Eucalyptus Wood Quality and Its Impact on Kraft Pulp Production and Utilization

J. L. Colodette, A. Magaton, A.F. Gomes, J.L.Gomide & P.H.D. Morais

Pulp & Paper Laboratory

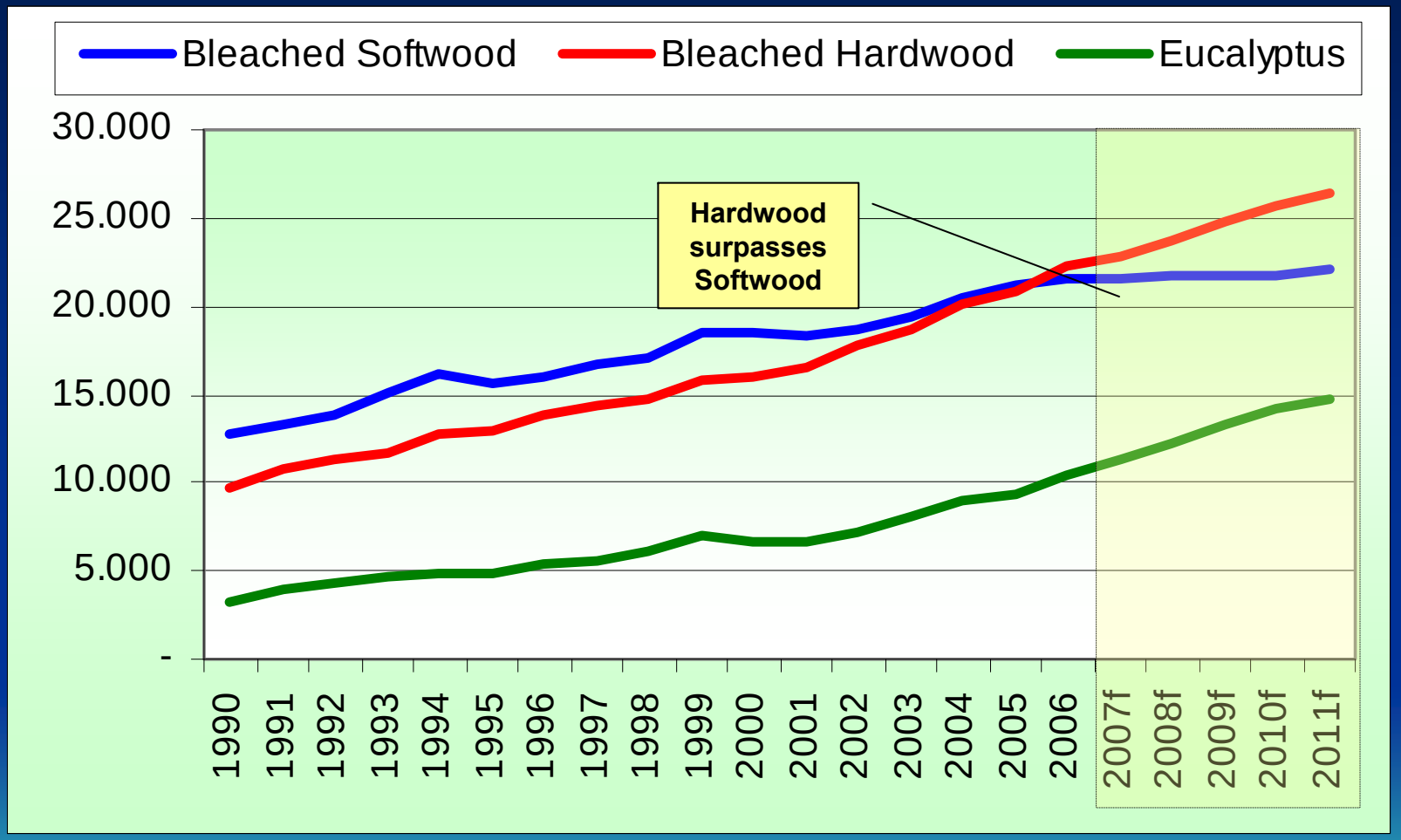
Federal University of Viçosa

Viçosa, MG Brazil 36.570-000

colodett@ufv.br

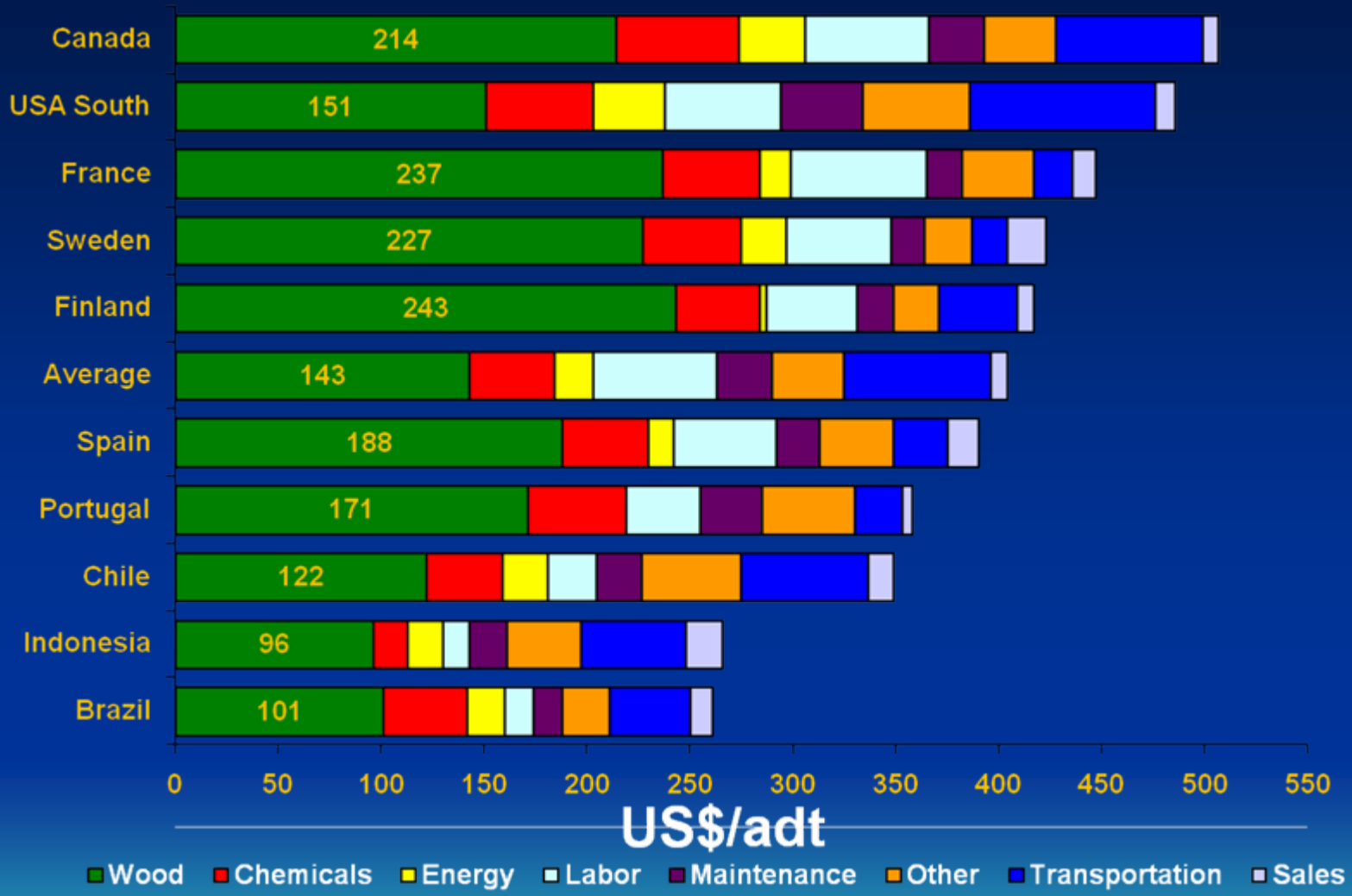
www.lcp.ufv.br

MARKET PULP DEMAND BY GRADE



Source: Cenibra/HW

Bleached HWD Fiber Production Cost Composition in 2006

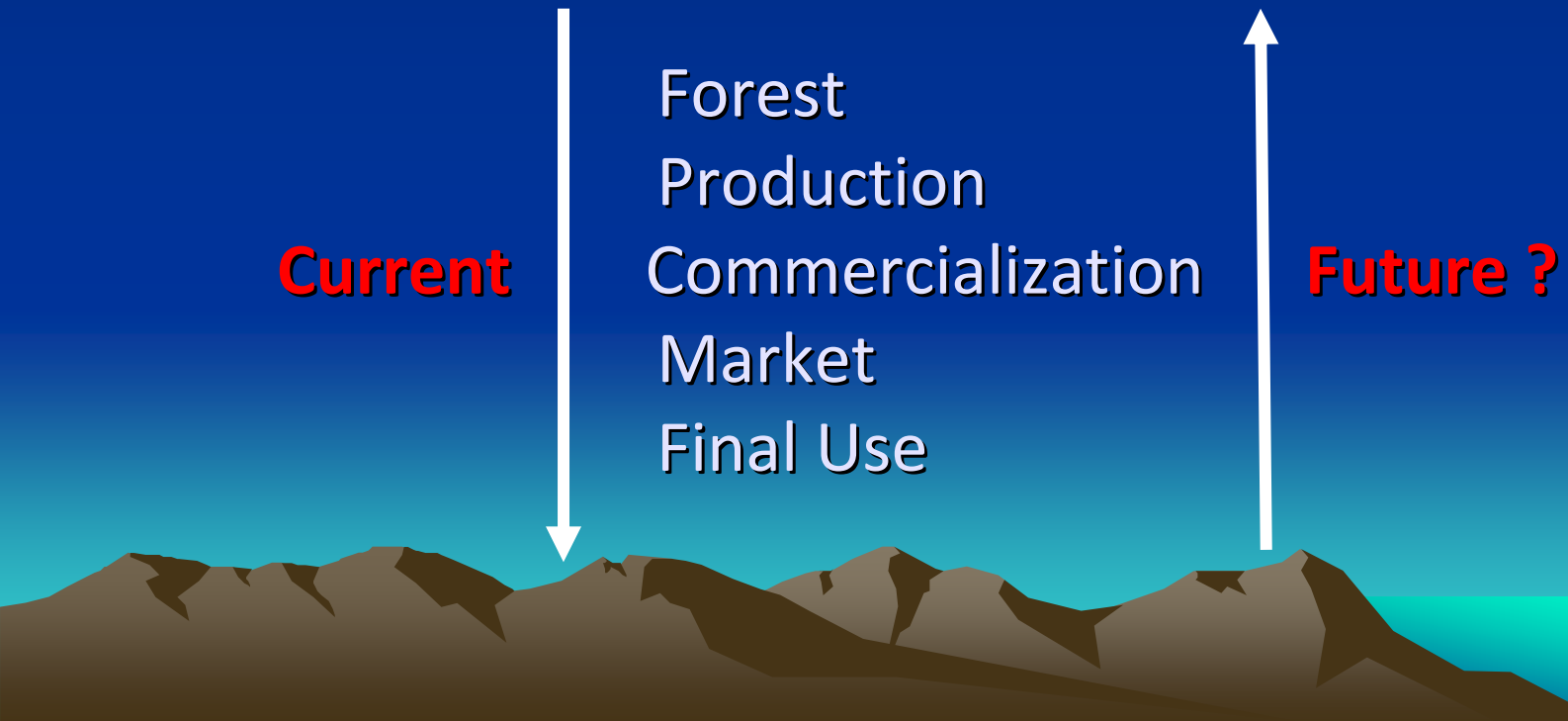


Source: Outlook for Market Pulp Demand, Supply, and Prices, HAWKINS WRIGHT LTD, July 2006.

Market Chain Value

- Wood Pulp
  - **commodity**
  - differentiated products

- Chain value from forest to product



Outline

- **Kraft Pulp Production**
  - Wood density
  - Wood extractives content
  - Wood lignin content
    - Lignin syringyl/guaiacyl ratio
  - Wood Cellulose content
  - Wood hemicelluloses/uronic acid contents
- **Pulp Refinability**
- **Pulp Drainability**

Kraft Pulp Production

Wood Quality Traits

- ↗ Wood density
- ↗ Wood Contents of:
  - Cellulose
  - Extractives
  - Lignin
    - Lignin S/G
  - Hemicelluloses
  - Uronic Acids

→

- PULPING YIELD ↑
- SWC ↓

SWC = Specific Wood Consumption = m^3 wood/odt pulp

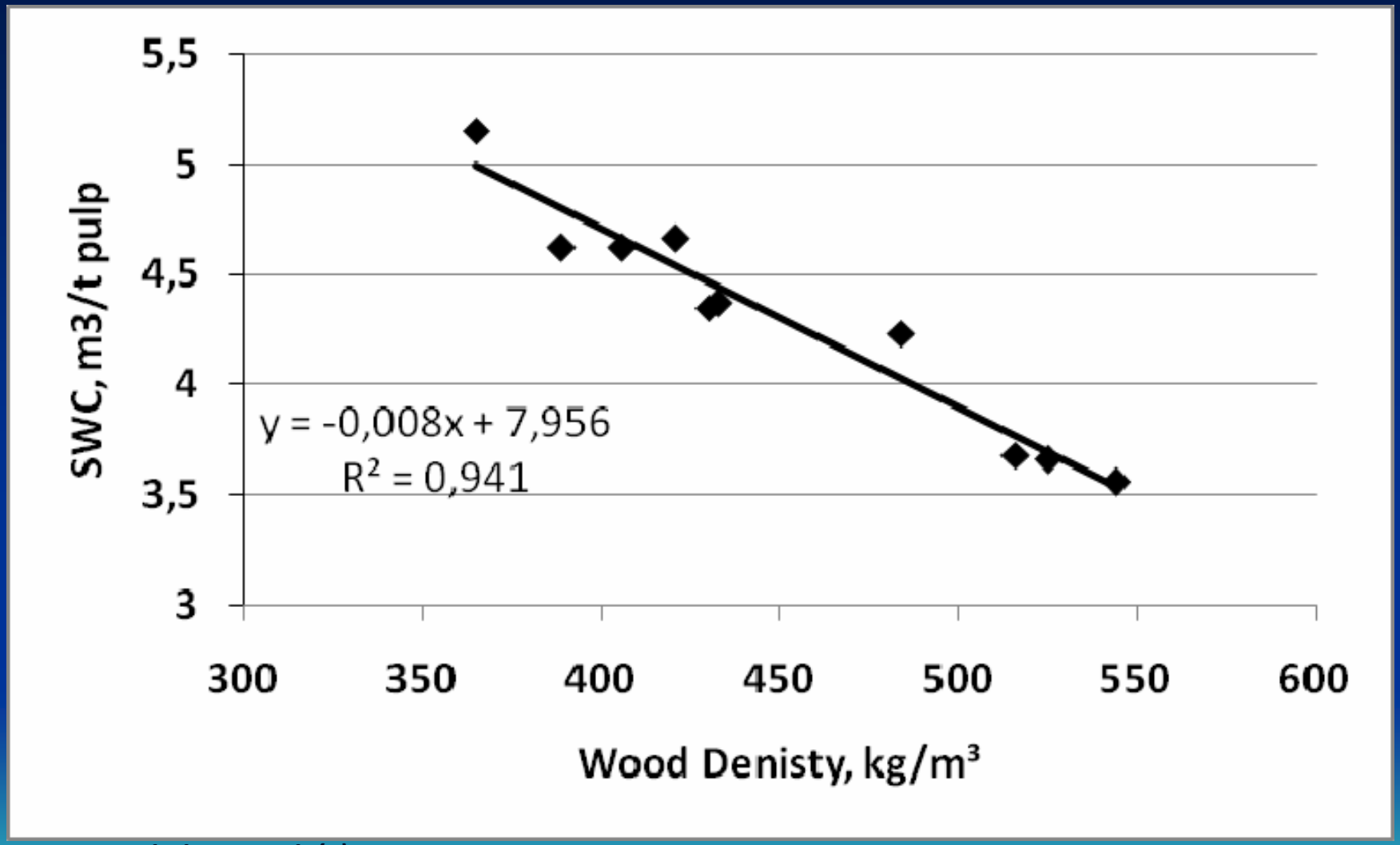
Wood Quality Traits

- ↗ Wood density
- ↗ Wood Contents of:
  - Cellulose
  - Extractives
  - Lignin
    - Lignin S/G
  - Hemicelluloses
  - Uronic Acids

→

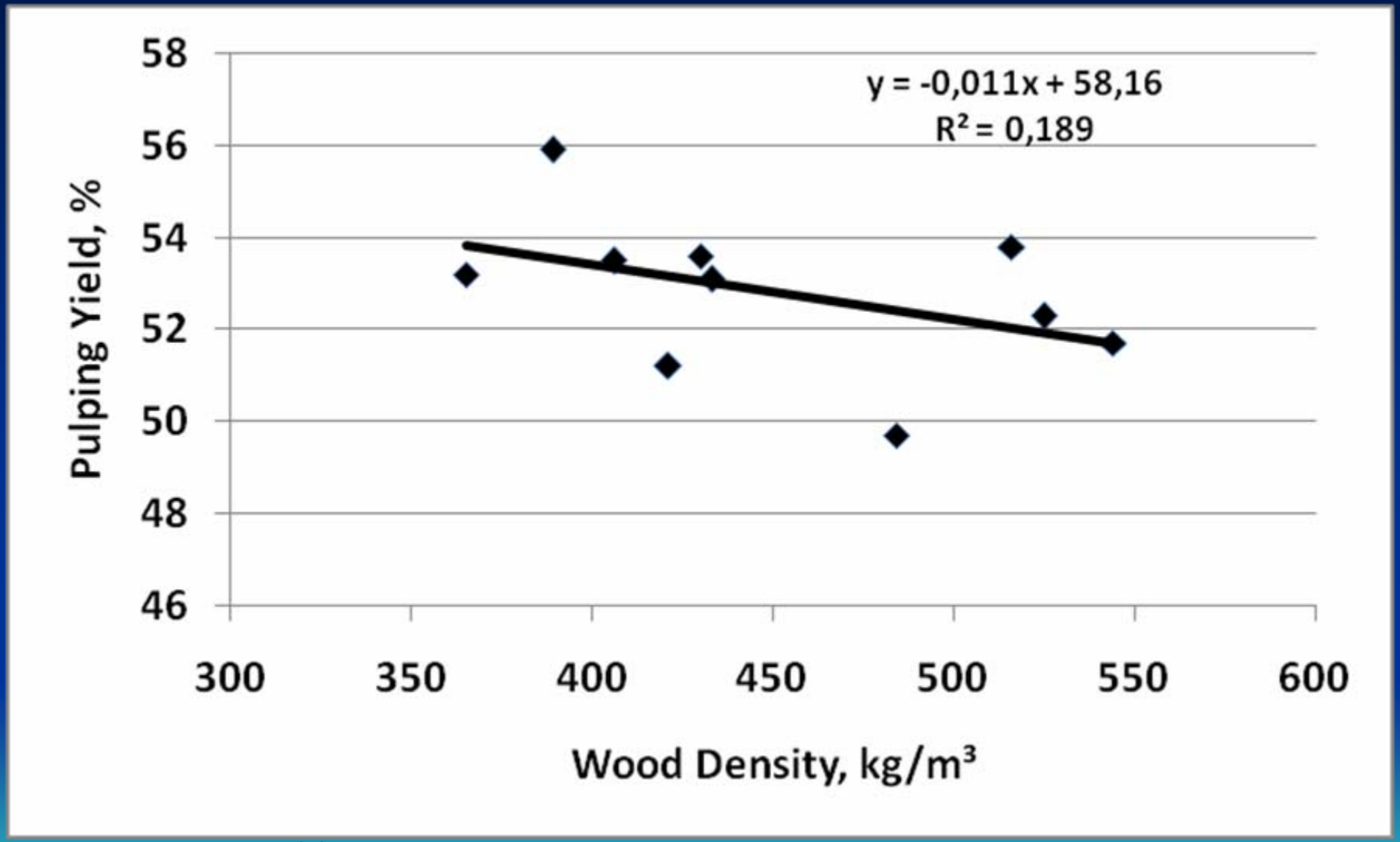
- PULPING YIELD ?
- SWC ↓

7-8 yr old eucalyptus samples cooked to kappa 17-18



Source: Colodette et al. (7)

7-8 yr old eucalyptus samples cooked to kappa 17-18



Source: Colodette et al. (7)

Effect of wood density and pulping yield on SWC for *Eucalyptus grandis* and *Eucalyptus urophylla* cooked to kappa 17-18

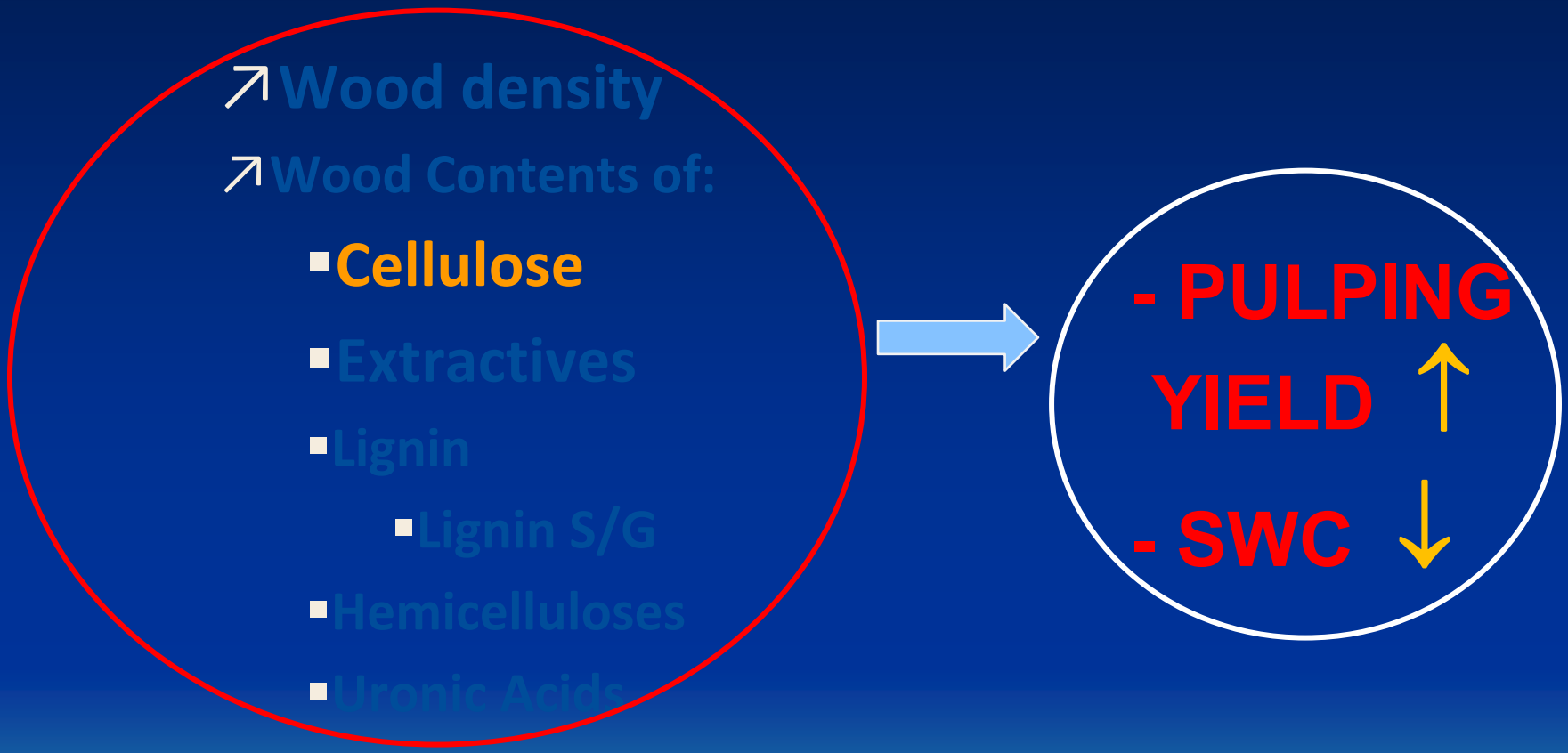
Trait	*Eucalyptus grandis*	*Eucalyptus urophylla*
Wood density, kg/m^3	389	544
Pulping yield, %	55.9	51.7
SWC, m^3/odt pulp	4.62	3.56

Source: Colodette et al. [7]

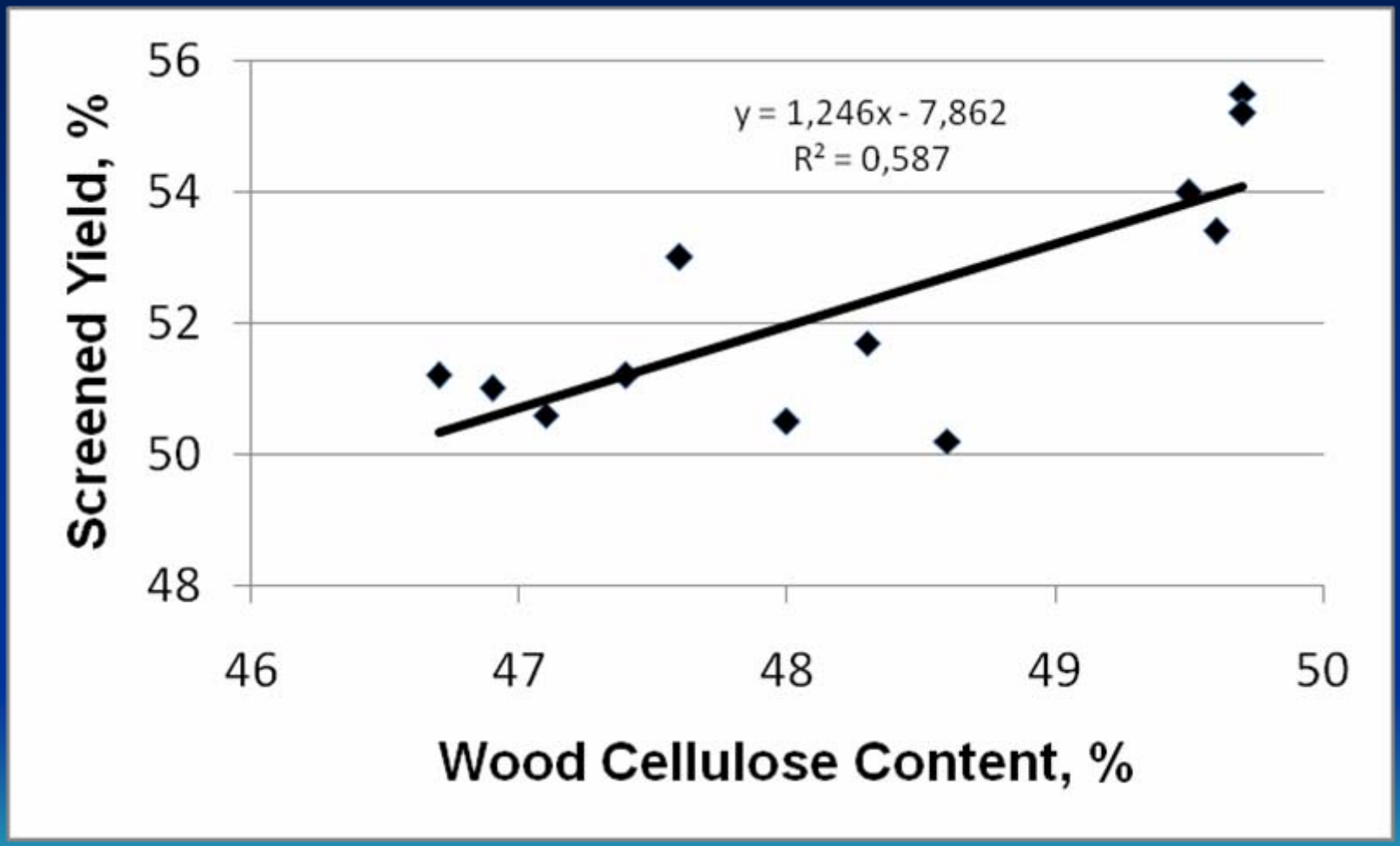
Conclusions: Wood Density

- Higher densities are desirable to minimize SWC
- No clear correlation with pulping yield for Brazilian grown eucalyptus
- Overall, one should strive for high wood densities

Wood Quality Traits



Effect of wood cellulose content on pulping yield at kappa 18±0.5 for twelve 7-9 year old *Eucalyptus* clones

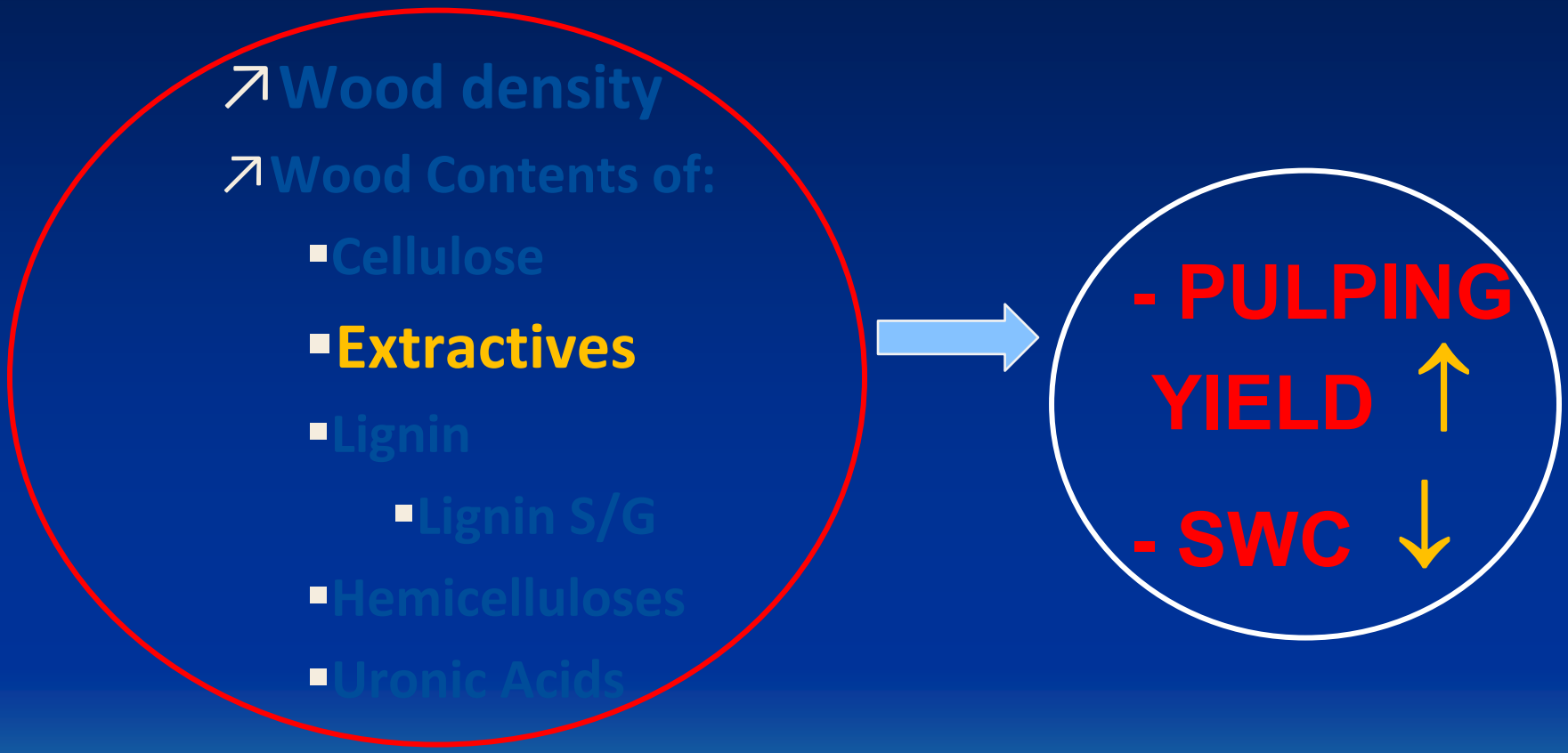


FERREIRA, C.R.S., FANTINI JUNIOR, M., GOMIDE, J.L., COLODETTE, J.L., CARVALHO, A.M.M.L.. Avaliação Tecnológica de Clones de Eucalipto. Parte I: Qualidade da Madeira para Produção de Celulose Kraft. Scientia Forestalis (IPEF). , v.70, p.161 - 170, 2006.

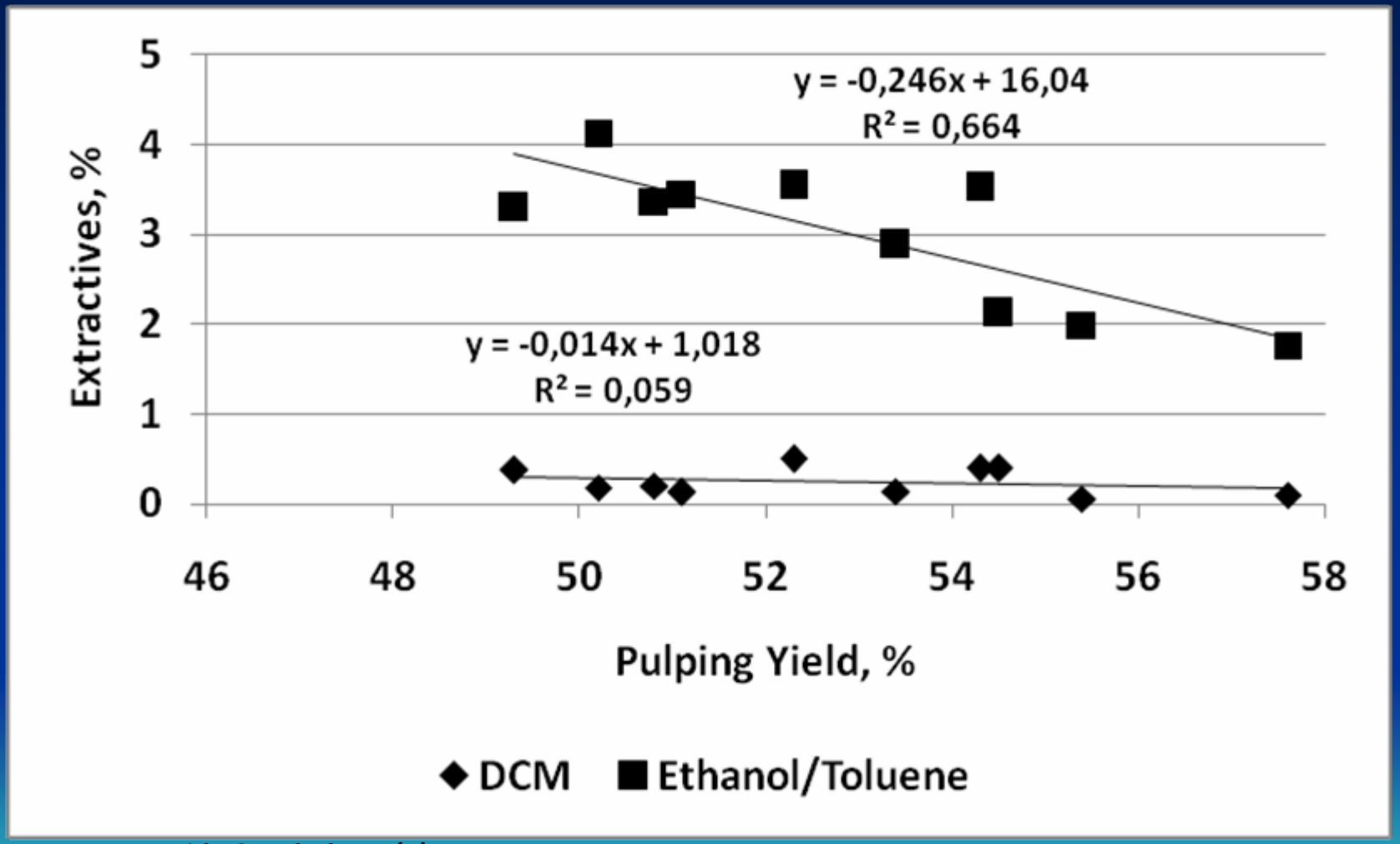
Conclusions: Cellulose

- Maintaining other traits constant, cellulose content should correlate very positively with pulping yield;
- Brazilian grown eucalyptus contain unusually high cellulose contents as compared to northern HWDs

Wood Quality Traits



Effect of wood ethanol/toluene and DCM extractive contents on pulping yield at kappa 18±0.5 for ten seven-year old *Eucalyptus*



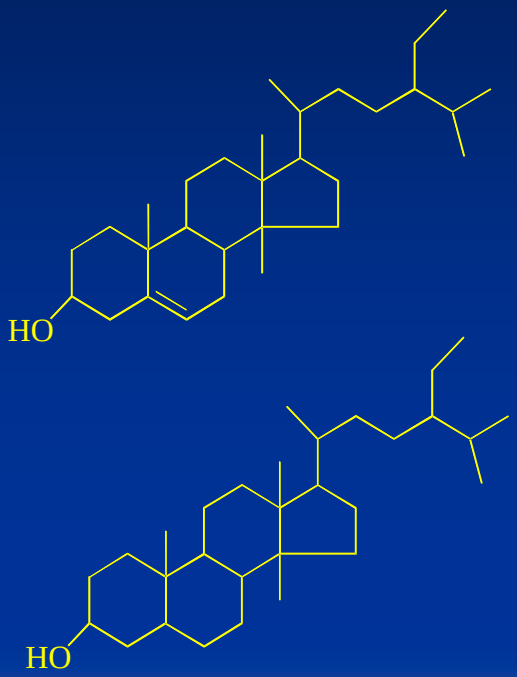
Source: Gomide & Colodette (9)

Effect of age on eucalyptus wood extractive content and pulping yield at kappa 17-21.5 (Uruguayan Plantations)

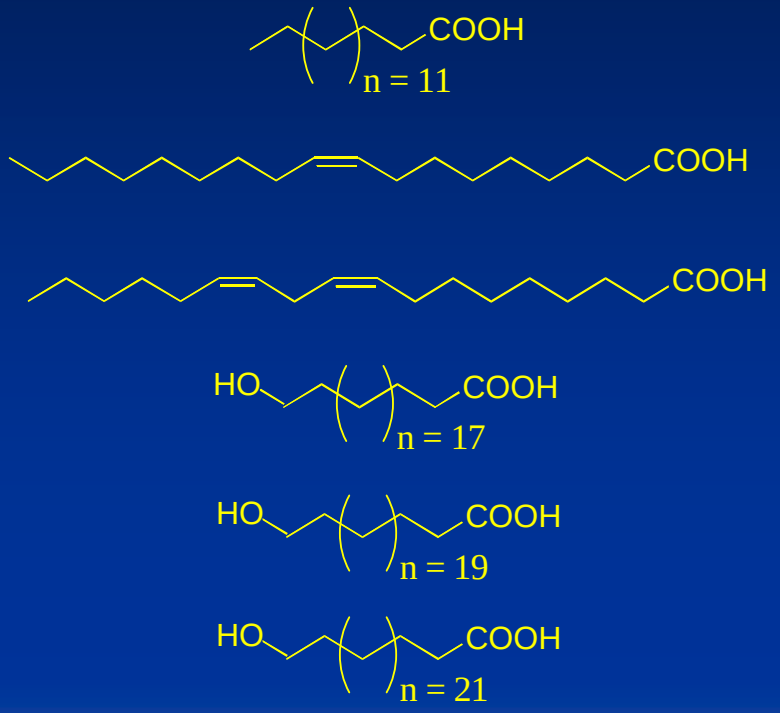
Species	*E. grandis*		*E. saligna*		*E. benthamii*	
Age, yr	**4**	**9**	**4**	**9**	**4**	**9**
Extractives, %	**0.8**	**2.9**	**0.9**	**3.2**	**1.0**	**4.3**
Density, kg/m^3	445	498	460	509	450	479
Kappa No.	19.7	17.2	21.5	18.5	19.9	17.1
Effective Alkali, %	16.5	17.0	15.7	17.9	16.3	18.0
Pulping Yield, %	**48.5**	**47.9**	**48.5**	**46.4**	**47.8**	**46.6**

Source: Backman et al. (8)

Eucalyptus low molecular weight (apolar = lipophyllic) extractives that cause pitch problems



Sterols



Aliphatic acids

Swan, B.; Akerblom, I.S. Svensk Papperstidn. 70(7), 239-244, 1967.

Wallis, A.F.A.; Wearne, R.H. 51st Appita Conference, Vol. I, Melbourne, Australia, pp. 45-50, 1997.

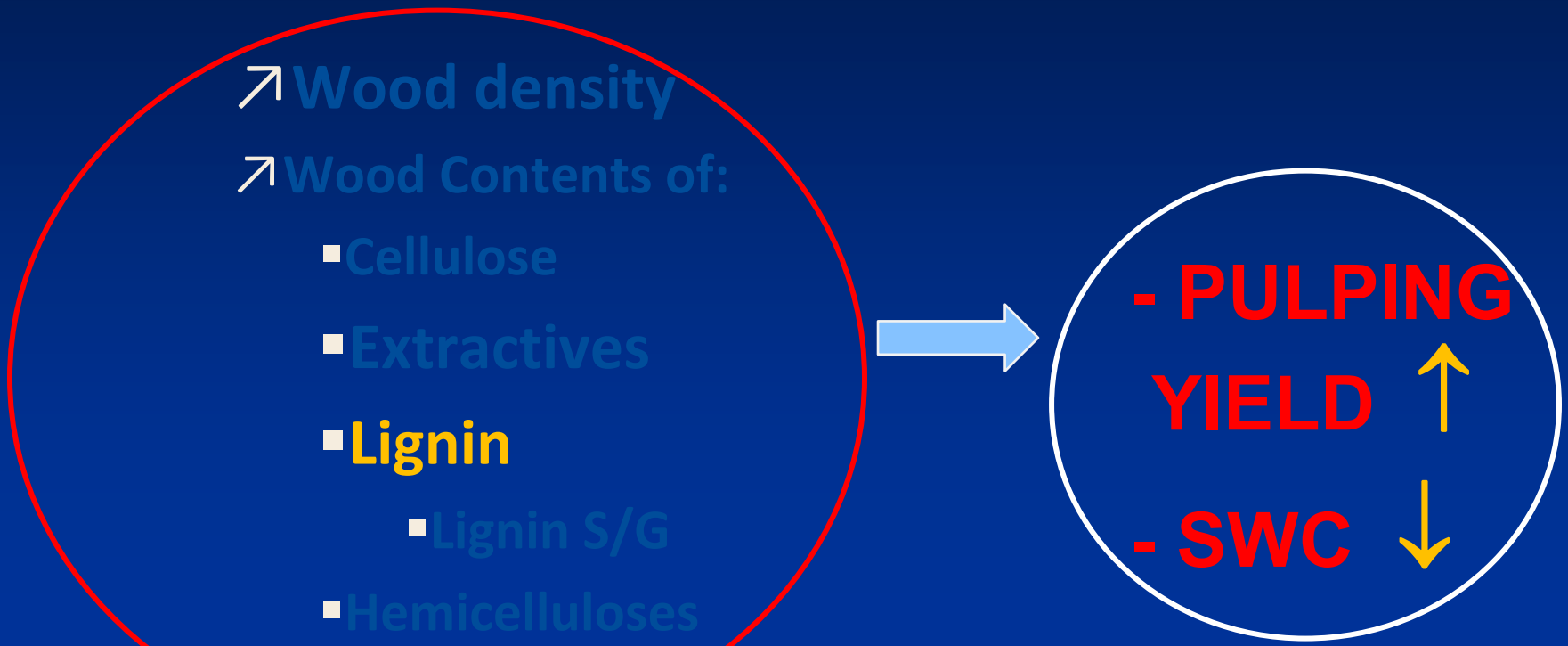
Freire, C.S.R. et al. Holzforschung, 56 (2), 143-149, 2002.

Gutierrez, A. et al. Holzforschung, 53(5) 481-486, 1999.

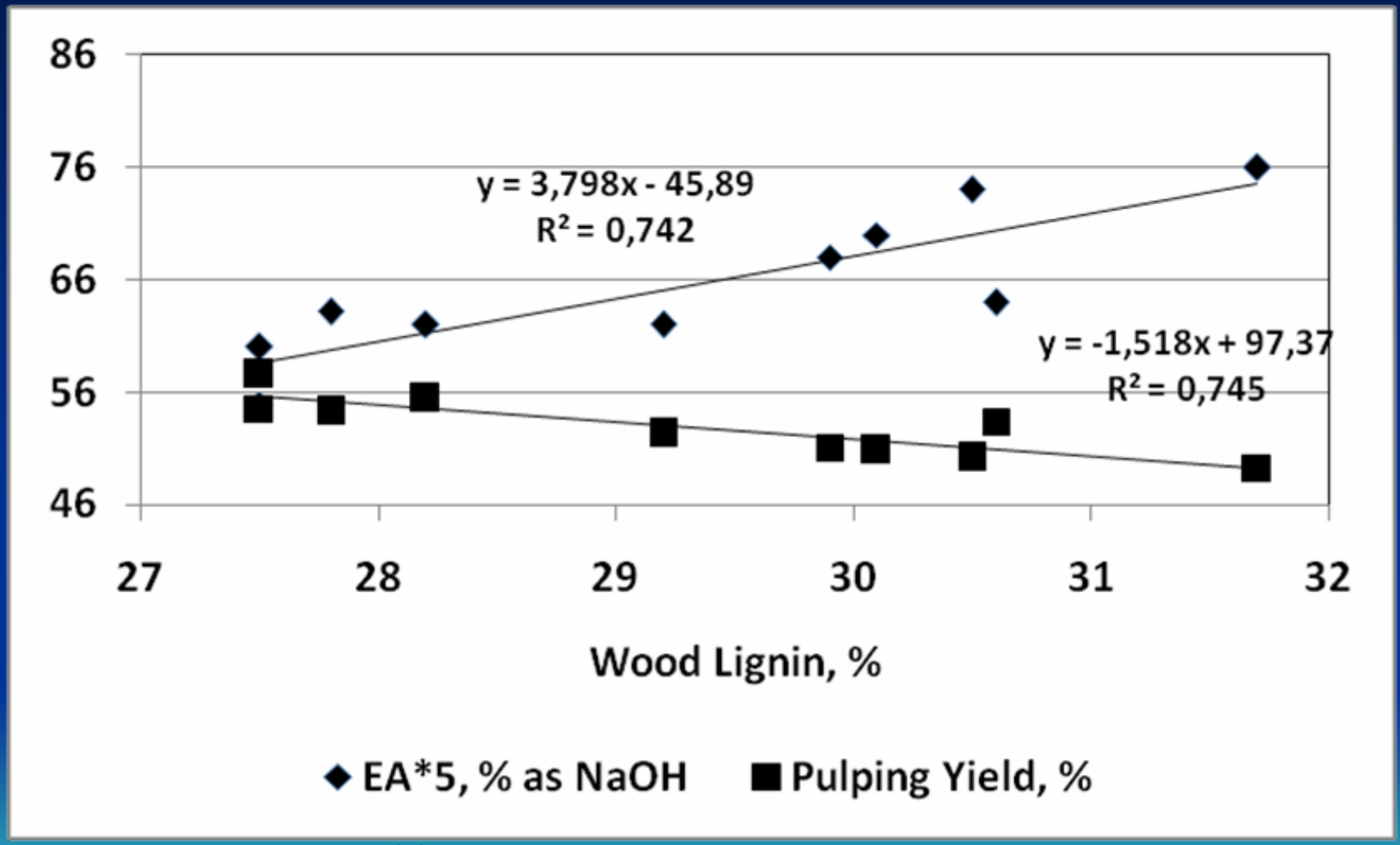
Conclusions: Extractives

- Extractives negatively affect pulping yield;
- Brazilian grown eucalyptus contains low extractives because of young harvesting age, but content increases fast with aging (premature formation of heartwood)
- Eucalyptus lipophyllic extractive fraction causes severe pitch problems (steryl esters)

Wood Quality Traits

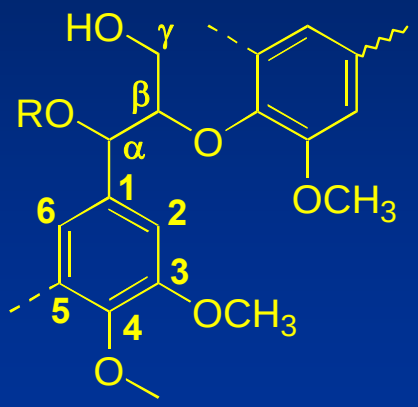


Effect of lignin content on pulping yield and effective alkali demand to kappa 18±0.5 for ten seven-year old samples



Source: Gomide & Colodette (8)

Main sustructures of *Eucalyptus globulus* lignin (RMN ^{13}C, ^{1}H, ^{13}C-^{1}H)

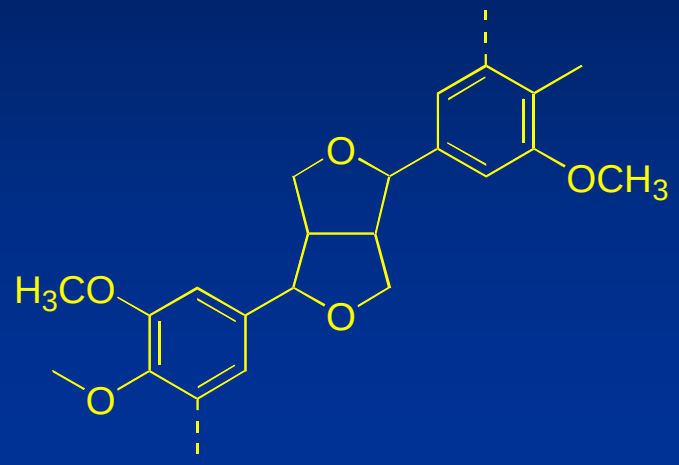


β-*O*-4

56%

α-*O*-4

23%



β-β + γ-*O*-α

(Pinoresinol/Seringaresinol)

10%

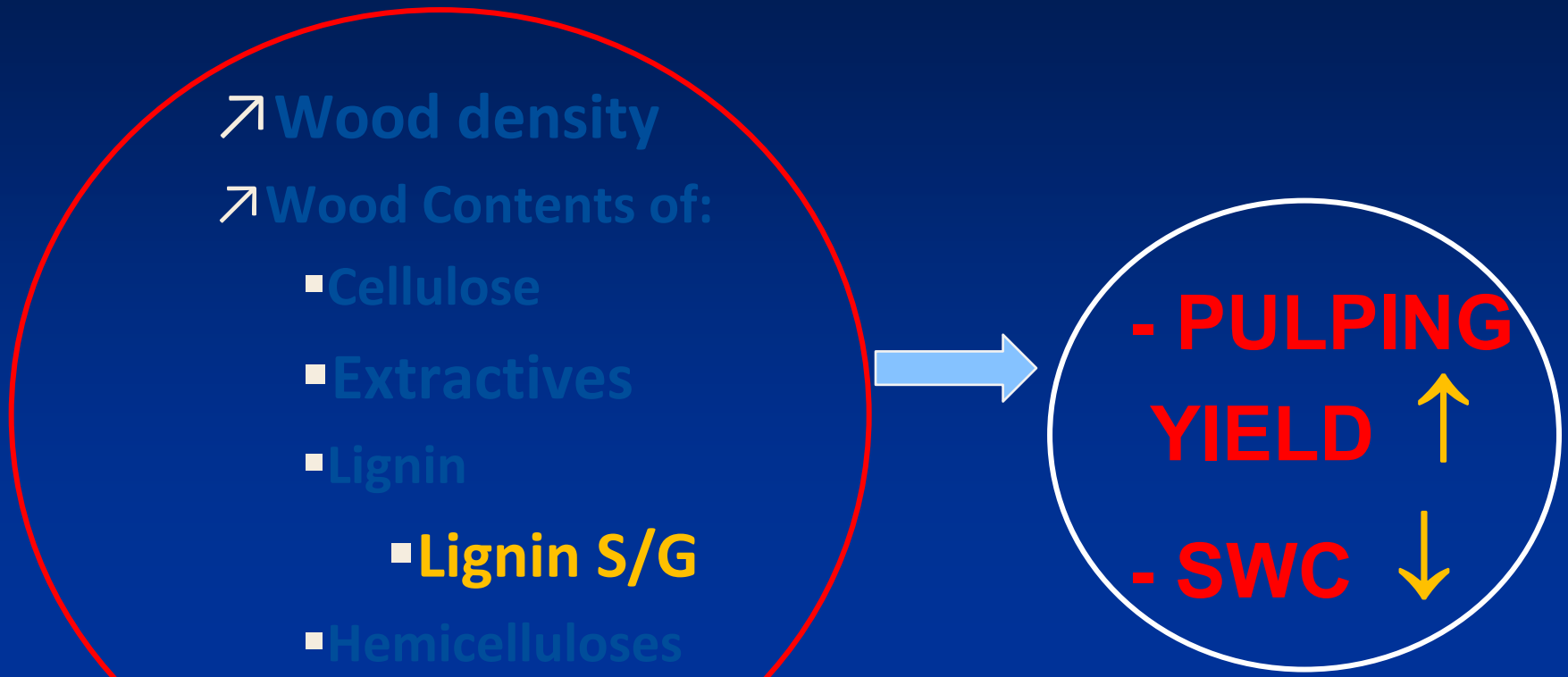
Evtuguin, D.V. et al. J. Agric. Food. Chem., 49, 4252-4261, 2001.

Conclusions: Lignin

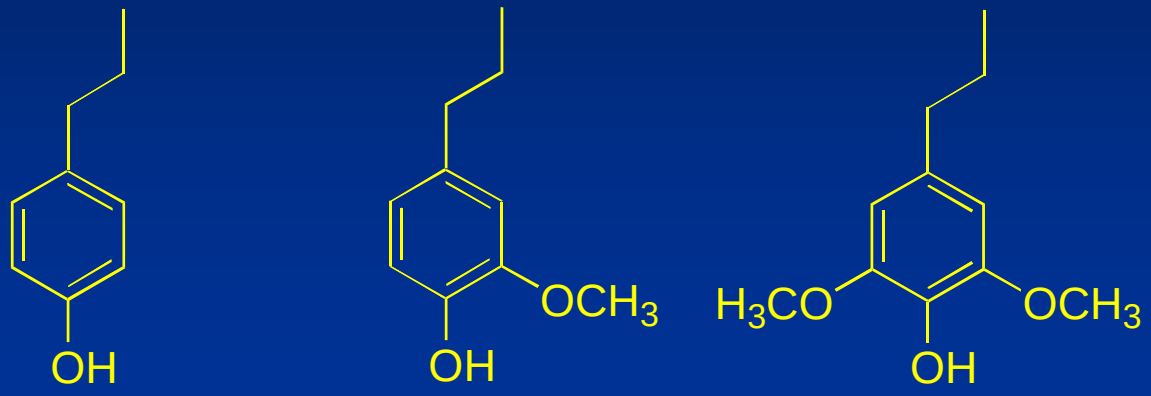
- For wood samples of similar densities, extractive contents and S/G ratios, lignin correlates significantly with pulping yield (negatively) and effective alkali demand (positively)

- Overall, one should strive for low lignin contents, if fiber line yield is main priority

Wood Quality Traits



Molar Proportion of *Eucalyptus globulus* basic structural Units



H: 2-3%

G: 12-18%

S: 80-86%

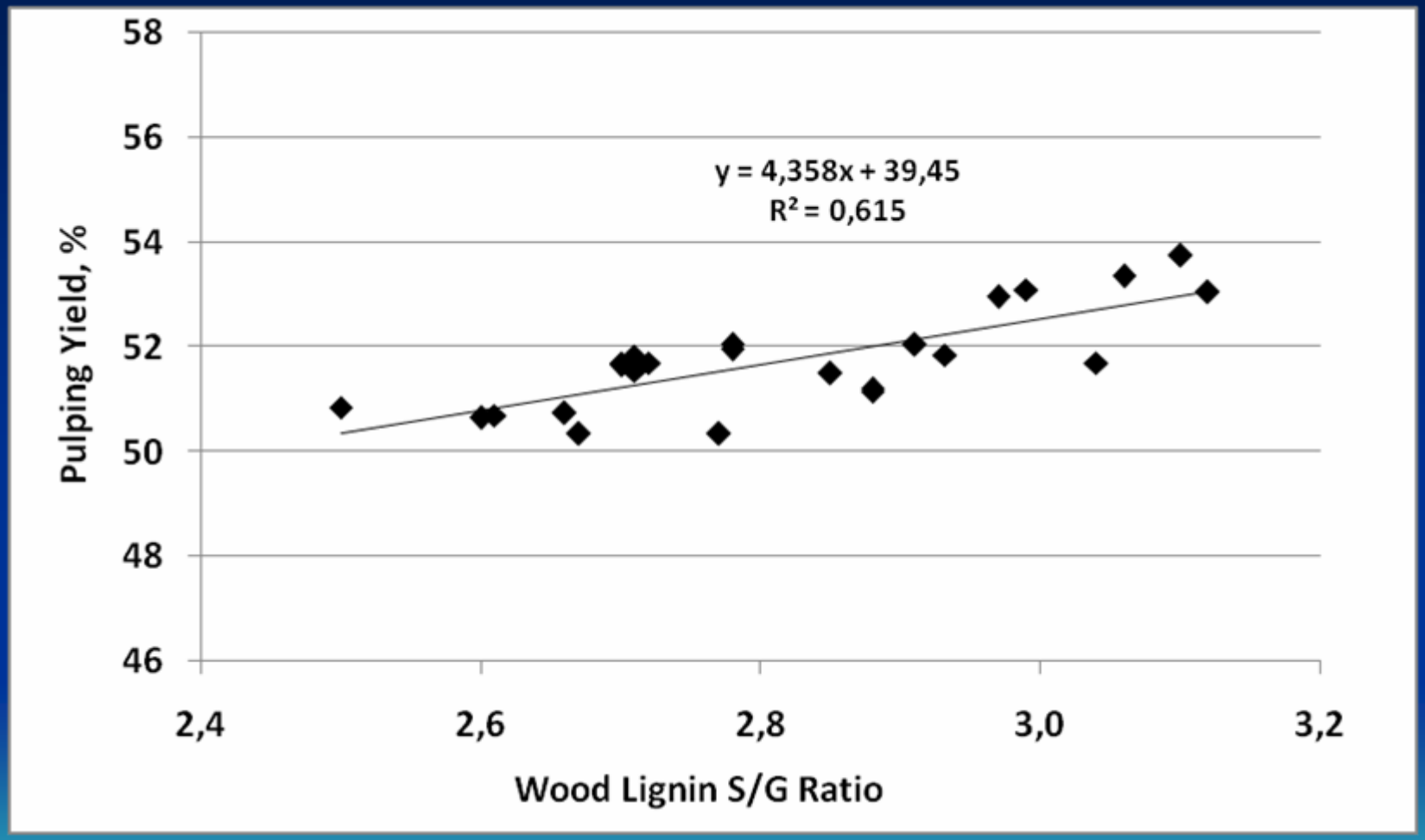
H: *p*-Hidroxyphenilpropane

G: Guaiacylpropane

S: Syringylpropane

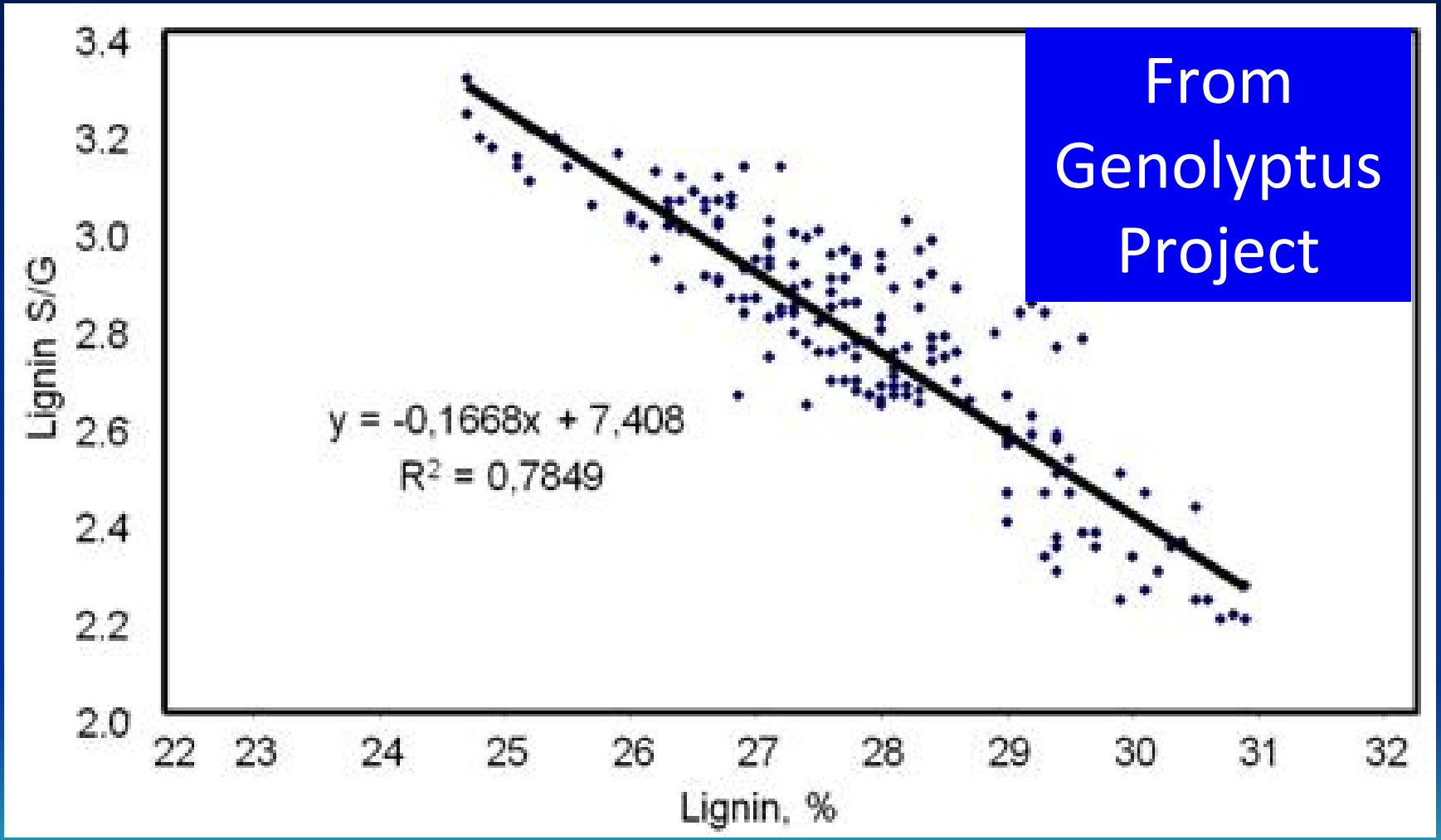
Evtuguin, D.V. *et al. J. Agric. Food. Chem.*, 49, 4252-4261, 2001.

Effect of lignin S/G ratio on pulping yield at kappa 17 for twenty four three-year old *Eucalyptus urograndis* wood samples.



Source: Gomes & Colodette (10).

Relationship between wood lignin content and syringyl/guaiacyl ratio for 100 samples of three-year old *Eucalyptus urograndis*



Source: Colodette et al. (20).

Conclusions: Lignin S/G

- For wood samples of similar densities, extractive contents and lignin contents, S/G correlates positively with pulping yield
- Lignin S/G ratio correlates negatively with wood lignin content
- Overall, one should strive for high lignin S/G

Wood Quality Traits

- ↗ Wood density
- ↗ Wood Contents of:
  - Cellulose
  - Extractives
  - Lignin
    - Lignin S/G
  - Hemicel. (xylans)
  - Uronic Acids

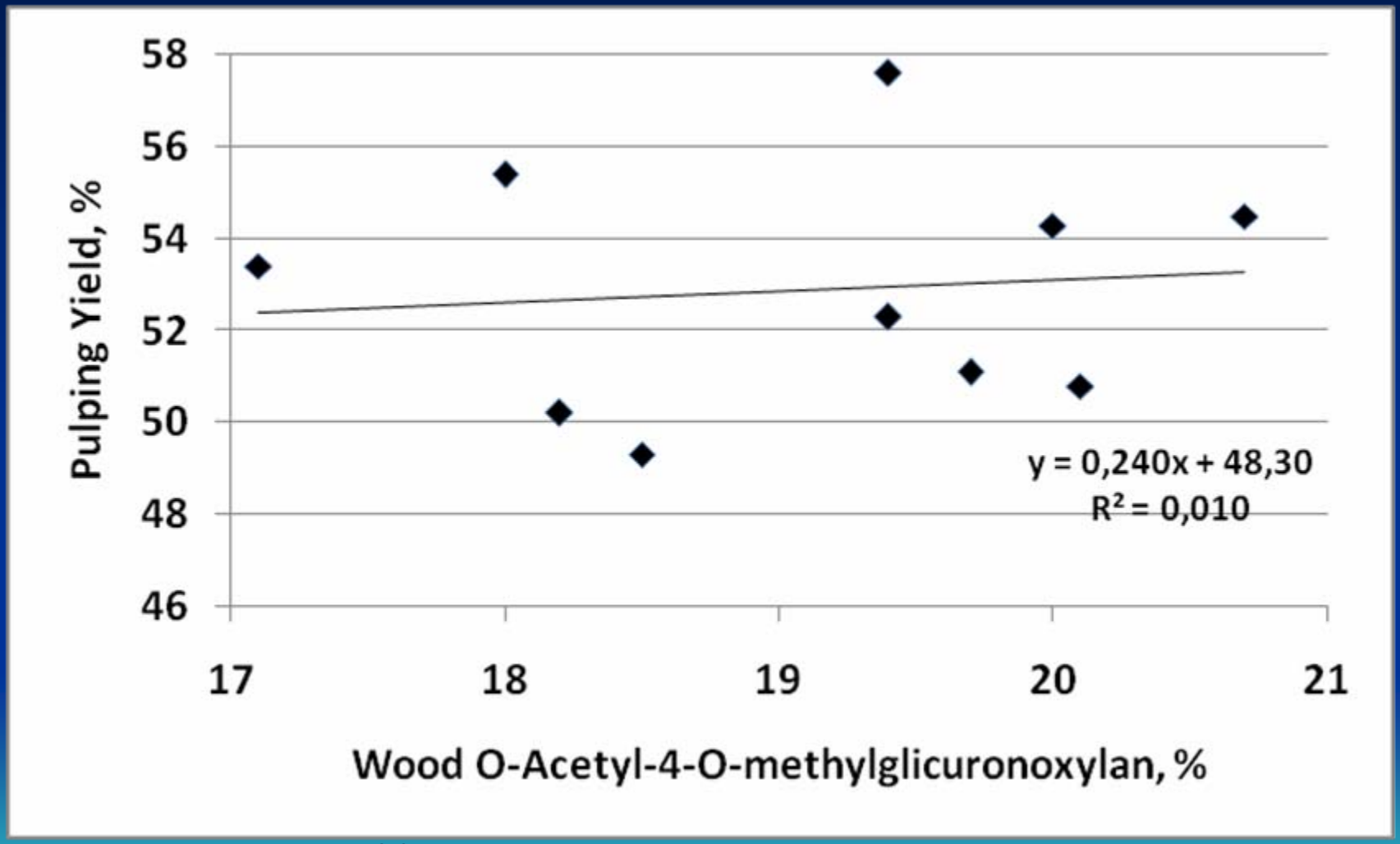
- PULPING YIELD ↑
- SWC ↓

Distribution of eucalyptus wood O-acetyl-4-O-methyglicuronoxylans xylans after kraft pulping to kappa 17, expressed in % of wood original value

Wood Species	Xylans, % of original wood		
	Pulp	Black Liquor	Degraded
E. dunni	51.3	7.3	41.4
E. globulus	54.1	7.7	38.2
E. grandis	57.3	6.9	35.8
E. nitens	52.6	4.0	43.4
E. urograndis	49.7	6.4	44.1
E. urophylla	58.7	7.5	33.8

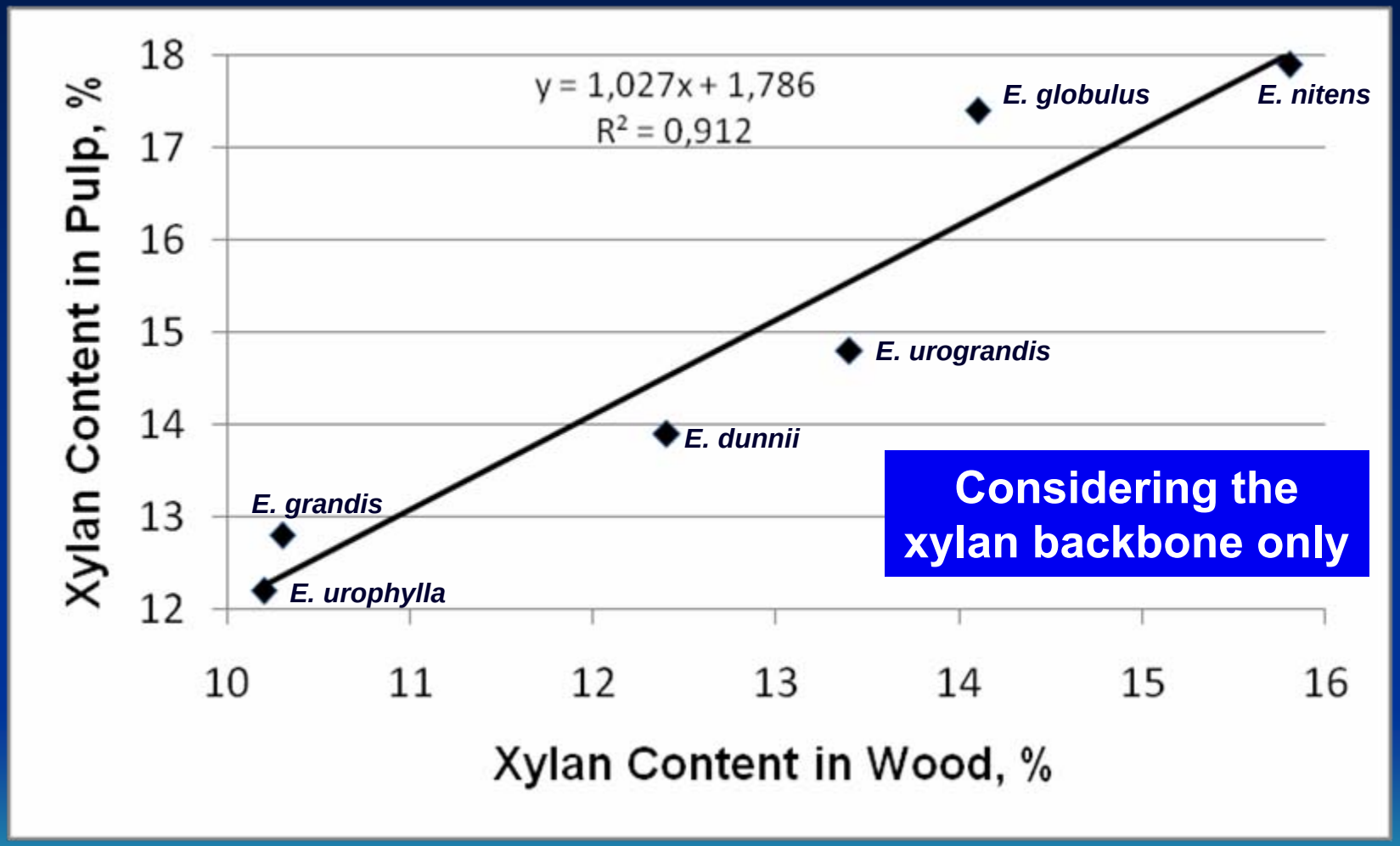
Source: Magaton & Colodette (5).

Effect of wood O-acetyl-4-O-methyl-glicuronoxylans content on pulping yield at kappa 18±0.5 for ten seven-year old clones



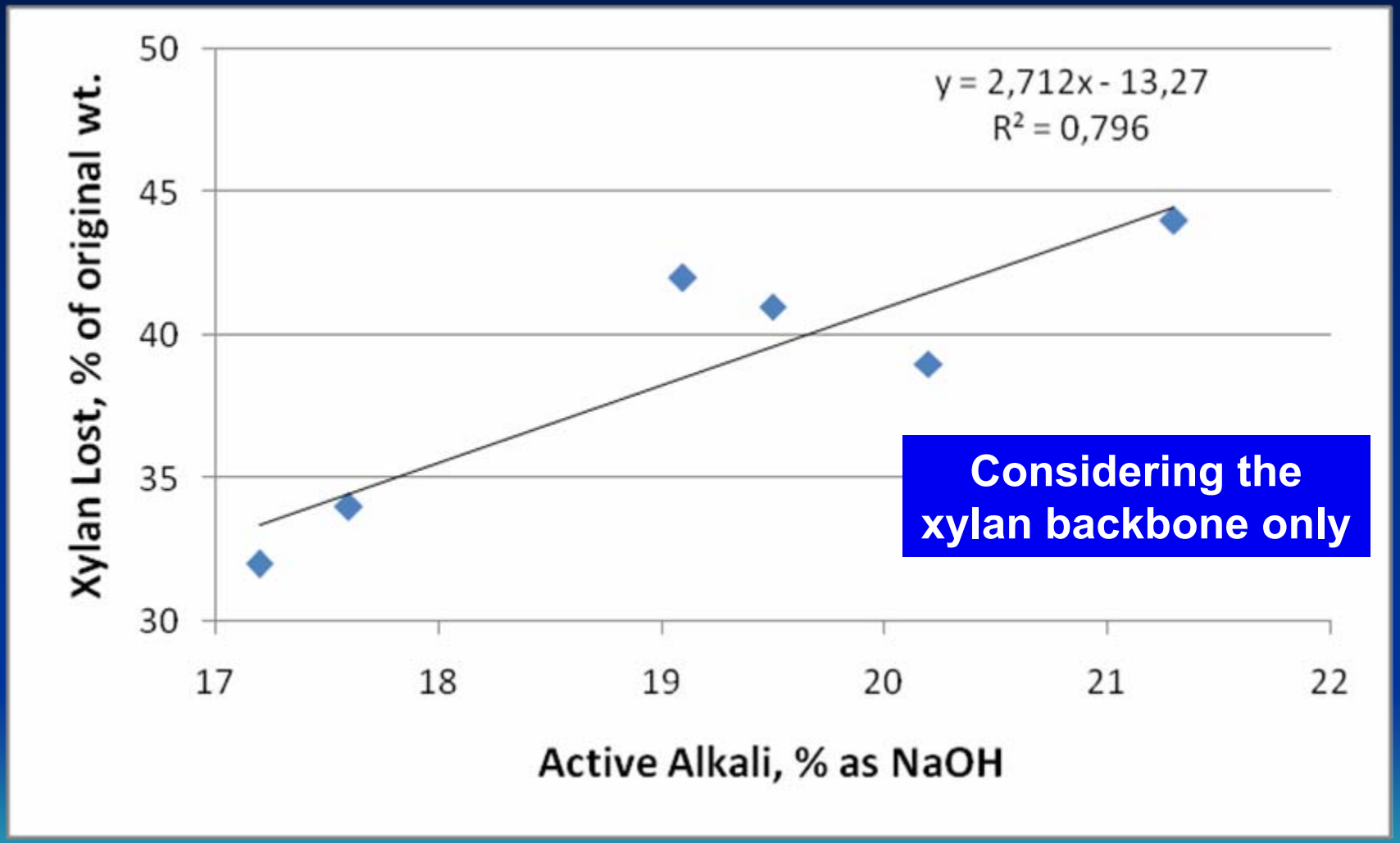
Source: Gomide & Colodette (8).

Effect of wood xylan content on kraft pulp xylan content for various eucalyptus species at kappa 17



Source: Magaton & Colodette (5).

Effect of active alkali dose on xylan degradation across pulping to kappa 17 for various eucalyptus species



Source: Magaton & Colodette (5).

Molar Ratio 4-O-MeGUA / 10 xyloses, in xylans from various eucalyptus species, measured by metanólise – GC/MS and ^{1}H NMR

Wood Species	4-O-MeGUA / 10 xyloses	
	Methanolysis – GC/MS	^{1}H NMR
E. dunni	1.5	2.1
E. globulus	1.7	2.6
E. grandis	2.2	2.8
E. nitens	1.4	2.1
E urograndis	1.3	1.9
E. urophylla	2.0	2.6

Source: Magaton & Colodette (5).

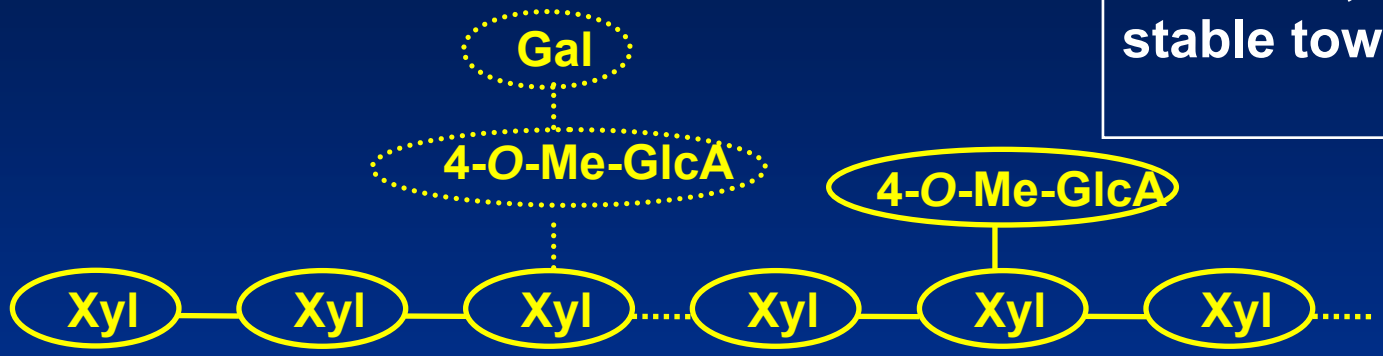
Molar Ratio between O_2 Substituted 4-O-MeGUA / Total 4-O-MeGUA , in xylans from various eucalyptus species, measured by ^1H NMR

Wood Sample	4-O-MeGUA/ 10 xyloses (mol/mol)	O_2 Substituted 4-O-MeGUA/ 10 xyloses (mol/mol)	O_2 Substituted 4-O-MeGUA / Total 4-O-MeGUA , %
E. dunni	2.1	0.40	19
E. globulus	2.6	0.44	17
E. grandis	2.8	0.64	23
E. nitens	2.1	0.19	9
E. urograndis	1.9	0.19	10
E. urophylla	2.6	0.68	26

Source: Magaton & Colodette (5).

Eucalyptus Special Xylan

Eucalyptus xylans possess galactose /glicose side chains, unusually high uronic acid contents, and are reasonably stable towards kraft pulping



- [β-D-Xyl*p*]-(1→4)-[β-D-Xyl*p*]$_7$-(1→4)-[β-D-Xyl*p*]$_{79}$-(1→4)-[β-D-Xyl*p*]$_3$-(1→4)-[β-D-Xyl*p*] -

2 ↑ 1 4-*O*-Me-α-D-Glc*p*A

2 ↑ 1 4-*O*-Me-α-D-Glc*p*A

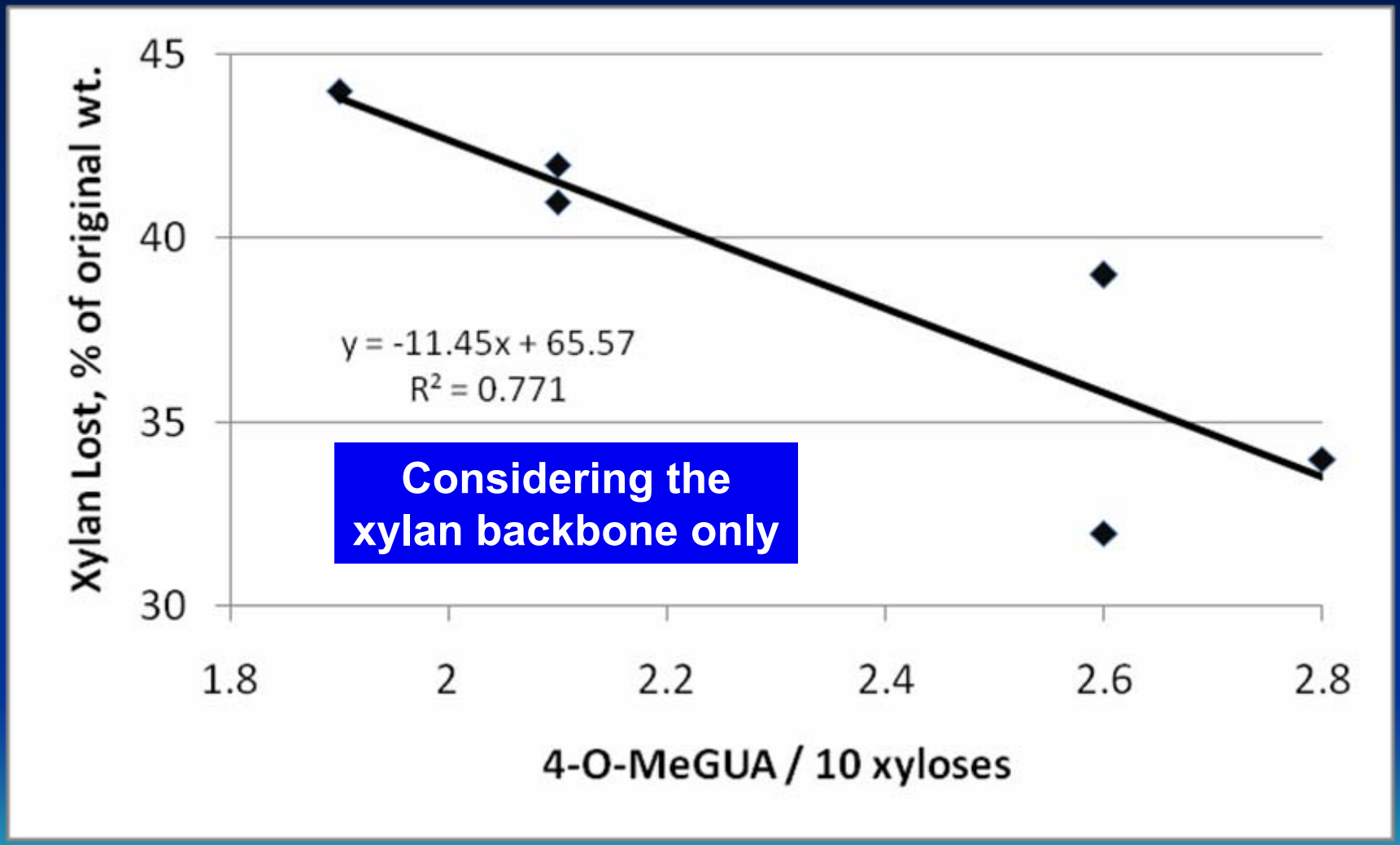
2 ↑ 1 α-D-Gal*p*

O_2 Substituted 4-O-MeGUA

2-*O*-α-D-galactopiranosyl-4-*O*-methyl-α-D-glucurono)-D-xilan

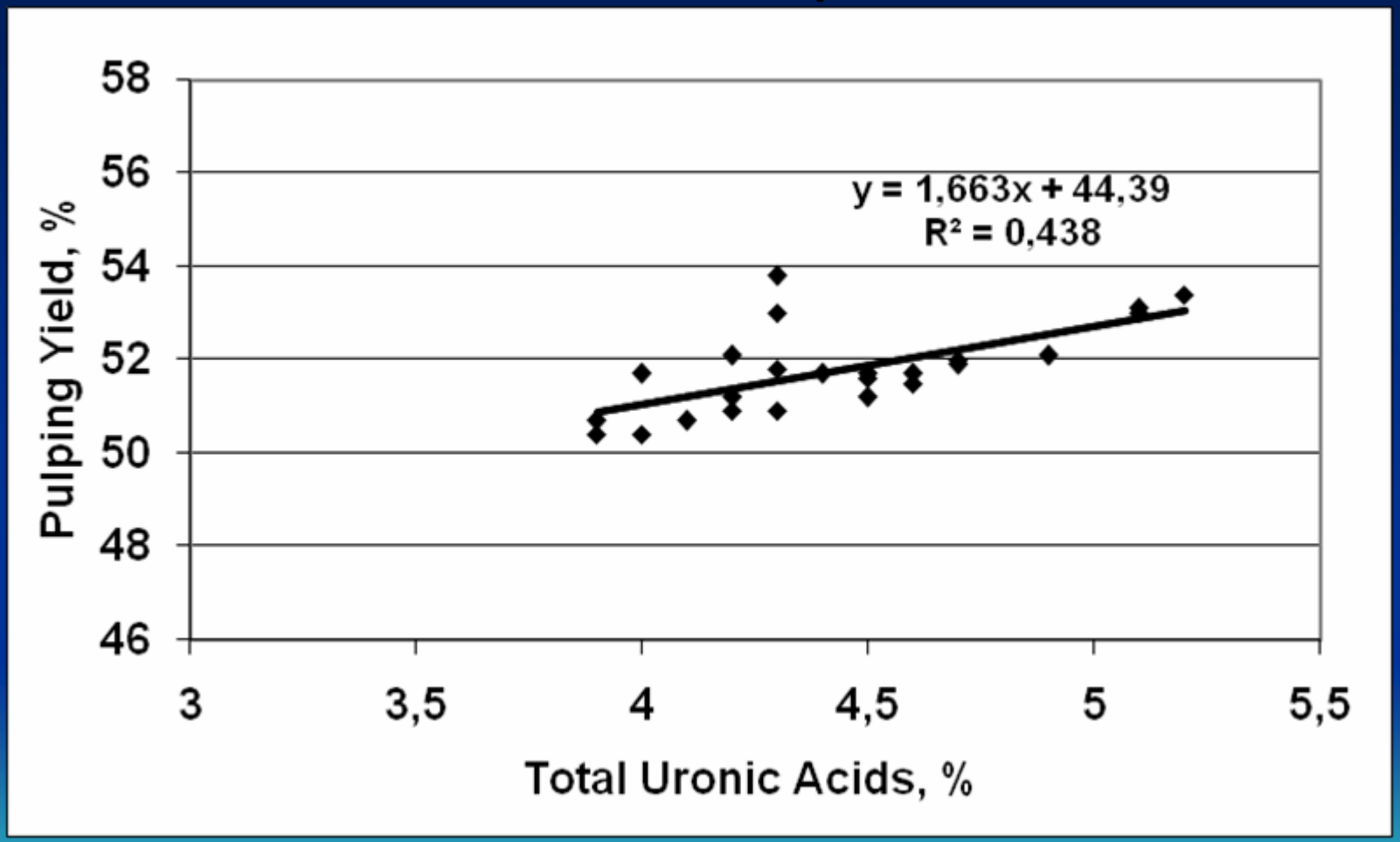
Shatalov, A. A. et al. Carbohydrate Research, 320, 93-99, 1999.

Effect of 4-O-MeGUA content on xylan degradation across pulping to kappa 17 for various eucalyptus species



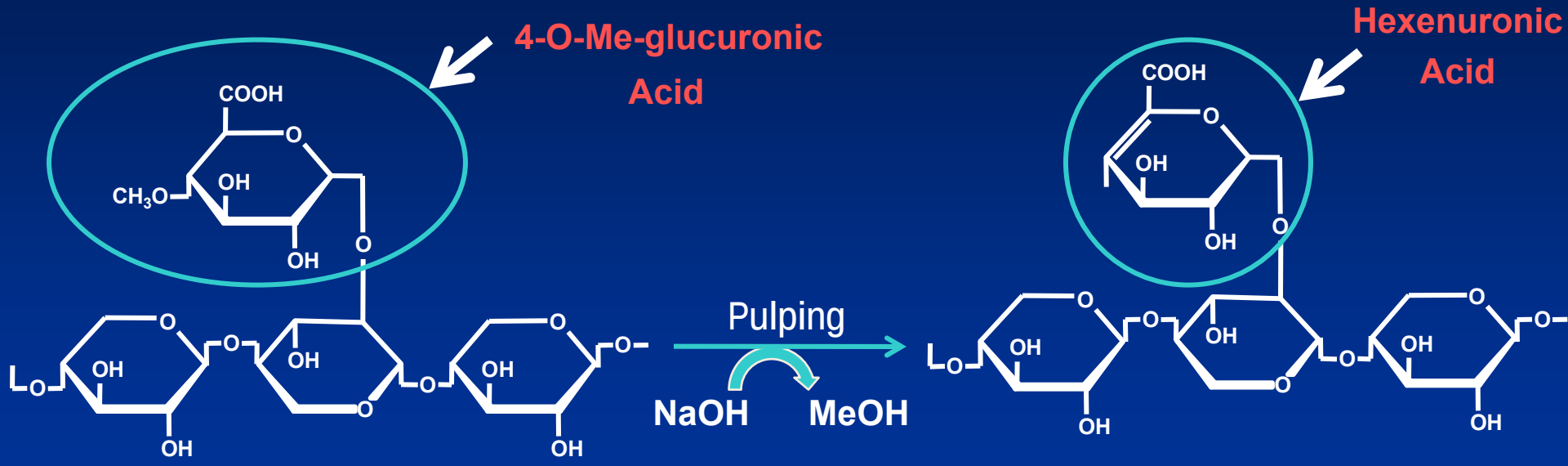
Source: Magaton & Colodette (5).

Effect of wood total uronic acid content on pulping yield at kappa 17 for twenty four three-year old *Eucalyptus urograndis* wood samples



Source: Gomes & Colodette (10).

Eucalyptus has twice as much uronic acids compared to northern HWD



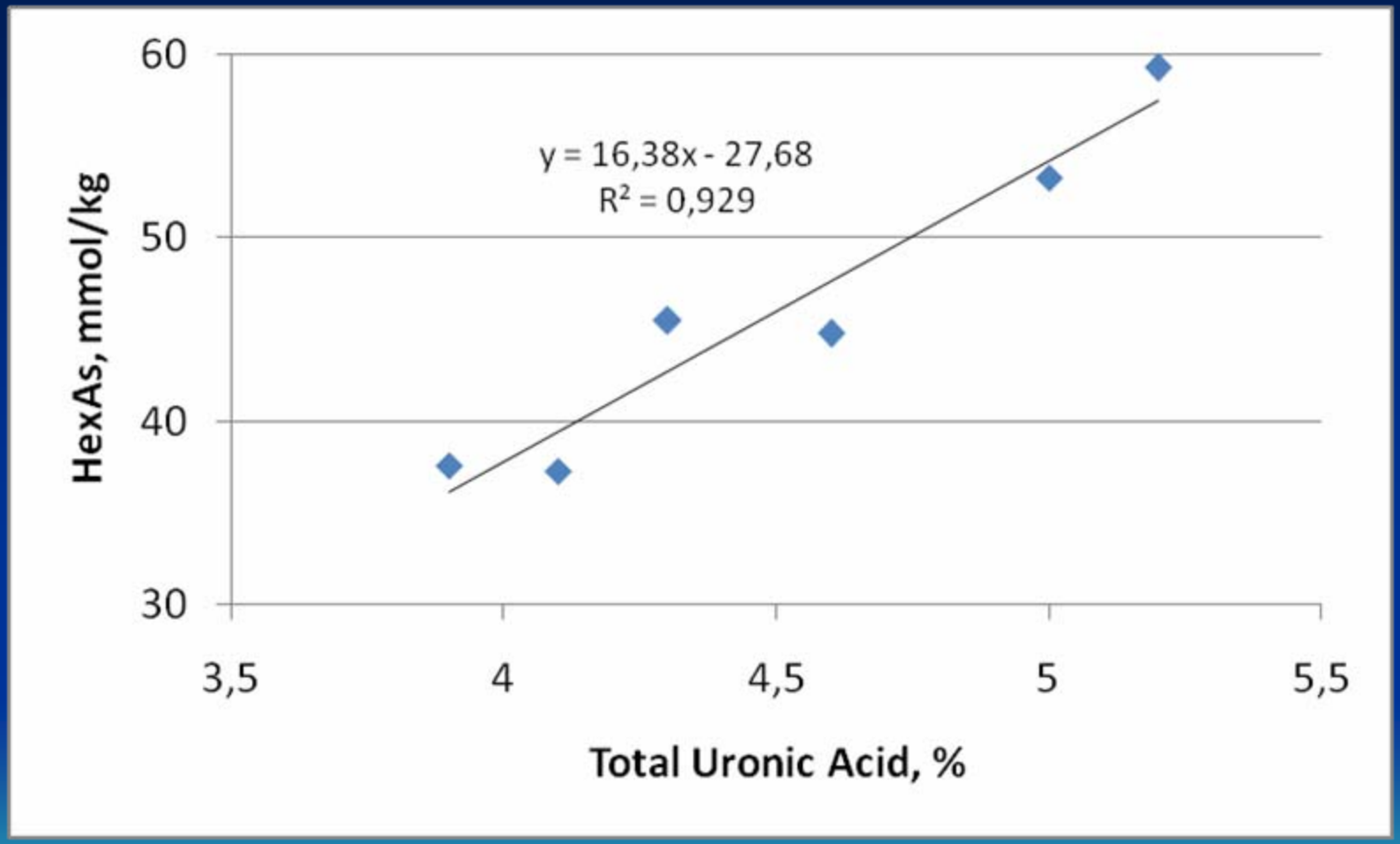
4-O-Me-glucuronic Acid

—Xil— Xil— Xil—

Hexenuronic Acid

—Xil— Xil— Xil—

Effect of uronic acid content on HexAs generation/degradation across pulping to kappa 17 for various eucalyptus species



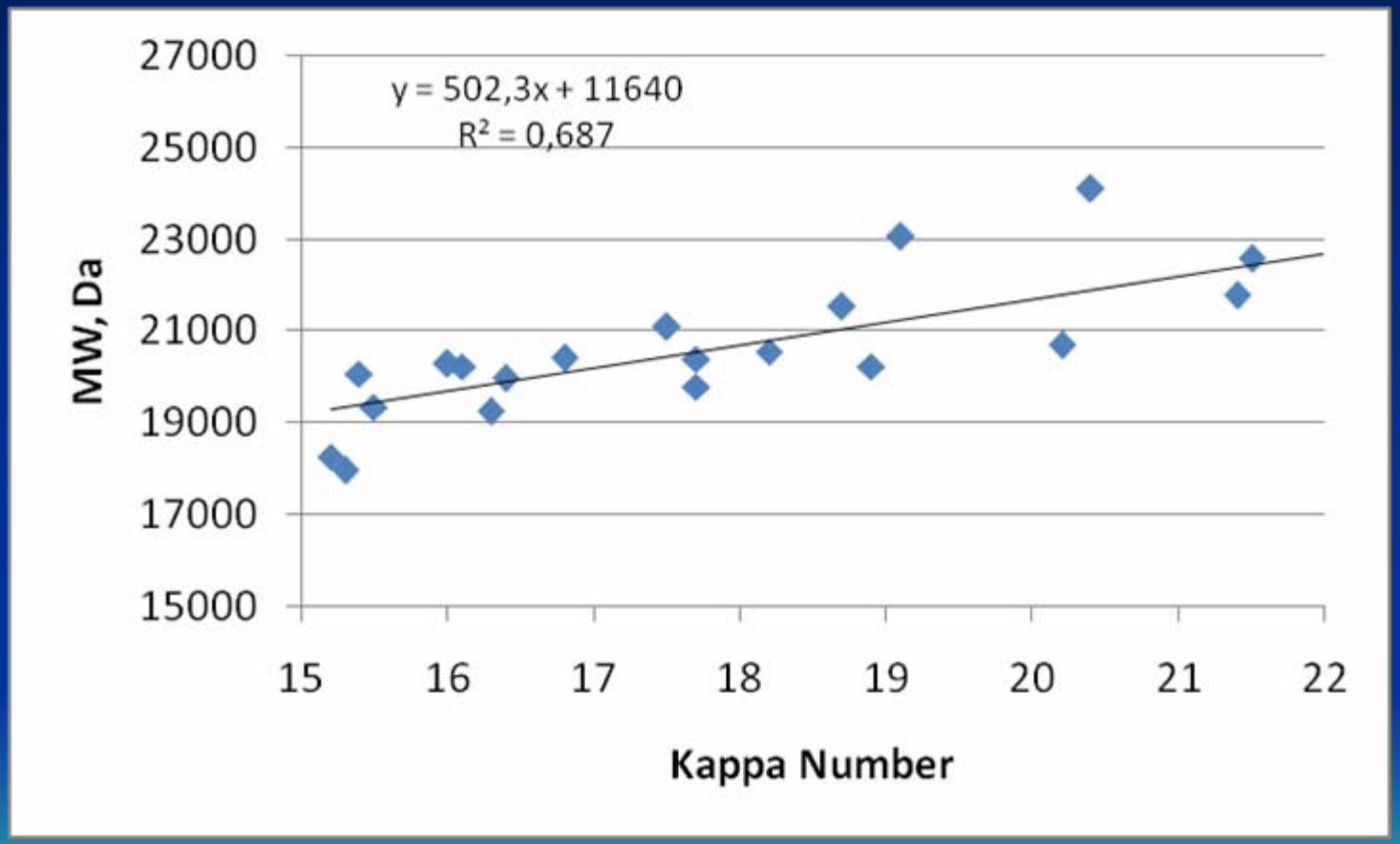
Source: Magaton & Colodette (5).

MW (kDa) of xylans in the wood and in the corresponding kraft pulp: harvesting age eucalyptus clones of various origins cooked to kappa number 17 [5]

Species	Wood	Kraft Pulp*	Black Liquor
E. dunni	36.7	19.4	13.4
E. globulus	33.0	19.6	14.3
E. grandis	37.9	20.9	14.7
E. nitens	33.2	19.8	13.8
E. urograndis	34.9	19.9	14.3
E. urophylla	39.4	21.1	18.1

* Two fractions: 70-80% (23-25 kDa) and 20-30% (6-7 kDa)

Effect of pulp delignification degree (Kappa No.) on pulp xylan molecular weight (kDa) : harvesting age eucalyptus clones of various origins cooked to kappa number 15-22



Higher MW xylans are more desirable to improve pulp properties

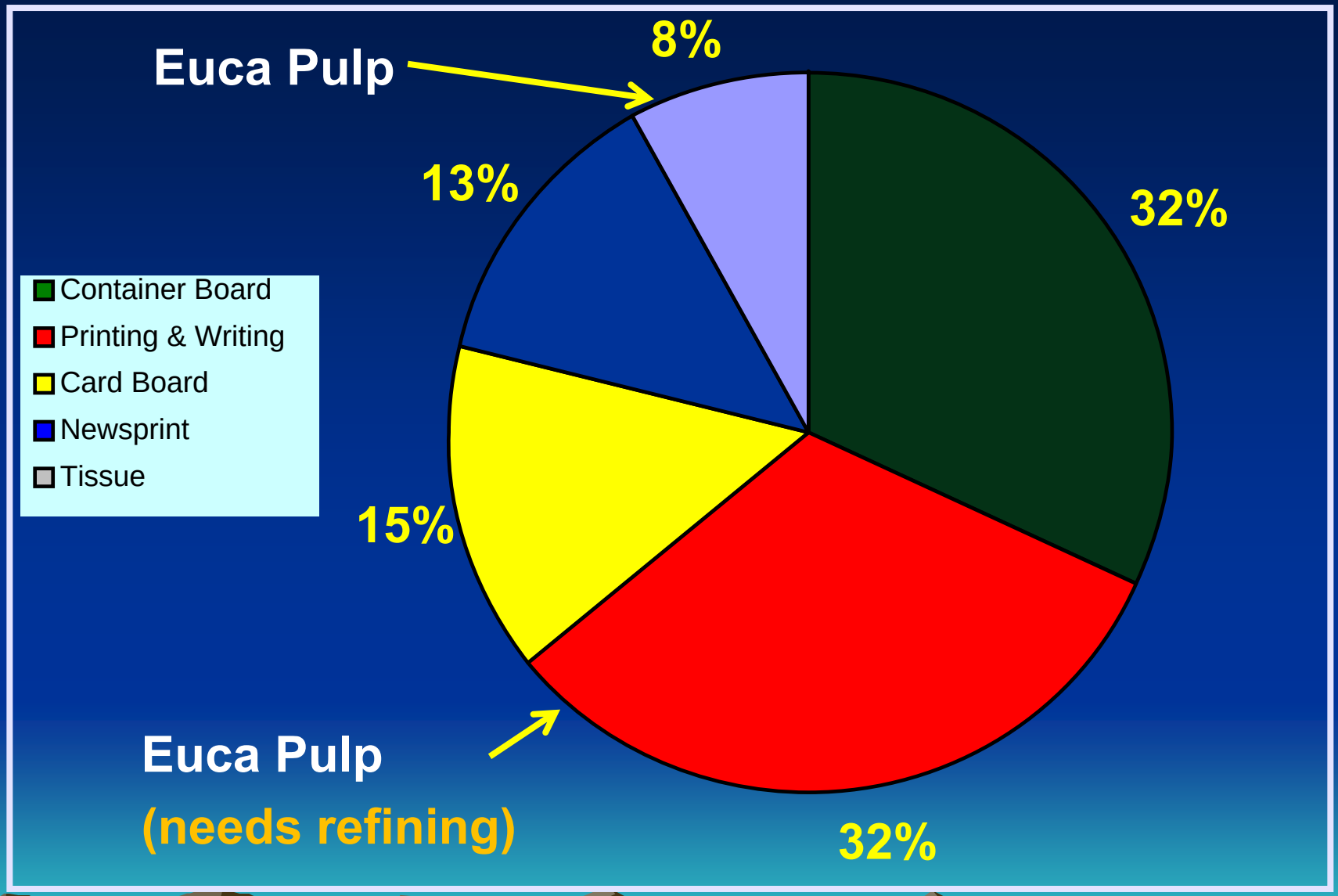
Source: Magaton & Colodette (5).

Conclusions: Xylans/ Uronic Acids

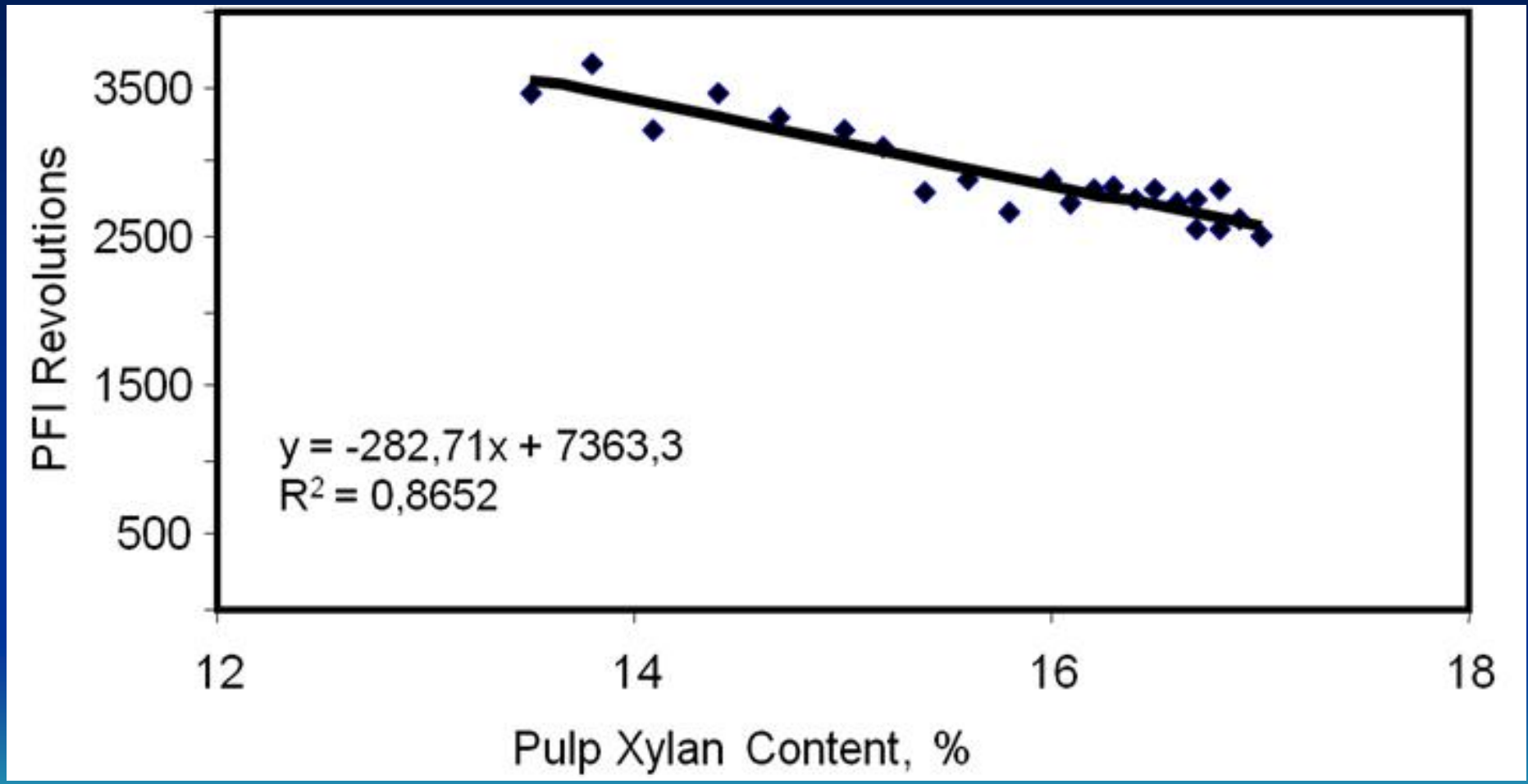
- Brazilian grown eucalyptus have low xylan content, but they are rich in uronic acid (2-2.5/10 xyloses) and reasonably stable towards kraft pulping as compared to northern HWDs
- Xylan MW in the wood is in the range of 30 kDa and decreases to about half of that after pulping to kappa 17. Pulp xylan MW increases with increasing kappa no.
- High xylans in the wood means high xylans in the pulp, but xylans are very sensitive to EA dosed during pulping
- Overall, one should strive for high xylans and uronic acids in the wood, but cook the wood properly.

Pulp Refinability and Drainability

World Paper Production



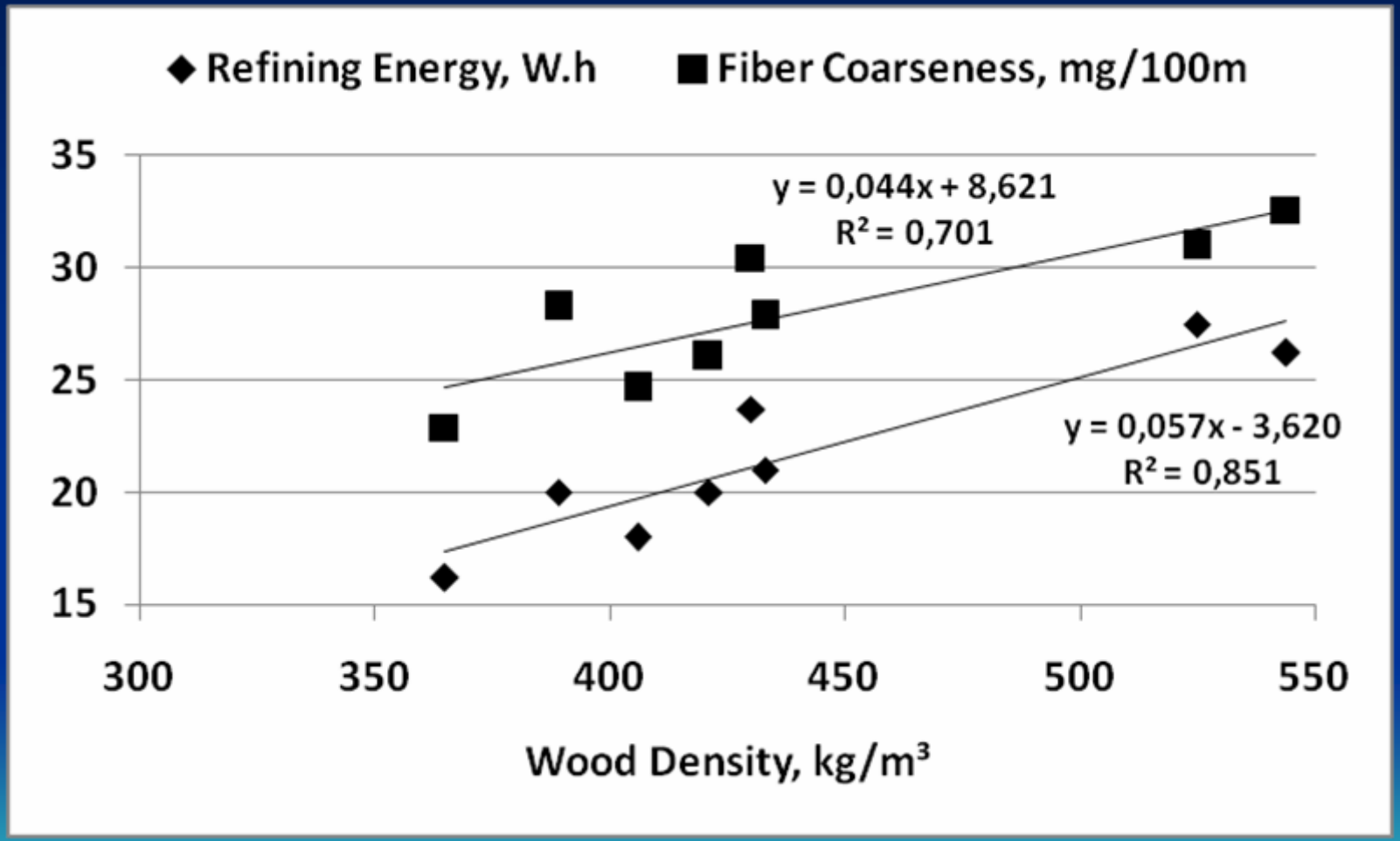
Effect of pulp xylan content on energy demand to achieve 70 N.m/g tensile index. Twenty four three-year old *Eucalyptus urograndis* wood samples cooked to kappa 17 and ECF bleached to 90% ISO brightness.



Source: Gomes & Colodette (10).

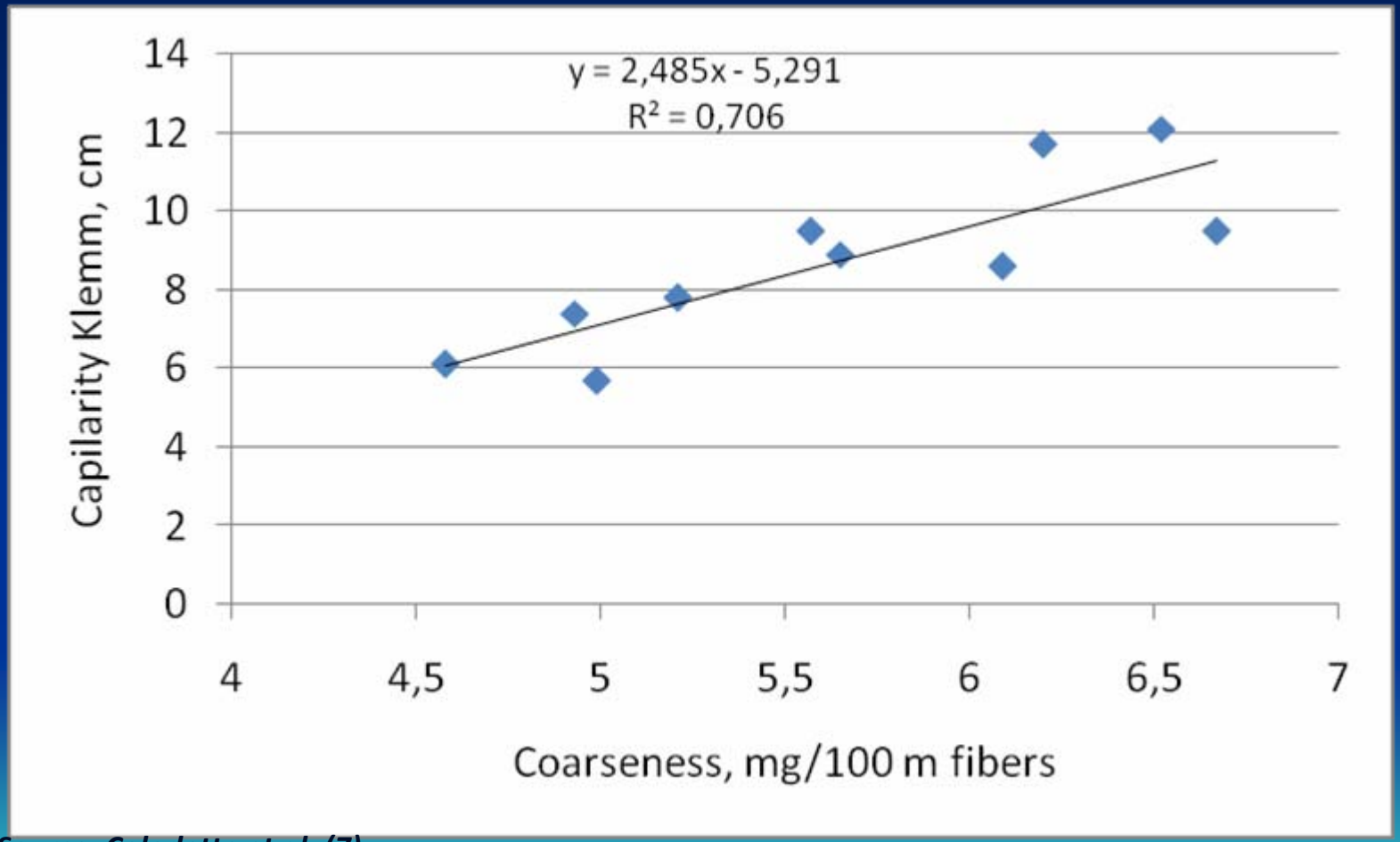
“At 70 N.m/g tensile, an increase in pulp xylan content from 13.5 to 17% decreased energy demand by 28%, which signifies about 8% energy savings per one percent xylan increase”

Effect of wood density on bleached pulp fiber coarseness and refinability to 30 ºSR. Eight harvesting age eucalyptus wood samples cooked to kappa 17-18 and ECF bleached to 90% ISO brightness



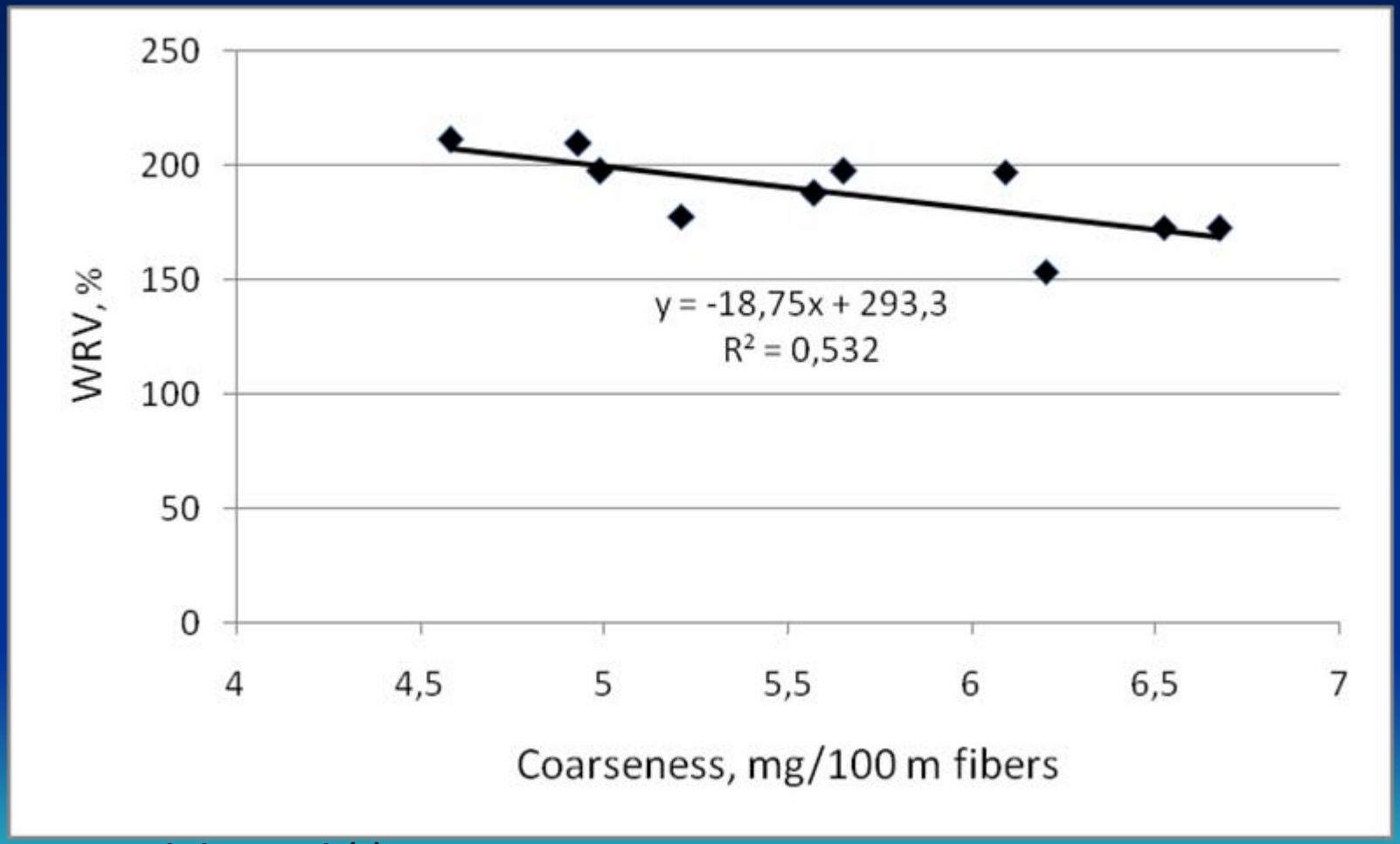
Source: Colodette et al. (7).

Effect of wood fiber coarseness on capilarity Klemm (unrefined pulp). Eight harvesting age eucalyptus wood samples cooked to kappa 17-18 and ECF bleached to 90% ISO brightness



Source: Colodette et al. (7).

Effect of wood fiber coarseness on WRV (unrefined pulp). Eight harvesting age eucalyptus wood samples cooked to kappa 17-18 and ECF bleached to 90% ISO brightness



Source: Colodette et al. (7).

Conclusions: Refinability / Drainability

- Refinability improves with increasing pulp xylan content and decreasing fiber coarseness, with the opposite being observed for drainability

- Increasing pulp xylan content is desirable, but decreasing fiber coarseness is questionable since it means use of lower density woods and poorer drainability in the paper machine (hampers throughput)