Natural Resources Research Institute

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NRRI TECHNICAL REPORT

# Comparison of hybrid poplar wood breakeven prices as affected by current and improved genetics

*Submitted by:*

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**Abstract**

The impact of improved genetics from the University of Minnesota Duluth Natural Resources Research Institute (NRRI) hybrid poplar breeding program on breakeven hybrid poplar wood prices is discussed in this paper. After a review of previous economic analyses, the breakeven prices are presented that would cover costs other than land rent. Then, factors are provided for adjusting the price to reflect the land rental rate for a given location. The breakeven prices are presented both as stumpage and delivered to a mill. Breakeven delivered prices include the stumpage values plus conventional harvest and transportation costs to a hypothetical processing plant. Breakeven land rental rates are also provided at which poplar production would be profitable at recent aspen stumpage prices.

The analysis is based on a scenario where a biorefinery/bioproducts company owns and/or leases the land, controls the harvest and transportation of the wood, and delivers the wood to their own mill. The evaluation is based on two hybrid poplar annual growth increments: 3.6 dry tons and 5.4 dry tons per acre per year with a 9-, 10-, or 12-year rotation. 3.6 dry tons per acre per year is yield potential with current genotypes. 5.4 tons per acre per year is yield potential with new Gen 1.0 elite clones from our breeding. Stumpage prices without land cost included are lower than aspen stumpage prices for both unimproved and improved clones. Other things being equal, the improved genetics could be capitalized into a $36.37-per-acre increase in the financially permissible rental rate. Carbon credit markets could further improve returns on hybrid poplar plantations.

**Introduction**

One of the objectives of the USDA NIFA grant to NRRI (Genetic Development, Evaluation and Outreach for Establishing Hybrid Poplar Biomass Feedstock Plantations in the Midwestern United States; Nelson et al., 2018b) is an economic assessment, closely linked to the genetics results from our breeding program, of economic tradeoffs between poplar versus other commodity production. Comparisons need to include breakeven wood prices in relation to returns from agronomic crops as reflected in land rents and in comparison to aspen stumpage prices in Minnesota. The agronomic crop comparison is relevant because hybrid poplar is grown on marginal agricultural land where agronomic crop returns represent an opportunity cost. The aspen comparison is appropriate, as hybrid poplar produces fiber similar, but more uniform, to aspen from the natural forest and can be an alternative to aspen as a wood source.

There is a history of studies of the economics of hybrid poplar plantation forestry in the north central United States. Those studies covered different clones, spacings, rotations, and end uses, under different regional natural resource and macroeconomic settings. Some examples are Rose et al. (1981), Ferguson et al. (1981), Lothner (1991), and Lazarus et al. (2015). Townsend et al. (2018) described barriers to adoption and economic success of hybrid poplar, including inconsistent markets and policies, lack of awareness of the uses of hybrid poplar and the environmental services they can provide, low petroleum prices, management and economic uncertainties, uneven and short-term policy support, and overall perception of risk by investors.

Lazarus has developed a spreadsheet decision tool to evaluate the financial performance of hybrid poplar plantations in Minnesota (Lazarus, 2021b). The recent attainment of Generation 1.0 (first improved generation) genetically improved planting stock within the NRRI Hybrid Poplar Program (Nelson et al., 2021b) provides data on improved yields (Nelson et al., 2018a) that can be used to compare financial performance of hybrid poplar plantations based on current (Volk et al., 2018) and improved genetics (Nelson et al., 2018b), using the Lazarus (2021b) spreadsheet framework.

All yields and calculations are based on bolewood harvested with conventional pulpwood feller bunchers that produce 100-inch-long logs to a three-inch top log diameter. Tops and limbs are assumed to have no value or cost. However, if viable biomass conversion technologies are found that can utilize top and limb biomass, conclusions of this paper can be viewed as conservative, as additional biomass in tops and limbs could be converted to a usable product. Logs are assumed to be transported to a mill as conventional pulpwood. The potential yield estimates do not consider variation in management quality, harvesting losses, or the probability of hazards and increased mortality, all possible factors in deployment on a large industrial scale (Mola-Yudego et al., 2015).

All results are specific to Minnesota and northwest Wisconsin, but they may be similar the rest of northern Wisconsin and Michigan with similar latitudes, soils, and climates to those of Minnesota.

The intended primary audiences for this technical report are industrial companies considering establishing hybrid poplar plantations, agronomy and forestry consultants, state and local economic development agencies and policymakers, and researchers.

We use English, rather than metric units, throughout this report to facilitate use by agronomists, foresters, consultants, and industrial companies.

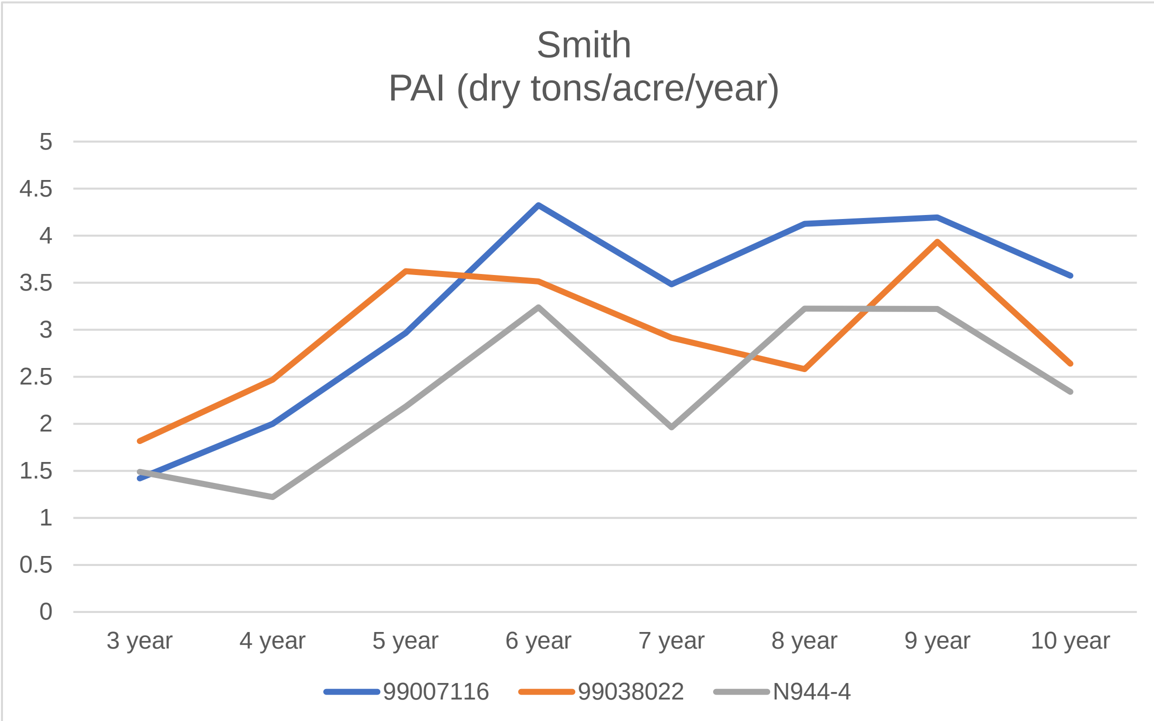
**Improved Yields from Breeding by the NRRI Hybrid Poplar Program**

Yields of unimproved hybrid poplar in Minnesota, based on yield trials designed to mimic commercial growing conditions, are documented in Volk et al. (2018). Modeled weighted average yields of total biomass of unimproved hybrid poplars in Minnesota, based on eight yield trials and geographically distributed as shown in Figure 8 in Volk et al. (2018), are 4.2 dry tons/acre/year. Tops and limbs constitute approximately 15% of total biomass (internal unpublished data). Thus, bolewood biomass yields of unimproved hybrid poplars are 0.85 x 4.2 = 3.6 dry tons/acre/year, or a yield at harvest of 43 dry tons per acre for a 12-year rotation.

Nelson et al. (2018a) found a genetic gain in growth rate for the top genetically improved clone (NRRI-bred and tested experimental hybrid poplar clone InnovaTree™ [aka '99059016']) of 49% **versus the population of clones in clone trials** on six sites in Minnesota. Genetic gain of our top clone versus current commercial check clones (NM6, DN2, DN5) is greater than 49% for bolewood volume growth, partially because these current commercial clones have *Septoria* (*Sphaerulina musiva*) canker on many sites (Nelson et al., 2018a; Nelson et al., 2019; Netzer et al., 2002 ). The fastest-growing six clones in those tests, which includes the top clone InnovaTree™, have an average genetic gain in growth of 46%, similar to the InnovaTree™ gain. Using the 49% increased growth rate of the InnovaTree™ clone to represent the genetic growth potential our Generation 1.0 best clones, we calculate a predicted genetic gain in bolewood yield of 3.6 x 0.49 = 1.8 dry tons/acre/year. Thus, the predicted yield of our improved clones is: 3.6 + 1.8 = 5.4 dry tons/acre/year, or a yield at harvest of 65 dry tons per acre for a 12-year rotation.

Increased growth of the improved clones will also allow a shorter rotation. In this analysis we assume a 12-year rotation for currently used commercial clones (NM6, DN5), which is the usual harvest cycle in our field tests and in the former Verso Paper industrial hybrid poplar program in central Minnesota (internal unpublished data). Most of the Verso plantings no longer exist because a fire destroyed the paper mill that the poplar plantations supplied, and the plantations have been converted back to agriculture. The shortening of the rotation length for the new improved clones will be less impactful than the difference in yields of current and improved clones because of minimum-diameter limits for harvesting and debarking. We know from well-established allometry, e.g. Krinard (1988), that yield is proportional to $DBH^2$ (diameter breast height squared). Assume $DBH^2$ = yield. Thus, the square root of yields will be proportional to DBH. The square root of 5.4 = 2.32 (improved clones); square root of 3.6 = 1.90 (current clones); and the estimate gain ratio 2.32/1.90 = 1.22. Thus, DBH of trees at 12 years old at a yield of 5.4 tons/acre/year is 1.22 larger than the average DBH of trees at a yield of 3.6 tons/acre/year. Thus, one could theoretically reduce rotation age by 0.22 x 12 = 2.62 years. 12- 2.62 = 9.38 years. Therefore, we can set a new rotation for the higher yield using Gen 1.0 improved clones to either 9 years (aggressive) or 10 years (conservative). These two shortened rotation lengths are used in the spreadsheet analyses for the genetically improved clones.

An important factor in practice for choosing a harvest age is the quality of growing seasons. This is more relevant for the compressed rotations for hybrid poplar than it is in the usual forestry situation. With only 9 – 12 years of growing seasons, one or two poor growing seasons could extend the planned harvest age. This is illustrated in Figure 1 by the variation in Periodic Annual Increment (PAI) for the three fastest-growing clones out of nine clones tested in the Smith NRRI yield trial in Clearwater County in northern Minnesota, which had a 10 x 10 feet spacing. A detailed description for the Smith site can be found in (Nelson et al., 2021a). Plots of Mean Annual Increments (MAI) in Figure 1 are still increasing at 10 years, indicating that rotation age can be extended past 10 years for market or logistical reasons with little or no reduction in maximum yield at harvest had this experimental plantation been a commercial one. Plots of MAI for four other yield trials at 10 x 10 feet spacing in central Minnesota (data not shown) were flat or slightly increasing at 10 years, again indicating that harvest can be delayed for a few years past 10 years with little or no reduction in maximum yield for a 10 x 10 feet spacing.



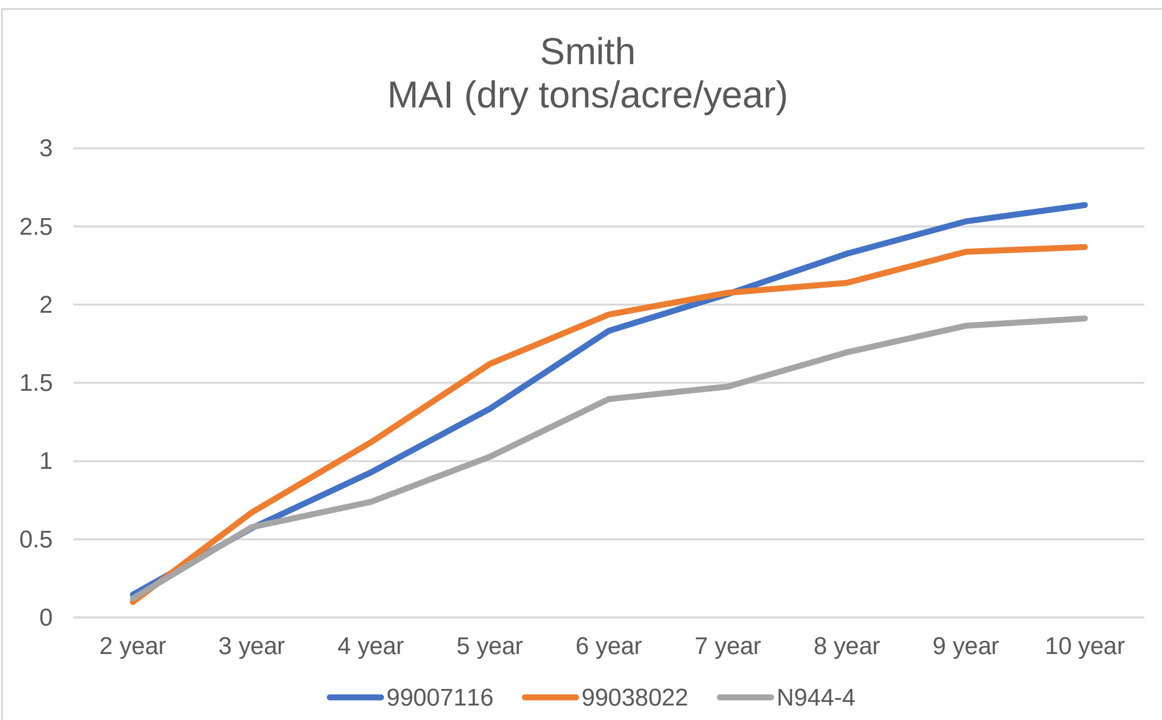




**Figure 1.** Periodic (PAI) and mean annual (MAI) increments for the three fastest growing clones in the Smith yield trial in Clearwater County in northern Minnesota. Yields are total above-ground biomass (bole, tops, limbs).

**Financial Performance Comparisons**

The spreadsheet workbook is designed for a scenario where a biorefinery/bioproducts company owns and/or leases the land, controls the harvest and transportation of the wood, and delivers the wood to their own mill. That scenario is considered most likely for the industrial adoption of hybrid poplar and was the primary model for the former Verso Paper hybrid poplar program in Minnesota, which covered over 25,000 acres at its apex.

Two hybrid poplar annual growth increments are compared in this paper: current genetics, assumed to be 3.6 dry tons of bolewood per year, and improved genetics at 5.4 dry tons per year. The calculations were performed using the spreadsheet available at (Lazarus, 2021b).

The poplar seedings are assumed to be planted into former marginal cropland with vegetative cover that can be eliminated with a contact herbicide. The standard establishment of poplars for fiber is by means of dormant hardwood cuttings (stem sections). The spacing is 10 feet by 10 feet, with 435 cuttings planted per acre. Three rotation lengths are evaluated: 9, 10, and 12 years. The chemical and fertilizer applications, along with other machinery operations, are shown by year in Table 1. Prices per unit for each input including planting are displayed in Table 2. The cost of cuttings in Table 2 is based on experience with large hybrid poplar commercial projects and assumes the industrial company owning the hybrid poplar project produces its own planting stock on a large scale, i.e., 500,000 to 1,000,000 unrooted cuttings each year, enough to plant 1,000 to 2,000 acres per year. The cuttings cost for improved genetics stock is 10% higher to reflect a royalty to the University of Minnesota. Two to three years' lead time is required to establish enough field propagation beds to support this level of production. This time period could be shortened with micropropagation in greenhouses (Stanton et al., 2019). Alternatively, the company could contract with private nurseries to supply planting stock, especially for the earliest years of the project. Current production of poplar cuttings at private nurseries in the Midwest is limited to roughly 100,000 – 250,000 cuttings per year.

**Table 1.** Machinery operations and chemical and fertilizer applications for hybrid poplar production, by year

| Year | Chemical & fertilizer applications | Machinery operations other than for applications |
|---|---|---|
| Planting year | Scepter/Pendulum/glyphosate | Chisel plow 2x, disk, mark rows |
| Maintenance year 1 | Scepter/Pendulum/glyphosate<br>Assure/Transline | Cultivate with a normal agricultural row cultivator 3x |
| Maintenance year 2 | Scepter/Pendulum/glyphosate<br>Assure/Transline | Cultivate with a single row cultivator |
| Maintenance years 3 & 7 | Sevin/Novador | |
| Maintenance years 4, 6, 8 & 10 | Urea | |
| Harvest year | Herbicide to stumps | |

**Table 2.** Prices (US$) per unit for cuttings, chemicals, fertilizer, machinery operations, and miscellaneous

| Item | Year | Price/unit (US$) |
|---|---|---|
| Cuttings, each | Planting year | 0.120 (current clones)<br>0.132 (improved clones) |
| Planting labor (per cutting) | Planting year | 0.06 |
| Chemicals & fertilizer: | | |
| Scepter (2.8 oz/acre) | Maintenance years 1 & 2 | 1.19 |
| Pendulum (1 qt/acre) | Maintenance years 1 & 2 | 12.35 |
| Glyphosate (1 qt/acre) | Maintenance years 1 & 2 | 8.00 |
| Assure (8 oz/acre) | Maintenance years 1 & 2 | 4.69 |
| Transline (10 oz/acre) | Maintenance years 1 & 2 | 15.71 |
| Sevin (1 qt/acre) | Maintenance year 3 | 14.52 |
| Novador (1 qt/acre) | Maintenance year 3 | 10.50 |
| Urea (60 lb elemental) | Maintenance years 4, 6, 8 & 10 | 27.60 |
| Herbicide for stump treatment ($/acre) | Harvest year | 100.00 |
| Machinery operations: | | |
| Apply contact herbicide | Planting year | 12.41 |
| Apply Scepter/Pendulum/glyphosate Assure/Transline | Maintenance years 1 & 2 | 6.60 |
| Apply Assure/Transline | Maintenance years 1 & 2 | 6.60 |
| Apply Sevin/Novador | Maintenance years 3 & 7 | 10.25 |
| Cultivate, normal agricultural row cultivator (3 passes) | Maintenance year 1 | 13.50 * 3x |
| Cultivate, single row cultivator | Maintenance year 2 | 24.00 |
| Apply urea | Maintenance years 4, 6 & 8 | 40.00 |
| Miscellaneous: | | |
| Cutting price for improved clones is 10 % higher than for current clones due to royalty | | |
| Interest rate (discount rate for NPV) | | 5.0% |
| Unplanted headlands (% of total land) | | 5.0% |

Insecticides such as Sevin and Novador are needed when pest outbreaks occur, which are random and will be needed at different times at each site. Two treatments of a Sevin/Novador mix are assumed here and are arbitrarily assumed to be applied in years 3 and 7.

The stumpage values, set equal to the cost of standing trees at harvest, are based on assumptions about machinery operations, chemical and fertilizer applications, and prices of inputs that are based on internal discussions among the project staff. The stumpage values are calculated two ways: 1) with no land cost, and 2) with variable land costs based on the opportunity cost of not growing the competing agronomic crops on the land. The stumpage values assume that the harvest is contracted one year prior to harvest, so the land cost is included through the last maintenance year but not for the harvest year.

Breakeven delivered prices include the stumpage values plus harvest and transportation costs to a hypothetical processing plant. The variable land costs are added for the harvest year for the calculation of the breakeven delivered prices. Harvest costs are $26.25/dry ton based on the authors' calculations using data from Happs et al. (2021), which assumes a conventional harvesting system. A chemical stump treatment costing $100/acre to prepare the site for replanting is included in the harvest year.

The trees are assumed to be grown on a circular area around the plant with 7.77 percent of the area in trees, based on the methodology in Happs et al. (2021). At the 3.6 dry ton/year yield, the total circular area required is 4,050 square miles. The average one-way haul distance from any point in the circle to the center is 24.1 miles. At the 5.4 dry ton/year yield, the area needed falls to 2,700 square miles and the average one-way distance is 19.7 miles. These transportation values are based on Happs et al. (2021). The transport distances also assume that sufficient land is available within the arc as defined above.

Transportation costs assume a base charge of $10.88/dry ton plus $0.236/dry ton/one-way mile, calculated based on 394,490 dry tons per year. Transportation distances assume a processing plant demand of 2,205 dry tons/day operating year-round with 90 percent process uptime, from Happs et al. (2021).

An underlying assumption of the project is that hybrid poplar production will not replace natural forests and also will not take place on prime cropland. Rather, poplar is thought to be well suited to marginal cropland and pasture that is currently or recently was in one of those uses but is relatively unprofitable there. As such, land cost is an index of agricultural marginality and is expected to be relatively low compared to areas of prime cropland. Cropland rental rates in Minnesota averaged $163 per acre in a 2020 survey by the USDA National Agricultural Service and averaged $170 per acre in 2019 on farms participating in the Minnesota State College Farm Business Management program and the Southwestern Minnesota Farm Business Management Association (Bau et al., 2020). The land cost for poplar production is expected to be less than those averages, but how much less is not specified here. Average land costs for agricultural land in some counties of northern Minnesota are much lower. The counties in northeastern Minnesota are lumped together in the 2020 USDA survey, with an average rental rate on cropland of $12 per acre, with $11.50 per acre on pasture (USDA National Agricultural Statistics Service, 2021). Without specific land cost information, the approach taken in this analysis is to calculate the breakeven prices of poplar stumpage and for delivered wood WITHOUT land cost in each scenario of annual yield increment and rotation length, and then to calculate the increase in those breakeven prices that would result from a $10/acre/year increment in land cost. Readers will then be able to use those increase factors to adjust the breakeven prices to whatever land cost is relevant to their situation.

Tables 3 and 4 show the breakeven stumpage values and breakeven delivered wood prices per dry ton.

**Table 3.** Breakeven stumpage values (cost, $/dry ton) based on annual bolewood yield and rotation length

| Annual growth (dry tons/year) | Rotation length, years | | |
|---|---|---|---|
| | 9 | 10 | 12 |
| | Without land cost | | |
| 3.6 | | | 24.50 |
| 5.4 | 19.25 | 18.10 | |
| | Impact of $10/acre/year added land cost | | |
| 3.6 | | | +3.402 |
| 5.4 | +1.973 | +2.080 | |

**Table 4.** Breakeven delivered prices ($/dry ton) based on annual bolewood yield and rotation length, with harvesting and transportation costs

| Annual growth (dry tons/year) | Rotation length, years | | |
|---|---|---|---|
| | 9 | 10 | 12 |
| | Without land cost | | |
| 3.6 | | | 67.32 |
| 5.4 | 61.03 | 59.88 | |
| | Impact of $10/acre/year added land cost | | |
| 3.6 | | | +3.878 |
| 5.4 | +2.388 | +2.452 | |

The breakeven prices for stumpage and delivered wood are calculated by first calculating the present value of the annual expenditures per acre over the rotation discounted at the discount rate (5 percent per year), as:

$$PV = \sum_{i=1}^{N} \frac{CF^i}{(1+r)^i}$$

Where PV is the present value as of the beginning of the rotation, N is the rotation length in years, CFi is the expenditure in year I, and r is the discount rate (5 percent per year).

In order to express the physical wood yield per acre Y (harvested in the last year N of the rotation) on the same scale as the discounted expenditures, the second step is to also discount that yield back to the beginning of the rotation using the same denominator as before. We denote this discounted yield as PVy :

$$PV_y = \frac{Y}{(1+r)^N}$$

The summation is not required in this second formula because the harvest only takes place in the last year of the rotation.

The breakeven price per dry ton P is then just the ratio of PV and PVy :

$$P = \frac{PV}{PV_y}$$

Figure 2 shows that the $27.50 per dry ton stumpage price (recent aspen price for Minnesota) would support a land rent of around $10 per acre with current genetics or around $40 per acre with the improved genetics available from the NRRI breeding program. Figure 3 shows that the breakeven delivered price with current genetics and $10 per acre land rent is approximately $70 per dry ton, while with improved genetics and $10 per acre land rent it is around $62 per dry ton.

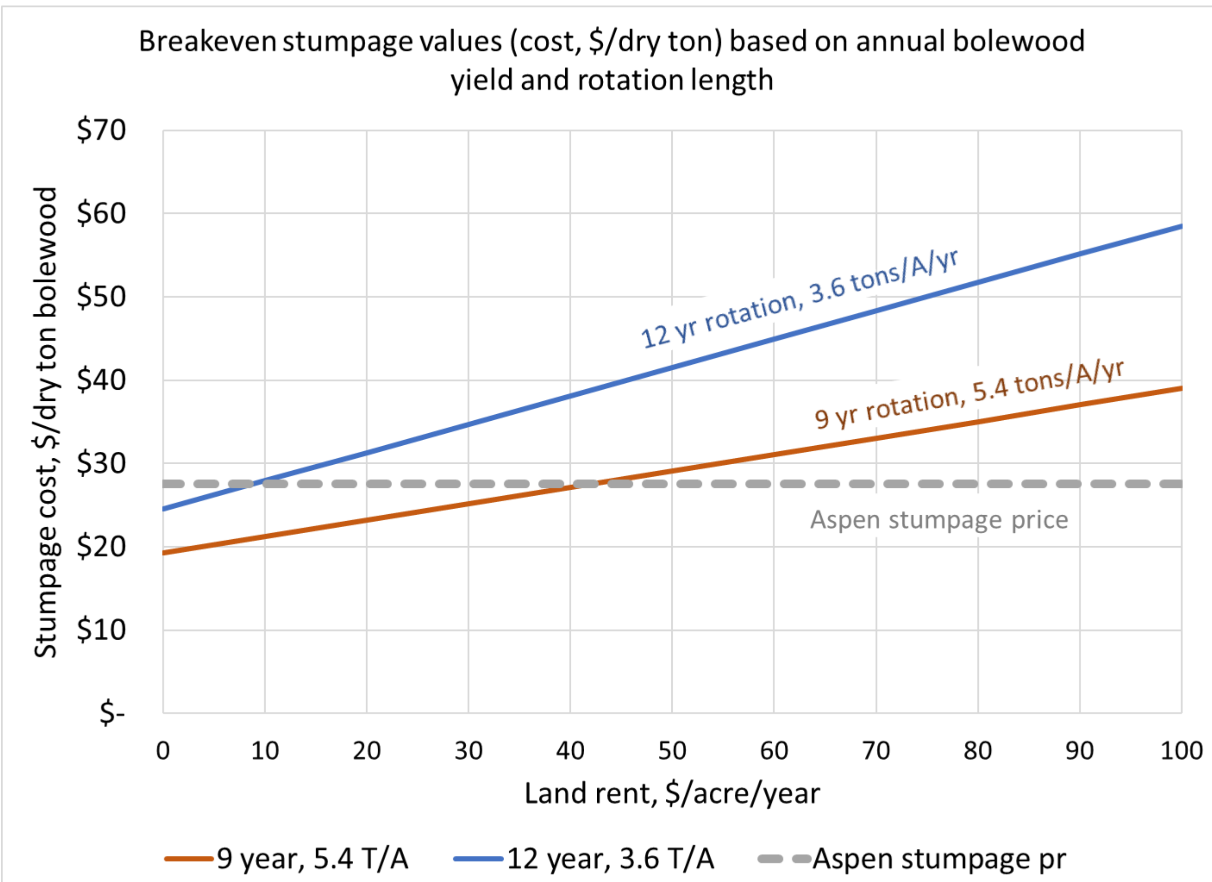



**Figure 2.** Breakeven stumpage values based on annual bolewood yield and rotation length

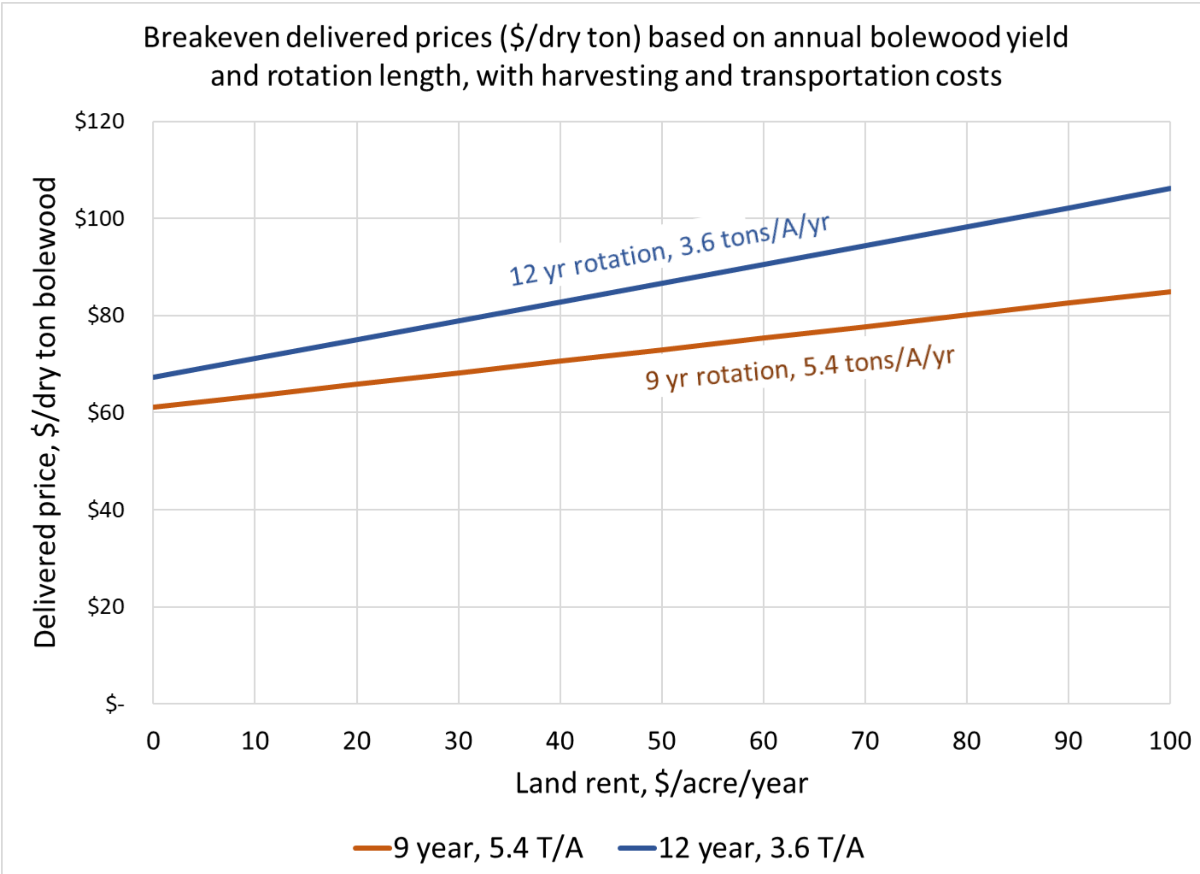



**Figure 3.** Breakeven delivered prices based on annual bolewood yield and rotation length, with harvesting and transportation costs

**Discussion**

There are numerous details, implications, and caveats stemming from the results that bear further discussion.

It is notable that the breakeven prices per dry ton without land cost at the 5.4-ton yield for both stumpage (Table 3) and delivered wood (Table 4) decline slightly at the 10-year rotation length compared with 9 years. For example, the stumpage value is $19.25/dry ton at 9 years and $18.10/dry ton at 10 years. This difference is because the growing costs per acre are the same for both rotations (PV in the above equation) while the 10-year rotation includes one more year of growth, which increases the magnitude of the denominator term PVy. The economic impact of the yield increase is partially offset by the greater discount due to delaying the harvest to the 10th year. Of course, there may be reasons to select the shorter rotation, including wood needs by the processing plant and the reduced hazard risk of harvesting one year earlier.

Uncertainties in these results include the fact that yields of unimproved planting stock are based on yield trials and are modeled for the whole state of Minnesota, whereas genetic gain estimates are based on six specific Minnesota clone trials. Individual trees (single-tree replications of a single clone) in clone trials are surrounded by trees of varying growth rate, while yield trials are designed so that an individual clone is embedded in a 49-tree plot (9-tree measurement plot) of the same clone, mimicking a commercial stand with more uniform competition than in a clone trial. A related question is what the yields will be on ag land that is marginal enough to have low enough land cost to assure returns from the poplar plantations. We have evidence (Nelson et al., 2018a; unpublished internal data) that poplar yields are not correlated with USDA Crop Productivity Index (Dobos et al., 2012), which indirectly indicates that poplars can grow well on some lower quality ag land. Our hypothesis is that hybrid poplars have higher nitrogen use efficiency than agronomic row crops, which may help to explain this comparison.

It is possible that the growth trials and modeling on which our analysis is based produced a systemic overestimation of yields on the northern Minnesota sites that are likely to be available for hybrid poplar production. Our network of experimental trials in Minnesota and northwestern Wisconsin do not provide a clear answer to this possibility. For example, in six simultaneous clone trials in Minnesota with the same clones, three sites in northern Minnesota ranked number 1, 2, and 3 for basal area growth, while the two sites in central Minnesota ranked number 4 and 5 (Nelson et al., 2018a). Differences in soils may have effects on growth that can compensate for colder temperatures and shorter growing seasons.

Another uncertainty in the growth estimates is the possible effect of genotype x environment interactions, as only the data from eight sites in the yield trials and six sites in the clone trials were used in the calculation of the genetic gain estimates. However, this uncertainty is ameliorated somewhat by the commercialization strategy for our genetically improved trees (Nelson et al., 2021b), which is to license geographically robust (geo-robust) clones for deployment in industrial plantations (Nelson et al., 2019). The geo-robustness of our genetically improved elite clones can be expected to reduce the growth variation of hybrid poplars on sites in different latitudes of Minnesota (Nelson et al., 2019). Only new yield trials of Gen 1.0 improved clones on the marginal agricultural land identified in this study will definitively determine actual yields to be expected.

Other uncertainties surround the input costs. The cost of two insecticide applications is included, but more or fewer treatments may be needed depending on pest outbreaks. The input quantities are based mainly on the experience on the project's field experimental plots and may be different in a larger-scale commercial operation. The cash flows are not adjusted for future inflation, and as such are discounted at a five percent discount rate (or interest rate) that should be viewed as a "real" rate that is adjusted for inflation. At this writing, nominal interest rates on risk-free assets are near zero in the U.S., while measures of annual inflation are under two percent (U.S. Bureau of Economic Analysis, undated). The five percent rate can be justified on the basis of the riskiness of poplar production and the likelihood of higher inflation and interest rates in the future.

Aspen and hybrid poplar have broadly similar wood characteristics and are interchangeable for some processing technologies. Examples include Bray and Paul (1942), Geimer and Crist (1980), Zarges et al. (1980), Phelps et al. (1985), Edmonds and Johnson (1992), Peters et al. (2002), and Francis et al. (2005). There has been some historical hesitancy by forest products companies in the United States to use hybrid poplar. However, hybrid poplar wood has been used regularly in mills in Canada, Italy, and Serbia and has been accepted and used successfully in kraft and dissolving pulp, OSB, and pallet mills in Minnesota. A veneer producer in northwestern Wisconsin that uses aspen has expressed willingness to try hybrid poplar for the same type of veneer. Some processes may be optimized by the greater uniformity in tree size and chemical composition of wood from hybrid poplar plantations in comparison to aspen trees harvested from the natural forest. Other reasons for a company to prefer hybrid poplar would be for control of their wood supply or where a plant is located too far from the natural forest to make aspen use possible. For processes where aspen and hybrid poplar can both be used it is instructive to compare the cost of hybrid poplar stumpage in Table 3 with the most current pre-pandemic aspen stumpage price (2019) for the Minnesota market (Minnesota Department of Natural Resources, 2020), which is $27.50 per cord (approximately equivalent to $27.50 per dry ton). Stumpage prices without land cost included are lower than aspen stumpage prices for both unimproved and improved clones. A $27.50 per ton stumpage value would support a land cost of $8.82 per acre per year at the 3.6-ton yield and the 12-year rotation (11 years of land cost because the stumpage is sold before the harvest year). At the 5.4-ton yield, that stumpage value would cover a land cost of $41.81 per acre per year with a 9-year rotation (8 years of land cost) or $45.19 per acre with a 10-year rotation (9 years of land cost). In other words, other things being equal, the improved genetics could be capitalized into a $36.37-per-acre increase in the rental rate ($45.19 minus $8.82).

> Note: Example land cost calculation for the 5.4-ton yield and a 9-year rotation, starting with a $19.25 without-land stumpage value and an incremental land cost factor of $1.973 per $10/acre rent factor:
>
> $27.50 per-ton market price minus $19.25/ton without-land breakeven price = $8.25/ton available to cover land cost
>
> $8.25 * $10 rent factor / 1.973 = $41.81/acre average over the 8 years of land cost

Figures 2 and 3 indicate that the use of improved genotypes from the NRRI poplar breeding program results in plantations that can be grown on a shorter rotation and also allows plantings on higher quality cropland, up to $40 per acre per year land rent. This may allow a broader range of sites for plantations and make it more likely that the higher yield potential of 5.4 dry tons per acre per year is achieved. A 10% rise in aspen stumpage price would allow up to $60 per acre for land rent for hybrid poplar plantations, opening up counties with better agricultural land to hybrid poplars.

It appears that some good opportunities for hybrid poplar plantations with current aspen prices are in northeastern and northcentral Minnesota and northwestern Wisconsin, where there is lower quality ag land and established pulpwood markets. For example, there is a diminished dairy farm industry in northwestern Wisconsin with potentially available acreage currently in grass, silage corn, and a few other agronomic crops (J. Fischbach, unpublished information 2021). Table 5 shows counties in Minnesota and northwestern Wisconsin with average rental rates on cropland and pasture for counties with cropland rental rates less than or equal to $50 per acre per year based on recent USDA surveys (USDA National Agricultural Statistics Service, 2021). Cropland rental rates in Itasca, Beltrami, and Koochiching counties averaged $19.50, $40.50, and $27.00 per acre per year, respectively, in 2020. Average pasture rents in northeastern Minnesota are $11.50 per acre. The proximity of wood-using plants using aspen for paper, OSB, and veneer in this region might also reduce the risk of poplar plantations in comparison to scenarios where there is only one market provided by one new bioenergy/bioproducts plant. Locations in Minnesota that are potentially promising are in the vicinity of Grand Rapids, Bemidji, and International Falls, all of which have significant acreages of marginal agricultural land and wood processing plants in or nearby that could use hybrid poplar wood. Figures 4 and 5 show the location of cropland and pasture in counties in Minnesota and northwest Wisconsin that have average cropland rental rates less than or equal to $50 per acre per year, and the location of mills that currently use aspen.

**Table 5.** Land area in cropland and pasture, average recent rental rates, and distance to the nearest mill using aspen for counties in Minnesota and northwest Wisconsin that have average cropland rental rates less than or equal to $50 per acre per year[a]

| County | Cropland[a] (acres) | Average cropland rent ($) | Pasture[a] (acres) | Average pasture rent ($) | Distance to mill using aspen[a] (miles) |
|---|---|---|---|---|---|
| **Minnesota** | | | | | |
| Aitkin | 54,095 | 24.50 | 24,908 | 10.00 | 5 |
| Beltrami | 79,842 | 40.50 | 55,849 | 17.00 | 35 |
| Carlton | 41,339 | 17.50 | 27,030 | 6.00[b] | 12 |
| Cass | 57,910 | 30.00 | 56,426 | 16.00 | 35 |
| Clearwater | 76,106 | 38.50 | 53,140 | 12.50 | 65 |
| Crow Wing | 41,839 | 35.00 | 24,694 | 15.50 | 42 |
| Hubbard | 53,391 | 22.00 | 23,909 | 12.00[c] | 67 |
| Itasca | 36,637 | 19.50 | 15,308 | 11.50 | 20 |
| Koochiching | 28,160 | 27.00 | 14,026 | 17.00 | 32 |
| Lake of the Woods | 67,779 | 38.50 | 5,719 | 6.00[c] | 96 |
| Northeast MN counties combined[d] | 68,691 | 12.00 | 31,137 | 11.50[e] | 67 |
| Pine | 81,694 | 38.00 | 38,265 | 19.50 | 50 |
| Wadena | 75,336 | 31.50 | 23,631 | 13.50 | 95 |
| **Wisconsin** | | | | | |
| Bayfield | 42,610 | 23.50 | 15730 | 8.40[b] | 32 |
| Douglas | 26,792 | 22.00 | 23214 | 10.50 | 40 |
| Ashland | 24,712 | 32.50 | 12,706 | 5.50[c] | 6 |
| Sawyer | 26,032 | 44.00 | 7,112 | 8.40[b] | 21 |

Source: (USDA National Agricultural Statistics Service, 2021)

[a]Areas are from the 2017 USDA Census of Agriculture. Rents are from USDA National Agricultural Statistics Service surveys done in 2020, unless otherwise indicated. Distance to mill using aspen is the approximate distance from the center of the county to a wood processing facility using a substantial amount of aspen.

[b]Rental rate from 2019 survey

[c]Rental rate from 2017 survey

[d]Cook, Lake and St. Louis Counties

[e]St. Louis County only

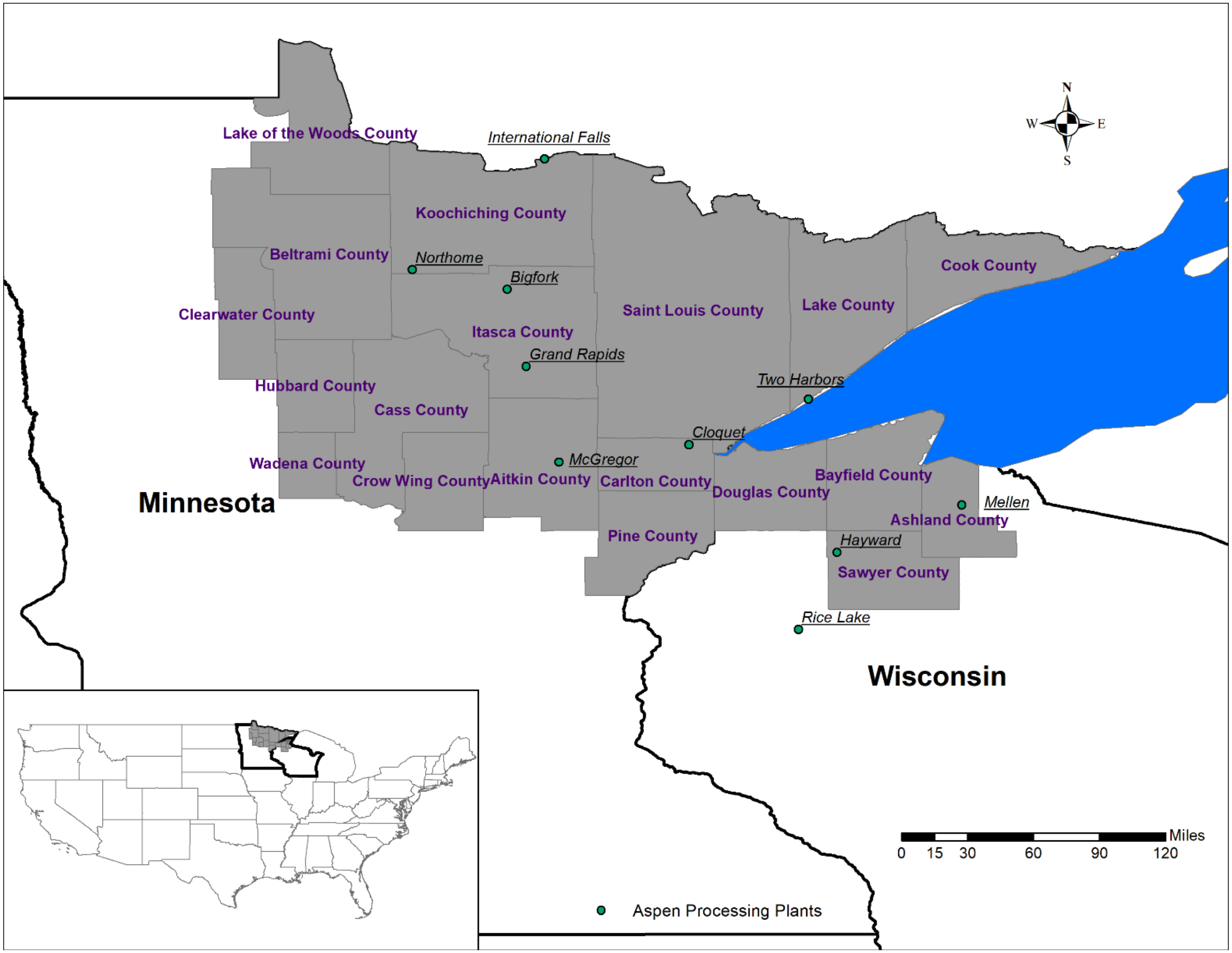



**Figure 4.** Counties in Minnesota and northwest Wisconsin that have average cropland rental rates less than or equal to $50 per acre per year, and mills using aspen (The cities and states map was downloaded from arcgis.com. The final map was produced by the software ArcMap 10.7.1.)

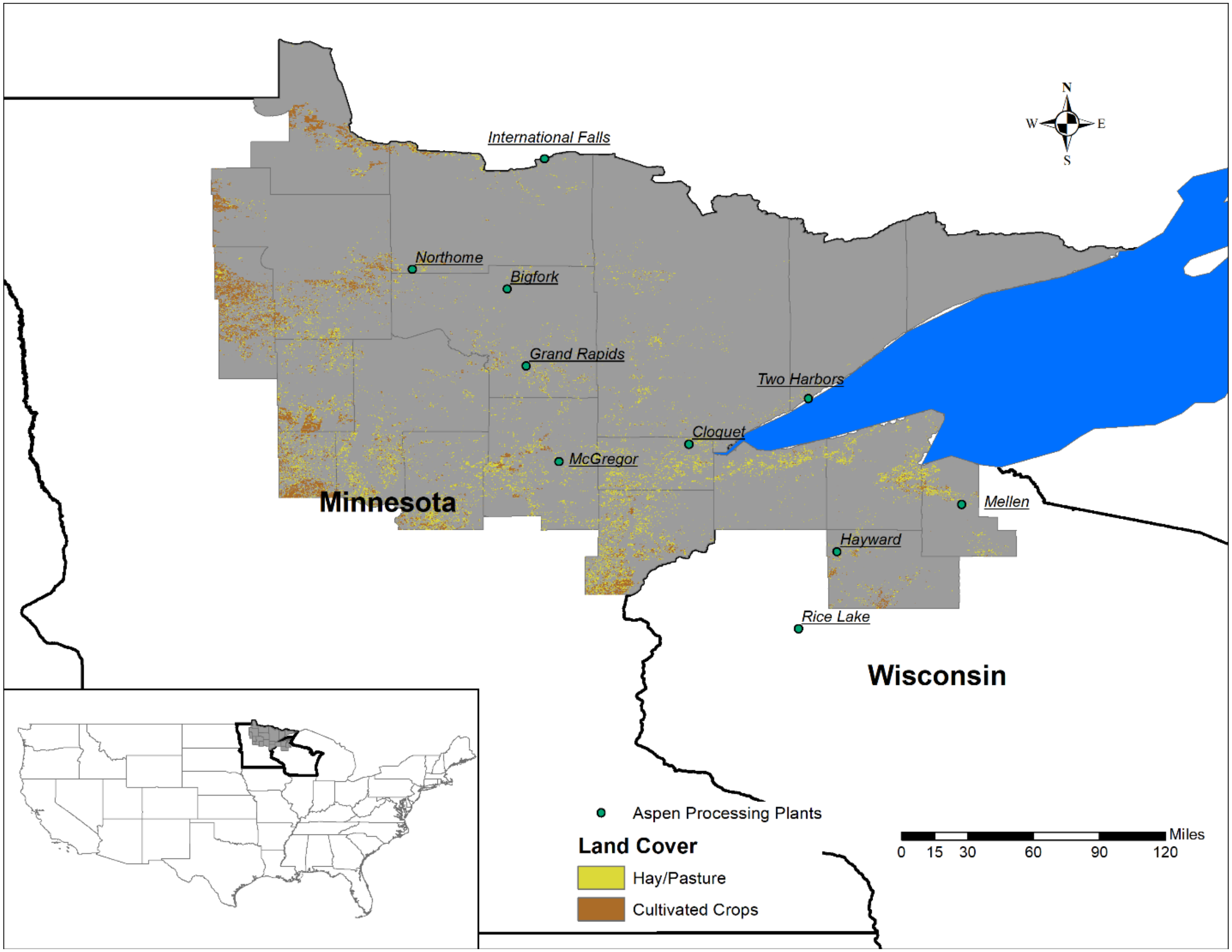



**Figure 5.** Location of cropland and pasture in counties in Minnesota and northwest Wisconsin that have average cropland rental rates less than or equal to $50 per acre per year, and mills using aspen (The land cover map comes from NLCD 2016, which was downloaded from https://www.mrlc.gov/data/nlcd-2016-land-cover-conus. The final map was produced by the software ArcMap 10.7.1.)

Figure 5 shows cropland and pastureland patterns that differ from Table 5 data due to the difference in databases, specifically how hay is classified. The most recent USDA databases cited above classify rotational pasture that could have been used for crops as pastureland, and include hay with cropland. No cropland or pastureland appears in Cook and Lake Counties (MN) in Figure 5, probably due to the smallness of the parcels in those counties. Only pastureland appears in Figure 5 for St. Louis County (MN) because the GIS database NLCD 2016, downloaded from https://www.mrlc.gov/data/nlcd-2016-land-cover-conus, includes hay with pasture, while the USDA surveys include hay with cropland. St. Louis County had 47,300 acres of hay in 2008, the most recent year of data available, so that makes up most of the 68,691 total acres of cropland in that county. When that hay acreage is added to the 31,137 reported acres of pasture as shown in Figure 5, the total acres of hay and pasture combined is 47,437 acres, while cropland minus hay is 21,391 acres.

A focus on marginal cropland will require avoidance of land that has wet or excessively sandy (droughty) soils, both of which are known to be unsuitable for hybrid poplar. Some land that has been in pasture more or less permanently may be excessively rocky and unsuitable for cultivation for that reason.

Based on experience with large industrial hybrid poplar projects and logging companies, the minimum individual parcel size that is practical for maintenance and harvest is approximately 25 – 40 acres (, M. Young, J. Isebrands 2021 personal communications ). A mean parcel size of about 125 acres has been proven as workable in large projects where a total of 1,000 to 2,000 acres per year is being established (M. Young 2021, personal communication). Table 6 shows that 53 percent of the agricultural land parcels sold in the listed counties over the past ten years (2011 – 2020) reported as having 25 acres or more of cropland. Eight percent contained 125 acres or more of cropland. This information is reported by real estate buyers and sellers to the Minnesota Department of Revenue on the Certificate of Real Estate Value form that is required for tax purposes. The tally was extracted from the Minnesota Land Economics website (Lazarus, 2021a). That data item is described on the form as “tillable acres,” so would presumably not include permanent pasture. The form also lists total deeded acres, but that number would include woodland and other land, so it is not useful for our purposes.

The developing market for carbon credits may also be a possibility for additional revenue from large hybrid poplar projects, which could improve the financial prospects for hybrid poplar plantations. Carbon credits for hybrid poplar would be generated through voluntary markets, which accept a shorter project lifetime than mandatory markets. The credits could be generated on plantations of either pure hybrid poplar or of hybrid poplar interspersed with longer-lived hardwood or softwood trees. The latter model has been proven for another *Populus* species. Green Trees, based in Plains, VA, is successfully generating carbon credits for landowners by planting eastern cottonwood interspersed with hardwood trees (ACRE Investment Management LLC, 2021). A recent report (DeJong-Hughes and Cates, 2021) on the potential of carbon credits in Minnesota agriculture cites a current range of $14 – $18 per carbon credit (one metric ton of carbon dioxide). According to the Jenkins Formula (Jenkins et al., 2003), the yield of improved genetic planting stock of 5.4 dry tons/acre/year would sequester approximately 11.92 metric tons $CO_2$/acre/year. At $14 per metric ton $CO_2$ the gross revenue for carbon credits would be $167/acre/year. Transaction costs, which are variable by project and broker, would be subtracted from gross revenue to calculate net to the grower. Even at 50% transaction costs, carbon credits could significantly reduce breakeven prices for hybrid poplar wood. Carbon markets may become an increasing focus of plantation forestry as traditional pulp and paper markets decline in the Midwest USA.

**Table 6.** Average cropland acres in agricultural land parcels sold in Minnesota counties between 2011 and 2020 that have average cropland rental rates less than or equal to $50 per acre per year, and percent with 25 or more, or 125 or more cropland acres

| | Number of sales | Average cropland acres | 25 acres or more of cropland | Estimated total cropland acres >= 25[a] | Average cropland acres >= 25 | 125 acres or more of cropland | Estimated total cropland acres >= 125[a] | Average cropland acres >= 125 |
|---|---|---|---|---|---|---|---|---|
| Aitkin | 27 | 57 | 30% | 1,526 | 184 | 15% | 8,014 | 314 |
| Beltrami | 142 | 74 | 71% | 10,559 | 99 | 16% | 12,932 | 229 |
| Carlton | 68 | 1 | 1% | 38 | 38 | 0% | 0 | na |
| Cass | 127 | 33 | 51% | 4,171 | 55 | 3% | 1,824 | 217 |
| Clearwater | 219 | 55 | 58% | 12,070 | 87 | 12% | 9,035 | 198 |
| Cook | 1 | 0 | 0% | 0 | na | 0% | 0 | na |
| Crow Wing | 66 | 26 | 38% | 1,688 | 51 | 2% | 634 | 150 |
| Hubbard | 55 | 51 | 60% | 2,816 | 80 | 11% | 5,824 | 175 |
| Itasca | 44 | 27 | 34% | 1,207 | 65 | 7% | 2,498 | 127 |
| Koochiching | 48 | 6 | 6% | 305 | 83 | 2% | 587 | 136 |
| Lake of the Woods | 41 | 153 | 90% | 6,273 | 169 | 27% | 18,185 | 426 |
| Pine | 137 | 37 | 63% | 5,011 | 50 | 2% | 1,789 | 147 |
| St. Louis | 32 | 52 | 59% | 1,680 | 84 | 9% | | 289 |
| Wadena | 90 | 47 | 68% | 4,272 | 64 | 7% | 5,022 | 149 |
| All included counties | 1,097 | 47 | 53% | 51,615 | 82 | 8% | 63,279 | 232 |

Source: Minnesota Department of Revenue, as reported by buyers and sellers on the Certificate of Real Estate Value. That term uses the term "tillable acres" for what we describe as "cropland acres."

[a]Total acres over 25 or 125 acres are estimated by multiplying the percentages from this table times total cropland acres from Table 5. In effect, this is extrapolating from the sold parcels to all parcels in the county.

**Summary and Conclusions**

The impact of improved genetics from the NRRI hybrid poplar breeding program (Gen 1.0) on breakeven hybrid poplar wood prices is discussed in this paper. After a review of previous economic analyses, the breakeven prices are presented that would cover costs other than land rent. Then, factors are provided for adjusting the price to reflect the land rental rate for a given location. The breakeven prices are presented both as stumpage and delivered to a mill. Breakeven delivered prices include the stumpage values plus conventional harvest and transportation costs to a hypothetical processing plant. Breakeven land rental rates are also provided at which poplar production would be profitable at recent aspen stumpage prices.

The analysis is based on a scenario where a biorefinery/bioproducts company owns and/or leases the land, controls the harvest and transportation of the wood, and delivers the wood to their own mill. The evaluation is based on two hybrid poplar annual growth increments: current genetics, assumed to be 3.6 dry tons of bolewood per year in a 12-year rotation, and improved genetics at 5.4 dry tons per year with a 9- or 10-year rotation.

It appears that some good opportunities for hybrid poplar plantations with current aspen prices are in northeastern and northcentral Minnesota and northwestern Wisconsin, where there is lower quality ag land and established pulpwood markets. Stumpage prices without land cost included are lower than aspen stumpage prices for both unimproved and improved clones. The current $27.50 per ton stumpage value would support a land cost of $8.82 per acre per year at the 3.6-ton yield and the 12-year rotation (11 years of land cost because the stumpage is sold before the harvest year). At the 5.4-ton yield, that stumpage value would cover a land cost of $41.81 per acre per year with a 9-year rotation (8 years of land cost) or $45.19 per acre with a 10-year rotation (9 years of land cost). In other words, other things being equal, the improved genetics could be capitalized into a $36.37-per-acre increase in the rental rate. The developing carbon credits market could further improve the economics of hybrid poplar production.

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