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Technical Note

Silviculture

What Size of Tree Should We Grow for Timber Production?

INTRODUCTION

Market value of a tree depends on species, tree size (diameter and bole length), and stem quality (tree form and vigour). Type of products (e.g., sawtimber, pulpwood...) or product combination that can be recovered from a tree is mainly related to tree size (i.e. DBH= diameter at breast height). Hardwoods in New Brunswick are considered merchantable for pulpwood when DBH \geq 10cm and for sawlogs when DBH > 20cm. Generally, larger trees are more valuable because: (1) high-value product recovery (per m³ of wood) increases and (2) timber processing cost (\$/m³) decreases with tree size up to a certain DBH. Once trees reach a certain diameter, growth rate (Baral et al. 2016) and individual tree quality (Danyagri et al. 2017) start to decline. Less vigorous and poor quality trees are associated with larger proportions of wood discolouration (Baral et al. 2013) and decay (Frank et al. 2018). As a result, after a certain diameter limit, product recovery and tree value will not increase any further (Havreljuk et al. 2014, Girouard 2015).

Therefore, it is important to know what size a tree should be grown for better utilizing the timber resources. Studies have shown that sugar maple (SM) and yellow birch (YB) trees can be grown up to a DBH of 60 cm (Eyre and Zilgitt 1953, Pothier et al. 2012) and beyond. However, it is important to assess whether this diameter limit applies or not to the tolerant hardwood stands of New Brunswick as such stands are located at the northern limit of temperate hardwood forests in North America. Thus, this document discusses biologically

HIGHLIGHTS

- It is recommended to grow hardwood trees up to 50cm DBH.
- Silviculture treatments do not affect growth of very large trees (DBH > 50cm) as such trees are generally less vigorous.
- Retaining trees having a DBH > 50cm is not beneficial for sawlog production as they possess more defects, thus are more likely to increase the proportions of decay and discoloration with increasing tree size.

meaningful tree size limit that can be grown for timber production based on the findings of tree growth and wood quality related studies for SM and YB trees grown in northwest New Brunswick.

SIZE-RELATED CHANGES IN TREE ATTRIBUTES

When trees grow, they add volume. However, growth is not constant in the life of a tree. Tree diameter (or basal area) grows slowly when trees are small (sapling stage). The diameter growth rate increases as trees reach pole and small-sawtimber size. Eventually, the diameter growth declines for large sawtimber sized trees (Figure 1). Similarly, merchantable height of the tree also increases as tree diameter also increases (Figure 3).

While trees increase their physical dimensions, logs in a tree would also change grade (upgrade) because the logs might meet minimal diameter criteria of a better grade log (e.g. from F3 to F2). However, there is a minimal change in merchantable bole length and log grade when trees grow from medium sawtimber (DBH of 40cm to 48cm) size to large sawtimber (DBH of more than 48cm) sized trees (Table 1). Several studies indicated that tree vigor and stem quality declines in larger trees (DBH of more than 48cm) (Baral et al. 2016; Danyagri et al. 2017). In such trees, discolouration and decay proportion increases rapidly (Baral 2015). This will eventually lead to a reduction in high-grade product recovery and then, a reduction in timber value (\$/m³) (Havreljuk et al. 2014) (Table 2).

Table 1: Potential distribution of logs by grade for different sized sugar maple trees. A tree of good form and free from defect was assumed. Taper equation by Weiskittel and Li 2012 was used to generate the stem profile. Tree height was estimated using observed height-diameter relationship in northwest New Brunswick.

DBH (cm)	Potential sawlog bole length, (m) (d _{top} =20 cm)	Total merchantable bole length, (m) (d _{top} =9 cm)	Number of sawlogs(length=10 feet)	Maximum potential Product grade
< 20	0.0	9.9	0	Pulp
20 to 28	4.5	12.0	1	F3, Pulp
28 to 34	8.8	14.1	2	F2 or F3, F3, Pulp
34 to 40	11.5	15.6	3	F2, F3,F3, Pulp
40 to 48	13.5	16.9	4	F1, F1 or F2, F2,F3, Pulp
48+	14.0	17.1	4	F1, F1 or F2, F2,F3, Pulp

Table 2: Tree growth and stem property relation to tree size for major tolerant hardwood species

Tree attributes	Species	Tree and/or stem properties	Tree growth and stem property relation to tree size	Study site	Reference
Growth	SM, YB	Individual tree basal area increment (BAI)	⇒ BAI increases up to 40cm DBH, and then declines for larger trees ⇒ Growth response to partial cut for larger trees (DBH > 45cm) is minimal	Northwest New Brunswick, Canada	Baral et al., 2016
	SM, YB	Volume growth	Volume growth stabilizes in larger trees (DBH > 55cm).	Michigan, USA	Eyre and Zilgitt, 1953
Tree quality	SM, YB	Tree quality (Likelihood of being AGS)	Tree quality sharply declines in trees with DBH > 50cm.	Northwest New Brunswick, Canada	Danyagri et al., 2017
	SM, YB, OHW	Stem quality	Stem quality declines in larger trees (DBH > 60cm)	Quebec, Canada	Pothier et al., 2013
Discolouration and decay	SM	Discoloured wood proportions	Larger trees (DBH > 50cm) add more discoloured wood volume than clear wood volume	Quebec, Canada	Baral et al., 2013
	SM, YB, RM	Decay	High probability of having decay in larger trees (DBH > 50cm)	Northwest New Brunswick, Canada	Baral, 2015
Product recovery	SM, YB, RM	Sawlog recovery	Sawlog recovery declines in trees larger than 45 cm DBH	Northwest New Brunswick, Canada	Girouard, 2015
Value	SM, YB	Timber value / m ³	Timber value/m ³ sharply declines in trees with DBH > 50cm.	Quebec, Canada	Havreljuk et al., 2014

TREE SIZE LIMIT FOR SM AND YB

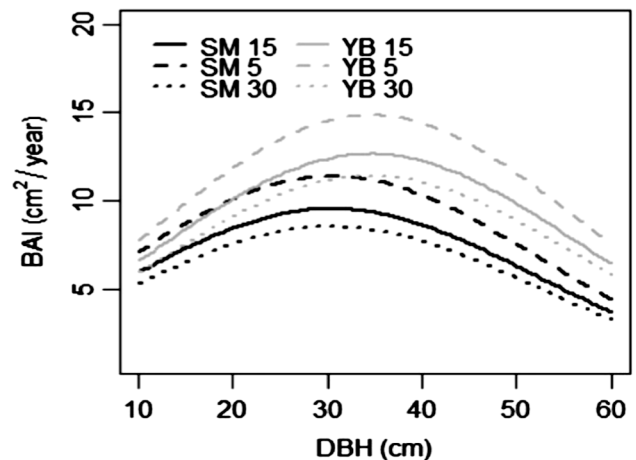
Case study: Tree value projection

Aim: To assess (1) change in total merchantable and sawlog volumes with tree diameter, and (2) change in tree value with unit change in tree diameter in order to explore the pattern of tree value increase with increasing tree size.

Data: The NHRI database and models (product recovery matrix, height-diameter, stem taper, and decay prediction models) were used to estimate total merchantable and sawlogs volumes for different diameter sugar maple trees. Tree value was estimated using stumpage value (sawlog = 112\$/m³ CND and pulpwood = 24\$/m³ CND) obtained from Maine Forest Service data published in 2017. Grade-value increase associated with increasing tree size, was not specifically reflected in the example. However, it is very relevant to the valuation process.

Result: For good quality trees, sawlog volume may increase up to 60cm DBH. However, tree value increment per unit change in tree size reached maximum at 45cm DBH (Figure 2A and 2B).

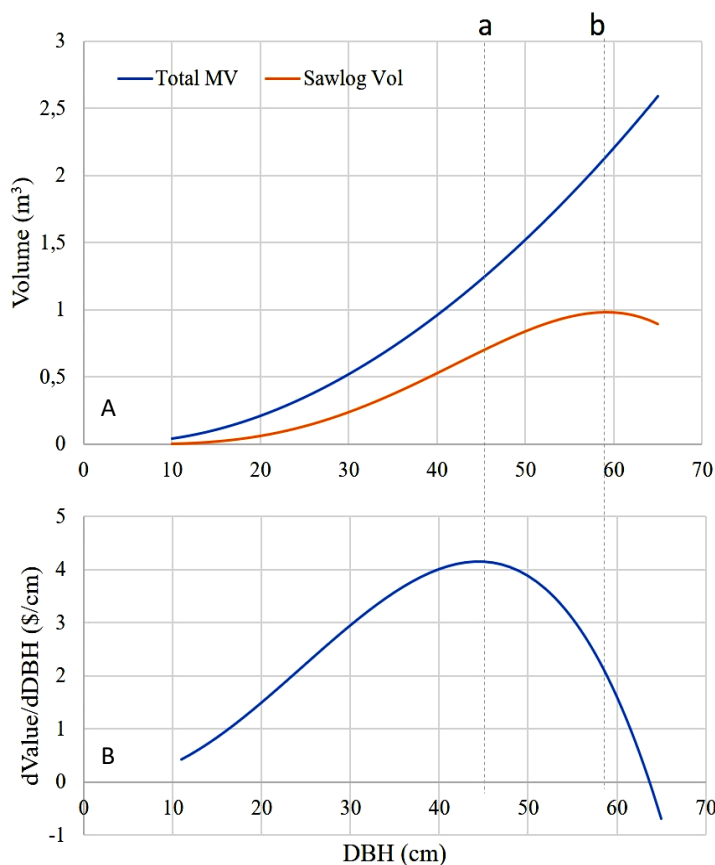
Figure 1: Individual tree basal area increment for sugar maple and yellow birch at different level of competition. SM = Sugar maple, YB = Yellow birch, numbers represent different residual stand basal area. Adapted from Baral et al. 2016.



Trees of all species do reach a biological maximum. Several physiological studies suggest that tree growth is limited by size (Ryan et al. 2006, Bond et al. 2007). The size is generally represented by DBH in most of the growth and yield studies. The shape of individual tree basal area (or volume) increment versus DBH is unimodal and has a maximum. In northwestern New Brunswick, the maximum growth has been observed between 30 and 40 cm DBH for sugar maple and yellow birch trees (Fig. 1).

Financial returns from a hardwood forest can be optimized only when trees are grown to maximize high quality sawlog production. Our analysis for good quality (F1 and R1) trees showed that sawlog volume per tree peaked at 58cm DBH and then decreased for larger diameter trees (Figure 2A). However, tree value increment reached maximum at 45cm DBH (Figure 2B) when an increase in sawlog volume starts to slow down (Figure 2, point a). After 45cm DBH, amount of decay (other defects as well) increases with tree diameter (Baral, 2015; Danyagri et al., 2017). This will decrease stem quality and thus negatively affect the sawlog production. Therefore, the sawlog ratio declines for larger diameter trees (Girouard 2015). Maximum size for hardwood trees to grow depends on landowner's objective, site, and species. We may wish to increase sawlog volume by increasing diameter growth and extending merchantable height through silviculture treatment. However, studies have shown that only the trees less than 50cm DBH respond well to silviculture treatments (Figure 1 and 3). These trends indicate that there would be no advantage in growing trees larger than 50cm DBH for producing high quality sawlogs or to get optimal tree value. Therefore, based on the knowledge synthesized in this study, 50cm DBH is recommended as the maximum tree size to grow while managing tolerant hardwood stands in New Brunswick for sawlog production.

Figure 2: Predicted total merchantable volume and sawlog volume for good form (F1) and good vigour (R1) sugar maple trees (A). Change in estimated tree value with increasing tree diameter (B). Point 'a' = Diameter at which a tree adds a maximum value when the tree diameter changes by a cm; Point 'b' = Diameter at which a tree attains maximum sawlog volume



SILVICULTURE IMPLICATIONS

Tree harvesting is an integral part of forest management. The NHRI Silviculture Prescription System (SPS) and Best Management Practices for harvesting operations in hardwoods also use tree size as one of the important criteria while determining pecking order for tree harvesting (Pelletier et al. 2016). The pecking order is a very important instruction for operators to achieve desired residual stand conditions while implementing different types and intensities of partial harvestings, e.g.: even-aged (group or uniform shelterwood), two-aged (irregular shelterwood systems), and uneven-aged (single tree or group selection) silviculture systems.

In such conditions, the NHRI Silviculture Prescription System recommends to harvest all trees greater than 50cm DBH for the stands that are managed for sawlog production. Unlike the so-called 'diameter-limit cutting' system, this Silviculture Prescription System rather highlights the need of removing slow growing (Figure 1) and/or poor quality trees (Figure 4) to provide growing space for vigorous trees with better quality stems that are currently present in smaller than 50cm diameter classes. This size limit will give priority to cut trees with sawlogs at risk of losing value. At the same time, the Silviculture Prescription System ensures the removal of non-desirable species, poor quality and small diameter trees with no potential to develop into quality sawlogs (also know as Unacceptable Growing Stock: UGS). Doing this, landowners get two benefits: (1) the volume of sawlog trees at risk of losing value will make harvesting operations financially feasible, and (2) the removal of UGS will improve growth and quality of the residual stand by increasing the proportion of vigorous and high quality trees of desirable species (AGS: Acceptable Growing Stock) in the residual stand.

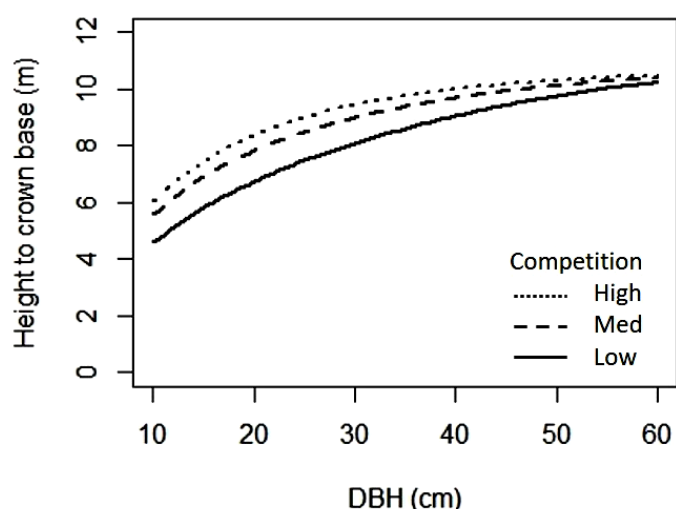


Figure 3: Effects of competition on height to live crown base for sugar maple trees (Adapted from Baral 2015). Based on field sampling done in three places (Mont-Laurier, Duchesnay and Biencourt) in Quebec in 2010 and 2011.

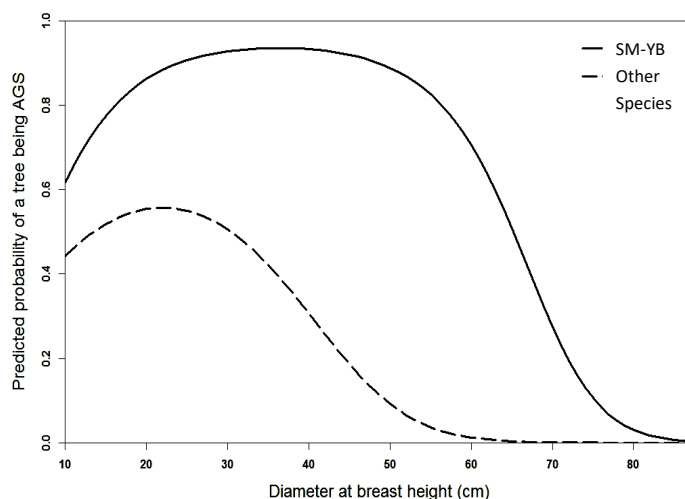


Figure 4: Probability of a tree being acceptable growing stock for different diameter trees. SM-YB: sugar maple and yellow birch, Other species: other hardwood species (Adapted from Danyagri et al. 2017). Based on field surveys conducted in northwestern New Brunswick in 2012.

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