Estimating the Capital Recovery Costs of Alternative Patch Retention Treatments in Eastern Hardwoods

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ABSTRACT

We used a simulation model to estimate the economic opportunity costs and the density of large stems retained for patch retention in two temperate oak stands representative of the oak/hickory forest type in the eastern United States. Opportunity/retention costs ranged from \$321.0 to \$760.7/ha [\$129.9 to \$307.8/acre] depending on the species mix in the stand, the logging technology used, and rotation lengths. The resulting capital recovery costs ranged from \$12.8 to \$30.4/ha/year [\$5.2 to \$12.3/acre/year] depending on the degree of retention desired, the logging technology used, and the species composition of the tract. Opportunity/capital recovery costs are greatest in stands that have high-value species mix, are harvested with low-cost logging technologies, and/or managed on longer rotations. The approach described in this paper can be used to help forest landowners, managers, loggers, and other decision/policy makers understand the opportunity/capital recovery costs and ecological benefits associated with patch retention.

Keywords: *capital recovery costs, patch retention, eastern hardwoods, logging systems, simulation, opportunity cost, economics, present net worth.*

INTRODUCTION

The world population increasingly demands more of our forests for wood products (veneer, sawlogs, pulpwood, fuelwood, etc.) and a variety of ecological benefits including forest biodiversity, habitat, water quality, and continual forest cover. Moreover in North America, widespread forest certification programs, such as the Forest Stewardship Council and the Sustainable Forestry Initiative require participating landowners to maintain forest biodiversity as they achieve their economic objectives [13]. Industrial forest landowners must perform a delicate balancing act to satisfy society's diverse demands for wood and ecological values [32]. Many landowners meet this challenge by using patch retention to maintain certain components of biodiversity [12]. Patch retention is the practice of leaving trees normally cut during a timber harvest. Patch retention is applied during harvests, thinnings, regeneration cuts, or other silvicultural treatments to achieve desired ecological characteristics at different scales, ranging from sub-stand to watersheds and landscapes [27].

Most guidelines for patch retention (patch retention, tree islands, leave patches, buffer strips, travel corridors) have evolved from our relatively limited ecological knowledge [5, 20, 21, 23, 34, 35, 38] and generally do not consider operational and other costs. Many landowners apply patch retention guidelines based on the perceived ecological benefits and economic costs because they lack accurate information necessary to assess the economic and ecological tradeoffs associated with different levels of patch retention [12]. One recent study assessed how patch retention might affect present and future timber volumes [2]. Other studies have evaluated the opportunity and capital recovery costs of one special case of patch retention: the application of alternative Best Management Practices (BMPs) for managing streamside zones (SMZs) [10, 15, 18, 26]. Landowners and managers need information about the tradeoffs between economic costs and ecological benefits to determine how to apply patch retention at levels consistent with their management goals [2, 35]. Typically with patch retention, landowners are trying to manage for late-successional habitat and late-successional species (among other ecological goals) [4, 6, 8, 20, 21]. Large tree density, measured in trees per unit area (\$50.8 cm or \$ 20 in DBH) is a good indicator of late-successional (LS) stands [37] because many late-successional species depend on large trees, large snags, and large downed stems for habitat [1, 4, 8, 11, 22] and because many ecological processes characteristic of LS stands depend on large trees [11, 33].

Patch retention costs are typically estimated by considering the value of the harvested timber, retained timber, and harvest costs (e.g., [3, 28]). Most approaches fail to consider the future value of the stand when estimating the opportunity cost and further fail to estimate future ecological benefits. Accordingly, we use a simulation model to illustrate a method of estimating the long-term opportunity/capital recovery costs and density of large trees (an indicator of the ecological benefits) associated

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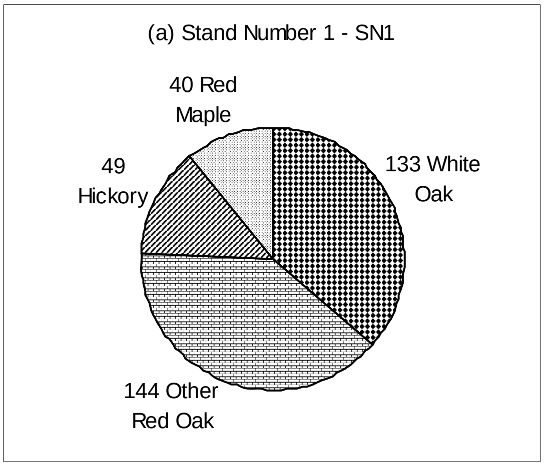
with patch retention treatments in eastern oak forests. Using this model approach we show how three types of timber harvesting technologies and tree species distributions in two stands can affect the costs and benefits associated with patch retention.

METHODS

Stand Data

Stand Number 1 (SN1) is a 40-year-old even-aged upland oak forest stand on a good quality site (site index 80) [30] and represents a substantial acreage in the oak/hickory forest type of the central hardwood region. The stand is dominated by white oak (*Quercus alba L.*) and black oak (*Quercus velutina*) but also contains hickory (*Carya ovata (Mill.)*) and red maple (*Acer rubrum L.*) (Fig. 1a). The stand has 904 trees/ha [366 trees/acre], a volume of 156.5 m^3/ha [2,235 ft^3/acre] and an average tree DBH of 17.5 cm [6.9 inches]. Stand Number 2 (SN2) is a 30-year-old mixed-hardwood stand that has 988 trees/ha [400 trees/acre], a volume of 104.3 m^3/ha [1490 ft^3/acre], and an average tree DBH of 14.5 cm [5.7 inches]. The stand is dominated by red maple and white oak but also is comprised of elm (Ulmus americana), yellow birch (*Betula alleghaniensis*), white ash (*Fraxinus americana*), northern red oak (*Quercus rubra L.*), other red oak species, hickory, other hardwoods, and a significant proportion of noncommercial species [7] (Fig. 1b). These stands were selected because robust individual tree data exists for each, their age structures are representative of substantial acreages of the oak/hickory forest type in the eastern United States [7, 30], and they contrast in their species composition and economic value. We used density of large trees (= 50.8 cm or = 20 inches DBH) as an indicator of ecological condition because this correlates well with stand age, ecological functions associated with LS and old growth stands, and LS species [4, 8, 11, 22, 33].

However it is noted that this is primarily an indicator of LS condition and may not reflect other biodiversity values (e.g., game cover, water quality, etc.) that may be important to landowners and society. Both stands were subjected to the same silvicultural clearcut treatment, that is, they were projected to their optimal economic rotation using MANAGE-PC [14].


(a) Stand Number 1 - SN1

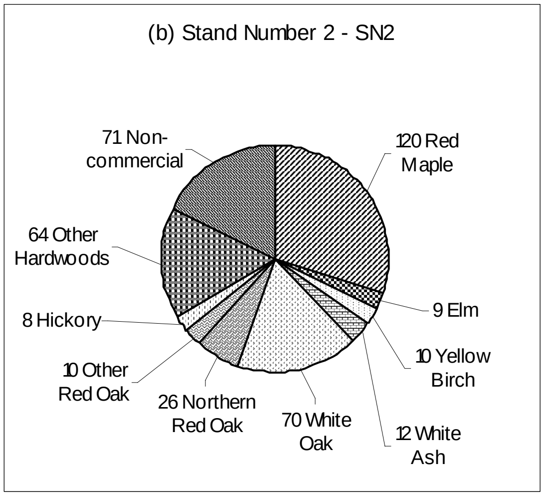

(b) Stand Number 2 - SN2

Figure 1(a-b). Distribution of tree species and number/ha.

Table 1. Logging technology machine configurations used to harvest SN1 and SN2 (each 48.6 ha).

Logging Technology	Description
A	Chainsaw felling with John Deere 640 cable skidder
B	Timbco 425 feller buncher with Valmet forwarder
C	Timbco 445 Cut-to-length harvester with Valmet forwarder

Logging Technology Evaluated

The costs associated with three logging systems were evaluated (Table 1). These logging systems were selected because robust time and motion study data were available for each and they represent common, contemporary methods being used to harvest eastern hardwood stands. The time and motion studies spanned the range of operating conditions in eastern hardwood forests [16, 17, 19].

Machine capacities were matched to the size of the logs to be removed from these 120 and 220-year-old stands. The machine configurations are ranked by their total operating cost for the control option with the Timbco 445 cut-to-length system being the most expensive and the John Deere 640 skidder with chainsaw felling being the least expensive. The operating cost of logging systems A and B are similar, but they differ because B is more mechanized than A. We assume that the harvesting technologies that are common today will be common at the extended rotations simulated.

Model Used

MANAGE-PC [14] integrates harvesting technology, silvicultural treatments, market prices, and economics continuously over the life of the stand. The simulation combines discrete and stochastic subroutines. Individual subroutines model harvesting activities, silvicultural treatments, growth and yield projections, market prices, and calculate discounted present net worth (PNW). The model can and has been used to develop optimal management guidelines for eastern hardwoods [16, 29]. Using stand data from SN1 and SN2, MANAGE-PC was used to estimate optimal economic rotation lengths, volume/production yield estimates, large tree density estimates, and logging costs for each patch retention treatment. The average delivered prices for sawlogs and pulpwood were estimated from Forest Products Price Bulletins [24, 25, 31] (Table 2).

Patch Retention Treatments

The stands were modeled as continuous 48.6 ha [120-acre] tracts that were to be regenerated at their respective optimal economic rotation, that is, the maximization of discounted present net worth (PNW). MANAGE-PC determined the optimal rotation age for each combination of stand and harvest system. We evaluated controls and three patch retention treatments for the PNW, rotation age, volume/ha, and other economic and stand attributes for each stand and logging system combination. The simulated harvests for the controls had no patch retention treatments (Tables 3 and 4).

The modeled patch retention treatments were: (1) leave 5 % of the area in patch retention at optimal rotation age [5, 23], (2) leave 10% of the area in patch retention at optimal rotation age [13], (3) leave 10% of the area in patch retention at optimal rotation age but allow harvesting of the patches left behind at rotation age of 220 years once the surrounding cut forests returned to precut conditions [6]. We selected these patch retention treatments because they represented an array of contemporary management objectives recommended by different agencies.

Table 2. Delivered prices for sawlogs and fuelwood/pulpwood by species.

	Product			
Species	Large[a] high-quality sawlogs	Medium[b] size and quality sawlogs	Small[c] low-quality sawlogs	Fuelwood[d]/ Pulpwood
White ash	420	302	269	40
Red maple	251	192	131	40
White oak	450	279	138	40
Yellow birch	207	186	155	40
Red oak	561	397	225	40
Elm	176	125	96	40
Hickory	210	160	150	40
Noncommercial	50	50	50	40
Other hardwoods	280	176	125	40

[a] Minimum small-end diameter $ 33.0 cm [13 in], length $ 3.1 m [10 ft].

[b] Minimum small-end diameter $ 27.9 cm [11 in], length $ 2.4 m [8 ft].

[c] Minimum small-end diameter $25.4 cm [10 in], length $ 2.4 m [8 ft.].

[d] 2.4 m^3/cord [89 ft^3/cord], minimum small-end diameter $ 10.2 cm [4.0 in] that will not make large, medium, or small sawlogs.

Table 3. Rotation age, stand, and economic attributes for SN1 (oak) by logging technology for each patch retention scenario.

						Revenue				
Patch Retention Scenario	Logging Technology	Optimal Rotation Age	Average DBH	Volume/Ha	Logging Cost	Mill Value	Net Revenue	PNW	Retention Cost	Capital Recovery Cost[c]
		(years)	(cm)	(m^3)	- - - - - - - -	- - - - $/ha	- - - -	- - - -	- - - -	$/ha/yr
None (control)										
	A	110	34.3	383.4	5441.6	13460.2	8018.7	515.0	NA	NA
	B	110	34.3	383.4	5643.7	13460.2	7816.5	502.0	NA	NA
	C	110	34.3	383.4	7040.8	13460.2	6419.4	412.3	NA	NA
5% Retention										
	A	110	34.3	362.2	5169.5	12787.2	7617.8	489.2	400.9[a]	16.1
	B	110	34.3	362.2	5361.6	12787.2	7425.7	476.9	390.8[a]	15.6
	C	110	34.3	362.2	6688.8	12787.2	6098.5	391.6	321.0[a]	12.8
10% Retention										
	A	110	34.3	345.1	4897.4	12114.2	7258.0	463.5	760.7[a]	30.4
	B	110	34.3	345.1	5079.4	12114.2	7076.0	451.8	740.5[a]	29.7
	C	110	34.3	345.1	6336.7	12114.2	5818.7	371.0	600.8[a]	24.0
10% Retention with harvesting at year 220										
	A	220	54.1	442.9	2089.7	30704.3	28614.7	24.6	490.4[b]	NA[d]
	B	220	54.1	442.9	5923.9	30704.3	24780.5	21.3	480.7[b]	NA[d]
	C	220	54.1	442.9	7368.3	30704.3	23336.0	20.0	392.2[b]	NA[d]

[a] Difference in net revenue from control conditions.
[b] Difference in present net worth from control conditions.
[c] Future series of end-of-period payments that will exactly recover a present capital sum with a real interest rate of 4 percent.
[d] Capital recovery costs not calculated because stand will be harvested at age 220.

Table 4. Rotation age, stand, and economic attributes for SN2 (mixed hardwood) by logging technology for each patch retention scenario.

Patch Retention Scenario	Logging Technology	Optimal Rotation Age (years)	Average DBH (cm)	Volume/Ha (m^3)	Logging Cost	Revenue Mill Value	Revenue Net Revenue	Revenue PNW	Retention Cost	Capital Recovery Cost[c]
					$/ha	$/ha	$/ha	$/ha	$/ha	$/ha/yr
None (control)										
	A	150	42.7	374.4	4033.3	12041.0	8007.7	72.6	NA	NA
	B	150	42.7	374.4	5371.4	12041.0	6669.5	60.3	NA	NA
	C	160	44.6	383.1	6367.3	14001.1	7633.8	46.6	NA	NA
5% Retention										
	A	150	42.7	355.6	3831.6	11438.9	7607.3	68.7	400.4[a]	16.0
	B	150	42.7	355.6	5102.9	11438.9	6336.0	57.3	333.5[a]	13.3
	C	160	44.6	363.9	6048.9	13301.0	7252.1	44.3	381.7[a]	15.3
10% Retention										
	A	150	42.7	336.9	3630.0	10836.9	7248.1	65.1	759.6[a]	30.4
	B	150	42.7	336.9	4834.3	10836.9	6043.7	54.2	625. 8[a]	25.0
	C	160	44.6	344.8	5730.6	12601.0	6911.6	41.9	722.2[a]	28.9
10% Retention with harvesting at year 220										
	A	220	57.3	448.6	1585.9	26086.0	24500.1	14.2	58.4[b]	NA[d]
	B	220	57.3	448.6	5959.8	26086.0	20126.2	11.7	48.6[b]	NA[d]
	C	220	57.3	448.6	7463.4	26086.0	18622.6	10.8	35.8[b]	NA[d]

[a] Difference in net revenue from control conditions.

[b] Difference in present net worth from control conditions.

[c] Future series of end-of-period payments that will exactly recover a present capital sum with a real interest rate of 4 percent.

[d] Capital recovery costs not calculated because stand will be harvested at age 220.

RESULTS

Without patch retention, the optimal economic rotation age differed between the two stands (Tables 3 and 4). The PNW values also differed between the two stands and were affected by logging technologies (Tables 3 and 4). Since the retention and capital recovery costs are calculated from the residual difference of the mill value and the logging costs, lower logging costs will lead to higher retention and capital recovery costs. The optimal rotation age for the oak stand (SN1) was 110 years with PNW ranging from $412.3 to $515.0/ha [$166.8 to $208.4/acre], depending on the logging system. The differences in PNWs ranged from $13.0 to $102.7/ha [$5.3 to $41.6/acre]. More expensive logging technology, such as system C, the Timbco 445 cut-to-length processor with the Valmet forwarder, resulted in lower PNW returns/ha at the optimal rotation age. The optimal economic rotation for SN2 ranged from 150 to 160 years with PNW values ranging from $46.6 to $72.6/ha [$18.9 to $29.4/ha]. The differences in PNWs ranged from $12.3 to $26.0/ha [$5.0 to $10.5/acre] and these differences are attributable to the logging system used. The rotation ages of SN1 and SN2 ranged from 110 to 160 years with PNW differences ranging from $339.7 to $468.4/ha [$137.5 to $189.5/acre]; these differences are largely attributable to the species mix of the two stands. Stands skewed toward more economically valuable trees species tend to reach their optimal economic rotation sooner than stands with lower value or noncommercial species mixes. The combination of a low value/noncommercial species mix (SN2) and the use of expensive logging technology (configuration C) resulted in the longest rotation of 160 years with the lowest PNW yield of $46.6/ha [$18.9/acre].

Patch retention treatments had a significant impact on harvest costs (Tables 3 and 4). Leaving 5% of the area in patch retention resulted in lower volume yields, lower mill values, lower PNW values, and retention costs ranging from $321.0 to $400.9/ha [$129.9 to $162.3/acre] for SN1 and SN2, respectively. Leaving 10% in patch retention (Tables 3 and 4) resulted in yet lower value yields, lower mill values, lower net returns to the landowner, and yet even greater retention costs. The retention costs/ha for this treatment ranged from $760.7 to $600.8/ha [$307.8 to $243.1/acre] depending on the logging technology used. Patch retention treatment 3 (retention patches that were left at age 110 but were later harvested at age 220) had substantially greater costs compared to other treatments (Tables 3 and 4). Although the trees are larger and more valuable, and the net revenue is greater, the revenue is not received until two centuries in the future, the time value of money reduces the PNW to single-digit dollar values. There was a substantial reduction in PNW for delaying harvest in these patches.

Revenue reductions attributed to patch retention treatments also can be calculated as an annual cost. Capital recovery cost will equal the revenue reductions estimated for patch retention treatments when compared to the control (no retention). One way to interpret these results is by viewing the capital recovery cost shown in Tables 3 and 4 for SN1 and SN2 by logging treatment as the annual economic benefit (cost) that would be required to offset the losses in PNW. For example, an annual benefit value of $30.4/ha [$12.3/acre] (Table 3) for SN1 with logging technology A would represent the benefit that would have to accrue on the trees/value left behind in order to offset the difference in PNW of $490.4/ha [$198.5/acre] (Table 3) for the same stand at harvest age 220.

Stands SN1 and SN2 began accruing big trees ($50.8 cm or $20 inches DBH) in different years (Figure 2). SN1 acquired big trees after age 60 while SN2 did not start to have trees of this size until after age 110. As SN1 aged to 150 years, big tree density began to decline due to mortality.

CONSIDERATIONS FOR MANAGERS

Although patch retention accomplishes a variety of ecological goals [35, 36], these treatments are expensive regardless of whether they are permanent or variable. Unless subsidized, landowners with significant economic goals may limit patch retention to inoperable sites, sites where timber is low value, or sites already mandated to be retention areas, such as riparian buffer strips. Our estimates of patch retention costs are comparable with a study in Minnesota, where logging contractors submitted two bids for the same harvest block: one bid without patch retention and a second including 10% patch retention [12]. Stumpage bids for the 10% patch retention option were $175.5/ha [$71.0/acre] (10.1%) less than the stumpage bid without patch retention. However, patch retention may not always be as economically favorable as indicated in this paper. In some forest types, harvest operations with patch retention may fail to break even economically (e.g., [9]).

Although revenue reductions from patch retention treatments occur only once at the beginning of the rotation, the ecological benefits of patch retention accrue throughout the next rotation. To compute future costs and benefits, we calculated the capital recovery factors needed to convert the revenue reductions to a series of uniform annual costs that begin at harvest and extend through the next rotation. Depending on the patch retention treatment, these costs from SN1 (Table 3) range from $12.8/ha/year [$5.2/acre/year] to $16.1/ha/year [$6.5/acre/year] (5%

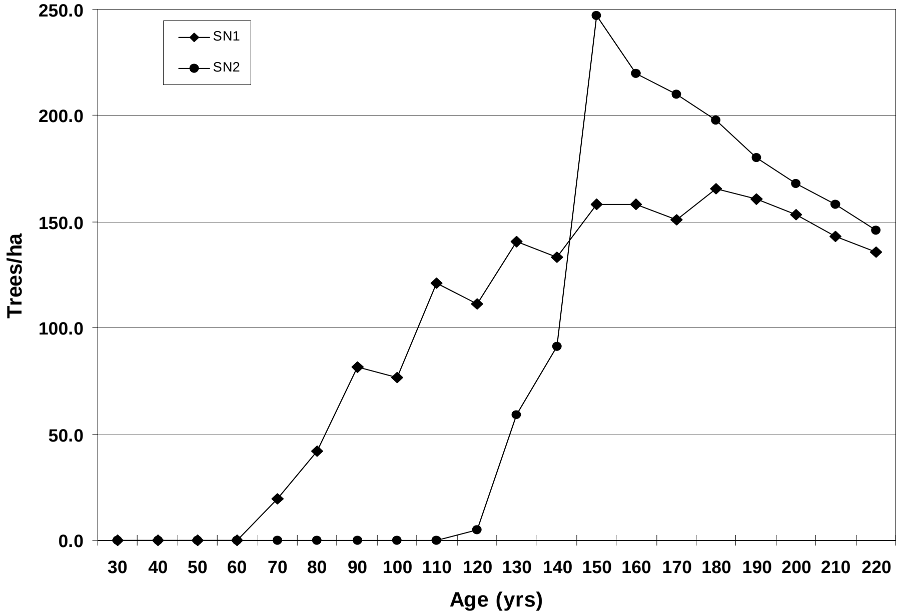


Figure 2. Large tree density by stand age (trees > 50.8 cm DBH) for SN1 and SN2. Median large tree density for northeastern old growth mesic oak forests is 64.3 trees/ha (calculated from [33]).

retention) and range from \$24.0/ha/year to \$30.4/ha/year [\$9.7/acre/year to \$12.3/acre/year] (10% retention) at a real interest rate of 4%. These capital recovery costs could be regarded as the tangible benefits that would have to accrue annually by a retention treatment to fully recover the upfront cost of implementing the respective retention/harvesting/stand combination. Alternatively, capital recovery costs could be regarded as the expense or loss that a landowner might use for tax accounting purposes. Some of these expenses could be written off for tax purposes, used as tax credits against taxable income, or in some cases, be subsidized. Finally, these capital costs could be regarded as the monetary benefit value required to provide for the sustainability of ecological processes or to accomplish wildlife/biodiversity objectives. Regardless of how these costs are interpreted, harvesting revenue forgone to implement retention treatments can represent, significant annual opportunity cost for landowners, against which future benefits must be weighed.

The opportunity/capital recovery costs of implementing retention treatments is impacted by the species mix, the logging technology, interest rates, product prices, and rotation lengths. The opportunity/ capital recovery costs must be weighed against accrued benefits of maintaining LS forests and possibly other biodiversity objectives. For example, Figure 3 shows the PNW revenue curve for SN1 with logging technology A. The further that retention treatments deviate from the optimal economic rotation at age 110, the higher the net losses to the landowner and the more expensive retention treatments become. The opportunity cost of patch retention can be minimized by applying the greatest retention levels in low-quality stands, and by using low-cost harvest systems when product prices are low and when rotation length is relatively short.

There are many combinations of forest types, logging technology, rotation lengths, retention treatments, and economic conditions that are beyond the scope of this paper. For example, in some applications, landowners can leave retention patches that are less productive/valuable or that have operability issues (wet, rocky, inaccessible). Some may combine retention areas with areas already included in riparian or other special designations. These areas also could also meet multiple objectives thus reducing retention costs. Layout costs will be different for alternative sizes and shapes of retention blocks. Additionally, some landowners may wish to use variants of individual tree retention within stands or blocks. Future research will focus on creative approaches that take some of the higher value tree species from within the retention units as they reach financial maturity. Each of these scenarios can be modeled and the resulting costs estimated. Although we only evaluated two stands, three logging technologies, four retention treatments and a set of fixed mill values and interest rate, the results provide insight into how combinations of the above impact short and long term costs for the scenarios simulated. Results from this research are specific to the conditions simulated and should not be inferred generally. However, for further scenario analyses, we have provided a step-by-step methodology for estimating the long-term opportunity/capital recovery costs of patch retention that others may use to assess the costs and benefits of patch retention.

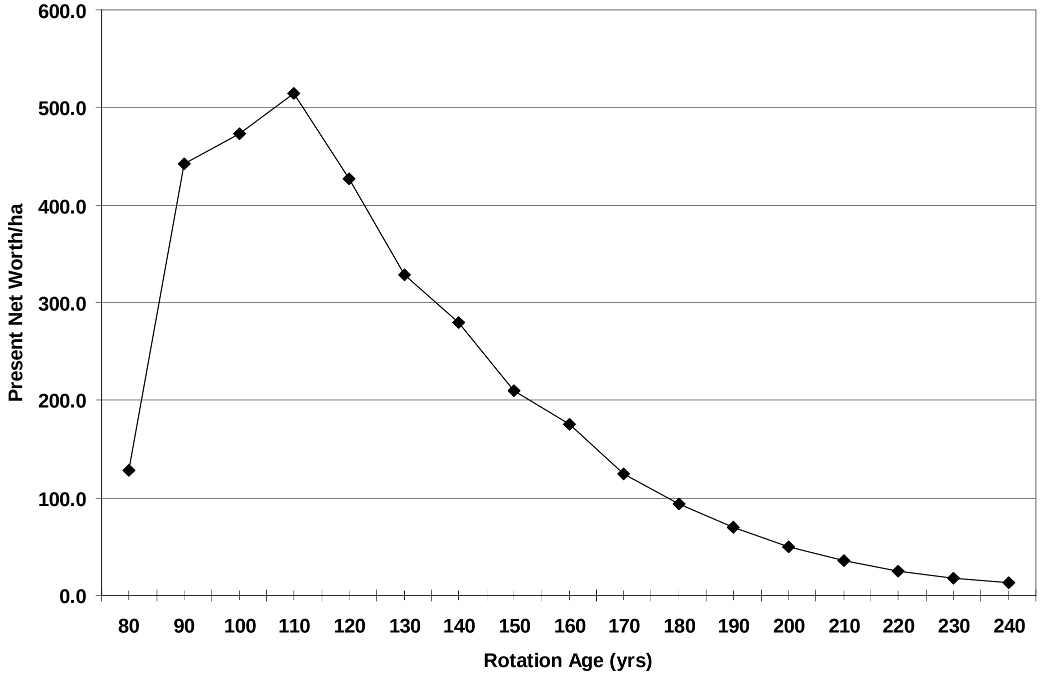


Figure 3. Present net worth (PNW) revenue curve for the SN1 with logging technology A, real interest rate is 4 percent.

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