VALUATION OF LOBLOLLY PINE PLANTING DENSITY, CULTURAL INTENSITY, AND THINNING SCENARIOS FOR TRADITIONAL TIMBER PRODUCTS USING CONVENTIONAL DISCOUNTED CASH FLOW AND REAL OPTIONS APPROACHES

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Introduction

- 32 million acres of pine plantations in the southeastern U.S. (Schultz, 1997).
- Loblolly pine (Pinus taeda L.) is a premier species in the southeastern U.S. for its commercial success and ecological significance.
- Traditional timber products (pulp, chip-n-saw, and sawtimber) major driver.
- Optimal return is dependent on site quality, planting density, cultural intensity, and thinning regime.
- Price uncertainties create value and an appropriate forest valuation model is required to capture such value.

Net Present Value (NPV) & Real Option Analysis (ROA)

- NPV is a classical stand valuation approach: >$0 invest.
- Real options is the right but the not obligation to invest in a project of real assets.
- The ROA takes advantage of large upside gain and abandon the project if downside (larger cost) is realized.
- The expected value increases as the uncertainty (potential upside) surrounding the underlying asset increases (Jacobsen and Thorsen, 2003).
- ROA should be taken as a complement not a substitute of static NPV (Luehrman, 1998).

Objectives

- Evaluate financial return of traditional forest products from different plantation regimes using NPV and ROA approaches.
- Identify optimum plantation regimes for different site classes and product mixes.
- Identify advantages and limitations of NPV and ROA approaches.

Materials and Methods

Mensurational and Financial

Mensurational - Major Data	
Data type	Tree level data
Plantation year	1996
Inventory dates	2, 4, 6, 8, 10, 12, 15, 16, 17, and 18
Planting densities (Trees per acre – TPA)	300, 600, 900, 1200, 1500, and 1800

Growth and Yield Projection
SiMS from age 18 for non-thinned stands.
SiMS from thinning age determined by thinning criteria.

Thinning Criteria	
Quadratic Mean Diameter	>= 6”
Basal area (BA)	>= 120 ft^2/ac
Dominant height	>=40 ft
Residual BA	75 ft^2/ac

Materials and Methods

- Cultural intensities: intensive and operational
  - Operational – Vegetation control at planting and less fertilizations (≈ average of 50 lbs/ac/yr of N).
  - Intensive – Complete and sustained vegetation control and more frequent fertilizations (≈ average of 100 lbs/ac/yr of N).
- Productivity levels: 3 (Lower Coastal Plain)
  - High site (installation 1) – 97 (site index) --Baker Co., FL
  - Medium site (installation 16) – 83 (site index) --Clinch Co., GA
  - Low site (installation 11) – 61 (site index) --Nassau Co., FL
- An "average site" was calculated from data from three sites to represent average condition.
- These three sites provide case studies for a range of sites in the Lower Coastal Plains.

Pienaar et al. (1987) equations were used for different products (over bark).

Product	DBH Limit	Top Dia. Limit
Pulpwood	4.5 inch – 8.4 inch	3 inch
Chip-n-saw	8.5 inch – 11.4 inch	6 inch
Sawtimber	>= 11.5 inch	8 inch

Financial Analysis

- Quarterly price time series data from Timber Mart South:1st Q. of 1986 to 4th Q. of 2014.
- Time series data was tested for stationarity using Augmented Dickey Fuller (ADF) test found non-stationary series (SAS 9.4) at 5% level of significance.
- Geometric Brownian Motion (GBM) was employed to forecast future prices beyond 2014 using historical drift rate and volatility (annualized).

$$d\,P_t = \alpha\,P_t\,dt + \sigma\,P_t\,dz$$

Where Pt is commodity price with a drift rate of α and variance rate of σ^2 (σ = standard deviation), dz is the standard wiener process of a Brownian motion.

- Annualized drift rate and standard deviation (volatility) along with RMSE is reported.

	Pulp	Chip-n-saw	Sawtimber
Drift	0.012	-0.007	-0.011
Standard Deviation	0.156	0.123	0.121
RMSE	0.633	1.279	2.006

- Interest rate: 5% risk-free.
- All values are pretax dollar; annual cost assumed to be offset by hunting lease.

Formula for Black-Scholes Model

$$V_{ROA} = S_t * N(d1) - ET_{pv} * N(d2)$$

And $St = Vt * Pt$

Where

V_{ROA}= Expected value of a stand or value of a call

St = PV of the asset; Vt = volume at time t; Pt = price at time t.

ET_{PV} = cumulative present value of cost. Also called exercise price.

r = real risk free interest rate

$d1 = \frac{\ln\left[\frac{Pt}{ETpv}\right]}{\sigma\sqrt{T}} + \frac{\sigma\sqrt{T}}{2}$ $\quad$ $d2 = d_1 - \sigma\sqrt{T}$ $\quad$ $ET_{PV} = \sum_{t=0}^{T}\left(\frac{ET_{(T-t)}}{e^{r(T-t)}}\right) + \frac{Et}{e^{rt}}$

N(d1) and N(d2) are risk adjusted probability factors σ = annualized price volatility

Discounted Cash Flow Techniques

$$\text{NPV} = \sum_{t=0}^{T} Rt * \exp^{(-\text{r}t)} - \sum_{t=0}^{T} Ct * \exp^{(-\text{rt})}$$

NPV = net present value

Rt = Total value of the asset at time t, and Ct is the total cost at time t

r= required rate of return

T = rotation age

Equivalent Annual Annuity (EAA)

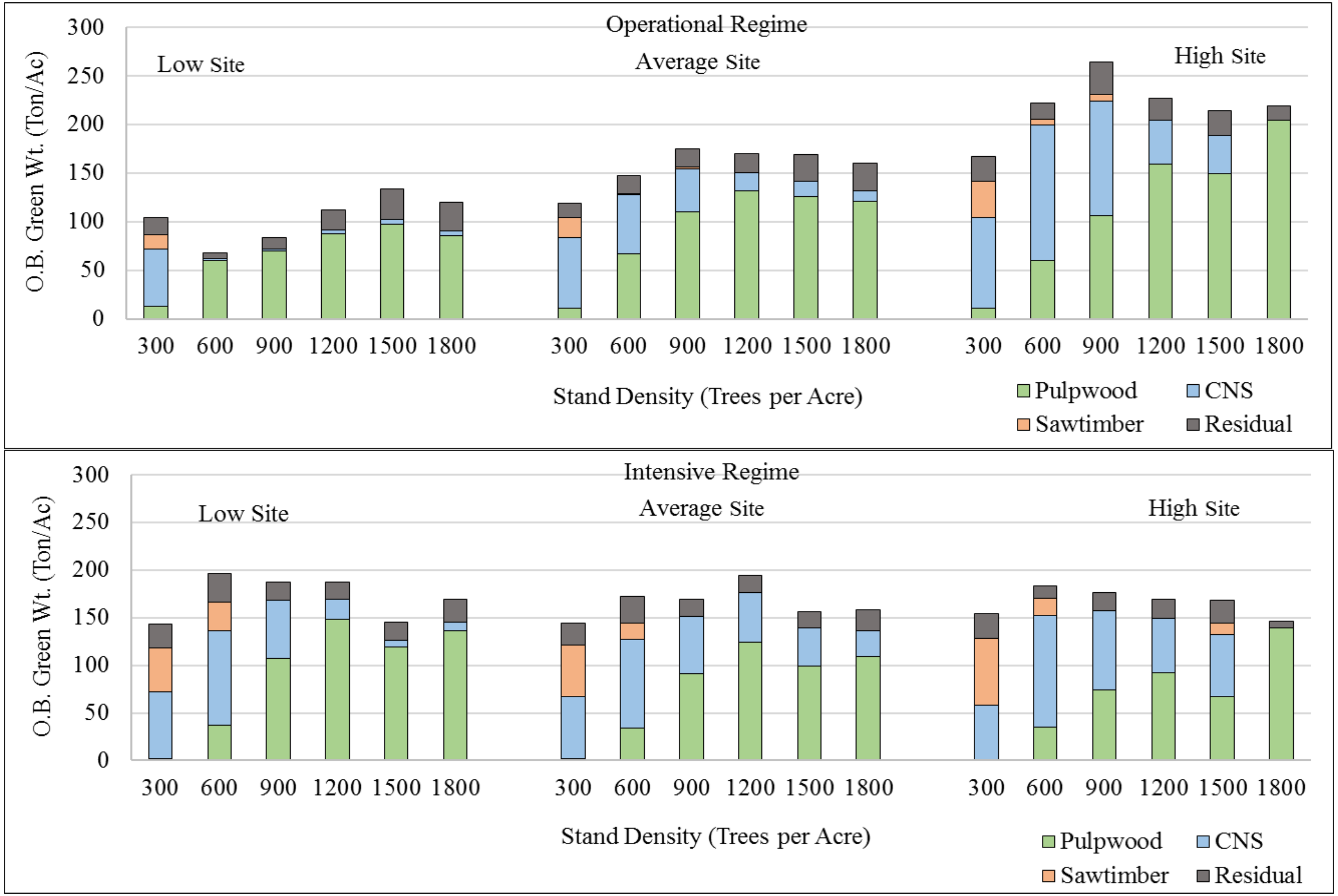
$$\text{EAA}_{\text{ROA}} = \frac{\text{r}*\text{V}_{\text{ROA}}}{1-\text{Exp}^{(-\text{rT})}} \qquad \text{EAA}_{\text{NPV}} = \frac{\text{r}*\text{NPV}}{1-\text{Exp}^{(-\text{rT})}}$$

RESULTS

Tree and stand attributes for 18-year non-thinned loblolly pine plantations located in the Lower Coastal Plain of Florida and Georgia on different sites for operational and intensive culture and varying planting densities.

	Operational Regime					Intensive Regime				
Planting Density (TPA)	Mean Dominant Height (ft)	QMD (in)	BA (ft^2/ac)	Merch Green Weight MAI (ton/ac)	Total Green MAI (tons/ac)	Mean Dominant height (ft)	QMD (in)	BA (ft^2/ac)	Merchantable Green Weight MAI (ton/ac)	Total Green MAI (tons/ac)
Low Site										
300	66	9.8	125	5.4	5.8	74	10.8	158	6.7	7.9
600	47	6.6	117	3.4	3.8	80	9.5	190	9.0	10.9
900	52	6.1	127	4.1	4.6	73	7.8	190	9.5	10.4
1200	56	5.5	157	5.3	6.2	68	6.7	202	9.7	10.4
1500	56	5.3	183	5.8	7.5	60	6.1	188	7.3	8.1
1800	56	5.1	163	5.0	6.7	66	6.0	199	8.3	9.4
Average Site										
300	71	9.7	133	5.8	6.8	77	10.9	147	6.7	8.0
600	66	7.6	159	7.2	8.2	78	9.1	166	8.0	9.6
900	68	6.9	185	8.7	9.8	75	7.9	171	8.4	9.4
1200	65	6.2	195	8.4	9.5	74	7.4	195	9.8	10.8
1500	65	5.8	192	7.9	9.4	69	7.0	174	7.7	8.7
1800	64	5.6	183	7.3	8.9	67	6.4	180	7.6	8.7
High Site										
300	82	10.6	154	7.4	9.3	84	11.4	142	7.2	8.6
600	83	8.8	197	10.7	12.4	85	9.3	161	8.9	10.2
900	86	8.2	229	13.0	14.7	82	8.5	157	8.4	9.8
1200	75	7.1	223	11.6	12.6	77	7.9	159	8.6	9.4
1500	77	6.6	208	10.9	12.3	78	8.1	159	8.3	9.4
1800	77	6.7	208	11.1	12.3	77	7.2	141	7.2	8.1

Stem O.B. green weight allocated to pulpwood, chin-n-saw, sawtimber, and residuals at age 18 by management intensity, for three sites and varying planting densities for loblolly pine plantations in the LCP of GA and FL.



Economic returns & optimal rotation ages for the **no-thin scenario** for varying site classes and planting densities for the **operational and intensive culture regime** for loblolly pine plantations in the LCP of GA and FL.

	Operational Regime					Intensive Regime				
Planting Density (TPA)	Optimal Rotation Age	ROA	NPV	EAA_{ROA}	EAA_{NPV}	Optimal Rotation Age	ROA	NPV	EAA_{ROA}	EAA_{NPV}
Low site										
300	22	$409	$387	$31	$29	$22	$436	$329	$33	$25
600	22	$0	($105)	$0	($8)	$24	$568	$471	$41	$34
900	22	$0	($69)	$0	($5)	$22	$318	$156	$24	$12
1200	22	$0	($4)	$0	($0)	$22	$222	$2	$17	$0
1500	26	$135	$1	$9	$0	$22	$0	($262)	$0	($20)
1800	26	$0	($66)	$0	($5)	$22	$0	($196)	$0	($15)
Average Site										
300	24	$509	$491	$36	$35	$24	$486	$380	$35	$27
600	24	$433	$405	$31	$29	$24	$434	$306	$31	$22
900	24	$465	$434	$33	$31	$24	$284	$95	$20	$7
1200	22	$338	$291	$25	$22	$22	$298	$118	$22	$9
1500	22	$290	$226	$22	$17	$22	$0	($121)	$0	($9)
1800	26	$239	$138	$16	$9	$26	$0	($191)	$0	($13)
High site										
300	24	$858	$852	$61	$61	$24	$627	$546	$45	$39
600	24	$944	$938	$68	$67	$24	$586	$492	$42	$35
900	24	$1,031	$1,024	$74	$73	$24	$380	$228	$27	$16
1200	22	$647	$628	$48	$47	$24	$272	$64	$19	$5
1500	22	$578	$552	$43	$41	$24	$279	$63	$20	$5
1800	22	$519	$483	$39	$36	$24	$0	($111)	$0	($8)

Key Results – No Thin Scenario

- Optimum rotation age was not highly influenced by planting densities; however, slight rotation age differences were observed.
- Optimum rotation age ranged from 22 to 26 and averaged 24 years.
- Lower densities (300 and 600) preferred for operational culture.
- Up to 900 TPA density preferred for operational culture.
- Greater response due to intensive culture on low site.
- The return from the high site negatively impacted by intensive culture.

Economic returns & optimal rotation ages for the **one-thin and two-thin scenario** for varying site classes and planting densities for the **operational culture regime** for loblolly pine plantations in the LCP of GA and FL.

Planting Density (TPA)	One Thin: Optimal Rotation Age	One Thin: ROA	One Thin: NPV	One Thin: EAA_{ROA}	One Thin: EAA_{NPV}	Two Thin: Optimal Rotation Age	Two Thin: ROA	Two Thin: NPV	Two Thin: EAA_{ROA}	Two Thin: EAA_{NPV}
Low site										
300	26	$491	$470	$34	$32	34	$560	$533	$34	$33
600	29	$0	($3)	$0	($0)	36	$351	$100	$21	$6
900	29	$154	$48	$10	$3	36	$217	$114	$13	$7
1200	33	$275	$185	$17	$11	38	$337	$249	$20	$15
1500	33	$319	$230	$20	$14	38	$377	$288	$22	$17
1800	33	$242	$120	$15	$7	38	$375	$319	$22	$19
Average Site										
300	24	$559	$545	$40	$39	29	$630	$612	$41	$40
600	26	$539	$517	$37	$36	29	$650	$630	$42	$41
900	26	$572	$547	$39	$38	32	$674	$646	$42	$40
1200	29	$526	$486	$34	$32	33	$623	$584	$39	$36
1500	29	$463	$411	$30	$27	35	$551	$495	$33	$30
1800	29	$388	$316	$25	$21	39	$500	$416	$29	$24
High site										
300	24	$1,108	$1,105	$79	$79	26	$1,185	$1,182	$81	$81
600	24	$1,153	$1,149	$82	$82	26	$1,193	$1,189	$82	$82
900	24	$1,375	$1,372	$98	$98	26	$1,405	$1,402	$97	$96
1200	26	$932	$920	$64	$63	29	$1,074	$1,062	$70	$69
1500	29	$948	$929	$62	$61	29	$1,088	$1,074	$71	$70
1800	29	$851	$825	$56	$54	30	$968	$945	$62	$61

Economic returns & optimal rotation ages for the **one-thin and two-thin scenario** for varying site classes and planting densities for the **intensive culture regime** for loblolly pine in the LCP of GA and FL.

Planting Density (TPA)	Optimal Rotation Age	One Thin ROA	One Thin NPV	One Thin EAA_{ROA}	One Thin EAA_{NPV}	Optimal Rotation Age	Two Thin ROA	Two Thin NPV	Two Thin EAA_{ROA}	Two Thin EAA_{NPV}
Low Site										
300	24	$629	$572	$45	$41	26	$718	$664	$49	$46
600	22	$956	$927	$72	$69	24	$1,267	$997	$91	$71
900	22	$714	$662	$53	$50	24	$843	$796	$60	$57
1200	26	$457	$339	$31	$23	29	$581	$475	$38	$31
1500	29	$257	$43	$17	$3	29	$336	$156	$22	$10
1800	29	$308	$104	$20	$7	33	$415	$229	$26	$14
Average Site										
300	24	$594	$532	$42	$38	25	$646	$587	$45	$41
600	24	$928	$892	$66	$64	24	$1,009	$977	$72	$70
900	24	$703	$642	$50	$46	26	$780	$720	$54	$49
1200	26	$553	$455	$38	$31	26	$646	$564	$44	$39
1500	29	$363	$193	$24	$13	30	$461	$314	$30	$20
1800	29	$340	$149	$22	$10	30	$413	$242	$27	$16
High Site										
300	24	$962	$932	$69	$67	26	$892	$852	$61	$59
600	24	$1,124	$1,098	$80	$79	24	$1,148	$1,123	$82	$80
900	24	$997	$961	$71	$69	26	$1,122	$1,087	$77	$75
1200	26	$678	$600	$47	$41	26	$756	$688	$52	$47
1500	24	$741	$673	$53	$48	29	$849	$773	$55	$50
1800	26	$445	$306	$31	$21	26	$561	$433	$39	$30

Key Results – Thinning Scenarios

- Optimum rotation age was highly influenced by planting densities due to thinning.
- Optimum rotation age ranged from 24 to 39 on all sites for both thinning scenarios - operational culture.
- Optimum rotation age reduced (22 to 33) on all sites for both thinning scenarios – intensive culture.
- Greater response due to intensive culture on low site.
- The return from the high site negatively impacted by intensive culture.

No-thinning vs Thinning Return

- The EAA criteria shows that thinning is financially better than no-thinning for the cases in this study.
- Two-thin returns were almost always greater than one-thin, except for the 300 TPA on high site intensive culture regime.
- The return on the 300 TPA with two-thin to one-thin was very marginal compared to other planting densities.
- Two-thin increases the rotation length.

Optimum Economic Regimes

Based on the cases in this study

- Low site
  - Plant 600 TPA. Apply intensive culture. Thin twice.
- Average site
  - Plant 600 TPA. Apply intensive culture. Thin twice.
- High site
  - Plant 900 TPA. Apply operational culture. Thin twice.

NPV vs ROA

- The optimal rotation ages determined by both approaches were identical.
- ROA returns were higher compared to conventional NPV.
- NPV is much easier to understand, calculate and apply in forest valuation.
- ROA (Black and Scholes model) is highly complex compared to NPV, particularly when you consider the assumptions of prices, and Black and Scholes model itself.
- ROA captures the value of price uncertainty and may be a better approach if price volatility is within reasonable range.
- ROA returns were inflated by price volatility – care should be taken where price volatility is exceptionally high.

Questions?

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