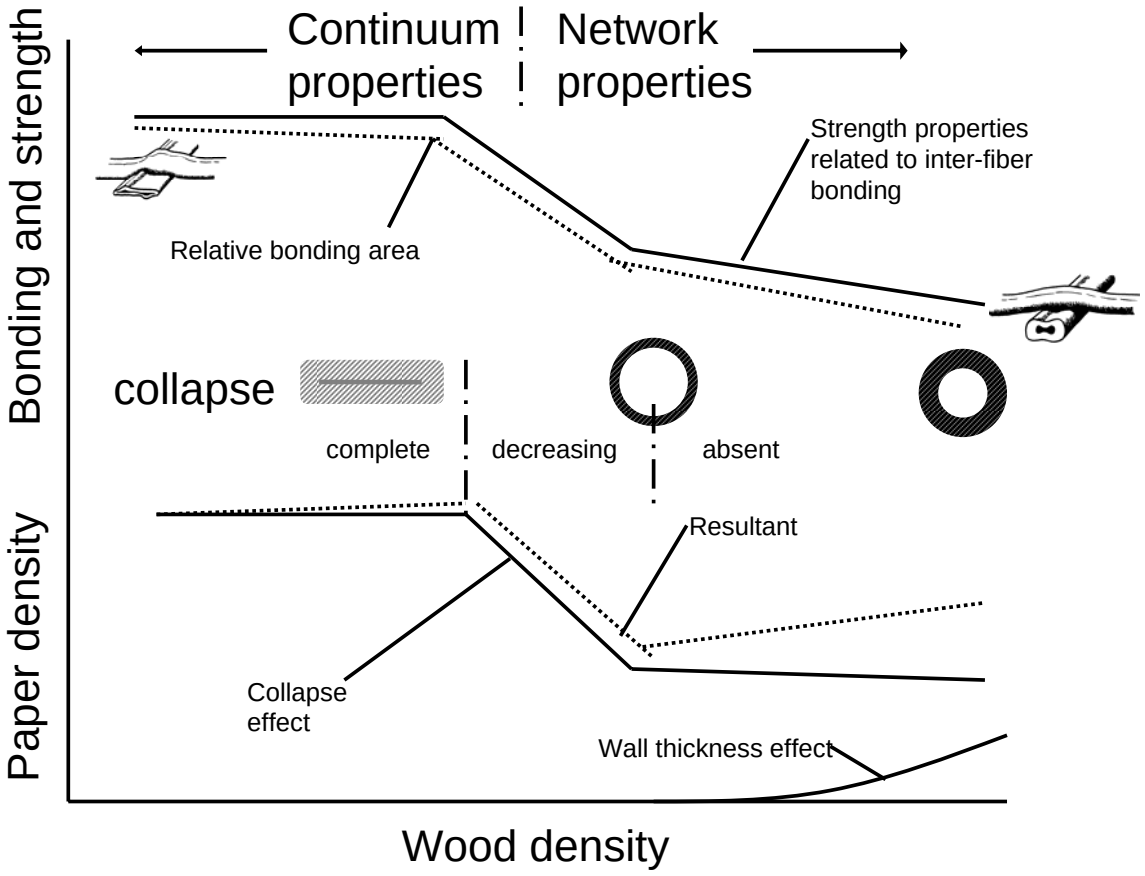
Modeling effects of site on fibre, pulp and handsheet properties of *Eucalyptus globulus*

Rupert Wimmer

Department of Material Sciences and Process Engineering
University of Natural Resources and Applied Life Sciences, Vienna, Austria

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

Linking wood and paper properties



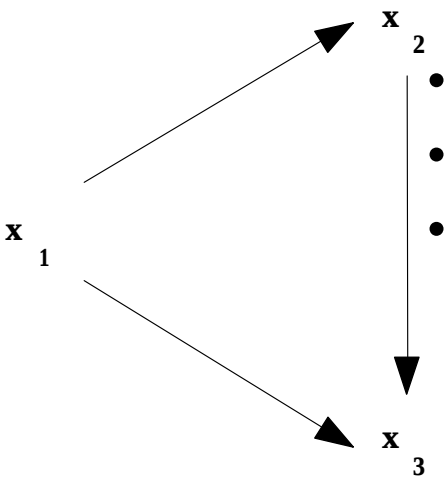
Wood, pulp and paper properties

	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)

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

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

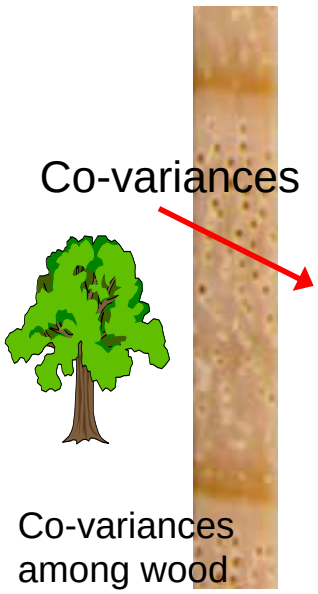
$$p = r - i$$

r = correlation coefficient

p = path coefficient

i = coefficient for indirect influence

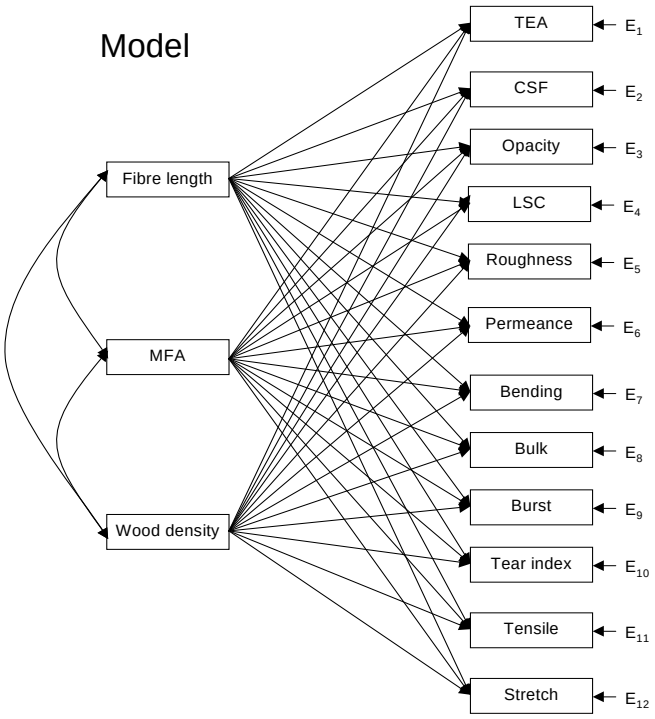
Using **path-analysis** to estimate handsheet properties

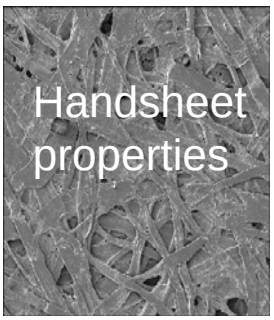


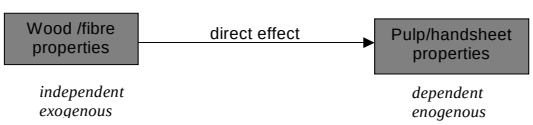
Co-variances

Co-variances among wood characteristics are considered

Model







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

Parameter	Fibre length		Microfibril angle		Wood density	
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	+0.27	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 R^2

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

Parameter	Path-coefficients						R^2	
	Fibre length		Microfibril angle		Wood density			
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 R^2

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

Parameter	Path-coefficients						R^2	
	Fibre length		Microfibril angle		Wood density			
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

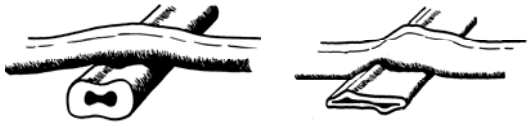
significant at p<1%, n=68

Path-coefficients and R^2

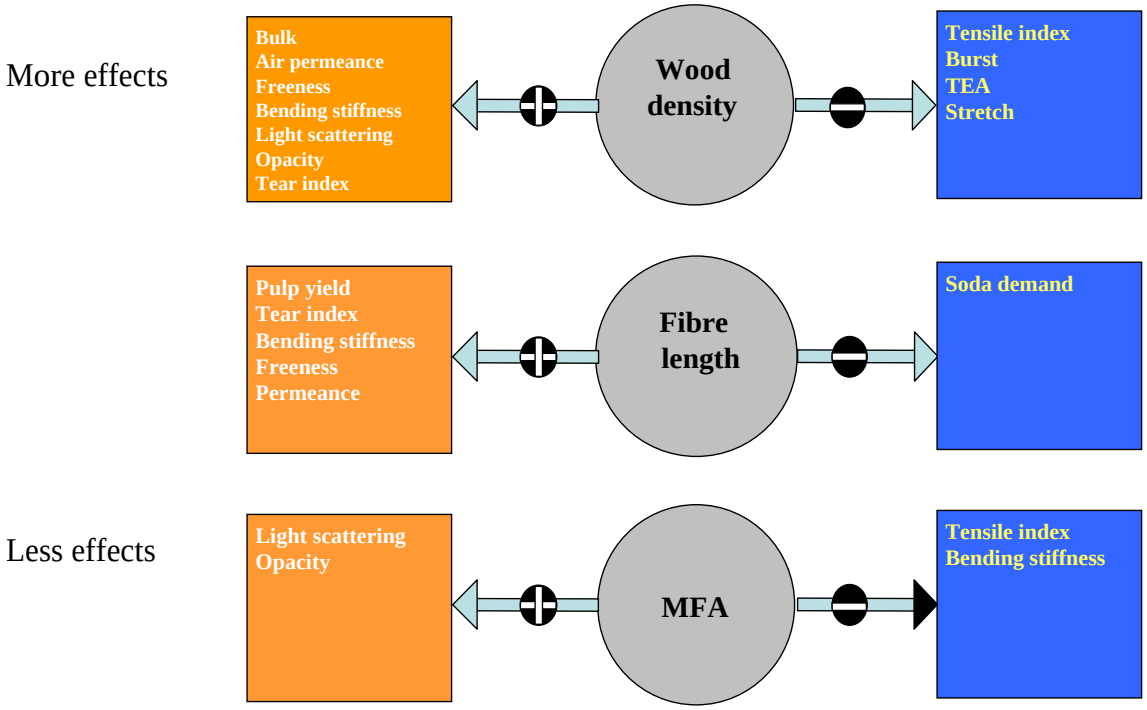
Direct links between **wood density** and pulp/handsheet properties

Parameter	Path-coefficients						R^2	
	Fibre length		Microfibril angle		Wood density			
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

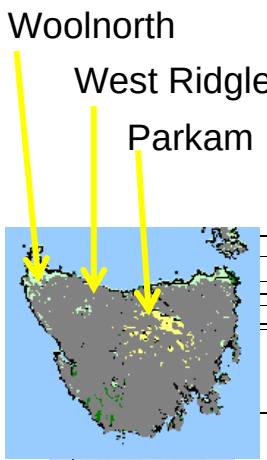


Direct effects on paper properties



Wimmer et al. (2002)

Sites, basic tree data, climate and site quality

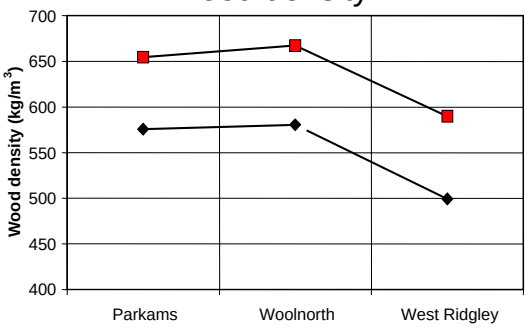


	poor — medium — good		
	Sample sites		
Parameter	**Parkham**	**Woolnorth**	**West Ridgley**
Latitude/Longitude	41°26'S /146°37'E	40°49'S / 144°53'E	41°08'S / 145°48'E
Altitude (m)	185	60	200
Tree species and provenance	**Eucalyptus globulus**		
Tree age (years)	8		
Planted / sampled	16Aug90/26Aug98	8Aug90/25Aug98	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		

Parameter	**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]

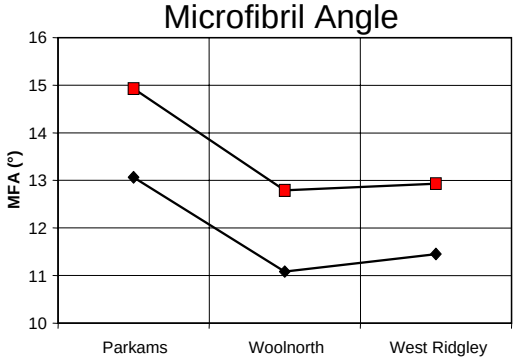
Wimmer et al. (2007)

Wood density

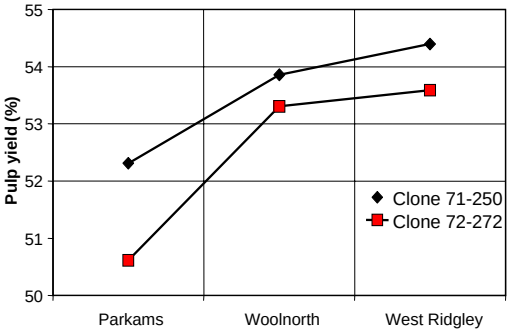


Fibre Length

Microfibril Angle



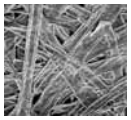
Pulp Yield



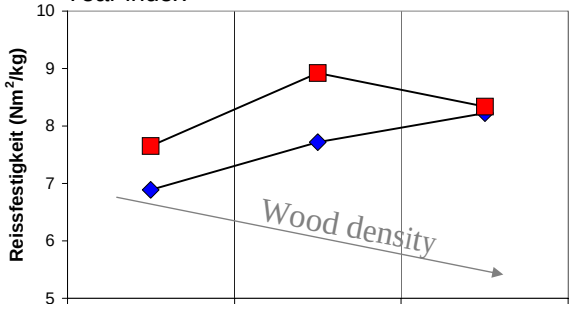
poor medium good

poor medium good

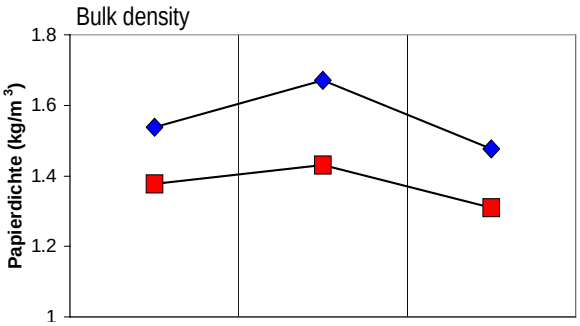
Handsheet properties



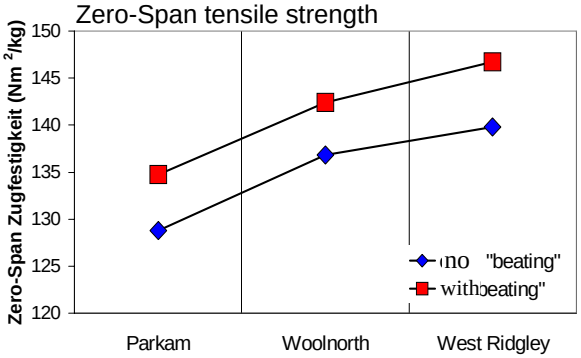
Tear index



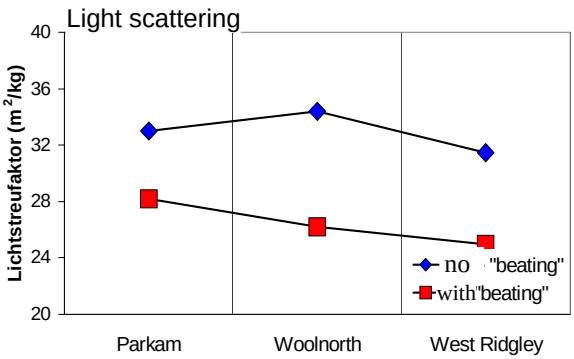
Bulk density



Zero-Span tensile strength



Light scattering



poor medium good

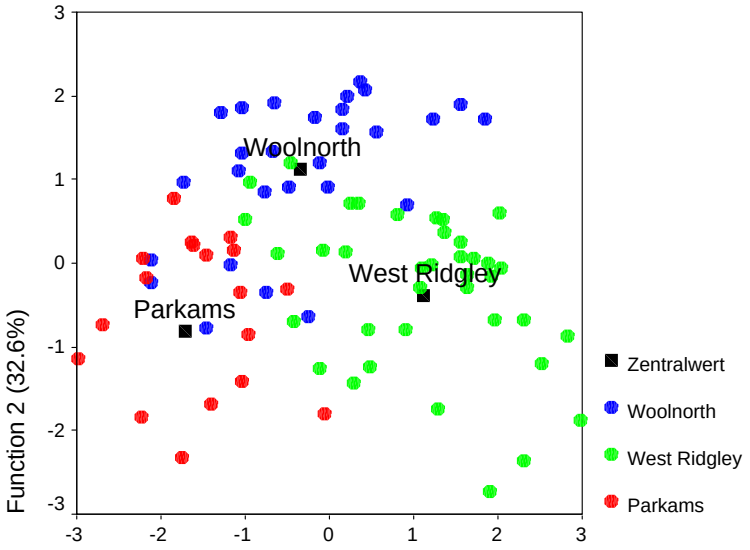
poor medium good

Wimmer et al. (2007)

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	Funktion 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