Description of NORTHERN SUPERIOR UPLANDS Subsection Forest Resource Management Plan (SFRMP) modeling

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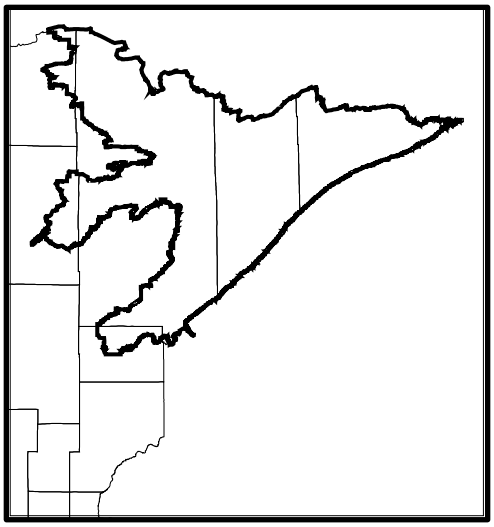
Resource Assessment Unit Forest Biometrics Report Number Fifty-One

September 2015

MNDNR

Introduction

The Minnesota Department of Natural Resources (DNR) has started to prepare the Northern Superior Uplands (NSU) Section Forest Resource Management Plan (SFRMP). This Plan will guide forest vegetation management for five ecological subsections in northeastern Minnesota: Border Lakes, Laurentian Uplands, Nashwauk Uplands, North Shore Highlands, and Toimi Uplands.



The majority of the land cover in the NSU is identified as upland forest; low ground forest and other wetlands, shrub, and open water comprise nearly 7.4 million acres of the Section; 66% is in public ownership, 35% is privately held, and 1% is tribal ownership. State ownership in NSU accounts for 2.1 million acres or 29%. From these acres this planning process will identify Forestry and Fish and Wildlife administered lands that will be site visited and possibly assigned a treatment prescription over the next ten years (10-year stand exam list).

As part of the SFRMP, landscape modeling was conducted. For this purpose, a software package called the Remsoft Spatial Planning System (RSPS) was used. Woodstock is a component of RSPS that allows users to examine how various land uses, management alternatives, and social policies will impact timber supply at a strategic-level, given the existing forest types and stand inventories. Strategic means at a large-scale, and ignores the spatial relationships between/among individual stands.

Within DNR's strategic-level plans the planning horizon is 150 years but only the initial 50 years are analyzed by the NSU planning teams. For this analysis the objective function in Woodstock is to maximize discounted revenues. Since Woodstock uses linear programming to find an optimal solution when trying to maximize revenues, which is merely a mathematical operation, if no constraints are included most stands will be harvested at year 150. Of course linear programming has no concept of the future beyond the 150 year planning period. Hence, the additional 100 years helps to provide a more realistic depiction of how stands will be managed near the end of the initial 50 year period.

It is felt this is advantageous to placing binding constraints (or constraints that must be met) to avoid illogical behavior 45 and 50 years into the future. Even-flows also help to avoid projected

harvesting spikes at the end of the 150 year planning period. For the part of the planning horizon that is analyzed, 10 five-year planning periods were used.

In general, individual stands are not projected throughout a planning horizon when using Woodstock. Rather, stands are grouped into categories and then acres within a category (where the acres are a conglomeration of many stands) receive treatments and are projected throughout the planning horizon. For example, all stands classified as a balsam fir cover type (within FIM/CSA coded as 62), could be grouped into site qualities using an interval of 5 feet (e.g. site quality class 50 could encompass all balsam fir cover type stands with site qualities ranging from 50 to 54 feet) and then these balsam fir cover type stands grouped by site quality class would receive treatments within Woodstock and be projected forward as a group. In this case, when treatments are assigned to a category, there is no way to tell what specific stands should be treated within a particular planning period.

As opposed to other optimization techniques, linear programming allows proportions of a landbase to receive treatments. For example, it could be that only 34% of aspen cover type, site index 65 stands receive a clearcut operation in a particular planning period. For other optimization techniques, such as integer programming, activities either occur or don't (either 1 or 0) in a particular planning period.

Harvest scheduling does not optimize management objectives of the target forest. Rather, it is about developing an optimal activity schedule for the transition of the existing forest to the desired future forest. For many stands, individual stand management may be less than optimal so that section/subsection objectives as a whole can be met.

NSU Geographic Information Systems (GIS) ARCMAP SHAPEFILE

To conduct a landscape level harvest scheduling analysis, the landbase must be quantified as to the amount of cover type acres by age and site productivity and potential management restrictions/actions that can occur on those acres. The most recent DNR FIM shapefile database (05/12/2014) for the NSU was queried. Cover type is determined based on internal DNR algorithms, site index is calculated based on measurement of dominant trees within the field and appropriate equations, and age is based on field measurements.

Within Woodstock, after excluding old growth stands and other stands designated as not allowing timber harvest, there is a total of 31,306 polygons totaling 620,439 acres – the smallest stand acreage is 0.2 acres and the largest stand acreage is 1,812 acres. For the commonly managed timber types, this landbase only includes harvestable stands, and is referred to as "timberlands" (hence excludes old growth and other non-harvestable stands). Prior to conducting the analysis within Woodstock, this original dataset was manipulated to prepare it for the modeling exercise. For instance, new cover types were created (e.g. red pine plantations are

coded as 521 rather than 52 to allow for different management treatments relative to natural red pine stands which remain coded as 52).

Number of acres by cover type are shown in Table 1. Table 2 shows modifications of the MN_CTYPE field for modeling purposes.

Table 1. MANAGEABLE (excludes old growth and other non-harvestable acres) cover type acreages within the NSU SFRMP dataset.

Cover Type Code	Cover Type Name	Number of Stands	Acres
1	Ash	1,182	15,564
9	Lowland Hardwoods	60	945
12	Aspen	8,803	191,548
13	Birch	1,169	28,406
14	Balm of Gilead	319	4,410
20	Northern Hardwoods	545	13,392
30	Oak	20	425
301	Oak - High Slope	2	32
51	White Pine	572	9,161
52	Red Pine Natural	514	8,074
521	Red Pine Plantation	1,298	25,361
53	Jack Pine	1,222	23,840
61	White Spruce	284	5,475
611	White Spruce Plantation	902	17,025
62	Balsam Fir	1,037	17,077
71	Black Spruce – High	894	12,948
710	BS – Low	946	17,997
711	BS - Medium	1,903	32,115
72	Tamarack – High	337	4,850
721	Tamarack - Low	319	6,202
74	Upland Black Spruce	377	6,094
Total		22,705	440,941
Non-merchantable Acreage			
54	Scotch Pine	1	0
64	Norway Spruce	1	2
70	Upland Larch	1	11
73	NWC	1,655	32,447
Low Productivity			
75	Stagnant Spruce	988	29,636
76	Stagnant Tamarack	118	6,574
77	Stagnant Cedar	426	10,986

Cover Type Code	Cover Type Name	Number of Stands	Acres
78	Offsite Aspen	14	330
79	Offsite Oak	18	223
81	Red Cedar	1	4
82	Cutover Area	8	78
83	Lowland Grass	257	3,228
84	Upland Grass	174	689
85	Lowland Brush	2,227	44,414
86	Upland Brush	190	2,376
90	Other	4	57
91	Agriculture	4	14
92	Industrial Development	276	11,489
93	Recreational Developmt	25	243
94	Roads	208	1,772
95	Rock Outcrop	98	1,069
96	Permanent Water	422	8,630
97	Non-permanent Water	930	14,194
98	Marsh	301	5,945
99	Muskeg	254	5,087
Grand Total		31,306	620,439

Old-Growth Forest(OG)

At the current time lowland conifer old growth acres have not been officially designated. Hence, these acres do not exist within the current GIS shapefile, do not exist on the current DNR landbase, and were not excluded from timber harvest consideration. Thus, within the model during the first planning period Woodstock assigned an old growth status to acres and this status was permanently maintained on these acres. These acres are tracked within Woodstock for a cover type separately from non-old growth (or harvestable) status using an OG designation.

For upland cover types, old growth designation has actually occurred and thus these acres were deleted from the GIS shapefile and from representation within the Woodstock modeling landbase.

Table 2. For the purposes of modeling, several cover types above have been split and in some cases new cover types have been created. Creating these treatment *regimes* provides more realistic model outcomes.

Cover Type Code	Cover Type Name	Creation	Reasoning
101	Regulated Ash	Created during model	-
109	Regulated Lowland Hardwoods	Created during model	-
120	Regulated Northern Hardwoods	Created during model	-
301	Oak – High Slope	Existing, TOPO = 3	High slope Oak sites not thinned
302	Once Thinned Oak	Created during model	To ensure stands can only be thinned **UP TO** 2 times prior to age 70
303	Twice Thinned Oak	Created during model	
151	Regulated White Pine	Created during model	-
152	Once Thinned Red Pine Natural Stand	Created during model	To ensure stands can only be thinned **UP TO** 6 times prior to age 100
252	Twice Thinned Red Pine Natural Stand	Created during model	
352	Three Thinned Red Pine Natural Stand	Created during model	
452	Four Thinned Red Pine Natural Stand	Created during model	
552	Five Thinned Red Pine Natural Stand	Created during model	
652	Six Thinned Red Pine Natural Stand	Created during model	
521	Red Pine Plantation	Existing, ORIGIN = 2 or 3	-
522	Once Thinned Red Pine Plantation	Created during model	To ensure stands can only be thinned **UP TO** 6 times prior to age 100
523	Twice Thinned Red Pine Plantation	Created during model	
524	Three Thinned Red Pine Plantation	Created during model	
525	Four Thinned Red Pine Plantation	Created during model	
526	Five Thinned Red Pine Plantation	Created during model	
527	Six Thinned Red Pine Plantation	Created during model	
71	Black Spruce – High	Existing, SI >=40	Allows for three different rotation ages for conventional runs of Woodstock
710	Black Spruce – Low	Existing, SI 23 to 29	
711	Black Spruce – Medium	Existing, SI 30 to 39	
72	Tamarack – High	Existing, SI >=40	Allows for two different rotation ages for

Cover Type Code	Cover Type Name	Creation	Reasoning
721	Tamarack – Low	Existing, SI < 40	conventional runs of Woodstock
161	Regulated White Spruce	Created during model	-
611	White Spruce Plantation	Existing, ORIGIN = 2 or 3	-
612	Once Thinned White Spruce Plantation	Created during model	To ensure stands can only be thinned
613	Twice Thinned White Spruce Plantation	Created during model	**UP TO** 2 times prior to clearcut
162	Regulated Balsam Fir	Created during model	-

Description of Yield Tables

For this analysis, cover type volumes are initially estimated using covertype-specific yield tables, then average covertype species compositions (calculated using FIA/FIM data) are used to determine the amount of individual species volume harvested.

Basal area, mean stand diameter, and total cordwood volume were estimated for each planning period. All equations require cover type, site index, and age. All clearcut even-aged systems were modeled using Walters and Ek forms (1993, Whole Stand Yield and Density Equations for Fourteen Forest Types in Minnesota, Northern Journal of Applied Forestry, 10:75-85) – these are values basically using only FIM data from within the NSU section. Yield tables were created for the section as a whole rather than by subsection.

For simplicity, all red pine and white spruce thinning operations were assumed to generate 10 cords per acre, regardless of cover type or age. All oak thinning operations were assumed to generate 8 cords per acre.

For uneven-aged types (partial cutting harvests) a reduced portion of the predicted yields were assumed to represent partial cuttings. For the ash, lowland hardwood, northern hardwood, uneven-aged balsam fir, uneven-aged white spruce, and white pine cover types, it was assumed each partial cutting generates 33% of the predicted clearcut yields.

For all clearcut harvests, only 95% of the expected volume (yield table estimate) was available at final harvest to reflect the current DNR practice of leaving 5% of the harvest area intact to address non-timber concerns.

Desired Future Forest Conditions (DFCs) and Constraints

The following values were utilized during this particular analysis (Tables 3 to 5).

Table 3. Normal rotation age (NRA) by cover type. BL refers to Border Lakes, NSH refers to Laurentian Uplands, North Shore Highlands, and Toimi Uplands, and NU refers to Nashwauk Uplands.

Cover Type	Subsection	Site Type	Age
Aspen/BG	All	All	45
Birch	BL	All	60
Birch < 60	NSH	All	55
Birch 60+	NSH	All	65
Birch	NU	All	50
Jack Pine	BL, NSH	All	60
Jack Pine	NU	All	50
Upland Black Spruce	BL, NSH	All	70
Upland Black Spruce	NU	All	50
BSL Low 23-29	All	All	120
BSL Medium 30-39	All	All	100

Cover Type	Subsection	Site Type	Age
BSL High 40+	All	All	80
Tamarack Low <40	BL, NU	All	90
Tamarack Low <40	NSH	All	100
Tamarack High 40+	BL, NU	All	60
Tamarack High 40+	NSH	All	85
White Spruce	BL	Planted	50
White Spruce	NSH	Planted	75
White Spruce	NU	Planted	60
Balsam Fir	All	All	50
Red Pine	BL, NSH	Natural	120
Red Pine	NU	Natural	100
Red Pine 65+	All	Planted	60
Red Pine 55-64	All	Planted	65
Red Pine <55	All	Planted	70
Oak	All	All	85

Table 4. "Older" forest age by cover type.

Cover Type	Site Index	Age
Aspen/BG	All	55
Birch	All	65
Jack Pine	All	65
BSL Low 23-29	All	125
BSL Medium 30-39	All	105
BSL High 40+	All	85
Tamarack Low <40	All	95
Tamarack High 40+	All	65
White Spruce	Planted	55
Balsam Fir	All	55
Red Pine	All	125
Oak	All	90
NWC	All	105

Table 5. "Younger" forest age by cover type.

Cover Type	Site Index	Age
Aspen/BG	All	30
Birch	All	35
Jack Pine	All	30
BSL Low 23-29	All	70
BSL Medium 30-39	All	60
BSL High 40+	All	40

Cover Type	Site Index	Age
Tamarack Low <40	All	50
Tamarack High 40+	All	30
White Spruce	Planted	25
Balsam Fir	All	30
Red Pine	All	25
Oak	All	35

Stands "Under Development"

At the time of the shapefile creation, many stands were scheduled to receive some type of treatment (based on past plans), these stands are specified as "Under Development" within FIM. Unfortunately the exact treatment is not specified within FIM. To account for changes to the landbase from these treatments, stand ages were specified based on revised ages provided within the GIS shapefile.

Potential Management Actions

Given the current number of acres by cover type, site quality, and age, and desired future forest conditions and management objectives, and potential management actions that can occur, Woodstock will find the optimal management scheme of all stands to move the existing forest to the desired future forest. For any acre, there are many potential management actions that could occur and the timing of those actions can vary. It is important that potential management actions within Woodstock reflect possible operational management options and the conditions that could impact choosing one alternative over another.

For instance, operationally, ABg stands are generally clear cut, and these clear-cut operations do not occur until a stand reaches age 45. There are many options for a particular stand, for instance it could be harvested at age 45 or it could be harvested at age 55. The timing of a specific operation depends on the projected yields and the desired future forest conditions. It could be that for a particular ABg stand, based on its site index, volume is maximized at age 46. However, because of age-class distribution constraints at the landscape level, the optimal time to harvest this stand is at age 54. Thus, in order to optimize landscape level management objectives, some stand-level harvested volume would be sacrificed.

Table 6. Potential clearcut operations by cover type.

Cover Type	Cover Type Code	Site Index (base age 50)	Ages
Aspen	12	All site qualities	> = 45
Balm of Gilead	14	All site qualities	> = 45
Birch	13	All site qualities	See Table 3
Red Pine (both natural and plantation)	52, 521	All site qualities	See Table 3
Jack Pine/Upland Black Spruce	53	All site qualities	See Table 3
White Spruce Plantation	611	All site qualities	See Table 3

Cover Type	Cover Type Code	Site Index (base age 50)	Ages
Balsam Fir	62	All site qualities	> = 50
Black Spruce – Low	710	<= 29 ft	> = 120
Black Spruce – Medium	711	>= 30 ft and <= 39 ft	> = 100
Black Spruce – High	71	>= 40 ft	> = 80
Tamarack – Low	721	<= 39 ft	See Table 3
Tamarack – High	72	>= 40 ft	See Table 3
Oak	30, 301	All site qualities	> = 85

For red pine, white spruce, and oak thinning regimes, at least 10, 15, and 15 years must pass before another thinning can occur, respectively. For red pine, up to 6 thinning entries can occur beginning at age 25 up to age 100, for oak up to 2 thinning entries can occur beginning at age 30 up to or before age 70, and for white spruce up to 2 thinning entries can occur beginning at age 25 before the final harvest.

Table 7. Potential thinning operations by cover type.

Cover Type	Cover Type Code	Site Index (base age 50)	Ages
Red Pine (both natural and plantation)	52, 521	>= 45	>= 25 years and <= 100 years
White Spruce Plantation	611	All site qualities	>= 25 years
Oak	30	>= 60	>= 30 years and <= 70 years

For any partial cutting (whether GROUP or REGULATED), at least 20 years must pass before another cutting can occur.

Table 8a. Potential uneven-aged (partial cutting) GROUP harvesting operations by cover type.

Cover Type	Cover Type Code	Site Index (base age 50)	Ages	Basal Area Per Acre	Cords Per Acre
Ash	1	>= 45	All	>= 85	>= 15
Lowland Hardwoods	9	>= 45	All	>= 80	>= 21
Northern Hardwoods – Young	20	All site qualities	>= 26 years and <= 55 years	>= 90	-
Northern Hardwoods – Old	20	All site qualities	>= 56 years	>= 100	-
White Pine	51	All site qualities	>= 125 years	-	-
White Spruce	61	All site qualities	>= 80 years	-	-
Balsam Fir	62	All site qualities	>= 50 years	-	-

Table 8b. Potential uneven-aged (partial cutting) REGULATED harvesting operations by cover type.

Cover Type	Cover Type Code	Site Index (base age 50)	Ages
Ash	101	All site qualities	All
Lowland Hardwoods	109	All site qualities	All
Northern Hardwoods	120	All site qualities	All
White Pine	151	All site qualities	All
White Spruce	161	All site qualities	All

Because of ecological concerns, we assumed no harvesting of northern white cedar stands. Due to low acreages, there are no management actions in Scots pine, Norway spruce, upland larch, and red cedar cover type stands. Due to low productivity and therefore relatively high logging costs per unit harvested, stagnant spruce, stagnant tamarack, stagnant cedar, offsite aspen, and offsite oak have no management actions.

Average Percent Species Compositions

To estimate individual species volumes, average percent species compositions were obtained by cover type. A combination of USDA Forest Service Forest Inventory and Analysis (FIA) and FIM data were used. Merchantable volume (as opposed to say total volume or basal area) was used to determine percent species compositions.

Lowland Conifer Designation

For scenarios requiring a certain amount of forest to be specified as “old growth,” acres were permanently assigned during the first period. Hence, these acres were removed from the harvest pool.

Conversion Actions

There were two different sets of cover type conversion goals identified to be achieved through forest management. One set considered the implications of climate change on cover type management goals while the other set specified conversion goals without consideration of climate change, to support other forest management directions such as conversions for wildlife habitat. The implications of climate change on cover type management and covertype conversion is a newly introduced management action into the SFRMP process, whereas conversion to support wildlife habitat has been a management action found in past SFRMPs.

Tables 9 through 13 identify factors and percentages used in modeling the conversion actions.

Table 9 identifies the modeled change in cover type acres based on past SFRMPs but modified for potential climate change. These reflect realistic percentages given the actual historic conversions proposed in past plans.

Table 9. Percent change in cover type acres achieved through clearcutting over the next 50 years FOR THE CLIMATE CHANGE SCENARIO. Percentages are cumulative.

Cover Type	Site Index	10-Year	20-Year	30-Year	40-Year	50-Year
Jack Pine	All	-17.083%	>=-17.083%	>=-17.083%	>=-17.083%	-34.165%
Aspen/BG	All	-	-	-	-	-1.815%
Birch	All	-	-	-	-	-1.815%
BS – High	All	-7.936%	>=-7.936%	>=-7.936%	>=-7.936%	-31.743%
BS – Medium	All	-7.936%	>=-7.936%	>=-7.936%	>=-7.936%	-31.743%
BS – Low	All	-7.936%	>=-7.936%	>=-7.936%	>=-7.936%	-31.743%
BF	All	-7.936%	>=-7.936%	>=-7.936%	>=-7.936%	-31.743%
WS – Natural	All	-7.936%	>=-7.936%	>=-7.936%	>=-7.936%	-31.743%
WS – Planted	All	-7.936%	>=-7.936%	>=-7.936%	>=-7.936%	-31.743%

Table 10 identifies the percent change in cover type acres which may be pursued to accommodate other conversion goals such as for wildlife habitat. These percentages are viewed as aggressive, not particularly achievable but are intended to show how changes in conversions compare among the scenarios.

Table 10. Percent change in cover type acres achieved through clearcutting over the next 50 years FOR THE SCENARIOS NOT CONSIDERING CLIMATE CHANGE. Percentages are cumulative.

Cover Type	Site Index	10-Year	20-Year	30-Year	40-Year	50-Year
Aspen	All	-5.0%	-10.0%	-15.0%	-20.0%	-22.0%
Balm	All	-5.0%	-10.0%	-15.0%	-20.0%	-22.0%
Birch	All	-5.0%	-10.0%	-15.0%	-20.0%	-22.0%

When considering potential climate change impacts (refer to Table 9), the following transitions of cover types are assumed:

Table 11. Cover type transitions by decade.

Cover Type	Site Index	10-Year	20-Year	30-Year	40-Year	50-Year
Aspen	All	56.916%	-	-	-	-
Birch	All	8.441%	-	-	-	-
Balm	All	1.310%	-	-	-	-
White Pine	All	7.169%	13.6861%	13.6861%	13.6861%	13.6861%
Red Pine – Natural	All	6.318%	12.0622%	12.0622%	12.0622%	12.0622%
Red Pine – Planted	All	19.846%	37.8881%	37.8881%	37.8881%	37.8881%
N Hardwood	All	-	27.2727%	27.2727%	27.2727%	27.2727%
Oak	All	-	9.0909%	9.0909%	9.0909%	9.0909%

For the conversion goals not accounting for climate change (refer to Table 10), percent of acres transitioning to other cover types differs whether a conversion is obtained through a clearcut operation or not. For conversions obtained through operations other than clearcutting **(Soft Conversion)**, the following percent transitions are assumed:

Table 12. Soft conversion transition percentages.

Cover Type	Site Index	10-Year
Balsam Fir	All	25.0%
White Spruce Natural	All	25.0%
White Pine	All	50.0%

For conversions obtained through clearcutting **(Hard Conversion)**, the following percent transitions are assumed:

Table 13. Hard conversion transition percentages.

Cover Type	Site Index	10-Year	20-Year	30-Year	40-Year	50-Year
Jack Pine	All	33.0%	33.0%	33.0%	33.0%	33.0%
White Spruce Natural	All	11.0%	11.0%	11.0%	11.0%	11.0%
Balsam Fir	All	11.0%	11.0%	11.0%	11.0%	11.0%
Red Pine Planted	All	17.0%	17.0%	17.0%	17.0%	17.0%
White Pine	All	17.0%	17.0%	17.0%	17.0%	17.0%
NWC-Upland	All	11.0%	11.0%	11.0%	11.0%	11.0%

Stumpage Prices by Species

Revenues per cord of harvested wood are presented below. For several species a blended pulpwood/bolt/sawtimber price was used. This was obtained by multiplying the per cord stumpage revenues associated with pulpwood exclusively, bolts/pulpwood, and sawtimber times their reported cords to produce a weighted-average cord revenue. Examples are provided for aspen, red pine, and birch.

A 3% interest rate was used when discounting stumpage revenues.

Table 14. Prices per cord of harvested wood. Applies to all scenarios. **Prices are from the 2013 Public Stumpage Price Review for DNR Forestry (http://files.dnr.state.mn.us/forestry/timber_sales/stumpage/stumpageReviewReport2013.pdf). The exceptions being Red Oak, White Oak, and NWC which were provided by Don Deckard, DOF Forest Economist.**

Species	Stumpage Price Per Cord of Pulpwood	Blended Stumpage Price Per Cord of Bolts/Pulpwood/Sawtimber	Real Price Adjustment (1)
Trembling Aspen	$24.97	-	-
Largetooth Aspen	$24.97	-	-
Balm	$20.66	-	-
Paper Birch	-	$10.19	-
Basswood	-	$13.67	-
Red Oak (2)	-	$40.00	Y
White Oak (3)	-	$30.00	Y
Maple (4)	-	$13.13	-
Ash (5)	-	$6.47	-
Elm (6)	-	$18.39	-
Balsam Fir	-	$11.04	-
Black Spruce	$17.62	-	-
Jack Pine	-	$27.70	Y
Red Pine on non-RP cover types (7)	-	$41.84	Y
Tamarack	$4.66	-	-
White Pine	-	$44.12	Y
White Spruce	-	$19.46	Y
White-cedar (8)	$5.00	-	-

Table Notes:

(1) For planning purposes, designated species increase in real terms at 0.5% per year.
(2) Includes black oak.
(3) Includes bur oak.
(4) Sugar and red maple.
(5) Black, green, and white ash.
(6) Includes American elm, red elm, black cherry, butternut, pin oak, hackberry, hickory, silver maple, cottonwood, willow, and misc.
(7) For red pine cover type, use red pine price table by age and silvicultural treatment.
(8) Includes northern white and eastern red cedar.

$$\text{Aspen}_{\text{Blend}} = \frac{\$0 \text{ per Sawtimber cord} * 0 \text{ cords} + \$0 \text{ per Pulp and Bolt cord} * 0 \text{ cords} + \$24.97 \text{ per pulpwood cord} * 400{,}759.1 \text{ cords}}{0.0 \text{ cords} + 0.0 \text{ cords} + 400{,}759.1 \text{ cords}} = \$24.97 \text{ per cord}$$

$$\text{Red Pine}_{\text{Blend}} = \frac{\$110.66 \text{ per Sawtimber cord} * 1{,}496.2 \text{ cords} + \$41.54 \text{ per Pulp and Bolt cord} * 52{,}880.8 \text{ cords} + \$13.50 \text{ per pulpwood cord} * 3{,}080.2 \text{ cords}}{1{,}496.2 \text{ cords} + 52{,}880.8 \text{ cords} + 3{,}080.2 \text{ cords}} = \$41.84 \text{ per}$$

$$\text{Birch}_{\text{Blend}} = \frac{\$0 \text{ per Sawtimber cord} * 0 \text{ cords} + \$16.98 \text{ per Pulp and Bolt cord} * 8246.8 \text{ cords} + \$7.45 \text{ per pulpwood cord} * 20{,}446.4 \text{ cords}}{0.0 \text{ cords} + 8246.8 \text{ cords} + 20{,}446.4 \text{ cords}} = \$10.19 \text{ per cord}$$

Table 15. Prices per cord of red pine harvested wood ON RED PINE COVER TYPES. Applies to all scenarios.

Age	**Stumpage Price per Cord**	**Stumpage Price per Cord**
	Thinning harvest	**Clearcut harvest**
30	$16.00	-
40	$26.00	-
50	$32.00	$50.00
60	$40.00	$65.00
70	$45.00	$70.00
80	$50.00	$75.00
90	$50.00	$75.00
100	$50.00	$75.00
110	-	$75.00
120	-	$75.00
130	-	$75.00
140	-	$75.00
150	-	$75.00

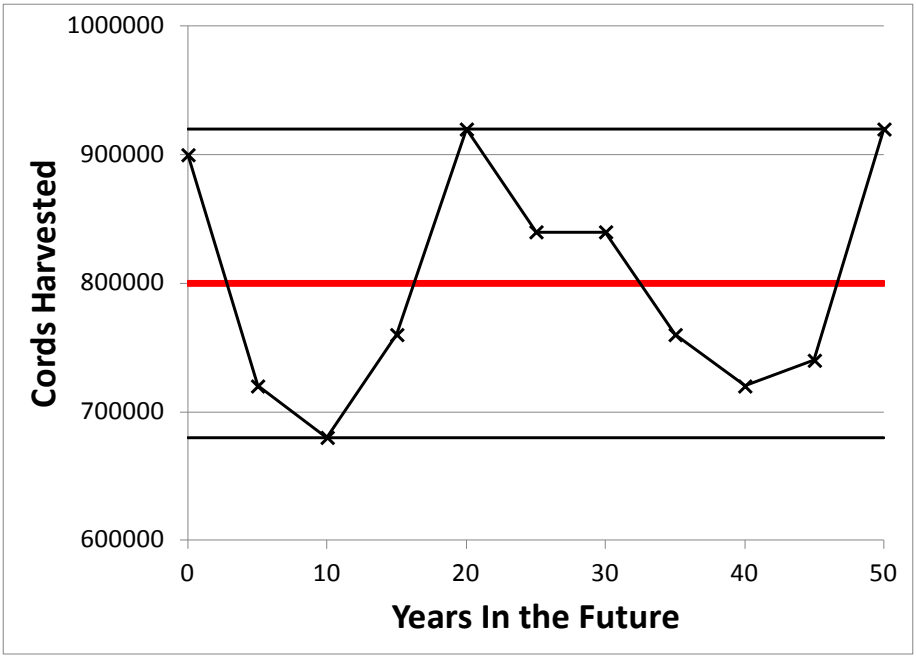
These prices reflect that a thinning at age 30 will generally only contain pulpwood, but with age the percent bolts (or small sawlogs) will likely increase; at older ages thinnings may even remove smaller sawlogs. For clearcuts, as age increases, the percentage of bolts and sawlogs will increase, but at some point a percentage of the tree diameters will become too large for current mill specifications, thereby eliminating the potential to sell that timber.

Even Flows

Even-flows by cover type provide a target relative range of harvested volume over the next 150 years, and represent the stability of harvested volumes. Quantifying the average amount of harvested volume and the likely variations from that average over the next 150 years provides industry some idea of the amount of fiber available for the production of primary wood products (e.g. pulpwood for oriented strand board and paper/pulp production and sawlogs for lumber, pallet, and veneer production) and even the production of secondary wood products.

Factors such as the rotation ages and yield tables (predicted volumes) all play an important part in estimating even-flows and their variation around the long-term average harvested volume. A greater percent even-flow allows for more flexibility as to the timing of harvests across the landscape and will likely result in slightly greater average harvested volumes. However, the greater average harvested volumes across time may result in periods of excessive supply and demand that could negatively impact the forest industry.

Figure 1. Example of a 15% even flow effect on harvested volume over time.



In the figure above, the average volume of wood harvested over the next 50 years is 800,000 cords. An even-flow constraint of 15% was utilized. Hence, in any one year, the amount of harvested volume could deviate +/- 15% from the average harvest of 800,000 cords.

Greater percent even-flows allow for more flexibility in choosing stands to harvest across time to meet desired future conditions (DFCs); this will generally result in a greater average harvested volume. However, greater percent even-flows result in more variation in the amount of harvested volumes from year to year which could negatively impact the forest industry.

SCENARIO MODELING

To address the variety of interests related to Minnesota DNR land management, four different scenarios were developed. These four scenarios use the same rotation ages, stand density management, and revenues but differ in their desired future conditions (DFC) for lowland conifer old growth (LCOG), even-flows of harvested volume, conversion goals (see Tables 9-13), and in their older forest goals. If a section planning team identified that existing forests may not provide enough older forest in the future ACROSS ALL OWNERSHIPS WITHIN THE BOUNDARIES OF THAT SECTION then the team could propose that purposeful management should be conducted on DNR LANDS to produce sufficient older forest in the future. The NSU section team identified certain cover types within particular subsections that may require management to produce additional older forest.

The reader must be cautioned that the value of these modeling scenarios is not in determining final numbers, volumes, or dollars; or to produce absolute numbers that will be used as targets in future management. Rather the intended value of this modeling exercise is in comparing how a mix of parameters in one Scenario results in outputs relative to outputs of other Scenarios with different combinations of parameters.

Table 16. Percent Lowland Conifer Old Growth (LCOG) percentages.

Cover Type	Cover Type Code	Site index (base age 50)	A	B	C	D
Black Spruce – Low	710	<= 29 ft	10%	5%	10%	1.5%
Black Spruce – Medium	711	>= 30 ft and <= 39 ft	10%	5%	10%	1.5%
Black Spruce – High	71	>= 40 ft	10%	5%	10%	1.5%
Tamarack – Low	721	<= 39 ft	10%	5%	10%	1.5%
Tamarack – High	72	>= 40 ft	10%	5%	10%	1.5%
Northern White Cedar	73	All	10%	5%	10%	1.5%

Table 17. Even-flow of harvested volume across all cover types and species, and also by individual cover type.

Cover Type	Cover Type Code	Site index (base age 50)	A	B	C	D
All cover types	-	-	5%	20%	40%	40%
ABg	12, 14	All	5%	20%	40%	40%
Birch	13	All	5%	20%	40%	40%
Jack Pine/Upland Black Spruce	53, 74	All	5%	20%	40%	40%
Black Spruce – Low	710	All	5%	20%	40%	40%
Black Spruce – Medium	711	All	5%	20%	40%	40%
Black Spruce – High	71	All	5%	20%	40%	40%
Tamarack – Low	721	All	5%	20%	40%	40%
Tamarack – High	72	All	5%	20%	40%	40%
White Spruce Plantation	611	All	5%	20%	40%	40%
Balsam Fir	62	All	5%	20%	40%	40%
Red Pine (Natural)	52	All	5%	20%	40%	40%
Red Pine (Plantation)	521	All	5%	20%	40%	40%

Table 18. Older forest percentages.

BL refers to Border Lakes, NU refers to Nashwauk Uplands, NSH refers to North Shore Highlands, TU refers to Toimi Uplands, and LU refers to Laurentian Uplands.

Cover Type	Cover Type Code	Subsection	A	B	C	D
ABg	12, 14	NU	12.0%	6.0%	12.0%	0.0%
Jack Pine/Upland Black Spruce	53, 74	NU	12.0%	6.0%	12.0%	0.0%
Jack Pine/Upland Black Spruce	53, 74	NSH	9.0%	4.5%	9.0%	0.0%
Jack Pine/Upland Black Spruce	53, 74	TU	9.0%	4.5%	9.0%	0.0%
White Spruce – Planted	611	BL	10.0%	5.0%	10.0%	0.0%
White Spruce – Planted	611	TU	10.0%	5.0%	10.0%	0.0%
White Spruce – Planted	611	NU	10.0%	5.0%	10.0%	0.0%
White Spruce – Planted	611	LU	10.0%	5.0%	10.0%	0.0%
White Spruce – Planted	611	NSH	12.0%	6.0%	12.0%	0.0%
Black Spruce – Low	710	NSH	10.0%	5.0%	10.0%	0.0%

Table 19. Summary of Desired Future Conditions (DFCs) for the four Scenario models.
Where CC Response refers to the use of conversion goals taking into consideration climate change and Original SFRMP does not consider climate change when specifying conversion goals.

SFRMP Modeling Scenarios

Parameter	Scenario A	Scenario B	Scenario C	Scenario D
Even Flow	Tight 5%	Moderate 20%	Relaxed 40%	Relaxed 40%
LCOG Designation	High 10%	Moderate 5%	High 10%	Low 1.5%
Cover Type Change	Climate Change Response	Original SFRMP	Original SFRMP	No Change
Older Forest (if needed for certain Cover Types)	More	Some	More	None

SCENARIO MODEL OUTPUTS

Figure 2. Estimated harvested cords by scenario and five-year projection period across all cover types and species.

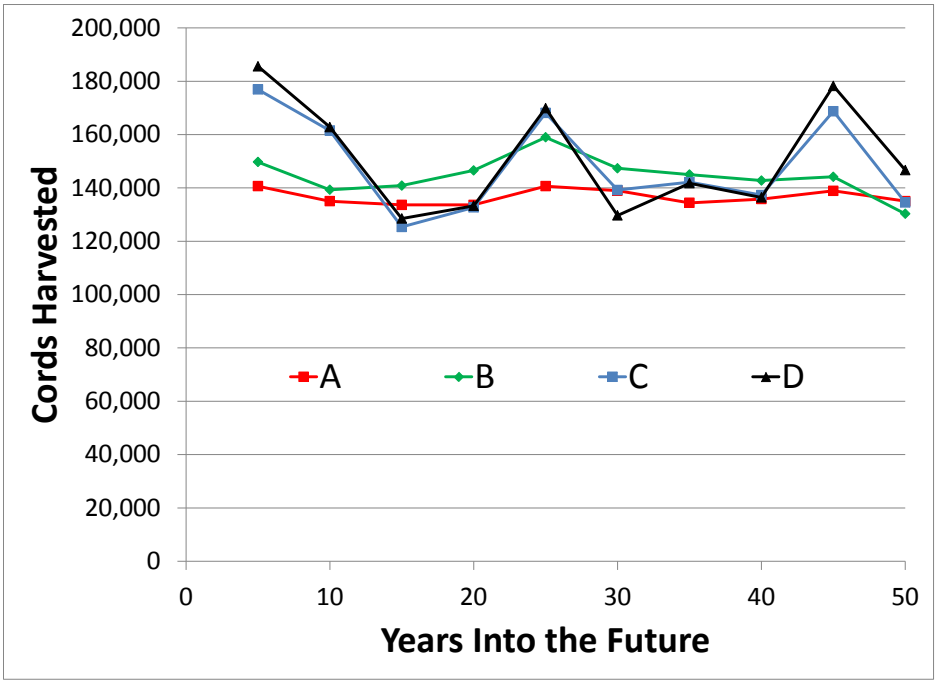


Figure 3. Estimated ASPEN and BALM-of-GILEAD SPECIES harvested cords by scenario and five-year projection period across all cover types.

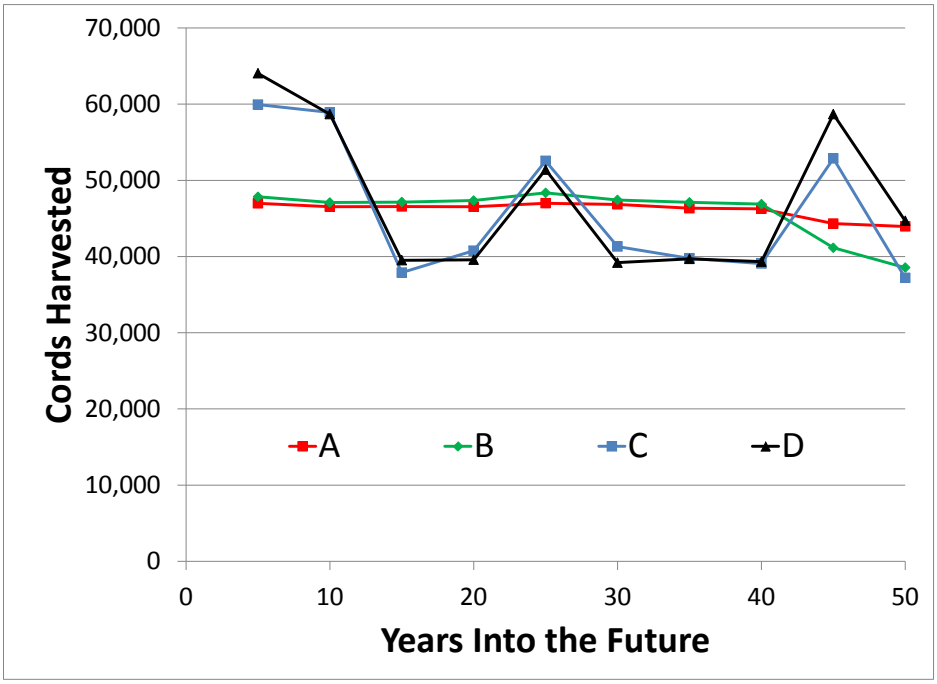


Figure 4. Estimated BIRCH SPECIES harvested cords by scenario and five-year projection period across all cover types.

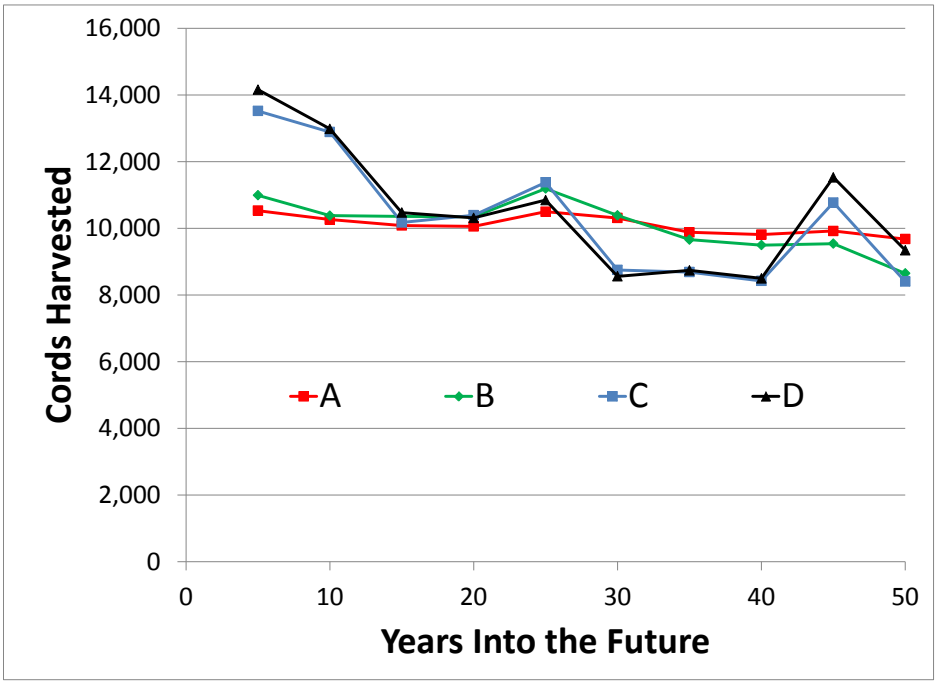


Figure 5. Estimated JACK PINE SPECIES harvested cords by scenario and five-year projection period across all cover types.

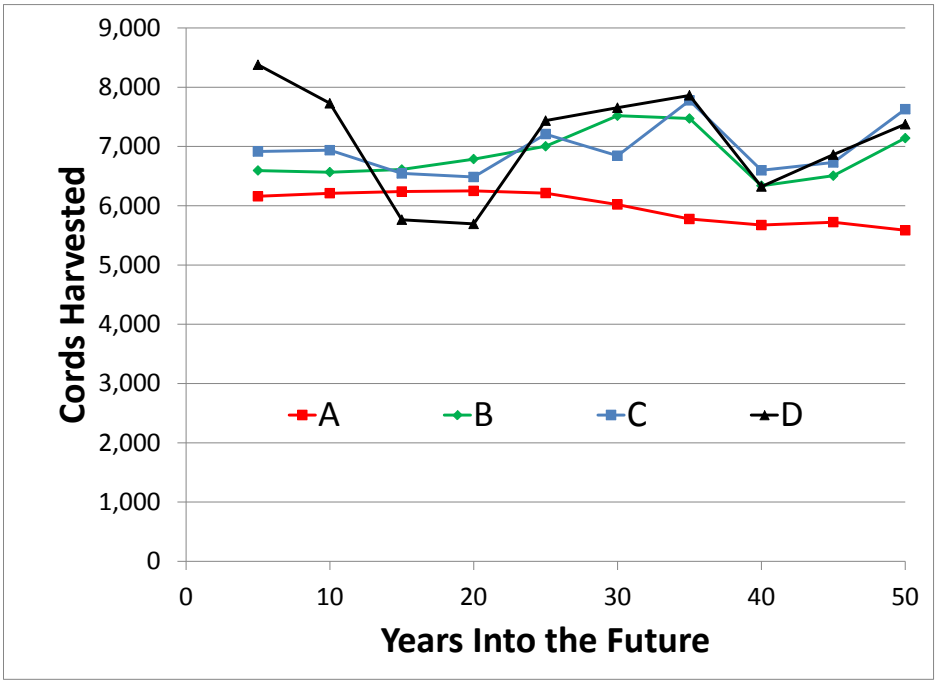


Figure 6. Estimated RED PINE SPECIES harvested cords by scenario and five-year projection period across all cover types.

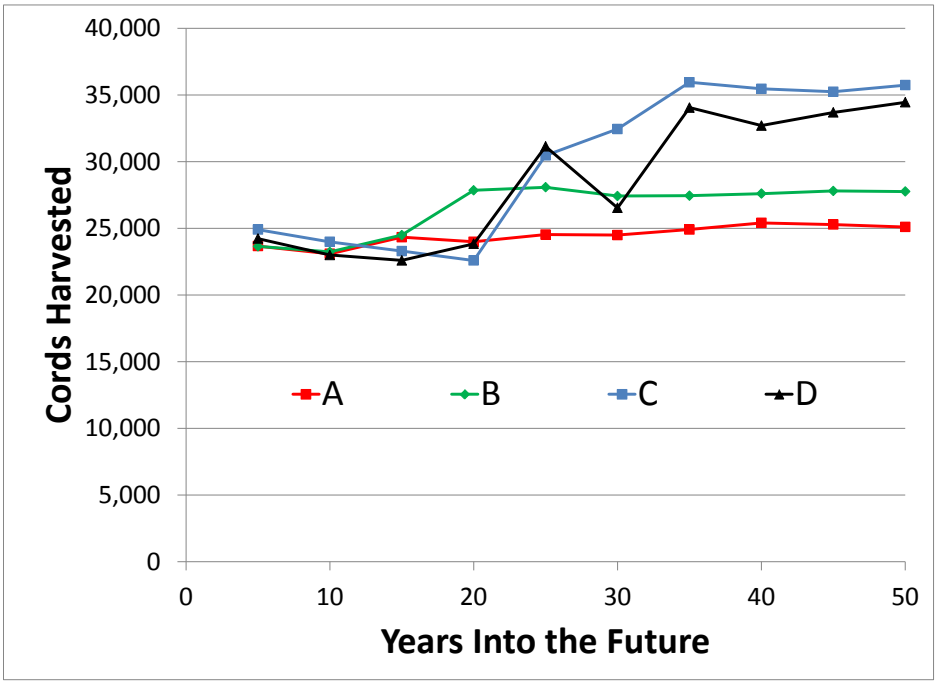


Figure 7. Estimated BLACK SPRUCE SPECIES harvested cords by scenario and five-year projection period across all cover types.

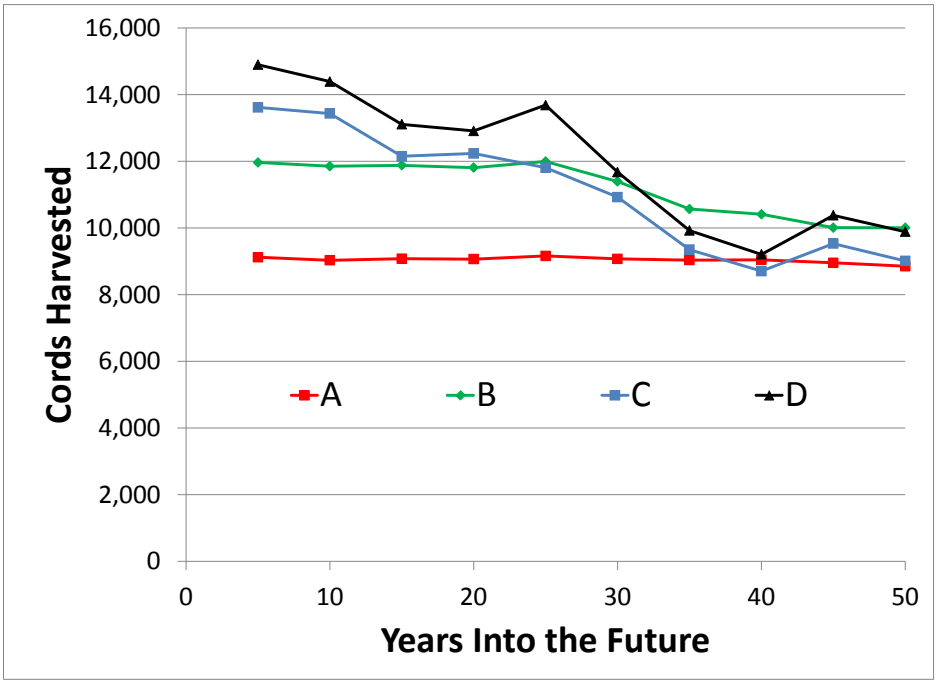


Figure 8. Estimated DISCOUNTED ANNUAL REVENUES over the next 10 (gray) and 50 years generated from harvested cords by scenario. A 3% interest rate was used.

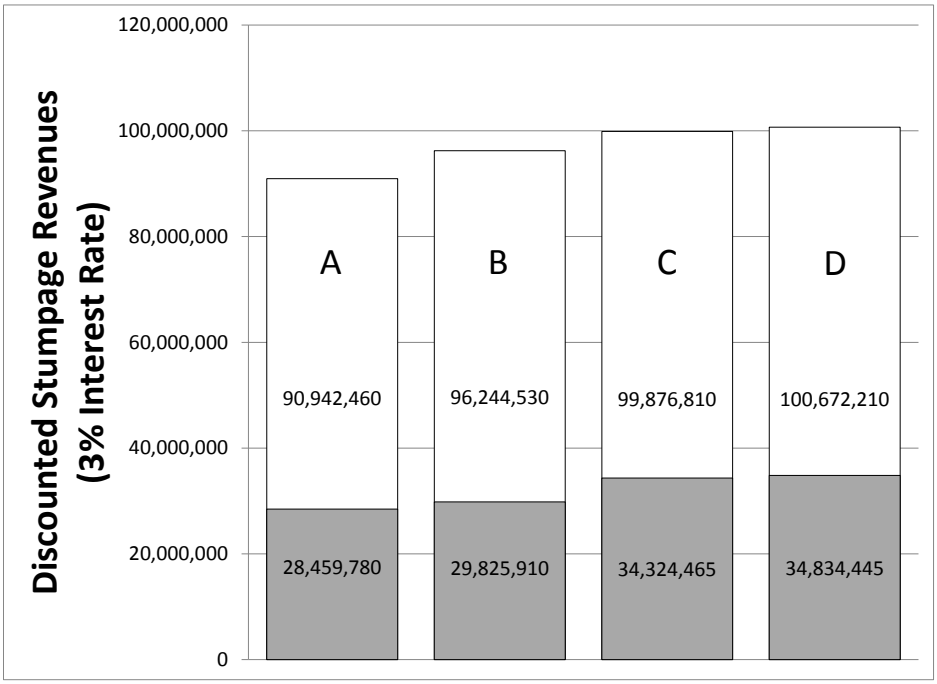


Figure 9. Percent Older forest of lowland conifers (includes Tamarack, Black Spruce, and NWC cover types) by scenario. (See Table 4, page 9, for definition of "Older" forest age by cover type).

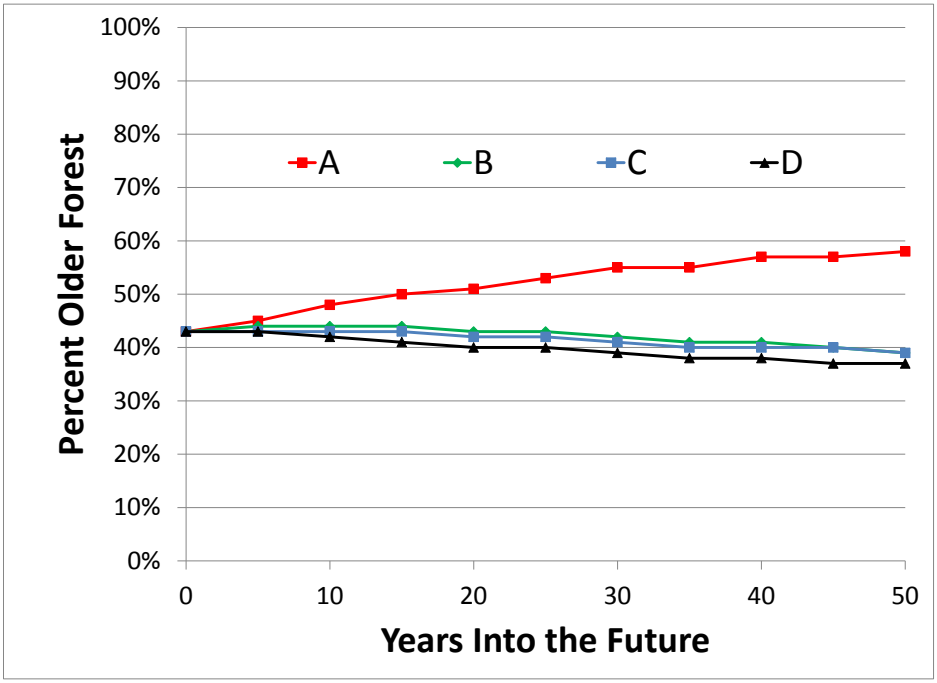


Figure 10. Percentage of older upland conifer forest.

Includes Red Pine Natural, Red Pine Plantation, Jack Pine, White Spruce Plantation, and even-aged Balsam Fir cover types, by scenario. (See Table 4, page 9, for definition of "Older" forest age by cover type).

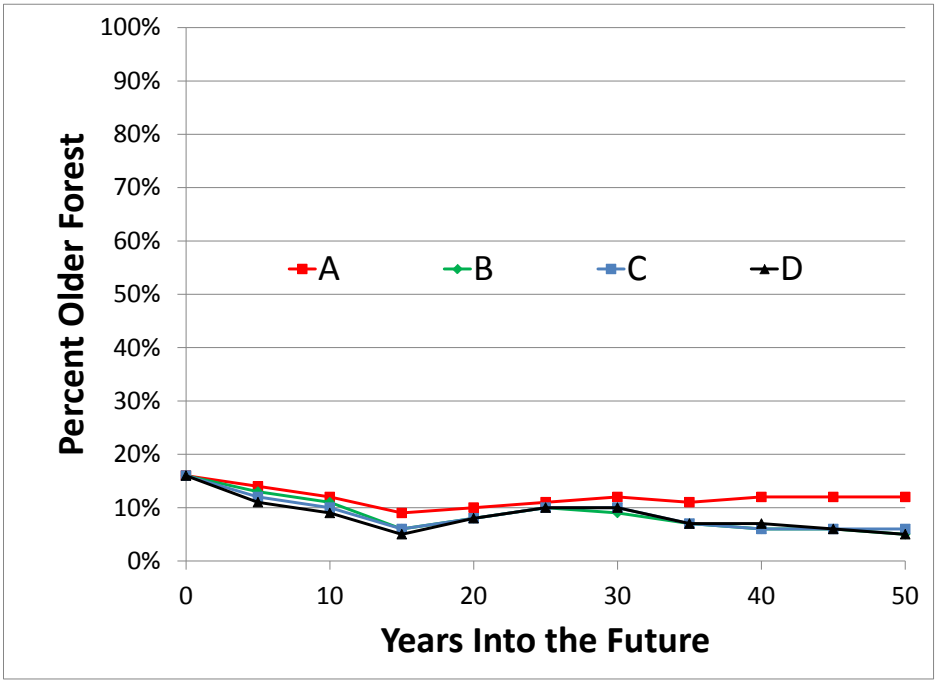


Figure 11. Percentage of older upland hardwoods forest (includes Aspen, Balm, Birch, and Oak cover types) by scenario. (See Table 4, page 9, for definition of "Older" forest age by cover type).

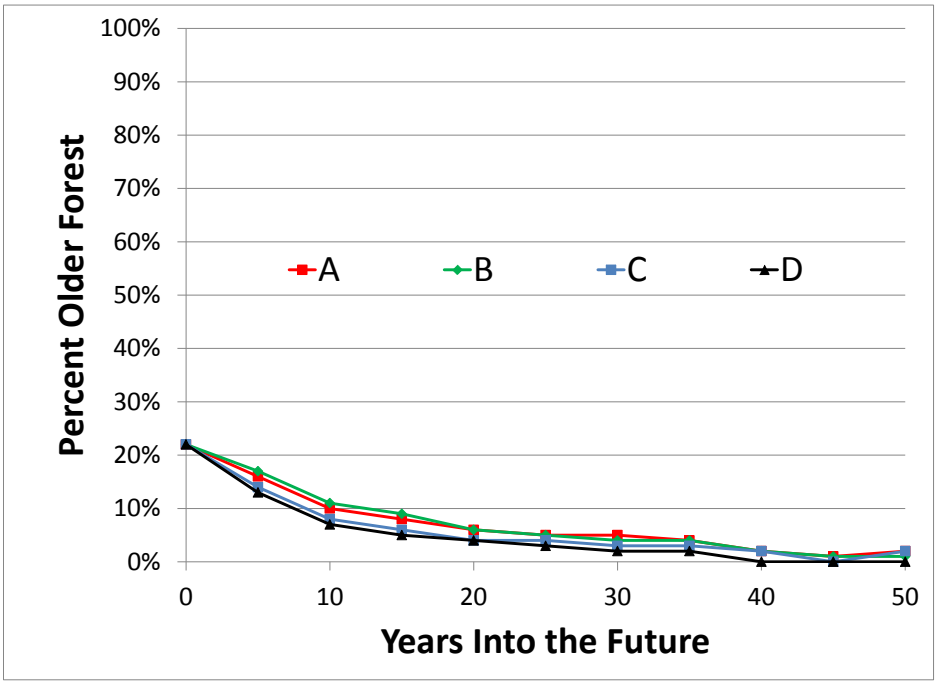


Figure 12. Percentage of younger lowland conifer forest (includes Tamarack and Black Spruce cover types) by scenario.

Due to the lack of final harvest northern white cedar, younger forest of that type was not included. (See Table 5, page 9, for definition of "Younger" forest age by cover type).

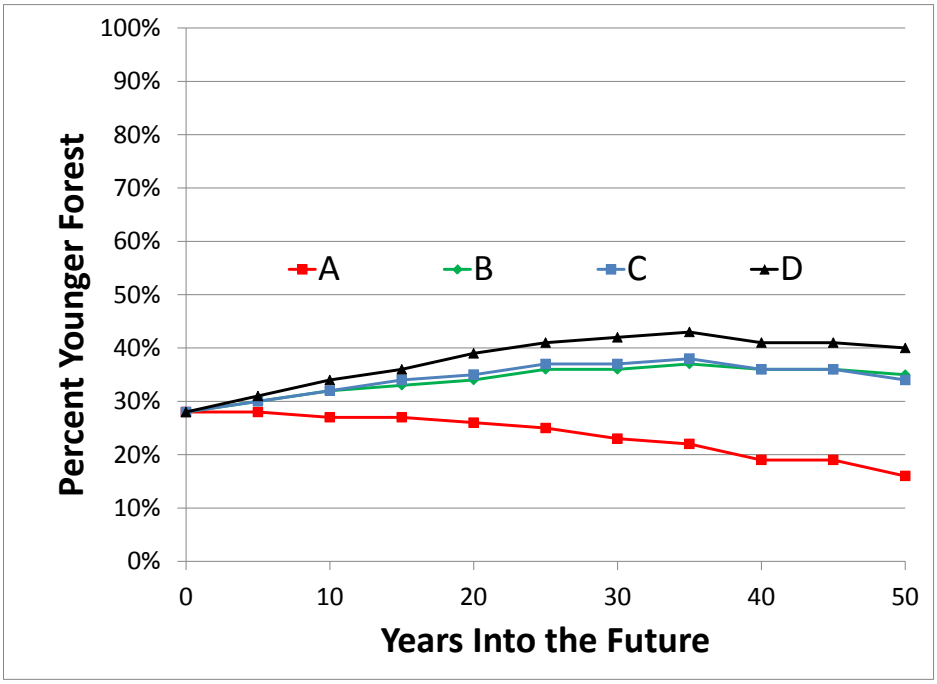


Figure 13. Percentage of younger upland conifer forest (includes red pine (natural), red pine (plantation), jack pine, white spruce (plantation), and even-aged balsam fir cover types) by scenario.

(See Table 5, page 9, for definition of "Younger" forest age by cover type).

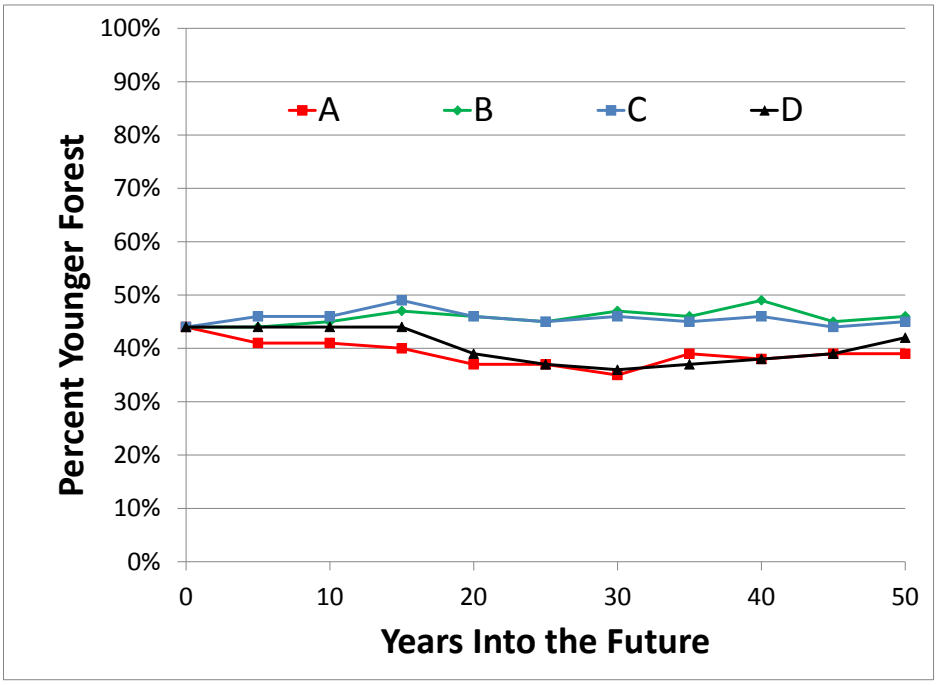


Figure 14. Percent younger forest of upland hardwoods (includes Aspen, Balm, Birch, and Oak cover types) by scenario.

(See Table 5, page 9, for definition of "Younger" forest age by cover type).

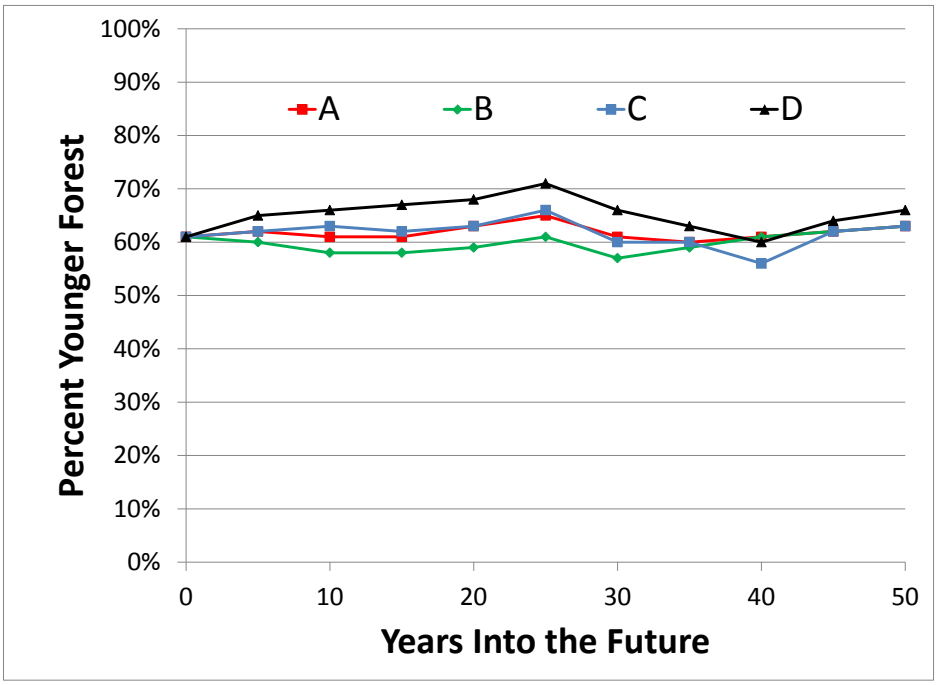


Table 20. Percent older forest by scenario and cover type and cover type grouping. Lowland conifers includes Tamarack, Black Spruce, and northern white cedar (NWC) cover types, Upland conifers includes Red Pine Natural, Red Pine Plantation, Jack Pine, White Spruce Plantation, and even-aged Balsam Fir cover types, and Upland hardwoods includes Aspen, Balm, Birch, and Oak cover types. (See Table 4, page 9, for definition of "Older" forest age by cover type).

	Years Into the Future																					
	Current				10				20				30				40				50	
Cover Type	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B
Abg	16%	16%	16%	16%	5%	5%	2%	1%	1%	1%	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%	3%	1%
Birch	65%	65%	65%	65%	50%	54%	50%	47%	35%	39%	32%	28%	22%	25%	21%	18%	9%	12%	9%	7%	0%	1%
Jack Pine	23%	23%	23%	23%	14%	10%	10%	4%	4%	1%	1%	0%	8%	2%	2%	2%	11%	1%	1%	0%	13%	1%
WS Plantation	6%	6%	6%	6%	17%	15%	16%	15%	36%	34%	37%	33%	48%	50%	53%	49%	56%	39%	43%	35%	64%	31%
Balsam Fir	39%	39%	39%	39%	29%	26%	22%	27%	23%	11%	9%	10%	14%	6%	6%	8%	4%	0%	0%	1%	10%	3%
BS High	32%	32%	32%	32%	35%	29%	28%	27%	36%	25%	23%	20%	40%	24%	24%	17%	39%	19%	20%	13%	37%	13%
BS Medium	22%	22%	22%	22%	27%	23%	22%	20%	30%	21%	20%	16%	35%	20%	18%	13%	38%	19%	18%	13%	38%	16%
BS Low	23%	23%	23%	23%	25%	22%	21%	19%	27%	22%	20%	16%	27%	19%	16%	11%	31%	18%	16%	10%	34%	17%
Tamarack High	41%	41%	41%	41%	35%	32%	31%	28%	33%	27%	26%	20%	30%	23%	25%	18%	27%	20%	23%	15%	23%	16%
Tamarack Low	34%	34%	34%	34%	34%	33%	32%	30%	37%	33%	32%	27%	35%	28%	26%	20%	32%	25%	23%	18%	28%	22%
Red Pine (all)	2%	2%	2%	2%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Lowland Conifer	43%	43%	43%	43%	48%	44%	43%	42%	51%	43%	42%	40%	55%	42%	41%	39%	57%	41%	40%	38%	58%	39%
Upland Conifer	16%	16%	16%	16%	12%	11%	10%	9%	10%	8%	8%	8%	12%	9%	10%	10%	12%	6%	6%	7%	12%	5%
Upland HW	22%	22%	22%	22%	10%	11%	8%	7%	6%	6%	4%	4%	5%	4%	3%	2%	2%	2%	2%	0%	2%	1%

Table 21. Percent younger forest by scenario and cover type and cover type grouping. **Lowland conifers includes Tamarack and Black Spruce cover types, Upland conifers includes Red Pine Natural, Red Pine Plantation, Jack Pine, White Spruce Plantation, and even-aged Balsam Fir cover types, and Upland hardwoods includes Aspen, Balm, Birch, and Oak cover types. (See Table 5, page 9, for definition of "Younger" forest age by cover type).**

	Years Into the Future																				
	Current				10				20				30				40				
Cover Type	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A
Abg	66%	66%	66%	66%	63%	60%	66%	69%	63%	59%	63%	68%	60%	55%	58%	65%	61%	63%	56%	60%	64
Birch	27%	27%	27%	27%	45%	41%	45%	48%	61%	57%	63%	68%	71%	68%	73%	75%	56%	50%	56%	58%	51
Jack Pine	48%	48%	48%	48%	40%	54%	55%	56%	41%	61%	62%	54%	33%	63%	63%	52%	46%	59%	57%	45%	41
WS Plantation	43%	43%	43%	43%	29%	28%	27%	29%	6%	13%	11%	15%	13%	14%	12%	14%	25%	40%	38%	44%	24
Balsam Fir	35%	35%	35%	35%	42%	50%	53%	47%	53%	72%	75%	72%	54%	72%	74%	69%	50%	64%	60%	59%	56
BS High	37%	37%	37%	37%	38%	45%	47%	48%	39%	53%	55%	58%	35%	55%	55%	62%	13%	45%	44%	50%	12
BS Medium	43%	43%	43%	43%	41%	48%	48%	51%	38%	52%	53%	57%	36%	58%	60%	65%	34%	61%	62%	67%	27
BS Low	41%	41%	41%	41%	40%	45%	46%	48%	38%	49%	51%	55%	33%	49%	52%	56%	28%	51%	53%	59%	24
Tamarack High	35%	35%	35%	35%	41%	43%	44%	47%	42%	48%	49%	55%	35%	41%	40%	47%	33%	37%	33%	37%	34
Tamarack Low	36%	36%	36%	36%	38%	40%	41%	43%	38%	42%	43%	48%	42%	49%	51%	57%	46%	52%	54%	60%	42
Red Pine (all)	47%	47%	47%	47%	45%	42%	44%	40%	41%	32%	30%	21%	39%	31%	27%	15%	36%	33%	29%	20%	37
Lowland Conifer	28%	28%	28%	28%	27%	32%	32%	34%	26%	34%	35%	39%	23%	36%	37%	42%	19%	36%	36%	41%	16
Upland Conifer	44%	44%	44%	44%	41%	45%	46%	44%	37%	46%	46%	39%	35%	47%	46%	36%	38%	49%	46%	38%	39
Upland HW	61%	61%	61%	61%	61%	58%	63%	66%	63%	59%	63%	68%	61%	57%	60%	66%	61%	61%	56%	60%	63