ALTERNATIVES TO ESTIMATE STATEWIDE CHANGES IN ASPEN COVER TYPE VOLUMES

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Abstract—For Minnesota, the only data available to conduct regional or state-wide level assessments across all ownerhips is the Forest Inventory and Analysis Program (FIA). Some of the many alternatives available to estimate regional changes in standing volume are referred to here as 1.) FIA alternative, 2.) a commonly applied growth and yield system referred to as Walters and Ek, 3.) a calibrated Walters and Ek alternative, 4.) a different calibrated Walters and Ek alternative, and 5.) Forest Vegetation Simulator (FVS) estimates. The purpose of this study is to quantify the ability of these alternatives to estimate standing merchantable volume five years into the future of unmanaged aspen cover/forest types, particularly to see whether FVS provides reliable estimates. Aspen forests are by far the dominant cover type in the state.

FIA data from 1999 and 2004 were used to calibrate models, and in some cases to project data. Projections were compared to 2009 plot data, considered to be the true values.

If large-scale, strategic, short term projections are needed, the FIA alternative (1) or the Walters and Ek Alternative Two (4) will be superior. However, for long-term planning, the FVS (5) or either the uncalibrated Walters and Ek alternative (2) or, if calibration can be easily calculated, Alternative One (3) will likely be best.

INTRODUCTION

Regional growth rate estimates are important for many natural resource analyses including silvicultural assessment, harvest scheduling, and resource planning. For Minnesota, the only statewide data available to conduct regional or statewide level assessments across all ownerhips is the Forest Inventory and Analysis Program (FIA).

Of the 15.9 million acres of timberland within Minnesota, 4.8 million (or 30%) is classified as aspen forest type. Total cubic foot volume on aspen forest types of trees greater in diameter than 5 inches is estimated to be 4.3 billion (around 55 million cords), or 25% of the 17.2 billion cubic feet of volume on Minnesota timberland. Aspen volume occurs throughout the state, most heavily concentrated in northcentral and northeastern Minnesota.

Several alternatives exist to estimate regional changes in standing volume, some based more on the subject data than others. The purpose of this study is to quantify the ability of different alternatives to estimate standing merchantable volume five years into the future of unmanaged aspen cover/forest types.

METHODS

Data used in model development were obtained statewide from USDA FIA annual surveys completed between 1999 and 2009. Due to time, only the plots remeasured during 2009 were analyzed in this study (hence, an initial measurement, a second measurement, and then a third measurement in 2009).

For comparison purposes, the dependent variable is the volume of trees of d.b.h. 5.0 inches and greater from a 1-foot stump to a 4-inch top d.o.b. (essentially trees merchantable for pulpwood, sawtimber, veneer, etc.).
Within FIADB, the variables VOLCFNET and TPA UNADJ are used to estimate individual tree volume on a plot.

**Estimate of Volume**

**Five Years Into the Future**

For this study, the true or known volume for a particular plot (i) is assumed to be the observed standing volume in 2009 obtained from FIADB, further referred to as [VT09i]. In a way, each individual FIA plot can be assumed to provide a statewide estimate of change in aspen volume.

**Estimation Alternatives**

A few of the more practical alternatives to estimate changes in the aspen forest type resource are compared in this paper.

**FIA Alternative**

An estimate of the standing volume for the plots measured in 2009 can be obtained by adding the change in standing volume for a FIA plot from 1999 to 2004 to the 2004 FIA plot volume.

\[
[VFIA09i] = [VT04i] + ([VT04i] – [VT99i])
\]  

Where:

- [VFIA09i] -- is the estimate of volume for plot i in 2009 using this alternative,
- [VT04i] -- is the observed volume obtained from FIADB for a particular plot in 2004, and
- [VT99i] -- is the observed volume from FIADB for a particular plot in 1999.

**Walters and Ek (1993) Alternative One**

Walters and Ek (1993) presented plot level equations to predict cover type yield (merchantable volume) using FIA data from the 1977-1978 Minnesota survey (plots actually measured from 1974 to 1980). For this alternative, site index is an external variable obtained from the 2004 FIA plot measurement – site index is assumed to be the same in 2009 as the value from 2004.

The estimate of standing volume for this alternative is further referred to as [VW09i].

**Walters and Ek (1993) Alternative Two**

A second approach using the Walters and Ek models was examined (Alan Ek, 2012, personal communication 02/05/2012). A calibration approach included taking the ratio between the observed 2004 FIA volume for a plot and an estimate using Walters and Ek for 2004, and then multiplying this ratio times the Walters and Ek estimate for 2009.

Estimates of merchantable volume in 2004 (V2004m) and 2009 (V2009m) were obtained using the model system presented in Walters and Ek (1993).

This alternative is obtained using the following ratio:

\[
[VWOne09i] = [V2009m] ([VT04i] / [V2004m])
\]  

**Walters and Ek (1993) Alternative Two**

A third approach using Walters and Ek (1993) involves estimating volumes for both 2004 and 2009 using their models, calculating the difference, and then adding this difference to the 2004 observed FIA data (Alan Ek, 2012, personal communication 02/05/2012):

\[
[VWTwo09i] = [VT04i] + ([V2009m] – [V2004m])
\]

**Forest Vegetation Simulator (FVS)**

The Forest Vegetation Simulator (FVS) is an individual tree based, distance independent growth and yield model fit in large part to individual tree growth data. The FVS variant used in this analysis is referred to as the Lake States variant (Dixon and Keyser 2013). Within FVS, to be as consistent as possible with the definition of volume used by FIA, the minimum merchantable d.b.h. was set to 5 inches, and the stump height was maintained at 1 foot. The form class was maintained at the default value of 80 and the National Volume Estimator library equations were used.

The estimate of standing volume for this alternative is further referred to as [VF09i].

**Statistical Measures of Estimation**

Since estimates are obtained on a plot by plot basis, estimates of variance and bias can be obtained and used to obtain an estimate of Mean Square Error (MSE):
Where:

\[ V_{\text{Errorki}} = [V_{T09i}] - [V_{k09i}] \]  \hspace{1cm} [4]

\[ [V_{k09i}] \text{ -- is the estimate of standing volume in 2009 using one of the five alternatives (k), and} \]

\[ [V_{T09i}] \text{ -- is the difference between the true standing volume in 2009 of plot } i \text{ obtained from FIADB} \]

Using values from equation [4], estimates of bias (average error), variance, and MSE for the five alternatives (k) were obtained using the following formulas:

\[ [\text{Bias}_k] = \frac{\sum_{i=1}^{n} V_{\text{Errorki}}}{n} \]  \hspace{1cm} [5]

\[ [\text{Variance}_{ek}] = \left( \frac{\sum_{i=1}^{n} (V_{\text{Errorki}} - [\text{Bias}_k])^2}{n-1} \right) \]  \hspace{1cm} [6]

\[ [\text{MSE}_k] = [\text{Bias}_k^2] + [\text{Variance}_{ek}] \]  \hspace{1cm} [7]

Where:

\[ n \text{ -- number of plots (n = 56).} \]

**Plot Removal**

Due to a variety of reasons, plots were excluded from the analysis. Plots/subplots that had any type of disturbance from 1999 to 2004 or from 2004 to 2009 were removed (e.g. harvesting \([\text{REMVCFL} > 0 \text{ for any tree in the plot}], \text{beaver/deer/disease/insect/wind damage, etc.} \text{ -- DSTRBCD and TRTCD} \). Plots were also removed if in 2004 or 2009 their cover/forest types changed from aspen. Some plots were actually measured during 2003 (even though the nominal year was 2004), for simplicity, these plots were removed from the analysis because FVS first estimated volume for 2003 to 2004, and then estimated volume from 2004 to 2009 -- hence an extra year of estimation was included for the FVS alternative. Additionally, within FVS, for a particular FIA plot, those condition classes not classified as an aspen forest type were grouped with the condition classes defined to be an aspen forest type -- thus, these plots were removed as well.

After plot removal, a total of 56 plots were included in the analysis (Table 1).

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### RESULTS AND DISCUSSION

Excluding the calibration approaches, the FIA alternative had the best statistical properties (Table 2 and Figure 1). The Walters and Ek (1993) alternative produced the largest Mean Square Error, but less bias than the FVS Alternative. Of the three basic approaches, it is not surprising that the FIA alternative produced the best results. The 2009 estimate is highly correlated with the 1999 and 2004 estimates, thus highly correlated with the growth rate used from 2004 to 2009.

Although independent data was used to fit the FVS models (e.g. mortality, height, volume, etc.), actual plot data from 2004 was used to, in a sense, calibrate the FVS model for that individual plot. Obviously, the 2009 FVS estimate is correlated with the 2004 FIA estimate because tree data from 2004 is used to project forward to 2009, despite the use of independent tree growth equations within FVS.

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**Table 1.--Summary statistics of the 56 aspen forest type plots included in the analysis across the three inventory years (1999, 2004, and 2009). Mean is defined as net volume of wood in the central stem of trees 5.0 inches in diameter or larger, from a 1-foot stump to a minimum 4-inch top d.o.b. (VOLCFNET within FIADB).**

<table>
<thead>
<tr>
<th>Species Group</th>
<th>Number of FIA plots</th>
<th>Mean (cubic feet/acre)</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspen (bigtooth and quaking)</td>
<td>56</td>
<td>767</td>
<td>738</td>
</tr>
<tr>
<td>Other hardwoods</td>
<td></td>
<td>220</td>
<td>264</td>
</tr>
<tr>
<td>Conifers</td>
<td></td>
<td>186</td>
<td>316</td>
</tr>
</tbody>
</table>

**Table 2—Bias, Variance, and Mean Square Error (MSE) estimates for the five alternatives.**

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Number of FIA plots</th>
<th>Bias</th>
<th>Variance</th>
<th>MSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIA</td>
<td>15</td>
<td>121,850</td>
<td>122,071</td>
<td></td>
</tr>
<tr>
<td>FVS</td>
<td>-185</td>
<td>142,951</td>
<td>177,302</td>
<td></td>
</tr>
<tr>
<td>Walters and Ek (1993)</td>
<td>56</td>
<td>-151</td>
<td>459,298</td>
<td>482,122</td>
</tr>
<tr>
<td>Walters and Ek Cali One</td>
<td>6</td>
<td>128,528</td>
<td>128,561</td>
<td></td>
</tr>
<tr>
<td>Walters and Ek Cali Two</td>
<td>-7</td>
<td>73,316</td>
<td>73,366</td>
<td></td>
</tr>
</tbody>
</table>
The Walters and Ek (1993) alternative produced the most variable results. This is most likely due to low correlations between the equations presented in Walters and Ek and the 2004 and 2009 FIA data. The calibration of the Walters and Ek model approaches produced substantial improvements.

LITERATURE CITED
