GROWTH OF A THINNED WHITE PINE STAND GROWING ON A RECLAIMED SURFACE MINE IN SOUTHWESTERN VIRGINIA

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Abstract

Little information exists on the productive potential of forests growing on reclaimed mined land and the response of these forests to intermediate stand treatments such as thinning. A thinning study was established as a random complete block design to evaluate the response to thinning of a 26-year-old white pine stand growing on a reclaimed surface mine in southwest Virginia. Stand parameters were projected to age 30 using a stand table projection. Site index of the stand was found to be 32.3 m at base age 50 years. Thinning rapidly increased the diameter growth of the residual trees to 0.84 cm yr^{-1} compared to 0.58 cm yr^{-1} for the unthinned treatment; however, at age 26, there was no difference in volume or value per hectare. At age 30, the unthinned treatment had a volume of 457.1 m^3 ha^{-1} but was only worth \$8807 ha^{-1}, while the thinned treatment was projected to have 465.8 m^3 ha^{-1}, which was worth \$11265 ha^{-1} due to a larger percentage of the volume being in sawtimber size classes. These results indicate that commercial forestry is a viable alternative for reclamation of surface mined lands, and that stands growing on reclaimed mined land can respond well to intermediate stand treatments.

Key Words: Reclamation, white pine, thinning, productivity, volume growth.

Introduction

The Appalachian coal-producing region of the eastern United States is predominantly forested prior to surface mining. The process of surface mining removes these forests and the native soils that support them. As these lands were primarily forested prior to mining, a logical post-mining land use would be return of the land to commercial forestry uses. Several cases of viable commercial forests have been documented. For example, Rodrigue and coworkers (2002) found that forests on 13 of the 14 mined sites studied in the eastern and midwestern coal-producing regions were equally or more productive than adjacent non-mined forests. Davidson (1979) found that after 10 years of growth on a surface mine in Pennsylvania, hybrid poplar averaged 25.4 cm in diameter breast height and 19.8 m in height. Annual volume growth in the stand was about 17.9 m^3 ha^{-1} yr^{-1}.

Eastern white pine has been planted extensively on surface mined lands because of its ability to grow rapidly on low-fertility soils that commonly exist after surface mining. Ashby (1996b) found that white pine had an average height of 21 m and an average diameter of 29.0 cm at age 47 on two mined sites in southern Illinois. In a reforestation case study on a surface mine in West Virginia, Torbert and coworkers (1991) found that after five years, white pine height was 2.7 m, which, based on site index curves for white pine in the southern Appalachians, should mean that these trees will reach heights greater than 30.5 m by age 50. These growth rates are comparable to the growth of white pine on native soils in the southern Appalachians (Doolittle, 1958).

Little information is currently available regarding the response of forests growing on surface mined lands to intermediate stand treatments such as thinning. The purpose of this study is to report the productivity and response to thinning in terms of volume and value of a 26-year-old white pine stand located on a surface mine in Wise County, Virginia.

Methods

The study site was a white pine plantation located on a surface mine in Wise County, Virginia, reclaimed prior to the passage of the Surface Mining Control and Reclamation Act of 1977 (SMCRA). Following surface mining of the coal, the overburden rock was simply pushed back across the site, creating a bench and highwall profile. The resulting spoil at this site was a mixture of sandstone, siltstone, and coal-derived materials. The stand was planted in 1978, and in 1996 a thinning study was installed. In 1996, at age 17, the stand contained 1438 stems ha^{-1}, with 30.1 $m^2 ha^{-1}$ of basal area. Three paired blocks of 0.02-ha plots were established in the stand prior to thinning. One plot in each block was randomly selected for thinning, and the basal area was reduced to 20.7 $m^2 ha^{-1}$, leaving a final stand density of 652 stems ha^{-1}. The second plot in each pair was left as a control and was not thinned. All plots were measured in 1996 for total height and diameter at breast height for all living white pines. Five randomly selected dominant or co-dominant trees from each plot were measured annually to evaluate the change in diameter increment due to thinning over time. Height and diameter of all trees in the plots were re-measured in 2004, nine years after the thinning, when the stand was 26 years old.

Site index was calculated based on the average height of trees in the upper quartile of total height to approximate dominant and co-dominant trees using site index equations for white pine in the southern Appalachians (Beck, 1971). Cubic foot volumes to a 10-cm top diameter inside bark (dib) were calculated using volume equations for white pine in the southern Appalachians (Vimmerstedt, 1962). Board foot volumes to a 15-cm top dib were calculated using equations for white pine plantations in southeastern Ohio (Dale et al., 1989). Minimum diameter for sawtimber was set at 30 cm. For pulpwood, cubic meter volumes were converted to cubic foot volumes and then to tons of pulpwood using a conversion factor of 35.9 $ft^3 ton^{-1}$. Stumpage prices for sawtimber and pulpwood (Timber Mart-South, 2004) were applied to stand volume estimates to obtain stand value estimates for thinned and unthinned treatments. Stand parameters measured at age 26 were projected to age 30 using a stand table projection (Avery and Burkhart, 2002). Total tree height at age 30 was predicted from site index equations (Beck, 1971) based on the site index of each tree at age 26.

Data from the 2005 inventory were analyzed for differences in dbh, basal area per hectare, trees per hectare, volume per hectare, volume per tree, proportion of volume in sawtimber, and value per hectare among treatments using a random complete block design with three blocks and two treatments per block. Analysis of variance was used to detect statistically significant differences among treatments. Proportion data were transformed using arcsine transformation prior to analysis of variance. The annual diameter measurements were analyzed using a repeated measures mixed model procedure to test the statistical significance of change in diameter increment with respect to thinning treatment over time. Transformation of the response variable using the natural log function was used to satisfy model assumptions. SAS version 8.2 (SAS Institute, Inc., 2001) was used for all statistical analyses, and significance was set at $P < 0.05$ for all comparisons.

Results and Discussion

Site index for the stand averaged 32.0 m at base age 50 years using equations from Beck (1971) for white pine in the southern Appalachians. This is well above the site index noted by Doolittle (1962), who found average site index for white pine in the southern Appalachians to be 24.4 m at base age 50. Dale and coworkers (1989) reported average site index of white pine in southeastern Ohio to be 23.5. The response to thinning from age 17 to age 26 is shown in Table 1. As expected, total height of the thinned treatment was greater than that of the unthinned treatment for both ages due to the removal of intermediate and suppressed trees from the plots treated with low thinning. Thinning increased dbh by nearly 4.5 cm over the nine years since treatment compared to the unthinned treatment (27.9 cm versus 23.4 cm for these treatments, respectively). The annual diameter increment calculated from the repeated measures data for the thinned treatment was 0.84 cm yr^{-1}, while that for the unthinned treatment was 0.58 cm $yr^{-1,}$ and this difference was significant ($P < 0.0001$) (Fig. 1). Basal area was not significantly different among treatments. Gillespie and Hocker (1986), in a study of white pine thinning response in New England, found that stand basal area was not affected by thinning, but mean diameter increment was significantly greater in the thinned plots. Both treatments have accrued a large amount of basal area (15.6 m^2 ha^{-1} and 12.9 m^2 ha^{-1} for thinned and unthinned, respectively). Comparing the stand density prior to thinning (1438 stems ha^{-1}) with the stand density in the unthinned treatment, it can be seen that substantial mortality has taken place in the unthinned treatment, as there remains only 63% of the original number of trees in the unthinned plots. Low thinning has been shown to decrease competition-induced mortality for white pine in the southern Appalachians (Della-Bianca, 1981). The volume per acre in the thinned treatment was not significantly different compared to the unthinned treatment. Additionally, the volume of the thinned plots is standing volume and does not account for the 94.2 m^3 ha^{-1} removed during the thinning. Individual tree volume was significantly different between treatments at age 26 (P = 0.0327), which is reasonable given the diameter growth response observed.

Table 1. Thinning effects at age 26, nine years after thinning, and projected thinning effects at age 30 for a white pine stand growing on a reclaimed surface mine in southwestern Virginia.

Treatment	DBH (cm)	Total Height (m)	Basal Area (m^2 ha^{-1})	Trees per Hectare	Stand Volume (m^3 ha^{-1})	Volume per Tree (m^3)	Volume in Sawtimber (%)	Value per Hectare ($)
Age 26:								
Thinned	27.9	19.3	36.3	566	289.6	0.52	62	5641
Unthinned	23.4	17.0	42.9	899	312.7	0.35	55	5481
Pr > F	0.018	0.017	0.111	0.044	0.360	0.033	0.514	0.593
Age 30:								
Thinned	33.0	22.1	49.8	566	465.6	0.84	92	11265
Unthinned	26.2	19.7	53.0	899	456.9	0.51	66	8807
Pr > F	0.007	0.018	0.415	0.044	0.796	0.015	0.015	0.008

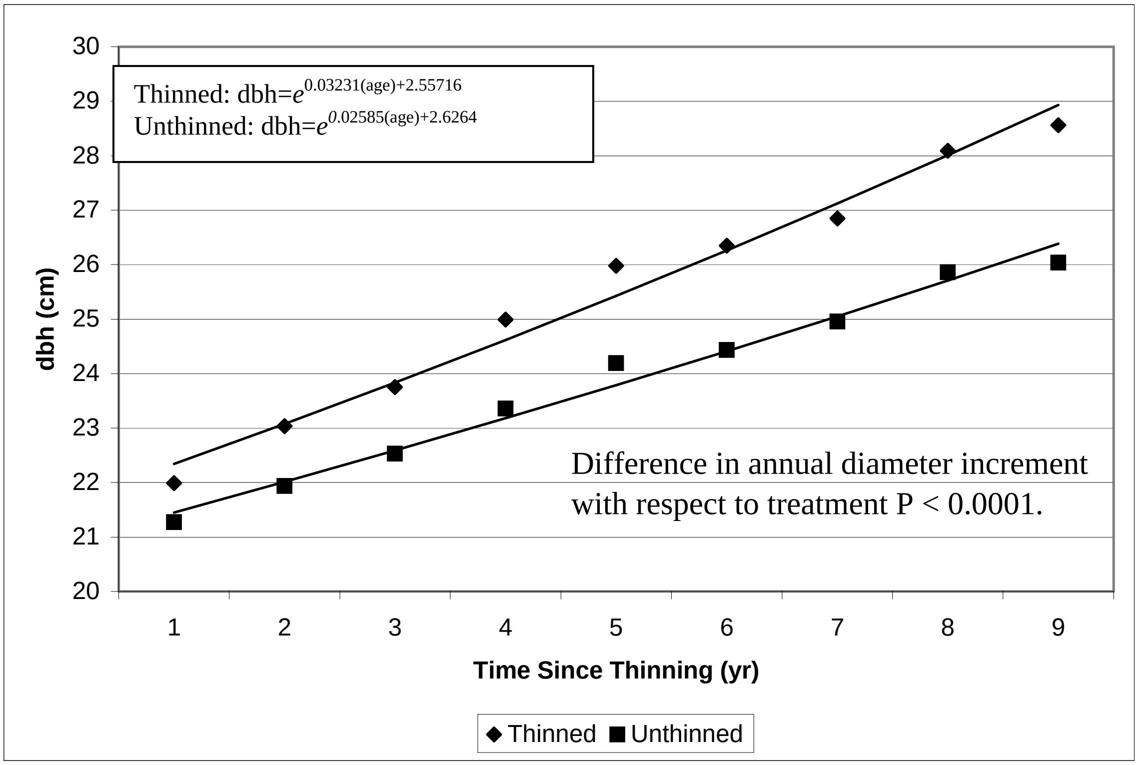

Figure 1. Diameter response to thinning of a 26-year-old white pine stand growing on a reclaimed surface mine site in southwestern Virginia. Horizontal axis represents stand ages 18 – 26.

At age 26, low thinning had not created a significant difference in the proportion of stand volume in the sawtimber size classes compared to the unthinned treatment, but with the continued increased diameter growth rates (Fig. 1), this shift would be expected in the near future. Stand table projection was used to predict the stand parameters at age 30. This projection indicated that there would be nearly a three-inch difference in dbh between the thinned and unthinned treatments, which was statistically significant ($P = 0.0066$) (Table 1). Due to the accelerated diameter growth, stand basal area would be very similar for thinned (49.8 m^2) and unthinned (53.0 m^2) treatments.

At age 30, standing volume in thinned plots was estimated to be 465.6 $m^3\ ha^{-1}$, which would surpass the volume of the 456.9 $m^3\ ha^{-1}$ in the unthinned treatment. Volume per tree was estimated to be nearly 0.34 $m^3\ tree^{-1}$ more in the thinned treatment than in the unthinned treatment at age 30, compared to an approximate 0.17 $m^3\ tree^{-1}$ difference between the same treatments, respectively, at age 26. It is estimated that at current diameter growth rates, 92% of the volume in the thinned treatment would be sawtimber compared to 66% for the unthinned treatment, and this difference would be statistically significant ($P = 0.0154$). Results of a white pine thinning study in the southern Appalachians found that at both 80 and 100 years, thinning had shifted the diameter distributions to larger size classes, but failed to increase cumulative yield compared to an unthinned control (Della-Bianca, 1981; McNab and Ritter, 2000). McNab and Ritter (2000) did note that site quality, as measured by site index, was higher in the unthinned control, indicating that if site qualities were equal, it might be possible for thinned plots to produce more cumulative yield. Due to higher stumpage values for sawtimber, the higher proportion of sawtimber in the thinned treatment would translate into a significantly higher value per acre for the thinned treatment (P = 0.0079), whereas at age 26, both treatments had similar standing volume and proportion of volume in sawtimber, and consequently there was no significant difference in value per acre at age 26. The magnitude of the shift into the sawtimber class for both treatments at ages 26 and 30 can be seen in Figure 2. The result of this shift is an approximate 200% increase in value for the thinned treatment from age 26 to age 30 (\$5641 and \$11265 ha^{-1} for ages 26 and 30, respectively) and an approximate 160% increase in value for the unthinned treatment (\$5481 and \$8807 ha^{-1} for ages 26 and 30, respectively).

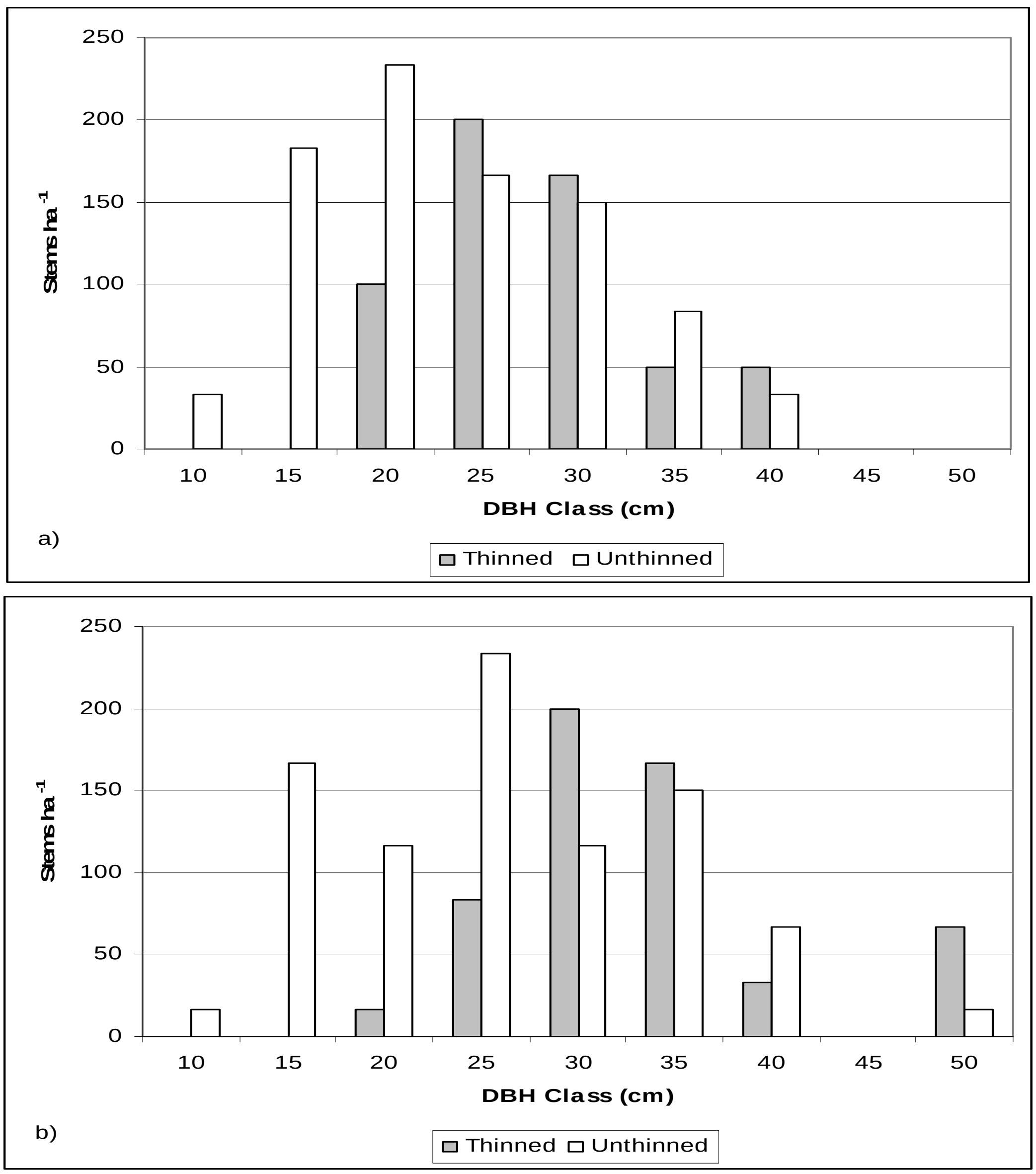

Figure 2. Diameter distributions for (a) stand at age 26 and (b) stand projected to age 30 for a 26-year-old white pine stand growing on a reclaimed surface mine in southwestern Virginia.

To examine the economic feasibility of establishing stands with this level of productivity on surface mined lands, it is important to understand that several factors have been found to limit tree productivity on post-SMCRA reclaimed surface mined land. The two major limitations are soil compaction and competing vegetation (Ashby, 1991) that result from SMCRA's requirement to return the land to approximate original contour and to stabilize the reclaimed landscape from erosion. Burger and Zipper (2002) have outlined procedures for restoring forests on surface mined lands. Part of their prescription includes the establishment of a tree-compatible ground cover, which is intended to minimize the need for competition control treatments when forestry is chosen as the post-mining land use; however, these treatments may still be required if other more aggressive herbaceous species become established on the site. As such, using the stand value information from this study, net present values (NPV) and internal rates of return (IRR) were calculated for four different management scenarios that are likely to face landowners who wish to establish forests on post-SMCRA mined lands. The NPV allows for comparison of the different scenarios while accounting for the opportunity costs associated with each investment scenario. Important assumptions include having a tree-compatible ground cover established by the mining company, having appropriate spoil materials for tree growth (Torbert and Burger, 2000), and having these materials returned to the surface in an uncompacted state. It was also assumed that the harvested volume resulting from thinning would cover the cost of the thinning operation at no net benefit or cost (harvestable volume would have generated \$667 ha^{-1} based on pulpwood prices and the cubic foot volume removed during thinning). A 6% discount rate was used in calculating NPV. The scenarios evaluated differ only with respect to costs incurred over the rotation and include:

Scenario 1. Establishment costs only of \$618 ha^{-1} (Burger and Zipper, 2002).

Scenario 2. \$618 ha^{-1} establishment cost and \$173 ha^{-1} herbicide cost (based on author estimates) in first year.

Scenario 3. \$618 ha^{-1} establishment cost and \$173 ha^{-1} herbicide cost in years 1 and 2.

Scenario 4. \$618 ha^{-1} establishment cost and \$173 ha^{-1} herbicide cost in years 1, 2, and 3.

Scenario 5. All establishment and herbicide costs borne by mining company up to year 5 to obtain bond release.

Cash flows for each scenario are depicted in Figures 3 and 4. The results of this simulation show that at age 26, the IRR's and NPV's are virtually the same between thinned and unthinned treatments for Scenarios 1 through 4 and ranged from approximately 9% when management inputs include only establishment costs to approximately 6.5% using the most intensive scenario (Table 2). Using projected values at age 30, the IRR's for Scenarios 1 through 4 differed by approximately 1% between the treatments, with the IRR of the thinned treatment being higher. For the thinned treatment, IRR's range from 10.2% to 8.1% from the least intensive to the most intensive scenarios, respectively. For the unthinned treatment the range is 9.3% to 7.2%, respectively. When commercial forestry is specified as the post-mining land use, mining companies are required by law to establish a minimum stocking of crop trees per hectare within a fixed time period to obtain bond release. In Virginia, 988 crop trees ha^{-1} are required (Burger and Zipper, 2002). It is important to understand that Scenario 5 is not typical for forestry business enterprises and represents a situation in which all harvest revenues are purely profit to the landowner, as there are no establishment costs to be considered. This resulted in NPV values that were approximately \$600 ha^{-1} greater under Scenario 5 when compared to Scenario 1, with this difference increasing as additional herbicide costs are incurred. Calculation of IRR for Scenario 5 was not possible, given that revenues were generated but no costs were incurred, meaning that regardless of the interest rate, NPV could not be set equal to zero.

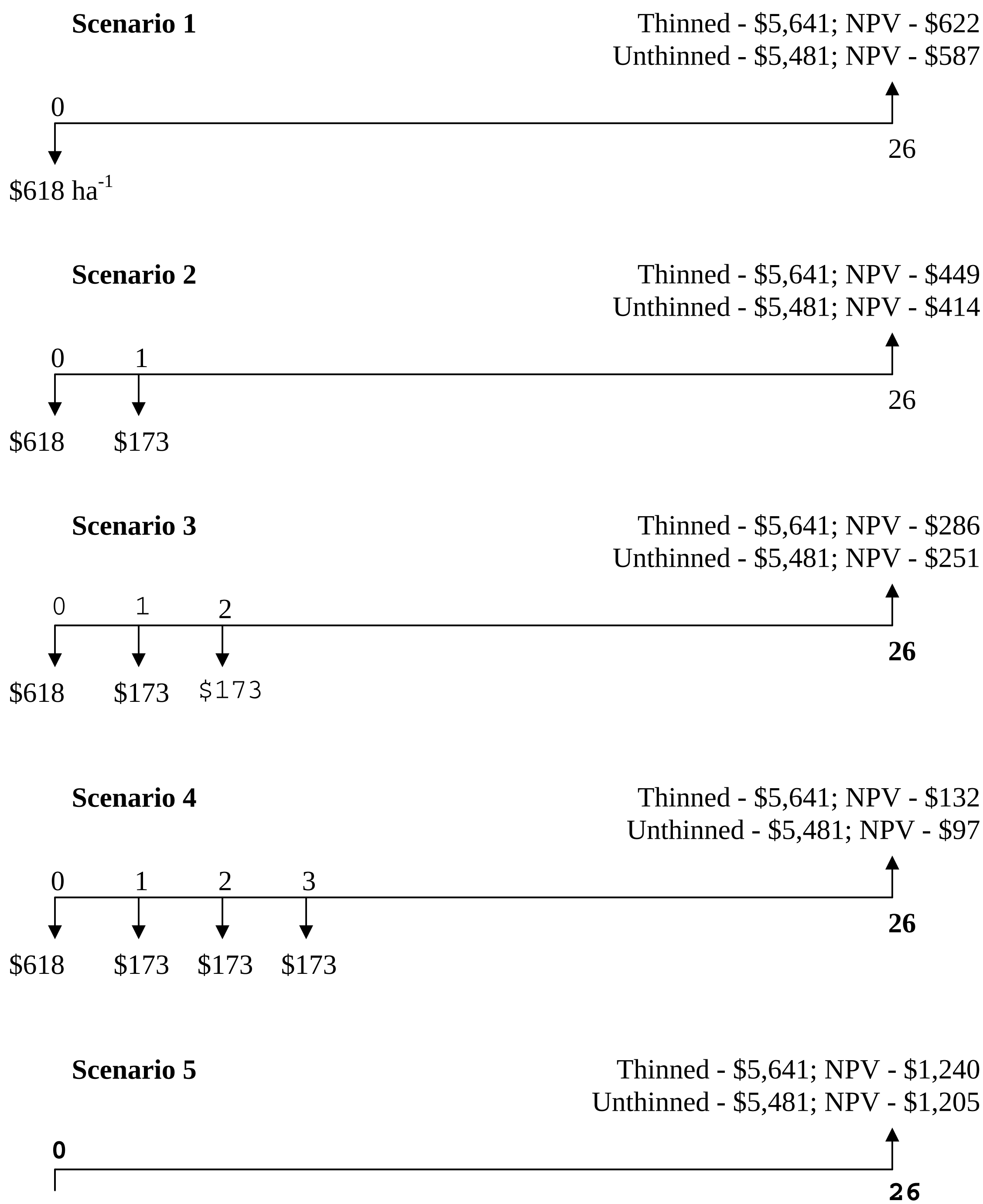

Figure 3. Cash flow diagrams for thinned and unthinned treatments under Scenarios 1-5 at age 26 for a white pine stand growing on a reclaimed surface mine in southwestern Virginia.

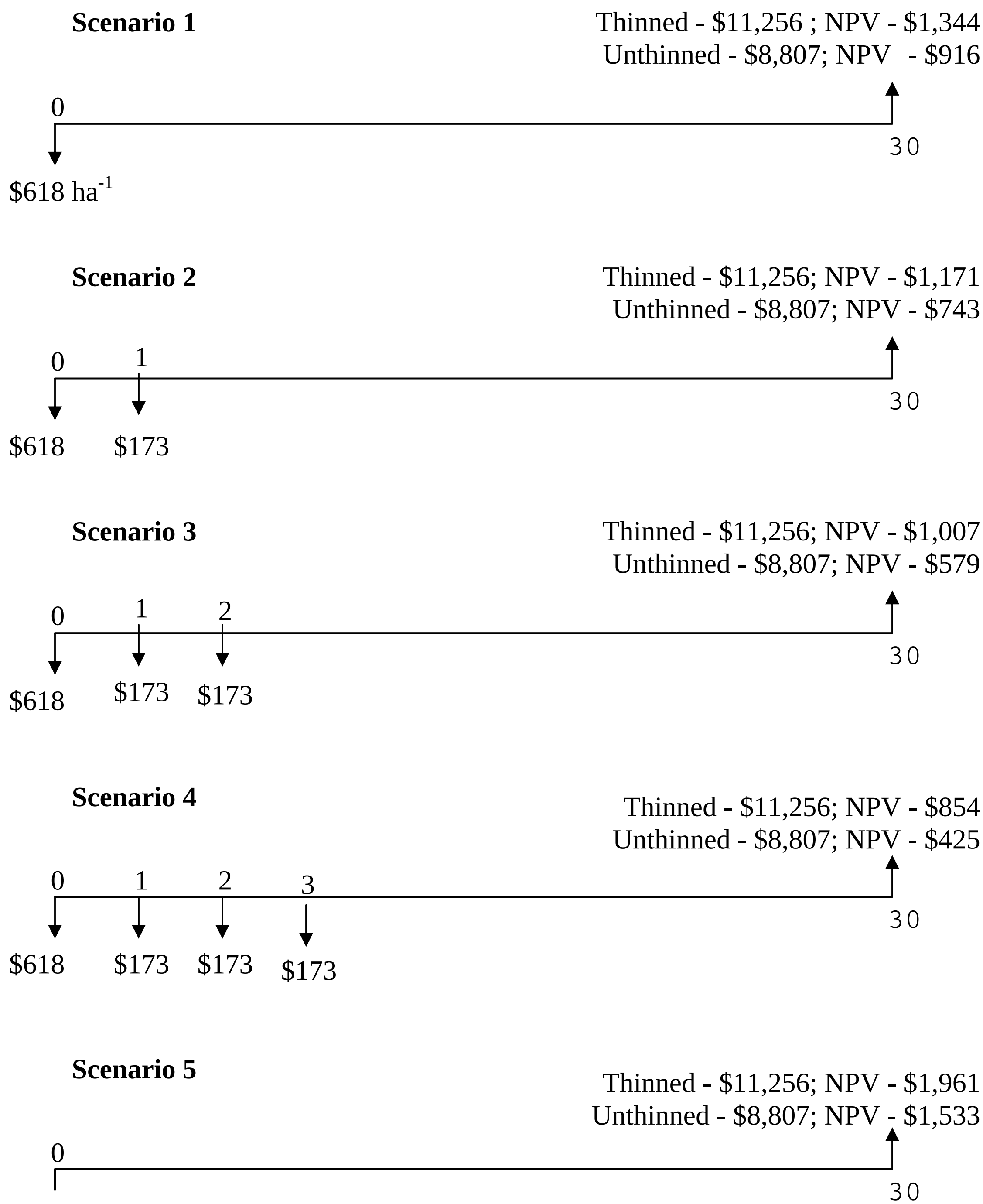

Figure 4. Cash flow diagrams for thinned and unthinned treatments under Scenarios 1-5 at age 30 for a white pine stand growing on a reclaimed surface mine in southwestern Virginia.

Table 2. Net present value ($ ha^{-1}) at 6% interest and internal rate of return by thinning treatment and stand age for a 26-year-old white pine stand growing on a reclaimed surface mine in southwestern Virginia.

Age and Treatment	Management Scenario*									
	1		2		3		4		5	
	NPV ($)	IRR (%)	NPV ($)	IRR (%)	NPV ($)	IRR (%)	NPV ($)	IRR (%)	NPV ($)	IRR (%)
Age 26:										
Thinned	622	8.9	449	7.9	286	7.1	132	6.5	1240	---
Unthinned	587	8.8	414	7.7	251	7.0	97	6.3	1205	---
Age 30:										
Thinned	1344	10.2	1171	9.3	1007	8.6	854	8.1	1961	---
Unthinned	916	9.3	743	8.4	579	7.7	425	7.2	1533	---

*Scenario 1: $618 ha^{-1} establishment costs only
Scenario 2: $618 ha^{-1} establishment cost and $173 ha^{-1} herbicide cost in first year
Scenario 3: $618 ha^{-1} establishment cost and $173 ha^{-1} herbicide cost in years 1 and 2
Scenario 4: $618 ha^{-1} establishment cost and $173 ha^{-1} herbicide cost in years 1, 2, and 3
Scenario 5: All costs to age 5 paid by mining company

From this simulation, it can be seen that if sawtimber production is the management objective, and the desired rotation age is around 30 years, thinning near mid-rotation is a better economic decision than leaving the stand to grow in an unthinned state, especially considering that the average diameter of unthinned trees is only projected to be 26.2 cm at age 30 and only 66% of the stand volume is in sawtimber.

Conclusions

The results of this investigation reveal that, at a site index of 32.3 m, this stand is more productive than established averages for white pine in the southeastern United States. Additionally, volume growth rates of 11.1 m^3 ha^{-1} yr^{-1} in the thinned plots compare favorably with productive stands of loblolly pine found in the southeastern U.S., thus demonstrating the potential of reclaimed surface mines to support productive forests. Thinning the stand at age 17 rapidly increased the diameter growth of the residual trees. Volumes and values for the stand were no different at age 26; however, at each treatment's respective growth rates based on a stand table projection, stand values were significantly higher for the thinned treatment by age 30 due to a shift in the diameter distribution of this treatment toward the sawtimber size classes. These trends in terms of thinning response are similar to trends found in white pine stands growing on native soils, and as such, it appears that white pine growing on reclaimed surface mines can be managed similarly to plantations on native soils. Economic analysis of stand value information revealed that stands growing at this level of productivity on reclaimed mined lands should provide landowners with favorable returns on their investment even when establishment and weed control costs are borne by the landowner. When establishment costs for stands at this level of productivity are borne by the mining companies as part of the reclamation process as required by the SMCRA, the before-tax NPV the landowner could realize is $1,961 ha^{-1}.

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