LARCH VIRTUAL EXPERIMENT STATION RESEARCH NOTE #9

Forecasting Stand Value of Native, Exotic, and Hybrid Larch in Maine's Stumpage Market

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November 1, 2018

ABSTRACT

In this paper, we look at the possibility for management of exotic species in Maine. Using periodic measurements from eight planted larch stands, we estimate biomass and sawlog yield for managed European, Japanese, a selection of hybrids, and Tamarack. We use stochastic regression imputation to complete our dataset and estimate larch yields using weighted least squares. To assign value to species unfamiliar in Maine's markets, we apply k-nearest neighbor classification to find proxies among Maine's common merchantable species. Finally, we compare larch to both spruce and fir stands based on net present value and soil expectation value. We find that larch is competitive economic option under certain scenarios. This is largely due sawlog production as early as age 18.

KEYWORDS

Exotic, softwood, larch, economic valuation, Maine

RECOMMENDED BACKGROUND

Undergraduate resource economics and statistics

ACKNOWLEDGEMENTS

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We appreciate the support of our advisors/professors, and colleagues, namely Mindy Crandall, Adam Daigneault, Craig Johnston, Bob Rice, Jonathan Rubin, and Ken Laustsen.

INTRODUCTION

Long dominated by natural regeneration and the pulp and paper industry, economic changes in Maine over the last few decades have piqued interest in plantation forestry, particularly in fast-growing, exotic softwoods (Seymour and Hunter, 1992; Root and Park, 2016; Einspahr et al., 1984). Beginning in the late 1980's, plantation stands of European, Japanese, and Hybrid Larch (*Larix spp.,* exotic counterparts to Maine's native Tamarack) were established to test the growth properties and production possibilities of these species in Maine. Using periodic measurements of these stands, we create yield projections for biomass and sawlogs up to age thirty for the larch species. We then apply k-nearest neighbor classification to assign a merchantable stumpage value to these novels species. Finally, we compare predicted larch yields with projected yields of business as usual in Maine.

DATA DESCRIPTION

The available data is drawn from eight test stands established between 1988 and 1998 as one-year saplings. The number of individuals planted ranges from under 200 to under 1,000 and the observations consist of species, age, height and DBH (diameter at 54 inches) measurements. Measurements were takes at various ages between 1 and 20. A summary of the stands may be found in Table 1. Almost all stands were measured at 10 years old, but all other age measurements are shared by roughly only half or fewer of the stands. While there is minimal missing data in the individual stand data sets, the scarcity of measurement at older ages between sites creates a challenge for estimating production after age 15. We attempt to partially combat the lack of information about older larches by leveraging information from longer established sites through imputation.

Site	ID	No. of Trees	DBH Measurement Ages	HGT Measurement Ages	Species
Chase Stream	SR 8801	370	5, 10, 16, 20	3, 5, 10, 16, 20	All (EL, HL, JL, TL)
Carrying Place	SR 8801	359	3, 5, 10, 16	3, 5, 10, 16	All (EL, HL, JL, TL)
Brighton	SR 8801	472	3, 5, 10, 16	3, 5, 10, 16	All (EL, HL, JL, TL)
Lily Bay	SR 8801	355	3, 5, 10, 15	3, 5, 10, 15	All (EL, HL, JL, TL)
West Forks	SR 9004	232	6, 10 ,15	2, 5, 6, 10,15	Hybrid
Hartland	TI 9802	900	3, 5, 10	1, 2, 3, 5, 10	Hybrid
Hartland	TI 9801	900	3, 5	1, 2, 3, 5	Hybrid
North Anson	SR 9004	194	6, 10 ,15	2, 5, 6, 10,15	Hybrid

Table 1. Experimental Larch Plantation Stands Observation Summary

Missing height and DBH observations were filled with stochastic regression imputation using age, species, and stand, as predictors, along with DBH or height, respectively, if available. Any height and DBH observations, true or imputed, which were zero or less were reset to 0.0001 feet or inches, respectively. Any height observations, true or imputed, which were shorter than 54” had their DBH set to 0.0001 inches. This is summarized by the two equations below.

$$Height^* = \begin{cases} Height\ if\ Height\ is\ recorded \\ \min(E[Height|DBH, Age,\ Species,\ Unit] + \varepsilon_{DBH},\ 0.0001)\ if\ DBH\ is\ recorded \\ \min(E[Height|Age,\ Species,\ Unit] + \varepsilon,\ 0.0001)\ otherwise \end{cases}$$

$$DBH^* = \begin{cases} DBH\ if\ DBH\ is\ recorded \\ \min\left(E[DBH|Height, Age,\ Species,\ Unit] + \varepsilon_{Hgt},\ 0.0001\right) if\ Height \geq 54"\ is\ recorded \\ 0.0001\ \ if\ Height < 54"\ is\ recorded\ or\ predicted \\ \min\left(E[DBH|Age,\ Species,\ Unit] + \varepsilon,\ 0.0001\right)\ otherwise \end{cases}$$

METHODS

Stand Properties and Yield Calculations

With our data completed, we make some operational assumptions to facilitate our analysis. Namely, larch trees are marketed primarily as sawlogs and biomass. We include a pulp valuation at the end in order to compare a strong pulp market scenario. Biomass stems may be cut to a 3.5 inch top (*bioDSE*), sawlog stems to a 9 inch top (*sawDSE*). To calculate volume, we treat all stems as perfect paraboloids. Larch weighs roughly 0.024 tons/ft^3, and we roughly follow the -3/2 log-log self-thinning rule (personal Correspondence, Dave Maass). Using these assumptions, we calculate diameter along the tree (including diameter at the large end, *DLE*, computed at ground level, *hgt* = 0), production (biomass and sawlog) heights, basal area, and trees per acre for each observation. These equations are presented below.

$$Diameter\ at\ hgt,\ \ Dia = \frac{DBH}{\sqrt{1-\frac{DBH.Hgt}{Hgt}}} * \sqrt{1-\frac{hgt}{Hgt}}$$

$Production\ Heights,$

$$Saw.Hgt = Hgt * (1 - (\frac{sawDSE}{DLE})^2),\ \ Bio.Hgt = Hgt * (1 - (\frac{bioDSE}{DLE})^2)$$

$$Parabolic\ Volume,\ \ Vol = \ \frac{\pi}{2} * Bio.Hgt * \left(\frac{DLE}{12*2}\right)^2$$

$$Basal\ Area,\ \ BA = \pi * \left(\frac{DLE}{12*2}\right)^2$$

$$Trees\ per\ Acre,\ \ TPA = \ \left(\frac{1237.7}{BA}\right)^{1/1.343}$$

Using the maximum saw production height, we calculate the number of 16-, 12- and 8 foot logs (with 6 inches of trim) we might cut and the height along the stem where they are cut (Figure 1). The diameter equation calculates the diameter at the small end of each log and, combined with the logs length, we can easily estimate board footage using the International ¼”

Rule. We then reduce this estimate by 10% to account for unusable cull and other anticipated losses.

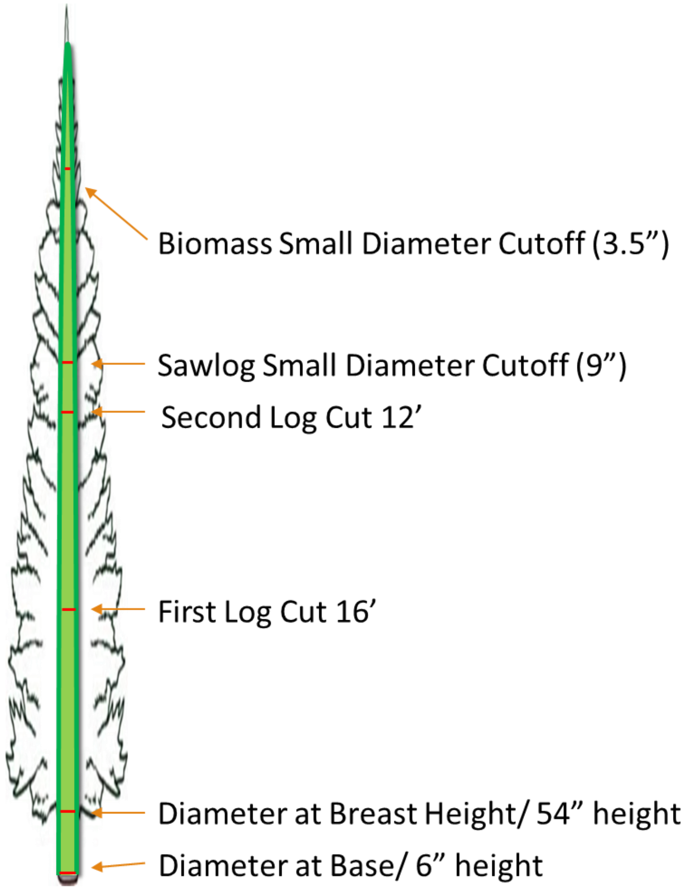

Figure 1. An example of how larch stems are broken into logs for a tree with sufficient base diameter.

We calculate the available biomass after sawlogs through simple subtraction:

$$Biomass(ft^3) = Volume(ft^3) - IntBF * \frac{1\ ft^3}{6\ BF}$$

We use six board feet per cubic foot to account for waste generated during sawing. This contrasts with the standard definition (twelve board feet per cubic foot), which generates a liberal estimate of biomass stumpage. While it is possible for sawmills to reclaim much of the biomass lost to sawlogs, any value this biomass has is lost in saw stumpage for the landowner. Thus, the estimate of total biomass produced should be conservative, but represents an estimate of how much biomass the landowner is compensated for. However, due to the relative value of biomass and sawlogs, the effect of these different board footage definitions on stand value is minimal and diminishing as the stand moves into sawlogs (<5% reduction in value for stands yielding >1 MBF).

Finally, summary results are generated for hypothetical stands on a per acre basis for each species from 1 to 20 years old: quadratic mean diameter, height, MBF of sawlogs, and tons of biomass. We then regress (using weighted least squares) each of these responses on the species and age alone, allowing for higher order terms and interactions, to generate the final predictive yield equations. These equations (see Appendix A) are then used to predict biomass and sawlog yields for the four larch varieties from ages 1 to 30. Due to the lack of later age data, predictions beyond year 20 have relatively large variances in contrast to estimates for before age 20. Similarly, all the larch varieties show no signs of decline in growth within the available data. This makes computing the age of peak MAI impossible.

Economic Valuation of Novel Species Markets

Given the 'exotic' nature of the species examined here, we have no previous price data for Larch in Maine markets. Tamarack, Maine's native, is sold locally, but rather irregularly and without recorded prices. To overcome this, we map the four variants to ten species commonly sold Maine based on six physical properties: moisture content (MC), specific gravity (SG, water adjusted density), modulus of rupture (MOR), modulus of elasticity (MOE), compression strength, and hardness. MOR and MOE are particularly important strength properties for NELMA (New England Lumber Manufacturers' Association) certification, required for the wood to be used in construction. In cases where all properties were not available for larch (notably, compression and hardness), only the remaining four or five properties were used for comparison. Using average standardized values of the properties above for 10 merchantable Maine species and the four larch species, drawn from previous studies of larch's physical properties, we find the five nearest neighbor merchantable species for each larch species (nine European, three Japanese, two hybrid, two tamarack; USDA Wood Handbook, 2010; Maine Forest Service Annual Stumpage Report 2015, 2016; Koizumi, Kitagawa, and Hirai, 2008; Chui and MacKinnon-Peters, 1995; Olson, Poletika, and Hicock, 1947). These neighbors are taken as proxies for the larch species sold in Maine markets.

These ten merchantable Maine species fall into five key commercial groups: cedar, white pine, hemlock, spruce/fir, and red pine. For each larch variety, the five top matching species are assigned to the respective commercial species group and the corresponding price is assigned to that larch variety, according to Figure 2. For example, European larch is most similar to Black Spruce, Red Pine, Eastern Hemlock, Red Spruce, and White Spruce. These species are mapped to the spruce/fir, red pine, hemlock, spruce/fir, and spruce/fir groups, respectively. Finally, we estimate the sawlog stumpage price for European larch by taking the average sawlog stumpage price of the matched commercial species; that is, we estimate the expected price of European larch sold in Maine to be

$$\frac{(\$205 + \$71 + \$73 + \$205 + \$205)/\mathrm{MBF}}{5} = \$151.80/\mathrm{MBF}.$$

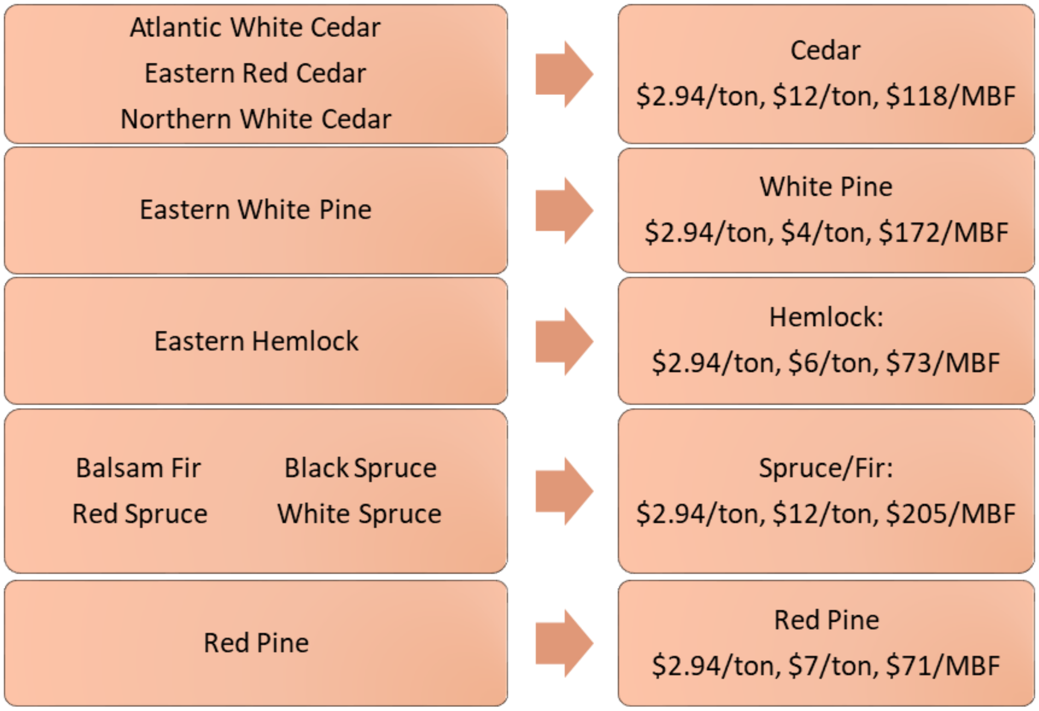

Figure 2: Mapping of Maine species to commercial species groups and associated stumpage prices.

Larch Species	Contributing Maine Merchantable Species Prices (2015)					Average
European Larch	$205 (from spruce/fir)	$71 (from red pine)	$73 (from hemlock)	$205 (from spruce/fir)	$205 (from spruce/fir)	$151.80
Japanese Larch	$118 (from cedar)	$205 (from spruce/fir)	$73 (from hemlock)	$172 (from white pine)	$205 (from spruce/fir)	$154.60
Hybrid Larch	$118 (from cedar)	$118 (from cedar)	$205 (from spruce/fir)	$172 (from white pine)	$205 (from spruce/fir)	$163.60
Tamarack	$205 (from spruce/fir)	$205 (from spruce/fir)	$73 (from hemlock)	$205 (from spruce/fir)	$205 (from spruce-fir)	$178.60

Table 2. Calculation of potential sawlog prices based on k-neighbor of each larch species

A similar process is completed for pulp and for biomass, however the price for biomass in Maine is consistent among species, thereby nullifying the procedure for this end use ($2.94/ton may be applied directly to larch biomass tonnage).

With the final prices for both outputs estimated, we apply them to the quantity estimates, respectively, and sum to calculate the estimated stand value for each species, at each age (again, 1 to 30). The same valuation techniques are applied to unmanaged second growth spruce and fir biomass and sawlog yields (a common makeup in Maine), derived from 90-year spruce and fir volume and sawlog yield curves (Seymour and Hunter, 1992). Initially and after each larch harvest, the stand is replanted for $200 and stand net present values and land expectation values are calculated using a 4% discount rate. We also assume no harvest costs, which favors shorter rotations.

RESULTS

Our analysis of a limited age range of larch suggests that planting and harvesting larch on 30 years rotations is economically viable compared to 'business as usual' in Maine. This is largely due to the production of sawlogs beginning as early as 15-16 years and showing no signs of slowly during our study period. We find that planted, fast-growing larch has a higher net present value at all ages, given our assumptions, than either white spruce or balsam fir as they are commonly managed in Maine, except on the best sites (Figure 3). In repeated rotations, larch is even more favorable due to its early sawlog growth and short rotations. Generally, shorter rotations look even more favorable since we do not include harvest costs (Figure 4). The meta-analysis of larch structural properties suggests that larch lumber is most like spruce and fir lumber, with some similarity to cedar, hemlock, and pine, depending on the variety. If pulp markets are strong and some or the biomass may be sold as pulp, the stand has additional value from this higher priced product. Additional net present value added from pulp sales range from $150 to $450, depending on species and age. The value of the pulp wood component rapidly increases during the teen years, peaking in the early- to mid-twenties before beginning to decline (Figure 5).

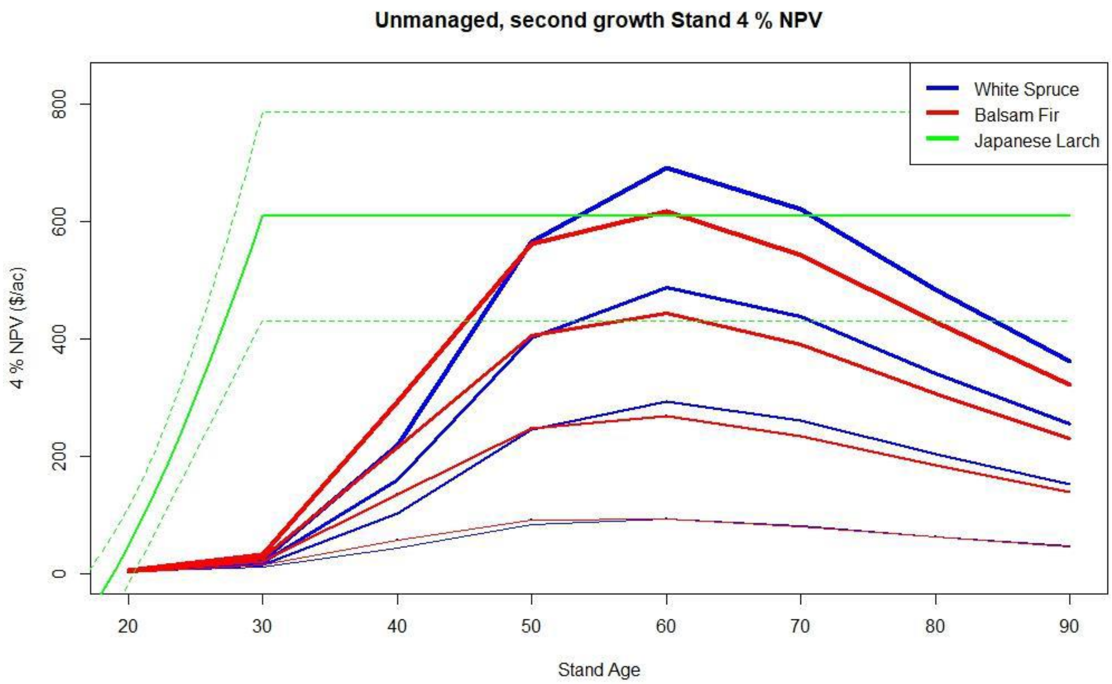

Figure 3: Plot of predicted returns for a single rotation of Japanese larch versus Spruce and Fir on sites of differing qualities. Spruce and fir site indices increases with line width.

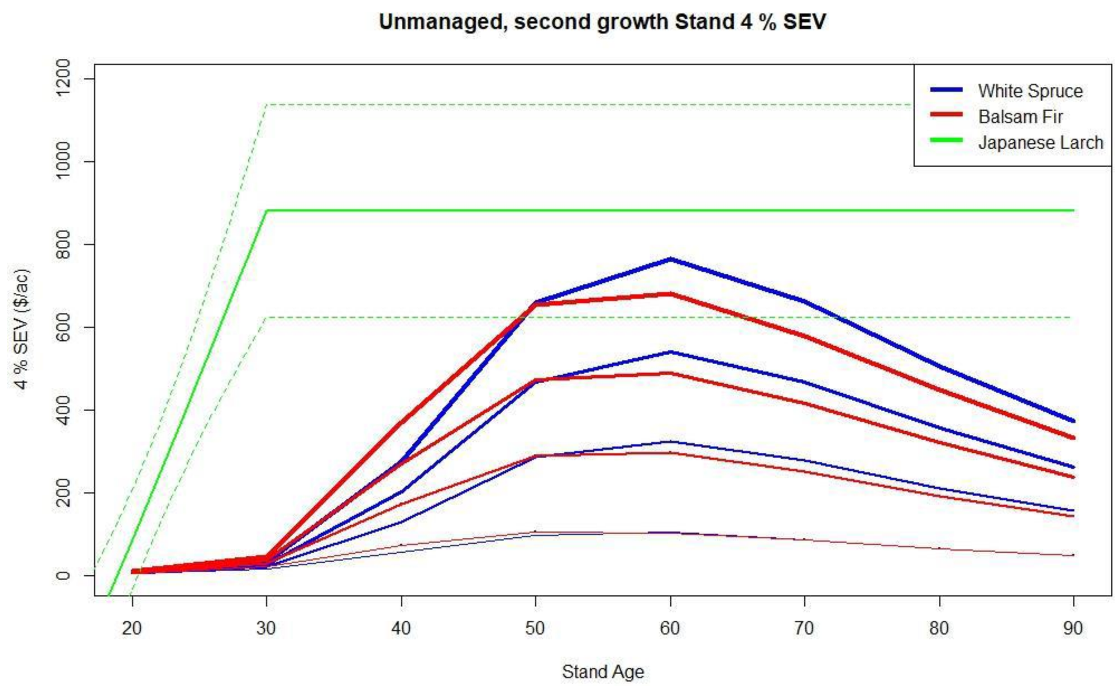

Figure 4: Predicted returns for a single rotation of Japanese larch versus Spruce and Fir on sites of differing qualities. Spruce and fir site indices increases with line width.

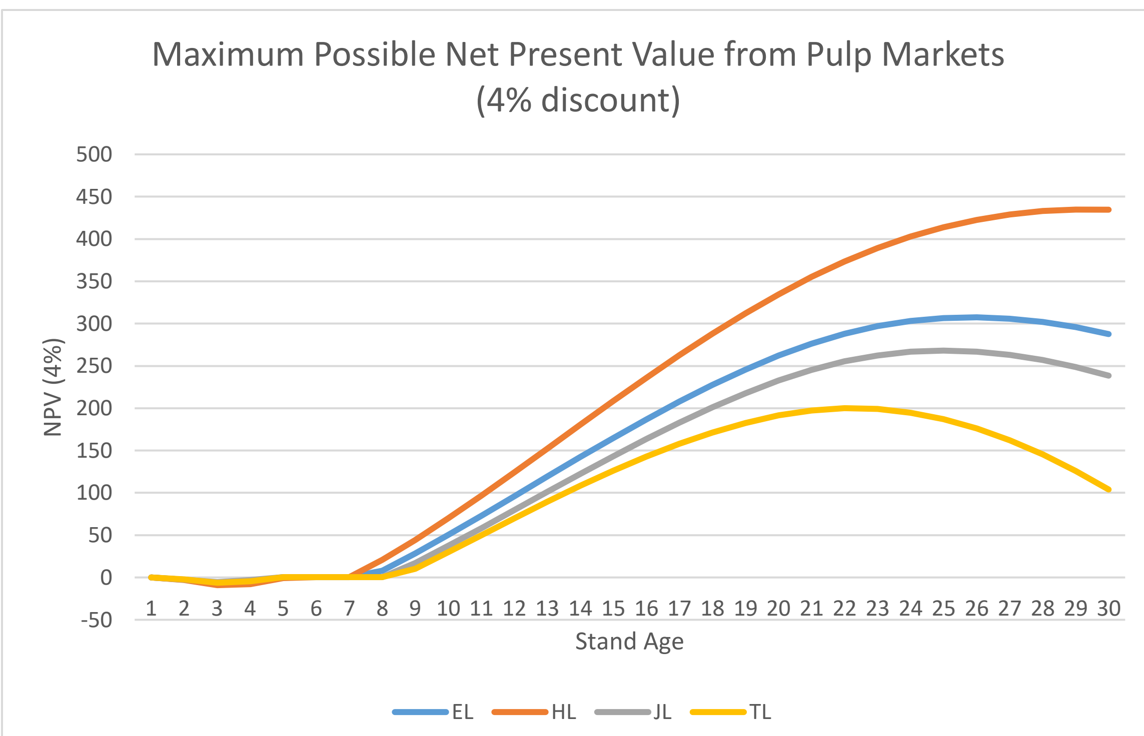

Figure 5: Predicted returns for pulp value in larch stands near viable pulp markets

DISCUSSION

Larch grow quite quickly, giving them a substantial advantage in an area like Maine where the predominant reforestation, natural regeneration, is slow. We estimate that larch grow in height around 2.9 ft/yr. The hybrid varieties grow, on average, an additional 0.4 feet/yr while the Maine native, Tamarack, lags by 0.6 ft/yr. While the relationship is nonlinear, larches add about 0.16” DBH per foot of height or roughly 0.47” DBH each year. The primary advantage of this physical characteristic is early production of sawlogs compared to typical New England rotation lengths. Some amount of sawlogs may be produced by age 18 (at least 1 MBF/ac) on high quality hybrid/exotic sites with an expected maximum five-year lag for poorer sites. We did not have enough data to calculate the ideal financial rotation, however the early emergence of larch sawlogs generates good returns before 30 years and simply reinvesting these returns is competitive. Further value may be extracted from the stand through pre-commercial thinning or mortality recovery and through use of larch as a nurse crop. To verify the estimated value of larch, it will be important to verify the structural properties of larch lumber. Our preliminary results suggest that it is structurally comparable to spruce/fir lumber, a common structural lumber; however, this must be verified by the ASTM before the lumber may be brought to major markets.

LITERATURE CITED

Chui, Y.H., and G. MacKinnon-Peters. 1995. Wood properties of exotic larch grown in eastern Canada and north-eastern United States. *The Forestry Chronicle*, 71(5), pp. 639-646.

Einspahr, D.W., G.W. Wyckoff, and M. (Harder) Fiscus. 1984. Larch - A Fast-Growing Fiber Source For the Lake States and Northeast. Journal of Forestry.

Forest Products Laboratory. 2010. Wood handbook—Wood as an engineering material. General Technical Report FPL-GTR-190. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 508 p.

Koizumi, A., M. Kitagawa, and T. Hirai. 2008. Effects of growth ring parameters on mechanical properties of Japanese larch (Larix kaempferi) from various provenances. *Eurasian Journal of Forest Research*, 8(2), pp. 85-90.

Maine Forest Service. 2015. Annual Stumpage Report 2015. http://www.maine.gov/dacf/mfs/publications/annual_reports.html. Accessed 2017 March 31.

Olson, A.R., N.V. Poletika, and H.W. Hicock. 1947. Strength Properties of Plantation Grown Coniferous woods. *Connecticut Experiment Station*, Bulletin 51.

Seymour, R.S., and M.L. Hunter Jr. 1992. New forestry in eastern spruce-fir forests: Principles and applications to Maine. Maine Agricultural and Forest Experiment Station Miscellaneous Publication 716.

Root, Kenneth A., Park, Rosemarie J. 2016. Surviving job loss: papermakers in Maine and Minnesota. Kalamazoo, Mich. W.E. Upjohn Institute for Employment Research. WE focus. ISBN 9780880995085.

Wheeler, D.E. 1987. A reevaluation of the -3/2 Power Rule of Plant Self-Thinning. *Ecological Monographs*, 57(1), pp. 23-43.

APPENDIX A

```
Call:
lm(formula = powertrans(QMD.est, 1) ~ sqrt(AGE) * SP, data = QMD.estim,
   weights = yield.wgts[, 4])

Weighted Residuals:
   Min      1Q  Median      3Q     Max
-39.209  -5.075  -0.730   4.104  48.887

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)    -3.11581    0.24610 -12.661  < 2e-16 ***
sqrt(AGE)       2.43460    0.08360  29.123  < 2e-16 ***
SPHL           -0.22936    0.28480  -0.805  0.42148
SPJL           -0.04107    0.41382  -0.099  0.92103
SPTL            0.74203    0.38114   1.947  0.05279 .
sqrt(AGE):SPHL  0.04141    0.09674   0.428  0.66903
sqrt(AGE):SPJL  0.03666    0.14057   0.261  0.79447
sqrt(AGE):SPTL -0.42241    0.12947  -3.263  0.00127 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 9.867 on 226 degrees of freedom
  (54 observations deleted due to missingness)
Multiple R-squared:  0.9505,	Adjusted R-squared:  0.9489
F-statistic: 619.4 on 7 and 226 DF,  p-value: < 2.2e-16
```

```
Call:
lm(formula = powertrans(HGT.est, 1) ~ AGE * SP, data = HGT.estim,
   weights = yield.wgts[, 4])

Weighted Residuals:
    Min       1Q   Median       3Q      Max
-111.799  -22.358  -10.190    3.865  146.481

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -2.50627    0.52198  -4.801 2.87e-06 ***
AGE          2.86377    0.04819  59.429  < 2e-16 ***
SPHL        -1.29491    0.60407  -2.144   0.0331 *
SPJL         0.51369    0.87772   0.585   0.5590
SPTL         3.31788    0.80840   4.104 5.67e-05 ***
AGE:SPHL     0.43144    0.05577   7.737 3.36e-13 ***
AGE:SPJL    -0.04204    0.08103  -0.519   0.6044
AGE:SPTL    -0.63022    0.07463  -8.445 3.72e-15 ***
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Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 31.77 on 226 degrees of freedom
  (54 observations deleted due to missingness)
Multiple R-squared:  0.9893,	Adjusted R-squared:  0.989
F-statistic:  2982 on 7 and 226 DF,  p-value: < 2.2e-16
```

```
Call:
lm(formula = powertrans(IntMBFyield, saw.lam) ~ AGE * I(AGE^2) *
    SP, data = Saw.Yield, weights = yield.wgts[, 4])

Weighted Residuals:
     Min       1Q   Median       3Q      Max
-12.9592  -0.5785  -0.1021   0.1528  30.8541

Coefficients:
                    Estimate Std. Error t value Pr(>|t|)
(Intercept)       -0.2080376  0.1406840  -1.479  0.14065
AGE                0.1703345  0.0635794   2.679  0.00795 **
I(AGE^2)          -0.0290474  0.0070834  -4.101 5.81e-05 ***
SPHL               0.0303764  0.1628089   0.187  0.85217
SPJL              -0.0463496  0.2365616  -0.196  0.84485
SPTL               0.2122164  0.2178802   0.974  0.33113
AGE:I(AGE^2)       0.0012445  0.0002228   5.587 6.85e-08 ***
AGE:SPHL          -0.0265168  0.0735782  -0.360  0.71890
AGE:SPJL           0.0352219  0.1069093   0.329  0.74213
AGE:SPTL          -0.1666090  0.0984666  -1.692  0.09207 .
I(AGE^2):SPHL      0.0045034  0.0081973   0.549  0.58331
I(AGE^2):SPJL     -0.0059710  0.0119108  -0.501  0.61666
I(AGE^2):SPTL      0.0287107  0.0109702   2.617  0.00949 **
AGE:I(AGE^2):SPHL -0.0001925  0.0002578  -0.747  0.45594
AGE:I(AGE^2):SPJL  0.0002539  0.0003746   0.678  0.49857
AGE:I(AGE^2):SPTL -0.0012359  0.0003450  -3.582  0.00042 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.961 on 218 degrees of freedom
  (54 observations deleted due to missingness)
Multiple R-squared:  0.7372,	Adjusted R-squared:  0.7191
F-statistic: 40.76 on 15 and 218 DF,  p-value: < 2.2e-16
```

```
Call:
lm(formula = powertrans(Biomass.ft3, bio.lam) ~ AGE + I(AGE^2) +
   SP + AGE:I(AGE^2) + AGE:SP + I(AGE^2):SP, data = Bio.Yield,
   weights = yield.wgts[, 4])

Weighted Residuals:
    Min      1Q   Median      3Q     Max
-12574.8   -859.2   -122.8   466.6  10646.7

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)    174.45076   67.13636   2.598  0.00999 **
AGE           -144.21759   22.78383  -6.330 1.35e-09 ***
I(AGE^2)        24.63511    2.05518  11.987  < 2e-16 ***
SPHL            44.11606   71.00198   0.621  0.53502
SPJL           -21.77416  103.16604  -0.211  0.83304
SPTL           -22.74114   95.01893  -0.239  0.81107
AGE:I(AGE^2)    -0.42496    0.06062  -7.011 2.85e-11 ***
AGE:SPHL       -26.98343   19.08510  -1.414  0.15881
AGE:SPJL         9.79375   27.73069   0.353  0.72429
AGE:SPTL        22.51809   25.54077   0.882  0.37892
I(AGE^2):SPHL    2.53357    0.91791   2.760  0.00626 **
I(AGE^2):SPJL   -0.42450    1.33372  -0.318  0.75057
I(AGE^2):SPTL   -3.79829    1.22840  -3.092  0.00224 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 2460 on 221 degrees of freedom
  (54 observations deleted due to missingness)
Multiple R-squared:  0.9872,	Adjusted R-squared:  0.9865
F-statistic:  1418 on 12 and 221 DF,  p-value: < 2.2e-16
```