

Modeling effects of site on fibre, pulp and handsheet properties of *Eucalyptus globulus*

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COST E50 Workshop Working Groups 3 & 4
Napier University, Edinburgh, Scotland
19-20th April 2007

Linking wood and paper properties

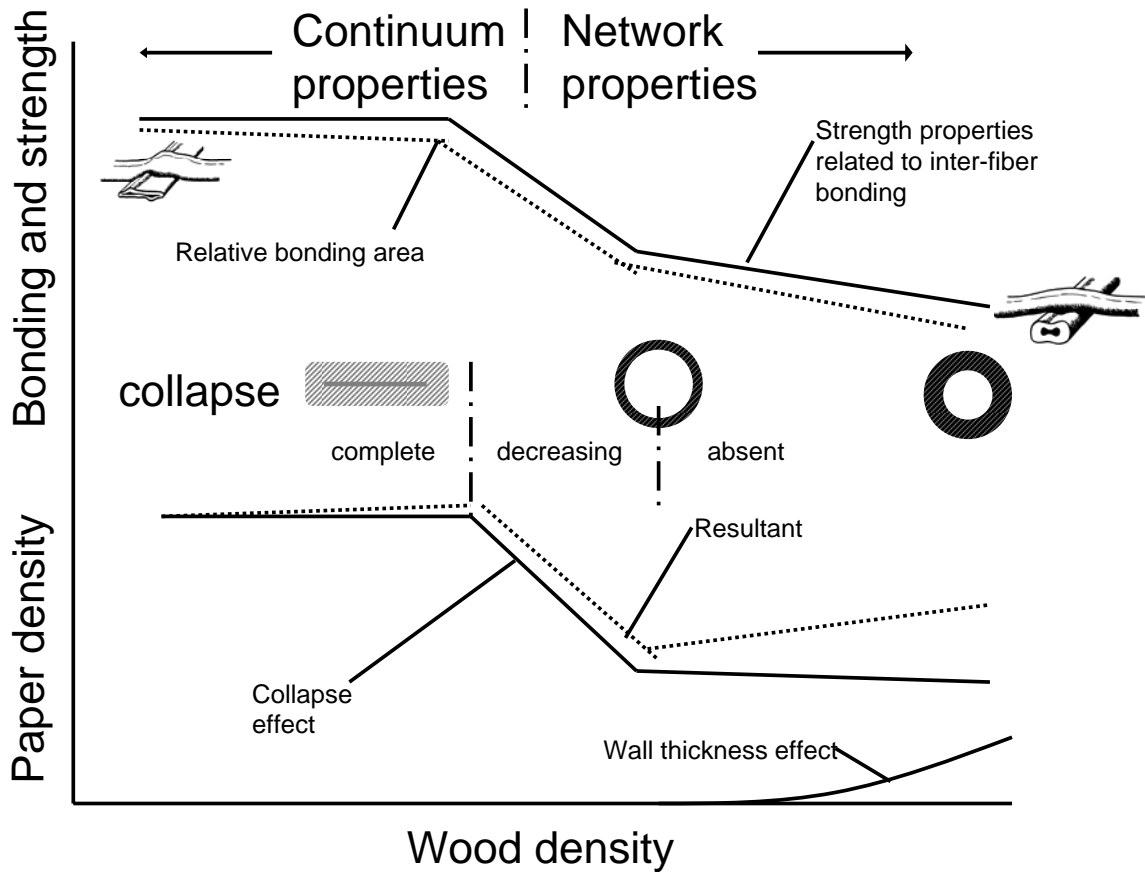
Wood / Fibre Properties
*unabhängig
ausserhalb*

Pulp/Paper Properties
*abhängig
innerhalb*

Material

- 8-year old *Eucalyptus globulus*, three sites
- 2 clones
- 4 trees per site, several samples / tree;
- cores for SilviScan-II
- Kraft-pulp process, Kappa 18
- 10kg fibres per batch (Tappi, AS/NZS)

CSIRO Cooperative Research Centre for Hardwood Fibre and Paper Science CRC



Wood, pulp and paper properties

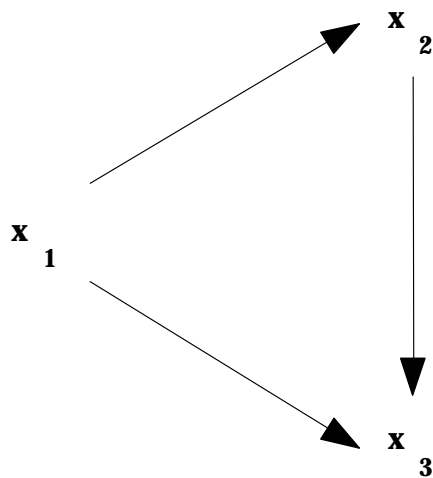


All batches beaten and unbeaten (PFI 5000 revs) (AS/NZS 1301.209rp-89)

	Property
Wood	Fibre length (mm) TAPPI T271pm-91 Microfibril angle (°) Density (kg/m ³)
Pulp	Pulp yield (%) Alkali consumption (%) Freeness (CSF) AS/NZS 1301.206s-88
Handsheet AS/NZS 1301.203s:1993	Bending stiffness (mNm) Bulk density (kg/m ³) Burst Index (MN/kg) Light scattering (m ² /kg) Opacity (%) Air permeance Roughness Stretch (%) TEA (J/m ²) Tear index (Nm ² /kg) Tensile index (kNm/kg)

Path analysis

- Investigates direct cause-effect relationships



- x_1 directly influences x_2 and x_3
- x_1 influences indirectly x_3 via x_2
- Separation of direct from indirect effects

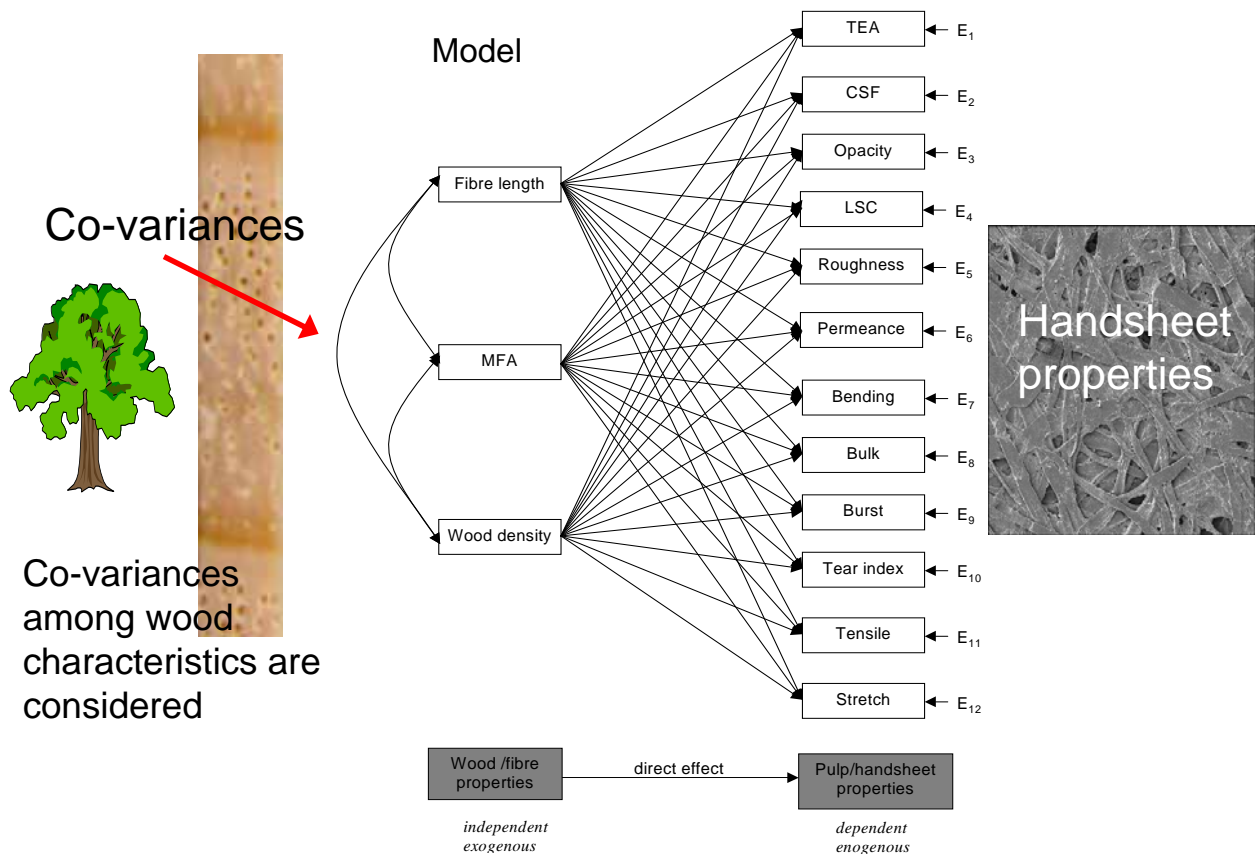
$$p = r - i$$

r = correlation coefficient

p = path coefficient

i = coefficient for indirect influence

Using path-analysis to estimate handsheet properties



Pearson correlation coefficients for wood variables with the 13 measured handsheet properties



Parameter	Fibre length		Microfibril angle		Wood density	
	0	5000	0	5000	0	5000
Fibre length	1		-0.55		-0.44	
Microfibril angle	-0.55		1		+0.36	
Density	-0.44		+0.36		1	
Beating level (revs)	0	5000	0	5000	0	5000
Bending stiffness	+0.47	n.s.	-0.39	n.s.	n.s.	+0.45
Bulk	n.s.	n.s.	n.s.	n.s.	+0.76	+0.74
Burst	+0.43	+0.56	-0.44	-0.51	-0.70	-0.74
Freeness	+0.41	+0.40	n.s.	n.s.	n.s.	n.s.
Light scattering	-0.33	-0.45	+0.35	+0.49	+0.53	+0.74
Opacity	n.s.	-0.34	+0.37	+0.50	n.s.	+0.56
Air permeance	n.s.	n.s.	n.s.	n.s.	+0.71	+0.67
Pulp Yield	+0.69		-0.52		-0.43	
Roughness	n.s.	n.s.	n.s.	n.s.	+0.33	+0.63
Soda demand	-0.65		+0.38		+0.43	
Stretch	n.s.	n.s.	n.s.	n.s.	-0.47	n.s.
TEA	+0.37	+0.37	n.s.	n.s.	-0.65	-0.56
Tear index	+0.80	+0.58	-0.50	n.s.	-0.60	n.s.
Tensile index	+0.49	+0.51	-0.46	-0.54	-0.72	-0.69

significant at p<1%, 2-tailed, n=68

Many spurious relationships ! Causality remains unclear !

Path-coefficients and R²

Direct links between **fibre length** and pulp/handsheet properties

Parameter	Path-coefficients						R ²	
	Fibre length		Microfibril angle		Wood density		0	5000
Beating level(revs)	0	5000	0	5000	0	5000	0	5000
Bending stiffness	+0.51	+0.39	-0.26	-0.29	+0.41	+0.73	0.38	0.49
Bulk density	n.s.	n.s.	n.s.	n.s.	+0.82	+0.82	0.59	0.57
Burst index	n.s.	n.s.	n.s.	n.s.	-0.60	-0.59	0.53	0.64
Freeness	+0.66	+0.71	n.s.	n.s.	+0.61	+0.58	0.47	0.44
Light scattering	n.s.	n.s.	n.s.	+0.23	+0.45	+0.63	0.31	0.60
Opacity	n.s.	n.s.	+0.40	+0.37	n.s.	+0.46	0.18	0.42
Air permeance	+0.28	n.s.	n.s.	n.s.	+0.84	+0.74	0.57	0.47
Pulp yield	+0.53		n.s.		n.s.		0.52	
Roughness	n.s.	n.s.	n.s.	n.s.	+0.35	+0.73	0.11	0.43
Soda demand	-0.57		n.s.		n.s.		0.45	
Stretch	n.s.	n.s.	n.s.	+0.27	-0.47	-0.25	0.23	0.09
TEA	n.s.	n.s.	n.s.	n.s.	-0.59	-0.49	0.43	0.34
Tear index	+0.65	+0.91	n.s.	n.s.	-0.31	+0.65	0.72	0.69
Tensile index	n.s.	n.s.	n.s.	-0.28	-0.60	-0.53	0.57	0.58

significant at p<1%, n=68

Path-coefficients and R²

Direct links between **microfibril angle** and pulp/handsheet properties

Parameter	Path-coefficients						R ²	
	Fibre length		Microfibril angle		Wood density		R ²	
	0	5000	0	5000	0	5000	0	5000
Beating level(revs)	0	5000	0	5000	0	5000	0	5000
Bending stiffness	+0.51	+0.39	-0.26	-0.29	+0.41	+0.73	0.38	0.49
Bulk density	n.s.	n.s.	n.s.	n.s.	+0.82	+0.82	0.59	0.57
Burst index	n.s.	n.s.	n.s.	n.s.	-0.60	-0.59	0.53	0.64
Freeness	+0.66	+0.71	n.s.	n.s.	+0.61	+0.58	0.47	0.44
Light scattering	n.s.	n.s.	n.s.	+0.23	+0.45	+0.63	0.31	0.60
Opacity	n.s.	n.s.	+0.40	+0.37	n.s.	+0.46	0.18	0.42
Air permeance	+0.28	n.s.	n.s.	n.s.	+0.84	+0.74	0.57	0.47
Pulp yield	+0.53		n.s.		n.s.		0.52	
Roughness	n.s.	n.s.	n.s.	n.s.	+0.35	+0.73	0.11	0.43
Soda demand	-0.57		n.s.		n.s.		0.45	
Stretch	n.s.	n.s.	n.s.	+0.27	-0.47	-0.25	0.23	0.09
TEA	n.s.	n.s.	n.s.	n.s.	-0.59	-0.49	0.43	0.34
Tear index	+0.65	+0.91	n.s.	n.s.	-0.31	+0.65	0.72	0.69
Tensile index	n.s.	n.s.	n.s.	-0.28	-0.60	-0.53	0.57	0.58

significant at p<1%, n=68

Path-coefficients and R²

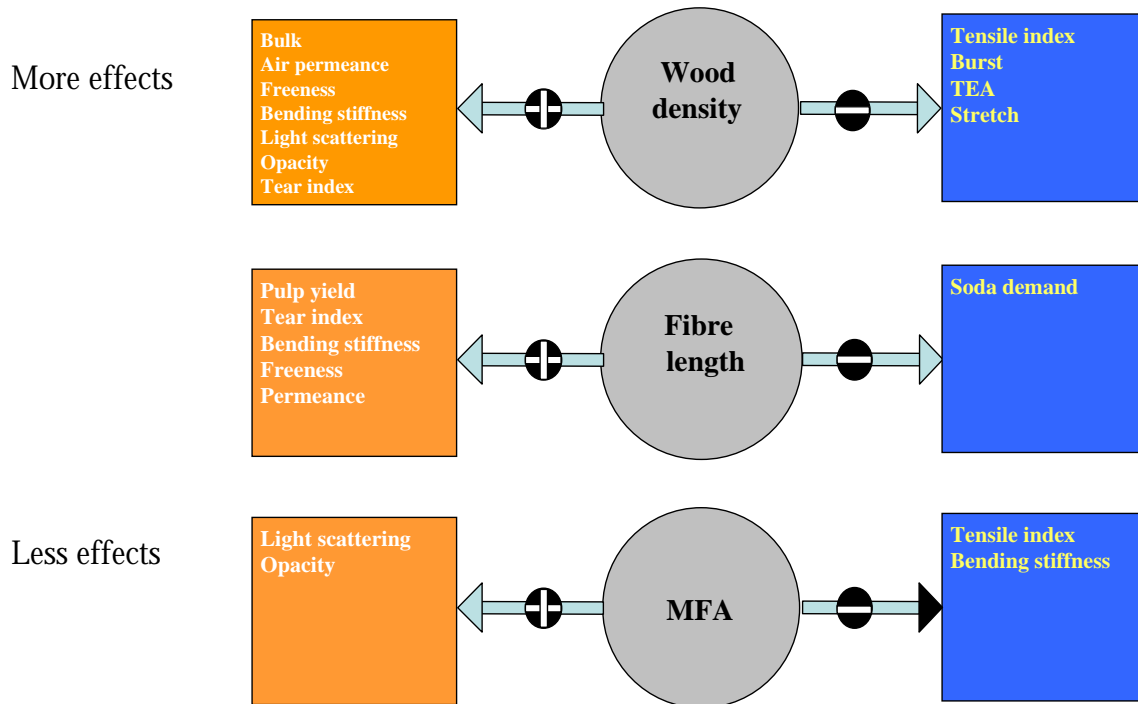
Direct links between **wood density** and pulp/handsheet properties

Parameter	Path-coefficients						R ²	
	Fibre length		Microfibril angle		Wood density		R ²	
	0	5000	0	5000	0	5000	0	5000
Beating level(revs)	0	5000	0	5000	0	5000	0	5000
Bending stiffness	+0.51	+0.39	-0.26	-0.29	+0.41	+0.73	0.38	0.49
Bulk density	n.s.	n.s.	n.s.	n.s.	+0.82	+0.82	0.59	0.57
Burst index	n.s.	n.s.	n.s.	n.s.	-0.60	-0.59	0.53	0.64
Freeness	+0.66	+0.71	n.s.	n.s.	+0.61	+0.58	0.47	0.44
Light scattering	n.s.	n.s.	n.s.	+0.23	+0.45	+0.63	0.31	0.60
Opacity	n.s.	n.s.	+0.40	+0.37	n.s.	+0.46	0.18	0.42
Air permeance	+0.28	n.s.	n.s.	n.s.	+0.84	+0.74	0.57	0.47
Pulp yield	+0.53		n.s.		n.s.		0.52	
Roughness	n.s.	n.s.	n.s.	n.s.	+0.35	+0.73	0.11	0.43
Soda demand	-0.57		n.s.		n.s.		0.45	
Stretch	n.s.	n.s.	n.s.	+0.27	-0.47	-0.25	0.23	0.09
TEA	n.s.	n.s.	n.s.	n.s.	-0.59	-0.49	0.43	0.34
Tear index	+0.65	+0.91	n.s.	n.s.	-0.31	+0.65	0.72	0.69
Tensile index	n.s.	n.s.	n.s.	-0.28	-0.60	-0.53	0.57	0.58

significant at p<1%, n=68



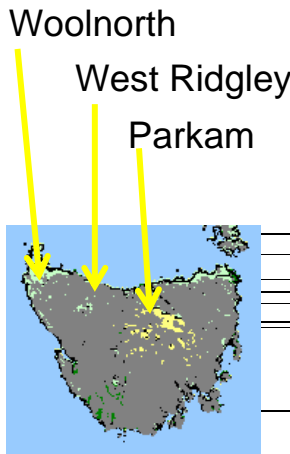
Direct effects on paper properties

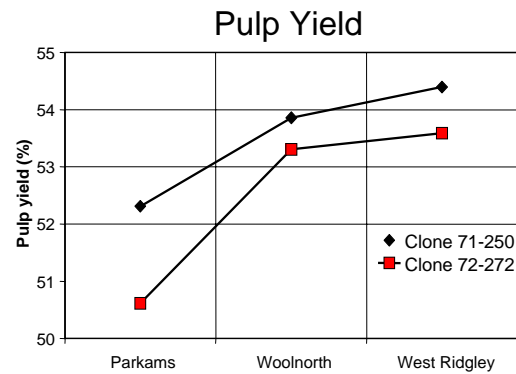
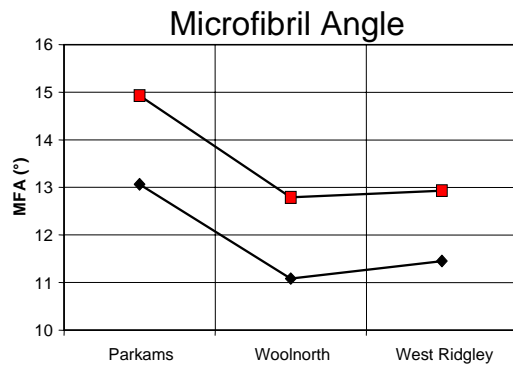
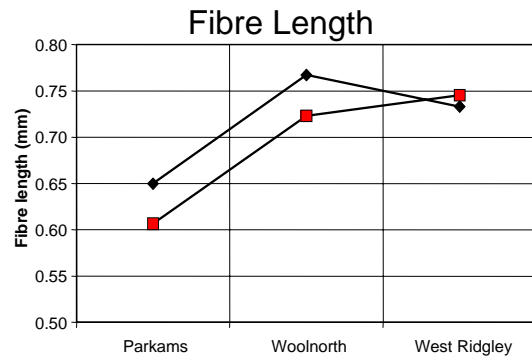
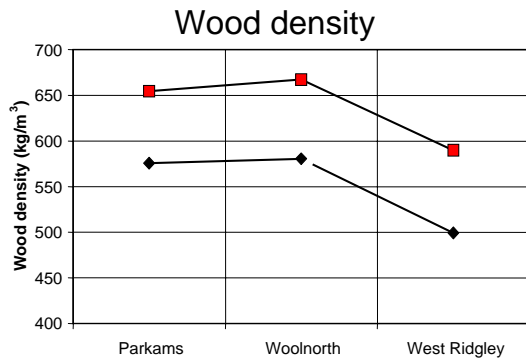


Wimmer et al. (2002)

Sites, basic tree data, climate and site quality

		poor	medium	good
		Sample sites		
		Parkham	Woolnorth	West Ridgley
Latitude/Longitude		41°26'S / 146°37'E	40°49'S / 144°53'E	41°08'S / 145°48'E
Altitude (m)		185	60	200
Tree species and provenance		Eucalyptus globulus		
Tree age (years)		8		
Planted / sampled		16Aug90/26Aug98	8Aug90/25Aug98	2Aug90/27Aug98
Total tree height (m), [s.d.]		13.1 [1.3]	16.3 [1.5]	20.6 [1.5]
Merchantable tree height (m),[s.d.]		6.7 [1.3]	10.2 [0.8]	13.3 [1.4]
DHB (m),[s.d.]		16.3 [3.0]	19.4 [3.0]	20.7 [1.6]
Annual rainfall (mm)		800 -1000	1000 -1200	1200 -1400
Mean temperature (°C)		12.6	15.6 / 12.2	15.6 / 11.4
Soil type		Sandy loam, clay subsoil	Yellow podzol	Kraznozem
General site quality		poor	Medium	good
SQ Index (m)		16.9	23.4	26.7
Initial spacing (m)		3 x 3		
Fertiliser history		100 g/m ² soon after trial establishment		
		Clone 71-250		Clone 72-272
Criteria of selection		low density		high density
DBH (cm), [s.d.]		18.7 [3.0]		20.1 [3.0]
Merchantable height (m) [s.d.]		9.6 [2.8]		10.5 [3.4]
Total height (m) [s.d.]		16.2 [3.3]		17.2 [3.9]

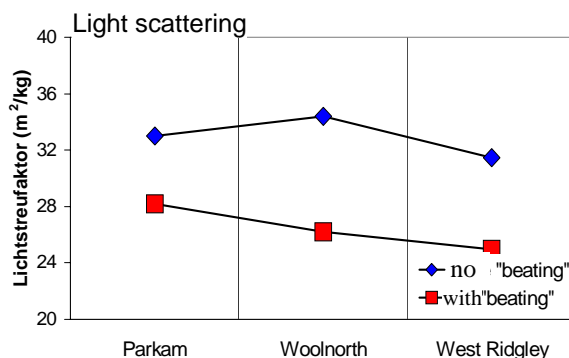
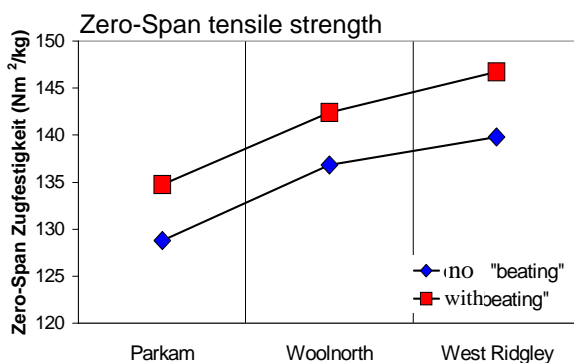
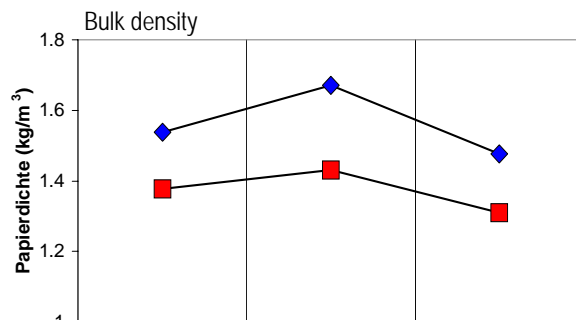
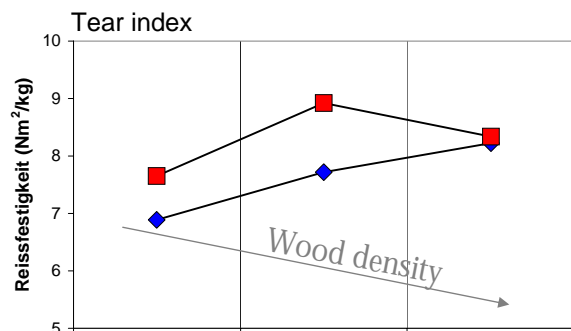
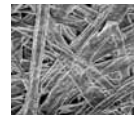




poor medium good

poor medium good

Handsheet properties



poor medium good

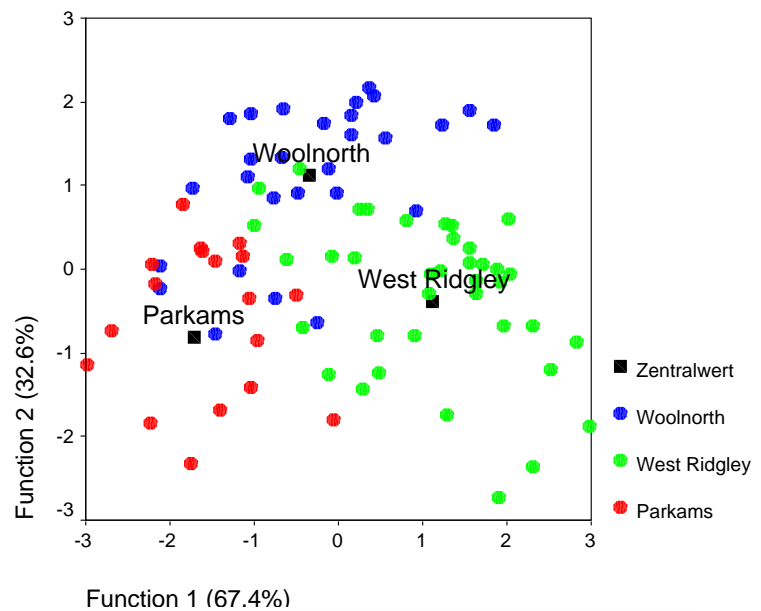
poor medium good



Site discriminant analysis

Parameter	Function 1	Function 2
MFA	-0.46	n.s.
Density	n.s.	+0.75
Fibre length	+0.82	n.s.

- * Sites separate well
- * Beating improves sites effect



	Parkams	Woolnorth	West Ridgley
Parkams	80	15	5
Woolnorth	19	71	11
West Ridgley	5	21	74

	Funktion	
	1	2
Tear Index	0.60*	0.16
Zero Span	0.23	0.62*
Apparent density	0.27	-0.58*
Light scattering	-0.19	-0.40*

Wimmer et al. (2007)

Summary

- Relationships between wood, fibres and paper properties tend to be complex
- An important approach in modeling is the understanding of direct and indirect, i.e. causal and spurious relationships.
- “Path analysis” has shown utility testing direct and indirect relationships within a suggested model.
- Statistical modeling has also demonstrated that paper properties reflect wood quality and different site conditions