Architecture of Sugar Maple wood components at branching points

Sharad K Baral[1] Robert Schneider[1], David Pothier[2], and Frank Berninger[3]*

[1]Université du Québec à Rimouski, Département de biologie, chimie et géographie (QC), Canada

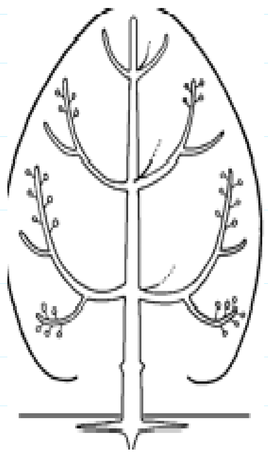
[2]Université Laval, Département des sciences du bois et de la forêt, (QC), Canada

[3]University of Helsinki, Department of Forest Sciences, Helsinki, Finland

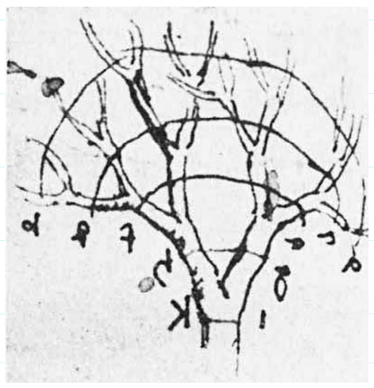
Introduction

If the branching of sugar maple follow:

Rauh's Model(1,2).

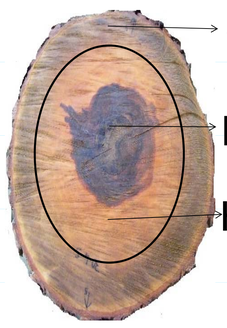


Leonardo's area preserving rule (3,4)



Then, how do the wood structure components branch?

Wood structure components

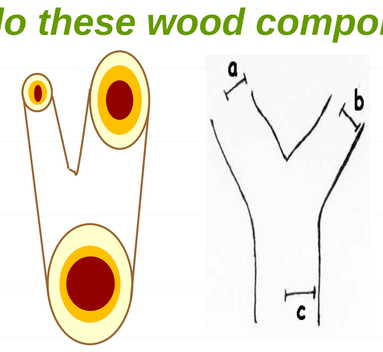


Sapwood: Functional

Discolored wood: injury initiated

Heartwood: White colored but non-functional

How do these wood components scale?



Leonardo's area preserving rule:

$$c^2=a^2+b^2$$

Area under node= $\sum_{i=1}^{n} A_i$

(sum of the basal area of all the branches above the node)

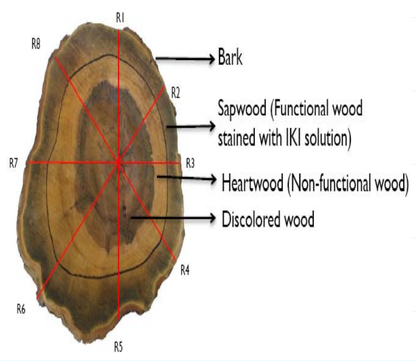
Methods

- A purposive sample of 30 trees was collected from Duchesnay, Québec
- Tree and branch characteristics were measured
- Disks were collected from the 119 nodes (above and below) and at the branch base

Descriptive statistics of sample

Tree/branch characteristics	Mean	Range Max	Range Min
Tree			
DBH (mm)	383	235	585
Height (m)	21.2	17.5	25.4
Age (years)	105	74	143
Branch			
Basal diameter (mm)	98	10	317
Length (m)	4.97	0.98	14.3
Insertion height (m)	14.9	5.1	22

Disk collection



Measurement

Results

Seemingly unrelated regression:

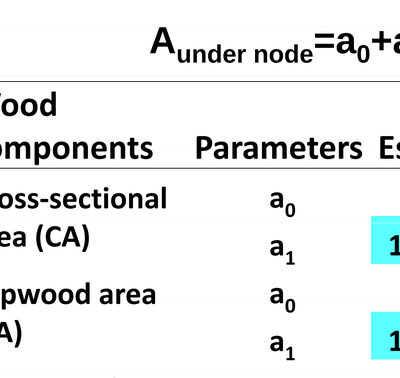
$$A_{\text{under node}}=a_0+a_1\times\Sigma A_{\text{above node}}$$

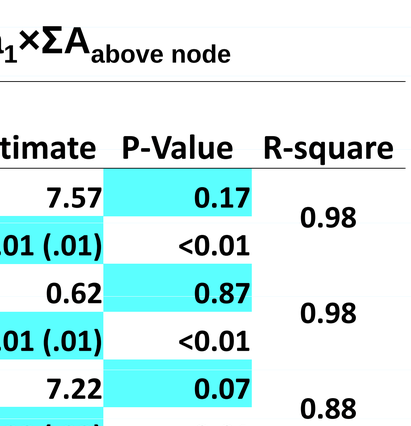
Wood components	Parameters	Estimate	P-Value	R-square
Cross-sectional area (CA)	a_0	7.57	0.17	0.98
	a_1	1.01 (.01)	<0.01	
Sapwood area (SA)	a_0	0.62	0.87	0.98
	a_1	1.01 (.01)	<0.01	
Heartwood area (HA)	a_0	7.22	0.07	0.88
	a_1	0.98 (.02)	<0.01	
Discolored wood area (DA)	a_0	7.04 (3.5)	0.04	0.74
	a_1	0.91 (.03)	<0.01	

For CA, SA and HA: a_0 =0, and $a_1 \approx 1$

For DA: $a_0 \neq 0$, and $a_1 \neq 1$

- Positive correlation between discolored wood area and heartwood area at the branch base





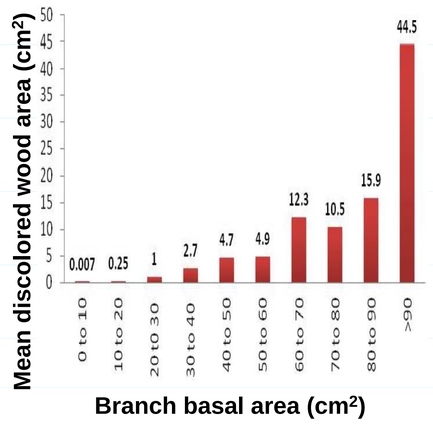
Results contd…

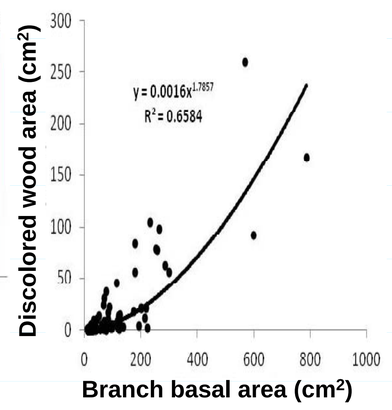
- Total heartwood area at branch base:
  - branch length
  - branch slenderness

Total heartwood area at branch base
$=a_0+a_1\times BL+a_2\times (BL/BD)$

Variables	Estimate	SE	P-value	Adj. R-square
Branch length (BL, m)	9.44	1.12	<0.01	0.41
(BL/BD (mcm^{-1})	-31.87	6.67	<0.01	

- In general, the branches > 35 mm diameter (BBA>10 cm2) started to have discoloration at branch base
- Discolored wood area at branch base increased non-linearly with increasing branch basal area





Conclusions

- **Area preservation on branching** of total cross-sectional, sapwood and heartwood areas indicate that this is the **optimal strategy of sugar maple, a shade tolerant angiosperm, for light capture, water transport and mechanical support** (5,6).
- Discoloration is **injury initiated** and it needs **non-functional wood to be expanded**. Thus, discolored wood branching might not follow any rule although it is highly correlated to heartwood (non-functional wood) area.
- In general, **commencement of discoloration in branches succeed heartwood formation**. Shaded, shorter and thicker branches likely have more heartwood area at branch base. Then, the discoloration increases non-linearly with branch basal area over time.

Objectives

- To explain sapwood, heartwood and discolored wood architecture at branching points along the main stem of sugar maple trees
- To develop a model to predict discolored wood area at the first order branch base

Acknowledgements

[1] Fonds de recherche du Québec-Nature et technologies (FQRNT) for financial support
[2] Filip Havreljuk, Université Laval , support for field work and sampling design
[3] CRB Lab, Université Laval for the support on sample processing

Correspondence

sharadbaral@gmail.com

UQAR, Département de Biologie, Chimie et Géographie, Aménagement et sylviculture

References

[1] Hallé, F. R. A., Oldeman, A. and Tomlinson, P. B. 1978. Tropical trees and forests: An architectural analysis. Springer-verlag.

[2] Raulier, F., Ung. C. H. and Bégin, J. 1998. Analytical estimation of branchwood volume in Sugar Maple linked to branchiness. Trees 12:395-405.

[3] Arastu, R. 1998. Trees conserve cross-sectional area despite vessel structure. Journal of young Investigators 1 (1).

[4] Bentley, L. P., Stegen, J. C., Savage, V. M., Smith, D. D., vonAlmen, A. I., Sperry, J. S., Reich, P. B. and Enquist, B. J. 2013. An empirical assessment of tree branching networks and implications for plant allometric scaling models. Ecology letters 16:1069-1078.

[5] Tomlinson, P. B. 1983. Tree architecture. American Scientists 71: 141-149.

[6] Fransworth, K. D. and Niklas, K. J. 1995. Theories of optimization, form and function in branching architecture in plants. Functional Ecology 9 (3):355-363.