

# **Maintaining Productivity and the Forest Resource Base**

## **A Technical Paper for a Generic Environmental Impact Statement on Timber Harvesting and Forest Management in Minnesota**

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## SUMMARY

This technical paper describes the analyses that were performed to address the question of the sustainability of various harvest levels over a 50-year planning horizon. The focus is on forest productivity and the resource base with special emphasis placed on timber supply. Environmental impacts of timber harvesting and forest management on soils, water quality, wildlife, recreation, etc. are addressed in other technical papers.

State-of-the-art planning models were used to develop schedules of forest management activities including harvesting, regeneration, and thinning for three different harvesting scenarios. The model scheduled these forest management activities by individual Forest Inventory and Analysis (FIA) plots over time. It was this schedule that formed the basis for detailed impact analyses of forest harvest activities on various timber and nontimber resources. To augment the understanding of the sustainability analysis, the structure and extent of the forest resource base was also examined. The results are presented here as a preface to the modelling and analysis effort.

Many factors influence how much wood is actually harvested from the forests of Minnesota at a certain point of time. The general level of harvesting is dictated by long-term economic conditions, legal restrictions, and biological and physical possibilities. Yearly fluctuations are more dependent on economic factors like stumpage prices, taxation burdens/incentives, and economics of other land uses.

The economic factors have a particular influence on nonindustrial private forest (NIPF) owners. In Minnesota, NIPF owners are a very important factor, as they hold 41 percent of the commercial forests and contribute approximately 37 percent of the annual harvest.

For the medium- and long-term it is important that the harvest level does not deviate too much from the *allowable cut*, this being the *harvest level* that the forests will be able to *sustain long-term* without jeopardizing the forest resource. The determination of the allowable cut is based on the size, composition and growth of the forest resource, and the principles for its management. Therefore, the allowable cut is a *dynamic concept* which evolves over time as the size, composition, growth, and management of the forest resource changes.

The Final Scoping Decision (FSD) specified study of three harvesting scenarios. The base scenario reflects current timber consumption levels by Minnesota's forest industry (4 million cords annually). The medium scenario reflects the demand of the forest industry after several of the plants now under construction or in the design or concept stage go on line (4.9 million

cords annually). The high scenario suggests an upper bound on biologically sustainable yields (7 million cords annually).

When the harvest levels under the three scenarios were met, they had distinct implications for the cost of producing timber, on the impacts associated with these harvest levels, and the future sustainability of these harvest levels past the 50-year planning horizon.

Harvesting at almost any level brings both human-induced and natural changes that impact the characteristics and condition of the forest, often for decades. The nature and severity of the impacts is documented here in terms of gross physical characteristics such as forest stand age class and species structure, spatial patterns and timber yields. Regarding specific impacts, two sets of model runs were developed. The first was unconstrained in the sense that all timberland in Minnesota (14,773,000 acres) was assumed available for harvest. The remaining two classes of forest land that were not available for harvest were reserved forest (1,113,100 acres) and unproductive forest (828,300 acres). This first set of runs illustrated the potential forest growth and yield under existing levels of management. The second set of runs was constrained to approximate actual timberland availability (for harvesting) by ownership, anticipated changes in forest area, various existing and prospective policies and procedures of the major forest land managers and mitigation strategies developed in the course of the study. As examples, existing and prospective policies included allowance for old growth and implementation of best management practices (BMPs). Mitigation strategies included extended buffers for wildlife that restricted clearcutting in certain riparian areas. The results of the two sets of runs were then used to assess the severity of impacts and to develop recommendations for preferred mitigation strategies.

### **First Model Runs and Analysis**

Results for the first model runs indicated that the overall study approach was feasible and produced realistic depictions of possible scenarios. The scenarios were developed using the FIA data and a combination of modelling tools. Specific results were:

1. Based on assumptions including minimal constraints on harvesting practices, all three levels of harvesting are feasible over the planning period and beyond. However, this conclusion does not incorporate all of the biological/ecological concerns dealt with in the second runs, or management intensification that could increase yields.
2. Achieving these harvest levels clearly impacts a large number of acres across all ecoregions. The area of timberland projected to be harvested one or more times during the 50-year study period varies from approximately 8.8 million acres in the base scenario, 10.2 million for

the medium, and 12.9 million in the high scenario. Adding the reserved and unproductive acreage to the timberland never cut also suggests considerable acreage is not disturbed by harvesting over the 50-year study period, notably 7.9, 6.5 and 3.8 million acres for the base, medium and high scenarios, respectively.

3. The greatest harvesting pressure will occur in the early part of the next century. The number of stands harvested will diminish towards the end of the planning period, reflecting assumed current management and harvesting of regenerated stands with improved stocking.
4. Stumpage prices for products are dependent on location and harvest levels.
5. The aspen coertype will experience the heaviest level of cutting and is projected to account for between 40 percent (high scenario) and 60 percent (base scenario) of the total area harvested.
6. The average age of aspen stands harvested in the northern region of the state drops significantly during the study period for all three scenarios as the minimum rotation age (40 years) is gradually implemented.
7. Harvesting modelled in the southern region of the state for the high scenario would affect most (all but 11,000 acres) of the oak-hickory stands on timberland in that region. The base scenario envisions 217,000 acres left uncut. The high demand scenario would likely not be sustainable in these coertypes in this region in the long-term.
8. A high proportion of the modelled increases in demand are projected to come from private property, particularly the medium and high scenarios in the northern region of the state.
9. The spruce and balsam fir coertypes would be subjected to much higher levels of harvesting under the high scenario compared to the base scenario.
10. The high demand scenario harvest levels for some of the coertypes, e.g., black spruce, jack pine, balsam fir, tamarack, and the northern hardwoods, led to age-class distributions indicating these high harvesting levels could not be sustained in the long-term, based on current levels of management.
11. Analysis of harvest volumes by owner and period for the three scenarios indicate that private ownerships will have to play an increasing role in supplying timber for harvest. The role of these ownerships will increase as the level of demand increases. These ownerships would also have the

greatest opportunity to intensify management to mitigate timber supply shortfalls elsewhere.

12. The aspen covertime plays an important role in all demand scenarios. Other covertypes such as the northern hardwoods and other softwoods also play an increasing role in the medium and high scenarios. Proportionally greater increases in the harvest from covertypes other than aspen will be needed to meet the higher demand scenarios. Development of facilities which can process species that are currently unmerchantable will increase the level of utilization in mixed species stands. This will also augment supplies of aspen and other species by making logging of mixed species stands commercially viable.
13. Overall, tree species composition on timberlands is moderately affected by these harvesting scenarios. This assumes most of the impact is due to changing age class distributions and not a reduction or elimination of covertypes. Individual covertypes can vary considerably in age related species composition, but the overall impact is reduced because of the high proportion of mixed species stands, i.e., most stands contain a number of tree species.
14. Covertime change trends are still strongly affected by the species and age class structure resulting from the logging and land clearing of the late 1800s and the early part of this century. In general, harvesting favors retention of pioneer species while long rotations favor more tolerant species. The long-term trends seem to show a decline in aspen acreage and an increase in maple-basswood. Lowland conifers in general appear to maintain their acreage. Perhaps most significant is that management or lack of it will largely determine future covertime acreage and age class structure of the forest. Many other characteristics or benefits of forests will then follow from that.
15. Reserved and unproductive forest, though not subjected to harvesting, also changed substantially through stand aging processes. In particular, these areas will be subject to successional processes that will likely diminish the extent of pine and other early successional stage covertypes.
16. External to the actual modelling process, a review of trends led to estimates that forest and timberland area will likely shrink in the north and expand in central and southern Minnesota over the period 1990-2040. However, constraints on harvesting (described in the second runs) will likely further reduce the availability of timberland in the north and reduce the impact of any expanded forest area in the south.

## **Second Model Runs and Analysis**

Analysis of the results of the first runs led to modelling refinements and the incorporation of ownership constraints and possible mitigations. Consequently, the second runs represent a more detailed and realistic look at the specified harvest levels and how they might be achieved, given various mitigations.

Among the existing and prospective agency policies and procedures and mitigations, accepted and/or modified by the Advisory Committee, those that were amenable to implementation in the second runs were:

- extended rotation forests (ERF), i.e., lengthened (usually by 50 percent) minimum rotation ages for approximately 20 percent of the timberland on state and USDA Forest Service ownerships;
- greater use of uneven-aged management (approximated by thinning practices);
- designation and reservation of old growth and acreage that might replace that;
- BMPs, i.e., thinning or ERF within 100 feet of water; and
- wildlife buffers (thinning only within 200 feet of water) on the national forests and in the southeastern part of the state.

In addition, estimates of the actual availability of timberlands for harvest or management, developed separately by ownership, were used to set aside a portion of the timberland as *not available* for various economic, environmental and social concerns. Table I.1 summarizes this acreage.

**Table I.1.** Approximate second run acreage availability by use and treatment category for timberland, statewide, 1990.

| Use and treatment category    | Acres      | Percent |
|-------------------------------|------------|---------|
| 1. Normal harvest             | 11,289,200 | 76.4    |
| 2. BMP and wildlife buffers   | 742,900    | 5.0     |
| 3. Extended rotation forest   | 899,400    | 6.1     |
| 4. Old growth and replacement | 57,500     | 0.4     |
| 5. Not available              | 1,784,400  | 12.1    |
| Total 1 to 3 (available)      | 12,931,500 | 87.5    |
| Total 4 to 5 (not available)  | 1,841,900  | 12.5    |
| Total                         | 14,773,400 | 100     |

Other model changes for the second runs included refinement of the silvicultural decision trees used in the first runs to lengthen minimum rotation ages from 40 to 50 or more years. The exceptions were for aspen and balsam poplar, where minimum rotation ages were retained at 40 years. Thinning options were also refined, notably to reflect desired practice within buffers and for approximating and encouraging uneven-aged management.

Forest and timberland area change from 1990 to 2040 was also implemented gradually throughout the 50-year period using estimates of annual change rates. Changes in forest area were assumed to occur on nonindustrial private lands in the northern part of the state with equal percentage changes applied across all forest types. For the southern part of the state, changes were assumed to occur equally across all ownerships. The area change translated into a 873,125 acre decrease in timberland in the two northern FIA units and a 979,174 acre increase in the southern two FIA units by the year 2040. While the net change is small, these changes clearly impact results by FIA unit and ecoregion and need to be considered in the interpretation of harvest scenario results.

Covertypes areas were further subjected to change occurring at the time of harvest and later via stand dynamics or succession. Change occurring at harvest was developed from (1) decision trees for planting and (2) covertype change determined from natural regeneration patterns. Subsequent to harvest, the individual tree based growth model projections were evaluated by a covertype determination algorithm at the end of each ten-year projection period. This evaluation allowed for estimating covertype change due to stand dynamics and successional processes. This was a major difference in procedure from the first model runs where essentially all cover types that were naturally regenerated were assumed to remain in that covertype.

Since the first runs, the USDA Forest Service FIA project has developed factors to adjust the tree growth and mortality in the growth model used. These factors were implemented in the second runs to improve predictions. In most cases the adjustment factors served to reduce estimates of forest growth.

Harvests from national forests were also constrained to the allowable sale quantities in their respective forest plans with the exception of the high scenario.

Timber product values and consumption by various markets were also updated as new information became available.

The various model changes do confound comparisons with the first runs as differences are due both to the addition of mitigative constraints and model changes in the revised runs.

#### **Impacts of Constraints and Mitigations on Results**

With all the ownership constraints, mitigative measures and model changes

incorporated in the second runs, the base scenario was at first found to be infeasible as the aspen consumption level could not be met when using even unrealistically high aspen shadow prices. Shadow prices are equivalent to the marginal costs of producing an additional unit of the associated product. Major reasons for the infeasibility were (1) the substantial shift of acres into categories considered unavailable for harvest or requiring long rotation lengths, (2) reduced forest growth estimates, and (3) reductions of timberland area in the north. Further review also suggested that contributing factors were (1) the short planning period and (2) the existing age-class imbalance of the forest.

Adjustments to achieve feasibility involved lengthening the planning horizon to sixty years, but that in itself did not overcome the infeasibility problems. In order to finally overcome this problem it was necessary to lower the aspen harvest target levels. This meant that some of the aspen demand would need to shift to other species in future periods of the planning horizon. It is likely that decreasing aspen supplies along with associated increases in prices relative to other species will stimulate a substantial shift in demand to those other species. Predicting the extent of the shift, however, is fraught with uncertainty. To move forward, it was assumed that the shift in the projected aspen consumption would be to hardwoods, as the latter exhibited the lowest marginal costs of production for the first model runs. For the medium scenario, it was found that harvest levels could be achieved if 10 percent of the aspen harvest level was shifted to northern hardwoods by the year 2000 with an additional shift in year 2010 for a total shift of 25 percent. For the base scenario, the same 25 percent shift was assumed even though it was clear that feasible schedules could be developed with somewhat smaller shifts. Final marginal cost estimates for the base and medium scenarios served to guide the development of targets for the high scenario. Given these assumptions, specific second run findings were:

1. Under the *base scenario* the rising and higher marginal costs for aspen confirm concerns for the future supply of aspen. Marginal costs for the pine group under the base scenario actually drop substantially over the planning horizon. This drop is likely due to past red pine reforestation efforts, as many plantations will reach harvestable age in later periods of the planning horizon. However, the short planning horizon as compared to typical rotation lengths for red and white pine does not fully address pine reforestation needs to meet potential harvest level targets for periods beyond 2040. Marginal costs for northern hardwoods remain low over time, as compared to all other species groups.

2. Under the *medium scenario*, marginal cost estimates again suggest that aspen is the species in shortest relative supply. Marginal costs rise to over \$80 per cord delivered for aspen while those for northern hardwoods remain relatively low. Marginal costs for spruce-fir under the medium scenario rise steadily and approach \$80 per cord by the end of the planning horizon. As with the base scenario, marginal costs for pine decline.
3. For the *high scenario*, marginal cost estimates increase substantially for all species. The marginal cost of producing hardwoods also rises substantially above the marginal cost of other species by the end of the planning horizon. This suggests that in achieving a seven million cord harvest level, the harvest for northern hardwoods was set too high. The high marginal costs for all species by the end of the planning horizon also suggests that these harvest levels could not be maintained over a longer time horizon. Maintaining them would require either reducing the constraints and mitigations imposed or implementing intensive forest management options not considered in these runs on a large-scale.
4. Marginal cost estimates for pine changed relatively little between the base and medium scenario. Substantially higher costs for the highest scenario reflected the much higher harvest targets for pine under that scenario. Marginal costs for spruce-fir changed substantially between the base and medium scenario, suggesting that a large spruce-fir harvest level increase would have a large impact on the future production cost and price for spruce-fir.
5. Constraints to implement the allowable sale quantities for each national forest carried a marginal cost estimate that measures the cost savings that could be achieved if an additional cord could be harvested from national forest timberland. Marginal cost estimates were not developed for the high scenario, as constraints defining allowable sale quantities were not imposed with that scenario. Considering the potential of national forest timberlands, it is apparent that both national forests could produce substantially more timber than is reflected in their allowable sale quantities. Model runs for the high scenario suggested that harvest level targets could not be met without additional harvesting on the national forests.
6. The southern region of the state showed marginal costs for red oak are higher and tend to rise fast over time for scenarios with higher red oak harvest levels. A relatively constant and low marginal cost for the "other wood" group for all three scenarios suggests that the harvest level targets for this group could have been raised more for the high

scenario. However, this region contains a relatively small component of the statewide timber supply and could not support a large increase.

7. The breakdown of harvest volumes by product category showed some changes in utilization. Under the base scenario, only aspen shows a large reduction in the quantity of sawlogs produced over time, dropping from over 1 million cords per year in period 1 to approximately 475,000 cords in period 4. This reduction is due to a change in age class and associated size of available timber as the scenario progresses. Similar drops occurred for the medium and high scenarios. However, even with the drop, production of aspen sawlog size material is still substantially above the estimate of 210,000 cords for current annual consumption of aspen sawlogs by sawmills. Under all three scenarios, pine sawlog production is above current pine sawlog consumption by sawmills. The highest scenario assumed more than a doubling of the pine sawlog consumption level over the medium scenario, as this product group appeared to have the potential for a large increase.
8. Results for the southern region of the state suggest a broad mix of species will continue to be harvested with an increase in the production of aspen and maple-basswood over time.
9. Changes in results for the second runs are not surprising. The forest area in the southern part of the state expanded and that in the north declined. Both of these changes were substantial. Additionally, several constraints reduced the proportion of forest area available for harvest overall, especially on public lands. The growth model adjustment further reduced estimated yields and the ERF options slowed realization of some of those yields. Prices thus rose, making management investments more attractive and probably increasing the harvest on private lands. Likewise, areas with harvesting constraints tend to reduce the long-term sustained yield. In terms of the resource, there is a slight buildup in the acreage of older age classes and associated values. In total, these changes will likely reduce the timber yield unless counteracted by investments in management that do not conflict with mitigations for other purposes. In reviewing the results, it is important to remember that these results are not a plan, but a refinement of the first run assessments.
10. Harvest acreages for the second runs are summarized in table I.2. The acres cut category includes those acres clearcut once, acres clearcut twice, acres thinned but never clearcut, and acres thinned and clearcut. Compared to the first model runs, the second runs reduced the overall acreage subject to harvesting over the 50-year planning horizon by harvesting some acres

more frequently. This reduction in acreage subject to harvesting uses a result of increased management constraints.

**Table I.2.** Original acres cut one or more times and never cut in the second runs, 1990–2040.

| Forest land use and harvest status | Second model runs<br>Total (acres) |
|------------------------------------|------------------------------------|
| Total forest land acres            | 16,714,800                         |
| Reserved/unproductive              | 1,941,400                          |
| Timberland                         | 14,773,400                         |
| Base Scenario                      |                                    |
| Acres never cut                    | 7,600,000                          |
| Acres cut                          | 7,173,400                          |
| Medium Scenario                    |                                    |
| Acres never cut                    | 6,156,400                          |
| Acres cut                          | 8,617,000                          |
| High Scenario                      |                                    |
| Acres never cut                    | 4,308,200                          |
| Acres cut                          | 10,465,200                         |

11. Revised long-term sustained yield analyses were performed in much the same manner as the earlier long-term sustained yield analyses. However, the revised analyses are based on the updated growth model and take into account ownership constraints, mitigative strategies and the results of the revised timber harvest scheduling runs. The ending inventory from the scheduling model was also analyzed. Marginal costs were used as timber prices to determine the management alternative for each FIA inventory plot that maximizes the soil expectation value of the plot. Using that alternative, average annual yields were determined for each plot and then summed over all plots representing timberland potentially available for harvest. Results varied substantially depending on whether the marginal costs of the base, medium or highest harvest level scenario were used in selecting the optimal management alternative. The biggest difference between scenarios was the area considered profitable for timber production. The resulting profitable acreage was 7.4, 9.7 and 12.5 million acres for the base, medium, and high scenarios, respectively.
12. With the above approach to analyze long-term sustainable yield, the acres harvested within the aspen forest type changed relatively little between scenarios, but the optimal rotation age for most aspen acres is sensitive to the prices assumed.
13. The lack of acreage in the red pine plantation category is a concern. Even under the highest scenario, shadow prices were not high enough to suggest shifting acres into this forest type. However, results would have been

different if a longer planning horizon had been used, giving more consideration to longer-term harvest level objectives. In terms of a sustained yield, shifting acres into the red pine plantation category would increase the sustainable yield as average annual growth rates for red pine are very high compared to most other species.

14. The *base scenario* analysis led to an estimate that a timberland area of approximately 7.4 million acres could sustain close to a 4 million cord annual harvest level. This would leave over 7 million potentially harvestable acres unharvested over the long-term. This explains why the forest industry sees development opportunities in Minnesota. The analysis further suggests that annual harvest levels higher than 4 million cords could be sustained in the long-term once the forest is regulated, i.e., when the age class structure is balanced. This also suggests that large areas of timberland could potentially be shifted towards other management objectives without severely impacting timber production at the 4 million cord level in the long-term.
15. The *medium scenario* analysis indicates that long-term sustained yield levels could be maintained at the 4.9 million cord annual harvest level by utilizing less than 10 million acres of timberland. With the potential to shift additional acreage to plantations or more intensive management options, results strongly suggest that a five million cord level could be maintained in the long-term once a regulated condition is achieved.
16. The *high scenario* analysis utilized most of the timberland acreage assumed to be available and yet fell over 1.5 million cords short of the assumed 7 million cord annual harvest level. This suggests that the high level could not be maintained in the long-term without a substantial increase in management intensification and/or reducing the loss of timberland acreage to other land uses. As one moves from the medium to the high scenario, the sustainable harvest level increases 680,000 cords but requires adding 2.7 million acres to the harvested land base. This is an average increase of only 0.25 cords per acre compared to an average annual harvest level of 0.53 cords per acre, based on the land base assumed for the base scenario. Clearly those additional acres are less productive sites. This highlights the need to recognize differences in site quality in decisions affecting timber production.
17. Overall, as in the first runs, tree species composition on timberlands was only moderately affected by these harvesting scenarios. Ownership constraints and mitigations also served to reduce the number of species that showed large declines in tree numbers.
18. Covertypes change trends remain strongly affected by the species and age

class structure resulting from the logging and land clearing of the past. In general, the higher harvesting scenarios favored an increase in aspen, but that covertime acreage on timberland still increased only slightly (14, 18 and 22 percent under the base, medium and high scenarios, respectively, over the 50-year planning horizon). Long-term trends also seem to show a significant decline in jack pine and black spruce covertime acreage. However, those changes are suspected to be due partly to stand dynamics, natural succession and the imprecision of covertime determination. For such mixed species stands, even small changes can lead to a new covertime designation— yet overall species composition is affected very little. Conversely, red and white pine covertime acreage increased. However, those changes are suspected to be due mostly to succession and/or covertime determination procedures as opposed to harvesting and management.

19. Reserved forest, though not subjected to harvesting, also changed through stand aging processes and successional processes.
20. Preferred mitigations to maintain the forest resource base include incentives for afforestation, reforestation and policy instruments that would reduce the loss of forest land, notably timberland, to other land uses. Preferred mitigations to improve the productivity of forest lands are management investments, including but not limited to species-site matching; regeneration to full stocking levels, and capturing mortality through shorter rotations and thinnings. Such investments can enhance timber supply and reduce conflict with other forest uses by improving per acre productivity, thereby reducing the acreage that might need to be harvested to meet any particular level of demand.

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