



Fundy Model Forest

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**Calculation of Mean Annual increment by Forest Type and
Reconciling With Expected Management Plan Yields Mean
Annual Increment**

January 2000

Mean Annual Increment of Management Yield Curves

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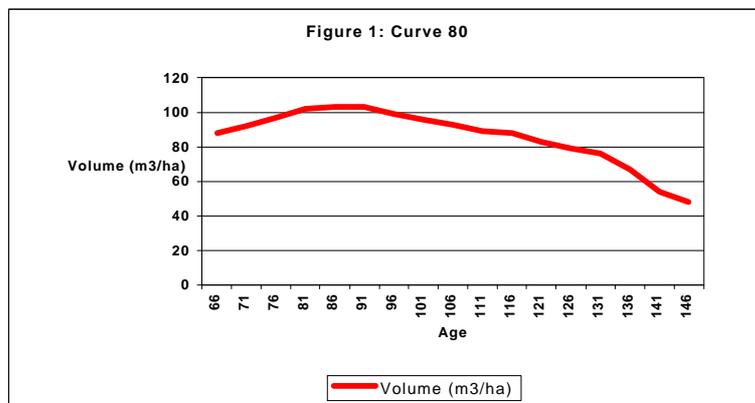
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Introduction

The purpose of this study is to verify the yield curves built by Fundy Model Forest (FMF), and to assess the provincial Permanent Sample Plot (PSP) database. In the past three years, the Fundy Model Forest has built yield curves based upon the Ecological Land Classification. The Ecological Land Classification system of assigning vegetative communities was used in an attempt to classify the land base more accurately than before. These yield curves were built as part of the Fundy Model Forests management planning process. Yield curves are the corner stone of wood supply models that are used in the management planning process. Forest productivity, wildlife habitat, recreation and biodiversity are some of the values that can be linked to yield curves. A yield curve is a cubic meter per hectare by age representation of forest stands growth over time. An example of this is shown in Figure 1 below. The vegetative communities were applied to the Forest Developmental Survey (FDS) data in the hope of producing more accurate yield curves. Yield curves were then built for the FMF, first for a case study area, then for the Grand Lake Eco-Region⁵. The curves were built over a number of years and were sent out to each of the landholders within the Fundy Model Forest for approval. However, this approval was based upon a visual inspection of the curves. If they looked reasonable to the landholders then they were approved. No verification was done other than this. As part of the criteria and indicator process, namely indicator 2.3a: Mean Annual Increment by Forest Type, this project was initiated to assess the yield curves.



In order to provide this verification, Mean Annual Increment (MAI) and Periodic Annual Increment (PAI) calculations were performed upon the management yield curves and the Permanent Sample Plots. Mean Annual Increment (MAI) is a measure of net biomass production of the forest and can be used to indicate its productivity. Periodic Annual Increment (PAI) is a calculation of net biomass between consecutive time periods. These periods could correspond to a five - year interval, which is the same as the usual management planning process.

⁵ MacLean, D., P. Etheridge, W. Emrich, and J. Pelham. 1999. Fundy Model Forest: Partners in sustainable forest management. *For. Chron.* 75:219-227.

A comparison between the two allows an analysis to be performed to see if that the management yield curves are realistic.

Methods and Materials

Several steps had to be taken in order to begin this project. The first was to acquire the management plan yield curves from the FMF. Secondly, the Provincial Permanent Sample Plot database (PSPDB)¹ had to be acquired. Thanks to Kevin Porter CFS Fredericton, this database, along with the Graphical User Interface (GUI) was received. The next piece of the puzzle was the yield curve stratification. Yield curves for the case study, were produced by Walter Emrich of JDI Woodlands. This study area excluded the Grand Lake Eco-Region. Steven Spears created the curves for the Grand Lake Eco-Region. The stratification for the case study, along with the land base stratification, was obtained from Joe Pelham of the FMF. This was necessary for the stratification of the PSP plots. The PSPDB unfortunately did not have all the information needed to perform the stratification. This extra forest inventory information was acquired from Hilary Veen of the Department of Natural Resources & Energy, Fredericton. Furthermore, the PSP forest inventory did not contain vegetative community stratification. The look up tables for the vegetative community stratification was produced by Hilary Veen, and was acquired through Joe Pelham at the FMF. [Table 3 Appendix C](#), shows the Vegetative Communities that correspond to each yield curve.

Permanent Sample Plot Stratification

Once all the information was gathered, several steps took place. The information on the PSP plots within the natural stands was exported out of PSPDB, and was saved as a database file. Matches were made, using plot number, between the PSP plots and the extra forest inventory data. This information was combined into one database file, which then contained all the necessary information for the stratification of the PSP plots. For the comparison to take place, the PSP plots had to be stratified in the same way as the yield curves had been. A comparison of number of FDS plots used for the yield curves to those represented by the PSP plots can be seen in Table 1, [Appendix A](#). This table presents each yield curve with the area within the FMF, the number of FDS plots used to make the curve, and the number of PSP plots used for analysis².

The appropriate plots from the PSPDB could then be compared to the management yield curves. Once the stratification method was acquired, queries in Paradox 7 were made to apply this stratification to the plots. Thus, each plot within the file was assigned a yield curve number.

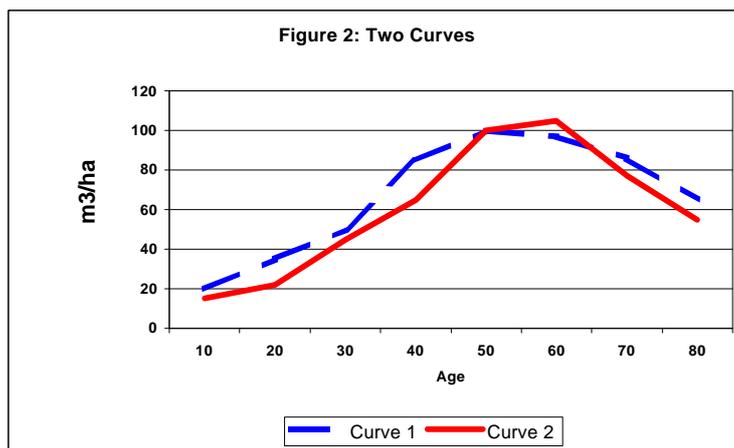
¹ Porter, K.B., D.A. MacLean, K.P. Beaton and J. Upshall. 1999. New Brunswick Permanent Sample Plot Database (PSPDB v1.0): Users Guide and Analysis. Can. For. Serv., Atlantic Centre, Fredericton. Inf. Rep M-X-205

² The numbers of PSPs used included those within and without the FMF boundaries, but within all Eco-Regions represented in the FMF.

This database file was then imported into the PSP database and was used to generate reports on the plots, which corresponded to each of the curve numbers.

MAI and PAI Calculations

MAI and PAI were calculated for both the yield curves and the corresponding PSP plots. Calculations were made on the total volume, soft/hard wood volume, and various species groupings. Mean Annual Increment is calculated by dividing the net volume of the curve by its age. For example, if a curve had 100 m³ at 50 years of age, its MAI would be 2 m³/ha/yr . Periodic Annual Increment is calculated by dividing the net difference in volume between two points in time, by the number of years between those two times. For example, the PAI between 100 m³ at 50 years and 110 m³ at 55 years is 2 m³/ha/period. The MAI gives a good representation of the growth, but does not give as good representation of the growth pattern. In Figure 2 below, two stands that have the same volume at age 50. However, they have different growth patterns from one another. They both have an MAI of 2 m³/ha/yr, but they are not growing in the same way. By using the PAI calculation for a comparison one can compare growth patterns within stand types.



This is an important comparison for this project. The PAI calculated will permit growth patterns seen in the yield curves to be compared to those within PSP plots. Macro programs were built in Excel and run on database files of each curve. This allowed for rapid calculation of MAI and PAI for each yield curve. The PAI was calculated on a 5-year basis. This was done for two reasons: first, because five years is the length of time used in management planning in NB. Secondly, because the program that creates the curves, STAMAN24, reports them on a five-year basis over an 80-year time line. Thus, there are 16 MAI and 15 PAI results for each yield curve.

The calculations were carried out somewhat differently with the PSP database. The PSPDB GUI³ allows the user to report on selected criteria within the PSPDB. As mentioned earlier, the database did not contain all the necessary information to perform the necessary

³ Porter, K.B., D.A. MacLean, K.P. Beaton and J. Upshall. 1999. New Brunswick Permanent Sample Plot Database (PSPDB v1.0): Users Guide and Analysis. Can. For. Serv., Atlantic Centre, Fredericton. Inf. Rep M-X-205

stratification on the PSP plots. A new database file containing this information, with the PSPs having been assigned curve numbers were imported into the PSPDB. This allowed reports to be generated on each of the PSPs, which corresponded to the selected yield curves. Several of the calculations can be performed with this GUI. However, the species MAI calculations and total and species PAI calculations had to be calculated manually in Excel. The GUI only supports volume calculations for species per year per plot. For total and species volume MAI calculations, only the most current measurement had been used. For the total volume, PAI can be calculated, but only to the last consecutive measurement. This provides a problem since the last measurement is usually only three years previous. For the comparison of PAI between the yield curves and PSPs, a period of 5 years is being used, because of the reasons given before. Most of the calculations involving PAI for the PSPs involve a 6-year period. This is due mostly to a 3-year interval between each measurement; thus, the first and third measurements have been used to calculate PAI for the PSP plots. If not done this way very few plots would be usable for analysis. Since the number of plots and measurements within plots are inconsistent, no macro could be programmed to handle these calculations.

Ages were present for each of the plot measurements for total volume calculations. However, they were not applied in the PSPDB to species calculations. The ages for each plot for the total volume had to be applied to each of the species to perform the calculations on them. To minimize the amount of data to be analyzed, the plot ages were classed into age classes of **Y**oung, **I**mmature, **M**ature and **O**ver-mature. These age classes were derived from DNR&E information and are shown below in Table 2.

Table 2: Age Class Definitions

Species Group	Young	Immature	Mature	Over-mature
Black Spruce	30-45	45-70	70-110	110+
Spruce	30-45	45-70	70-110	110+
Balsam Fir	25-35	35-50	50-70	70+
Tolerant HW	30-50	50-80	80-160	160+
Intolerant HW	20-35	35-50	50-70	70+
Jack Pine	20-40	40-70 ²	70-110	110+
Eastern Cedar	30-45	45-70	70-110	110+

Permanent Sample Plot Calculations

Twenty plots did not fall within the stratification. In order to apply them, reports were run in PSPDB and they were assessed to see which curves they might best belong too. Once accomplished the full stratification was checked to make sure all plots were assigned to their correct stratification. A database file was imported into PSPDB to allow for reports and calculations to be run on the PSP plots which corresponded to each yield curve. This table can be

⁴ Age Classes are in years. For example Tolerant Age Classes of Young is between 30 and 50 years of age.

opened in the GUI query and each curve can be selected. This simplifies generating reports on the PSP plots.

Reports on total and species volume plus MAI calculations on total volume could now be generated. Species groupings were then applied as well as ages and age classes to each of the PSP plots. Manual calculations were performed in Excel for the Species Groupings and Softwood/Hardwood volumes. Age classes were also applied to the yield curves and the results were tabulated. The MAI and PAI results are in [Appendix B](#).

PSP Database Assessment

In matching up the information from Hilary Veen and the PSP database, 850 plots were found usable. The Grand Lake Eco-Region, which was done separately, contained 30 plots while the other 815 made up those that went along with the curves made for the Model Forest area. However, though the curves used for examples were represented similarly to the yield curves, many of the other curves were not. Table 1, [Appendix A](#), shows the number of FDS plots used to make the curves, the corresponding PSP plots, the area taken up by each yield curve, and the associated vegetative communities. As can be seen the PSP plots do not represent thirty-two curves. After the stratification, twenty PSPs were left with no clear association with any of the curves. These were reviewed to see if they could be assigned to any of the curves.

Obstacles Encountered

Several obstacles came up in the project. First was the delay of the PSPDB from the Canadian Forest Service. Some anomalies were encountered when running the BETA version of the PSPDB and corrections had to be made. Kevin Porter of CFS Atlantic, corrected them. A new version of the database was then downloaded. The next obstacle encountered was the lack of pertinent forest inventory information for the stratification of the PSP plots. Thanks to Hilary Veen of DNR&E Fredericton this information was acquired.

The next obstacle dealt with the stratification itself. Twenty plots did not fall within any of the yield curve or land base stratification. These plots were examined to see where they might be best put to use. As mentioned above they were reviewed and fitted in to the best fit with the curves.

Another obstacle encountered was the application of ages to the species within each PSP plot. As was mentioned earlier, PSPDB does not apply ages to the species in each plot when a volume report is ran on them. In order to perform these calculations it was necessary to produce files from the PSPDB and associate the species in each plot with the age from the total volume report on that plot. This slowed progress. Each species may have a separate age within a plot. For example, PSP plot 8890 may have an average stand age of 68 for its measurement in 1988. The actual age of black spruce found within the plot maybe 80 years during that measurement. The average stand age of 68 though is applied since the actual age of 80 years for the black spruce is not reported in the database. Applying the same age to all the species within

the plot may not accurately reflect the conditions found in that PSP. Applying the same age within a plot to all species was the only option open for the analysis on a species level.

In regards to the calculations being made the manual application of the total and species PAI and species MAI took considerably longer than first thought. This slowed the process considerably. The calculations had to be performed, then summarized for each of the age classes applied to plot ages.

Results & Evaluation

In the research for this project, it was found that this sort of evaluation before using Permanent Sample Plots was not done before. Since that was the case, a way of evaluating the yield curve results was developed. The evaluation is in three parts: 1. Difference between FDS and PSP for each age class calculated and given a rating, 2. The number of age classes represented in the yield curve, 3. The amount of land represented by this yield curve in the FMF defined forest area.

Tables

There are two tables for each yield curve, one each for the MAI and PAI results. These tables can be seen in [Appendix B](#). The results were given a rating of Fair, Good or Excellent. The ratings were derived by examining the data, and coming up with a rating scale which is as follows.

Excellent: +/- 2 cubic meters difference
Good: +/- 2.1 to 4 cubic meters difference
Fair: +/- greater than 4.1 cubic meters difference

Age classes are also shown in each of the tables. By examining the results, one can see some curves have more age classes in one table than the other. This is due to averaging the age when a PAI calculation was performed. Some plots may fall or go up into another age class. An example would be a plot that has three measurements with the corresponding ages.

measurement 1: 67 years old
measurement 2: 69 years old
measurement 3: 72 years old

The MAI age would be 72 years old, since only the most current measurements were used to calculate MAI. When the PAI calculation was done, the average age would fall to 69.5 years old. If the cut off for the mature age class was 70 then the PAI calculation would fall to an immature age class. If there were only a few plots in the mature age class to begin with in the MAI and they all fell it is possible that the mature age class would not be represented in the PAI table. The more age classes represented in both tables the better the evaluation of the curve could be

made. A summary of the results are shown in Table 4 and Table 5. They summarize the count of the different ratings across all assessed curves and age classes. For example, if there were ten curves, each with 3 age classes and each had a rating of E in the spruce (SP) category, than there would be 30 ratings of E. However, in the Balsam Fir (BF) if there was no rating for E in one of the age classes in one curve, than 29 ratings would be counted for it.

Table 4: Sum of MAI Evaluation Ratings Across all Yield Curves and Age Classes

	SP	BF	OS	TOL	INTOL	SW	HW	Total
E	100	91	51	98	80	98	98	93
G	0	1	1	0	2	4	3	9
F	0	4	0	0	0	0	0	0
na	2	6	50	4	20	0	1	0

Table 5: Sum of PAI Evaluation Ratings Across al Yield Curves and Age Classes

	SP	BF	OS	TOL	INTOL	SW	HW	Total
E	66	72	47	74	73	58	71	46
G	15	6	1	6	2	19	8	30
F	1	2	0	1	3	5	3	7
na	1	3	35	2	5	1	1	0

These tables show that for the curves assessed, many of them have an excellent rating for the MAI calculations. The PAI calculations differ showing that the ratings are split between the excellent and good ratings. Since PAI is a better indication of development, closer attention should be paid to it than the MAI results.

Percent Area

Though not part of the calculations I believe it is a significant factor in relation to the yield curve. A yield curve might have only two age classes and may have only a range of fair to good for the results. However, if it represents only 0.30 percent of the total forested land base, its impact would probably be minimal. However, if another yield curve had the same results but represented 8.0 percent of the forested land base, then it could very well have a major impact on any management models produced. That yield curve should then be examined closely. The better the representation of all or any of these factors increase the likely hood that the yield curve is a good one. If representation is minimal though a review should be done of that yield curve and its construction to see how it can be improved.

Discussion & Recommendations

Out of 74 yield curves, only 42 have PSP plots which relate to the curves stratification. Thus, only 54% of the yield curves can be assessed. With such a low representation of the yield curves being assessed, a review in the construction of the yield curves should be made. One

suggestion would be not to develop yield curves at the vegetative community level, but at the group community level. This way more PSPs could then be amalgamated with the curve stratification and better assessments could be made. One recommendation would be to assess each curve using the PSP database, during the yield curve making process. Programs can be developed to perform the necessary calculations on the yield curve and corresponding PSP data. This would allow the management planner to assess the curves right away. By doing this the planner can try to minimize the uncertainty inherent in yield curves. Secondly, greater attention should be placed on those yield curves, that represent significant portions of the landbase, in question. These might be the areas where you need to break down the yield curves further than group community level, if there are sufficient FDS and PSP plots to do this for proper assessment.

The curves that were assessed did show remarkably good results, for the age classes represented. As can be seen in Tables 4 & 5 on page 11, Both MAI and PAI results had many excellent and good ratings. These ratings though can be somewhat misleading. As will be discussed later sources of error can have an affect on these results. However, taking the results as they are more emphasis should be placed on PAI as an indicator instead of MAI. As an indicator PAI can best represent the overall growth of the forest, whereas MAI can only indicate yield. As was discussed earlier a rating scheme was developed to represent the results of the calculations. This rating scheme does not take into consideration the amount of volume present in that curve for the representative age class. A difference between the curve and PSP MAI or PAIs of +/- 2 cubic meters may not seem much if the representative volume is 100 cubic meters for the curve for the age class. However, if the volume is 15 cubic meters an excellent rating is not entirely appropriate.

The PSP database has the makings of being a useful tool for management planning, however, the PSP database, while helpful, did present some problems for this project. These have been mentioned in the PSP assessment. The database was in a BETA format and an assessment of the finished database should be done with the following points in mind. One, can one easily perform periodic annual increment at a specified time interval? Second, can ages, other than average stand ages, be applied to each species in a plot? Thirdly can forest information about the stand be included (forest stand type, vertical stand structure, site, etc) so a planner can perform a proper assessment? The plot data may limit some of these, especially the species ages, but an effort to incorporate at least vegetative and group communities should be made for each plot. One recommendation would be to target those curves which could not be analyzed due to lack of PSP plots. First, assess to see if there were any errors in the PSP stratification. Next propose that the any new PSPs to be established be made in those stand type conditions which coincide with the yield curves which were not assessed.

Sources of error within the project have already been discussed to some extent already. Examples of such are the assignment of average stand ages to the species in the PSP plots.

Other sources of error include the assignment of vegetative communities to the PSP plots, the MAI and PAI results averaged into age classes, and stratification of the PSP plots to coincide with the yield curve stratification. Each will be discussed below.

As was mentioned before, the assignment of the average stand age to the species with in the PSP plot could be misleading in defining the age classes of the PSP plot. By assigning the average stand age to all the species in the plot, one is assuming that all species are at the same developmental stage. This of course could be far from the truth. The spruce in a plot with an average stand age of 86 might actually be only 35 years old. However, without species specific ages no other recourse was available but to assign average stand ages to each species.

The next source of error deals with assigning the vegetative communities to the PSP plots. While the stratification covers most species groupings, a few are not included. The vegetative community stratification is based on the old species assignment for forest stands. In the old typing three species were used in assigning a Forest Unit Name (FUNA). However, that has now changed to include up to five species. Thus, in order to apply the vegetative communities the five species have to be summarized down to the old three species level. Error in the summarization could inadvertently cause a stand to be typed differently than it should. In addition, some species pairings may occur that do not occur in the vegetative communities look up tables. At that point, it is up to the person to make a judgment call where that plot might fit which vegetative community.

The calculations for MAI and PAI are essentially averages of a condition. When these results are then again summarized as, an average for each developmental stage error begins to creep in. There is always some error possible when averaging a large amount of data. By averaging again in the results, error begins to increase. One way to possibly limit this is to apply the age classes to the plots before hand and then perform the calculations on the age classes for each plot. The average total volumes for each age class can be seen in Table 6, [Appendix D](#).

Another possible source of error deals with the stratification of the PSP plots to coincide with the yield curves. Though forest stand information was applied to each PSP plot, not all the PSP plots were found within the Fundy Model Forest defined area. In order to have enough PSP plots for this project, all PSP plots within each of the Eco-regions were used. Thus, there were some PSP plots, which did not exactly coincide with the yield curve stratification. For example, one yield curve could be stratified as SPBF, site class 2. However, there could be PSP plots, which were SPBF, site class 3. For situations like this, one had to make a judgement call whereas these plots would fit into what yield curve stratification. Error in properly applying these could cause a misrepresentation of the PSP plots for a yield curve.

Conclusion

The Fundy Model Forest natural management yield curves are a mixed success. The yield curves that were assessed, at least on some levels, were representative of the stratification applied to them. Unfortunately, this can not be said for all developmental stages of these yield curves. These yield curves could be used to show others how one might go about trying to refine management planning. However, I would not recommend using these yield curves for any serious management planning or habitat analysis. At this point, there is no way to account for the certainty of the other 32 yield curves, which could not be assessed. Thus, any analysis done with them could also be called into question. By establishing new permanent sample plots in the stand conditions, that correspond with the unassessed yield curves, a future assessment could be made. Until such a time this is possible, the best recommendation would be to produce the curves on a group community level. If a large number of FDS and PSP plots are present for one of these group communities, breaking it down for ecological or habitat considerations, to a vegetative community may be called for. Though, only if the new yield curve(s) have a good representation of both FDS and PSP plots.

The permanent sample plot database was a useful tool in this project. However, this was only the case once forest information was added to the database. The database did provide invaluable assistance in organizing the data and performing some of the volume calculations, but a stronger link to pertinent forest information needed by programmers should be included.

In conclusion, I would say this project has been both educational and an eye opener for me personally in regards to management yield curves. The work done by the Fundy Model Forest in producing these yield curves shows that it is possible to further define forest characteristics, but more data is needed to be able to adequately assess the outcome of these definitions. Also as an indicator mean annual increment proves to fall short. Combining both MAI and PAI calculations to monitor forest growth and yield would prove to be a better indicator overall