An Approach to Mixedwood Yield Curve Development in Ontario

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Abstract
As part of an objective of maintaining wood supply on a shrinking land base, Tembec initiated a project in Ontario to improve the yield estimates for their land base. Using permanent sample plot data from provincial, federal, and industrial sources, stand level empirical yield curves were developed for the major forest types. The plots represent a range of sites and conditions with many being measured for more than 40 years. This paper presents some of the challenges of modeling boreal mixedwoods and some of the approaches taken. These challenges arise from the complexity of the mixedwood stands in terms of species composition, structure, development, and silvicultural options. This paper will describe the modeling approaches and present some of the results. It will illustrate some of the inaccuracies that arise from treating mixedwoods as a homogenous forest type from a yield perspective and the improvements that result from stratifying the mixedwoods

Keywords: Mixedwood yields, yield modeling

Introduction

Forest yield predictions in Ontario have relied on Plonski's normal yield tables (Plonski 1972) for almost 50 years. These tables provide yield information for fully stocked, even-aged, pure species, undisturbed stands. The predictions are still appropriate for the conditions for which they were developed. Over the past decade, modifications have been made to these normal yield tables to incorporate additional data and to adapt them for more mixed species conditions. Many of these modifications have little or no documentation associated with them.

In 2000, the Forestry Research Partnership (a partnership between the Ontario Ministry of Natural Resources, the Canadian Forest Service, Tembec, and the Canadian Ecology Centre) initiated a project to derive empirical yield curves appropriate for use in forest management planning based on permanent sample plot data. The yield curves were developed to represent natural and plantation origin stands in support of Ontario's forest unit (FU) planning unit. The yield curves build on the thousands of permanent sample plots (PSPs) established over a wider range of conditions than those of Plonski. All assumptions behind the derivation of the yield curves have been documented and made available to the user.

Objective

The objective of this report is to compare several approaches to developing mixedwood yield curves based on empirical data.

Ontario's Boreal Mixedwoods

Ontario's mixedwoods represent 22% of the productive forest land in the planning area, over one billion cubic metres (m^3) of gross total volume and have an average mean annual increment (MAI) of 2.0 m^3/hr/yr. Some areas of Ontario are facing wood supply shortages due in part to land withdrawals for parks and age class imbalances. Mixedwoods have generally been underutilized and are potentially part of the solution to meeting wood supply shortages. Ontario's boreal mixedwoods contain a wide variety of species but can generally be characterized as having the main leading species as either black spruce (*Picea mariana* (Mill.) B.S.P.) [Sb], trembling aspen (*Poplulus tremuloides* Michx.) [Po], or white birch (*Betula papyrifera* Marsh.) [Bw] (Figure 1a). Mixedwoods also arise in a number of ways. Some mixedwoods arise from natural disturbances, post-harvesting conditions, or unsuccessful attempts of artificially regeneration (Figure 1b). Some stands are mixedwoods from early ages. Other stands start off dominated by a single species but as the stands become overmature, the dominant species succumbs to natural mortality and the stand becomes a mixture of minor species.

Forest units are used in Ontario's forest management planning and volumetric wood supply analysis. In the forest management planning manual (OMNR 2004) a forest unit is defined as "an aggregation of forest stands for management purposes which have similar species composition, develop in a similar manner, (both naturally and in response to silvicultural treatments) and are managed under the same silvilcultural system." This definition successfully characterizes the majority of purer species FUs. Unfortunately, mixedwood FUs tend to be be just that, mixed, and tend to "fall-short" of meeting all aspects of the FU definition.

In northeastern Ontario, there are two mixedwood forest units Mixedwood1 (MW1) and Mixedwood2 (MW2), with MW2 representing the dominant area of the two. It is described as 'mixed coniferous – deciduous stand comprised largely of trembling aspen, white birch, black and white spruce and balsam fir. They occupy fresh to moist, medium loamy to clayey soils." (Watt et al. 2000).

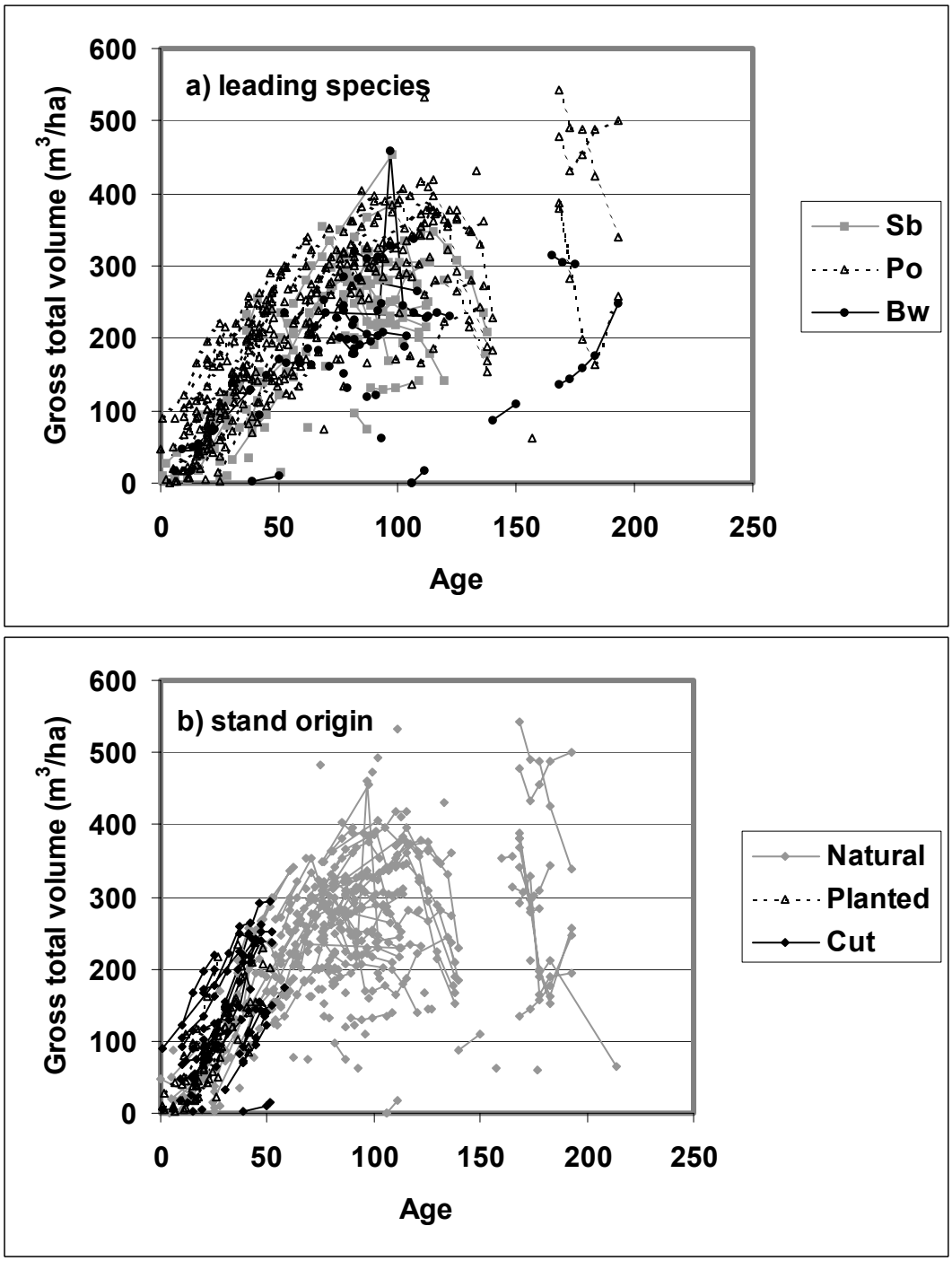

Figure 1. The relationship between gross total volume and age are given by leading species (a) and stand origin (b). Successive measurements from the same PSP are joined by a solid line.

The majority of forest management planning in Ontario is aspatial. Yield curves are developed by forest unit and management intensity. Bell et al. (2000) summarized definitions of levels of intensity of forest management and silviculture, drawing largely from Natural Resources Canada (1995) and Dunster and Dunster (1996). Essentially the management intensities reflect species composition, stocking, and tree size targets. All stands within a forest unit with the same management intensity are assumed to have the same yield curve. There is the potential to refine

yield estimates by subdividing the FU into more homogenous units and use these in management planning.

Approaches to Mixedwood Yield Curve Development

Several approaches are described below. The example data is taken from the Romeo Malette Forest (Figure 2). The average species composition of the stands in the MW2 forest unit is $Bw_{43}Po_{25}Sb_{32}$, a site index (SI) of 17.5m and a stocking of 0.65. Stocking is a percentage of the traditional full stocking and is estimated through aerial photo interpretation.

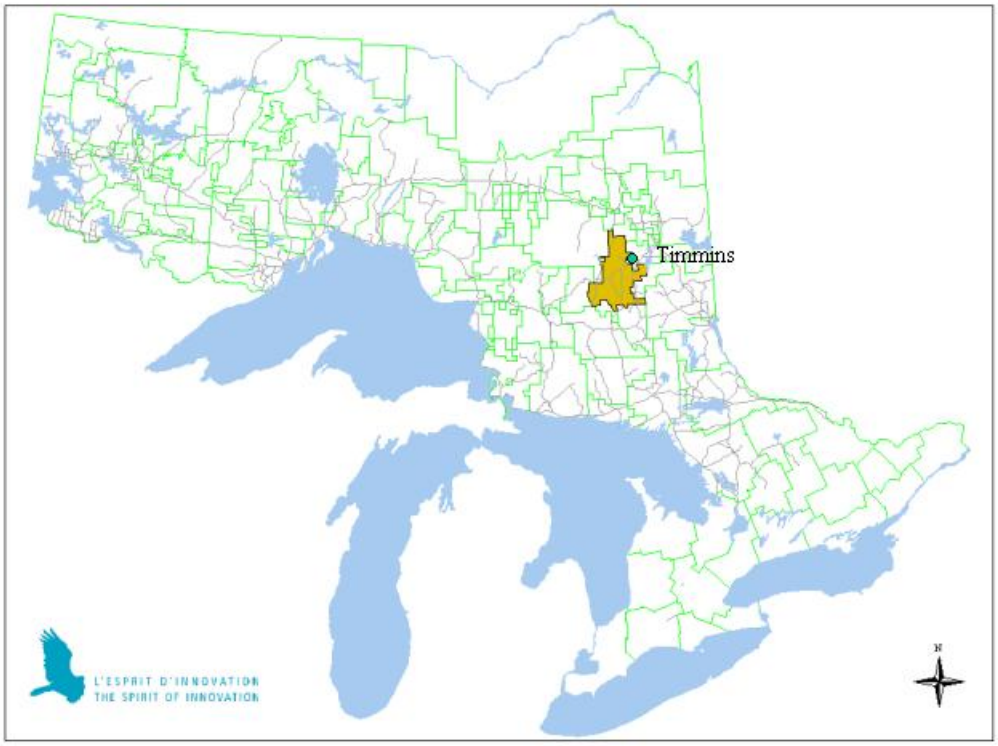

Figure 2. The location of the Romeo Malette Management Unit, the management unit used in this report for illustrating the results.

Plonski Approach

The Plonski approach uses Plonski's normal yield tables to estimate yields for mixedwoods stands. For a pure species stand, the site class of a stand is based on the stand height and age and the volume is estimated as the volume in the normal yield table multiplied by the stocking. For a mixed species stand, the site class of a stand is based on the leading species, stand height and age. The species volumes take the site class for the leading species and the normal yield tables for the individual species multiplied by the stocking and by the proportion of basal area the species represents.

As an example, assume the mixedwood stand consists of $Bw_{43}Sb_{32}Po_{25}$, a site index (SI) of 17.5m and a stocking of 0.65 (Table 1). White birch is the leading species and a SI of 17.5 corresponds to a Plonski site class (SC) of 1.65. All the other species are assumed to be SC 1.65. Note the effect this assumption has on the differing SIs in Table 1. Instantly, the corresponding SIs, basal areas (BA), and volume (V) estimates for the other species are compromised. The black spruce BA and V components are calculated for much shorter trees while the poplar is

Table 1. The Plonski approach is demonstrated for the sample data.

Species	Species proportion	SC	SI (m @ bh age 50)	Stocking	Predicted net merchantable volume at age 90 (m^3/ha)
Bw	0.43	1.65	17.5	0.65	39.0
Sb	0.32	1.65	10.1	0.65	30.8
Po	0.25	1.65	22.5	0.65	44.2
Total					114.0

estimated on much higher than the original white birch leading species values. In addition, the normal or fully stocked basal area varies by leading species. The stand basal area is estimated as the fully stocked basal area multiplied by the stocking. In the Plonski approach, the basal area is estimated as the sum of the basal area in the Plonski's normal yield tables multiplied by the stocking and the species proportion. This is not the same as the basal area estimate based on the leading species and stocking.

Forest Unit

A mixedwood yield curve for the MW2 forest unit was constructed by selecting all the PSPs classified as MW2 and estimating relationships between age, basal area and volume. The results are provided in Table 2. Height development was predicted using published site index curves.

Table 2. The Forest Unit approach is demonstrated for a sample stand in the MW2 forest unit.

Species	SC	SI (m @ bh age 50)	Stocking	Predicted net merchantable volume at age 90 (m^3/ha)
$Bw_{43}Sb_{32}Po_{25}$	1.65	17.5	0.65	88.0

Leading species weighted by area

In the leading species approach, yield curves were developed by leading species and weighted by area. This is similar to Plonski's yield curve method except the leading species curves used all the available PSP information (including remeasurements) and covered a wider range of conditions including understocked stands and managed stands (including plantations). Essentially, the MW2 is split into subunits. Within the Romeo Mallete Forest, stands within the MW2 were stratified by leading species and the results are given in Table 3.

Table 3. The Leading species weighted by area approach is demonstrated for the sample data.

Species	Species proportion	SC	SI (m @ bh age 50)	Stocking	Predicted net merchantable volume at age 90 (m^3/ha)
Sb	0.48	1.2	11.4	0.62	53.3
Bw	0.36	2.2	16.1	0.75	23.8
Po	0.17	1.9	21.5	0.71	23.0
Total					100.0

Leading species weighted by age

The leading species weighted by age approach is similar to the leading species weighted by area but rather than weighting the leading species yield curves by area, yield curves are weighted by the area for each age class. The leading species area by age class for the MW2 is given in Figure 3. Note the dominance of poplar at the younger ages, white birch in the middle ages and black spruce in the older ages.

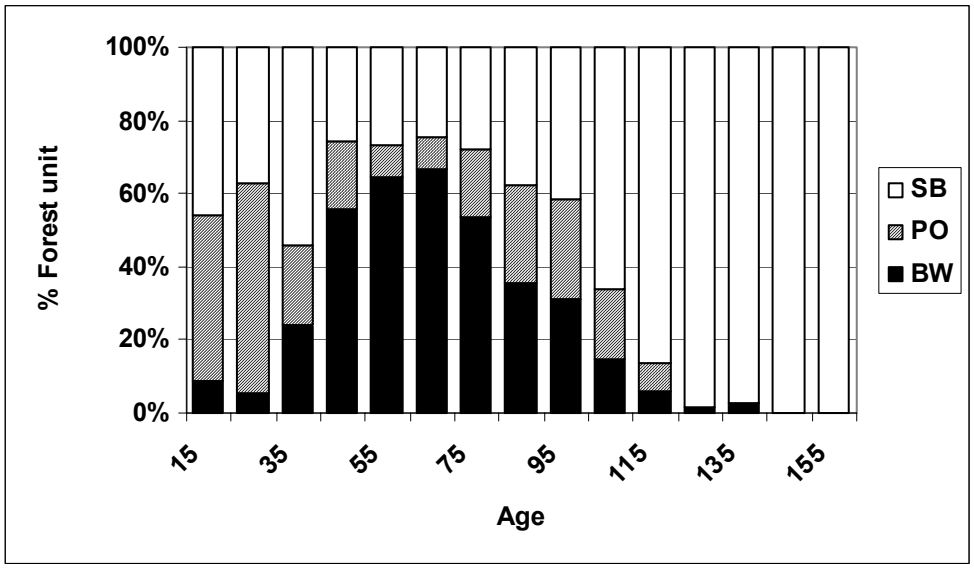

Figure 3. The area of the MW2 for the Romeo Malette Forest is given by leading species.

The results are given in Table 4.

Table 4. The Leading species weighted by age approach is demonstrated for the sample data.

Species	Species proportion	SC	SI (m @ bh age 50)	Stocking	Predicted net merchantable volume at age 90 (m^3/ha)
Bw	0.38	2.2	16.1	0.75	24.8
Sb	0.35	1.2	11.4	0.62	39.2
Po	0.27	1.9	21.5	0.71	36.5
Total					100.6

Comparison of the methods

The results of the various methods for predicting forest unit yields are given in Figure 4.

The biggest differences in the forest unit yield curves given in Figure 4 are for older ages (age 100+). Plonski's yield curves for intolerant hardwoods stop at about age 100 so predictions beyond this require some sort of extrapolation. Figure 5 compares the results of the forest unit, area-weighted and age-weighted approaches. The best agreement is around age 90 where there is the most data and probably the most industrial interest. At the forest unit level, the differences between the forest unit and the area-weighted approaches are minor. The area-weighted approach predicts more black spruce and less white spruce and other conifers. For long term planning involving large area, both approaches will give similar results. This is similar to the results reported by the British Columbia Ministry of Forests (2000) where they found that aggregating growth and yield predictions for wood supply analysis had little impact in determining the maximum constant-area harvest rate. However, at the stand level, the predictions are quite different, depending on the leading species. If harvesting operations for the next year were focused on the birch leading part of the mixedwood2 forest unit, the forest unit approach would overestimate the volumes and the proportion of poplar.

The area-weighted and age-weighted approaches give nearly identical results around age 90 but diverge beyond that when the black spruce leading species starts to dominate the age-weighted approach.

Figure 4 and Figure 5 give the results for the entire forest unit. Table 5 and Figure 6 give predictions for three PSP. The Plonski approach consistently overpredicts the volumes, on average by 19%, due mainly to the overprediction of poplar and white birch volumes. The forest unit approach consistently under predicts, on average by 19%, especially the hardwood volumes. The leading species approach underpredicted all species volumes for the birch-leading plot (AC35) but was close for the other two plots. In general, the leading species approach was closest to the actual volumes at the stand level.

Discussion

For strategic level planning (large areas, long planning horizon) there is little difference between the approaches presented. There are differences at the stand level in terms of total volume and volumes by species. This has implications for short term planning and allocations. As forest

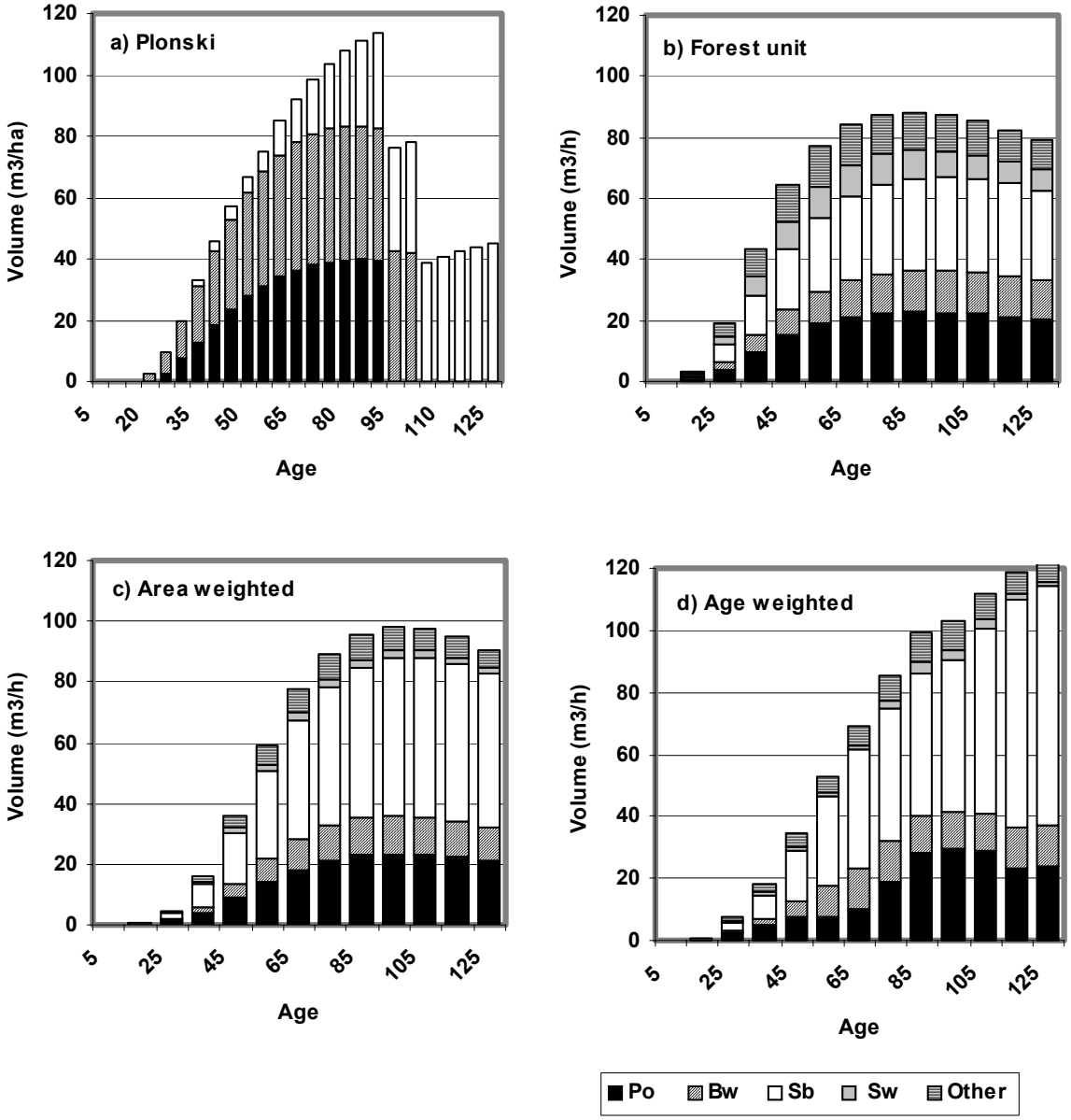

Figure 4. Results of the various approaches to mixedwood yields are given for the Romeo Malette Management Unit.

management planning becomes more detailed and as we move toward spatial modeling, the area- and age-weighted average approaches will have an impact on wood supply.

Limitations

The current approach has a number of limitations that need to be addressed.

1. Validity of the approach - Testing is currently underway to evaluate the predictions against an independent dataset.

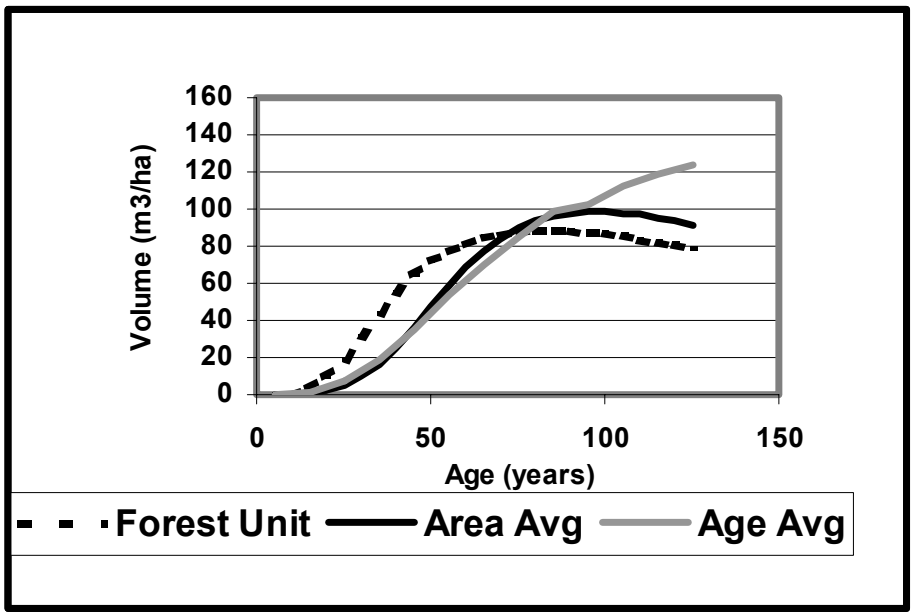

Figure 5. The relationship between net merchantable volume and age is given for three methods of yield curve construction.

Table 5. Predictions are given for three mixedwood PSPs. The area-weighted and age-weighted leading species approaches give identical results.

Plot	Spp Comp	Site Class	Age (yrs)	Ht (m)	Gross total volume (m^3/ha)			
					Actual	Plonski	Forest Unit	Leading species
AC124	$Sb_{47}Po_{27}Bw_{14}Pj_{11}Bf_1$	1	72	15.2	297	344	176	294
AC35	$Bw_{52}Sb_{38}Bf_9Po_1$	3	79	13.6	198	226	174	137
KC042	$Po_{45}Sb_{37}Bw_7Bf_6Pj_5$	2	97	23.6	333	415	317	330
Average					276	328	222	253

2. Accuracy and resolution of the forest inventory – Operational use of digital photography with LIDAR is demonstrating the ability to improve the accuracy, resolution, and timeliness of forest inventories.

3. Succession – Succession plays a major role in strategic wood supply modeling. Currently in Ontario, succession is modeled separately from yields curves. Long term observations (PSPs) are yielding information that can be used to link yield curves to successional shifts in species composition.

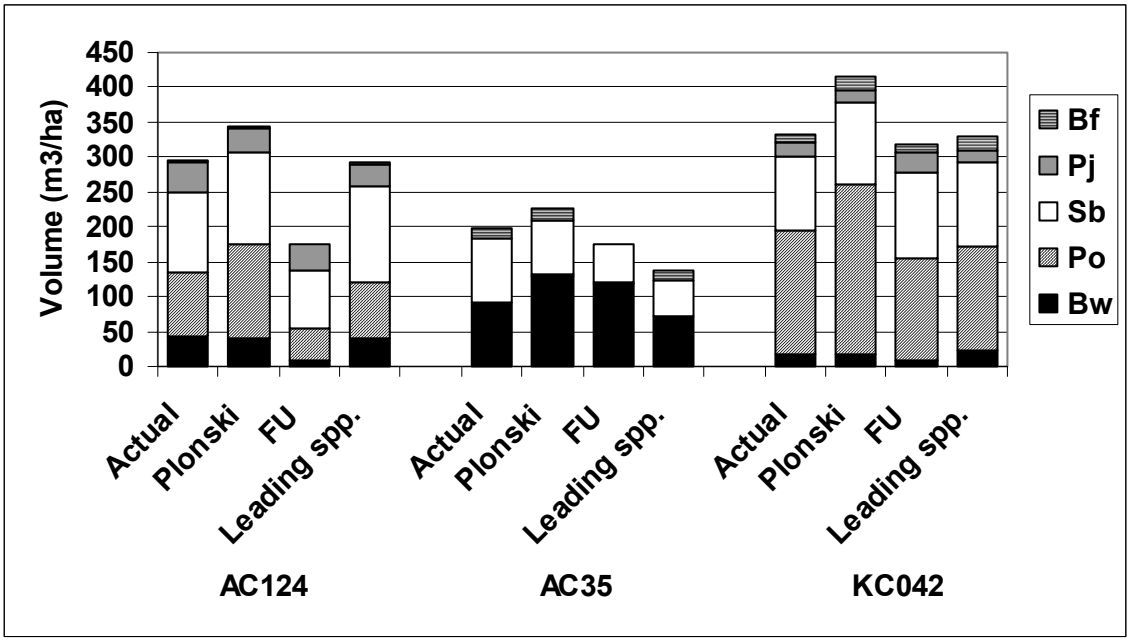

Figure 6. The species volumes associated with the predictions in Table 5. AC124 is black spruce dominated, AC35 is white birch dominated and KC042 is poplar dominated.

4. Silvilcultural options – The methods described here are appropriate for unmanaged stands. Mixedwoods can be managed a number of ways including partial harvesting to remove an early successional species and then a later harvest to remove the more tolerant species. This sort of partial harvesting either requires considerable empirical data or a tree-level model calibrated for the mixedwood conditions. Calibration and testing of an Ontario variant ($FVS^{Ontario}$) (Lacerte et al. 2004) is currently underway.

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