



**Allegheny College Bousson Environmental Research Reserve
Kiser Hill Red Pine Plantation : Red Pine Growth Decline and Deer Browsing**

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Abstract

The Allegheny College Bousson Environmental Research Reserve contains a plantation of red pine (*Pinus resinosa*) at the Kiser Hill portion of the property. Red pines are not native to northwestern Pennsylvania, and this stand appears to be exhibiting extensive mortality and declines in annual growth. To provide input for managing this plantation, we determined the growth rate and economic value of the stand, and estimated the pressure of white-tailed deer (*Odocoileus virginianus*) browsing on potential forest regeneration if the stand is harvested. We randomly selected nine plots across the site and cored the red pines to measure their growth in five-year increments over the last thirty years. We also surveyed hardwood tree seedlings within the plots for rates of deer browsing. The red pines are in steady decline, with the rate of biomass addition slowing 38% from 1992-1997 to 2017-2022. We also found that deer are affecting potential forest regeneration through browsing, with 84% of seedlings having their terminal buds browsed, and 95% of seedlings having been browsed at least once in the past five years. Commercially harvesting the red pines could yield a net income of approximately \$9,500, however regeneration of the stand by native hardwood trees will be hampered by intensive deer browsing. Successful regeneration might occur if individual seedlings are protected by tree tubes or if the site is fenced to exclude deer.

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Introduction

Non-native species placed into a new environment as a direct or indirect result of human action cause changes to the ecosystems in which they are introduced (Jeschke et al. 2014). Red pines (*Pinus resinosa*) are not native to northwestern Pennsylvania, although they are found in the north central part of the state. They are generally considered a northern Great Lakes tree, but are also found in northern Illinois, eastern West Virginia, and Newfoundland (USDA 2026a). Red pine is a fire-adapted species (Thomas-Van Gundy and Nowacki 2016) that is typically found on well-drained sandy soils (USDA 2026a). Red pines are not very resilient or adaptable to environments outside of their native range.

Besides being widely planted within its historical range for its commercial value, red pine plantations have long been established south of the species' natural range (Benzie and McCumber 1983, Butler 2018). Red pine plantations in the Great Lakes region have been showing declines in growth and increases in mortality (Nadir and Raffa 2002), which was first reported in 1975 (Klepzig and Cummings-Carlson 1988, Raffa and Hall 1988) and appears to be the result of an insect-fungal association (Klepzig et al. 1991). Declining growth, increased

mortality, and a tendency to reproduce slowly, with substantial seed crops being produced only every three to seven years (Hauser 2008), reduce the viability of red pine plantations and forests.

Declining red pine stands can be replaced by native hardwoods, however seedling success is hindered by excessive whitetail populations. Deer populations in Pennsylvania have exploded since their natural predators, cougars and wolves, were extirpated, hunting was regulated, and food became readily available during forest regeneration in the early 1900s (Ward and Stephens 1995). Deer are browsers, often feeding on the buds of seedlings during winter when other food sources are limited (Dumont et al. 2005). Their uncontrolled browsing stunts growth of seedlings and, in turn, the regeneration of the forest (Tremblay et al. 2007). This slowed regeneration can allow for invasive shrubs to outcompete native species, slowing regeneration even further (Ward et al. 2018). Browsing, combined with the declining growth and slow reproduction of red pines, harms the regeneration of native trees and overall productivity of the forest (Côté et al. 2004).

As red pine plantations decline, especially in areas outside their historic range, forest managers are faced with decisions on how to treat these forests. They can be left alone, allowing red pines to wane and other vegetation to take its place through natural regeneration, or they can be actively managed, with preemptive harvest of the pines, and efforts to foster regeneration of native vegetation. Allegheny College Bousson Environmental Research Reserve contains an approximately 80-yr old red pine plantation (Kiser Hill) that is showing signs of increased mortality, and there is some indication from tree cores that growth has slowed dramatically in recent years. Presently, the college has no plans to actively manage this plantation despite this apparent decline in forest health and growth. Importantly, excessive deer browsing in this area (Brozell et al. 2020) suggests that loss of the red pines will not automatically result in replacement by native hardwoods.

The objectives of this study were to determine if red pines were declining in growth rate at Kiser Hill, and to estimate the financial return if the red pines were commercially harvested. We also sought to determine the potential impact of deer browsing on forest regeneration at this location. Collectively, answering these questions will assist Allegheny College in its informed decision on management of the red pine plantation at Kiser Hill.

Methods

The research site at Kiser Hill is a 7.1 acre red pine plantation located in the Allegheny College Bousson Environmental Research Reserve (Fig. 1) in Meadville, PA. In Bousson, the land is used primarily for ecological research and education. The Kiser Hill site is on a gentle slope with an elevation of approximately 1,500 ft above sea level. Air temperatures average at 80°F in the summer, and 20°F in the winter with yearly precipitation of approximately 40 inches (National Oceanic and Atmospheric Administration 2023). The soil surface is relatively flat due to former agricultural use. The red pines are uniform in age (approx. 80 years) and the forest contains a number of native tree species (i.e. beech, sugar maple, black cherry) interspersed

among the pines, with little understory growth. Across the site, red pines averaged 11.2 ± 0.2 inches in diameter and had 100.7 ± 3.9 square inches in basal area per tree.

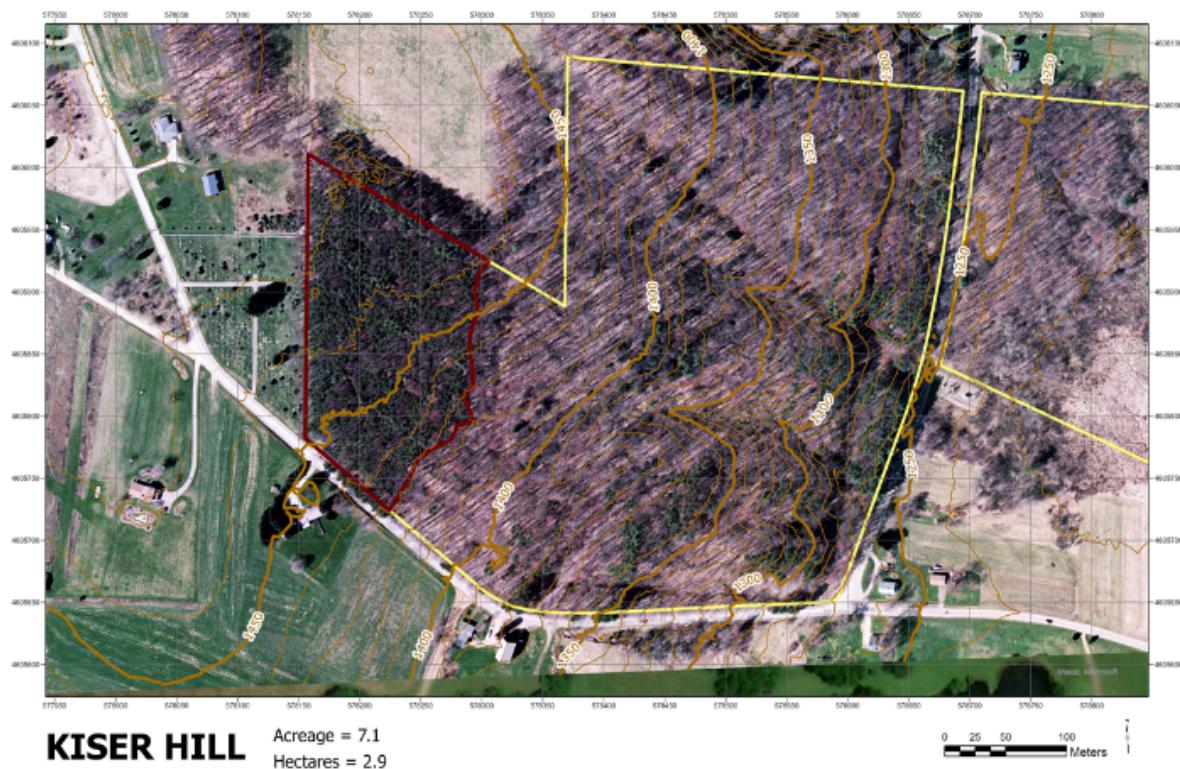


Figure 1. Kiser Hill red pine plantation (outlined in red) at the Allegheny College Bousson Environmental Research Reserve. Yellow lines are Bousson property lines.

To estimate annual tree biomass and standing red pine timber, we divided the plantation into three zones along the elevation gradient of the site, giving us an upper, middle, and lower zone. In each zone, three 16.4x16.4 yd (15x15 meter) plots were randomly selected. All living trees were tagged, identified, and diameters measured at breast height (dbh: tree diameter at 4.4 ft above ground level). Among the nine total plots, 87 trees were recorded, 47 of which were red pine.

The red pines were cored using an increment borer, extracting core lengths (approximately 4in) sufficient to measure radial and hence diameter growth over the last 30 years. Tree cores were dried (221°F, 48 h) in wooden tree core holders. We then measured diameter growth in five-year increments from 1992 to 2022, and calculated biomass growth for the five-year increments using a published equation (Tritton and Hornbeck 1982). Basal area (the area of the stem at dbh) was determined based on tree diameter; changes in basal area over time were calculated by using the tree diameters at each 5-year increment.

To determine the commercial timber value of red pines in the site, we first estimated the number of 16-ft logs (to the nearest half log) of red pines in each plot using a Biltmore international 1/4-inch rule stick. We then estimated the total number of red pines within the plantation by scaling the number of trees per plot to the area of the plantation. We calculated the current economic value of red pine timber using data for white pine (red pine was not available) in the Pennsylvania State Extension Timber Market Report (Pennsylvania State University 2022), and estimated net revenue using a forest operation invoice from a recent logging operation by a local forestry firm (Firth Maple Products, personal communication) that provided gross and net profit on a recent timber sale.

Deer browsing pressure on seedlings was then estimated at each plot. Starting at the center of each plot, we found the 10 closest tree seedlings less than 79 in (2 m) tall and first determined if the terminal bud had been browsed since the prior autumn leaf senescence, and then if seedlings had also experienced browsing in years prior to last autumn. We also measured the height of each seedling.

Statistical analysis was carried out using one-way ANOVAs and Tukey post-hoc tests for data that were normally distributed and had homogeneity of variance. Kruskal-Wallis and Dunn's post-hoc tests were used if data were not normally distributed or did not have homogeneity of variance.

Results

The biomass of individual trees (Fig. 2) increased consistently over the 30-yr study interval, increasing from 426 ± 32 (SE) lbs tree⁻¹ to 694 ± 37 lbs tree⁻¹. Despite the consistent growth in tree mass, however, diameter growth declined exponentially (Kruskal-Wallis H test, $p < 0.001$), decreasing 39% over the 30-year study period (Fig 3), from 0.52 ± 0.04 inch per tree per 5-year to 0.32 ± 0.02 in per tree per 5-year. Similarly, annual basal area growth (the area of the stem at breast height) also declined (Kruskal-Wallis H test, $p = 0.007$), decreasing 21% over the 30 years (Fig. 4). The decline in basal area growth means that the tree is adding less volume each year (Kruskal-Wallis H test, $p < 0.001$), which is reflected in the 38% decline in the annual rate of biomass growth (Fig. 5). Biomass growth declined from 18.4 ± 1.4 lbs per tree per 5-year to 11.3 ± 0.7 lbs per tree per 5-year.

There was some difference in tree size from the upper to lower site (Table 1). Tree diameters did not differ among the sites, but the lower site had 50% more logs per tree and 130% more board feet per tree than the upper site. The lower and mid sites did not differ significantly.

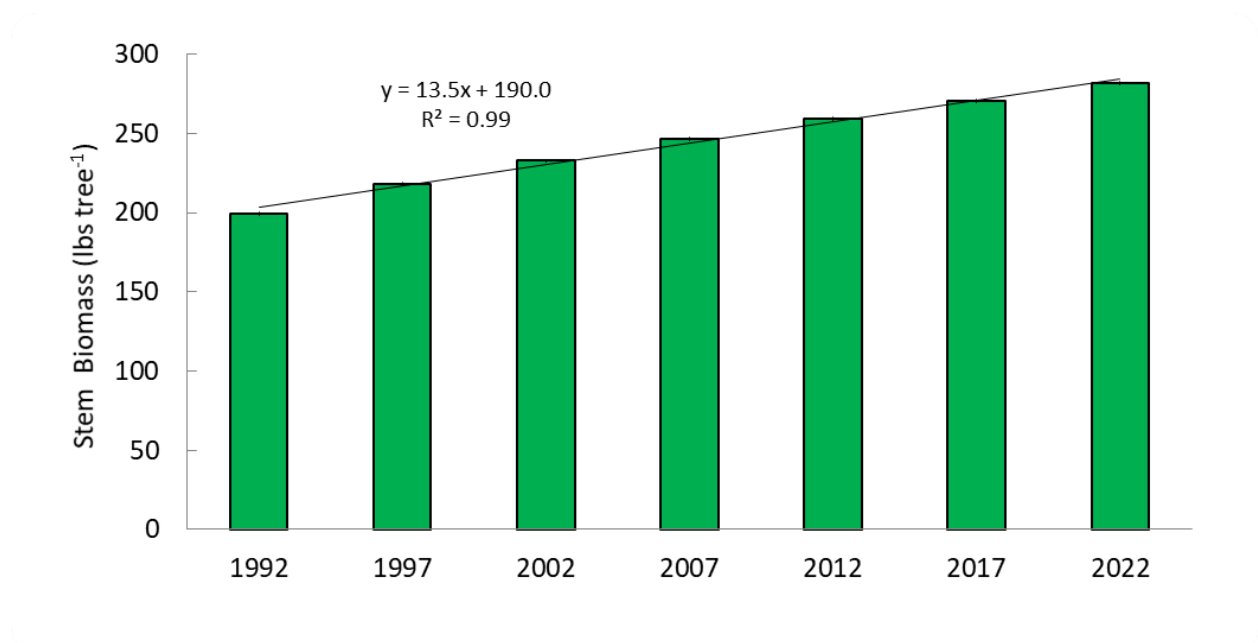


Fig 2. Average biomass of individual red pine trees at the Kiser Hill red pine plantation from 1992 to 2022. Bars are standard errors.

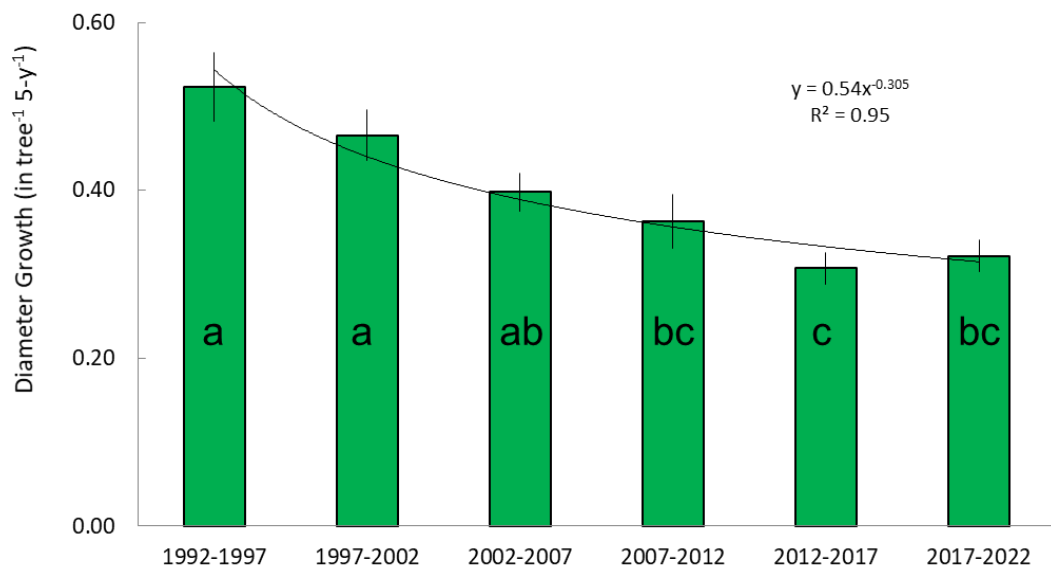


Fig. 3. Average red pine annual diameter growth at the Kiser Hill red pine plantation from 1992 to 2022. Bars are standard errors. Means with the same letter are not significantly different.

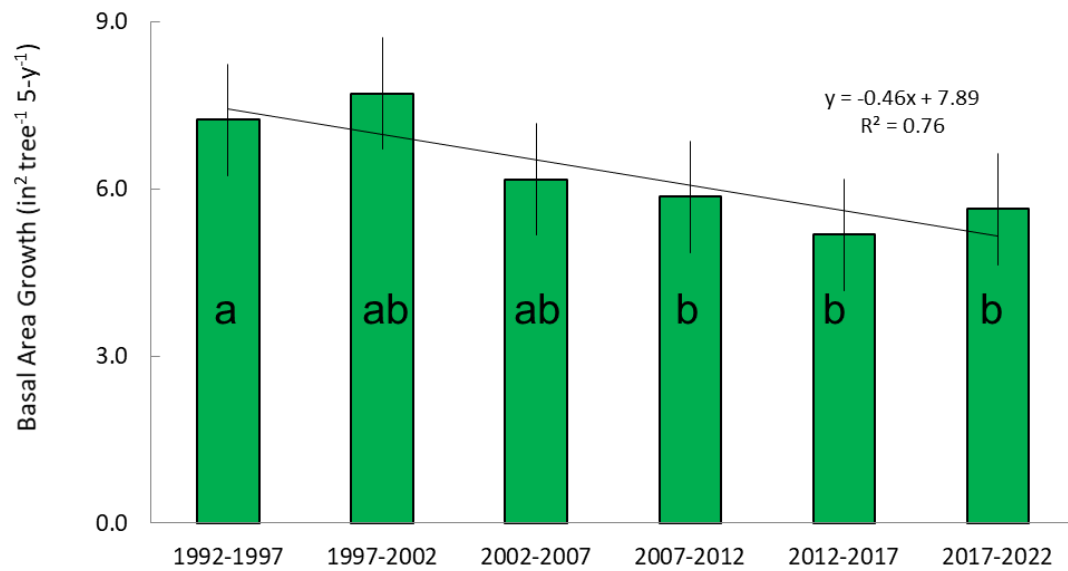


Fig. 4. Average individual tree basal area growth at the Kiser Hill red pine plantation from 1992 to 2022. Bars are standard errors. Means with the same letter are not significantly different.

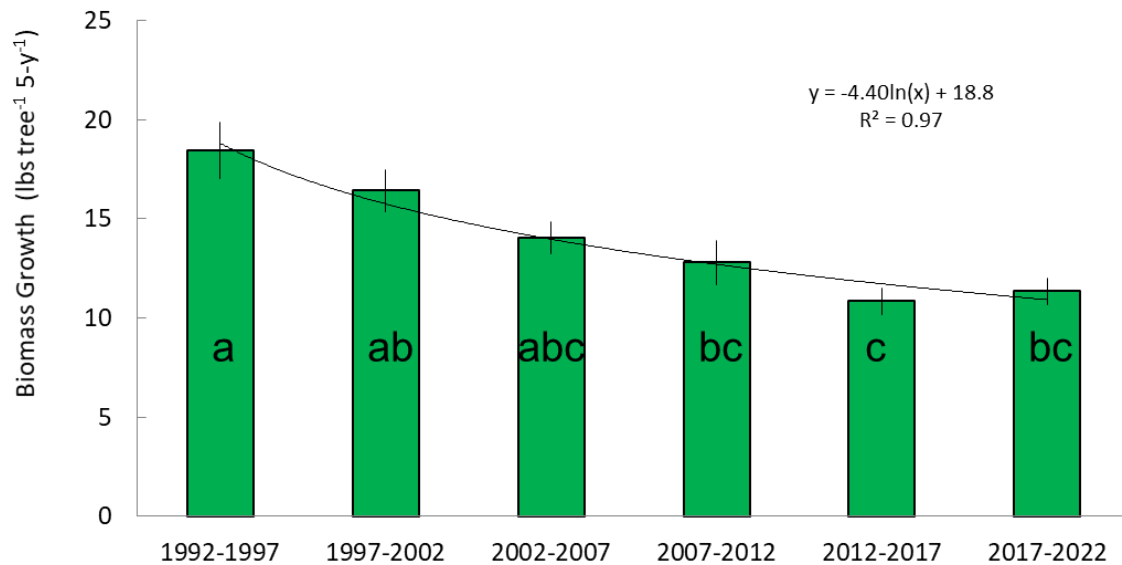


Fig 5. Average individual tree biomass growth at the Kiser Hill red pine plantation from 1992 to 2022. Bars are standard errors. Means with the same letter are not significantly different.

Table 1. Tree diameter (at breast height (dbh)), logs (16-ft), and board feet of red pine trees at the Kiser Hill red pine plantation.

Site Location	Dbh (in)		Logs per tree		Board feet per tree	
	Ave	SE	Ave	SE	Ave	SE
Upper	11.6 ^a	0.4	2.6 ^a	0.3	258 ^a	65
Mid	10.9 ^a	0.4	3.4 ^{ab}	0.2	380 ^{ab}	66
Lower	11.3 ^a	0.3	3.9 ^b	0.3	565 ^b	88

Seedling height (Fig. 6) differed among the sites ($p=0.004$), with seedlings in the middle area being taller than seedlings in the lower area, though not different from seedlings in the upper area. Across the entire site, seedlings averaged 18.0 ± 1.3 in tall, with only 4% exceeding 39 in. Tree seedlings were heavily browsed. We found 98.7% of all seedlings have been browsed, with 84.1% having the recent terminal shoot browsed, and 94.5% of seedlings showing browsing in previous years (Table 2).

There are a number of native tree species within the Kiser Hill Plantation that are mature enough to facilitate regeneration (Table 3.) Black cherry (*Prunus serotina* Ehrh.) is the most abundant, followed by American beech (*Fagus grandifolia* Ehrh.) and sugar maple (*Acer saccharum* Marsh.) Although the least abundant tree, red oak (*Quercus rubra* L.) has the largest diameter.

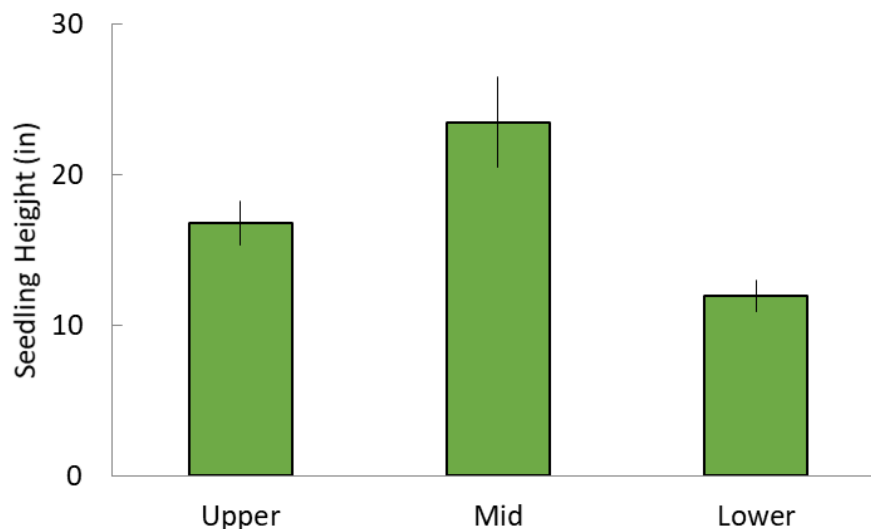


Fig 6. Tree seedling height among the elevation area at the Kiser Hill red pine plantation. Bars are standard errors. Means with the same letter are not significantly different.

Table 2. Percentage of tree seedlings not browsed, having recent terminal buds (2023), and browsed in years prior to current year. SE = Standard Error.

Plantation location	% Not browsed	% 2023 Terminal bud browsed	% Browsed previous years
Upper	0.0	89.3	96.4
Mid	4.0	88.0	92.0
Lower	0.0	75.0	95.0
Site Ave	1.3	84.1	94.5
SE	1.3	4.6	1.3

Table 3. Hardwood tree species abundance and size (dbh) at the Kiser Hill red pine plantation. SE = Standard Error.

		dbh	
	# per acre	Ave	SE
Red oak	2	19.7	na
Sugar maple	10	13.3	1.2
Red maple	4	8.7	0.1
American beech	14	7.6	0.3
Black cherry	34	15.5	0.3

Based on the density of red pine trees per acre within the study plots, the total number of trees in the plantation is estimated to be 653 (Table 4). Using the average board foot value per tree (371) across the entire plantation, there is a total of 242,147 board feet of red pine. At the time of this study, we estimated the value of red pine at \$0.086 per board foot, providing a gross value of \$20,825. A commercial harvest would incur costs about 54.4% of the gross value due to forestry, logging, and trucking costs, thus providing a potential net economic value to the college of \$9,503.

Table 4. Red pine timber board feet (BF), forestry expenses, and net timber value of the Kiser Hill red pine plantation.

Total trees and board feet of timber	
Red pine trees/acre	92
Total acres	7.1
Total red pine trees	653
Average BF/tree	371
Total red pine BF	242147
Forestry Expenses (% of Gross Value)	
Forestry cost	15.5
Logging cost	25.5
Trucking cost	13.4
Total harvest costs	45.6
Net value	54.4
Economic Value (\$)	
\$/BF	0.086
Total gross value	20825
Total Net Value	9503

Discussion

Red Pine Growth

Red pine growth at Kiser Hill is in decline. Annual diameter increments are currently lower than they were three decades ago, and even though the red pines are still adding biomass annually, the rate at which they are doing so has decreased. The red pines at Kiser Hill are already living at the upper limits of their temperature range, given that they are far outside their normal range at higher latitudes. Additionally, red pines have generally low resilience, so they do not tend to thrive in temperatures that are higher than they experience in their native range

(USDA n.d.). This may decrease their resistance to stress or disturbance. Growth of red pine may also be negatively affected by further increases in temperature due to climate change (Sharma 2022). Temperatures of 90 degrees Fahrenheit are hypothesized to become commonplace in PA by the midcentury (Union of Concerned Scientists 2008), likely to further stress red pines.

As observed at other locations, red pine is in general decline throughout this region (Klepzig and Cummings-Carlson 1988, Raffa and Hall 1988, Klepzig and Smalley 1991). We did not measure the rate of mortality in this study, however we did observe a considerable amount of standing dead trees and fallen trees. Some mortality is expected, as self-thinning occurs as trees age and compete with one another. We expect that growth will continue to decline, and mortality will increase as has been noted elsewhere. Thus, this stand will in time cease to exist, and will eventually be replaced by hardwoods typical of this region.

The difference in the number of 16-ft logs/tree across the site may be a result of wind slowing the growth of trees at the westward-most, upslope location of the plantation. Wind in this area is predominately westerly (Pennsylvania State University 2026). Soil conditions may also play a role. Soils at this site are silt loams (USDA 2026b), not the sandy, well-drained soil soils where red pine is typically located (USDA 2026a). Additionally, the flat soil surface of the upper location suggests that this area had been plowed prior to plantation establishment, and may have led to nutrient loss over time. Nutrients may also be higher in the lower area due to runoff from upslope.

Economic Analysis

Red pine has a relatively low timber value, especially in comparison to higher-value hardwoods that typify this area. Due to its low overall abundance in the area, red pine is not even included in the Pennsylvania State University Quarterly Timber Market Report, but white pine and eastern hemlock are usually included. The value for white pine was used as a proxy for red pine, but even white pine itself is not that common in the area or in mills across the state. In the most recent timber report (First Quarter 2026), there were no data for white pine from mills in the northwestern part of Pennsylvania.

Whether or not Allegheny harvests this plantation will first require the college to consider its long-standing, unwritten policy that the Bousson Experimental Forest is reserved for education and research, not for timber harvest or economic gain. Harvesting would require input from relevant college administration officials and faculty members who use Bousson for teaching or research. If this timber is harvested, then the estimated net value of \$9503 is only 0.01% of Allegheny's estimated annual budget of \$80 million, and hence would have no significant impact on the overall college budget.

Deer Browsing

Allowing the pines to die gradually, assuming that no large-scale, rapid die-off occurs, could allow for gradual replacement of the pines as gaps are opened in the forest and seeds are

provided by the diverse hardwoods already present on the site. However, deer browsing is a prevalent issue at Bousson and throughout the state, with the high browsing rate at Kiser Hill indicating that seedling growth will be challenged. Indeed, very few seedlings, based on the low overall seedling height, show the potential of moving into the overstory. Intensive browsing can lead to impaired growth and regeneration of the forest because excessive deer populations significantly reduce seedling growth (Tilghman 1989).

Managing deer can include fencing, contraceptives, and hunting, which are all options to try to reduce the overpopulation of deer and subsequent browsing of seedlings. Using contraceptives is an expensive and temporary solution (Walker et al. 2021), would require the approval from the PA Game Commission, and will not influence deer populations on the relatively small area of Bousson because deer will easily traverse property boundaries. Hunting can reduce deer herds, however this solution is not likely to be effective at Kiser Hill. First, Allegheny College currently does not allow hunting at Bousson, thus the college would need to amend this policy, and such an alteration would need to overcome social barriers before hunting could be allowed. These barriers include student opinions about hunting, storage of firearms on campus, and potential safety and liability issues. Allegheny College could allow archery-only hunting, but this would limit the available number of hunters. Second, deer are not limited to small areas. They may move out of the area during hunting seasons and then return later during non-hunting seasons. Even if some deer are harvested, deer from surrounding areas will fill the void left by harvested deer. With a range of approximately one mile, deer from surrounding areas can certainly be expected to visit this property during their normal movements throughout the year.

Other options for protecting tree seedlings include fencing and tree tubes. Temporary fences can exclude deer during the time needed for seedlings to grow beyond the reach of deer, however fencing is expensive, costing an estimated \$1.5-\$2.50 per linear foot (Jacobson 2007). When adjusted for inflation, this amounts to \$5,400 - \$9,100 to fence the red pine plantation. Fences also require continual monitoring for damage from fallen branches or trees, can disrupt movement of wildlife (Xu 2021), and removal of deer that might enter the area if the fence is compromised would be challenging. Tree tubes are also a management option. These tubes, typically five feet tall, enclose seedlings and saplings, allowing them to grow out of the reach of deer. Tubes can be obtained from the Crawford County Conservation District during their annual tree sale, for approximately \$6.00 apiece, including a wooden stake. Protecting 75 seedlings per acre across Kiser Hill would cost approximately \$3,195, exclusive of labor costs. Fences and tree tubes can be used to foster forest regrowth even if the forest is not harvested.

An additional strategy that can be employed if the area is harvested is to leave the tree tops in place. These tops serve as barriers to deer, and allow sanctuaries for tree seedlings. By the time that the tree tops have decomposed and become lower in height, tree saplings have usually grown beyond the reach of deer.

Recommendations

If the college decides to harvest the trees, we suggest working with Firth Maple Products, the forestry firm that the college has used to harvest the forest at the Robertson Athletic Complex. Firth typically harvests trees using horse teams rather than heavy machinery to remove logs, which reduces soil compaction (Picchio et al. 2020). Firth also leaves tree tops in place to enhance tree sapling survival. The presence of hardwood trees on the site indicates that there will be a seed source that can facilitate regeneration of the forest.

By design, plantations are generally intended to be monocultures, and this stand is nearly entirely red pine. Monocultures typically lack the resilience and productivity of diverse ecosystems (Brockeroff et al. 2008, Tilman et al. 2014). Harvesting the red pines could accelerate the transition of this forest from a low diversity plantation into a diverse hardwood forest of native tree species.

Based on the relatively low cost, we also suggest that tree tubes should be used to help existing seedlings survive into the overstory. Due to the high cost, and given that Allegheny is not looking to develop a commercially viable forest, fencing is not an economically viable option.

Additionally, hunting will pose no significant benefits to forest regeneration at Kiser Hill. The college may explore hunting at Bousson to include opportunities for students or to participate in responsible land stewardship efforts, but hunting will not reduce deer numbers enough to ensure tree seedling survival.

We also believe that harvesting the trees can offer students and faculty educational opportunities to examine forest regeneration, as well as provide students with opportunities to debate the merits of forest harvest using a real-life situation of relevance to the college. Harvesting this forest is not seen as a profit-seeking venture, but rather a means of responsible stewardship and creation of a valuable educational opportunity. If harvesting occurs, then the proceeds, though limited, should be allocated directly to maintaining the Bousson Environmental Research Reserve. Many of these costs are often covered by departmental budgets (Biology, Environmental Science and Sustainability) or extramural research grants.

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