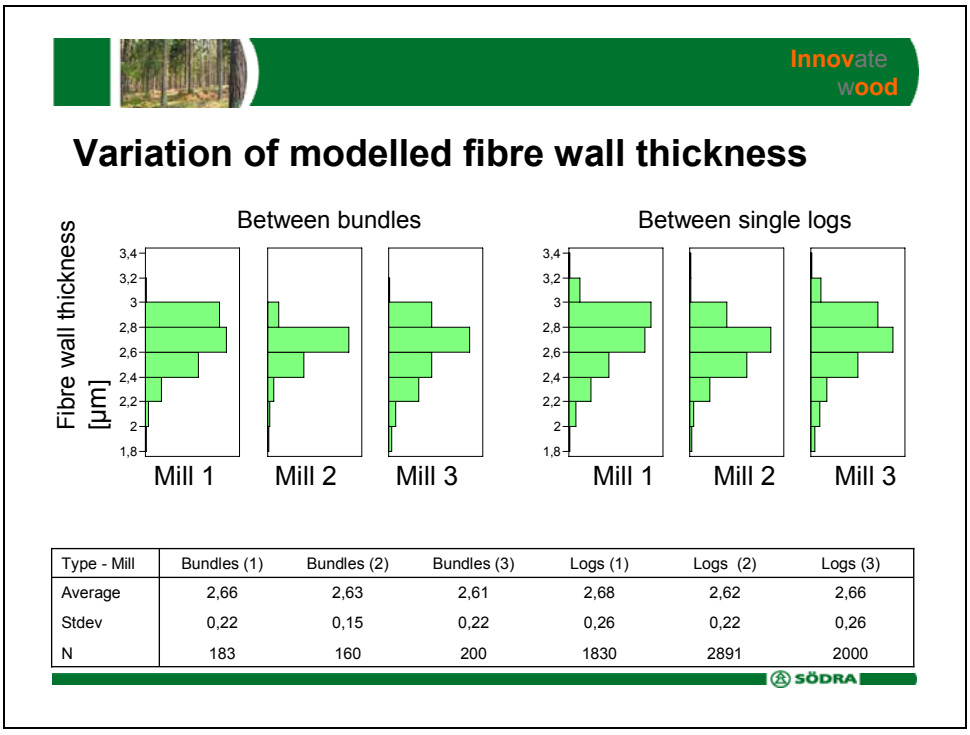


Type - Mill	Bundles (1)	Bundles (2)	Bundles (3)	Logs (1)	Logs (2)	Logs (3)
Average	34,8	33,8	35,0	34,8	33,4	35,2
Stdev	0,9	1,2	1,0	1,5	1,6	1,5
N	183	160	200	1830	2891	2000



Type - Mill	Bundles (1)	Bundles (2)	Bundles (3)	Logs (1)	Logs (2)	Logs (3)
Average	2,66	2,63	2,61	2,68	2,62	2,66
Stdev	0,22	0,15	0,22	0,26	0,22	0,26
N	183	160	200	1830	2891	2000

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Variation of modelled pulp & paper properties

Unbleached, unrefined, never-dried pulp

Modelled Property	Mill 1		Mill 2		Mill 3	
	Average	St.dev	Average	St. dev	Average	St.dev
WRV	1,65	0,062	1,68	0,059	1,66	0,060
Sheet density	668	42	686	35	669	42
Tensile index	83,8	11,2	85,9	9,1	82,9	12,1
Z-span	210	7,9	203	8,3	208	8,0
Tear index	18,5	2,9	17,3	2,6	18,1	2,8

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Scenarios: wood segregation

- How will different segregation “rules” influence on amount and properties of wood compared to current wood classes?
- Simulation of two cases with the presented data and models
  - S. pine separated from N. spruce wood
  - Top logs separated from final cut

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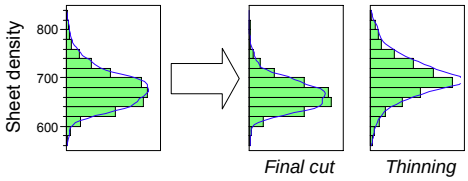
Current wood classes: thinning and final cut



Mill	Wood class	Portion of volume per mill	Log age	Log ring width	Fibre length	Fibre wall thickness	Sheet density
1	Final cut	52 %	41,3	2,4	3,05	2,82	647
	Thinning	48 %	22,8	3,6	2,65	2,53	691
2	Final cut	79 %	40,4	1,9	2,76	2,67	679
	Thinning	21 %	21,3	3,0	2,46	2,43	713
3	Final cut	60 %	42,0	2,5	2,96	2,75	654
	Thinning	40 %	21,1	3,8	2,55	2,52	692

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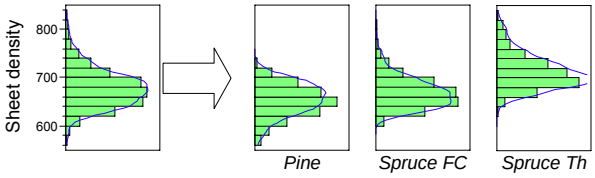
Separation of pine



Mill	Wood class	Portion of volume per mill	Log age	Log ring width	Fibre length	Fibre wall thickness	Sheet density	
	Pine	18 %	32,8	3,0	2,68	2,83	636	
1	Spruce, final cut	43 %	41,1	2,4	3,09	2,81	650	647
	Spruce, thinning	39 %	22,9	3,6	2,69	2,47	703	691
	Pine	20 %	40,5	2,1	2,53	2,64	671	
2	Spruce, final cut	64 %	38,7	2,0	2,80	2,67	681	679
	Spruce, thinning	16 %	21,4	3,1	2,52	2,37	726	713
	Pine	33 %	34,0	2,9	2,65	2,80	640	
3	Spruce, final cut	40 %	41,8	2,6	3,05	2,73	661	654
	Spruce, thinning	27 %	20,9	3,8	2,60	2,38	717	692

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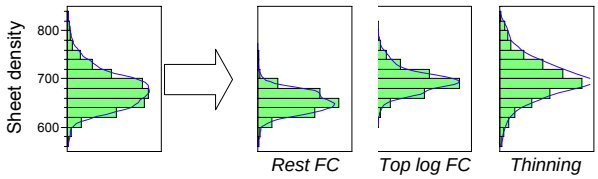
Separation of top logs from final cut



Mill	Wood class	Portion of volume per mill	Log age	Log ring width	Fibre length	Fibre wall thickness	Sheet density	
	Final cut, rest	39 %	47,6	2,2	3,14	2,87	636	647
1	Final cut, top logs	13 %	23,0	3,0	2,77	2,65	677	
	Thinning	48 %	22,8	3,6	2,65	2,53	691	691
	Final cut, rest	50 %	51,2	1,6	2,92	2,76	663	679
2	Final cut, top logs	28 %	21,0	2,6	2,49	2,50	708	
	Thinning	21 %	21,3	3,0	2,46	2,43	713	713
	Final cut, rest	42 %	50,0	2,2	3,07	2,82	643	654
3	Final cut, top logs	18 %	23,4	3,2	2,71	2,60	680	
	Thinning	40 %	21,1	3,8	2,55	2,52	692	692

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More wood classes:

- The quality potential from more segregated wood must be weighted against costs
  - Increased pulp quality does not give higher prices!
- Example: segregating pine or top logs from other wood
  - Transportation and handling costs may increase
  - Small suppliers may have difficulties fulfil minimum volumes
  - More complex wood handling at mill

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Conclusions

- Several pulp and paper properties were found to be highly dependent of fibre dimensions.
- Differences in origin and composition of wood between 3 pulp mills resulted in differences in both level and variance of fibre and pulp properties for the same mills
- Separation of pine and top logs from the other wood classes resulted in more extreme pulp and paper properties
- Such models are very useful when comparing segregation strategies for one ore more pulp mills

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