2010 Outlook for Forest Biomass Availability in Minnesota: Physical, Environmental, Economic, and Social Availability

by

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2010 Outlook for Forest Biomass Availability in Minnesota: Physical, Environmental, Economic and Social Availability

A report to:

Minnesota Next Generation Energy Board

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Executive Summary

The growing interest and investment in forest biomass for energy production in Minnesota has created the need for accurate estimates of supply. This report estimates the total physical supply of residual forest biomass in Minnesota using a spreadsheet based Forest Age Class Change Simulator (FACCS) to model changes in forest growth and productivity at different harvest target levels, biomass retention levels, forest type, ownership, and biomass attribute (e.g., bolewood, limbs and tops). The findings are presented statewide and by region for different harvest levels and forest management scenarios. Total economic and social availability are further modeled for private woodland owners to determine the probability of their willingness to sell biomass in conjunction with ongoing forest management activities. The results provide a transparent analysis of biomass availability that illuminates policy dialogue and planning regarding the incremental increases in demand for forest biomass and the level of production that is ecologically sustainable within an area.

Physical and Environmental Availability

Biomass estimates in this analysis reflect the most current inventory information available in the study region (2004 to 2008) and are based on current management and harvesting practices. This study presents annual average biomass availability estimates over a 100-year planning period for each of three different harvest levels (3.47 million cords, 4.90 million cords, 5.50 million cords) and at different residual biomass retention levels for a range of forest management scenarios: increased bolewood utilization for bioenergy (10% and 20% bolewood use), early stand treatments, and increases and decreases in the average harvest rotation age.

Using FACCS to model Forest Inventory and Analysis (FIA) data, we estimate statewide and regional distributions of all living biomass by ownership, species group, and biomass attribute (e.g., bolewood, tops and limbs). The Aspen-birch forest type occupies about 40% (6,065,332 acres) of the total timberland area in the state with more than 60% of those acres less than 50 years old. The Spruce-fir forest type occupies 23% (3,468,861 acres) of total timberland with 70% of those acres older than 50 years. Statewide, 14% of all living biomass is in tops and limbs, which is the primary resource upon which emerging bioenergy markets depend. By comparison, bolewood comprises 54% of all living biomass and saplings 11%, with the remaining in stumps and roots (Table 3.2). Of the residual biomass (tops and limbs), the majority is on private woodlands (35%), followed by county and municipal (22%), and state forest land (20%).

Assuming 33% of biomass is retained on site at the 3.47 million cord harvest level, an estimated 661,983 oven-dry tons (ODT) of tops and limbs are annually available (Tables 4.3-4.5). Assuming the 2008-2009 utilization level of approximately 200,000 ODT (MNDNR 2010b), this represents a surplus of about 462,000 ODT not utilized in statewide (Figure 6.1). At the 4.90 million cord harvest level, an estimated 931,208 ODT of residual biomass is annually available, which is an increase of 41% over the 3.47 million cord harvest level. Surplus availability at this level is about 732,000 ODT. Finally, at the 5.50 million cord harvest level, an estimated 1.05 million ODT of residual biomass is annually available, which is an increase of 58% and 13% over the 3.47 and 4.90 million cord harvest levels, respectively. Surplus availability at this level is 805,000 ODT.

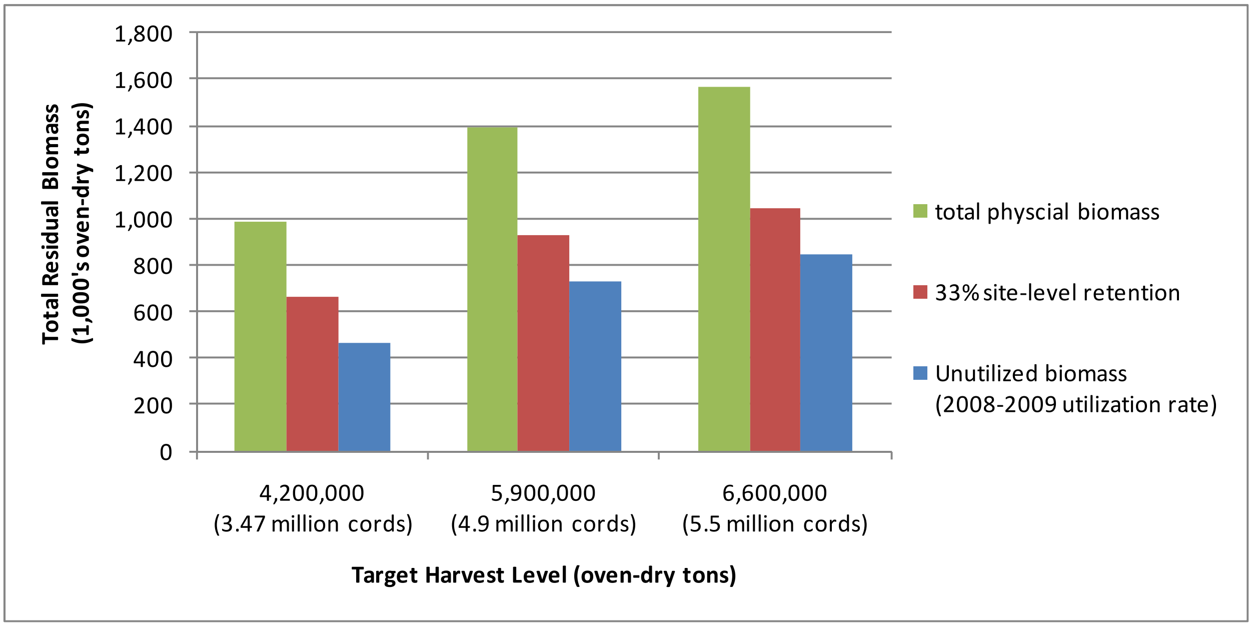

Figure 6.1. Unutilized residual biomass assuming 2008-2009 statewide utilization rate (excludes biomass imports and exports, and supplements to residual biomass of bolewood and saplings).

Assuming that bioenergy markets compete for pulpwood, and that on average 10% of bolewood is chipped for energy production as is estimated for 2008-2009 (MNDNR 2010b), an additional 357,368 ODT is available annually at the 3.47 million cord harvest level. Assuming 20% of bolewood is chipped, an additional 714,737 ODT is available annually. At the 4.90 million cord harvest level, 10% bolewood yields an additional 499,339 ODT and 20% yields an additional 998,673 ODT. And, at the 5.50 million cord harvest level, 10% and 20% bolewood yields an additional 561,281 ODT and 1.12 million ODT, respectively (Tables 4.3-4.5).

Early stand treatments increased statewide residual biomass by approximately 26% (169,999 ODT) for the 3.47 million cord harvest level, from 681,983 ODT to 831,982 ODT (33% retention). At the 4.9 and 5.5 million cord harvest levels, early stand treatments increase residual biomass by 19% (177,150 ODT) and 18% (185,264 ODT), respectively. Increases in residual biomass at the site level will be much less and may not increase yield sufficiently to offset treatment costs.

Decreasing the average rotation age by 10 years for all forest types decreases available residuals by approximately 2% for the 3.47 million cord harvest level, and by approximately 1% for both the 4.90 and 5.50 million cord harvest level. Lengthening the rotation age by 10 years for all forest types increases available residuals by approximately 1% for both the 3.47 and 4.9 million cord harvest levels and decreases available residuals by approximately 1% for the 5.5 million cord harvest level. These findings illustrate the minimal impact that shortening or lengthening the rotation age has on biomass availability.

Tables 4.3 - 4.5. Statewide annual oven-dry tons of residual biomass by ownership, forest management scenario, and harvest level.[1]

		---------- Government ----------			Private		
Harvest level	**Scenario**	**Federal**	**State**	**Local**	**industrial[2]**	**Woodlands**	**Total**
3.47 million cords (10-yr average)	33% residual retention (baseline)	101,301	130,029	141,440	48,366	240,847	661,983
	+ 10% Bolewood	157,248	202,683	216,726	74,511	368,182	1,019,351
	+ 20% Bolewood	213,196	275,338	292,013	100,657	495,517	1,376,720
	Early stand treatments	128,740	160,436	179,263	60,750	302,792	831,982
	Shortened rotation (-10 yrs)	99,294	128,188	138,435	46,707	238,444	651,068
	Extended rotation (+10 yrs)	103,186	131,182	144,194	49,824	241,792	670,179
4.90 million cords (GEIS threshold)	33% residual retention (baseline)	123,587	168,032	184,974	76,056	378,560	931,208
	+ 10% Bolewood	191,478	260,461	283,141	116,763	578,704	1,430,547
	+ 20% Bolewood	259,368	352,891	381,309	157,470	778,847	1,929,887
	Early stand treatments	152,183	199,767	224,408	89,019	442,981	1,108,358
	Shortened rotation (-10 yrs)	120,950	165,076	182,039	73,723	377,412	919,199
	Extended rotation (+10 yrs)	125,839	169,606	188,008	78,113	381,351	942,918
5.50 million cords (Schwalm 2009)	33% residual retention (baseline)	138,736	188,988	206,470	86,558	426,935	1,047,687
	+ 10% Bolewood	214,861	292,800	316,662	132,465	652,179	1,608,968
	+ 20% Bolewood	290,986	396,612	426,853	178,373	877,424	2,170,249
	Early stand treatments	169,426	222,901	247,240	101,263	492,121	1,232,951
	Shortened rotation (-10 yrs)	137,245	186,674	203,862	84,463	425,180	1,037,425
	Extended rotation (+10 yrs)	140,627	190,775	209,420	88,730	430,120	1,059,673

[1] Residual biomass includes tops, limbs, branches and needles as defined by from the USDA Forest Service FIA biomass attributes.

[2] Includes corporate, nongovernmental conservation/natural resources organizations, unincorporated local partnerships/associations/clubs, and Native American timberlands.

Economic and Social Availability

State, county and municipal forests comprise about 40% of timberland acres in the state and are capable of producing between 37-41% of total residual biomass on an annual basis depending on the harvest level. Private forest land, which includes woodlands and industrial forests as well as tribal forests, were about 47% of timberland area in the state in 2009 and about 45% of harvested timber (MNDNR 2010a). Woodlands are capable of providing about 39% of residual biomass statewide on an annual basis, representing a significant opportunity for expanded bioenergy production. However, a range of economic and social factors dictates the ultimate availability of biomass from these lands.

A probabilistic analysis based upon a representative sample of woodland owners in northern Minnesota identified that half of owners are willing to pay up to $9.25/acre to remove the residual biomass generated from a commercial timber sale on their property, including of those who are not willing to conduct a timber sale. When no payment was offered, an estimated 59% were willing to allow the material to be removed, which increased to 72% when offered $15/acre (Figure 5.2). Payment was one of eight explanatory variables in the willingness to accept (WTA) payment model that contributed to owners' decisions to harvest biomass. Influence of consulting foresters, concern for soil health and forest aesthetics in conjunction with timber harvesting, concern for U.S. energy independence, absentee ownership, age, and desire to generate income from woodlands were statistically significant.

Figure 5.2. Estimated probability of woodland owner willingness to remove residual biomass in conjunction with a commercial timber harvest. Acceptance is displayed as a percent of all landowners willing to remove biomass at a given per acre payment.

Similar to the findings of physical and environmental availability, aggregate availability from woodlands is greatest for forest management scenarios where 20% of the bolewood is chipped and utilized for bioenergy applications, which for the 3.47 million cord harvest level with 33% retention, is nearly 370,000 ODT of residual biomass annually from woodlands in the 22 northern counties at a price of $0/acre offered. The amount increases to about 490,000 ODT at a price of $30/acre. The effect of early stand treatments and changes in rotation ages had a modest to negative impact on availability across all payment levels. Similar trends are observed for the 4.90 and 5.50 million cord harvest levels. Unknown is the amount of this material that is in addition to what was previously utilized, in other words the proportion of this material from woodlands new to the market.

There is potential for biomass to be generated from a myriad of forest management activities, including activities that do not generate income or involve payments of any kind. 79% of sampled woodland owners reported that they plan to conduct forest management activities within the next 10 years that will generate some amount of biomass, and that they are interested in finding an outlet for this material. The Theory of Planned Behavior (TPB) was employed to model nonfinancial factors influencing availability within each of three dimensions (attitudes and beliefs, external influences, and perceived control). Findings show that woodland owners' intent to harvest biomass was significantly influenced by their desire to utilize the material for energy purposes and to contribute to the local bioeconomy, a concern for the impact harvesting would have on their woodlands (e.g., soil health), and the influence of loggers in getting them to remove the material.

The willingness of woodland owners to remove biomass does not alone ensure the availability of that biomass to the market. Given the small size of woodland parcels (75% of sampled parcels were less than 120 acres) where residual biomass is about 14% of the total per acre yield, and of that 33-50% is retained on site per the harvest guidelines, there may be insufficient residues to justify the mobilization of equipment unless in proximity to a processing facility or other planned harvest projects.

Other Considerations for Minnesota's Forest Biomass Industry

As of the latest industry survey in 2005, only about 5% of forest resources are used for wood energy purposes (MNDNR 2007). However, as it becomes cost efficient to harvest biomass independent of commercial timber harvesting operations, this percent is likely to increase. Correspondingly, competition with existing industries may also increase forcing an expansion in the size of supply regions. Failure to include the range of constraints associated with increased biomass removal could result in a potential overestimation of available supply, which in turn threatens the viability of new businesses and existing forest products industries. This overestimation could also threaten the sustainability of the forest resource when policies designed to enhance utilization create scenarios leading to overharvesting within economically defined supply regions. Given the excess residual biomass identified with each of the forest management scenarios, expansion of the forest biomass industry in the state is constrained more by the demand for biomass products than the supply of residuals.

This research provides an important step in understanding factors influencing supply and in particular the amount of biomass available from woodlands at different price points. However, the price elasticity of demand for biomass from industrial and public lands is unknown and is an important factor to understand the impact of increased competition on the stumpage price paid for biomass. Additional research beyond the scope of this study would improve estimates on the amount of residual biomass and bolewood that is economically available within a certain area and the distance industries are able to travel to procure feedstocks.

1.0 Introduction

Currently, Minnesota has approximately 17 million acres of forest land, which is about one-third of the total land base in the state. More than one million acres of this land is set aside as protected areas or considered nonproductive forest land, whereas approximately 8.3 million acres are publicly managed in federal, state, and county ownership. The remaining 7.3 million acres (47%) are privately owned by tribal, industrial, and nonindustrial landowners (Butler 2008). Biomass from these forests collectively offers significant potential for bioenergy production (Becker et al. 2009b).

The purpose of this study is to quantify the *physical* and *environmental* availability of forest biomass in Minnesota over a 100-year timeframe and to compare to estimates of *economic* and *social* availability. Physical availability is the total amount of biomass by species and ownership type. Environmental availability is the sum total of biomass available at different thresholds of biomass retention, as well as exclusion of areas with management objectives that in most cases preclude timber harvesting (e.g., Wildlife Management Areas, Scientific and Natural Areas, state and national parks, and wilderness areas). Economic availability, in the context of this report, refers to the amount of biomass historically available at different price points, and projected availability on nonindustrial private forest lands, referred to as woodlands. Social availability is that amount of forest biomass that is not socially contested and is otherwise compatible with landowner management objectives.

For the purpose of this study, *forest biomass* includes all living and dead trees and their components, brush, and residue material generated as a byproduct of commercial timber harvesting and timber stand improvement activities, wildlife habitat improvement (early thinning and reduction of competition for retained trees), hazardous fuel reduction treatments, mill residues, dedicated energy crops, land clearing, brush from brushlands, urban forest maintenance, and storm cleanup (MNDNR 2010a). Our analysis focuses specifically on the availability of the residual biomass generated from timber harvesting activities (e.g., tops, limbs, needles, and leaves) and material generated from timber stand and wildlife habitat improvement activities. *Biomass utilization* is the use of forest biomass resulting in the production of a full range of wood products including lumber, pulp and paper, engineered panels and lumber, biobased products, thermal energy, electricity, and biofuels.

Despite the potential for significant utilization of forest biomass for these products, little is known about the collective availability in the state or the cumulative effects of increased demand. By comparing physical, environmental, economic and social availability, this study provides a composite outlook of biomass supply on public and private forest lands and its sensitivity to forest management scenarios. This study does not provide an estimate of market demand or an in-depth analysis of how factors such as harvest costs affects the amount utilized or profitability of biomass consuming industries. Such factors are critical in determining the amount of biomass available to the market and at what price, but are beyond the scope of this study. The study findings may inform economic development opportunities within the state including the potential for emerging bioenergy applications and feedstock availability, as well as analyses of potential impacts, be they environmental, economic or social.

2.0 Forest Management Scenarios

The potential to harvest increased amounts of biomass from existing managed forests has the potential to accomplish multiple objectives including: increasing the value of sales and revenue to the state, increase jobs and economic development opportunities in rural areas, improve forest health and reduce wildfire risk, increase regeneration success, make productivity-enhancing forest treatments economical, and increase the supply of biomass to new and emerging bioenergy enterprises.

For our analysis, forest management scenarios were designed to estimate physical and environmental availability following current management practices in the state and over the next 100 years, and under scenarios based on more and less intensive management. Using data derived from the USDA Forest Service, Forest Inventory and Analysis (FIA), we simulate availability by species, ownership, and for each of three different harvest targets. A baseline harvest target of 3.47 million cords (4.2 million oven-dry tons) was derived from the average annual harvest level in the state between the years 1999 and 2008. A second harvest target of 4.9 million cords (5.9 million oven-dry tons) was derived from the statewide GEIS, which estimated total available timber that could be sustainably removed using current forest management practices (Jaakko Pöyry Consulting 1994). The third and highest harvest target of 5.5 million cords (6.6 million oven-dry tons) was derived from analyses employing intensive forest management practices throughout the state (Schwalm 2009).

In addition to the three harvest levels described, the scenarios listed below were further applied to each of five levels of assumed on-site biomass retention, which is important for assessing the impact of environmental safeguards on biomass availability. The lowest level of retention assumed 100% removal (0% retention) to depict a theoretical physical maximum. A second level assumed 15% retention (85% removal), which approximates the maximum amount that can be operationally removed given equipment and resource constraints (e.g., type of equipment used, tree breakage) (Stokes and Watson 1991). The third level of biomass retention assumed adherence to the Minnesota Forest Resources Council (MFRC) biomass harvest guidelines in which a 33% retention level (67% removal) was identified as the minimum threshold necessary to maintain soil productivity, water quality, and wildlife habitat (MFRC 2007). The next higher level of retention assumes that an average of 50% of biomass material remains on site after harvesting either because of loggers unwillingness to remove more or because of site conditions leading to increased breakage and downed and dead material (Dirkswager et al. in press). This is also the level modeled in the Minnesota Logged Area Residue Analysis (MNDNR 2007). The fifth and highest retention level assumes that 75% remains on site (25% removal) and depicts a low level of utilization. Each biomass retention level was modeled for each harvest target level and for each of the following scenarios (A to E):

A. **Roundwood competition (+10% bolewood)** – This scenario assumes that 10% of harvested bolewood is chipped and utilized for bioenergy production. 10% is the estimated amount of bolewood used in bioenergy related markets in 2009 (MNDNR 2010b), and represents a scenario where there is greater demand for biomass.

B. **Roundwood competition (+20% bolewood)** – This scenario assumes that 20% of harvested bolewood is chipped and utilized for bioenergy production. This represents a scenario where the price paid for biomass is competitive with pulpwood over time either through increased market competition, subsidies paid for biomass removal or transport, reduced pulpwood production, or any combination.

C. **Early stand treatments** – This scenario assumes the utilization of biomass from early and commercial thinnings in the 21-30 year age class for Aspen-birch and White-red-jack pine types, which results in increased live biomass yield in subsequent harvests (3rd quartile values by age class). Research in red pine stands demonstrates that thinnings every ten years beginning at age 25 to 35 salvages volume otherwise lost to natural morality, resulting in 150-170% increase in bolewood over unthinned stands (Buckman et al. 2006). Early and commercial thinnings in aspen growing on productive sites show similar results (Gilmore 2003). Early stand treatments are not widely implemented because of a lack of markets and the added cost they impose on the landowner.

D. **Shortened rotation age (-10 years)** – This scenario shortens the recommended harvest rotation age (MN DNR 1997) by 10 years for each forest type to model the effect of early thinnings, which can produce high-valued products by reallocating resources to residual growing stock (Penner et al. 2001).

E. **Extended rotation age (+10 years)** – This scenario extends the recommended harvest rotation age (MNDNR 1997) by 10 years for each forest type to model changes in growing stock from reduced harvest frequency, which may be driven by depressed markets, landowner willingness to harvest, state policy, and other factors.

3.0 The Physical Resource and Historic Utilization

Table 3.1 provides a breakdown of total acres of timberland by age class and forest type group for the most recent FIA reporting period (2004-2008). The Aspen-birch type occupies 40% (5,821,375 acres) of the total timberland area and more than 60% of acres are less than 50 years old. The Spruce-fir forest type, which includes other exotic softwoods, occupies 3,459,071 acres (24% of total timberland) with about 60% of acres older than 50 years. The hardwood groups (Oak-hickory, Elm-ash-cottonwood, Maple-beech-birch) have similar distributions with the majority acres greater than 50 years. The White-red-jack pine group occupies 840,545 acres with a relatively even distribution across age classes and 60% less than 50 years of age.

Table 3.2 displays the average oven-dry tons (ODT) per acre for all biomass attributes by forest type group. For the purpose of this analysis, biomass is classified into bolewood, limbs and tops, saplings, stumps, and roots (USDA Forest Service 2010). Stumps and roots, which cumulatively accounts for 20% of total live biomass, are not typically removed in the region, are not recommended for removal under the state harvest guidelines (MFRC 2007), and are therefore removed from our analysis. Also excluded are areas formally designated wilderness areas, old-growth reserves, wildlife management areas, state parks, and urban areas. In total, more than 1.3 million acres of timberland were excluded for these purposes (Table 3.3).

Table 3.1. Age class distribution of timberland in Minnesota by FIA forest type group, 2004-2008 inventory period (nonstocked areas excluded).

Age Class	White-red-jack pine	Spruce-fir[1]	Oak-pine	Oak-hickory	Elm-ash-cottonwood	Maple-beech-birch[2]	Aspen-birch
0-10	53,818	90,524	19,086	110,089	60,438	120,802	874,022
11-20	73,969	143,681	23,470	49,342	32,130	52,841	784,396
21-30	142,509	183,014	25,834	53,680	56,409	44,377	694,483
31-40	120,667	223,174	17,971	72,956	81,630	35,301	580,081
41-50	116,381	391,367	25,293	206,598	114,007	90,482	662,170
51-60	82,864	432,816	46,942	251,997	200,262	131,939	747,010
61-70	71,457	461,762	35,237	310,352	217,846	243,447	765,427
71-80	64,158	379,067	19,973	294,178	175,626	193,993	438,626
81-90	59,377	283,891	16,798	215,901	121,474	174,928	163,001
91-100	21,507	228,504	2,902	116,204	74,653	63,017	63,147
100+	33,838	641,271	17,062	127,407	132,952	66,105	49,012

[1] Other exotic softwoods and Exotic softwoods were combined with the Spruce-fir forest type.
[2] Other hardwoods and Exotic hardwoods were combined with the Maple-beech-birch forest type.

Table 3.2. Average per acre oven-dry tons (ODT) of biomass by forest and biomass type (percent of total living biomass).

	------------------------ Biomass type (ODT) ------------------------				
Forest type group	**Bolewood**	**Tops and limbs**	**Saplings**	**Stumps**	**Roots**
White-red-jack pine	20.93 (54%)	5.16 (13%)	3.49 (9%)	1.41 (4%)	7.86 (20%)
Spruce-fir	11.37 (47%)	2.40 (10%)	5.05 (21%)	0.81 (3%)	4.48 (19%)
Oak-pine	24.67 (56%)	5.84 (13%)	4.43 (10%)	1.33 (3%)	7.68 (17%)
Oak-hickory	25.39 (56%)	6.80 (15%)	3.99 (9%)	1.48 (3%)	7.44 (16%)
Elm-ash-cottonwood	17.11 (52%)	4.80 (14%)	4.65 (14%)	1.08 (3%)	5.58 (17%)
Maple-beech-birch	26.36 (55%)	7.40 (15%)	4.64 (10%)	1.56 (3%)	7.95 (17%)
Aspen-birch	20.74 (53%)	5.73 (15%)	5.00 (13%)	1.19 (3%)	6.67 (17%)
Average	**20.94 (54%)**	**5.49 (14%)**	**4.47 (11%)**	**1.26 (3%)**	**6.76 (17%)**

[1] Site-level variation does not differ significantly within forest types in the state.

Table 3.3. Acres of Minnesota timberland excluded from the analysis by forest cover type.

	---------------------- Supply Region ----------------------			
Forest cover type	**Northwest**	**East-central**	**Northeast**	**Total**
White-red-jack pine	3,378	2,193	50,267	**155,838**
Spruce-fir[1]	62,657	-	349,939	**412,596**
Oak-pine	2,685	-	44,295	**46,980**
Oak-hickory	15,685	65,246	10,983	**91,914**
Elm-ash-cottonwood	30,441	24,462	57,504	**112,407**
Maple-beech-birch[2]	13,452	1,521	66,649	**81,622**
Aspen-birch	41,927	11,112	381,892	**434,931**
Total	**170,225**	**104,534**	**1,061,529**	**1,336,288**

[1] Other exotic softwoods and Exotic softwoods were combined with the Spruce-fir forest type.
[2] Other hardwoods and Exotic hardwoods were combined with the Maple-beech-birch forest type.

3.1 Annual Harvest Level

The average annual harvest in the state, between the years 1999 and 2008, was 3.47 million cords (4.2 million ODT). The majority of that was in the Aspen-birch forest type group, followed by Spruce-fir and White-red-jack pine types (Table 3.4). By comparison, the total harvest level in 2008-2009 was 3.50 million cords (4.2 million ODT) (MNDNR 2010b). The total amount made available across all ownerships in the same year was 5.25 million cords. The unutilized portion, 1.75 million cords, was used for personal firewood consumption, piled and burned, or otherwise left in the woods and not available for market purposes. Of the amount utilized, 3.1 million cords (3.7 million ODT) was used for lumber, manufactured wood, and pulp and paper. The remaining 0.4 million cords (0.5 ODT) was used in electricity and pellet production, of which 0.1 million cords (0.1 million ODT) was derived from logging residues (MNDNR 2010b).

Table 3.4. Average annual statewide harvest by forest type group, 1999 to 2008.

Forest Type	Average annual harvest (cords)	Proportion of statewide harvest	ODT/cord	Average annual harvest (ODT)
White-red-jack pine	423,882	0.1221	1.1417	483,932
Spruce-fir	430,263	0.1239	1.0500	451,776
Oak-pine	22,363	0.0064	1.3750	30,749
Oak-hickory	122,923	0.0354	1.3750	169,019
Elm-ash-cottonwood	54,810	0.0158	1.2917	70,796
Maple-beech-birch	164,834	0.0475	1.2500	206,042
Aspen-birch	2,253,245	0.6489	1.1583	2,610,009
TOTAL	**3,472,320**	**1.0000**	**--**	**4,022,324**

3.2 Existing Biomass Demand

Annual harvest levels are a function of market demand, which in the past few years has declined substantially. Still, market demand for tops and limbs is expected to increase in the near term to maximize benefits associated with reduced dependence on foreign energy, diversified income streams for loggers, and opportunities for timber stand improvement and wildlife management. In addition, the Minnesota Next Generation Energy Act of 2007 (Chapter 136–S.F.No. 145) mandates a portion of energy production in the state be accomplished with renewable energy, of which bioenergy provides an appealing prospect of dispersed baseload energy. The extent and pace of growth, however, will depend largely on the demand for sawlogs and pulpwood from which the tops and limbs are sourced, biomass removal costs, and transportation costs.

Since 2002, total nonbolewood utilization has increased from 15,400 ODT (MNDNR 2004) to more than 100,000 ODT in 2009 (pers. com. D. Deckard, Forest Economist MNDNR, July 13, 2010). The number of residual biomass-using facilities has likewise increased in number to a total of 43 in 2010 (MNDNR 2010c). Total direct employment in related sectors in 2007, the latest available data, was 134 jobs not including indirect employment in the harvesting and transport sectors. Table 3.5 displays existing commercial facilities and planned biomass facilities publicly announced as of May 2010. Figure 3.1 shows the location and clustering of biomass using facilities in the state. Three major processing clusters were chosen (Duluth/Cloquet, Grand Rapids/Bemidji and St. Cloud/Twin Cities) based upon currently active bioenergy industries. These clusters are used to analyze the degree to which transport distances affect the availability of biomass from woodland owner parcels.

Table 3.5 Commercial forest biomass-using facilities in Minnesota, 2010 (MNDNR 2010c)

Commercial facility[1]	**Location**	**Oven dry tons utilized per year**	**Facility type**[2]
Existing users			
SAPPI	Cloquet	>150,000	Industrial CHP
Fibrominn	Benson	>100,000	Industrial CHP
Verso Paper	Sartell	25,000–100,000	Industrial CHP
Boise Cascade	International Falls	<25,000	Industrial CHP
Potlatch	Bemidji	<25,000	Industrial heat
UPM-Rapids Energy Center	Grand Rapids	>150,000	CHP
MN Power-Hibbard Energy Center	Duluth	>100,000	CHP
Laurentian Energy Authority	Virginia - Hibbing	>100,000	CHP
District Energy	St Paul	>100,000	CHP
Rahr Malting – Koda Energy	Shakopee	25,000–100,000	CHP
Valley Forest Wood Products	Marcell	<25,000	Wood pellets/heat
Oak Creek Pellets	Hillman	<25,000	Wood pellets/heat
Bio Pellets	Deer River	<25,000	Wood pellets/heat
Lone Tree Hardwoods	Bagley	<25,000	Wood pellets/heat
Total existing capacity		**925,000 (appox)**	
Publicly announced facilities			
US Steel Keetac	Keewatin	100,000	CHP
CMEC/Sun Opta	Little Falls	200,000	CHP/Cellulosic ethanol
Renewafuels (Cleveland Cliffs)	Warroad	100,000	Industrial briquettes
Former Ainsworth Facility	Grand Rapids	100,000	Wood pellets
Mountain Timber	Mountain Iron	100,000	Wood pellets
Total planned capacity		**600,000 (approx)**	

[1] 24 additional forest biomass using facilities exist in Minnesota utilizing less than 5,000 ODT/year each.
[2] CHP is combined heat and power production.

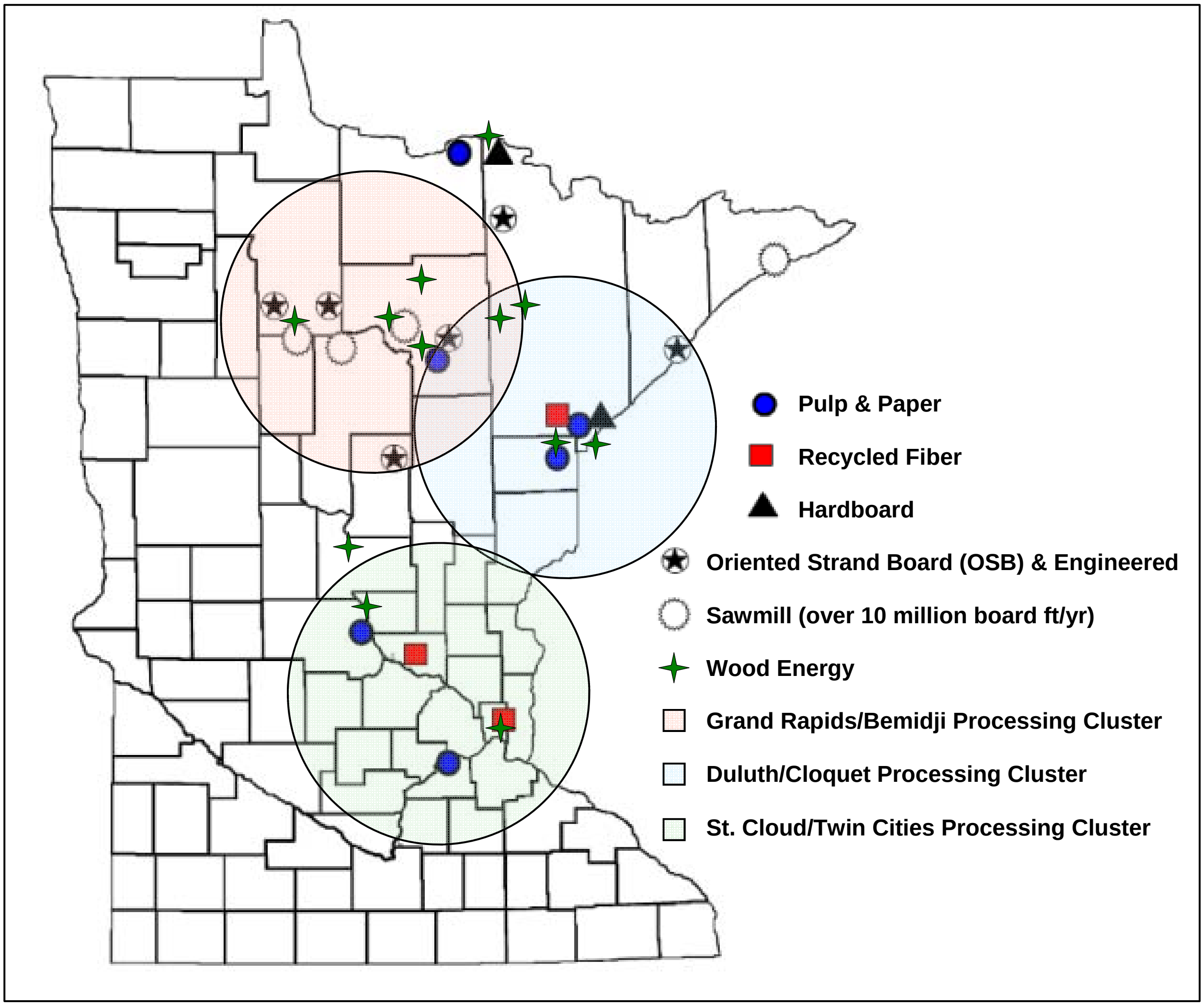

Figure 3.1. Existing forest products industries in Minnesota, 2010 (MNDNR 2010c). Small sawmills are omitted from the figure.

4.0 Physical and Environmental Availability

4.1 Model Development

The Forest Age Class Change Simulator (FACCS) (Domke and Ek 2009) was used to estimate current and future forest-derived biomass available under different land management scenarios. The model operates in a series of spreadsheets that rely on data from customized lookup tables. In its simplest form, for a one year projection, the acres pertaining to a one year age class move to the next older age class. Those acres then take on the yields per acre for the older age class, minus adjustments for harvest, where the projected yields embody the yields determined for the older age class. In this analysis, timberland area, biomass attributes, and ownership information were summarized by the FIA-defined forest type groups in Table 3.1 for the entire state and by FIA-defined regions. FACCS was applied to each forest type over a 100-year timeframe, which was chosen to capture at least one rotation for each forest type. Any remaining unharvested forest type returns to the year-one age class at the end of the final user-defined age class.

FAACS relies on a few important assumptions: (1) forest type area is fixed with no conversion to other types or additions or losses due to land use change or major disturbance; (2) harvest and management inputs remain fixed over the planning horizon; (3) there are no disturbances (e.g., insects, disease, fire) other than that embodied in the yields per acre and assumed forest management and harvest, should that occur; (4) harvest intensity measured as the percent cut in each age class for each forest type is adjusted based on rotation length and the proportion of the total harvest assigned to each forest type in Table 3.4; and (5) individual species harvest information (i.e., oak, maple, red pine) from the MNDNR Minnesota's Forest Resources reports were assigned to a particular forest type group used in this study. In reality, individual species may be found in multiple forest type groups with many different species associates. It is important to note that estimates of biomass availability derived in FAACS rely on historical harvest data, which take into account existing forest management plans such as maintaining old-growth forest or implementing extended rotation forest harvesting schedules.

Physical availability was estimated in FACCS using data derived from more than 6,000 field plots in Minnesota, which were used to model the impacts of choices for the timing, frequency, and intensity of harvesting for the forest type groups. FIA data from the most recent inventory period (2004 to 2008) were used to estimate forest type group area and to generate per acre estimates of oven-dry tons of biomass in the bole (from trees ≥5 inches diameter at breast height [dbh]), tops and branches (from trees ≥5 inches dbh), stumps (from trees ≥5 inches dbh), saplings (trees from 1 to 4.9 inches dbh), and roots (> 0.1 inch in diameter for trees > 1 inch dbh) (FIADB version 4.0) (USDA Forest Service 2010). Data from the MNDNR (MNDNR 2004, 2005, 2006, 2007, 2008), the GEIS (Jaakko Pöyry Consulting 1994), and Schwalm (2009) were used to establish target harvest levels. The baseline harvest level and associated proportion that each forest type group contributed to a given harvest level were computed using the 10-year averages reported in Table 3.4. The same harvest proportions were used for all the forest management scenarios for consistency. Harvest rotation ages were based upon a statewide assessment of silvicultural practices (D'Amato et al. 2009) and the state *Forest Development Manual* guidelines (MNDNR 1997) (Table 4.1).

Table 4.1. Assumed average harvest rotation age by forest type.

Forest type group	Average rotation age (yrs)
White-red-jack pine	100
Spruce-fir	75
Oak-pine	75
Oak-hickory	75
Elm-ash-cottonwood	75
Maple-beech-birch	75
Aspen-birch	50

Weighted least squares (WLS) regression was used to predict yield for each forest type and biomass attribute. The regression equation used was:

$$\text{Biomass yield attribute (oven-dry tons)} = \eta_0 + \eta_1 \text{ (age class)} \qquad \text{[Equation 4.1]}$$

Where biomass yield is the per acre oven-dry weight of the biomass attribute, η_0 is the estimated intercept, $\eta 1$ is the estimated slope, and age class is the forest type stand age. WLS regression lines were fit to third quartile values from the summarized biomass yield data for use in Scenario C below.

4.2 Findings of Physical and Environmental Availability

Outputs of physical and environmental availability are reported for all public and private forests in the state by FIA-defined regions. Total average annual living biomass is presented in Table 4.2. Private woodlands, which comprise the largest portion of timberland acres in the state, have approximately 39% of total living biomass. Industrial timberlands occupy the smallest number of acres and correspondingly account for 10% of the total living biomass.

Tables 4.3-4.5 present statewide average annual residual biomass by forest management scenario and level of assumed harvest (3.47 million cords, 4.90 million cords and 5.50 million cords). Appendices A–D provide the same breakdown but by FIA-defined regions. An estimated 988,034 ODT of residual biomass (tops and limbs) is annually available at the current 3.47 million cord harvest level (4.1 million ODT), assuming 100% utilization, which is operationally unrealistic but provides a baseline from which to calculate availability at different retention levels. For our analysis and subsequent discussion, we focus on the 33% and 50% retention levels, which represent the minimum level necessary for soil nutrification and forest regeneration as established by the MFRC (2007), and the higher retention level modeled in the Minnesota Logged Area Residue Analysis (MNDNR 2007) to depict realistic removal practices in conjunction with commercial timber harvests. An estimated 661,983 ODT of residual biomass (tops and limbs) is annually available at the 33% residual level at the current 3.47 million cord level, which represents a surplus of approximately 462,000 ODT of residual biomass not utilized in biomass production. This is derived by subtracting the estimated 2008-2009 utilization level of 200,000 ODT (MNDNR 2010b) from the total available. Assuming a 50% retention level, total available biomass is decreased by 25% (169,488 ODT) from the 33% MFRC retention guidelines, representing a surplus of approximately 93,000 ODT.

Assuming bioenergy markets compete for pulpwood, and that 10% of annual bolewood harvested is chipped for energy production, an additional 358,143 ODT is available resulting in 1.02 million ODT. Assuming 20% of bolewood is chipped, an additional 357,369 ODT is available and 1.38 million ODT total. The majority of available biomass statewide is from woodlands followed by state and county forest land. Similar patterns emerge regionally with a greater proportion of federal forest land in northeast Minnesota (Appendix A) and less state and county land in east-central Minnesota (Appendix C). Analyses of four counties in northwest Wisconsin are also provided (Appendix D) based on their proximity to the Duluth processing cluster (Figure 3.2).

Early stand treatments for the White-red-jack pine and Aspen-birch forest types yielded 169,999 ODT of additional biomass annually over the statewide estimate of 661,983 ODT for the 3.47 million cord harvest level and 33% retention. When rotation periods are shortened by 10 years across all forest types, annual availability decreases by 10,915 ODT and when extended by 10 years it increases by 8,196 ODT. The difference and inverse relationship is likely because of the larger diameter trees produced by the extended rotation scenarios, which contain increased amounts of total biomass in branches and tops.

At the 4.90 million cord harvest level (5.90 million ODT), an estimated 931,208 ODT of residual biomass (tops and limbs) is annually available at the 33% retention level. This is a 41% increase over the 3.47 million cord harvest level and within the sustainability threshold established in the GEIS (Jaakko Pöyry Consulting 1994). Surplus biomass available to bioenergy markets is approximately 731,000 ODT assuming the 2008-2009 utilization level (MNDNR 2010b). Assuming a 50% retention level, total available biomass decreases by 25% (236,276 ODT) from the 33% MFRC retention guidelines to 694,932 ODT and a utilization surplus of approximately 495,000 ODT. Assuming bioenergy markets compete for pulpwood, and that 10% of annual bolewood harvested is chipped for energy production, an additional 499,399 ODT is available resulting in 1.43 million ODT. Assuming 20% of bolewood is chipped, an additional 499,340 ODT is available and 1.93 million ODT total.

Early stand treatments at the 4.90 million cord harvest level yielded 177,150 ODT of additional biomass annually over the statewide estimate of 931,208 ODT where early stand treatments where omitted and at the 33% retention level. This results in 1.11 million ODT available with early stand treatments. When rotation periods are shortened by 10 years across all forest types, annual availability decreases by 12,009 ODT and when extended by 10 years it increases by 11,710 ODT at a 33% retention level. This trend suggests that decreasing the typical rotation age (Table 4.1) by 10 years for all forest types decreases available residuals by slightly more that 1%, which is driven by increased harvesting (> 65% of the total harvest) in the fast-growing, short-lived aspen-birch forest type. The culmination of mean annual increment in aspen stands on productive sites in Minnesota is often reached by age 30 (Perala and Russell 1983). Reducing the rotation age by 10 years means the fast-growing aspen-birch forest type maintains a high growth rate over the life of the stand and subsequent stands reach rotation age sooner, resulting in only a small decrease in bolewood and residual biomass over the 100-year planning horizon.

At the 5.50 million cord harvest level (6.6 million ODT), an estimated 1.05 million ODT of residual biomass (tops and limbs) is annually available at the 33% retention level. This is a 58% increase over the 3.47 million cord harvest level and a 13% increase over the 4.9 million cord harvest. Surplus biomass available to bioenergy markets at this highest harvest level is approximately 805,000 ODT assuming the 2008-2009 utilization level (MNDNR 2010b). Assuming that bioenergy markets compete for pulpwood, and that 10% of annual bolewood harvested is chipped for energy production, an additional 561,281 ODT is available resulting in a total of 1.61 million ODT. Assuming 20% bolewood is chipped, an additional 1.12 million ODT is available and 2.17 million ODT total. Early stand treatments yielded 185,264 ODT of additional biomass annually over the statewide estimate of 1.05 million. When rotation periods are shortened by 10 years across all forest types, annual availability decreases by 10,262 ODT and when extended by 10 years it increases by 11,986 ODT.

Table 4.2. Estimated oven-dry tons (ODT) of living biomass on Minnesota timberland by stand attribute and ownership (based on 3.47 million cord annual harvest).

Biomass	---------- **Government** ----------			**Private**		
attribute	**Federal**	**State**	**Local**	**industrial**	**Woodlands**	**Total**
Bolewood	20,864,262	31,893,861	30,447,010	17,182,948	69,360,697	169,748,778
Tops and limbs	5,663,335	8,512,962	8,490,353	4,816,259	19,487,695	46,970,605
Stumps	1,334,828	2,053,847	1,930,673	1,075,673	4,294,443	10,689,464
Saplings	9,926,636	15,765,104	14,186,581	6,953,321	24,398,497	71,230,139
Belowground	8,363,791	12,810,150	12,066,265	6,501,099	24,983,356	64,724,660
Total	46,152,852	71,035,924	67,120,882	36,529,300	142,524,688	363,363,646

Table 4.3. Statewide annual ODT of residual biomass by ownership and forest management scenario (3.47 million cord harvest).[1]

Scenario	Description	---------- Government ---------- Federal	State	Local	Private industrial[2]	Woodlands	Total
0% Residual retention	Total physical availability	151,196	194,073	211,104	72,188	359,473	988,034
	+ 10% Bolewood	207,143	266,727	286,391	98,334	486,808	1,345,403
	+ 20% Bolewood	263,090	339,382	361,677	124,479	614,143	1,702,771
	Early stand treatments	192,149	239,457	267,557	90,672	451,929	1,241,764
	Shortened rotation (-10 yrs)	148,200	191,326	206,620	69,712	355,886	971,744
	Extended rotation (+10 yrs)	154,009	195,794	215,215	74,364	360,884	1,000,267
15% Residual retention	Operational maximum removal rate	128,516	164,962	179,438	61,360	305,552	839,829
	+ 10% Bolewood	184,464	237,616	254,725	87,505	432,887	1,197,198
	+ 20% Bolewood	240,411	310,271	330,012	113,650	560,222	1,554,566
	Early stand treatments	163,327	203,538	227,423	77,071	384,140	1,055,499
	Shortened rotation (-10 yrs)	125,970	162,627	175,627	59,256	302,503	825,982
	Extended rotation (+10 yrs)	130,908	166,425	182,933	63,210	306,751	850,227
33% Residual retention	MFRC biomass guidelines	101,301	130,029	141,440	48,366	240,847	661,983
	+ 10% Bolewood	157,248	202,683	216,726	74,511	368,182	1,019,351
	+ 20% Bolewood	213,196	275,338	292,013	100,657	495,517	1,376,720
	Early stand treatments	128,740	160,436	179,263	60,750	302,792	831,982
	Shortened rotation (-10 yrs)	99,294	128,188	138,435	46,707	238,444	651,068
	Extended rotation (+10 yrs)	103,186	131,182	144,194	49,824	241,792	670,179
50% Residual retention	Assumed current removal rate	75,598	97,036	105,552	36,094	179,737	494,017
	+ 10% Bolewood	131,545	169,691	180,839	62,239	307,072	851,386
	+ 20% Bolewood	187,492	242,345	256,125	88,384	434,407	1,208,754
	Early stand treatments	96,075	119,729	133,778	45,336	225,964	620,882
	Shortened rotation (-10 yrs)	74,100	95,663	103,310	34,856	177,943	485,872
	Extended rotation (+10 yrs)	77,005	97,897	107,608	37,182	180,442	500,133
75% Residual retention	Low utilization rate	37,799	48,518	52,776	18,047	89,868	247,009
	+ 10% Bolewood	93,746	121,173	128,063	44,192	217,203	604,377
	+ 20% Bolewood	149,693	193,827	203,349	70,337	344,538	961,746
	Early stand treatments	48,037	59,864	66,889	22,668	112,982	310,441
	Shortened rotation (-10 yrs)	37,050	47,831	51,655	17,428	88,972	242,936
	Extended rotation (+10 yrs)	38,502	48,949	53,804	18,591	90,221	250,067

[1] Residual biomass includes tops, limbs, branches and needles as defined by from the USDA Forest Service FIA biomass attributes.

[2] Includes corporate, nongovernmental conservation/natural resources organizations, unincorporated local partnerships/associations/clubs, and Native American timberlands.

Table 4.4. Statewide annual ODT of residual biomass by ownership and forest management scenario (4.90 million cord harvest).[1]

		---------- Government ----------			Private		
Scenario	Description	Federal	State	Local	industrial[2]	Woodlands	Total
0% Residual retention	Total physical availability	184,458	250,794	276,080	113,517	565,015	1,389,863
	+ 10% Bolewood	252,349	343,223	374,248	154,224	765,159	1,889,202
	+ 20% Bolewood	320,240	435,653	472,415	194,931	965,302	2,388,541
	Early stand treatments	227,139	298,159	334,937	132,865	661,166	1,654,266
	Shortened rotation (-10 yrs)	180,522	246,382	271,700	110,034	563,301	1,371,939
	Extended rotation (+10 yrs)	187,820	253,144	280,609	116,586	569,181	1,407,340
15% Residual retention	Operational maximum removal rate	156,789	213,175	234,668	96,489	480,263	1,181,384
	+ 10% Bolewood	224,680	305,604	332,836	137,196	680,406	1,680,723
	+ 20% Bolewood	292,571	398,034	431,003	177,903	880,550	2,180,062
	Early stand treatments	193,068	253,435	284,697	112,935	561,991	1,406,126
	Shortened rotation (-10 yrs)	153,444	209,425	230,945	93,529	478,806	1,166,148
	Extended rotation (+10 yrs)	159,647	215,172	238,518	99,098	483,804	1,196,239
33% Residual retention	MFRC biomass guidelines	123,587	168,032	184,974	76,056	378,560	931,208
	+ 10% Bolewood	191,478	260,461	283,141	116,763	578,704	1,430,547
	+ 20% Bolewood	259,368	352,891	381,309	157,470	778,847	1,929,887
	Early stand treatments	152,183	199,767	224,408	89,019	442,981	1,108,358
	Shortened rotation (-10 yrs)	120,950	165,076	182,039	73,723	377,412	919,199
	Extended rotation (+10 yrs)	125,839	169,606	188,008	78,113	381,351	942,918
50% Residual retention	Assumed current removal rate	92,229	125,397	138,040	56,758	282,507	694,932
	+ 10% Bolewood	160,120	217,827	236,208	97,465	482,651	1,194,271
	+ 20% Bolewood	228,011	310,256	334,375	138,173	682,795	1,693,610
	Early stand treatments	113,569	149,080	167,469	66,432	330,583	827,133
	Shortened rotation (-10 yrs)	90,261	123,191	135,850	55,017	281,650	685,970
	Extended rotation (+10 yrs)	93,910	126,572	140,305	58,293	284,590	703,670
75% Residual retention	Low utilization rate	46,114	62,698	69,020	28,379	141,254	347,466
	+ 10% Bolewood	114,005	155,128	167,188	69,086	341,397	846,805
	+ 20% Bolewood	181,896	247,558	265,355	109,793	541,541	1,346,144
	Early stand treatments	56,785	74,540	83,734	33,216	165,291	413,566
	Shortened rotation (-10 yrs)	45,131	61,596	67,925	27,508	140,825	342,985
	Extended rotation (+10 yrs)	46,955	63,286	70,152	29,146	142,295	351,835

[1] Residual biomass includes tops, limbs, branches and needles as defined by from the USDA Forest Service FIA biomass attributes.

[2] Includes corporate, nongovernmental conservation/natural resources organizations, unincorporated local partnerships/associations/clubs, and Native American timberlands.

Table 4.5. Statewide annual ODT of residual biomass by ownership and forest management scenario (5.50 million cord harvest).[1]

Scenario	Description	---------- Government ---------- Federal	State	Local	Private industrial[2]	Woodlands	Total
0% Residual retention	Total physical availability	207,068	282,072	308,164	129,191	637,216	1,563,712
	+ 10% Bolewood	283,193	385,884	418,356	175,098	862,460	2,124,993
	+ 20% Bolewood	359,319	489,696	528,547	221,006	1,087,705	2,686,273
	Early stand treatments	252,874	332,688	369,014	151,139	734,510	1,840,225
	Shortened rotation (-10 yrs)	204,844	278,618	304,272	126,065	634,598	1,548,396
	Extended rotation (+10 yrs)	209,891	284,738	312,568	132,433	641,971	1,581,601
15% Residual retention	Operational maximum removal rate	176,008	239,761	261,940	109,812	541,634	1,329,155
	+ 10% Bolewood	252,133	343,573	372,131	155,720	766,878	1,890,436
	+ 20% Bolewood	328,258	447,385	482,323	201,627	992,123	2,451,717
	Early stand treatments	214,943	282,785	313,662	128,468	624,333	1,564,192
	Shortened rotation (-10 yrs)	174,117	236,826	258,631	107,155	539,408	1,316,137
	Extended rotation (+10 yrs)	178,408	242,028	265,683	112,568	545,675	1,344,361
33% Residual retention	MFRC biomass guidelines	138,736	188,988	206,470	86,558	426,935	1,047,687
	+ 10% Bolewood	214,861	292,800	316,662	132,465	652,179	1,608,968
	+ 20% Bolewood	290,986	396,612	426,853	178,373	877,424	2,170,249
	Early stand treatments	169,426	222,901	247,240	101,263	492,121	1,232,951
	Shortened rotation (-10 yrs)	137,245	186,674	203,862	84,463	425,180	1,037,425
	Extended rotation (+10 yrs)	140,627	190,775	209,420	88,730	430,120	1,059,673
50% Residual retention	Assumed current removal rate	103,534	141,036	154,082	64,595	318,608	781,856
	+ 10% Bolewood	179,659	244,848	264,274	110,503	543,853	1,343,137
	+ 20% Bolewood	255,784	348,660	374,465	156,411	769,097	1,904,418
	Early stand treatments	126,437	166,344	184,507	75,570	367,255	920,113
	Shortened rotation (-10 yrs)	102,422	139,309	152,136	63,032	317,299	774,198
	Extended rotation (+10 yrs)	104,946	142,369	156,284	66,216	320,985	790,801
75% Residual retention	Low utilization rate	51,767	70,518	77,041	32,298	159,304	390,928
	+ 10% Bolewood	127,892	174,330	187,233	78,205	384,549	952,209
	+ 20% Bolewood	204,017	278,142	297,424	124,113	609,793	1,513,490
	Early stand treatments	63,219	83,172	92,254	37,785	183,627	460,056
	Shortened rotation (-10 yrs)	51,211	69,655	76,068	31,516	158,649	387,099
	Extended rotation (+10 yrs)	52,473	71,185	78,142	33,108	160,493	395,400

[1] Residual biomass includes tops, limbs, branches and needles as defined by from the USDA Forest Service FIA biomass attributes.
[2] Includes corporate, nongovernmental conservation/natural resources organizations, unincorporated local partnerships/associations/clubs, and Native American timberlands.

5.0 Economic and Social Availability

5.1 Economic Factors Affecting Biomass Availability

As previously discussed, economic availability is the amount of biomass available at different price points, which is a function of market demand. This section of the report provides an overview of factors affecting the price of biomass including the cost of biomass stumpage, harvesting, and transportation. It also provides an in-depth analysis of the social factors affecting private woodland owners' intent to harvest biomass. Social availability is that amount of biomass that is not contested and is otherwise compatible with landowner management objectives. Estimates of economic and social availability are modeled for only private woodlands. Private industrial forest lands were excluded from this portion of the analysis due to data availability. Future harvest levels and subsequent biomass removal from public forest lands are assumed constant.

Figure 5.1 provides an estimate of logging residues, pulpwood and sawlogs available at different price points, across all ownerships in Minnesota, which is based on a 10-year market history and a five-year outlook for mature forest industries (e.g., pulp and paper, lumber, OSB) (MNDNR 2010b). All available species are assumed utilized with minimal restrictions by process or product. The figure illustrates that logging residues have been highly inelastic over the past 10-years in the bioenergy sector. Regardless of the price paid for residuals, only so much of it has been available to the market. Alternatively, the quantity of pulpwood is highly influenced by the delivered price, of which stumpage costs may be as much as one third of the total, but less than 10% for logging residues. Table 5.1 shows the average price received from stumpage sold as pulpwood by public land agencies in Minnesota, 2000-2008 (MNDNR 2010a). Increasing quantity supplied above the 2008-2009 recessionary bottom level will require a corresponding increase in stumpage prices paid.

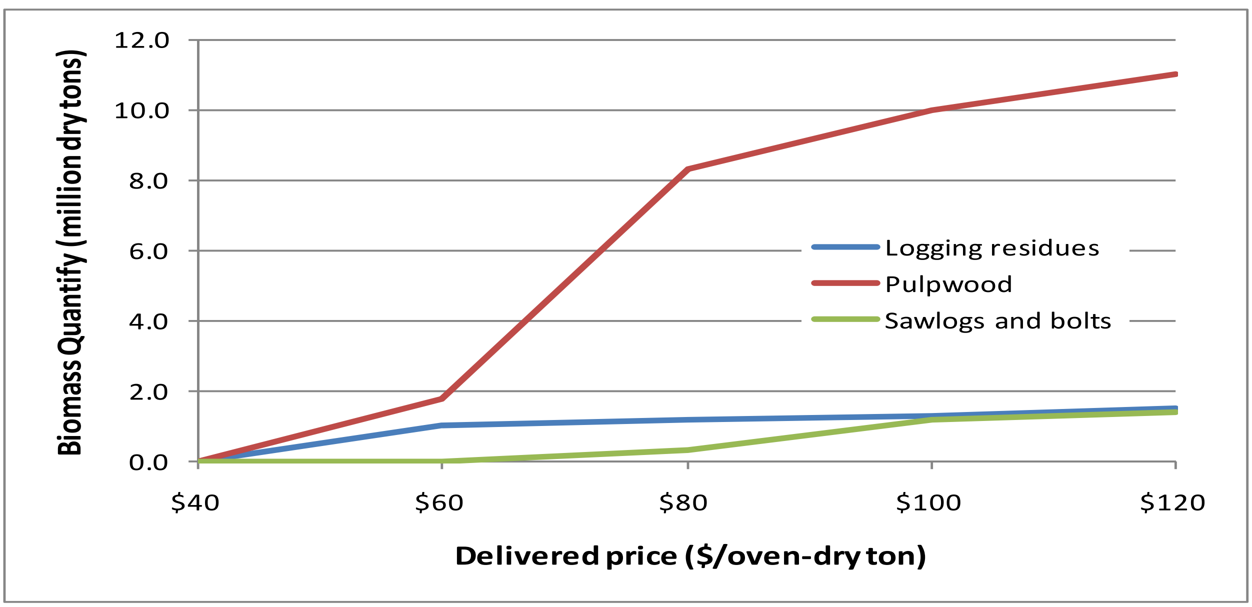

Figure 5.1. Residual forest biomass supply curve for Minnesota forest industries (MNDNR 2010b).

Table 5.1. Average price received ($/cord) for stumpage sold as pulpwood by public land agencies in Minnesota by tree species (2000-2008) (MNDNR 2010a).

		---------- Year ----------							
Species	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Aspen	25.28	28.76	27.36	28.95	37.20	59.70	47.52	27.50	26.14
Balm	25.27	32.06	27.53	25.12	31.71	45.25	38.85	17.00	21.18
Birch	7.69	8.31	8.16	9.04	12.21	20.57	14.76	9.68	9.06
Ash	4.09	3.91	5.86	3.62	5.51	5.43	8.22	6.21	6.86
Oak	9.27	7.74	5.77	4.35	8.28	16.28	18.27	16.23	8.39
Basswood	5.68	5.48	6.51	6.05	6.58	10.64	8.06	10.35	7.41
Balsam Fir	14.84	14.61	13.99	13.46	21.12	33.54	30.56	18.36	15.98
W. Spruce	32.63	29.90	30.51	21.87	31.80	43.39	35.06	21.49	18.69
B. Spruce	22.23	29.17	27.05	31.96	31.50	43.39	35.06	21.49	20.05
Tamarack	5.67	6.40	4.11	4.56	6.42	9.84	5.96	3.18	4.61
W. Cedar	8.46	6.74	7.06	4.68	4.60	5.50	9.26	6.39	4.10
J. Pine	21.94	21.63	22.18	21.37	29.46	30.66	37.62	28.50	9.87
Pine	18.61	20.79	20.99	19.55	19.18	29.06	36.59	27.15	11.99
Maple	--[1]	--[1]	--[1]	--[1]	--[1]	13.3	7.98	7.91	8.86

[1] Insufficient data.

5.1.1 Harvesting and Transport Costs

Biomass removal costs are a significant factor in the price paid for biomass and its subsequent availability (Becker et al. 2009a; Han et al. 2004). Removal costs, which include harvesting, collection, and transport to processing facilities vary widely based on operator and equipment productivity and tree species utilized. We quantify an average removal cost to compare to the price paid to woodland owners for removal of their biomass, and to illustrate how changes in costs nodes, for instance transportation distance, affect value and subsequent availability.

The equipment set used reflects a commonly used set-up for industrial-scale forestry in the region and is typical of aspen, northern hardwoods, and conifer stands (Brinker et al. 2002; Sturos et al. 1983). We assumed that all harvested wood is used for biomass or pulpwood removed using appropriate harvest systems. For hardwoods, equipment included a 177-horsepower (hp) whole tree feller-buncher, 175-hp skidder with 500-ft average skid to a landing, 500-hp horizontal chipper with a 120 cu yard van. For conifers, harvest equipment included the same whole tree feller-buncher and skidder, 138-hp stroke delimber, and 130-hp knuckle-boom log loader. Wages, benefits, and employer costs for workers' compensation and unemployment insurance are held constant.

Transportation costs are calculated as a function of distance traveled and fuel cost. A study at the Idaho National Laboratory (Blackwelder and Wilkerson 2008) estimated transportation costs of $11.58/ODT based on a 50-mile distance to processor. Becker et al. (2009) estimate that transport costs can be as much as 65% of total delivered costs of biomass. Sampled woodland owner parcels in this study were on average 56 miles from the closest biomass processing facility (Figure 3.2). Using the Blackwelder and Wilkerson (2008) methodology and fuel costs of $2.90/gal (August 2010), the average transport costs are $20.78/ODT ($0.37/ODT/mile) for parcels within 50 miles on improved roads. 16% of sampled parcels were within 25 miles of a processing cluster with an average transport cost of $9.25/ODT. Sampled parcels within 75-miles had an average cost of $27.75/ODT, and those within 100 miles had an average cost of $37.00/ODT. The average distance of sampled parcels to major processing clusters and facilities (inputs greater than 100,000 ODT annually) (MNDNR 2010c) is presented in Table 5.2.

Table 5.3 presents a breakdown of fixed and variable equipment costs for harvesting, handling and transport. Total fixed costs range from approximately $23/scheduled machine hour (SMH) for the loader to $73/SMH to chip the material for harvesting and in-woods processing. Variable costs similarly range with the loader being the least expensive input and the chipper the most expensive. The harvesting and skidding equipment fall in between these two cost extremes. In order for a logger to justify moving their equipment onto a site to process biomass they need enough throughput to offset these hourly costs. Small parcel sizes, long distances between harvest sites to mobilize equipment, and long transport distances to processing facilities (e.g., biomass power plant) are all disincentives for loggers to participate in biomass markets, unless they can pass those costs on to the landowner. In the next section, we model landowner factors, including price, affecting willingness to participate in biomass markets.

Table 5.2. Average distance to nearest processing cluster from sampled parcel.

Biomass processing cluster	Percent sampled parcels	Average distance to cluster (miles)
Potlatch-Bemidji Cluster	27%	64.6
Duluth Cluster	22%	58.3
Cloquet Cluster	14%	44.5
Grand Rapids Co-Gen Cluster	11%	38.2
St. Cloud Cluster	5%	45.6
Fibro-Minn Cluster	5%	89.6
Boise Cluster	4%	68.4
Hedstrom Cluster	4%	52.1
Hill Wood Products Cluster	3%	43.8
Valley Forest Wood Products Cluster	3%	32.1
Laurentian Cluster	2%	30.2
District Energy Cluster	1%	74.9

Table 5.3. Fixed and variable harvest and collection costs as a function of equipment type and productivity.

Machine costs	JD 843 feller-buncher	JD 748 skidder	Chain flail delimber	Knucklboom loader	Horizontal chipper	120 cubic yard chip van
Fixed cost inputs						
Purchase price	$217,000	$227,000	$354,900	$181,030	$580,000	$125,000
Scheduled hours/yr (SMH)	2000	2000	2000	2000	2000	2000
Production hours/yr (PMH)	1300	1200	1300	1300	1300	1300
Machine life (yrs)	4	5	5	5	5	8
Salvage value (% of new)	0.20	0.25	.20	0.20	0.20	0.20
Interest rate (%)	0.10	0.10	0.10	0.10	0.10	0.10
Insurance (annual prem.)	$7,600	$10,200	$7,100	$3,600	$12,000	$6,000
Taxes/tags (% of new)	0.00	0.00	0.00	0.00	0.00	0.00
Operating cost inputs						
Tire cost (total)	--	--	--	--	--	$3,500
Tire life (years)	--	--	--	--	--	2
Local fuel cost ($/gal)	$1.80	$1.80	$2.00	$1.80	$1.80	$2.00
Local oil cost ($/gal)	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00
Horsepower	200	169	225	174	860	450
Fuel consumption (g/hp-hr)	0.026	0.028	0.028	0.022	0.028	6.0
Oil and lube use (% of fuel)	0.37	.037	0.37	0.37	0.13	0.10
Repair/maintenance (% of dep)	1.0	0.90	0.90	0.90	0.75	0.60
Misc consumables ($/op hr)	--	--	--	--	$9.28	--
Labor cost inputs						
Basic labor rate	$18	$18	$18	$18	$18	$18
Benefits (% of base)	0.33	0.33	0.33	0.33	0.33	0.33
Total costs breakdown						
Fixed cost ($/SMH)	$28.06	$29.74	$42.87	$22.71	$73.00	$13.62
Variable costs ($/PMH)	$37.15	$36.62	$56.86	$25.87	$102.38	$17.15
Labor costs ($/SMH)	$23.94	$23.94	$23.94	$23.94	$23.94	$23.94

Source: Brinker et al. (2002); Blackwelder and Wilkerson (2008)

5.2 Social Factors Affecting Biomass Availability from Woodlands

Private woodland owners comprise an estimated 47% of timberlands in Minnesota (Butler 2008) and about 45% of harvested timber in 2009 (MNDNR 2010). Opportunities to expand bioenergy production, therefore, hinges significantly on the ability to secure a consistent and sustainable supply from these lands. However, the supply of forest products from woodlands is greatly influenced by a range of social factors known to affect landowner behaviors and intent to harvest timber. The literature describes woodland owners as a diverse group of individuals with varying attitudes, motivations, and concerns (Bliss and Martin 1988; Butler 2006). Understanding how the variation in these factors affects their behaviors with respect to the availability of biomass is an important objective of this study.

The availability of biomass from woodlands is a function of the willingness of landowners to allow harvesting, which is in turn a function of their attitudes about timber harvesting, competing forest uses (e.g., recreation, hunting, carbon storage), and knowledge of biomass markets. The literature focuses on two key areas with respects to these issues. The first is financial feasibility, which includes the cost of harvesting biomass (Pan et al. 2008; Hartsough et al. 2001) and market sensitivity (Becker et al. 2009b; Galik et al. 2009; Perlack et al. 2005; Prestemon et al. 2008). A larger body of research exists pertaining to the effect of woodland owner attitudes on forest management practices. For example, woodland owner attitudes have been found to significantly influence their willingness to harvest timber (Beach et al. 2005), conduct thinning and related timber stand improvement activities (Joshi and Arano 2009), restore or improve wildlife habitat (Dennis 2003; Bishop 1998; DellaSala et al. 1995), and provide recreation access (Kilgore et al. 2008). The willingness to sell biomass is subsequently influenced by individuals' perceptions of the compatibility of its removal, and type of removal, with their primary forest management objectives. For the purposes of this study, biomass from woodlands is determined to be a function of forest land characteristics, woodland owner characteristics, and woodland owner attitudes. An important determinant is the compensation woodland owners receive for their biomass, which is in turn a function of the price received for the timber removed, if any, the cost of harvesting and transport, and market demand. Biomass may be removed in conjunction with a timber harvest, or from other timber stand improvement or and wildlife habitat restoration activities.

5.2.1 Forest Land Characteristics

The physical characteristics of forest lands have been shown to affect woodland owners' management decisions. Factors such as parcel size, site quality, and site accessibility (proximity to roads) help predict willingness to conduct certain activities. Parcel size, for instance, has been shown to have a positive impact on willingness to conduct activities because profitability generally tends to increase as the project area increases (marginal equipment mobilization costs are greater and return on investment can be smaller for smaller parcels). Larger parcels may also reflect indices of owner wealth and interest in forest management (Beach et al. 2005). Site quality helps predict willingness to partake in forest management activities in that higher quality sites have the potential to be more profitable for timber harvesting, thus increasing a woodland owner's desire to actively manage (Zhang and Pearse 1996).

A final predictor examined here is site access. As accessibility becomes more difficult, harvest and transport costs increase (Hartsough et al. 2001; Pan et al. 2008), which makes woodland parcels less desirable than more easily accessible parcels from a financial standpoint. Related to access is the effect a parcel's proximity to a biomass processing facility may have on landowner knowledge or ability to supply biomass markets. The closer the parcel is to a processing facility or the presence of efficient road networks, the more likely woodland owners may be to harvest timber and residual biomass for those markets. These aspects are modeled to estimate their effect on willingness of woodland owners to harvest residual biomass, including limbs, tops, and trees too small for roundwood markets.

5.2.2 Landowner Characteristics

Landowner characteristics such as age, income, residence, reason for ownership, and the influence of others have been found to affect woodland owners' management decisions (Cubbage et al. 2007; Romm et. al. 1987; Young and Reichenbach 1987). As woodland owners get older they become more interested in bequeathing the value of their forests to their heirs (Beach et al. 2005), and are thus less likely to harvest timber. In terms of income, wealthier landowners may be less likely to harvest timber than lower income landowners may (Binkley 1981). Conversely, wealthier landowners have been shown to be more willing to pursue innovative forest management strategies that lead to biomass removal on their property by way of forest thinning and habitat restoration (Best and Wayburn 2001).

In terms of landowner residence, absenteeism has been found to affect the rate at which owners seek information and assistance from professional foresters (Morgan and Martin 1995), with absentee owners more likely than on-site owners to access this knowledge. The use of professional foresters has been an often used source of forestry information and may be predictive of willingness to engage in forest management activities (Butler 2008). The degree to which absentee landowners own woodlands for hunting may also influence their willingness to remove biomass for purposes of habitat maintenance. Conversely, on-site owners were more likely to own woodlands for purposes of timber production, with 67% of Minnesota's on-site owners having harvested since purchasing their woodlands compared to 49% of absentee owners (Butler 2008). Finally, several studies have verified that ownership for the purposes of generating income from timber harvesting is a positive predictor of willingness to engage in forest management activities (Hyberg and Holthausen 1989; Dennis 1990).

5.2.3 Landowner Attitudes

Landowner attitudes with respect to removing residual woody biomass are a critical component affecting biomass availability. Factors such as attitudes toward timber harvesting, biomass removal, ecological concerns, and pressure from family and friends to either conduct or abstain from forest management may influence a woodland owner's decision to harvest biomass. Landowner attitudes are further characterized by factors influencing individual behaviors, or behavior intent. For the purposes of this study, individual behaviors and behavior intent include past forest management activities, and intent to conduct forest managment activities in the next ten years. The Theory of Planned Behavior (TPB), which organizes behavioral intent into the categories of individual attitudes, social norms, and perceived control over the behaviour (Ajzen 1991), relates strongly to behavior under a wide variety of conditions. This is particularly true where the target behavior is explicitly stated, within short time periods, and when the individual has the ability and volitional control to engage in the behavior (Ajzen 1991; Ajzen and Fishbein 1980).

Individual attitudes are the sum of a person's beliefs about a behavior and their evaluation of the expected outcomes (Ajzen 1991). Applied to residual forest biomass harvesting, the attitudes modeled include beliefs about the impact of harvesting on the environment, asthetics, and local economies, as well as attitudes toward general forest management practices (Abrams, in press). The second dimension, social norms, includes the subjective beliefs about how others think a person should perform the behavior and the motivation to comply with the wishes of others. Applied to residual biomass harvesting, this includes landowners' perceptions about how others think they should manage their property and if biomass harvesting is compatable with these external influences (Young and Reichenbach 1987). Family members, friends, and neighbors have been found to have a strong influence on landowner behaviors (Karppinen 1998). Also, the manner in which harvesting is conducted and landowner's introduction to ideas and market opportunities can be positively affected by trusted professionals, such as foresters or loggers (Young and Reichenbach 1987). These influences ultimately affect availability of biomass from woodland parcels.

The final dimension of TPB, perceived behavioral control, is the individual's perceived power to control, facilitate or inhibit performance of the given behavior (Ajzen 1991). In other words, it is a measure of an individual's beliefs about barriers to engaging in the behavior. For residual biomass harvest, this might include knowing who to contact to set up a timber sale or who will harvest the biomass. It might also include beliefs about control over harvest operations. For instance, the landowner may decide against harvesting the residual biomass because they fear the logger might build temporary roads in unsuitable locations or remove trees the landowner wishes to retain.

5.2.4 Willingness to Supply Forest Biomass

As described above, the supply of residual biomass from woodlands is a function of many factors, not the least of which is the compensation landowners receive for biomass removal. However, the markets for woodchips and other material used for bioenergy production are sporadic, and the price paid and amount of biomass procured varies widely from location to location. Its utilization offers loggers an additional revenue stream, but its value relative to the cost of removal makes it financially infeasible in many cases (Peterson 2005).

Contingent valuation is a method commonly used to estimate the value of natural resource goods and services where there is no established market or where prices are difficult to observe (Daniel et al. 1989; Hanley and Ruffell 1993). The contingent valuation method, applied to forest biomass, relies on the stated preferences of individuals where they are asked their willingness to pay or accept payment for a desired forest condition or outcome (Kramer et al. 2003). A population of woodlands owners was surveyed to elucidate their preferences, which was accomplished by presenting them with a specific situation having a clearly understood, realistic, and mutually exclusive outcome.

Little research exists in which woodland owners have been asked about their preferences for harvesting biomass or willingness to participate in biomass markets. Preliminary results of recent studies indicate that size of woodland, education, and having wildlife objectives are significant positive indicators of a landowner's willingness to remove woody biomass. Likewise, landowner age and a landowning placing value on timber production on their property have been shown to be significant negative indicators of willingness to provide woody biomass (Joshi and Mehmood 2009).

5.3 Findings of Economic and Social Availability

Economic and social availability is modeled as a function of the level of compensation woodland owners would receive in return for allowing the removal of residual biomass from their property. The study area includes a 26-county region in northern Minnesota and northwestern Wisconsin, which was identified by the extent of forest biomass present and importance of the forest products industry to local communities. The four northwestern Wisconsin counties of Douglas, Bayfield, Washburn, and Burnett were also included in this part of the study because of the proximity to major biomass using industries in the Duluth, MN, area.

A survey questionnaire was administered to a random sample of eligible woodland owners to estimate the minimum compensation they would be willing to accept to allow the removal of residual forest biomass from their property, and to identify key factors influencing their decision whether to harvest biomass. Eligible woodlands consisted of land classified for property tax purposes as forested (2b, 2c classes in Minnesota; Forested [F], Forest Crop Law [FCL], Managed Forest Law [MFL] classes in Wisconsin), and at least 20 acres in size. County assessors were contacted to obtain mailing lists of all parcels meeting these criteria.

Two focus groups were organized with a sample of woodland owners, one in St. Paul, MN, at the University of Minnesota, and the other in Cloquet, MN, at the Cloquet Forestry Center. Focus group responses were recorded and analyzed for responses to pilot questions, types of language used, general attitudes toward residual biomass removal, and woodland uses. A survey questionnaire was then developed based upon these findings, which was administered to a random sample of 100 woodland owners in the same study region.

The final survey questionnaire was administered to a random sample of 1,109 woodland owners during the fall of 2009. The sample was stratified by county based upon total forested acres within each county. Mail-back survey procedures developed by Dillman (2000) were used in which a pre-survey postcard was sent one week prior to sending the questionnaire, followed approximately one week later by a postcard reminder. A second questionnaire was sent to respondents one week after this, followed by a final postcard reminder approximately one week later.

A total of 644 usable questionnaires were returned for a 58% response rate (11 returned with bad addresses; 28 filled incompletely or otherwise unusable). A nonresponse bias check was conducted to determine if there were significant differences in survey return rates based upon parcel size, individual counties, or regional clusters (eastern and western portions of the study region). Analysis of variance (ANOVA) results indicated no statistical differences in these three metrics at an alpha level of 0.05 between respondents and nonrespondents based on parcel size and both county and regional cluster of ownership. Further logistic regression analysis was conducted to determine if regional clusters of woodland ownership played a significant role in landowner WTA payment for forest biomass removal in conjunction with a commercial timber harvest. First, four binary dummy variables indicating if a landowner's woodland was located in a given region (northeast MN, northwest MN, east-central MN, and northwest WI) were introduced into the LOGIT model to determine if any regions would be significant predictors of landowner WTA payment for biomass removal. None of these variables proved significant predictors at an alpha level of 0.05. Thus we could determine that region of woodland ownership was not a significant predictor of landowner WTA and we could therefore generalize our findings and supply curves to the regional. We had hoped to be able to generalize these findings on the county level, but lacked the necessary data to do so.

The survey requested information on reasons for forest ownership, past and future forest management activities, likelihood of removing residual biomass, personal values and external influences on forest management, and WTA payment for biomass removal (Appendix E). Responses were analyzed using a binary logit model (Equation 5.1). The logit modeling was used to estimate the effects of a vector of independent variables on a response variable, in our case woodland owner willingness to remove residual biomass in conjunction with a commercial timber harvest.

$$\text{Logit}(Y) = \ln(p/1\text{-}p) = \alpha + \beta' x \qquad \text{[Equation 5.1]}$$

Where:
p = Probability of removing biomass
α = Intercept
β' = Vector of regression coefficients
x = Vector of predictor variables (Table 5.2)

The survey findings are organized into three sections, the first providing general information on woodland owners and forest characteristics. The second focuses on the willingness of landowners to allow the removal of residual forest biomass in return for compensation. The third section focuses on woodland owners' attitudes and behavioral intent concerning biomass utilization.

5.3.1 Woodland Owner and Forest Characteristics

Data obtained from the mail-back survey allowed us to describe woodland owner characteristics within the study region. On average woodland owners owned 1.8 parcels with each parcel averaging approximately 116 acres; 75% of woodlands were smaller than 120 acres with an average size of 51 acres. Post-hoc ANOVA analysis indicated that landowners with larger sized parcels (>80 ac) were significantly more likely ($p < 0.05$) to have conducted a timber harvest in the past 10 years, while smaller sized forest landowners were more likely ($p < 0.05$) to have a timber harvest planned in the next 10 years. These results indicate a possible shift to smaller and potentially less profitable timber harvests in the future, and that these woodland owners may be limited by a variety of constraints such as reduced profitability or decreased knowledge concerning commercial timber harvesting. While parcel size was a significant indicator of past harvesting and future intent, it was not a significant predictor of involvement in past or anticipated timber stand or wildlife habitat improvement activities. These results indicate that there is no statistical difference in the likelihood of noncommercial forest managment activities occurring on small and large size nonindustrial private woodlands.

In terms of woodland owner characteristics, the average survey respondent was 58 years old, and more than 80% of surveys were completed by a male woodland owner. Just less than half (44%) of those surveyed indicated that they lived more than 50 miles from their woodland. For the purposes of our analysis, these landowners are considered absentee owners and is similar in proportion to the national estimate of 40% reported by the National Woodland Owner Survey (Bulter 2006). In terms of distance to a major biomass processing facility, the average woodland property surveyed was 56 miles away. The most commonly cited reasons for woodland ownership were to view wildlife, enjoy solitude and quiet, to pass along the property to future generations, and a place to hunt. The least common reasons cited for ownership were producing income from agriculture or timber harvesting, motorized recreation, or personal firewood production.

5.3.2 Probability of Biomass Availability

Payment in exchange for residual biomass removal is one of several aspects hypothesized to influence a landowner's decision regarding whether to harvest biomass. This section analyzes the effect payment amount has on a woodland owners' willingness to allow the removal of residual biomass. We hypothesized that the compensation landowners are offered will impact their willingness to supply residual forest biomass.

Our selection of variables that explain a landowner's decision to allow residual forest biomass harvest (beyond simply the payment amount offered) was based upon a review of the literature concerning factors influencing woodland owners' forest management decisions, and by information obtained from the two focus groups. We hypothesized that a woodland owner's willingness to allow the removal of residual forest biomass was a function of personal characteristics, forest land characteristics, past management activities, and landowner attitudes and beliefs. These factors converge to form a stated opinion about whether woodland owners are willing to accept a specific payment level offered for the harvest of residual biomass in conjunction with a commercial timber harvest.

The model's dependent variable, WTA payment for residual biomass removal, was generated by proposing to landowners a hypothetical timber harvest scenario in which residual biomass could either be removed or left on site. Respondents were asked to respond "yes" or "no" to the question, "*Would you accept the logger's offer to pay you an additional $X/acre to remove the residual woody biomass after the commercial harvest is complete?*" One of five payment offers ($0, $2, $5, $10, $15) was randomly assigned to each survey respondent so that one fifth of all respondents received one of the five payments (Table 5.4). Payments were derived by considering current market prices for residual biomass in Minnesota in 2009, which were then tested during the focus groups and pilot surveys. The no payment option in exchange for allowing the removal of residual biomass was included after identifying a number of focus group participants who indicated they would be willing to accept no compensation, and in some instances, would be willing to pay, or had paid in the past, for the removal of residual biomass to accomplish forest management or wildlife habitat restoration objectives.

Table 5.4. Landowner willingness to remove residual woody biomass at various per acre payment levels offered to respondents.

Payment offered	Response	No. of responses	Percent of responses
$0	Yes	53	43
	No	58	48
	Don't Know	11	9
$2	Yes	64	56
	No	30	26
	Don't Know	21	18
$5	Yes	73	58
	No	36	29
	Don't Know	17	14
$10	Yes	70	54
	No	44	34
	Don't Know	15	12
$15	Yes	65	53
	No	32	26
	Don't Know	26	21

Responses were analyzed using the binary logit model outlined in Equation 5.1 to estimate the overall probability of removing biomass based upon the mean response levels of each of the independent variables. The independent variables were converted to binary responses except for landowner age and forest acreage, which were left as continuous variables. In order to maintain a large enough number of responses for our desired level of confidence, missing data were converted to the series mean for each variable allowing us to utilize the questionnaires in which a valid "yes" or "no" response was given. This method resulted in a total sample size of 525 respondents.

The remaining 108 responses coded as "not sure" were assessed for inclusion in the analysis using a procedure developed by Cramer and Rider (1989), in which the regression coefficients for the multinomial model were compared to the binomial model where the "not sure" responses were recoded to “yes” or “no.” Recoding responses to “no” produced a chi-square test statistic of 591, and recoding to “yes” produced a test statistic of 433, indicating that the “not sure” responses were distinct from those who stated they would or would not be willing to accept payment for biomass removed. All “not sure” responses were therefore eliminated from the analysis.

In total, we identified 13 explanatory variables that were hypothesized to have an effect on landowners’ willingness to allow the removal of residual biomass in conjunction with a commercial timber harvest. These variables are described in Table 5.5, and each variable’s influence on landowner willingness is hypothesized. Table 5.6 displays the descriptive statistics for each explanatory variable.

Figure 5.2 displays the estimated probability of allowing the removal of residual biomass at different payment levels when all other explanatory variables are held at their mean values. Our analysis shows that at an offer of $5/acre, an estimated 63% of landowners are likely to sell residual biomass. An estimated 72% of the landowners would allow biomass removal when offered $15/acre. The median payment accepted, the payment at which 50% of the landowners would allow the removal of residual biomass, is negative, estimated at -$9.25/acre. This implies that half of woodland owners would be willing to pay to remove residual forest biomass from their property.

Table 5.5. Variables hypothesized to impact landowner willingness to accept payment for residual woody biomass removal.

Variable	Description	Hypothesized effect on allowing residual biomass removal
Economic Characteristics		
PAYMENT	A categorical variable indicating the payment amount offered for biomass removal ($/acre)	Positive
Landowner Attitudes and Beliefs		
CONTACT	A binary variable indicating whether landowner's ability to remove residual woody biomass is limited by not knowing who to contact.	Negative
SOIL	A binary variable indicating whether landowner agrees with the statement "removing residual woody biomass on my property depletes soil nutrient levels."	Negative
ENERGY	A binary variable indicating whether landowner agrees with the statement, "utilization of residual woody biomass for energy could positively impact the United States' energy independence."	Positive
AESTHETICS	A binary variable indicating whether landowner is deterred from harvesting biomass because of the resulting forest aesthetics.	Negative
Landowner Characteristics		
ABSENTEE	A categorical variable indicating the distance a landowner lives from the forest parcel surveyed.	Negative
PROCESSING DISTANCE	A continuous variable indicating the distance a landowner lives from the nearest major biomass processing facility (miles)	Negative
AGE	A continuous variable indicating the landowner's age (years).	Negative
EXTRAINCOME	A binary variable indicating that the primary ownership objective is to produce income from either timber or agriculture.	Positive
FUTHARVEST	A binary variable indicating a landowner's intent to conduct a commercial timber harvest in the next ten years.	Positive
FUTWILDLIFE	A binary variable indicating a landowner's intent to conduct forest management activities concerning wildlife habitat improvement in the next ten years.	Positive
CONSULT	A binary variable indicating if a landowner had consulted a professional forester since owning their woodlands.	Positive
Forest Land Characteristics		
ACREAGE	A continuous variable indicating the size of a woodland owner's forest (acres).	Positive

Table 5.6. Descriptive statistics of WTA payment for biomass removal predictor variables.

Variable	Mean	Minimum	Maximum	Standard deviation
Economic Characteristics				
PAYMENT ($)	6.52	0	$15.00	5.46
Landowner Attitudes and Beliefs				
CONTACT	0.53	0	1	0.46
SOIL	0.69	0	1	0.38
ENERGY	0.80	0	1	0.36
AESTHETICS	0.45	0	1	0.46
Landowner Characteristics				
ABSENTEE	2.01	1	3	0.92
PROCESSING DISTANCE (miles)	55.46	1.8	150.0	24.33
AGE (years)	59.22	23	95	11.88
EXTRAINCOME	0.49	0	1	0.49
FUTHARVEST	0.38	0	1	0.42
FUTWILDLIFE	0.80	0	1	0.36
CONSULT	0.37	0	1	0.48
Forest Land Characteristics				
ACREAGE (acres)	123.92	19	3,610	271.63

Figure 5.2. Estimated probability of woodland owner willingness to remove residual biomass in conjunction with a commercial timber harvest. Acceptance is displayed as a percent of all landowners willing to remove biomass at a given per acre payment.

5.3.3 Significant Predictors

Eight of the 13 variables tested in the model proved to be significant predictors of a woodland owners' interest in selling residual biomass at $p \leq 0.10$ (Table 5.7). Significant predictors at $p \leq 0.05$ included the payment amount offered, landowner belief that biomass utilization positively affects US energy independence, belief that biomass removal depletes soil nutrients, and concern that biomass harvesting could negatively affect aesthetics. Landowner age was a significant predictor of willingness to sell residual woody biomass at $p \leq 0.10$.

Table 5.7. Probability model results (dependent variable is probability a landowner will allow for the removal of residual woody biomass).

Variable	Coefficient	Wald	Std. error	Odds ratio	Marginal Effect
Economic Characteristics					
PAYMENT	0.038**	3.950	0.019	1.038	0.009
Landowner Attitudes and Beliefs					
CONTACT	0.739***	10.741	0.226	2.098	0.17
SOIL	-0.632**	5.689	0.265	0.532	-0.14
ENERGY	0.596**	5.349	0.258	1.814	0.14
AESTHETICS	-0.475**	4.454	0.225	0.622	-0.11
Landowner Characteristics					
ABSENTEE	-0.360*	2.988	0.208	0.698	-0.08
PROCESSING DISTANCE	-0.006	2.153	0.004	0.994	-0.001
AGE	-0.015*	3.275	0.008	0.985	-0.003
EXTRAINCOME	-0.392*	3.381	0.213	0.676	-0.09
FUTHARVEST	0.369	1.923	0.266	1.446	0.08
FUTWILDLIFE	-0.282	0.850	0.305	0.756	-0.06
CONSULT	0.129	0.336	0.223	1.138	0.03
Forest Land Characteristics					
ACREAGE	< 0.001	0.152	< 0.001	1.000	0.00004
Constant	2.155	7.993	0.762	8.624	
-2 Log likelihood	585.609				
Model Chi-square	50.545				
Obs. with payment acceptance = 1	297				
Obs. with payment denial = 0	192				
Overall % correct	62.0				
Overall Model Significance	<0.001				

*$p \leq 0.1$, **$p \leq 0.05$, ***$p \leq 0.01$

Landowners were responsive to the amount of payment offered, with the estimated probability of removing biomass increasing by approximately 1% with every additional dollar per acre offered within the middle range of payments (-$30/ac to $30/ac). Belief that biomass utilization for energy improves the US energy independence was similarly found to positively influence willingness to harvest biomass. These landowners were 14% more likely to allow the removal of biomass than those who did not believe it would affect energy independence. Alternatively, landowners who were not concerned about the aesthetics of their woodlands after a biomass harvest were 11% more likely to allow biomass removal than other respondents were. Similarly, if a landowner felt that biomass removal would deplete soil nutrients they were 14% less likely to remove biomass. Finally, in terms of the age, younger landowners were more likely to remove biomass than older landowners at a rate of 0.3% for every year.

Feeling limited in one's ability to harvest biomass by not knowing whom to contact was also a significant predictor at $p \leq 0.001$. However, the effect was opposite of what was hypothesized. A landowner who feels limited by lack of contact knowledge was actually 17% more likely to harvest biomass than a landowner who did not feel limited by this constraint. Similarly, if extra income from timber or agriculture was the primary reason for woodland ownership, landowners were 9% less likely to accept payment for biomass in conjunction with a commercial timber harvest. Lastly, absenteeism proved to have a negative impact on willingness to remove biomass. Landowners living within 50 miles of their woodlands were 8% less likely to remove biomass as a landowner living more than 50 miles away.

Eight variables tested in the WTA model did not predict willingness to harvest. Using parcel tax data, we calculated the distance of each woodland property surveyed to the nearest major biomass-processing cluster. Processing clusters were determined based upon the 2009 level and number of biomass processing facilities within an area, taking the geographic center point (Figure 3.1). Processing clusters were generally located near larger towns or where facilities were within 10-miles of one another. Distance to processor was statistically insignificant, meaning that proximity to a biomass processor had no effect on landowner willingness to allow the removal of residual forest biomass. It was hypothesized that the closer a respondent's woodlands were to a processing facility, the more likely they would be to remove biomass because of an increased awareness of biomass markets. The lack of significance may be attributed to the infancy of biomass markets, which are inconsistent in price and amount of biomass utilized within and among facilities. Landowners may also lack awareness of biomass markets as a whole, whether they own property near or far from biomass utilizing industries.

We initially hypothesized that the size of woodlands would be a significant predictor of WTA payment. The model results indicate that size plays a minimal role in biomass removal decision. While landowners may receive less revenue from residual forest biomass removal from a small parcel, they are no less likely to remove biomass. It is important to note however, that market situations would likely limit opportunities to remove biomass on smaller parcels because a logger would likely offer a lower payment for its removal than from larger parcels because of the increased marginal costs of equipment mobilization and product recovery on smaller parcels.

We had also hypothesized that landowner willingness to accept payment would increase if one were planning to conduct a commercial timber harvest or engage in wildlife habitat improvement activities within the next ten years. The rational was that those landowners with plans for future forest management would likely be more knowledgeable, have managed their woodlands in the past, and be more inclined to participate in emerging forest management techniques, including biomass removal. However, future management intention was not found to be predictive of WTA payment. The implication is that landowners who are not planning future management may be just as likely to remove biomass as those who are engaged in such planning, making identification of potential willing sellers more difficult.

Finally, consulting a professional forester was hypothesized to have a positive effect on a landowner's willingness to sell residual forest biomass. We assumed that a landowner in contact with a forester would be actively managing their forest and more knowledgeable of emerging forestry techniques, thus increasing the likelihood of removing biomass in conjunction with a commercial harvest. However, the model indicates a landowner who has consulted a forester was no more likely to remove biomass than landowners who have not, which contributes to the difficulty of identifying willing woodland owners.

5.3.4 Aggregate Woodland Biomass Availability

Aggregate annual biomass availability was modeled for woodland owners for each forest management scenario and reported by the three target harvest levels (3.47 million cords, 4.90 million cords, and 5.50 million cords) and two levels of biomass retention. Only the MFRC (2007) harvest guidelines of 33% retention and the 50% retention modeled in the Minnesota Logged Area Residue Analysis (MNDNR 2007) are presented. The aggregated statewide supply curves presented in Figures 5.3 to 5.8 are based on modeled levels of woodland owner compensation offered for residual biomass removal in conjunction with a commercial timber harvest. Aggregate woodland owner supply curves are also presented for each FIA defined region in Appendices A to D. Individual supply curves for each county are not presented because of small sample sizes and discrepancies of total acres of woodlands in some counties.

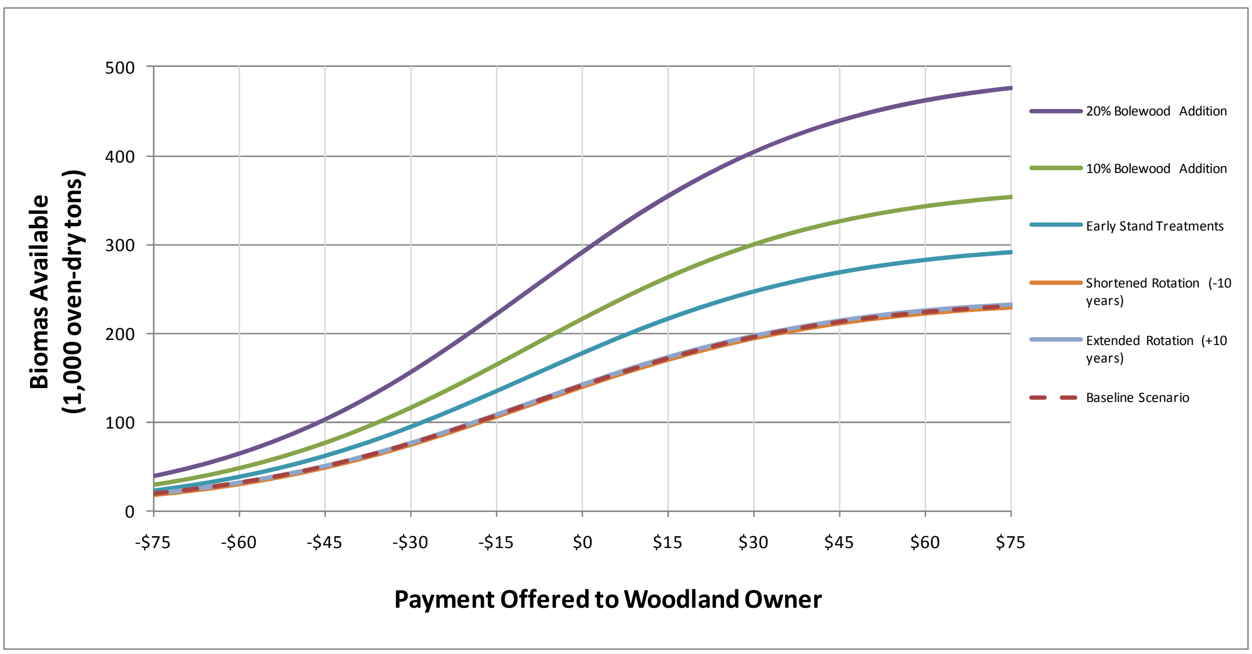

Figure 5.3. Estimated residual biomass supply from woodlands owners in the 22 northern Minnesota counties (3.47 million cord harvest; 33% on-site residual retention).

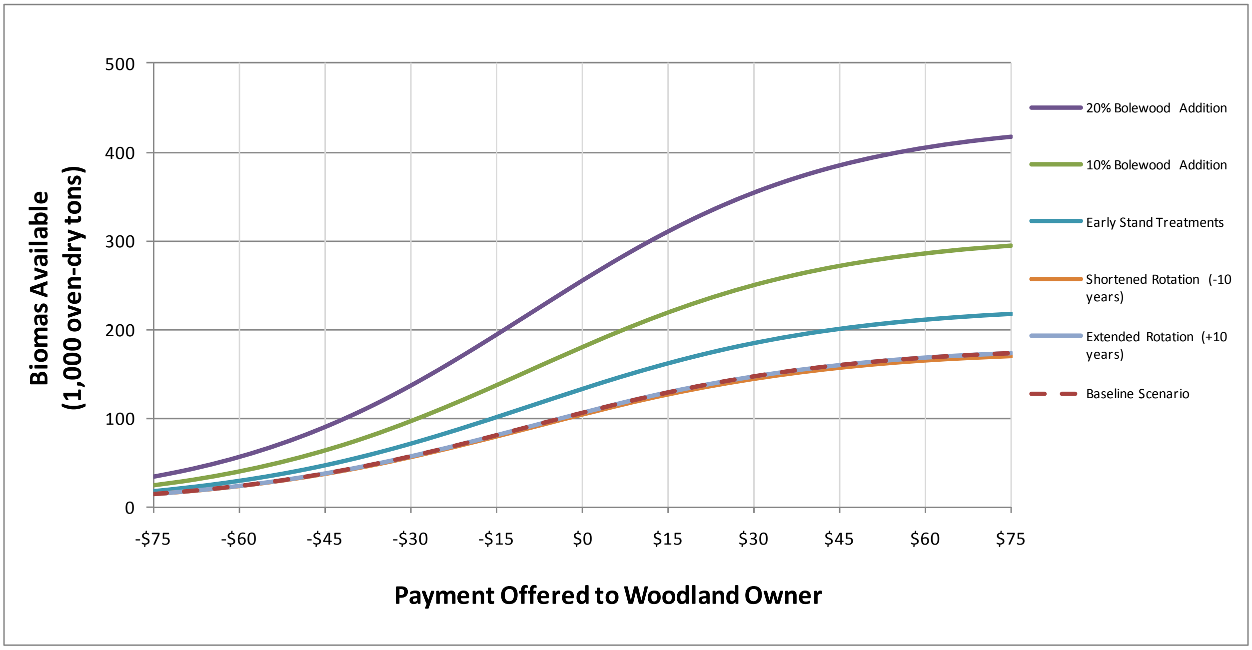

Figure 5.4. Estimated residual biomass supply from woodlands owners in the 22 northern Minnesota counties (3.47 million cord harvest; 50% on-site residual retention).

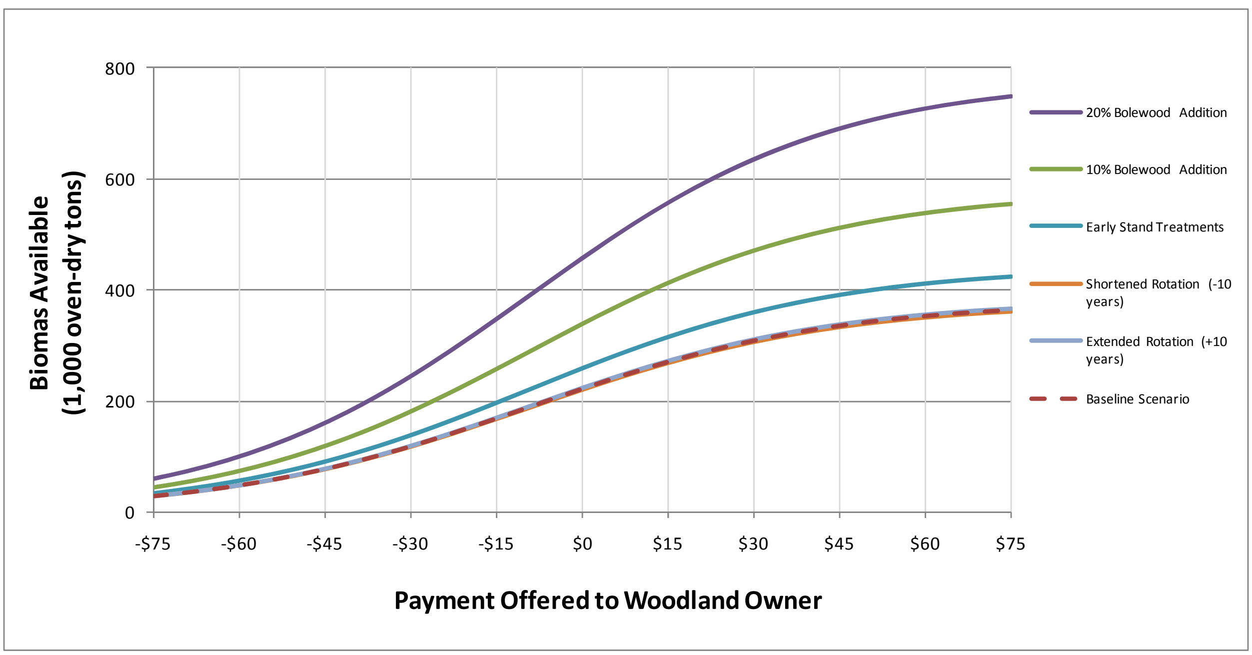

Figure 5.5. Estimated residual biomass supply from woodlands owners in the 22 northern Minnesota counties (4.90 million cord harvest; 33% on-site residual retention).

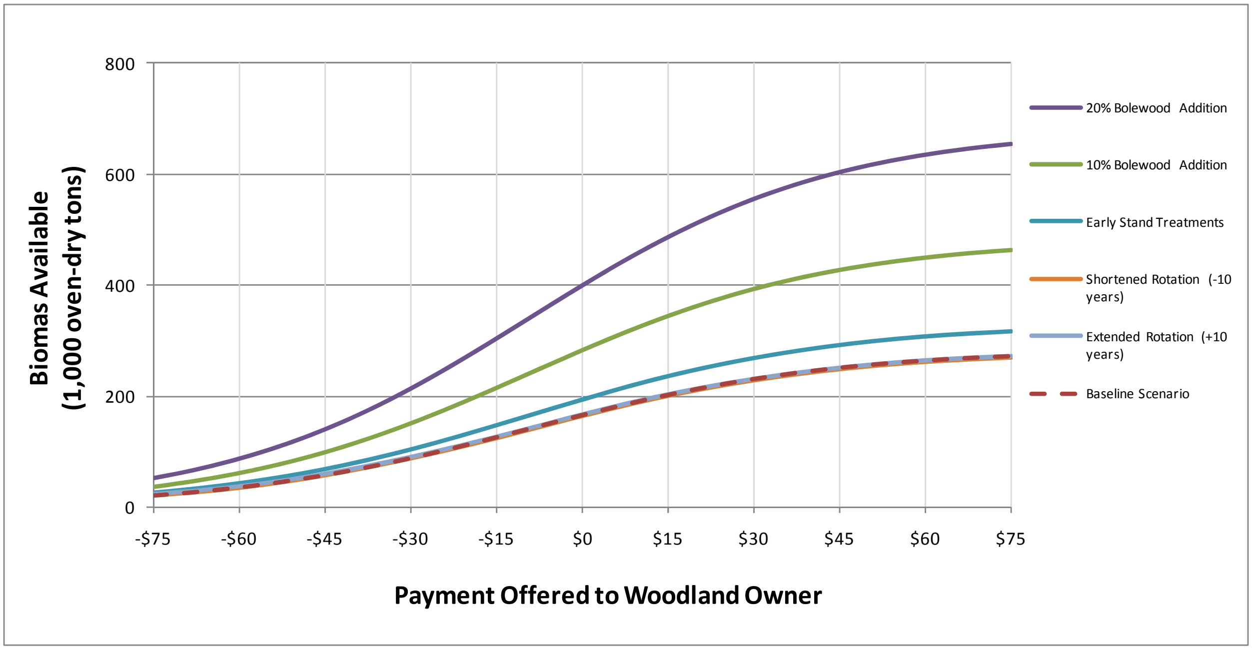

Figure 5.6. Estimated residual biomass supply from woodlands owners in the 22 northern Minnesota counties (4.90 million cord harvest; 50% on-site residual retention).

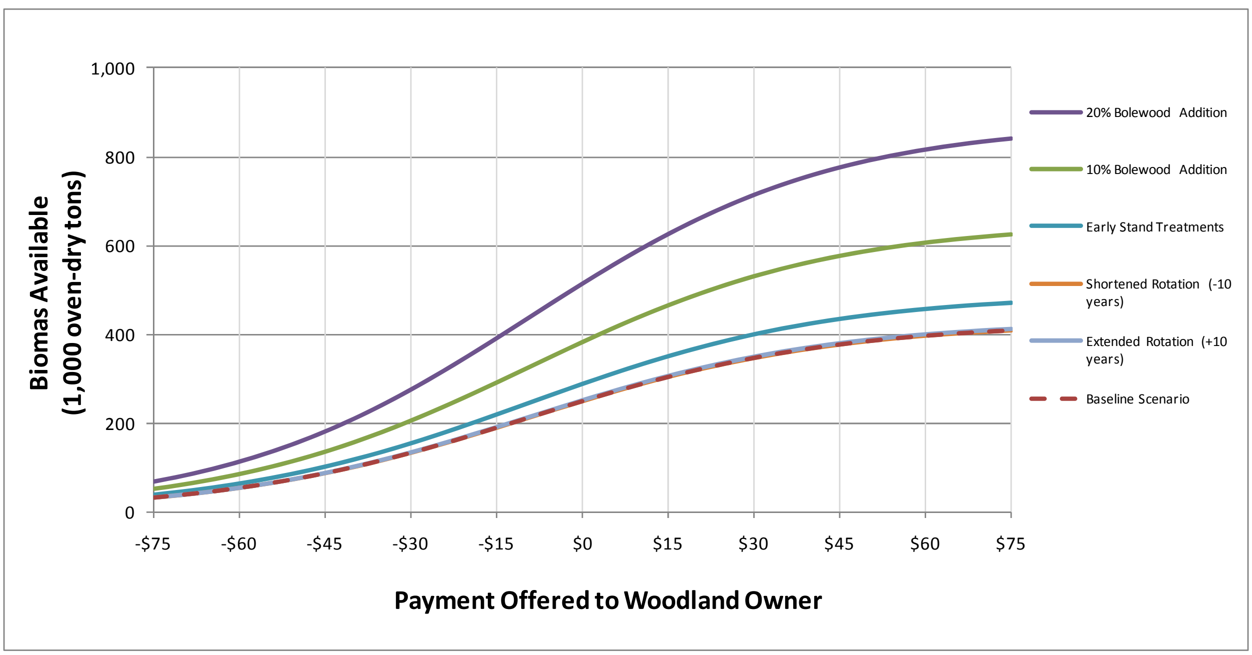

Figure 5.7. Estimated residual biomass supply from woodlands owners in the 22 northern Minnesota counties (5.50 million cord harvest; 33% on-site residual retention).

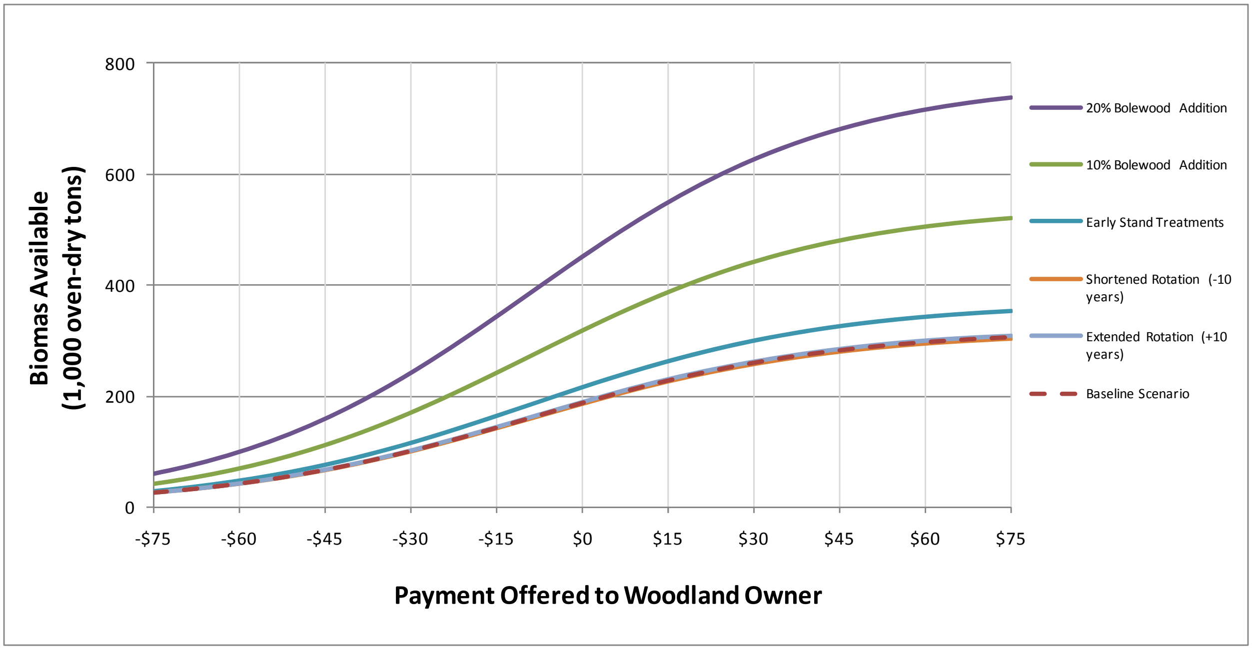

Figure 5.8. Estimated residual biomass supply from woodlands owners in the 22 northern Minnesota counties (5.50 million cord harvest; 50% on-site residual retention).

5.3.5 Behavioral Intent to Harvest Biomass

The analysis of landowner's willingness to sell residual biomass estimates availability from woodland parcels in the study region, but only as it relates to an activity that is carried out in conjunction with commercial timber harvesting. Focus group responses incidated that landowners are willing to harvest biomass for nontimber related purposes such as wildlife habitat improvement, species restoration, timber stand improvement. The previous analysis confirms that a majority of landowners would even be willing to pay to have residual forest biomass removed in conjunction with a commercial timber harvest, presumably for purposes other than site preperation. This section therefore analyzes landowner likelihood of allowing residual forest biomass removal in conjunction with other forest management activities.

This section presents results of our analysis of factors affecting behavioral intent of woodland owners. Rather than presenting respondents with a specific scenario, such as in conjunction with a timber harvest, we used responses to the question, "H*ow likely are you to remove residual woody biomass in conjunction with: (a) commercial timber harvest, (b) silvicultural practices related to timber stand improvement activities (i.e., remove dead/dying trees, pre-commercial thinning), or (c) improving wildlife habitat*." For the purpose of our behavioral intent analysis, survey respondents indicating that they were "somewhat" or "extremely likely" to remove biomass in conjunction with one or more of these activities were considered "likely biomass producers." This derived variable was used as the dependent variable in logistic regression analysis, which allowed us to estimate how likely woodland owners would be to remove residual biomass in conjunction with noncommercial timber harvesting activities. Table 5.8 displays response frequencies for each activity included in the dependent variable, and the frequencies for the aggregate dependent variable.

Of the three activities examine, wildlife habitat improvement yielded the greatest likelihood of biomass removal with 62% of respondents stating that they would likely remove biomass if there were an opportunity to do so on their property. Silvicultural practices related to timber stand improvements such as removal of dead or dying trees and precommercial or commercial thinning yielded a 56% likelihood of biomass removal. Commercial timber harvest yielded 44% likelihood. Overall, 78% of respondents said that they would be likely to remove biomass in conjunction with at least one of these activities.

There was statistically significant correlation ($p < 0.001$) in the likelihood of biomass removal among all three activities included in the dependent variable. The greatest correlation was found between silvicultural activities and wildlife habitat improvement, which indicates that woodland owners who are likely to generate biomass from any one of these three activities are also likely to generate biomass from the other two activities.

Table 5.8. Landowner likeliness to remove residual woody biomass in conjunction with forest management activities.

Variable	Response	No. of responses	Percent of responses
Commercial timber harvest	Likely	294	44
	Unlikely	279	46
	Not sure	60	10
Silviculture activities (i.e., timber stand improvement)	Likely	357	56
	Unlikely	221	35
	Not sure	55	9
Wildlife habitat improvement	Likely	395	62
	Unlikely	192	30
	Not sure	46	7
Derived overall likelihood of biomass removal*	Likely	493	78
	Unlikely	97	15
	Not sure	43	7

*Respondents determined to be likely to remove biomass if they responded that they would be likely to remove residual woody biomass in conjunction with any of the three forest management activities.

5.3.5.1 Probability Estimation

Eight explanatory variables relating to dimensions of behavioral intent were selected from the survey data to predict the probability that a landowner would be likely to remove residual biomass in conjunction with a vector of noncommercial forest management activities. Table 5.9 provides a list of these variables and their hypothesized effect on likelihood to remove biomass. Table 5.10 displays descriptive statistics for each explanatory variable included in the behavior intent logit model. While some of these same variables were also included in the probability of selling residual forest biomass reanalysis, it is important to differentiate the two models. The WTA payment analysis presents a specific harvest scenario and utilizes the contingent valuation method for analysis whereas the behavioral intent analysis utilizes predictive indicators derived from the TPB to estimate the likelihood that biomass would be generated from a myriad of forest management activities, not solely commercial timber harvest. Initially, more than eight variables were selected but significant co-linearity existed among the independent variables forcing us to choose proxies for the larger data set. Co-linearity was determined to be occurring when correlation coefficients were greater than 0.4. The resulting variables used in the analysis display independent effects on landowner likeliness of biomass generation. The probability that woodland owners will remove biomass is derived using Equation 5.1, the same logit modeling as used in the WTA payment analysis.

Table 5.9. Behavioral intent variables hypothesized to impact landowner likelihood of residual woody biomass removal.

Variable	Description	Hypothesized effect on allowing residual biomass removal
Landowner Attitudes and Beliefs		
LOCAL ECONOMY	A binary variable indicating whether landowner agrees with the statement, “utilization of residual woody biomass for energy could positively impact the local economy.”	Positive
ENERGY PRODUCED	A binary variable indicating whether landowner agrees with the statement “I would be more willing to allow removal of residual woody biomass on my property if I knew it was to be used to produce energy as opposed to a nonenergy use.”	Positive
External Influences		
FAMILY FRIENDS	A binary variable indicating whether a landowner’s forest management decisions are influenced by family or friends.	Positive
LOGGERS	A binary variable indicating whether a landowner’s forest management decisions are influenced by loggers.	Positive
Perceived Landowner Control		
CONTACT	A binary variable indicating whether the landowner’s ability to remove biomass is limited by not knowing who to contact.	Negative
OPPOSE HARVESTING	A binary variable indicating whether landowner feels limited in their ability to remove biomass because they are opposed to timber harvesting.	Negative
SMALL	A binary variable indicating whether landowner feels limited in their ability to remove biomass because their woodlands are too small.	Negative
SOILS	A binary variable indicating whether landowner feels limited in their ability to remove biomass because it would deplete soil nutrients.	Negative

The three elements of TPB discussed in Section 5.2.3 are represented by the independent variables in this analysis. In order to gauge landowner attitudes and beliefs concerning biomass and how it relates to their woodlands, we chose to include analysis concerning landowners' beliefs about how woody biomass utilization impacts their local economy and if they would be more likely to remove residual woody biomass if they knew it were going to be used for energy production. In order to represent the external influences that affect the decisions of woodland owners we included analysis concerning responses regarding the extent to which landowners feel influenced in their management decisions by loggers and either friends or family. To assess woodland owner perceived control over the outcome in a biomass removal scenario, we analyzed whether landowners felt limited that not knowing who to contact to remove biomass, being opposed to timber harvesting, feeling that their woodlands are too small, or feeling that a biomass harvest would deteriorate their soils to an unfavorable extent. Each variable included could then be examined as to determine how the elements of TPB affected the likelihood of a woodland owner removing biomass in the future.

Table 5.10. Descriptive statistics of likelihood to remove biomass predictor variables

Variable	Mean	Minimum	Maximum	Standard Deviation
Landowner Attitudes and Beliefs				
LOCAL ECONOMY	0.84	0	1	0.32
ENERGY PRODUCED	0.63	0	1	0.43
External Influences				
FAMILY FRIENDS	0.62	0	1	0.49
LOGGERS	0.46	0	1	0.48
Perceived Landowner Control				
CONTACT	0.47	0	1	0.46
OPPOSE HARVESTING	0.74	0	1	0.40
SMALL	0.55	0	1	0.45
SOILS	0.59	0	1	0.45

The behavioral intent logit model is significant at the $p < 0.001$ level, indicating that landowner likelihood of removing residual biomass is significantly affected by their attitudes toward the use of biomass, the influence of family members and other woodland owners, and their perceived control over the impacts on their property. The model indicates that 79% of landowners are likely to contribute biomass in conjunction with either a commercial timber harvest, silvicultural activity like timber stand improvement, or wildlife habitat improvement.

5.3.5.2 Significant Predictors

Four of the eight variables tested in the behavior intent model proved to be significant predictors of a landowner's likelihood to remove residual woody biomass at $p \leq 0.05$ (Table 5.11). Landowner attitudes toward the contribution of biomass to the local economy was significant at $p \leq 0.05$ as was using biomass for energy production as opposed to other nonenergy uses. Using the marginal effects of each explanatory variable we can determine its estimated impact on the overall likelihood of biomass generation. If a landowner believes that biomass utilization has a positive impact on the local economy they were estimate to be 11%

more likely to generate and remove biomass than one who did not have this belief. A landowner who believed that removal of biomass for energy was preferred to nonenergy purposes was 9% more likely to generate and remove biomass than one who did not. In terms of external influences, landowners' decisions to remove biomass were positively affected by their relationships with loggers. These landowners were 8% more likely to generate and remove biomass than landowners whose land management decisions were not influenced, positively or negatively, by loggers. Finally, perceived control over the impacts of biomass harvesting on soil nutrients was found to be a contributing factor in a landowner's decision to remove biomass at $p \leq 0.05$. If landowners felt hindered in their ability to remove biomass because of the potential for soil nutrient depletion, they were 8% less likely to generate and remove biomass. Cumulatively, the model suggests landowner's biomass harvesting decisions are affected by several factors, and the TPB dimensions offer a new and useful way to characterize factors influencing landowners' behavioral intent.

Table 5.11. Probability model results (dependent variable is probability of producing residual woody biomass in conjunction with noncommercial timber harvesting activities).

Variable	Coefficient	Wald	Std. error	Odds ratio	Marginal Effect
Landowner Attitudes and Beliefs					
LOCAL ECONOMY	0.623*	4.953	0.280	1.865	0.11
ENERGY PRODUCED	0.556*	5.531	0.237	1.744	0.09
External Influences					
FAMILY FRIENDS	0.206	0.989	0.207	1.229	0.03
LOGGERS	0.466*	4.321	0.224	1.594	0.08
Perceived Landowner Control					
CONTACT	-0.363	2.537	0.228	0.695	-0.06
OPPOSE HARVESTING	-0.067	0.065	0.262	0.935	-0.01
SMALL	-0.174	0.531	0.233	1.190	0.03
SOILS	0.465*	3.961	0.234	1.592	-0.08
Constant	-0.016	0.002	0.357	0.984	
-2 Log likelihood	633.509				
Model Chi-square	35.424				
Obs. Biomass Producer = 1	493				
Obs. Biomass Producer = 0	140				
Overall % correct	77.9				
Overall Model Significance	<0.001				

*p ≤ 0.05

The influence of family and friends on management decisions, not knowing who to contact for biomass removal, opposition to timber harvesting, and perceptions that woodlands are too small were not significant predictors. Interestingly, the influence of loggers and not family or friends was significant, contrary to past research (Karppinen 1998). This could have important implications when designing education programs for landowners or loggers. A program that offers the opportunity for contact with area loggers may have greater success in convincing landowners to remove biomass than programs that do not. Nonetheless, landowners who selfselect to participate in such programs may also be more willing to consider biomass removal regardless of their communication with loggers. This finding suggests that it is important for loggers to communicate the potential for biomass removal when working with landowners.

In terms of not knowing whom to contact to remove biomass, landowners did not perceive this as a significant obstacle. It was not so significant an obstacle that landowners felt it limited their ability to participate in biomass markets. Similarly, the size of woodlands also did not affect likelihood to remove biomass. This is important because while a logger or forester may not feel inclined to prescribe certain silvicultural activities on small woodlots, a landowner's willingness to remove biomass was not a factor. A practical implication is that if biomass markets become widespread and more profitable than at current, loggers and foresters may increasingly wish to target smaller parcels. Economies of scale tip in the favor of larger parcels in terms of per unit cost of harvesting biomass (Mckendry 2002), but where appropriate, biomass utilization should not be limited to only large landholders.

Finally, landowner opposition to commercial timber harvesting was not a significant predictor of likelihood of removing biomass. Landowners were just as likely to remove biomass in conjunction with other forest management activities (i.e., timber stand improvement, wildlife habitat improvement, invasive species removal) as landowners who were not opposed to timber harvesting. The implication is that timber harvesting is but one activity that may produce biomass. This was supported by the focus group findings, which suggested that concern over soil and related impacts from timber harvesting impeded willingness to harvest timber, not landowners' general philosophical beliefs about the activity itself. Focus group participants were quite willing to engage in nontimber activities in order to enhance the quality of their woodlots. Nontimber harvesting activities may produce less biomass volume than a commercial harvest, but it is important to consider opportunities to procure biomass from a range of forest management activities.

6.0 Discussion

6.1 Physical and Environmental Availability

Biomass estimates in this analysis reflect the most current inventory information available in the study region (FIA inventory period 2004 to 2008) and are based on current management and harvesting practices. This study presents annual average estimates over a 100-year planning period for each of three different harvest levels (3.47 million cords, 4.90 million cords, 5.50 million cords) and at different biomass retention levels. While these long-range forecasts are useful for projecting changes in age class distributions and biomass availability, there are unknown factors that could substantially alter projections (e.g., market disruptions, wildfire, insect and disease infestations, and agency appropriations). As such, these results should be used with caution and as a tool to support decision-making. Additional analysis and due diligence is necessary when making investments in related enterprises.

The Aspen-birch forest type occupies 40% (6,065,332 acres) of the total forest area in the state with more than 60% of those acres less than 50 years old. The Spruce-fir forest type, which includes other exotic softwoods, occupies 23% (3,468,861 acres) of total timberland with 70% of those acres older than 50 years. Statewide, approximately 14% of all living biomass is in tops and limbs, which is the primary resource upon which emerging bioenergy markets depend. By comparison, bolewood comprises 54% of all living biomass and saplings about 11%, with the remaining in stumps and roots (Table 3.2). Of the residual biomass (tops and limbs), the majority is on private woodlands (41%), followed by state forest land (18%), and county and municipal forests (18%) (Table 4.2). Approximately 1.3 million acres of timberland were removed from subsequent analysis to exclude designated wilderness areas, old-growth reserves, wildlife management areas, state parks, and urban areas (Table 3.3).

In our analysis, we focused on the 33% and 50% retention levels, the lower of the two represents a minimum threshold for soil nutrification and forest regeneration as established by the MFRC (2007). The higher retention level was used in the Minnesota Logged Area Residue Analysis (MNDNR 2007) to depict realistic removal practices in conjunction with commercial timber harvests. Key findings of physical and environmental availability include the following:

- State, county and municipal forests comprise about 40% of timberland acres in the state and are capable of producing between 37-41% of total residual biomass (tops and limbs) on an annual basis depending on the harvest level (Tables 4.3 to 4.5). Private forest land, which includes woodlands and industrial forests as well as tribal forests, were about 47% of timberland area in the state in 2009 and about 45% of harvested timber (MNDNR 2010a). Subtracting the industrial production of residual biomass of about 8%, woodlands are capable of providing about 39% of residual biomass on an annual basis, which represents a significant opportunity for expanded bioenergy production but are constrained by various economic and social factors discussed below.
- Assuming 33% biomass retention at the 3.47 million cord harvest level, an estimated 661,983 ODT of residual biomass (tops and limbs) is annually available (Table 4.3). Assuming the 2008-2009 utilization level of approximately 200,000 ODT (MNDNR 2010b), this represents a surplus of approximately 462,000 ODT not currently utilized in statewide bioenergy production. At the 4.90 million cord harvest level established by the GEIS (Jaakko Pöyry Consulting 1994), an estimated 931,208 ODT of residual biomass is annually available at the 33% retention level, which is an increase of 41% over the 3.47 million cord harvest level (Table 4.4). Surplus availability at this harvest level is approximately 731,000 ODT. Finally, at the 5.50 million cord harvest level, an estimated 1.05 million ODT of residual biomass is annually available at the 33% retention level (Table 4.5). This is a 58% increase over the 3.47 million cord harvest level and a 13% increase over the 4.9 million cord harvest. Surplus biomass available to bioenergy markets at this highest harvest level is approximately 805,000 ODT (Figure 6.1).

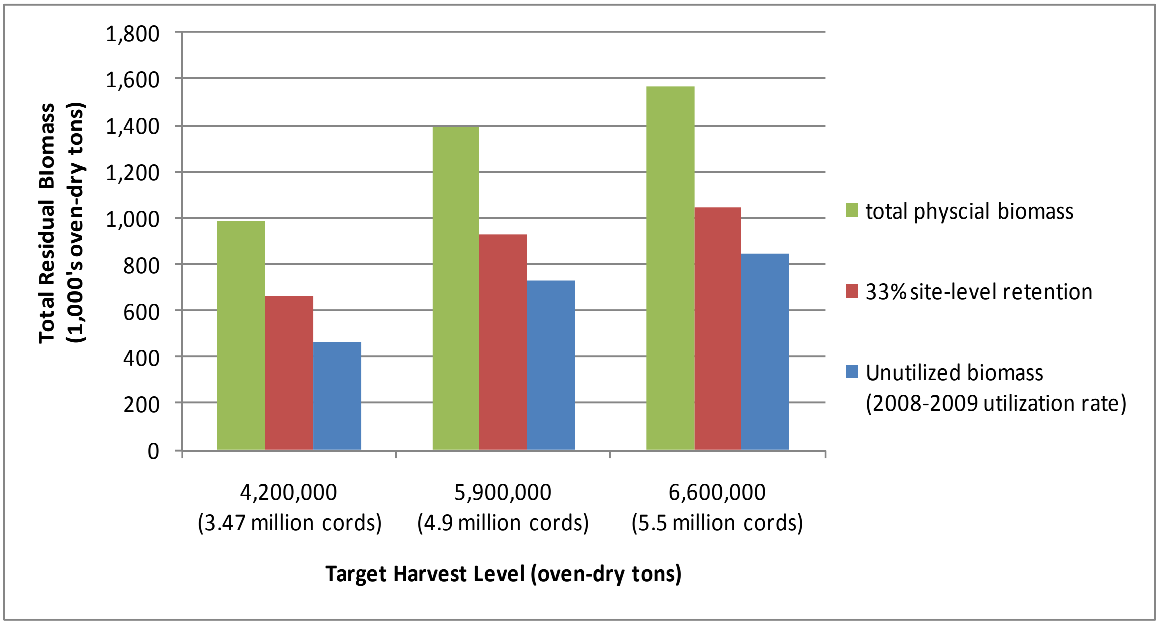

Figure 6.1. Unutilized residual biomass assuming 2008-2009 statewide utilization rates (excludes biomass imports and exports, and supplements to residual biomass of bolewood and saplings).

- The proportion of unutilized residual biomass is an estimate based upon 2008-2009 utilization rates (MNDNR 2010b), and does not include the impact of imports or exports on what was utilized internally in the state or the degree to which availability was augmented by the utilization of bolewood, saplings or other forms of biomass. The amount of unutilized biomass within a particular area that is available for bioenergy production will be constrained by the cost of procurement, transportation distances, and the willingness of landowners to sell or remove biomass.
- The 2008-2009 harvest level was approximately 2.88 million cords, which significantly reduces the amount of residual biomass available to markets. A total of 526,592 ODT of residual biomass was available in 2009-2009 at the 33% retention level, which is a 20% reduction from the 10-year harvest average
- Assuming bioenergy markets compete for pulpwood, and that on average 10% of bolewood harvested is chipped for energy production as is estimated for 2008-2009 (MNDNR 2010b), an additional 357,368 ODT is available annually at the 3.47 million cord harvest level. Assuming 20% of bolewood is chipped, an additional 714,737 ODT is available annually. At the 4.90 million cord harvest level, 10% bolewood yields an additional 499,399 ODT and 20% bolewood yields an additional 998,679 ODT. At the 5.50 million cord harvest level, 10% bolewood yields an additional 561,281 ODT and 20% bolewood yields an additional 1.12 million ODT (Tables 4.3 to 4.5).
- Early stand treatments increased statewide residual biomass by about 26% (169,999 ODT) for the 3.47 million cord harvest level (Table 4.3), from 661,983 ODT to 831,982 ODT (33% retention). At the 4.90 and 5.50 million cord harvest levels, early stand treatments increase residual biomass by approximately 19% (177,150 ODT) and 18%

(185,264 ODT), respectively. Increases in residual biomass at the site level will be much less and may not increase yield sufficiently to offset treatment costs.

- Decreasing the average rotation age by 10 years for all forest types (Table 4.1) decreased available residuals by approximately 2% for the 3.47 million cord harvest level (Table 4.3). Conversely, lengthening the rotation age by 10 years for all forest types increased available residuals by 1%. Changes in availability are likely due to the added growth in bolewood resulting from extending the rotation age.

6.2 Economic and Social Availability

In addition to physical and environmental availability, market prices and a wide range of social factors influence the ultimate availability of biomass. In this report, economic and social availability are modeled for only private woodlands. Price information on industrial private forest lands including projections of future timber harvest levels and rotation ages are confidential and therefore excluded from this analysis. Historic price information and harvest levels on public lands were included (Figure 3.1, Table 3.5) and assumed constant in future years. Key findings of economic and social availability include the following:

- A probabilistic analysis based upon a representative sample of woodland owners in northern Minnesota identified that half of owners are willing to pay up to $9.25/acre to remove the residual biomass generated from a commercial timber sale on their property, including of those who are not willing to conduct a timber sale. When no payment was offered, an estimated 59% were willing to allow the material to be removed, which increased to 72% when offered $15/acre (Figure 5.2).
- Payment amount was one of eight explanatory variables in the willingness to accept (WTA) payment model that contributed to owners' decisions to harvest biomass. Influence of consulting foresters, concern for soil health and forest aesthetics in conjunction with timber harvesting, concern for U.S. energy independence, absentee ownership, age, and desire to generate income from woodlands were statistically significant (Table 5.7).
- Distance of woodlands to the nearest processing facility affects the delivered price of biomass (Table 5.2), but was not found to influence woodland owners' decisions to harvest biomass or the WTA payment level (Table 5.7).
- Similar to the findings of physical and environmental availability, aggregate availability from woodlands is greatest for forest management scenarios where 20% of the bolewood is chipped and utilized for bioenergy applications, which for the 3.47 million cord harvest level with 33% retention, is nearly 300,000 ODT of residual biomass annually from woodlands in the 22 northern Minnesota counties at a price of $0/acre offered. The amount increases to approximately 400,000 ODT at a price of $30/acre (Figure 5.3). The effect of early stand treatments and changes in rotation ages had a modest to negative impact on availability across all payment levels. Similar trends are observed for the 4.90 and 5.50 million cord harvest levels (Figures 5.5 and 5.7). Unknown is the amount that is in addition to what was harvested in recent years, in other words the proportion of this material that is potentially new to the market.

- There is potential for biomass to be generated from a myriad of forest management activities, including activities that do not generate income or involve payments of any kind. 79% of sampled woodland owners reported that they plan to conduct forest management activities within the next 10 years that will generate some amount of biomass, and that they are interested in finding an outlet for this material. The Theory of Planned Behavior (TPB) was employed to model nonfinancial factors influencing availability within each of three dimensions (attitudes and beliefs, external influences, and perceived control). Findings show that woodland owners' intent to harvest biomass was significantly influenced by their desire to utilize the material for energy purposes and to contribute to the local bioeconomy, a concern for the impact harvesting would have on their woodlands (e.g., soil health), and the influence of loggers in getting them to remove the material (Table 5.11). These factors were analyzed in the context of removing biomass in conjunction with wildlife habitat improvement activities, timber stand improvement, and commercial timber harvesting. To our knowledge, this is the first application of the TPB model in this context and allows us to consider a broader range of factors known to influence landowner behaviors, beyond financial factors.
- Additional research is needed to determine the extent to which land tenure influences the willingness to accept payment for biomass removal. This variable was overlooked in the generation of our questionnaire and past research points to its importance.

6.3 Other Considerations for Minnesota's Forest Biomass Industry

As of the latest industry survey in 2005, only about 5% of forest resources are used for wood energy purposes (MNDNR 2007). However, as it becomes cost efficient to harvest biomass independent of commercial timber harvesting operations, this percent could increase. Correspondingly, competition with existing industries may also increase forcing an expansion in the size of supply regions.

- A 2008 harvest survey identified that the percentage of harvests in which bolewood was sold as a bioenergy feedstock ranged from 0-36% (D'Amato et al. 2009). To the extent that new bioenergy applications compete with the pulp and paper industry for bolewood, existing forest industries could be negatively affected.
- Failure to include the range of constraints associated with increased biomass removal could result in a potential overestimation of supply, which in turn threatens the viability of new businesses and existing forest products industries. It also threatens the sustainability of the forest resource when policies designed to enhance utilization create scenarios leading to overharvesting within economically defined supply regions.
- Forest biomass can also be generated from a range of noncommercial management activities such as timber stand improvement (TSI) or wildlife habitat improvement. These activities are capable of generating some income, but may be insufficient to offset the costs of forest entry and harvesting. To help defray these costs, several cost-share programs are offered by the Minnesota Department of Natural Resources including Reinvest in Minnesota (RIM) and the Sustainable Woodlands Program that provide direct investment matches to encourage landowners to improve wildlife habitat, offer

recreational opportunities, improve forest aesthetics or enhance forest productivity. These programs may also offer further incentive for woodland owners to conduct management activities leading to increased biomass supply.

- The willingness of woodland owners to remove biomass does not alone ensure the availability of that biomass to the market. Given the small size of woodland parcels (75% of sampled parcels were less than 120 acres) where residual biomass is about 14% of the total per acre yield (Table 3.2), and of that 33-50% is retained on site per the harvest guidelines, there may be insufficient residues to justify the mobilization of equipment unless in proximity to a processing facility or other planned harvest projects.
- The choice of biomass harvesting systems is, in part, a function of existing equipment and may be ill suited for efficient and cost-effective biomass removal needed for further expansion of the biomass industry.
- While forest biomass will likely require improvements in cost competitiveness compared to natural gas and oil for it to achieve widespread use, increases in fossil fuel prices also increase the cost of biomass collection and transport. Decreasing the distance traveled to processing facilities is one key strategy to reducing those variable costs.
- Given the excess residual biomass under each of the forest management scenarios, including the 10-year baseline of 3.47 million cords, expansion of the biomass industry in the state is constrained more by the demand for biomass products than the supply of biomass residuals.

6.4 Study Limitations

The physical availability analysis was based on the most recent USDA Forest Service FIA data (2004-2008) for the 49 counties of interest. FIA information is based on a systematic national sampling design where plots on forested lands are consistently measured on a five-year cycle (20% annually) with state inventory reports every five years. This standardized inventory system allows users to organize data by county, ownership, or other forest land attributes across large spatial scales making it well suited for our analysis. While FIA has national precision standards, localized estimates may vary relative to county-level or ownership-specific inventory information for a variety reasons, including but not limited to: (1) the number of FIA plots within an area, (2) differences in photo interpretation and geospatial analyses, (3) scaling error from area expansion factors within the FIA sampling design, or (4) disparities between FIA and other inventory specific biomass equations. To this end, a number of assumptions related to the FACCS model and other analyses were necessary.

- Commercially important species in this study were found in multiple forest types potentially leading to over or underestimation of exact biomass harvested by species. This is due to combining species into single forest type groups and assuming all species are harvested for biomass within an individual group.
- The biomass estimates, both residual availability and total living biomass, represented annual averages over a 100-year planning horizon. Actual annual biomass estimates will vary considerably based upon the age class distribution by forest type and management intensity. Major disturbances such as insect outbreaks, wildfire, or wind events could

substantially alter estimates. In addition, increased levels of harvest within certain forest groups, such as the elm-ash-cottonwood group, in response to emerging insect and disease concerns will also affect short- and long-term availability.

- Although the baseline harvest target was based on the most recent 10-year average, actual annual harvest levels varied considerably (2,830,000 cords to 3,820,000) with changes in supply and demand and would likely continue to vary, potentially outside the range of values used in this analysis.
- Sampled woodland parcels are representative of owners in the state but that removal of biomass from those lands depends on several factors beyond the scope of this study, including demand for biomass products, the price that businesses are willing to pay for biomass derived from a variety of locations and situations, and the effect of state and federal policies and programs to incent landowner behaviors.
- Additional research is needed to generate supply curves from public and private timberlands in addition to the woodland estimates provided in this study to identify the price points at which residual biomass is economically available.
- This research provides an important step in understanding factors influencing supply and in particular the amount of biomass available from woodlands at different price points. However, the price elasticity of demand for biomass from industrial lands is unknown and is an important factor to understand the impact of increased competition on the stumpage price paid for biomass. Additional research beyond the scope of this study would improve estimates on the amount of residual biomass and bolewood that is economically available within a certain area and the distance industries are able to travel to procure feedstocks.

7.0 Conclusion

The outcome of this research is a statewide assessment of forest biomass availability from public and private forest lands. Supply estimates include physical, environmental, economic, and social availability and projected availability given different management activities at various harvest levels. The results provide a transparent analysis of biomass availability that illuminates policy dialogue and planning regarding the incremental increases in demand for forest biomass and the level of production that is ecologically sustainable within an area. Informed planning based upon accurate estimates of availability can promote sustainable economic development and industry retention. This analysis may also be used to augment due diligence for proposed bioenergy applications. Because actual availability depends on a number of site-specific factors, the information contained in this report should not replace sound financial planning and a detailed assessment of the cost of biomass feedstocks by landowner. Finally, this analysis provides a snapshot of the resource and market conditions. Periodic analysis of biomass availability, including expanded analysis of economic availability, will be necessary.

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Appendix A. Aggregate Biomass Availability in Northeast Minnesota

Table A.1. Estimated timberland area (acres) by FIA forest type group for northeast Minnesota (nonstocked areas not included).

Age Class	White-red-jack pine	Spruce-fir[1]	Oak-pine	Oak-hickory	Elm-ash-cottonwood	Maple-beech-birch[2]	Aspen-birch
0-10	17,872	66,998	7,311	9,306	22,569	50,172	414,680
11-20	25,221	106,390	6,506	0	18,870	19,376	333,759
21-30	59,083	97,742	8,201	4,875	22,239	25,329	256,902
31-40	58,791	129,185	2,932	0	23,088	10,988	228,290
41-50	29,950	237,533	1,457	4,146	33,179	31,326	294,994
51-60	19,738	263,409	0	11,001	64,945	40,157	360,406
61-70	32,544	268,220	6,211	6,183	68,472	79,786	410,449
71-80	37,683	249,557	2,902	2,922	61,810	59,261	245,322
81-90	36,242	172,280	8,563	2,430	37,906	39,727	77,503
91-100	9,402	143,895	2,902	0	23,728	7,713	35,771
100+	29,562	456,917	3,484	2,613	54,670	17,392	28,616

[1] Other exotic softwoods and Exotic softwoods were combined with the Spruce-fir forest type.
[2] Other hardwoods and Exotic hardwoods were combined with the Maple-beech-birch forest type.

Table A.2. Estimated living biomass (ODT) on timberland by stand attribute and ownership in northeast Minnesota (based on 3.47 million cord annual harvest).

Biomass	---------- Government ----------			Private		
attribute	Federal	State	Local	industrial	Woodlands	Total
Bolewood	13,159,703	13,363,657	13,544,366	5,437,748	13,072,384	58,577,858
Tops and limbs	3,552,292	3,449,346	3,734,418	1,535,243	3,759,862	16,031,162
Stumps	848,932	877,114	872,408	346,423	843,090	3,787,968
Saplings	6,724,057	7,308,290	7,083,707	2,647,824	7,275,786	31,039,664
Belowground	5,414,801	5,554,673	5,593,154	2,193,397	5,537,989	24,294,015

Table A.3. Northeast Minnesota annual ODT of residual biomass by ownership and forest management scenario (3.47 million cord harvest).[1]

Scenario	Description	---------- Government ---------- Federal	State	Local	Private industrial[2]	Woodlands	Total
0% Residual retention	Total physical availability	103,004	80,159	101,862	27,253	128,001	440,280
	+ 10% Bolewood	141,205	110,996	138,521	37,044	172,860	600,626
	+ 20% Bolewood	179,407	141,833	175,180	46,835	217,718	760,973
	Early stand treatments	130,983	97,283	128,640	34,760	164,460	556,126
	Shortened rotation (-10 yrs)	100,874	79,364	99,733	26,314	126,731	433,015
	Extended rotation (+10 yrs)	104,903	80,528	103,985	28,229	128,135	445,778
15% Residual retention	Operational maximum removal rate	87,553	68,135	86,583	23,165	108,801	374,238
	+ 10% Bolewood	125,755	98,972	123,242	32,956	153,660	534,585
	+ 20% Bolewood	163,956	129,809	159,901	42,747	198,518	694,931
	Early stand treatments	111,335	82,690	109,344	29,546	139,791	472,707
	Shortened rotation (-10 yrs)	85,743	67,459	84,773	22,367	107,721	368,063
	Extended rotation (+10 yrs)	89,167	68,448	88,387	23,995	108,914	378,912
33% Residual retention	MFRC biomass guidelines	69,013	53,706	68,248	18,260	85,761	294,987
	+ 10% Bolewood	107,214	84,543	104,907	28,051	130,619	455,334
	+ 20% Bolewood	145,415	115,380	141,566	37,842	175,478	615,681
	Early stand treatments	87,758	65,179	86,189	23,289	110,188	372,604
	Shortened rotation (-10 yrs)	67,585	53,174	66,821	17,630	84,910	290,120
	Extended rotation (+10 yrs)	70,285	53,953	69,670	18,913	85,850	298,672
50% Residual retention	Assumed current removal rate	51,502	40,079	50,931	13,627	64,001	220,140
	+ 10% Bolewood	89,703	70,916	87,590	23,418	108,859	380,487
	+ 20% Bolewood	127,905	101,753	124,249	33,209	153,718	540,833
	Early stand treatments	65,491	48,641	64,320	17,380	82,230	278,063
	Shortened rotation (-10 yrs)	50,437	39,682	49,867	13,157	63,365	216,508
	Extended rotation (+10 yrs)	52,451	40,264	51,992	14,114	64,067	222,889
75% Residual retention	Low utilization rate	25,751	20,040	25,466	6,813	32,000	110,070
	+ 10% Bolewood	63,952	50,877	62,125	16,604	76,859	270,417
	+ 20% Bolewood	102,154	81,714	98,783	26,395	121,717	430,763
	Early stand treatments	32,746	24,321	32,160	8,690	41,115	139,031
	Shortened rotation (-10 yrs)	25,218	19,841	24,933	6,578	31,683	108,254
	Extended rotation (+10 yrs)	26,226	20,132	25,996	7,057	32,034	111,445

[1] Residual biomass includes tops, limbs, branches and needles as defined by from the USDA Forest Service FIA biomass attributes.
[2] Includes corporate, nongovernmental conservation/natural resources organizations, unincorporated local partnerships/associations/clubs, and Native American timberlands.

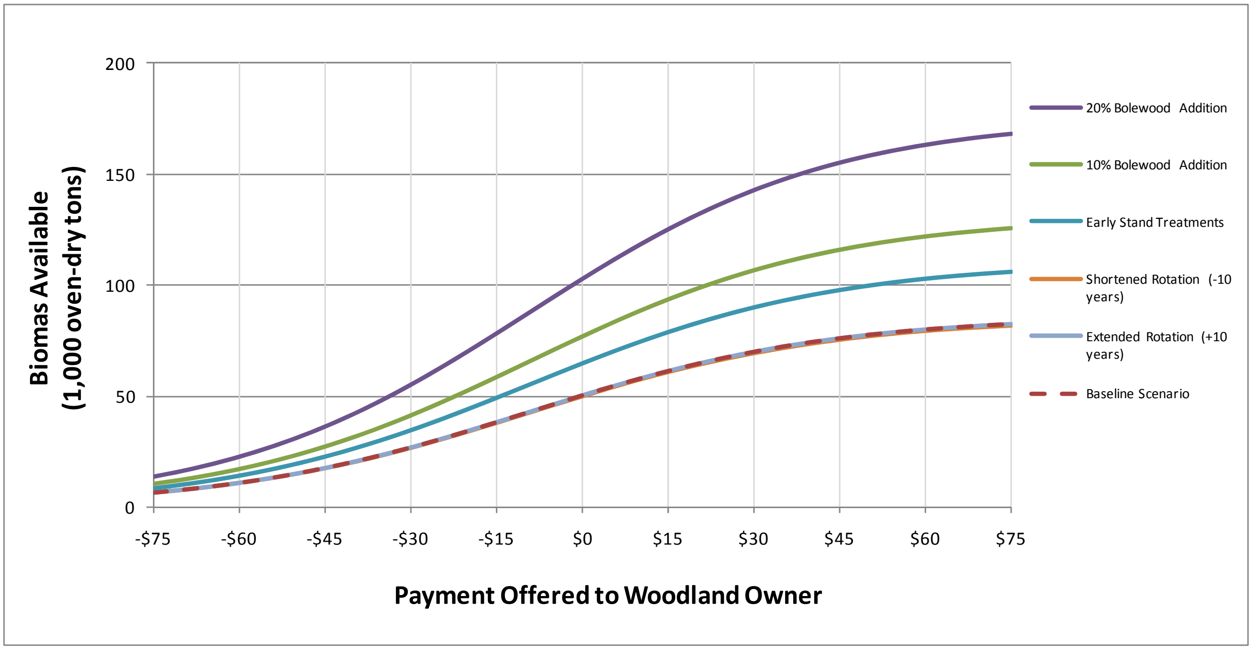


Figure A.1. Estimated northeast Minnesota residual biomass supply from woodlands owners (3.47 million cord harvest; 33% on-site residual retention).

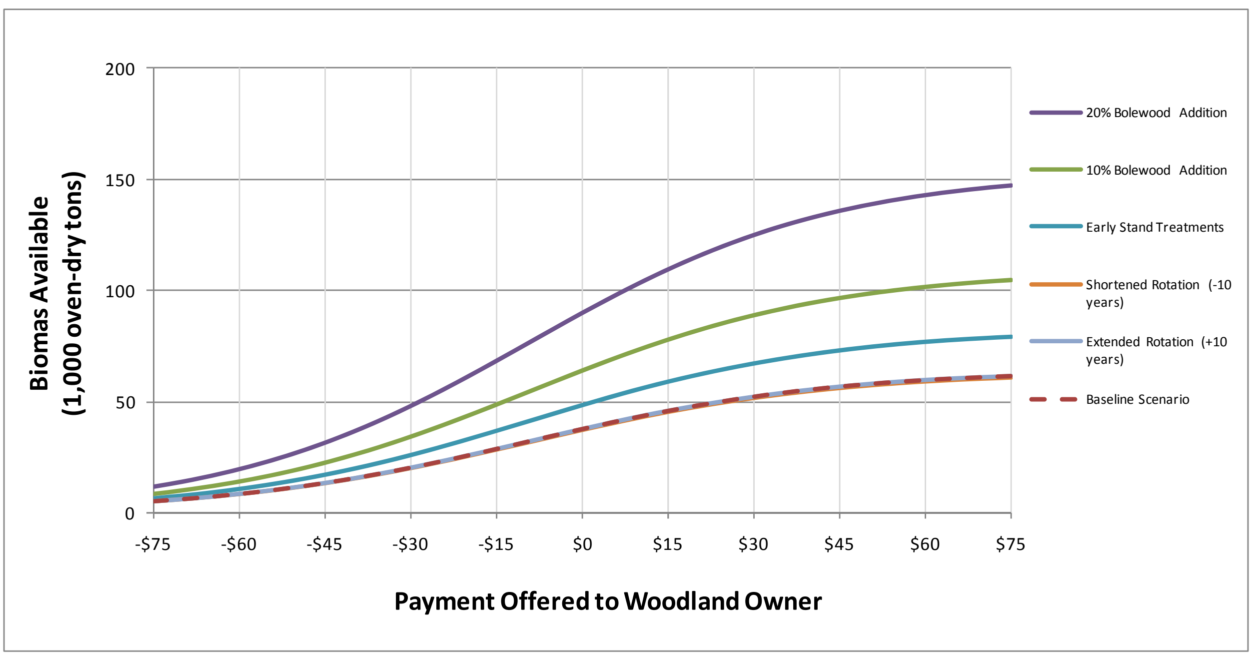


Figure A.2. Estimated northeast Minnesota residual biomass supply from woodlands owners (3.47 million cord harvest; 50% on-site residual retention).

Table A.4. Northeast Minnesota annual ODT of residual biomass by ownership and forest management scenario (4.90 million cord harvest).[1]

Scenario	Description	---------- Government ----------			Private		
		Federal	State	Local	industrial[2]	Woodlands	Total
0% Residual retention	Total physical availability	120,949	96,137	125,696	35,752	153,546	532,079
	+ 10% Bolewood	165,555	132,439	170,634	48,451	207,189	724,267
	+ 20% Bolewood	210,161	168,741	215,572	61,149	260,832	916,455
	Early stand treatments	150,207	114,010	153,841	43,623	191,692	653,373
	Shortened rotation (-10 yrs)	118,254	94,443	123,841	34,586	156,509	527,634
	Extended rotation (+10 yrs)	123,088	96,654	127,548	36,857	152,426	536,572
15% Residual retention	Operational maximum removal rate	102,806	81,716	106,841	30,389	130,514	452,267
	+ 10% Bolewood	147,413	118,018	151,780	43,088	184,157	644,455
	+ 20% Bolewood	192,019	154,320	196,718	55,786	237,800	836,643
	Early stand treatments	127,676	96,908	130,764	37,080	162,938	555,367
	Shortened rotation (-10 yrs)	100,516	80,277	105,265	29,399	133,033	448,489
	Extended rotation (+10 yrs)	104,625	82,156	108,416	31,328	129,562	456,086
33% Residual retention	MFRC biomass guidelines	81,036	64,412	84,216	23,954	102,876	356,493
	+ 10% Bolewood	125,642	100,714	129,154	36,653	156,519	548,681
	+ 20% Bolewood	170,248	137,016	174,093	49,351	210,162	740,869
	Early stand treatments	100,639	76,386	103,073	29,228	128,434	437,760
	Shortened rotation (-10 yrs)	79,230	63,277	82,974	23,173	104,861	353,515
	Extended rotation (+10 yrs)	82,469	64,758	85,457	24,694	102,125	359,503
50% Residual retention	Assumed current removal rate	60,474	48,068	62,848	17,876	76,773	266,040
	+ 10% Bolewood	105,081	84,371	107,786	30,575	130,416	458,228
	+ 20% Bolewood	149,687	120,673	152,724	43,273	184,059	650,416
	Early stand treatments	75,104	57,005	76,920	21,812	95,846	326,687
	Shortened rotation (-10 yrs)	59,127	47,222	61,921	17,293	78,254	263,817
	Extended rotation (+10 yrs)	61,544	48,327	63,774	18,428	76,213	268,286
75% Residual retention	Low utilization rate	30,237	24,034	31,424	8,938	38,386	133,020
	+ 10% Bolewood	74,843	60,336	76,362	21,637	92,029	325,208
	+ 20% Bolewood	119,450	96,638	121,300	34,335	145,672	517,396
	Early stand treatments	37,552	28,502	38,460	10,906	47,923	163,343
	Shortened rotation (-10 yrs)	29,564	23,611	30,960	8,647	39,127	131,908
	Extended rotation (+10 yrs)	30,772	24,164	31,887	9,214	38,106	134,143

[1] Residual biomass includes tops, limbs, branches and needles as defined by from the USDA Forest Service FIA biomass attributes.

[2] Includes corporate, nongovernmental conservation/natural resources organizations, unincorporated local partnerships/associations/clubs, and Native American timberlands.

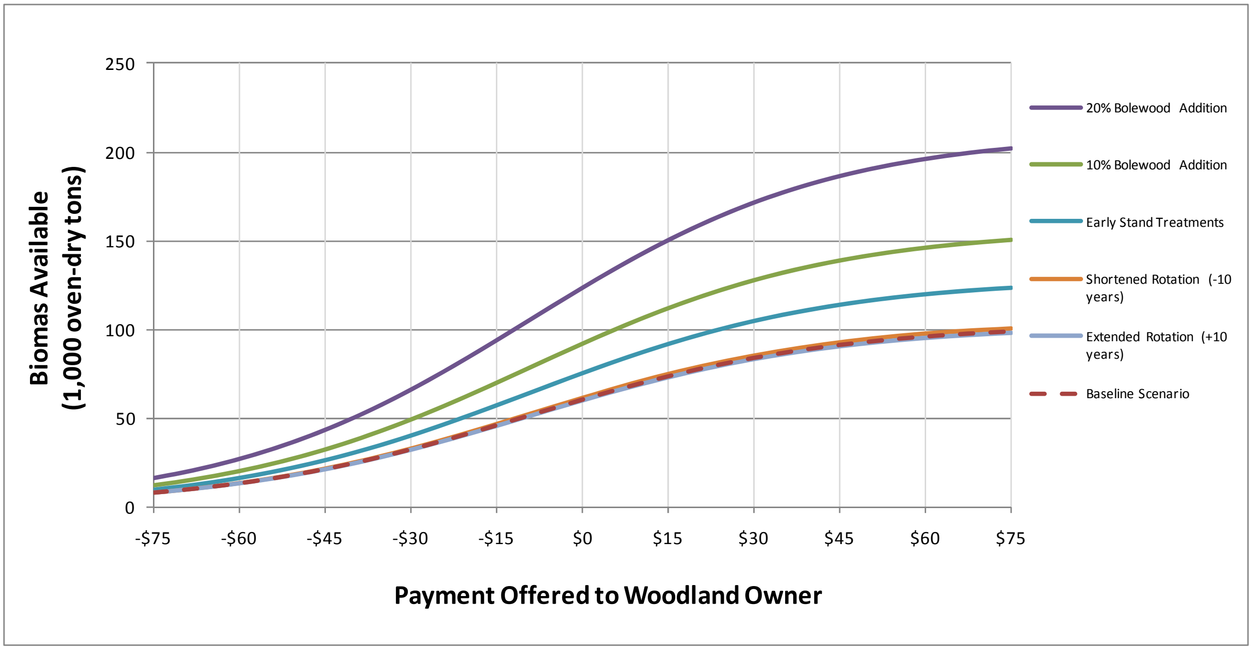


Figure A.3. Estimated northeast Minnesota residual biomass supply from woodlands owners (4.90 million cord harvest; 33% on-site residual retention).

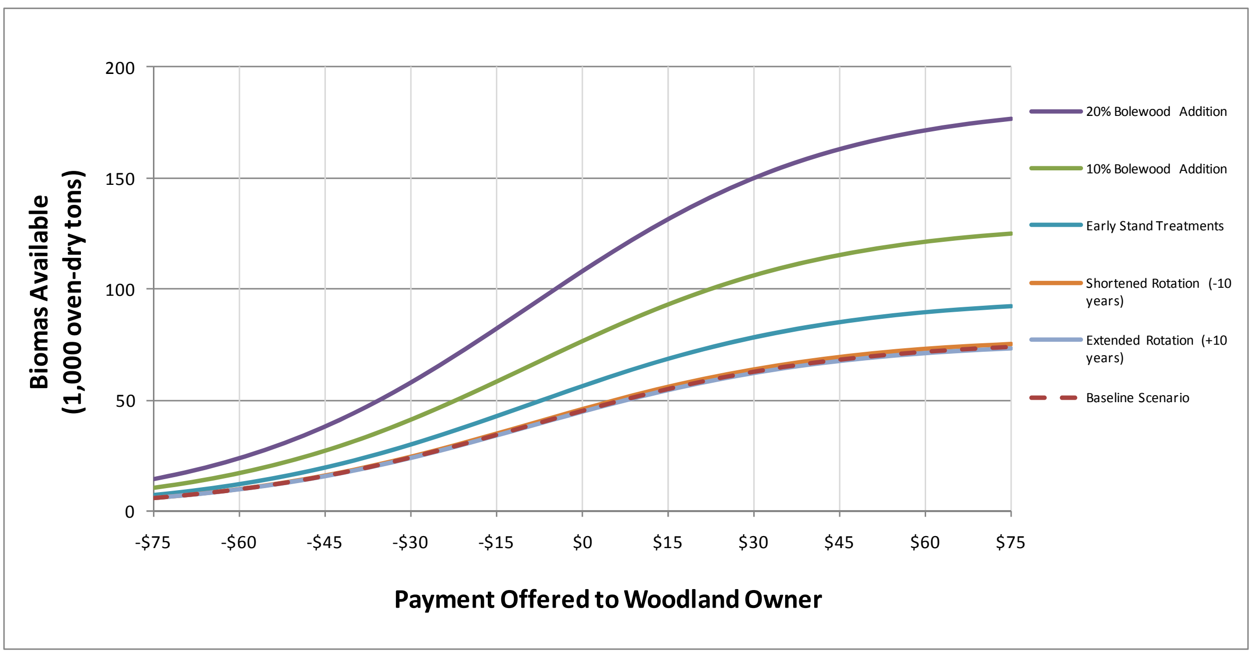


Figure A.4. Estimated northeast Minnesota residual biomass supply from woodlands owners (4.90 million cord harvest; 50% on-site residual retention).

Table A.5. Northeast Minnesota annual ODT of residual biomass by ownership and forest management scenario (5.50 million cord harvest).[1]

		---------- Government ----------			Private		
Scenario	Description	Federal	State	Local	industrial[2]	Woodlands	Total
0% Residual retention	Total physical availability	134,528	107,103	139,558	40,956	161,942	584,088
	+ 10% Bolewood	184,168	147,598	189,949	55,364	218,526	795,606
	+ 20% Bolewood	233,808	188,093	240,340	69,772	275,110	1,007,124
	Early stand treatments	165,972	126,128	168,657	49,880	200,371	711,009
	Shortened rotation (-10 yrs)	133,417	105,791	138,167	39,829	164,916	582,121
	Extended rotation (+10 yrs)	136,061	107,859	141,494	42,019	160,827	588,261
15% Residual retention	Operational maximum removal rate	114,349	91,038	118,624	34,813	137,651	496,475
	+ 10% Bolewood	163,989	131,533	169,015	49,221	194,235	707,993
	+ 20% Bolewood	213,629	172,027	219,406	63,629	250,819	919,510
	Early stand treatments	141,076	107,209	143,358	42,398	170,316	604,358
	Shortened rotation (-10 yrs)	113,405	89,922	117,442	33,855	140,179	494,803
	Extended rotation (+10 yrs)	115,652	91,680	120,270	35,716	136,703	500,021
33% Residual retention	MFRC biomass guidelines	90,134	71,759	93,504	27,441	108,501	391,339
	+ 10% Bolewood	139,774	112,254	143,895	41,849	165,085	602,857
	+ 20% Bolewood	189,414	152,749	194,286	56,256	221,669	814,375
	Early stand treatments	111,201	84,506	113,000	33,420	134,249	476,376
	Shortened rotation (-10 yrs)	89,390	70,880	92,572	26,686	110,494	390,021
	Extended rotation (+10 yrs)	91,161	72,265	94,801	28,153	107,754	394,135
50% Residual retention	Assumed current removal rate	67,264	53,552	69,779	20,478	80,971	292,044
	+ 10% Bolewood	116,904	94,046	120,170	34,886	137,555	503,562
	+ 20% Bolewood	166,544	134,541	170,561	49,294	194,139	715,080
	Early stand treatments	82,986	63,064	84,328	24,940	100,186	355,504
	Shortened rotation (-10 yrs)	66,709	52,895	69,084	19,915	82,458	291,061
	Extended rotation (+10 yrs)	68,030	53,929	70,747	21,010	80,414	294,130
75% Residual retention	Low utilization rate	33,632	26,776	34,889	10,239	40,486	146,022
	+ 10% Bolewood	83,272	67,271	85,280	24,647	97,070	357,540
	+ 20% Bolewood	132,912	107,766	135,671	39,055	153,654	569,058
	Early stand treatments	41,493	31,532	42,164	12,470	50,093	177,752
	Shortened rotation (-10 yrs)	33,354	26,448	34,542	9,957	41,229	145,530
	Extended rotation (+10 yrs)	34,015	26,965	35,374	10,505	40,207	147,065

[1] Residual biomass includes tops, limbs, branches and needles as defined by from the USDA Forest Service FIA biomass attributes.
[2] Includes corporate, nongovernmental conservation/natural resources organizations, unincorporated local partnerships/associations/clubs, and Native American timberlands.

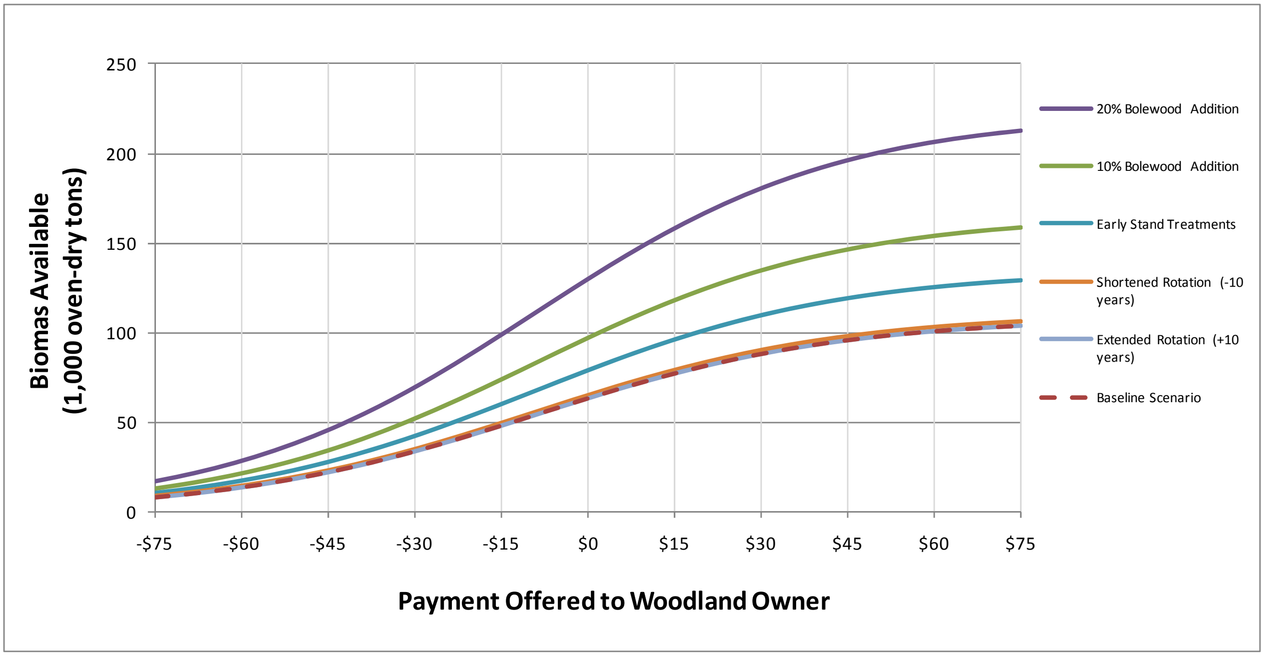


Figure A.5. Estimated northeast Minnesota residual biomass supply from woodlands owners (5.50 million cord harvest; 33% on-site residual retention).

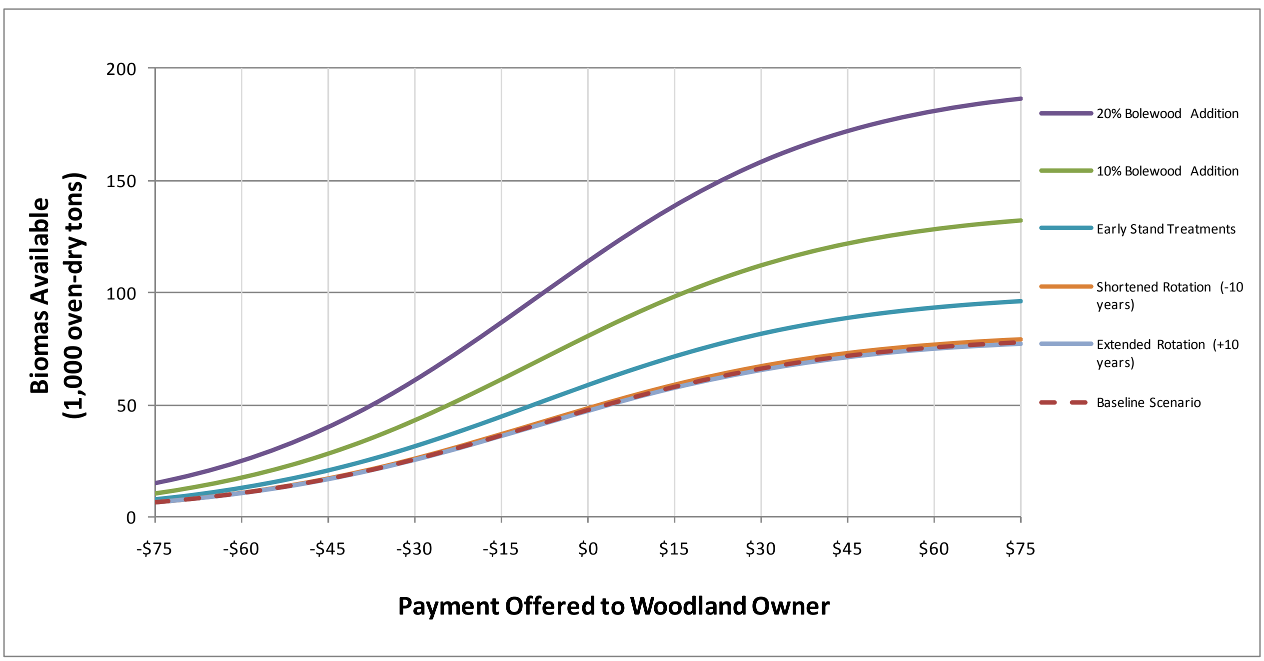


Figure A.6. Estimated northeast Minnesota residual biomass supply from woodlands owners (5.50 million cord harvest; 50% on-site residual retention).

Appendix B. Aggregate Biomass Availability in Northwest Minnesota

Table B.1. Estimated timberland area (acres) by FIA forest type group for northwest Minnesota (nonstocked areas not included).

Age Class	White-red-jack pine	Spruce-fir[1]	Oak-pine	Oak-hickory	Elm-ash-cottonwood	Maple-beech-birch[2]	Aspen-birch
0-10	33,122	21,217	11,775	68,152	18,988	42,843	381,481
11-20	39,268	34,327	12,435	28,162	5,678	22,001	408,730
21-30	71,134	73,684	12,838	20,566	10,000	4,884	346,546
31-40	53,017	86,977	15,039	21,039	19,257	7,039	271,881
41-50	65,924	145,788	14,047	79,506	17,127	31,759	294,844
51-60	60,047	143,799	41,529	95,532	75,424	46,103	313,021
61-70	34,499	180,105	24,737	123,492	78,111	92,868	296,944
71-80	26,475	112,598	13,992	131,636	70,532	93,757	173,114
81-90	17,201	110,837	6,634	83,378	64,775	91,239	71,952
91-100	9,348	82,186	0	41,960	36,343	27,950	24,524
100+	4,276	183,306	13,578	15,714	68,060	25,158	19,665

[1] Other exotic softwoods and Exotic softwoods were combined with the Spruce-fir forest type.
[2] Other hardwoods and Exotic hardwoods were combined with the Maple-beech-birch forest type.

Table B.2. Estimated living biomass (ODT) on timberland by stand attribute and ownership in northwest Minnesota (based on 3.47 million cord annual harvest).

Biomass attribute	---------- Government ---------- Federal	State	Local	Private industrial	Woodlands	Total
Bolewood	7,167,197	14,051,226	14,917,175	9,466,304	23,960,238	69,562,139
Tops and limbs	1,958,459	3,808,474	4,198,261	2,643,775	6,701,711	19,310,681
Stumps	452,068	903,954	937,488	590,077	1,485,700	4,369,287
Saplings	3,048,574	7,179,668	6,536,032	3,682,198	8,830,919	29,277,390
Belowground	2,768,797	5,735,288	5,798,556	3,542,509	8,795,586	26,640,736

Table B.3. Northwest Minnesota annual ODT of residual biomass by ownership and forest management scenario (3.47 million cord harvest).[1]

Scenario	Description	---------- Government ---------- Federal	State	Local	Private industrial[2]	Woodlands	Total
0% Residual retention	Total physical availability	46,711	97,748	101,959	38,813	140,348	425,579
	+ 10% Bolewood	63,919	133,799	138,039	52,924	190,283	578,965
	+ 20% Bolewood	81,127	169,851	174,119	67,036	240,219	732,352
	Early stand treatments	59,365	122,358	130,043	48,744	178,170	538,680
	Shortened rotation (-10 yrs)	45,874	95,977	99,741	37,458	139,326	418,376
	Extended rotation (+10 yrs)	47,607	98,880	103,843	39,866	140,776	430,972
15% Residual retention	Operational maximum removal rate	39,705	83,086	86,665	32,991	119,296	361,742
	+ 10% Bolewood	56,913	119,137	122,745	47,102	169,231	515,128
	+ 20% Bolewood	74,121	155,188	158,825	61,214	219,167	668,515
	Early stand treatments	50,460	104,004	110,536	41,433	151,445	457,878
	Shortened rotation (-10 yrs)	38,993	81,581	84,780	31,839	118,427	355,619
	Extended rotation (+10 yrs)	40,466	84,048	88,266	33,886	119,660	366,327
33% Residual retention	MFRC biomass guidelines	31,297	65,491	68,312	26,005	94,033	285,138
	+ 10% Bolewood	48,505	101,542	104,393	40,116	143,969	438,524
	+ 20% Bolewood	65,713	137,594	140,473	54,227	193,904	591,911
	Early stand treatments	39,775	81,980	87,129	32,659	119,374	360,916
	Shortened rotation (-10 yrs)	30,736	64,305	66,827	25,097	93,348	280,312
	Extended rotation (+10 yrs)	31,897	66,250	69,575	26,710	94,320	288,752
50% Residual retention	Assumed current removal rate	23,356	48,874	50,979	19,407	70,174	212,789
	+ 10% Bolewood	40,564	84,925	87,060	33,518	120,110	366,176
	+ 20% Bolewood	57,772	120,977	123,140	47,629	170,045	519,562
	Early stand treatments	29,682	61,179	65,021	24,372	89,085	269,340
	Shortened rotation (-10 yrs)	22,937	47,989	49,871	18,729	69,663	209,188
	Extended rotation (+10 yrs)	23,803	49,440	51,921	19,933	70,388	215,486
75% Residual retention	Low utilization rate	11,678	24,437	25,490	9,703	35,087	106,395
	+ 10% Bolewood	28,886	60,488	61,570	23,815	85,023	259,781
	+ 20% Bolewood	46,094	96,540	97,650	37,926	134,958	413,168
	Early stand treatments	14,841	30,590	32,511	12,186	44,543	134,670
	Shortened rotation (-10 yrs)	11,469	23,994	24,935	9,364	34,831	104,594
	Extended rotation (+10 yrs)	11,902	24,720	25,961	9,967	35,194	107,743

[1] Residual biomass includes tops, limbs, branches and needles as defined by from the USDA Forest Service FIA biomass attributes.

[2] Includes corporate, nongovernmental conservation/natural resources organizations, unincorporated local partnerships/associations/clubs, and Native American timberlands.

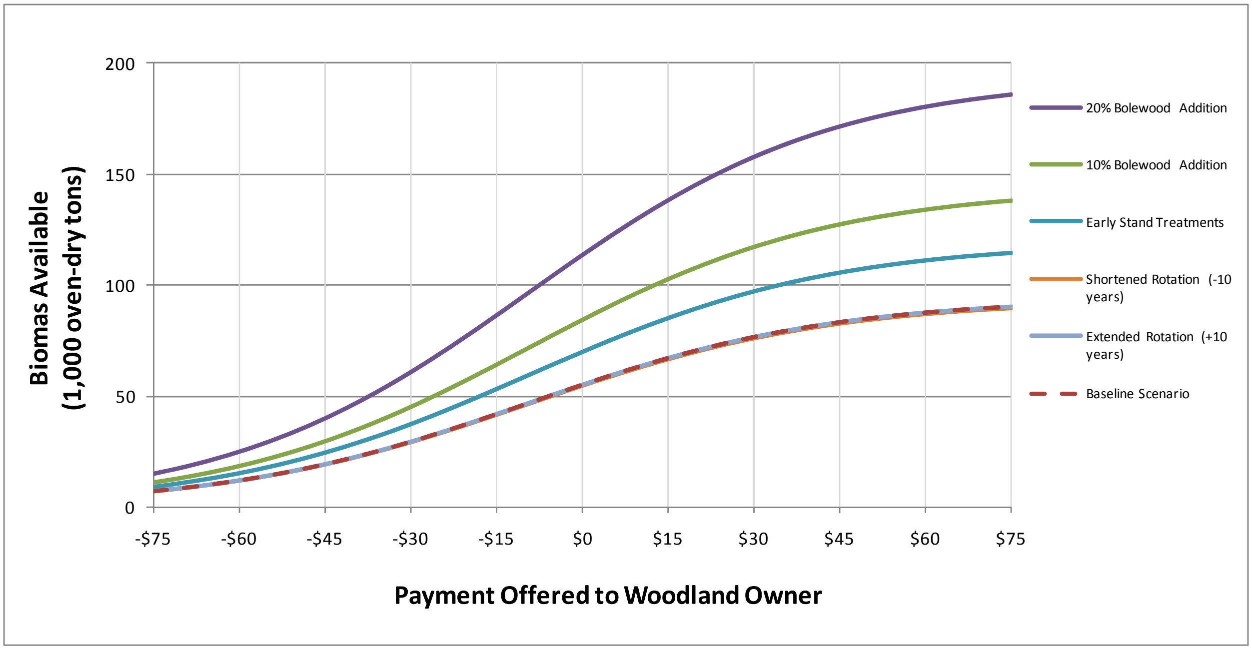


Figure B.1. Estimated northwest Minnesota residual biomass supply from woodlands owners (3.47 million cord harvest; 33% on-site residual retention).

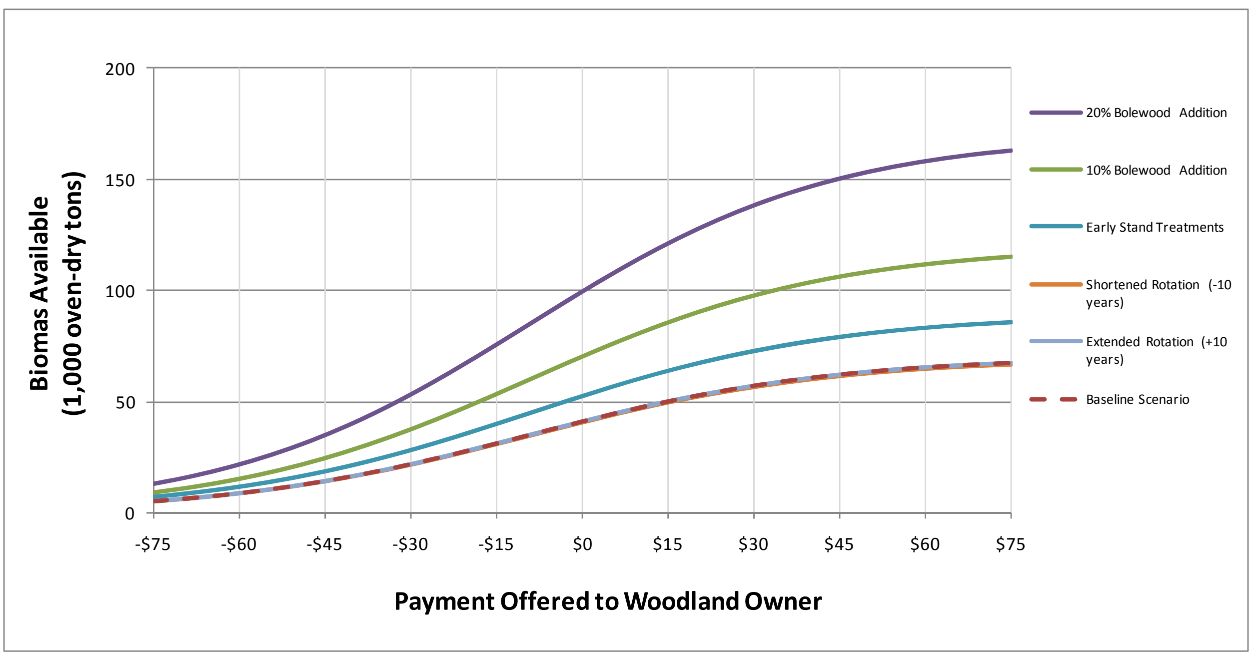


Figure B.2. Estimated northwest Minnesota residual biomass supply from woodlands owners (3.47 million cord harvest; 50% on-site residual retention).

Table B.4. Northwest Minnesota annual ODT of residual biomass by ownership and forest management scenario (4.90 million cord harvest).[1]

Scenario	Description	---------- Government ---------- Federal	State	Local	Private industrial[2]	Woodlands	Total
0% Residual retention	Total physical availability	60,157	121,783	135,581	62,865	209,467	589,853
	+ 10% Bolewood	82,242	166,212	183,582	85,514	284,120	801,669
	+ 20% Bolewood	104,327	210,640	231,584	108,162	358,773	1,013,485
	Early stand treatments	73,252	147,465	164,581	73,253	248,790	707,341
	Shortened rotation (-10 yrs)	58,984	119,606	133,323	60,939	208,142	580,994
	Extended rotation (+10 yrs)	61,331	123,083	138,052	64,512	211,444	598,423
15% Residual retention	Operational maximum removal rate	51,134	103,516	115,243	53,435	178,047	501,375
	+ 10% Bolewood	73,218	147,944	163,245	76,084	252,700	713,191
	+ 20% Bolewood	95,303	192,372	211,246	98,732	327,353	925,007
	Early stand treatments	62,264	125,346	139,894	62,265	211,472	601,240
	Shortened rotation (-10 yrs)	50,136	101,665	113,324	51,799	176,921	493,845
	Extended rotation (+10 yrs)	52,132	104,620	117,344	54,835	179,728	508,659
33% Residual retention	MFRC biomass guidelines	40,305	81,595	90,839	42,120	140,343	395,202
	+ 10% Bolewood	62,390	126,023	138,840	64,768	214,996	607,018
	+ 20% Bolewood	84,475	170,451	186,842	87,417	289,649	818,834
	Early stand treatments	49,079	98,802	110,269	49,079	166,689	473,919
	Shortened rotation (-10 yrs)	39,519	80,136	89,326	40,829	139,455	389,266
	Extended rotation (+10 yrs)	41,092	82,465	92,495	43,223	141,668	400,943
50% Residual retention	Assumed current removal rate	30,079	60,892	67,790	31,433	104,733	294,927
	+ 10% Bolewood	52,163	105,320	115,792	54,081	179,386	506,743
	+ 20% Bolewood	74,248	149,748	163,793	76,730	254,039	718,558
	Early stand treatments	36,626	73,733	82,290	36,626	124,395	353,671
	Shortened rotation (-10 yrs)	29,492	59,803	66,661	30,470	104,071	290,497
	Extended rotation (+10 yrs)	30,666	61,541	69,026	32,256	105,722	299,211
75% Residual retention	Low utilization rate	15,039	30,446	33,895	15,716	52,367	147,463
	+ 10% Bolewood	37,124	74,874	81,897	38,365	127,020	359,279
	+ 20% Bolewood	59,209	119,302	129,898	61,013	201,673	571,095
	Early stand treatments	18,313	36,866	41,145	18,313	62,198	176,835
	Shortened rotation (-10 yrs)	14,746	29,902	33,331	15,235	52,035	145,249
	Extended rotation (+10 yrs)	15,333	30,771	34,513	16,128	52,861	149,606

[1] Residual biomass includes tops, limbs, branches and needles as defined by from the USDA Forest Service FIA biomass attributes.

[2] Includes corporate, nongovernmental conservation/natural resources organizations, unincorporated local partnerships/associations/clubs, and Native American timberlands.

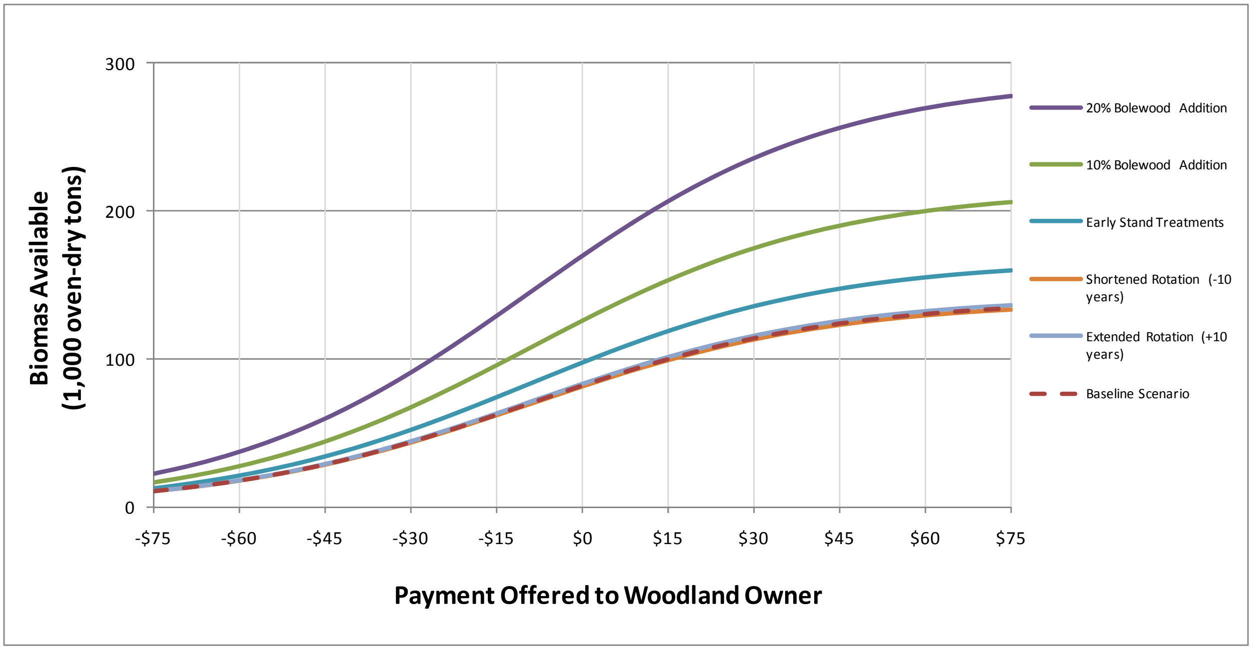


Figure B.3. Estimated northwest Minnesota residual biomass supply from woodlands owners (4.90 million cord harvest; 33% on-site residual retention).

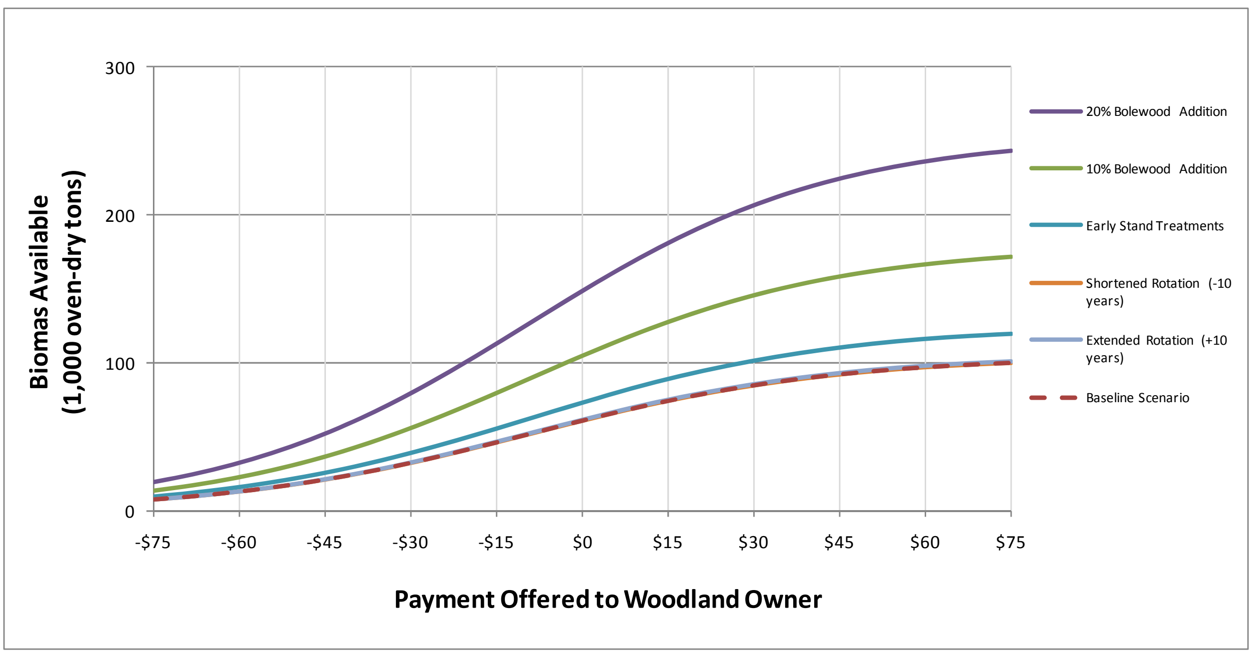


Figure B.4. Estimated northwest Minnesota residual biomass supply from woodlands owners (4.90 million cord harvest; 50% on-site residual retention).

Table B.5. Northwest Minnesota annual ODT of residual biomass by ownership and forest management scenario (5.50 million cord harvest).[1]

		---------- Government ----------			Private		
Scenario	Description	Federal	State	Local	industrial[2]	Woodlands	Total
0% Residual retention	Total physical availability	68,271	135,629	151,245	71,302	231,355	657,803
	+ 10% Bolewood	93,259	185,028	204,924	96,770	313,705	893,685
	+ 20% Bolewood	118,247	234,426	258,602	122,238	396,055	1,129,567
	Early stand treatments	82,284	163,146	181,235	83,105	271,306	781,077
	Shortened rotation (-10 yrs)	67,226	134,030	149,018	69,704	229,743	649,722
	Extended rotation (+10 yrs)	69,505	137,023	153,492	73,156	233,496	666,671
15% Residual retention	Operational maximum removal rate	58,030	115,285	128,559	60,607	196,652	559,133
	+ 10% Bolewood	83,018	164,683	182,237	86,075	279,002	795,015
	+ 20% Bolewood	108,007	214,082	235,915	111,542	361,352	1,030,897
	Early stand treatments	69,941	138,674	154,050	70,640	230,610	663,915
	Shortened rotation (-10 yrs)	57,142	113,926	126,666	59,249	195,282	552,264
	Extended rotation (+10 yrs)	59,079	116,470	130,468	62,182	198,471	566,671
33% Residual retention	MFRC biomass guidelines	45,742	90,871	101,334	47,772	155,008	440,728
	+ 10% Bolewood	70,730	140,270	155,013	73,240	237,358	676,610
	+ 20% Bolewood	95,718	189,669	208,691	98,708	319,708	912,492
	Early stand treatments	55,130	109,308	121,428	55,681	181,775	523,321
	Shortened rotation (-10 yrs)	45,041	89,800	99,842	46,702	153,928	435,314
	Extended rotation (+10 yrs)	46,569	91,805	102,839	49,014	156,442	446,670
50% Residual retention	Assumed current removal rate	34,136	67,815	75,623	35,651	115,678	328,902
	+ 10% Bolewood	59,124	117,213	129,301	61,119	198,027	564,784
	+ 20% Bolewood	84,112	166,612	182,979	86,586	280,377	800,666
	Early stand treatments	41,142	81,573	90,618	41,553	135,653	390,538
	Shortened rotation (-10 yrs)	33,613	67,015	74,509	34,852	114,872	324,861
	Extended rotation (+10 yrs)	34,753	68,512	76,746	36,578	116,748	333,336
75% Residual retention	Low utilization rate	17,068	33,907	37,811	17,826	57,839	164,451
	+ 10% Bolewood	42,056	83,306	91,489	43,293	140,189	400,333
	+ 20% Bolewood	67,044	132,704	145,168	68,761	222,538	636,215
	Early stand treatments	20,571	40,786	45,309	20,776	67,827	195,269
	Shortened rotation (-10 yrs)	16,806	33,508	37,255	17,426	57,436	162,431
	Extended rotation (+10 yrs)	17,376	34,256	38,373	18,289	58,374	166,668

[1] Residual biomass includes tops, limbs, branches and needles as defined by from the USDA Forest Service FIA biomass attributes.
[2] Includes corporate, nongovernmental conservation/natural resources organizations, unincorporated local partnerships/associations/clubs, and Native American timberlands.

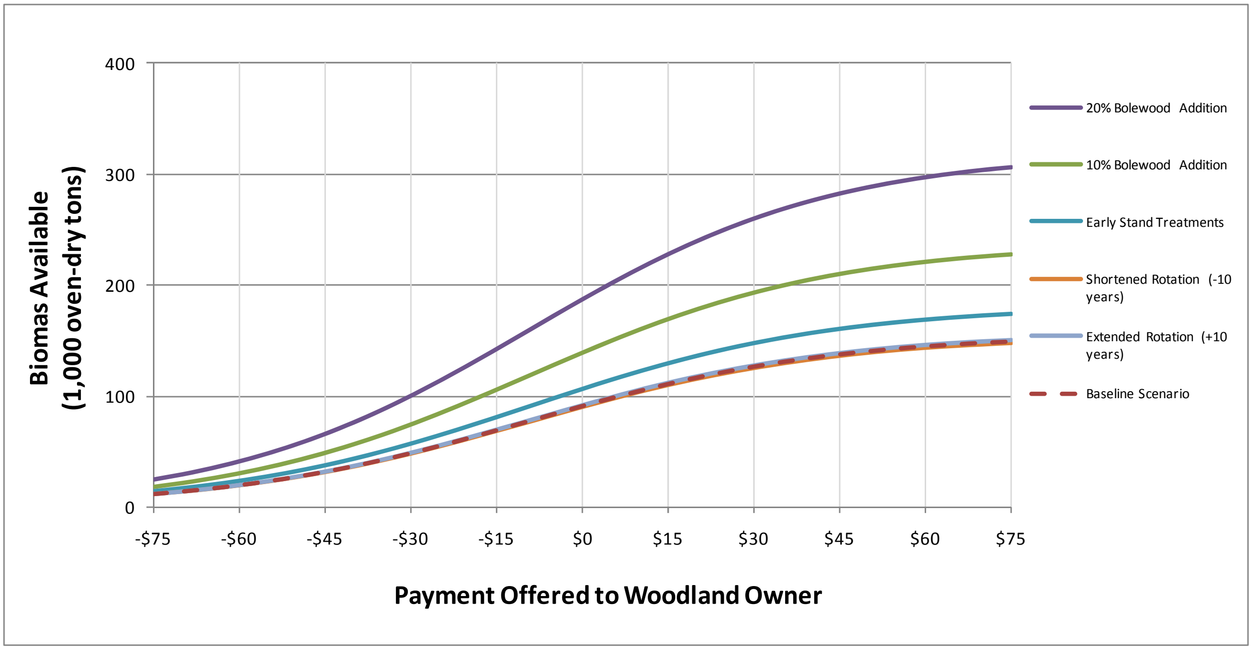


Figure B.5. Estimated northwest Minnesota residual biomass supply from woodlands owners (5.50 million cord harvest; 33% on-site residual retention).

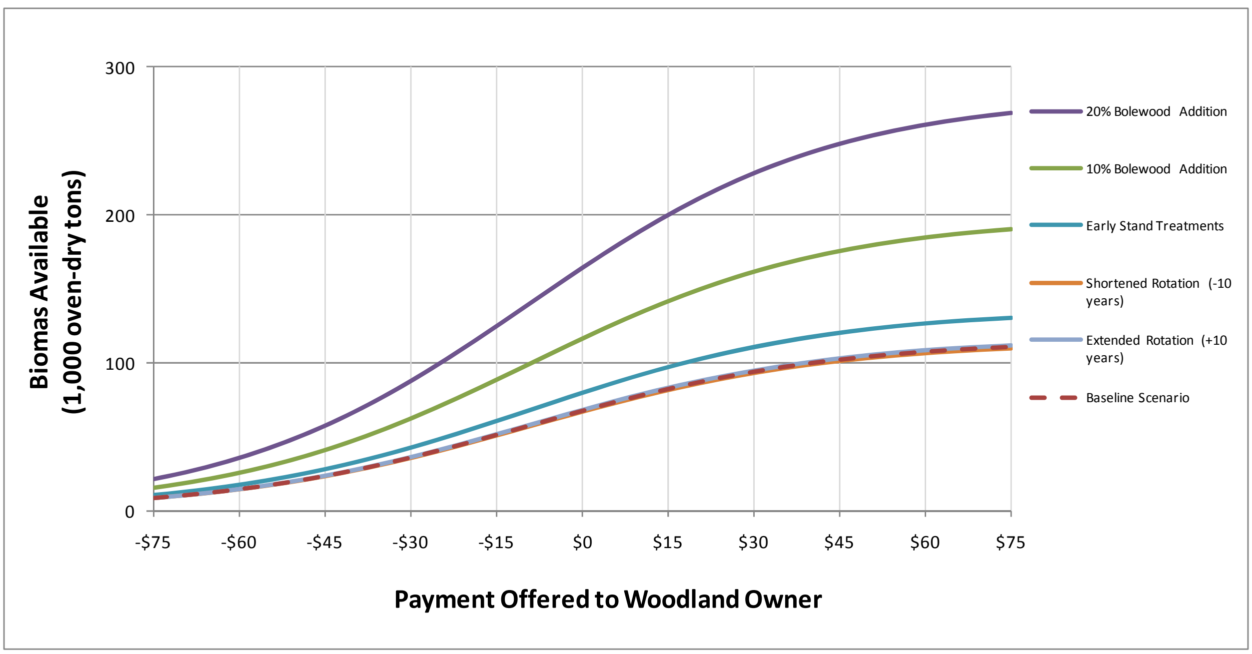


Figure B.6. Estimated northwest Minnesota residual biomass supply from woodlands owners (5.50 million cord harvest; 50% on-site residual retention).

Appendix C. Aggregate Biomass Availability in East-central Minnesota

Table C.1. Estimated timberland area (acres) by FIA forest type group for east-central Minnesota (nonstocked areas not included).

Age Class	White-red-jack pine	Spruce-fir[1]	Oak-pine	Oak-hickory	Elm-ash-cottonwood	Maple-beech-birch[2]	Aspen-birch
0-10	2,824	2,309	0	32,631	18,881	27,787	77,861
11-20	9,480	2,964	4,529	21,180	7,582	11,464	41,907
21-30	12,292	11,588	4,795	28,239	24,170	14,164	91,035
31-40	8,859	7,012	0	51,917	39,285	17,274	79,910
41-50	20,507	8,046	9,789	122,946	63,701	27,397	72,332
51-60	3,079	25,608	5,413	145,464	59,893	45,679	73,583
61-70	4,414	13,437	4,289	180,677	71,263	70,793	58,034
71-80	0	16,912	3,079	159,620	43,284	40,975	20,190
81-90	5,934	774	1,601	130,093	18,793	43,962	13,546
91-100	2,757	2,423	0	74,244	14,582	27,354	2,852
100+	0	1,048	0	109,080	10,222	23,555	731

[1] Other exotic softwoods and Exotic softwoods were combined with the Spruce-fir forest type.
[2] Other hardwoods and Exotic hardwoods were combined with the Maple-beech-birch forest type.

Table C.2. Estimated living biomass (ODT) on timberland by stand attribute and ownership in east-central Minnesota (based on 3.47 million cord annual harvest).

Biomass attribute	---------- Government ----------			Private		
	Federal	State	Local	industrial	Woodlands	Total
Bolewood	537,363	4,478,978	1,985,469	2,278,896	32,328,075	41,608,781
Tops and limbs	152,583	1,255,142	557,674	637,241	9,026,122	11,628,762
Stumps	33,828	272,778	120,776	139,174	1,965,653	2,532,209
Saplings	154,005	1,277,147	566,842	623,298	8,291,792	10,913,085
Belowground	180,193	1,520,188	674,554	765,192	10,649,781	13,789,909

Table C.3. East-central Minnesota annual ODT of residual biomass by ownership and forest management scenario (3.47 million cord harvest).[1]

		---------- Government ----------			Private		
Scenario	**Description**	**Federal**	**State**	**Local**	**industrial[2]**	**Woodlands**	**Total**
0% Residual retention	Total physical availability	1,481	16,166	7,283	6,122	91,124	122,176
	+ 10% Bolewood	2,019	21,932	9,830	8,365	123,665	165,811
	+ 20% Bolewood	2,556	27,698	12,378	10,608	156,206	209,446
	Early stand treatments	1,802	19,816	8,874	7,168	109,299	146,958
	Shortened rotation (-10 yrs)	1,452	15,985	7,145	5,941	89,830	120,353
	Extended rotation (+10 yrs)	1,500	16,387	7,388	6,269	91,973	123,516
15% Residual retention	Operational maximum removal rate	1,259	13,741	6,190	5,204	77,456	103,849
	+ 10% Bolewood	1,796	19,507	8,738	7,446	109,996	147,485
	+ 20% Bolewood	2,334	25,273	11,286	9,689	142,537	191,120
	Early stand treatments	1,532	16,844	7,543	6,092	92,904	124,914
	Shortened rotation (-10 yrs)	1,235	13,587	6,073	5,050	76,355	102,300
	Extended rotation (+10 yrs)	1,275	13,929	6,279	5,329	78,177	104,989
33% Residual retention	MFRC biomass guidelines	992	10,831	4,880	4,102	61,053	81,858
	+ 10% Bolewood	1,530	16,597	7,427	6,345	93,594	125,493
	+ 20% Bolewood	2,068	22,363	9,975	8,587	126,135	169,128
	Early stand treatments	1,207	13,277	5,945	4,802	73,230	98,462
	Shortened rotation (-10 yrs)	973	10,710	4,787	3,980	60,186	80,636
	Extended rotation (+10 yrs)	1,005	10,979	4,950	4,200	61,622	82,756
50% Residual retention	Assumed current removal rate	740	8,083	3,641	3,061	45,562	61,088
	+ 10% Bolewood	1,278	13,849	6,189	5,304	78,103	104,723
	+ 20% Bolewood	1,816	19,615	8,737	7,547	110,644	148,358
	Early stand treatments	901	9,908	4,437	3,584	54,649	73,479
	Shortened rotation (-10 yrs)	726	7,992	3,572	2,970	44,915	60,176
	Extended rotation (+10 yrs)	750	8,193	3,694	3,135	45,986	61,758
75% Residual retention	Low utilization rate	370	4,042	1,821	1,530	22,781	30,544
	+ 10% Bolewood	908	9,808	4,368	3,773	55,322	74,179
	+ 20% Bolewood	1,446	15,574	6,916	6,016	87,863	117,814
	Early stand treatments	450	4,954	2,218	1,792	27,325	36,739
	Shortened rotation (-10 yrs)	363	3,996	1,786	1,485	22,457	30,088
	Extended rotation (+10 yrs)	375	4,097	1,847	1,567	22,993	30,879

[1] Residual biomass includes tops, limbs, branches and needles as defined by from the USDA Forest Service FIA biomass attributes.
[2] Includes corporate, nongovernmental conservation/natural resources organizations, unincorporated local partnerships/associations/clubs, and Native American timberlands.

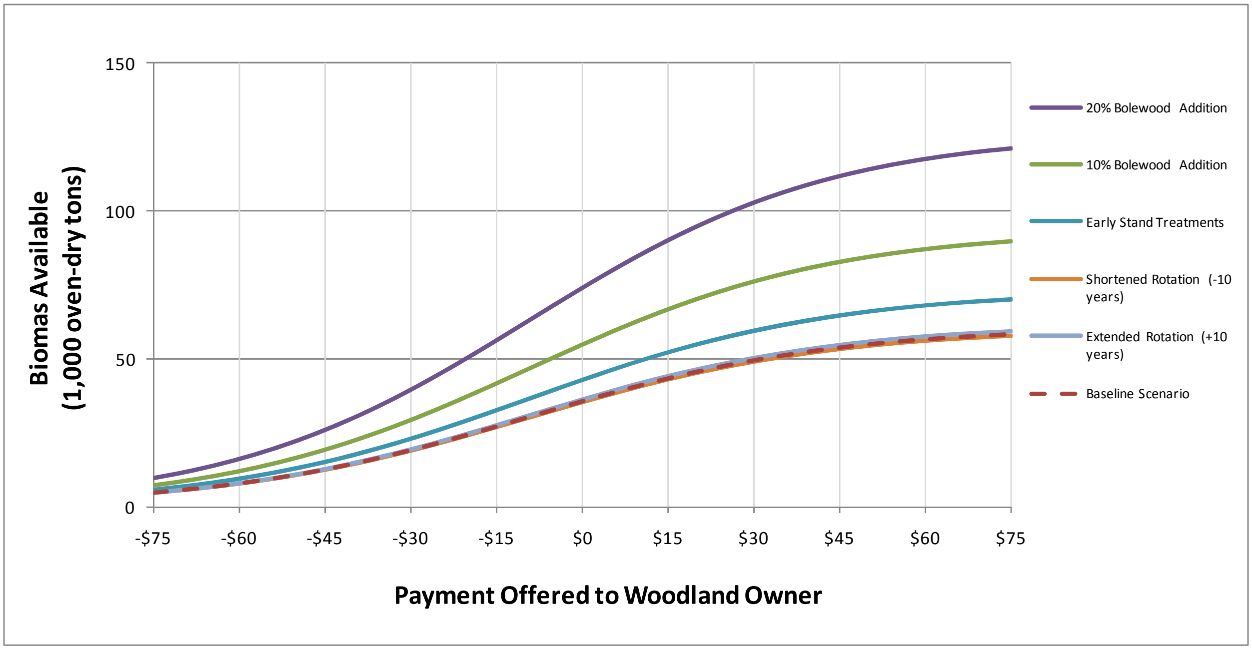


Figure C.1. Estimated east-central Minnesota residual biomass supply from woodlands owners (3.47 million cord harvest; 33% on-site residual retention).

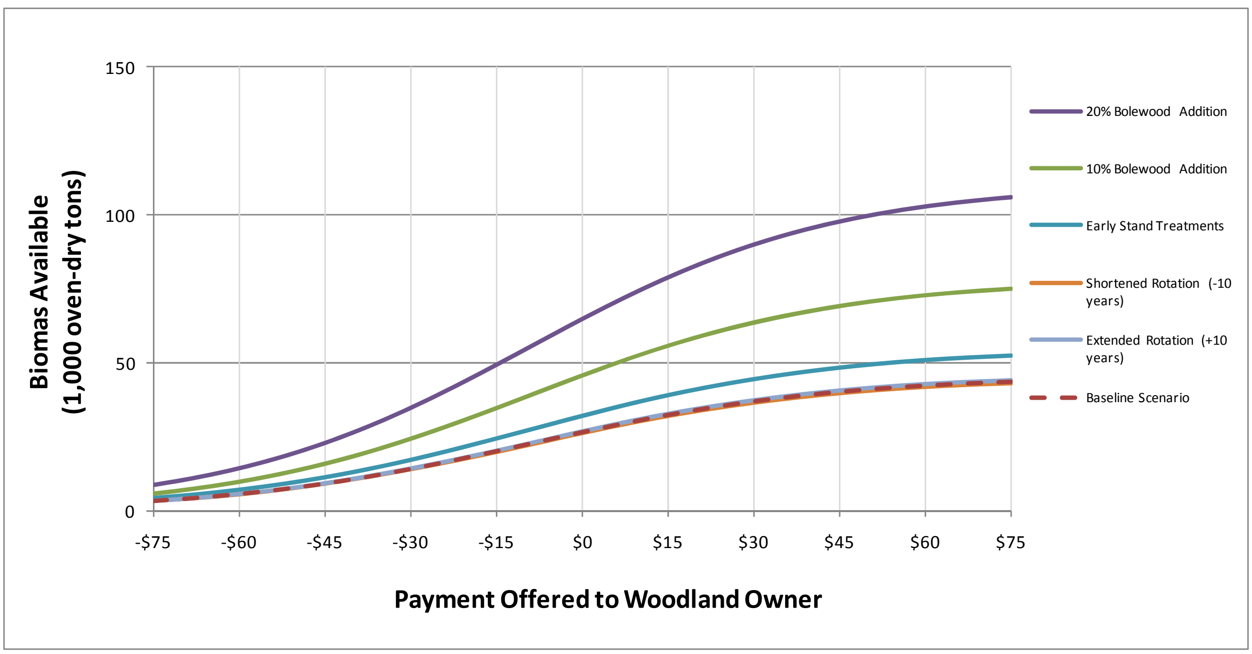


Figure C.2. Estimated east-central Minnesota residual biomass supply from woodlands owners (3.47 million cord harvest; 50% on-site residual retention).

Table C.4. East-central Minnesota annual ODT of residual biomass by ownership and forest management scenario (4.90 million cord harvest).[1]

		---------- Government ----------			Private		
Scenario	**Description**	**Federal**	**State**	**Local**	**industrial**[2]	**Woodlands**	**Total**
0% Residual retention	Total physical availability	3,352	32,874	14,804	14,899	202,002	267,931
	+ 10% Bolewood	4,552	44,573	20,032	20,259	273,850	363,266
	+ 20% Bolewood	5,752	56,272	25,260	25,619	345,698	458,601
	Early stand treatments	3,680	36,684	16,516	15,989	220,683	293,551
	Shortened rotation (-10 yrs)	3,284	32,333	14,536	14,508	198,650	263,311
	Extended rotation (+10 yrs)	3,400	33,407	15,009	15,218	205,311	272,345
15% Residual retention	Operational maximum removal rate	2,849	27,943	12,583	12,664	171,702	227,741
	+ 10% Bolewood	4,049	39,642	17,811	18,024	243,550	323,076
	+ 20% Bolewood	5,249	51,341	23,039	23,385	315,397	418,411
	Early stand treatments	3,128	31,181	14,039	13,590	187,581	249,519
	Shortened rotation (-10 yrs)	2,792	27,483	12,355	12,332	168,853	223,815
	Extended rotation (+10 yrs)	2,890	28,396	12,758	12,935	174,514	231,493
33% Residual retention	MFRC biomass guidelines	2,246	22,025	9,918	9,982	135,342	179,513
	+ 10% Bolewood	3,446	33,725	15,147	15,343	207,189	274,849
	+ 20% Bolewood	4,646	45,424	20,375	20,703	279,037	370,184
	Early stand treatments	2,465	24,578	11,066	10,712	147,858	196,679
	Shortened rotation (-10 yrs)	2,201	21,663	9,739	9,720	133,096	176,418
	Extended rotation (+10 yrs)	2,278	22,383	10,056	10,196	137,558	182,471
50% Residual retention	Assumed current removal rate	1,676	16,437	7,402	7,450	101,001	133,965
	+ 10% Bolewood	2,876	28,136	12,630	12,810	172,849	229,300
	+ 20% Bolewood	4,076	39,835	17,858	18,170	244,697	324,636
	Early stand treatments	1,840	18,342	8,258	7,994	110,342	146,776
	Shortened rotation (-10 yrs)	1,642	16,167	7,268	7,254	99,325	131,656
	Extended rotation (+10 yrs)	1,700	16,703	7,505	7,609	102,655	136,172
75% Residual retention	Low utilization rate	838	8,218	3,701	3,725	50,501	66,983
	+ 10% Bolewood	2,038	19,918	8,929	9,085	122,348	162,318
	+ 20% Bolewood	3,238	31,617	14,157	14,445	194,196	257,653
	Early stand treatments	920	9,171	4,129	3,997	55,171	73,388
	Shortened rotation (-10 yrs)	821	8,083	3,634	3,627	49,663	65,828
	Extended rotation (+10 yrs)	850	8,352	3,752	3,804	51,328	68,086

[1] Residual biomass includes tops, limbs, branches and needles as defined by from the USDA Forest Service FIA biomass attributes.
[2] Includes corporate, nongovernmental conservation/natural resources organizations, unincorporated local partnerships/associations/clubs, and Native American timberlands.

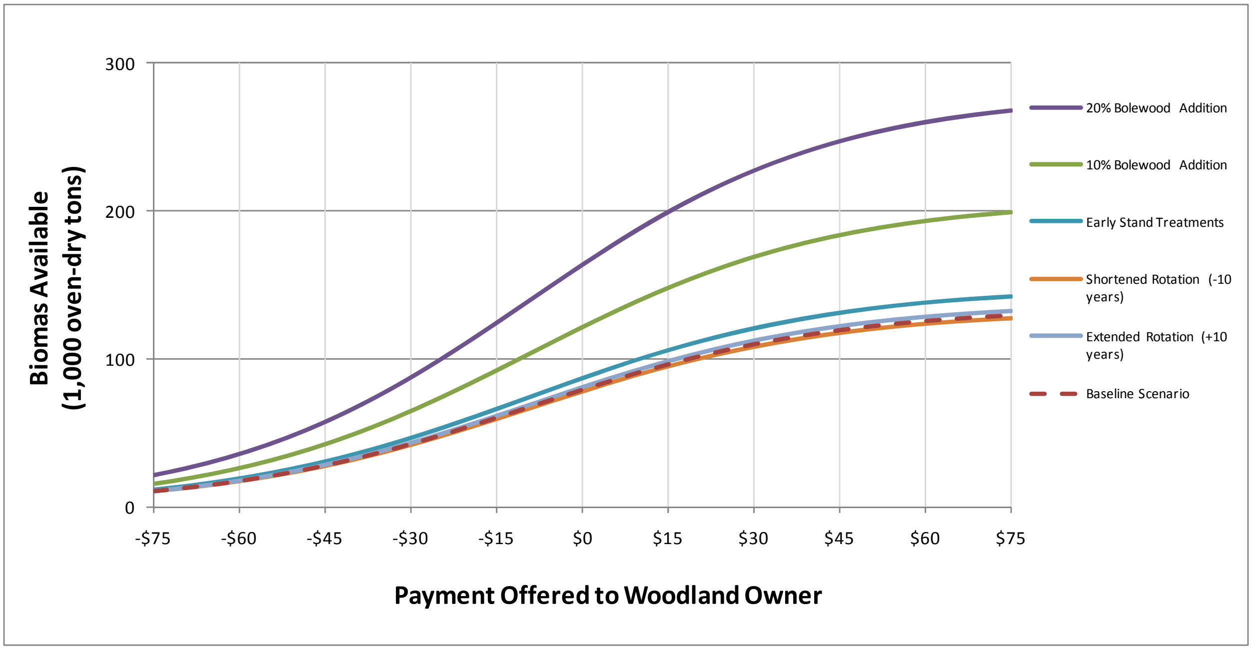


Figure C.3. Estimated east-central Minnesota residual biomass supply from woodlands owners (4.90 million cord harvest; 33% on-site residual retention).

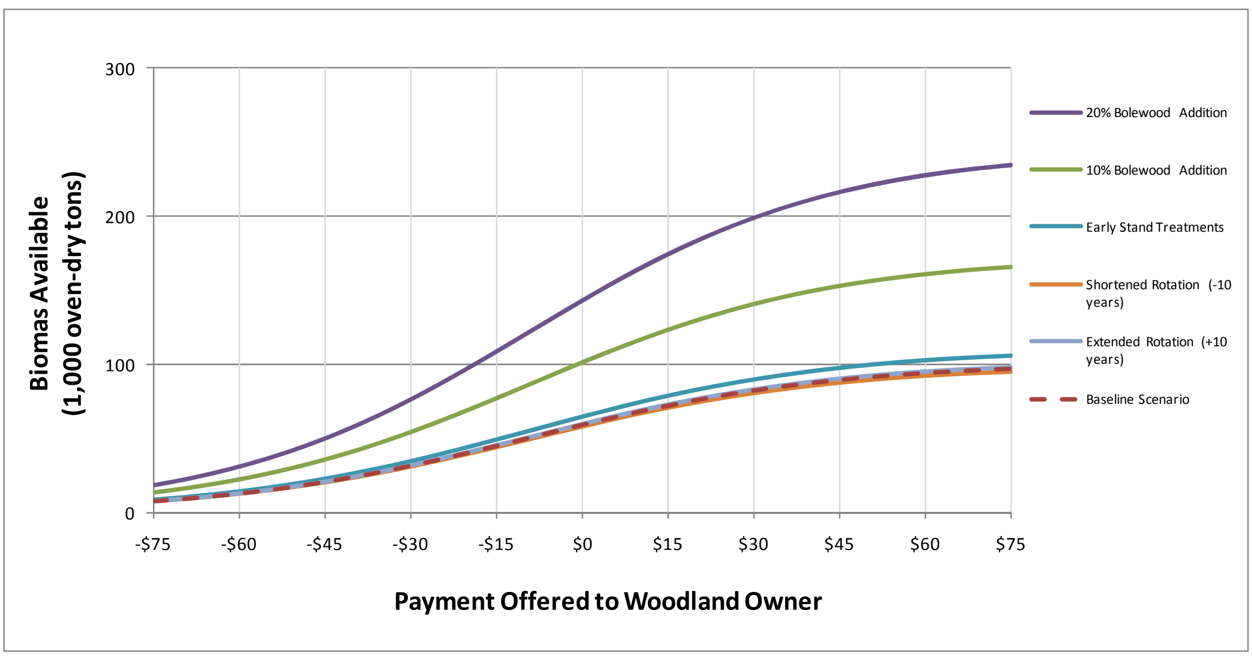


Figure C.3. Estimated east-central Minnesota residual biomass supply from woodlands owners (4.90 million cord harvest; 50% on-site residual retention).

Table C.5. East-central Minnesota annual ODT of residual biomass by ownership and forest management scenario (5.50 million cord harvest).[1]

		---------- Government ----------			Private		
Scenario	Description	Federal	State	Local	industrial[2]	Woodlands	Total
0% Residual retention	Total physical availability	4,269	39,340	17,361	16,932	243,918	321,821
	+ 10% Bolewood	5,766	53,258	23,484	22,964	330,229	435,702
	+ 20% Bolewood	7,263	67,177	29,606	28,997	416,540	549,582
	Early stand treatments	4,618	43,414	19,122	18,154	262,832	348,140
	Shortened rotation (-10 yrs)	4,200	38,797	17,086	16,531	239,938	316,553
	Extended rotation (+10 yrs)	4,325	39,857	17,582	17,257	247,647	326,669
15% Residual retention	Operational maximum removal rate	3,629	33,439	14,757	14,392	207,330	273,548
	+ 10% Bolewood	5,126	47,357	20,879	20,425	293,641	387,428
	+ 20% Bolewood	6,622	61,276	27,002	26,457	379,952	501,309
	Early stand treatments	3,925	36,902	16,254	15,431	223,407	295,919
	Shortened rotation (-10 yrs)	3,570	32,978	14,523	14,051	203,948	269,070
	Extended rotation (+10 yrs)	3,677	33,878	14,945	14,669	210,500	277,669
33% Residual retention	MFRC biomass guidelines	2,861	26,358	11,632	11,345	163,425	215,620
	+ 10% Bolewood	4,357	40,276	17,755	17,377	249,736	329,501
	+ 20% Bolewood	5,854	54,195	23,877	23,409	336,047	443,382
	Early stand treatments	3,094	29,087	12,812	12,163	176,098	233,254
	Shortened rotation (-10 yrs)	2,814	25,994	11,448	11,076	160,759	212,090
	Extended rotation (+10 yrs)	2,898	26,704	11,780	11,562	165,924	218,868
50% Residual retention	Assumed current removal rate	2,135	19,670	8,681	8,466	121,959	160,910
	+ 10% Bolewood	3,631	33,589	14,803	14,498	208,270	274,791
	+ 20% Bolewood	5,128	47,507	20,926	20,530	294,581	388,672
	Early stand treatments	2,309	21,707	9,561	9,077	131,416	174,070
	Shortened rotation (-10 yrs)	2,100	19,399	8,543	8,265	119,969	158,276
	Extended rotation (+10 yrs)	2,163	19,928	8,791	8,629	123,824	163,335
75% Residual retention	Low utilization rate	1,067	9,835	4,340	4,233	60,980	80,455
	+ 10% Bolewood	2,564	23,754	10,463	10,265	147,290	194,336
	+ 20% Bolewood	4,061	37,672	16,585	16,297	233,601	308,217
	Early stand treatments	1,154	10,853	4,781	4,538	65,708	87,035
	Shortened rotation (-10 yrs)	1,050	9,699	4,271	4,133	59,985	79,138
	Extended rotation (+10 yrs)	1,081	9,964	4,395	4,314	61,912	81,667

[1] Residual biomass includes tops, limbs, branches and needles as defined by from the USDA Forest Service FIA biomass attributes.
[2] Includes corporate, nongovernmental conservation/natural resources organizations, unincorporated local partnerships/associations/clubs, and Native American timberlands.

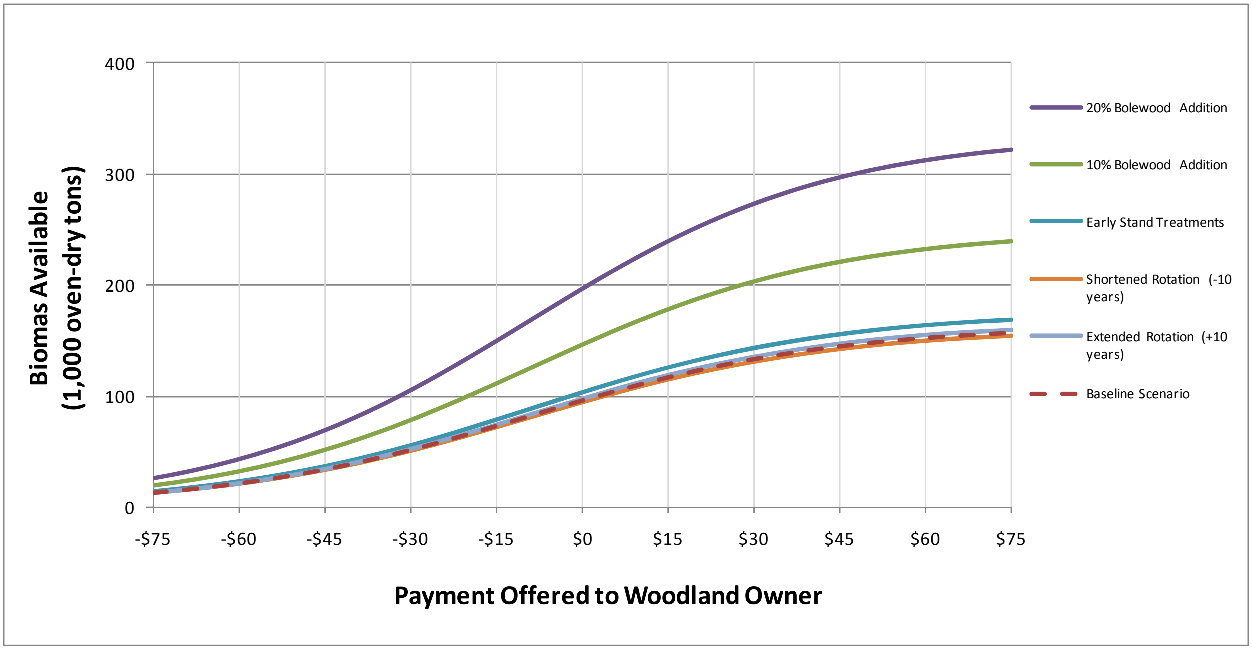


Figure C.5. Estimated east-central Minnesota residual biomass supply from woodlands owners (5.50 million cord harvest; 33% on-site residual retention).

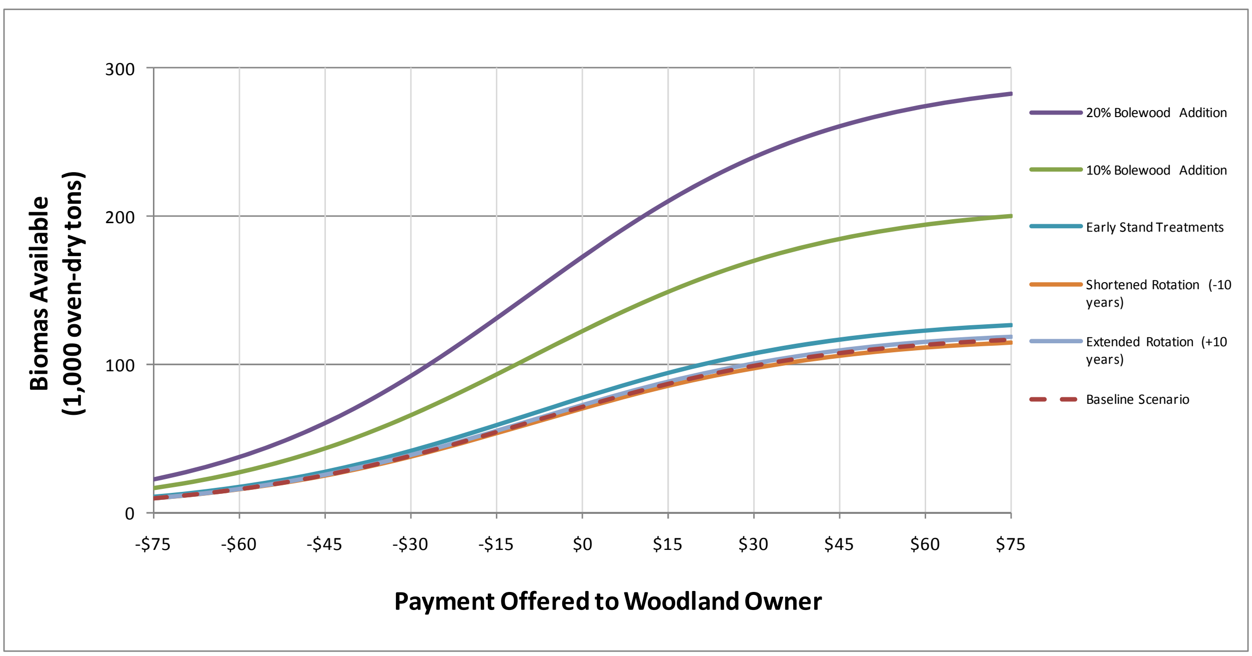


Figure C.6. Estimated east-central Minnesota residual biomass supply from woodlands owners (5.50 million cord harvest; 50% on-site residual retention).

Appendix D. Aggregate Biomass Availability in Northwest Wisconsin

Table D.1. Estimated timberland area (acres) by FIA forest type group for northwest Wisconsin (nonstocked areas not included).

Age Class	White-red-jack pine	Spruce-fir[1]	Oak-pine	Oak-hickory	Elm-ash-cottonwood	Maple-beech-birch[2]	Aspen-birch
0-10	24,726	2,084	19,108	68,406	3,105	15,750	104,366
11-20	24,185	3,922	16,778	14,226	4,102	18,235	107,687
21-30	57,738	5,064	6,926	16,661	7,962	5,129	93,517
31-40	50,425	3,140	6,080	15,594	8,389	20,423	70,415
41-50	41,196	10,376	24,378	30,676	5,306	25,164	97,643
51-60	49,131	18,472	16,258	55,064	16,764	33,801	95,926
61-70	19,582	20,105	0	59,539	23,819	100,059	86,383
71-80	2,738	23,107	11,794	79,854	26,756	64,666	39,900
81-90	14,570	18,587	2,672	60,441	22,603	37,713	15,701
91-100	1,880	3,759	0	3,301	25,314	10,333	3,651
100+	0	17,707	1,253	12,562	12,113	2,659	0

[1] Other exotic softwoods and Exotic softwoods were combined with the Spruce-fir forest type.
[2] Other hardwoods and Exotic hardwoods were combined with the Maple-beech-birch forest type.

Table B.2. Estimated living biomass (ODT) on timberland by stand attribute and ownership in northwest Wisconsin.

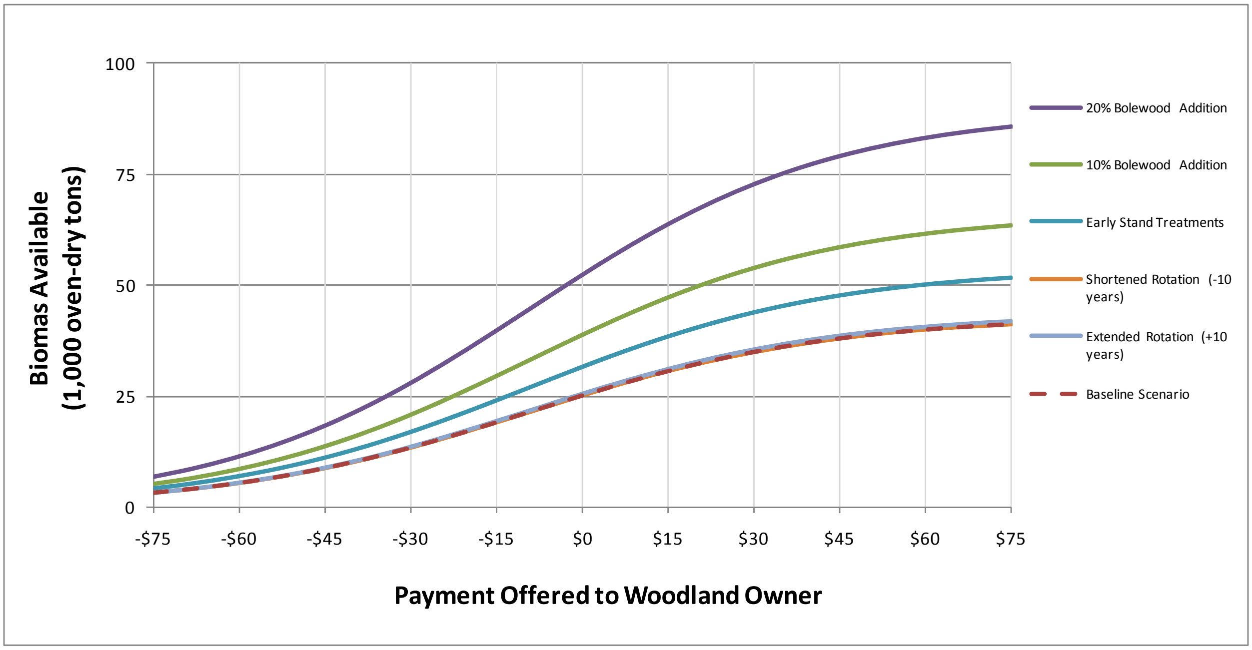
Biomass attribute	---------- Government ---------- Federal	State	Local	Private industrial	Woodlands	Total
Bolewood	3,864,155	1,536,241	7,944,813	3,377,594	13,145,199	29,868,002
Tops and limbs	1,040,851	432,803	2,172,750	946,347	3,645,198	8,237,950
Stumps	239,933	95,686	494,288	208,598	808,581	1,847,086
Saplings	1,244,157	551,667	2,666,281	1,150,180	4,221,711	9,833,996
Belowground	1,376,733	558,194	2,850,079	1,217,230	4,646,325	10,648,561

Table D.3. Northwest Wisconsin annual ODT of residual biomass by ownership and forest management scenario (3.47 million cord harvest).[1]

Scenario	Description	---------- Government ---------- Federal	State	Local	Private industrial[2]	Woodlands	Total
0% Residual retention	Total physical availability	19,180	8,233	38,793	13,273	64,041	143,521
	+ 10% Bolewood	26,592	11,190	53,288	18,154	87,251	196,476
	+ 20% Bolewood	34,004	14,146	67,783	23,036	110,462	249,431
	Early stand treatments	24,014	10,495	48,665	16,469	80,427	180,070
	Shortened rotation (-10 yrs)	18,742	8,040	37,984	12,859	64,069	141,694
	Extended rotation (+10 yrs)	19,508	8,375	39,305	13,636	64,908	145,732
15% Residual retention	Operational maximum removal rate	16,303	6,998	32,974	11,282	54,435	121,993
	+ 10% Bolewood	23,715	9,955	47,469	16,164	77,645	174,948
	+ 20% Bolewood	31,127	12,911	61,964	21,045	100,855	227,903
	Early stand treatments	20,412	8,921	41,365	13,998	68,363	153,060
	Shortened rotation (-10 yrs)	15,930	6,834	32,287	10,930	54,458	120,439
	Extended rotation (+10 yrs)	16,582	7,119	33,409	11,591	55,172	123,872
33% Residual retention	MFRC biomass guidelines	12,850	5,516	25,992	8,893	42,908	96,159
	+ 10% Bolewood	20,263	8,473	40,486	13,774	66,118	149,114
	+ 20% Bolewood	27,675	11,429	54,981	18,656	89,328	202,069
	Early stand treatments	16,090	7,032	32,605	11,034	53,886	120,647
	Shortened rotation (-10 yrs)	12,557	5,387	25,449	8,615	42,926	94,935
	Extended rotation (+10 yrs)	13,070	5,611	26,334	9,136	43,488	97,640
50% Residual retention	Assumed current removal rate	9,590	4,117	19,397	6,637	32,021	71,760
	+ 10% Bolewood	17,002	7,073	33,891	11,518	55,231	124,715
	+ 20% Bolewood	24,415	10,029	48,386	16,399	78,441	177,670
	Early stand treatments	12,007	5,248	24,332	8,234	40,214	90,035
	Shortened rotation (-10 yrs)	9,371	4,020	18,992	6,429	32,034	70,847
	Extended rotation (+10 yrs)	9,754	4,188	19,652	6,818	32,454	72,866
75% Residual retention	Low utilization rate	4,795	2,058	9,698	3,318	16,010	35,880
	+ 10% Bolewood	12,207	5,015	24,193	8,200	39,220	88,835
	+ 20% Bolewood	19,620	7,971	38,688	13,081	62,431	141,790
	Early stand treatments	6,004	2,624	12,166	4,117	20,107	45,018
	Shortened rotation (-10 yrs)	4,685	2,010	9,496	3,215	16,017	35,423
	Extended rotation (+10 yrs)	4,877	2,094	9,826	3,409	16,227	36,433

[1] Residual biomass includes tops, limbs, branches and needles as defined by from the USDA Forest Service FIA biomass attributes.
[2] Includes corporate, nongovernmental conservation/natural resources organizations, unincorporated local partnerships/associations/clubs, and Native American timberlands.

Figure D.1. Estimated northwest Wisconsin residual biomass supply from woodlands owners (3.47 million cord harvest; 33% on-site residual retention).



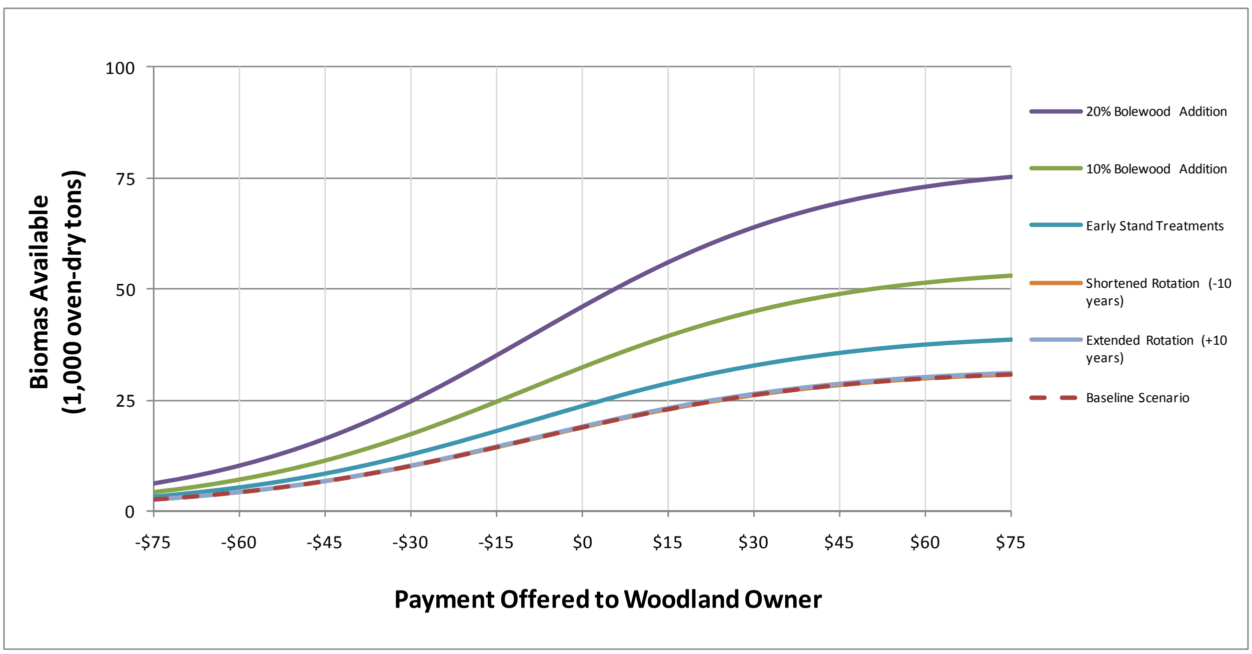


Figure D.2. Estimated northwest Wisconsin residual biomass supply from woodlands owners (3.47 million cord harvest; 50% on-site residual retention).

Table D.4. Northwest Wisconsin annual ODT of residual biomass by ownership and forest management scenario (4.90 million cord harvest).[1]

		---------- Government ----------			Private		
Scenario	**Description**	**Federal**	**State**	**Local**	**industrial[2]**	**Woodlands**	**Total**
0% Residual retention	Total physical availability	29,151	13,030	61,032	23,300	105,997	232,510
	+ 10% Bolewood	40,158	17,661	83,482	31,712	144,173	317,187
	+ 20% Bolewood	51,166	22,291	105,932	40,124	182,350	401,863
	Early stand treatments	34,136	15,392	71,150	26,644	123,136	270,457
	Shortened rotation (-10 yrs)	28,453	12,734	59,819	22,579	105,177	228,762
	Extended rotation (+10 yrs)	29,674	13,229	62,079	23,860	107,102	235,943
15% Residual retention	Operational maximum removal rate	24,778	11,076	51,877	19,805	90,097	197,634
	+ 10% Bolewood	35,786	15,706	74,327	28,217	128,274	282,310
	+ 20% Bolewood	46,793	20,337	96,777	36,629	166,450	366,987
	Early stand treatments	29,016	13,083	60,478	22,647	104,665	229,888
	Shortened rotation (-10 yrs)	24,185	10,824	50,846	19,192	89,401	194,448
	Extended rotation (+10 yrs)	25,223	11,245	52,767	20,281	91,037	200,552
33% Residual retention	MFRC biomass guidelines	19,531	8,730	40,891	15,611	71,018	155,782
	+ 10% Bolewood	30,538	13,361	63,341	24,023	109,194	240,458
	+ 20% Bolewood	41,546	17,991	85,791	32,435	147,371	325,135
	Early stand treatments	22,871	10,312	47,671	17,851	82,501	181,206
	Shortened rotation (-10 yrs)	19,064	8,532	40,079	15,128	70,469	153,271
	Extended rotation (+10 yrs)	19,881	8,863	41,593	15,986	71,758	158,082
50% Residual retention	Assumed current removal rate	14,575	6,515	30,516	11,650	52,999	116,255
	+ 10% Bolewood	25,583	11,146	52,966	20,062	91,175	200,932
	+ 20% Bolewood	36,590	15,776	75,416	28,474	129,351	285,608
	Early stand treatments	17,068	7,696	35,575	13,322	61,568	135,228
	Shortened rotation (-10 yrs)	14,227	6,367	29,910	11,289	52,589	114,381
	Extended rotation (+10 yrs)	14,837	6,614	31,039	11,930	53,551	117,972
75% Residual retention	Low utilization rate	7,288	3,258	15,258	5,825	26,499	58,128
	+ 10% Bolewood	18,295	7,888	37,708	14,237	64,676	142,804
	+ 20% Bolewood	29,302	12,519	60,158	22,649	102,852	227,480
	Early stand treatments	8,534	3,848	17,788	6,661	30,784	67,614
	Shortened rotation (-10 yrs)	7,113	3,184	14,955	5,645	26,294	57,191
	Extended rotation (+10 yrs)	7,418	3,307	15,520	5,965	26,775	58,986

[1] Residual biomass includes tops, limbs, branches and needles as defined by from the USDA Forest Service FIA biomass attributes.
[2] Includes corporate, nongovernmental conservation/natural resources organizations, unincorporated local partnerships/associations/clubs, and Native American timberlands.

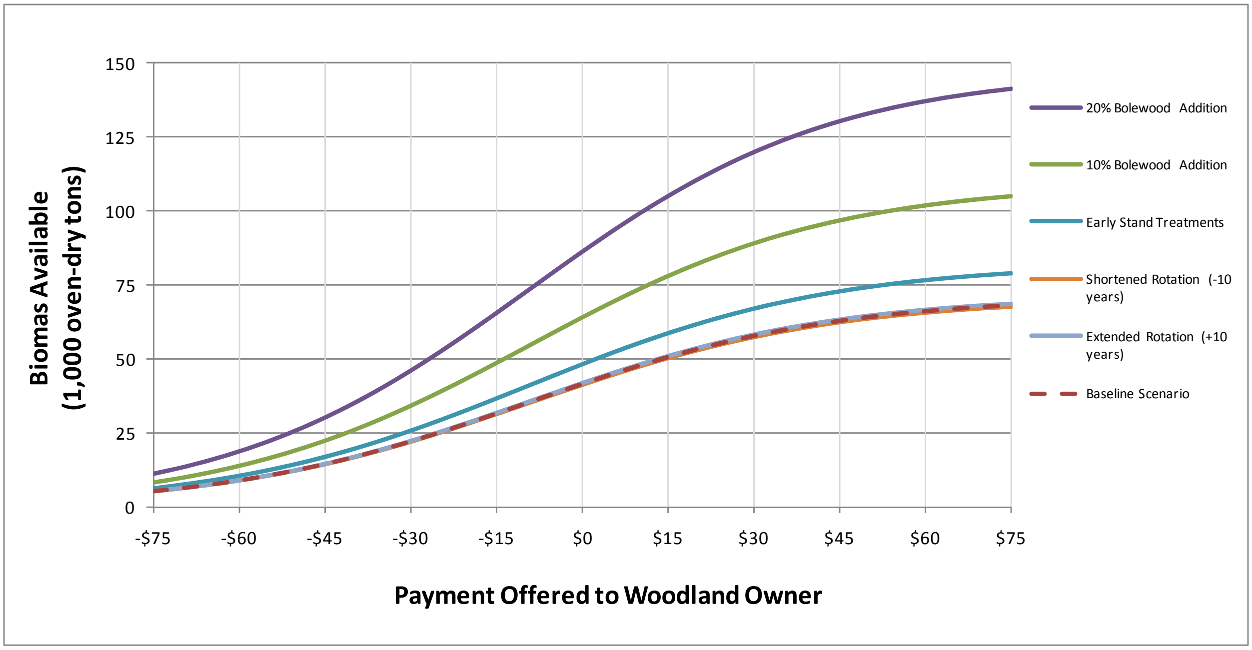


Figure D.3. Estimated northwest Wisconsin residual biomass supply from woodlands owners (4.90 million cord harvest; 33% on-site residual retention).

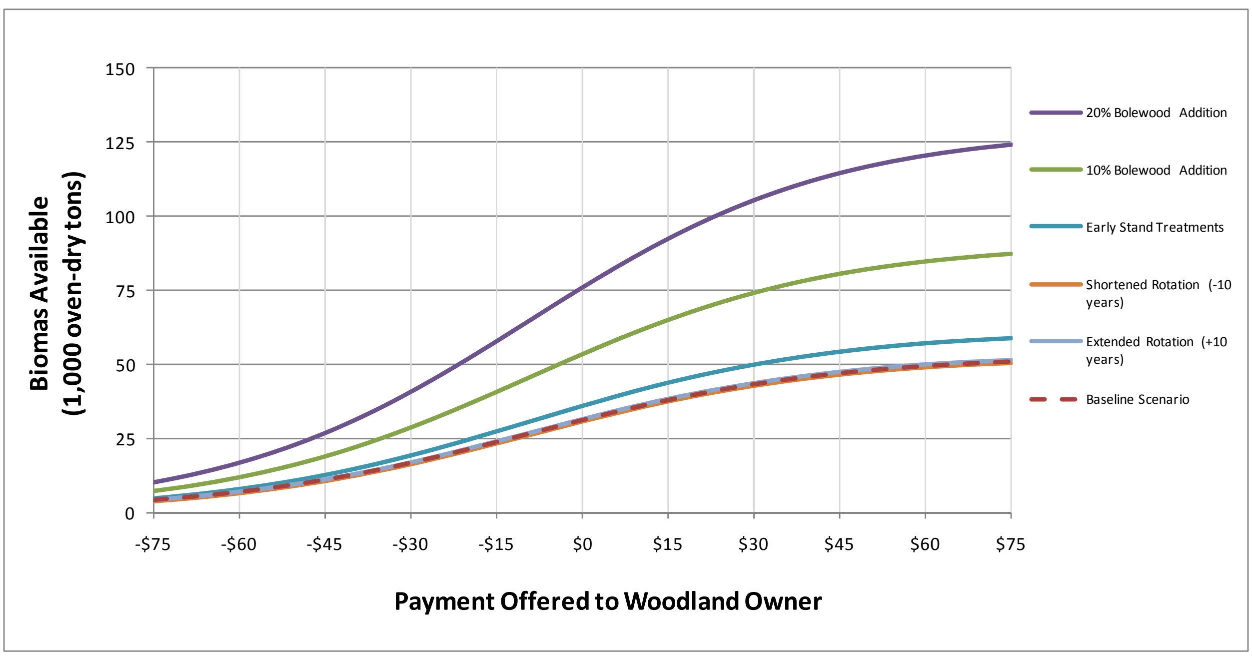


Figure D.4. Estimated northwest Wisconsin residual biomass supply from woodlands owners (4.90 million cord harvest; 50% on-site residual retention).

Table D.5. Northwest Wisconsin annual ODT of residual biomass by ownership and forest management scenario (5.50 million cord harvest).[1]

Scenario	Description	---------- Government ---------- Federal	State	Local	Private industrial[2]	Woodlands	Total
0% Residual retention	Total physical availability	33,089	14,473	68,795	25,714	117,559	259,630
	+ 10% Bolewood	45,524	19,606	93,991	34,940	159,816	353,877
	+ 20% Bolewood	57,958	24,739	119,187	44,166	202,074	448,124
	Early stand treatments	38,504	16,989	79,222	29,531	135,128	299,374
	Shortened rotation (-10 yrs)	32,470	14,215	67,581	24,977	116,655	255,898
	Extended rotation (+10 yrs)	33,643	14,665	69,861	26,275	118,702	263,146
15% Residual retention	Operational maximum removal rate	28,126	12,302	58,476	21,856	99,925	220,685
	+ 10% Bolewood	40,560	17,435	83,672	31,083	142,182	314,932
	+ 20% Bolewood	52,995	22,568	108,868	40,309	184,440	409,179
	Early stand treatments	32,729	14,441	67,339	25,101	114,859	254,468
	Shortened rotation (-10 yrs)	27,599	12,083	57,444	21,230	99,157	217,514
	Extended rotation (+10 yrs)	28,597	12,465	59,382	22,333	100,897	223,674
33% Residual retention	MFRC biomass guidelines	22,170	9,697	46,093	17,228	78,764	173,952
	+ 10% Bolewood	34,604	14,830	71,289	26,454	121,022	268,199
	+ 20% Bolewood	47,038	19,963	96,484	35,680	163,280	362,446
	Early stand treatments	25,798	11,383	53,079	19,785	90,536	200,580
	Shortened rotation (-10 yrs)	21,755	9,524	45,280	16,734	78,159	171,452
	Extended rotation (+10 yrs)	22,541	9,825	46,807	17,604	79,530	176,308
50% Residual retention	Assumed current removal rate	16,545	7,237	34,397	12,857	58,779	129,815
	+ 10% Bolewood	28,979	12,370	59,593	22,083	101,037	224,062
	+ 20% Bolewood	41,413	17,503	84,789	31,309	143,295	318,309
	Early stand treatments	19,252	8,494	39,611	14,765	67,564	149,687
	Shortened rotation (-10 yrs)	16,235	7,108	33,791	12,488	58,328	127,949
	Extended rotation (+10 yrs)	16,822	7,332	34,930	13,137	59,351	131,573
75% Residual retention	Low utilization rate	8,272	3,618	17,199	6,428	29,390	64,907
	+ 10% Bolewood	20,707	8,751	42,395	15,655	71,647	159,155
	+ 20% Bolewood	33,141	13,884	67,591	24,881	113,905	253,402
	Early stand treatments	9,626	4,247	19,805	7,383	33,782	74,843
	Shortened rotation (-10 yrs)	8,117	3,554	16,895	6,244	29,164	63,975
	Extended rotation (+10 yrs)	8,411	3,666	17,465	6,569	29,676	65,786

[1] Residual biomass includes tops, limbs, branches and needles as defined by from the USDA Forest Service FIA biomass attributes.
[2] Includes corporate, nongovernmental conservation/natural resources organizations, unincorporated local partnerships/associations/clubs, and Native American timberlands.

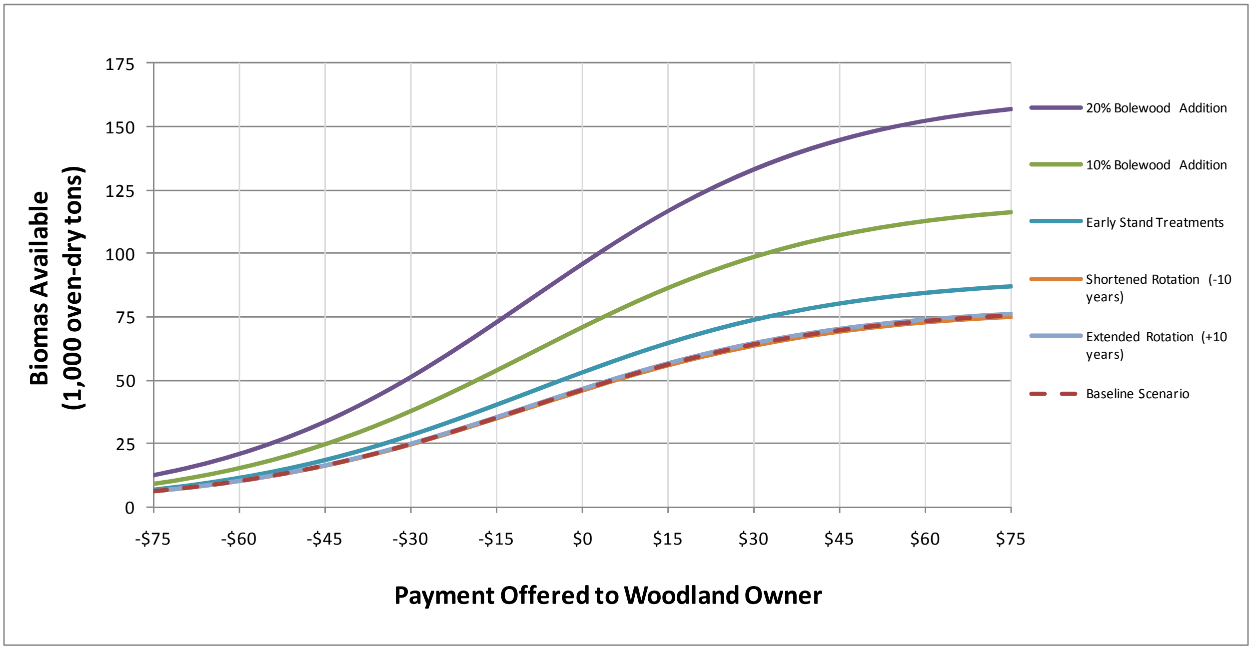


Figure D.5. Estimated northwest Wisconsin residual biomass supply from woodlands owners (5.50 million cord harvest; 33% on-site residual retention).

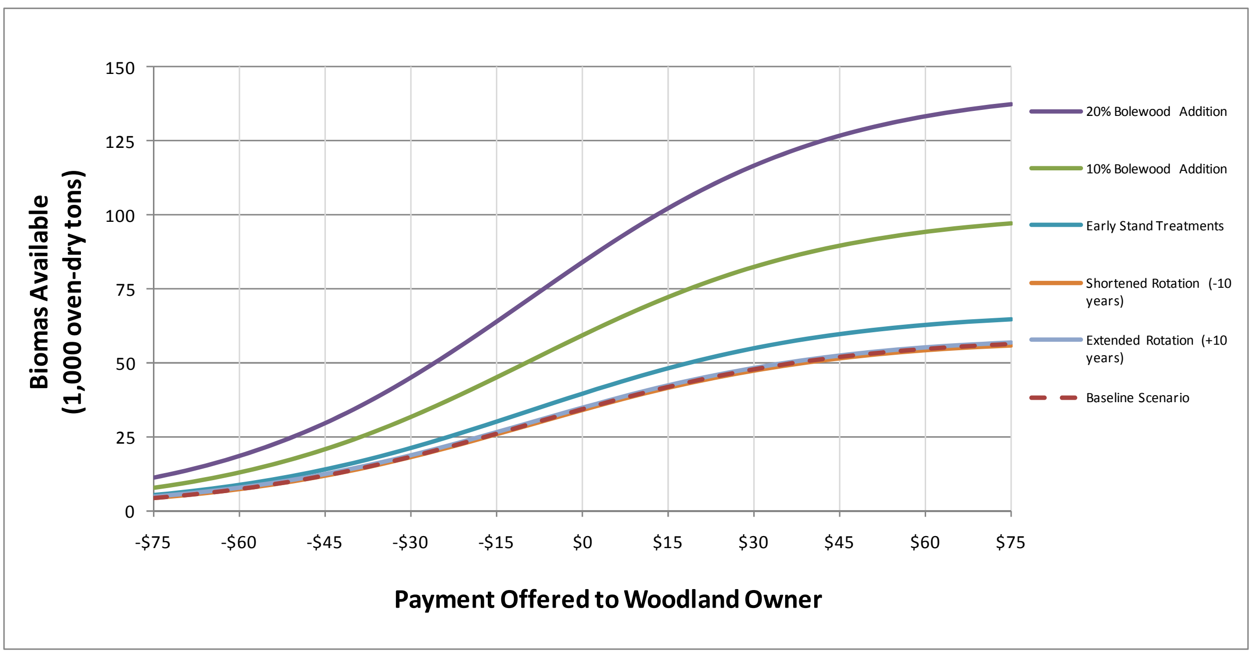


Figure D.6. Estimated northwest Wisconsin residual biomass supply from woodlands owners (5.50 million cord harvest; 50% on-site residual retention).

Appendix E.   Landowner Questionnaire

Private Woodland Owner Survey of Residual Woody Biomass

Dear Woodland Owner,

The Department of Forest Resources at the University of Minnesota is conducting a study to better understand the attitudes and perceptions of woodland owners with respect to woody biomass harvesting.

You have been selected to complete this questionnaire because you own land that is classified for property tax purposes as woodland within a 26 county region in northern Minnesota and northern Wisconsin. This should take about 15 minutes and is entirely voluntary. All of the information you provide will be completely confidential and anonymous. No individual responses will be reported. When responding to the questions please consider the specific parcel that you own in

County:

Please return the questionnaire in the enclosed, self-addressed, postage-paid envelope within **ten days of receipt**. Once we receive your completed questionnaire, your name and any identifying information will be removed from our database.

If you have any questions or concerns about the survey, please contact me at 612-624-7286 or email at drbecker@umn.edu. Thank you in advance for participating in this important project.

Sincerely,

Dennis R. Becker

Dennis R. Becker, Ph.D.
Project Leader

Department of FOREST RESOURCES
UNIVERSITY OF MINNESOTA

Section I. Landowner and Property Profile

1. How many acres and number of individual woodland properties do you own in Minnesota or Wisconsin?

_____ **Total acres** owned in MN or WI   _____ **Number of woodland properties** owned in MN or WI

2. Whether you live on, beside, near, or far from your property, how often do you spend time at your woodland for any reason (for example, walking, hunting, snowmobiling, cutting firewood, etc.)? *Please choose the one answer that best describes your experience over the past 12 months*

____ Once or more per week

____ Once or more per month

____ Once or twice every three months

____ Once or twice per year

____ Less than once per year

3. Indicate how important each of the following reasons for owning your woodlands are to you. *Please circle the number corresponding with the level of importance for each reason*

Reason for woodland ownership	Not Important	Slightly Important	Moderately Important	Very Important
Produce timber for income	1	2	3	4
Produce agricultural products for income	1	2	3	4
Obtain firewood for personal use	1	2	3	4
Place for motorized recreation (ATV riding)	1	2	3	4
Place to hunt or fish	1	2	3	4
Place for hiking, skiing or camping	1	2	3	4
Enjoy solitude and quiet	1	2	3	4
View wildlife	1	2	3	4
Own as a financial investment	1	2	3	4
Pass on to future generations	1	2	3	4
Protect the forest from development	1	2	3	4

Section II. Residual Woody Biomass

DEFINITION: Residual woody biomass is defined as the by-product of forest management activities including trees not used for timber production and tree limbs, treetops, needles and leaves. **Biomass utilization** is the use of residual woody biomass resulting in the production of electricity, thermal heating, biofuels, animal bedding, landscape materials, and related products. *Please answer the following questions using this definition.*

4. **This question has two parts. First, indicate whether you have completed the following forest management activities on your woodland property in the past 10 years. Second, indicate whether you plan to complete the following forest management activities in the next 10 years.** *Please circle the numbers corresponding to the appropriate response for each forest management activity.*

	Activity taken in past 10 years			Activity planned for the next 10 years		
Forest management activity taken	**Yes**	**No**	**Don't Know**	**Yes**	**No**	**Don't Know**
Harvest timber	1	2	9	3	4	9
Harvest firewood	1	2	9	3	4	9
Remove less desirable trees	1	2	9	3	4	9
Develop or maintain trails	1	2	9	3	4	9
Improve wildlife habitat	1	2	9	3	4	9
Prune trees	1	2	9	3	4	9
Remove dead or dying trees	1	2	9	3	4	9
Plant trees	1	2	9	3	4	9
Build roads	1	2	9	3	4	9
Remove invasive plants (e.g., buckthorn)	1	2	9	3	4	9

5. **Please indicate how likely you would be to remove residual woody biomass after the following forest management activities if there were an opportunity?** *Please circle the number which corresponds with your degree of likelihood.*

Forest management activity taken	Extremely Unlikely	Somewhat Unlikely	Somewhat Likely	Extremely Likely	Don't Know
Harvest trees other than for firewood	1	2	3	4	9
Remove less desirable trees	1	2	3	4	9
Harvest firewood	1	2	3	4	9
Develop or maintained trails	1	2	3	4	9
Improve wildlife habitat	1	2	3	4	9
Prune trees	1	2	3	4	9
Remove dead or dying trees	1	2	3	4	9
Plant trees	1	2	3	4	9
Built roads	1	2	3	4	9
Remove invasive plants (e.g., buckthorn)	1	2	3	4	9

Section III. <u>Opinions About Residual Woody Biomass</u>

6. **If you own additional woodland properties to the one considered in this survey, would you be more or less willing to harvest biomass on your other property(s)?** *Circle the response which best represents your willingness to harvest biomass on your other woodland properties.*

Do Not Own Other Woodlands	Less Willing to Harvest Biomass	About the Same Willingness	More Willing to Harvest Biomass	Don't Know
1	2	3	4	9

7. **Please indicate the extent to which you agree or disagree with the following statements.** *Please circle the corresponding number.*

	Strongly Disagree	Slightly Disagree	Slightly Agree	Strongly Agree	Don't Know
Utilization of residual woody biomass for energy could positively impact the local economy	1	2	3	4	9
Utilization of residual woody biomass for energy could positively impact United States energy independence	1	2	3	4	9
Utilization of residual woody biomass for energy could positively impact the United State's ability to address climate change	1	2	3	4	9
I know what steps to take to harvest residual woody biomass on my property	1	2	3	4	9
I would be willing to allow the removal of residual woody biomass on my property if I received <u>additional</u> payment for the material	1	2	3	4	9
I would be willing allow the removal of residual woody biomass on my property even if I received <u>no additional</u> payment for the material	1	2	3	4	9
I would be more willing to allow removal of residual woody biomass on my property if I knew it was to be used to produce energy as opposed to a non-energy use	1	2	3	4	9
I believe that residual woody biomass utilization is an important aspect of forest management	1	2	3	4	9
I am likely to include residual woody biomass removal in a future timber harvest	1	2	3	4	9
I would prefer that any future residual woody biomass resulting from forest management activities on my property be removed and utilized for any purpose	1	2	3	4	9
Leaving residual woody biomass in piles on my property is important to wildlife habitat	1	2	3	4	9
Removing residual woody biomass on my property depletes soil nutrient levels	1	2	3	4	9
I am likely to harvest timber from my property in the next 10 years	1	2	3	4	9

Section IV. External Influences on Land Management

8. Many people other than yourself can influence the decisions you make regarding the use and management of your woodlands. Please indicate the degree to which each of these following influence your woodland use and management decisions. *Please circle the number that corresponds with your experience.*

	No Influence	Slight Influence	Moderate Influence	Considerable Influence	Not Applicable
Family	1	2	3	4	9
Friends	1	2	3	4	9
Neighbors	1	2	3	4	9
Other forest landowners I know	1	2	3	4	9
Professional forester or logger	1	2	3	4	9
Others who use your woodlands	1	2	3	4	9
Woodland or conservation organization	1	2	3	4	9
Newspapers, newsletters, media	1	2	3	4	9
Other (please specify): __________________	1	2	3	4	9

9. Indicate the degree to which each of the following factors limits your ability to remove residual woody biomass from your woodlands. *Please circle the number that corresponds with your experience.*

Limiting Factors	Not Limiting	Slightly Limiting	Moderately Limiting	Very Limiting	Not Applicable
Don't know who to contact	1	2	3	4	9
Don't know how much to charge	1	2	3	4	9
Inadequate revenue will be generated	1	2	3	4	9
Opposed to timber harvesting	1	2	3	4	9
Don't like how forest would look afterwards	1	2	3	4	9
Depletion of nutrients in soil	1	2	3	4	9
Extra harvesting equipment needed	1	2	3	4	9
Opposition from friends or family	1	2	3	4	9
Lack of financial resources	1	2	3	4	9
Lack of interest from loggers	1	2	3	4	9
Woodlands are too small	1	2	3	4	9
Lack of control over harvest operations	1	2	3	4	9
Other (explain): _______________________	1	2	3	4	9

Section V. <u>Willingness to Harvest Woody Biomass Removal</u>

PLEASE READ THE FOLLOWING SCENARIO AND ANSWER THE FOLLOWING QUESTION

10. Assume that you are planning to conduct a timber harvest on a portion of your woodlands. This harvest includes the removal of most trees 5-inches in diameter or greater in the area to be harvested in exchange for a payment. Before the harvest begins, the logger asks if you would like the residual woody biomass removed after the timber harvest is completed. He tells you this means bringing a wood chipper and a semi truck onto your land in order to remove all but one-third of the residual tree limbs, tops and other woody debris created from harvesting. If the residual woody biomass is not removed, the logger plans to leave this material scattered on the ground or in piles about your property.

Would you accept the logger's offer to pay you an additional $15/acre to remove the residual woody biomass after the commercial harvest is complete (in addition to the payment received from selling the timber)? *Please check one response*

____ Yes **____ No** **____ Don't Know (explain:______________________)**

11. Are there circumstances that may lead you to <u>pay the logger</u> to have the residual woody biomass removed from your woodlands? Please indicate your willingness to <u>pay for its removal</u> following each of these forest management activities. *Please circle the number corresponding with your willingness to pay to have woody biomass removed*

Forest management activity	Not Willing	Slightly Willing	Moderately Willing	Very Willing
Harvest timber	1	2	3	4
Harvest firewood	1	2	3	4
Remove less desirable trees	1	2	3	4
Develop or maintain trails	1	2	3	4
Improve wildlife habitat	1	2	3	4
Prune trees	1	2	3	4
Remove dead or dying trees	1	2	3	4
Build roads	1	2	3	4
Remove invasive plants (e.g., buckthorn)	1	2	3	4
Other (please specify): _______________	1	2	3	4

Section V. Additional Information

12. Since owning your woodlands, have you consulted with a professional forester?

____ Yes ____ No ____ Don't Know

13. Since owning your woodlands, have you participated in a forest landowner education program?

____ Yes ____ No ____ Don't Know

14. What is your gender? *Check one*

____ Male ____ Female

15. What year were you born? *Write in year*

____

16. What is your employment status? *Check one*

____ Employed full time ____ Unemployed ____ Student

____ Employed part time ____ Retired ____ Other

17. Is your permanent home located on your woodlands? *Check only one*

____ YES, my home is located on my woodland indicated in this survey

____ NO, I live within 10 miles from my woodlands

____ NO, I live between 11 and 50 miles from my woodlands

____ NO, I live between 51 and 151 miles from my woodlands

____ NO, I live more than 151 miles from my woodland

18. Is there anything else you would like to share with us?

****

Thank you for taking the time to complete this questionnaire.

Please return the questionnaire in the self-addressed stamped envelope included in this mailing.
Feel free to contact us if you have any questions.

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