# SHORT-TERM HARVEST SCHEDULE SENSITIVITY TO FUTURE STUMPAGE PRICE ASSUMPTIONS

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## ABSTRACT

Forest planning models have long been used as an analytical tool for providing information to facilitate effective decision making and planning. Inherent to the financial analyses conducted with these models are assumptions concerning key financial parameters contained in the model such as discount rates, future costs, and future stumpage prices. While projecting timber prices into the future with any accuracy is an extremely difficult exercise, price forecasting is nonetheless a critical part of forest planning analyses. The ramifications of these assumptions over a long planning horizon can be significantly different product flows, activity levels, and cash flows. The purpose of this study is to investigate the impact of different future stumpage price assumptions on the short-term (5-year) timber harvest schedule for a southern pine forest, and to examine how much of the schedule is financially driven. The findings indicate that the short-term harvest schedule is sensitive to different price projections. This result is significant especially with respect to the timing of short-term timber harvest decisions to take advantage of market prices.

KEYWORDS: Stumpage prices, harvest schedule, forest planning.

## INTRODUCTION

Forest planning models have long been used as an analytical tool for providing information to facilitate effective decision making and planning. Application of these models includes timber harvest scheduling, timberland acquisition and divestiture analysis, long-term sustainable wood supply forecasts, intensive silvicultural investment identification, and the determination of strategic forest management directions. Inherent to the financial analyses conducted with these models are assumptions concerning key financial parameters contained in the model such as discount rates, future costs, and future stumpage prices. Due to the uncertainty associated with projecting costs, interest rates, and timber prices, it is customary to undertake sensitivity analysis of key model parameters to examine the effect on results, and thus to further guide the decision making process.

While projecting timber prices into the future with any accuracy is an extremely difficult exercise, price forecasting is nonetheless a critical part of forest planning analyses. For example, it is well known that timber price fluctuations are a significant factor with regard to timberland returns. The ramifications of these assumptions over a long planning horizon can be significantly different product flows, activity levels, and cash flows. The purpose of this study is to investigate the impact of different future stumpage price assumptions on the short-term (5-year) timber harvest schedule. Various stumpage price projections were devised, with the resulting short-term harvest schedules compared for purposes of examining how much of the schedule is financially driven. These price projections were applied to a case study of a southern pine forest to evaluate their influence on short-term timber harvest decisions.

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## BACKGROUND

**The Forest—**The (hypothetical) forest modeled for this study is 100,000 acres in size, and consists entirely of loblolly pine (*Pinus taeda*) plantations. There are 126 stands, and the age of these stands ranges from 1 to 30 years. A uniform age class distribution was modeled.

**The Stumpage Price Projections—**Three future stumpage price forecasts were modeled in this study:

1. Flat real prices over a 100-year planning horizon (*flat prices*).
2. A 1% real annual increase (over and above inflation) in all products over the planning horizon (*increasing prices*).
3. A 1% real annual increase (over and above inflation) in years 1 to 5 for all products except pine sawtimber. For pine sawtimber, there was an equal annual price decrease in years 1 to 5 such that the resulting stumpage price for pine sawtimber would equal the stumpage price for pine chip 'n' saw. Prices were then held flat over the remaining years of the planning horizon (*modified prices*).

**The Model—**A model II linear programming formula tion was used to develop the timber harvest schedule for the forest in this study. The LP-based model consisted of an objective function maximizing net present value (NPV) over a 100 year planning horizon composed of 1-year periods.

In developing the harvest scheduling model, several assumptions were made, including: (1) clear-cut stands are site prepped the year following harvest and planted two years following harvest; (2) all stands that are thinned receive a post-thin fertilization the year following thinning; (3) thinning is optional, there is only one thinning per rotation, and thinning can be scheduled for ages 14-20; (4) minimum rotation age is 20; and (5) the financial analysis is before tax using a real discount rate (net of inflation) of 8%.

**Growth & Yield—**Growth and yield projections by product were developed using a proprietary Forest Technology Group loblolly pine plantation growth and yield model. Per acre harvest volumes generated by the growth and yield model were used as production coefficients in the harvest scheduling model.

## RESULTS

A total of six harvest scheduling model runs were conducted for this study, based on the three alternative stumpage price scenarios and two alternative model formulations: a model constrained to produce a positive cash flow (net revenue) of greater than or equal to $25 million in each of years 1 to 5, and a model without this cash flow constraint (unconstrained). The six model results were used to evaluate the sensitivity of the short-term harvest schedule to different stumpage price projections. Comparison of the results provides valuable insight concerning the extent to which the short-term harvest schedule is financially (price) driven.

**Table 1—Average harvest ages for the first 50 years under alternative price projections.**

| Prices | Avg. Clearcut | Avg. Thin Age |
|---|---|---|
| Flat | 24 | 15 |
| Increasing | 25 | 15 |
| Modified | 22 | 0 |

* Same results for both the unconstrained & constrainede model runs.

**Long-Term Results—**A brief look at some long-term results is valuable for gaining perspective into the impact of the different price projections on the timing of thinnings and regeneration harvests, and the mix of forest products produced. The average harvest ages over the first 50 years of the planning horizon are shown in Table 1.

As expected, the rotation age is longest under the increasing prices scenario, and shortest under the modified prices scenario. Under modified prices, there are no thinnings scheduled after year 10, as there is no price premium attached to the production of sawtimber.

Average annual pine harvest volumes by product over the first 50 years of the planning horizon are summarized for both the unconstrained and constrained models in table 2.

As expected, the flat and increasing price scenarios result in a mix of products weighted towards the production of sawtimber (PST), while the modified prices scenario results in a product mix heavy to the production of chip 'n' saw (PCNS). Further, due to a shorter rotation with no thinnings, the modified prices scenario results in a greater total pine harvest volume. Lastly, comparison of results between the unconstrained and constrained models shows no appreciable difference.

**Short-Term Results—**Again, for this study the short-term has been defined to be the first five years of the model. The short-term results to be examined here are harvest acres, harvested stands, silvicultural costs, harvest volumes, and net revenue. Acres clear-cut and thinned under the

**Table 2—Average annual pine harvest volumes by product under alternative price projections and model formulations for mixes of sawtimber (PST), chip 'n' saw (PCNS), and pulpwood (PPWD) production.**

| Unconstrained | Flat | Increasing | Modified | Constrained | Flat | Increasing | Modified |
|---|---|---|---|---|---|---|---|
| PST | 306,085 | 331,087 | 135,498 | PST | 305,901 | 329,009 | 135,625 |
| PCNS | 162,384 | 149,418 | 414,697 | PCNS | 162,622 | 153,085 | 402,900 |
| PPWD | 205,224 | 194,012 | 190,827 | PPWD | 205,705 | 198,258 | 184,499 |
| Total | 673,693 | 674,518 | 741,022 | Total | 674,228 | 680,352 | 723,024 |

**Table 3—Total and annual acres clear-cut under alternative price projections and model formulations for years 1-5.**

| | | Unconstrained | | | | Constrained | |
|---|---|---|---|---|---|---|---|
| Year | Flat | Increasing | Modified | Year | Flat | Increasing | Modified |
| 1 | 27,159 | 24,714 | 27,635 | 1 | 12,460 | 12,222 | 12,524 |
| 2 | 3,087 | 4,310 | 7,056 | 2 | 6,223 | 5,644 | 7,347 |
| 3 | 417 | 1,639 | 2,500 | 3 | 7,729 | 7,933 | 8,268 |
| 4 | 3,384 | 859 | 6,294 | 4 | 7,702 | 7,196 | 8,921 |
| 5 | 3,194 | 4,192 | 2,942 | 5 | 9,739 | 8,275 | 12,940 |
| Total | 37,241 | 35,713 | 46,427 | Total | 43,415 | 41,269 | 50,000 |

**Table 4—Total and annual acres thinned under alternative price projections and model formulations for years 1-5.**

| | | Unconstrained | | | | Constrained | |
|---|---|---|---|---|---|---|---|
| Year | Flat | Increasing | Modified | Year | Flat | Increasing | Modified |
| 1 | 10,429 | 10,429 | 3,106 | 1 | 8,737 | 9,489 | 1,389 |
| 2 | 5,635 | 5,635 | 1,310 | 2 | 5,635 | 5,159 | 1,726 |
| 3 | 4,053 | 4,053 | 3,750 | 3 | 4,053 | 4,529 | 3,750 |
| 4 | 1,667 | 1,667 | 0 | 4 | 0 | 1,667 | 0 |
| 5 | 3,333 | 3,333 | 1,667 | 5 | 5,000 | 3,333 | 2,500 |
| Total | 25,117 | 25,117 | 9,832 | Total | 23,425 | 24,177 | 9,365 |

different price projections are summarized in tables 3 and 4 respectively.

As expected, the modified prices scenario results in the highest total acres clear-cut and the lowest total acres thinned. Also, clear-cut acres are greater in the constrained model for all three price projections. The increasing prices scenario had the lowest total acres clear-cut under both model formulations.

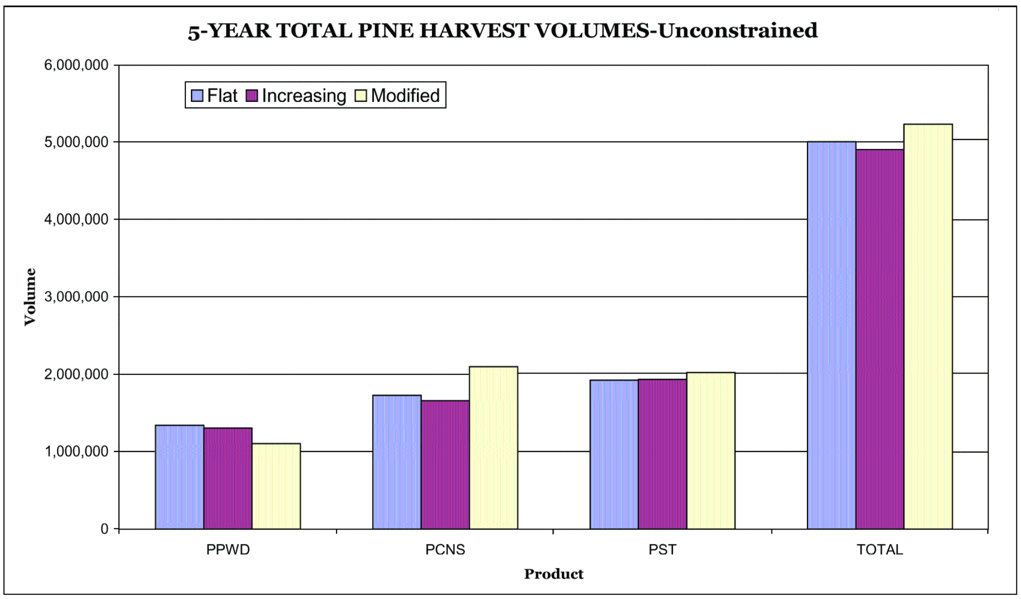
Comparison of results between the unconstrained and constrained models with regard to acres thinned shows slightly fewer acres thinned in the constrained models. Worth noting for the unconstrained model is that the same thinning acreages are chosen under both flat and increasing prices.

The silvicultural costs under the different price projections and model formulations are summarized in table 5.

For the unconstrained model, total silvicultural costs are highest under the modified prices scenario. This reflects the much higher stand establishment costs associated with this price scenario having the highest number of acres clear-cut.

**Table 5—Total and annual silvicultural costs under alternative price projections and model formulations for years 1-5.**

| | Unconstrained | | | | Constrained | | |
|---|---|---|---|---|---|---|---|
| Year | Flat | Increasing | Modified | Year | Flat | Increasing | Modified |
| 1 | 683,334 | 683,334 | 783,335 | 1 | 683,334 | 683,334 | 783,335 |
| 2 | 6,486,808 | 5,997,916 | 6,106,918 | 2 | 3,428,603 | 3,433,655 | 2,964,540 |
| 3 | 3,960,007 | 3,947,785 | 4,608,023 | 3 | 3,043,784 | 2,869,635 | 3,108,929 |
| 4 | 766,215 | 1,138,995 | 1,578,340 | 4 | 2,470,472 | 2,571,172 | 2,762,547 |
| 5 | 987,188 | 610,470 | 1,746,381 | 5 | 2,456,033 | 2,583,728 | 2,877,255 |
| Total | 12,883,553 | 12,378,500 | 14,822,998 | Total | 12,082,226 | 12,096,525 | 12,496,607 |



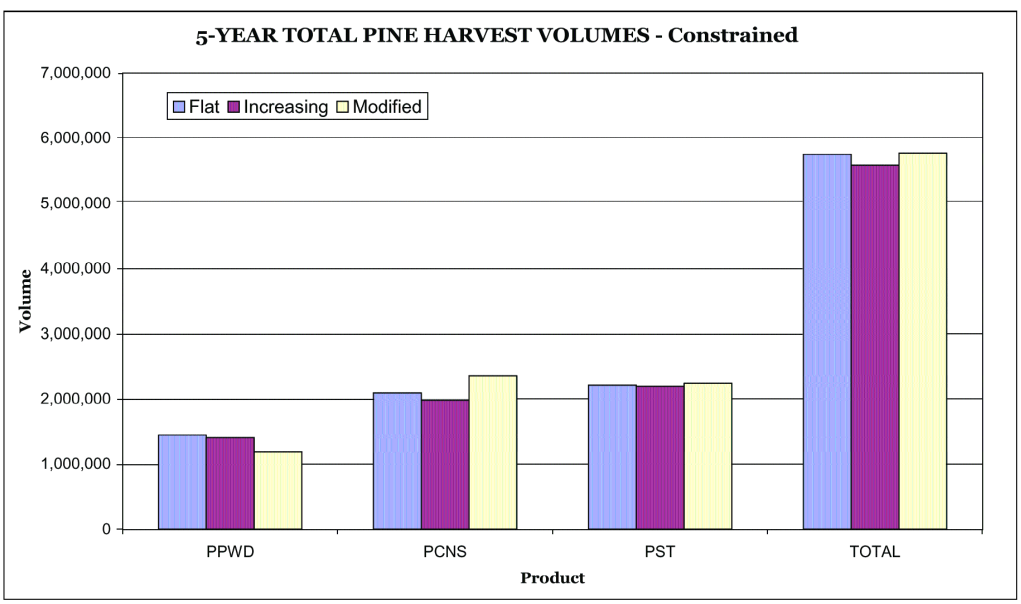




Figure 1—Total pine harvest volumes by product under alternative price projections for a) the unconstrained model, and b) the constrained model.

**Table 6—Total and annual pine harvest volumes by product under alternative price projections and model formulations for years 1-5.**

**Unconstrained**

| | PPWD | | | PCNS | | | PST | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Flat | Increasing | Modified | Flat | Increasing | Modified | Flat | Increasing | Modified |
| 1 | 722,153 | 654,352 | 500,924 | 1,198,969 | 1,067,491 | 1,106,572 | 1,531,317 | 1,508,183 | 1,557,361 |
| 2 | 234,418 | 268,907 | 205,360 | 201,826 | 278,260 | 453,921 | 101,855 | 118,566 | 230,744 |
| 3 | 95,186 | 127,031 | 165,140 | 3,071 | 68,838 | 92,748 | 0 | 17,622 | 13,028 |
| 4 | 150,324 | 106,672 | 113,054 | 196,491 | 47,419 | 293,817 | 2,30,036 | 36,985 | 145,776 |
| 5 | 145,222 | 156,068 | 2,877,255 | 130,792 | 195,008 | 2,877,255 | 67,125 | 257,554 | 79,189 |
| Tota | 1,347,303 | 1,313,030 | 1,104,814 | 1,731,149 | 1,657,017 | 2,105,187 | 1,930,333 | 1,938,910 | 2,026,099 |

**Constrained**

| | PPWD | | | PCNS | | | PST | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Flat | Increasing | Modified | Flat | Increasing | Modified | Flat | Increasing | Modified |
| 1 | 310,789 | 320,668 | 110,804 | 330,277 | 345,046 | 198,816 | 1,009,552 | 965,723 | 1,174,429 |
| 2 | 310,018 | 283,265 | 163,818 | 381,305 | 340,721 | 408,714 | 353,200 | 378,586 | 364,057 |
| 3 | 239,549 | 271,101 | 288,135 | 420,467 | 452,737 | 533,330 | 324,869 | 280,922 | 270,560 |
| 4 | 200,645 | 278,631 | 219,233 | 452,835 | 420,761 | 575,352 | 292,002 | 289,778 | 255,876 |
| 5 | 388,624 | 254,948 | 398,489 | 505,272 | 423,879 | 636,373 | 235,333 | 283,670 | 177,455 |
| Tota | 1,449,625 | 1,408,612 | 1,180,570 | 2,090,156 | 1,983,145 | 2,352,585 | 2,214,955 | 2,198,679 | 2,242,379 |

Silvicultural costs in the constrained model are lower in comparison to the unconstrained model for all three price projections. With flat prices, stand establishment costs are lower due to fewer acres clear-cut during years 1 to 4. Primarily, this reflects lower planting and herbaceous weed control costs. In addition, fewer acres thinned results in lower post-thin fertilization costs.

With increasing prices, the higher number of acres clear-cut during years 1 to 4 resulted in increased site prep costs. But this was offset by lower planting and herbaceous costs, and slightly lower post-thin fertilization costs.

With modified prices, stand establishment costs are significantly lower in the constrained model due to fewer acres clear-cut during years 1 to 4 (about 6400 acres less).

Total and annual pine harvest volumes by product under the different price projections are summarized for both the unconstrained and constrained models in table 6. Additionally, these total harvest volumes by product are shown in figure 1a for the unconstrained model, and figure 1b for the constrained model.

For both model formulations, there is less pulpwood (PPWD) harvested under modified prices due to the lower number of acres thinned, while the higher number of acres clear-cut under this price scenario results in a higher PCNS harvest and a slightly higher PST harvest.

For the unconstrained model, total pine harvest volumes range from 4.9 million tons (increasing prices) to 5.2 million tons (modified prices). For the constrained model, total pine harvest volumes range from 5.6 million tons (increasing prices) to 5.8 million tons (both flat and modified prices). Thus, constraining the model to meet or exceed a minimum cash flow target results in higher harvest volumes for each product (and, as follows, in total), and a slightly narrower difference in total harvest volume between the different price projections. These results are in line with expectations.

Total and annual net revenue under the different price projections is shown in figure 2a for the unconstrained model and figure 2b for the constrained model. Note that net revenue as reported here is not the objective function value, which is NPV.

For the unconstrained model, total net revenue is highest under the modified prices scenario. This follows from this price scenario having the highest harvest volume, particularly concerning PCNS and PST. Net revenue is negative in year three for all pricing scenarios due to 1) a low number of acres clear-cut and a higher number of acres thinned, and 2) the significant number of acres clear-cut in year one are planted and receive herbaceous treatment in year three. Total net revenue ranges from $129 million (both increasing and flat prices) to $140 million (modified prices).

As described previously, the constrained model employed a minimum positive cash flow constraint covering years 1 to 5. Total net revenue is higher in comparison to the unconstrained model for all three price projections. Total net revenue ranges from $153 million (increasing prices) to $157 million (modified prices), with all of the difference in net revenue occurring in year 1. Following from the earlier outcomes regarding harvest volumes, constraining the model results in higher total net revenue, and a narrower difference in total net revenue between the different price projections (from $11 million to $4 million).

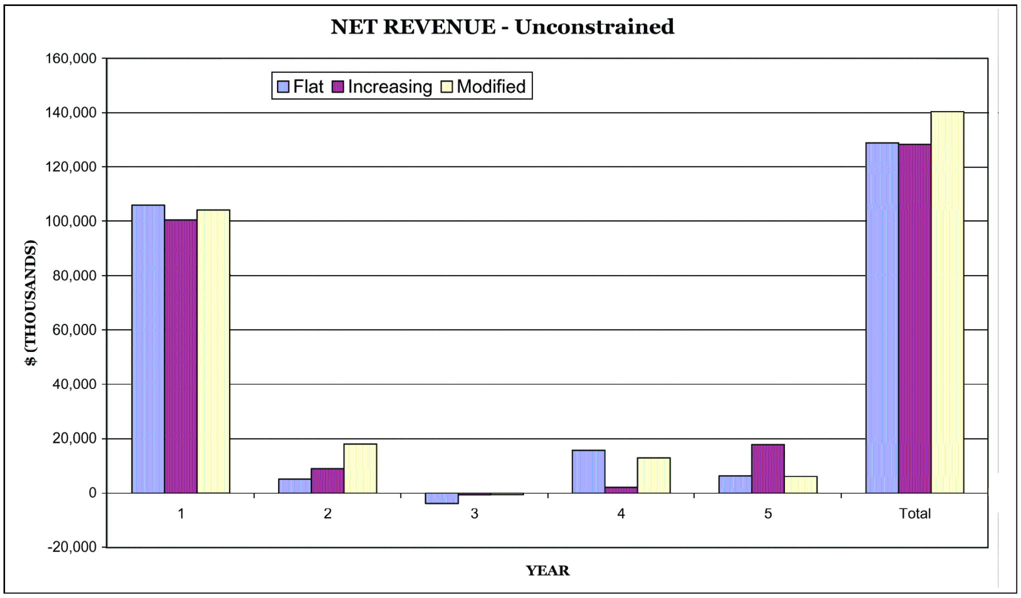
## CONCLUSIONS

The results of this study indicate that the short-term harvest schedule is sensitive to the different price projections modeled in both the unconstrained and constrained models. This result is significant especially with respect to the timing of short-term timber harvest decisions to take advantage of market prices. Financial objectives may indicate the need for flexibility concerning targeting short-term harvesting decisions in response to market prices. That is, the timing of harvests with regard to the mix of forest products produced is important, especially as it concerns financial goals.

The price sensitivity is related to both the forest examined in this study and the model formulation of the harvest scheduling problem. The uniform age class distribution of this forest allowed flexibility in relation to the stands scheduled for harvest and the timing of these short-term harvest decisions. The model formulation also provided flexibility. Some examples of this flexibility are that thinning is optional, and age 20 stands could be either thinned or clear-cut. Lastly, with regard to the constrained model, the cash flow constraint was not so burdensome as to entirely dictate the solution.

Along these lines, there are several factors worthy of investigation in terms of their impact on the sensitivity of the short-term timber harvest schedule to different future stumpage price assumptions. A few of these factors would include:

1. A skewed age class distribution or age class gaps. Clearly, forest age class structure would be a key driver with respect to price sensitivity. A younger



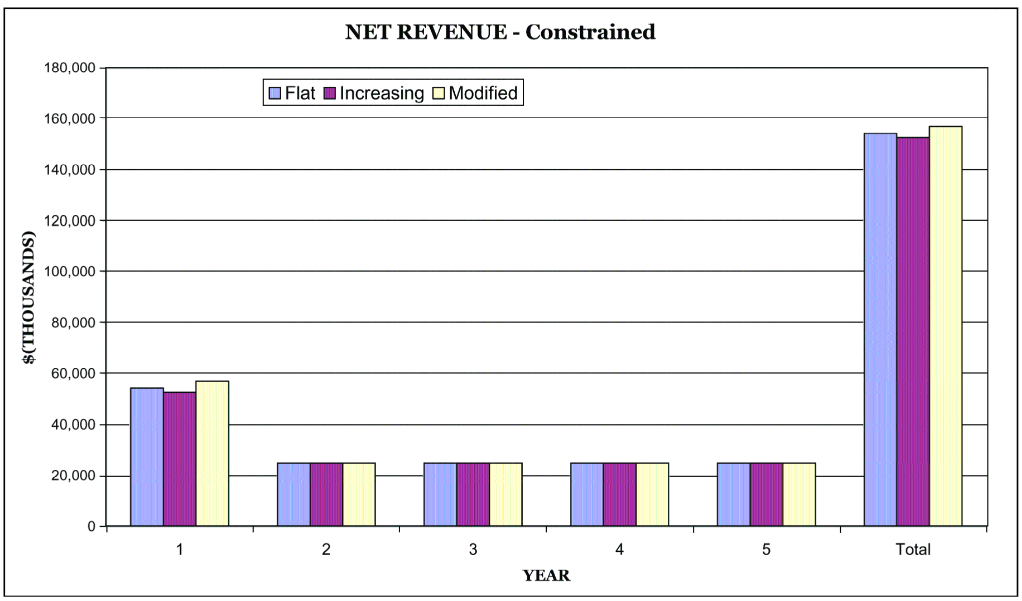




Figure 2—Total and annual net revenue under alternative price projections for a) the unconstrained model, and b) the constrained model.

forest with limited merchantable stands in the short-term would likely result in a more biologically driven solution. An older forest with many slow-growing stands would likely result in a more biologically driven solution. That is, the sensitivity to the prices modeled could be muted in both these instances where the forest age class structure dictates the solution.

2. Forest policy constraints. Much like the cash flow constraint, other forest policy constraints are likely to reduce price sensitivity.
3. Price increases/decreases by product. As many analyses have confirmed, this can have a significant impact with regard to optimal silvicultural prescriptions. Thus, model sensitivity to price could differ with the price projections modeled.
4. Spatial harvest planning. Large contiguous blocks of the same species of very similar age can significantly affect the results of operational harvest planning due to adjacency issues, perhaps reducing the effect of the prices modeled.

Further investigation of these or other factors would make important contributions to the theme of stumpage price sensitivity of short-term forest planning results.