

# AN ANALYSIS OF THE BENEFITS AND PROFITS OF SINGLE-TREE SELECTION SILVICULTURE: A CASE STUDY OF PIONEER FOREST IN MISSOURI'S OZARKS

Makoto Hamatani and Katherine M. Goslee<sup>1</sup>

**Abstract**—The profitability of single-tree selection is analyzed using Pioneer Forest as a case study. Uneven-aged management has resulted in an increase in standing volume over time, but stands have not yet attained their maximum volume. The 2000 asset value in real terms is three times higher than in 1980 and nine times higher than in 1960 due to an increase in volume per acre and a real increase in stumpage price. Whereas there are both advantages and disadvantages to uneven-aged management, particularly for small, nonindustrial private forest landowners, it is clear that single-tree selection is profitable for landowners, and may even compete financially with even-aged management. Ultimately, the combination of ecological benefits, continuous forest cover, and economic incentives make single-tree selection a valuable tool.

## INTRODUCTION

Pioneer Forest is a 154,000-acre privately owned forest, established in 1951. These woodlands are located in Missouri's Ozark region, within the Jack's Fork, Current, and Black River watersheds, and have a canopy dominated by oak, hickory, and pine. Pioneer Forest, under the ownership of the L-A-D Foundation, is the largest private landbase in Missouri. The forest is a working landscape, managed for timber, as well as many other purposes, including preservation of unique features in natural areas and forest reserves, watershed protection, and recreational activities such as hunting, fishing, camping, and hiking. Forest staff also use the forest as a model for other private timberland owners.

Since its establishment, Pioneer Forest has been under a method of uneven-aged management called single-tree selection. Uneven-aged forests contain trees in all age and size classes, with at least three age classes present on any given acre. Each harvest removes some of the financially mature trees and thins other trees from the forest structure. With each entry, only 40 percent of standing volume may be harvested, which allows the forest to maintain continuous forest cover of a variety of tree species over multiple generations. The residual trees are generally healthier than harvested trees and have increased space, light, water, and nutrition available for growth. Using these methods, any given area of the forest may be harvested approximately every 20 years.<sup>2</sup>

The purpose of this paper is to examine the profitability of single-tree selection using Pioneer Forest as a case study. First, the biological effects of Pioneer Forest's management over the last 50 years are described, including change in volume and tree growth on the forest. Next, the resulting asset value, sales, and profitability of Pioneer Forest are addressed, along with

the economic potential for single-tree selection on private land in general. Finally, uneven-aged management and even-aged management are compared and advantages and drawbacks of uneven-aged management for small landowners are discussed in this paper.

## CHANGE IN VOLUME OF STANDING TREES

Since 1952, Pioneer Forest has carried out a Continuous Forest Inventory (CFI), measuring and recording tree species, diameter, height, health/vigor, volume, and quality of standing trees every 5 years.<sup>3</sup> There are 486 2/10-acre permanent plots in which all trees 5 inches in diameter and greater at breast height (d.b.h.) are measured. For the past three inventories, all trees 1.6 inches to 5.0 inches in d.b.h. also have been measured in order to provide a better indication of the size and species composition of regeneration. Through single-tree selection, the volume of standing trees has been increasing over time. The annual rate of increase in standing volume was an average of about 2 percent through 1987 (aside from the period between 1972 and 1977). Since 1987, volume has been increasing at a rate of nearly 4 percent per year (fig. 1). Due to these increases, current volume of standing trees is more than three times higher than when Leo Drey acquired the land. Volume reached 3,680 board feet per acre in 2002 from 1,128 board feet per acre in 1952. Uneven-aged management at Pioneer Forest has resulted in an increase in standing volume over time, and ultimately the forest will reach its potential maximum volume. This increase in standing volume is due partly to the reallocation of resources to healthy trees by focused cutting on poor quality trees. However, based on the trend of a continued increase in standing volume, the forests on Pioneer Forest have not yet reached their maximum volume and may continue to increase for some time into the future.

<sup>1</sup> Makoto Hamatani, Graduate Student, Nicholas School of the Environment and Earth Sciences, Duke University, Durham, NC; Katherine M. Goslee, Director, Appalachian Voices, Boone, NC, now with the U.S. Forest Service, Cooperative Forestry, Washington, DC.

<sup>2</sup> Over the more than 50-year existence of Pioneer Forest, it has been determined that 20-25 years is the best rotation period. This interval allows maximum growth and minimum mortality, resulting in an increase in standing volume. It is important to note that rotation is determined by climatic and topographic conditions and will vary in different environments.

<sup>3</sup> Volume of trees is measured in board feet, the volume of wood in a board 1-inch thick by 1-foot wide by 1-foot long.

(MBF = 1,000 board feet.) Size of trees refers to diameter at breast height (d.b.h.), which is the diameter of the tree trunk 4.5 feet above the tree base.

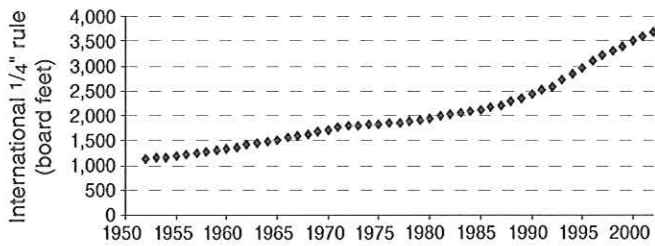


Figure 1—Change in volume of standing trees per acre.

## TREE GROWTH

Annual increment is the net annual increase in volume of standing trees per acre after mortality and sales are taken into account. Average annual tree growth is the gross increase in volume and is calculated by adding annual increment and the volume harvested for timber sales. Figure 2 shows average annual increment of standing volume, sales proportion, and annual tree growth. Because volume is measured every 5 years, the rate of annual increment appears to be stable. However, the ratio of sales to total volume fluctuated substantially every year until the 1990s.<sup>4</sup> It is important to note that growth rate is likely to be stable, whereas annual increment is actually likely to change every year, although the average of each of these rates should be very close to the actual rate.

The ratio of sales to total volume fluctuated until the middle of the 1980s, and has since been decreasing, as seen in figure 2. Whereas sales volume has remained relatively constant over time, total volume has risen incrementally until reaching a relatively stable level. Average annual net volume of standing trees has remained higher over the last decade because the ratio of sales to total volume has decreased. Prior to 1985, sales

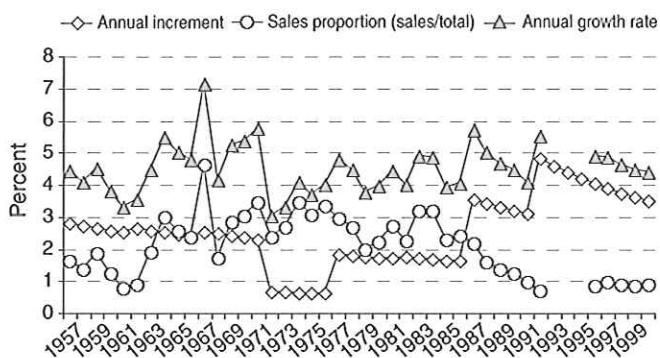


Figure 2—Timber sales relative to tree growth rate.

<sup>4</sup> Because of the different intervals of sampling data and heavy harvesting in terms of ratio of sales volume on total volume, the data in the early 1950s are eliminated to avoid distortion of the average growth rate. Also from 1993 to 1995, sales data is not available; the tree growth in the 3 years is not calculated.

<sup>5</sup> For hardwood species in Missouri timber markets, merchantable size is 11-inch d.b.h.; for softwood species, merchantable size is 9-inch d.b.h.

averaged 2.4 percent of total volume, tree growth rate was 4.3 percent, and net growth was nearly 2 percent. After 1985, sales averaged 1.5 percent of total volume, growth rate was 5.1 percent, and net growth was 3.6 percent.

Whereas growth rate has not changed very much over time (3 percent to 7 percent), annual growth in volume has increased yearly. As shown in table 1, the annual increase in volume of standing trees in 1957 was only 54.4 board feet per acre. Over the past 50 years, annual volume increase has become 2.5 times as high as that of 1957, based on an average growth rate of 4.4 percent. Continuous uneven-aged management improves the quality of forests and has led to an increase in annual growth every year thus far. However, it is unclear how long this trend will continue, and it is necessary to continue to analyze results from the forest inventory in order to pinpoint the maximum annual growth on Pioneer Forest.

## CHANGE IN VOLUME PER ACRE BY DIAMETER CLASS

Figure 3 shows increases in volume per acre for all measured diameter classes; the highest increase in volume is seen in trees with a diameter between 11 and 16 inches.<sup>5</sup> The volume of trees with a diameter greater than 21 inches increased by less than 100 board feet per acre for 45 years. This is due to the fact that it takes larger diameter trees more time to grow,

Table 1—Annual volume increase

Year	Annual increase <i>bd ft/acre</i>
1957	54.4
1962	62.0
1967	70.2
1972	79.1
1977	81.6
1982	89.1
1987	96.8
1992	113.9
1997	141.3
2002 <sup>a</sup>	134.76

<sup>a</sup> The slight drop in annual increase for 2002 is attributed to mortality from drought.

and harvesting only a few of these trees as they reach financial maturity greatly affects that particular class average. In addition, the number of trees per acre decreases with increasing size, explaining much of the variability in the larger diameter classes because fewer trees sampled leads to a higher variation in statistical results. Despite the slower increases in volume of larger trees, it is clear that in all diameter classes, there has been an increase in volume over the past 50 years (fig. 4). Additionally, figure 5 shows the percentage of volume per acre by diameter class, indicating that 11- to 16 -inch diameter trees have comprised a significant and stable proportion of total volume over time.

### CHANGE IN ASSET VALUE

The relative value of the standing trees per acre on Pioneer Forest has been increasing steadily over the past 50 years. As seen in figure 6, these values slowly changed until the 1980s, when the relative value of standing volume per acre began increasing dramatically. The circles represent actual or nominal value, and the squares represent the relative value adjusted

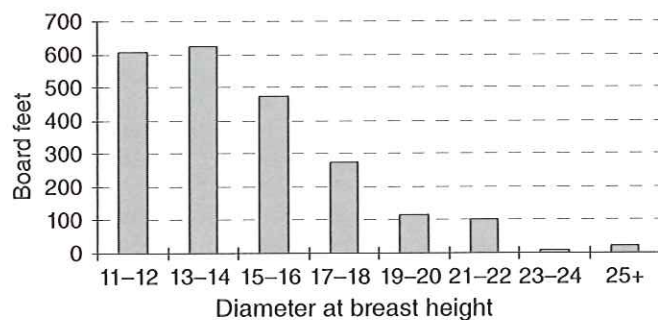


Figure 3—Increase in volume per acre by diameter class from 1952 to 2002.

for inflation.<sup>6</sup> The 2000 asset value in real terms is three times higher than in 1980 and nine times higher than in 1960. There are two reasons for this increase in the value: an increase in volume per acre as previously described and an increase in timber price.

Though there have been some fluctuations, overall stumpage price has been rising since 1970. The current price for stumpage is 4.3 times higher than that of 1970. In figure 7, the lower line and the upper line represent nominal and real prices of stumpage from Pioneer Forest, respectively.<sup>7</sup> Until 1970, an increase in timber price was lower than inflation, which indicates that price of timber in real terms decreased.

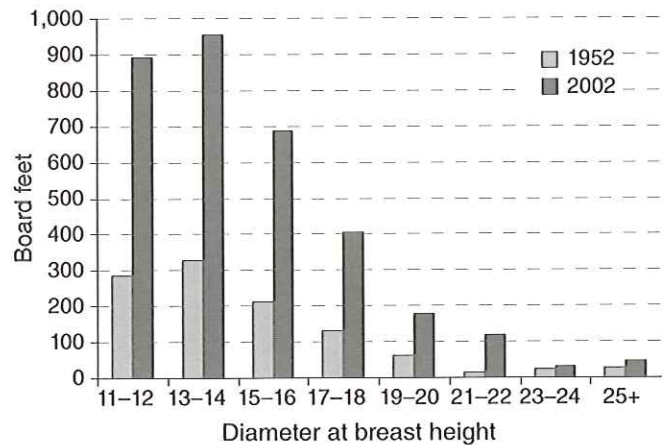


Figure 4—Distribution by diameter class in 1952 and 2002.

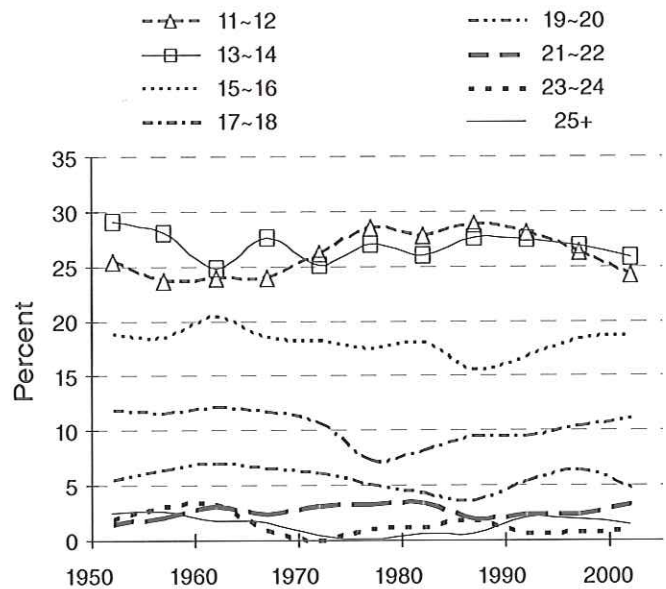


Figure 5—Percentage of volume by diameter class.

Since there have been simultaneous large increases in both price and standing volume per acre for the last 30 years, the value of standing trees has risen significantly. In 2001, Pioneer Forest had 2.47 times more volume at 4.3 times higher price than in 1972. This results in an average value per acre approximately 9 times higher in 2001 than in 1972.

<sup>6</sup> In this paper, the base of real term is the price in 2002. Real term value allows for a comparison of prices over time, as the value of the dollar changes.

<sup>7</sup> The prices in the graph are not average prices in this region; prices for Pioneer Forest are set higher than average prices in almost any year. The trend of average price in this area must be very similar to that in the graph. There are many related price determinants such as timber supply, quality of timber, and market power.

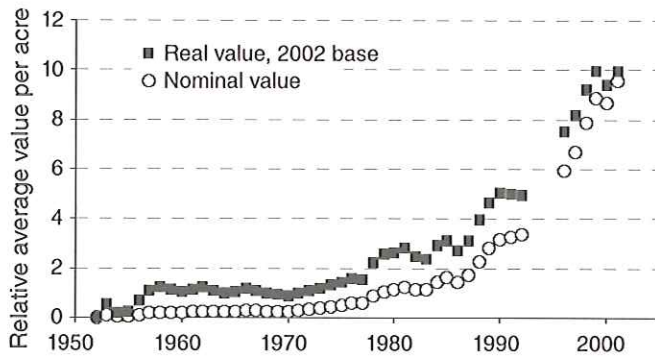


Figure 6—Value of standing trees.

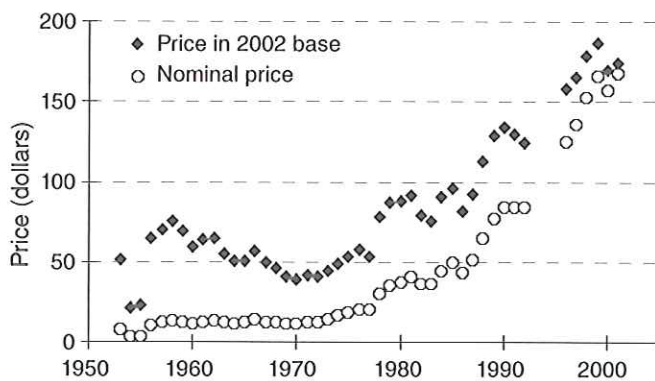


Figure 7—Price trends for stumpage from Pioneer Forest.

There are a number of factors that can impact asset value. Purchasing land has an effect on total asset value, and Pioneer Forest has purchased a large amount of land. However, over the past 30 years, the contribution of acquisition to the change in asset value is not significant. Timber grade also has an effect on asset value; the range of veneer timber price is from 3 times to 10 times as high as that of saw log price.<sup>8</sup> Assuming that the veneer price in this region of Missouri is just \$600 per thousand board feet (MBF), and 1 percent of the standing volume of Pioneer Forest is classified as veneer-quality timber, the total asset value including veneer-quality logs is 30 percent higher than the value in the graph.<sup>9</sup> However, it is often difficult to separate veneer-quality timber from saw logs, and this distinction is not generally made in timber sales. A final consideration is the inherent flaw in the concept of asset value, which is a hypothetical figure that cannot be accurately assessed until assets are actually sold.

<sup>8</sup> <http://www.conservation.state.mo.us/forest/products/prices/>, Missouri Timber Price Trends-Quarterly Market Report Index, Missouri Department of Conservation.

<sup>9</sup>  $[(\text{Asset Value in 2001})^{.99} + (\text{Asset Value in 2001})^{.01} / (\text{Real Price in 2001})^{.99} (\text{Price of Veneer}=600)] / (\text{Asset Value in 2001})$  nearly equal to 1.3.

<sup>10</sup> As mentioned previously, Pioneer Forest does not harvest timber from all of their land but manages some areas as old growth or for their unique ecological characteristics.

<sup>11</sup> Since no compatible data exists earlier than 1995, the ratio of incomes on expenses until 1996 is not clear.

## SINGLE-TREE SELECTION AND MARKET COMPETITION

In order to understand the economic benefits of single-tree selection, it is necessary to know how much timber per acre has been harvested from Pioneer Forest and the level of earnings from harvests over time. Since 1952, Pioneer Forest has made two or three entries into each harvest unit of their land,<sup>10</sup> although the intervals for entry differ depending on site conditions. This difference does not affect the number of board feet per acre that has been harvested, but it does affect profit because the same price in different years has different purchasing power due to inflation. Using actual data since 1952, adjusted to a 2002 base price, the average per acre volume of harvested timber and average sales per acre for 50 years are 2,708 board feet and \$238.85, respectively.

Based on the average volume of timber sold and the average profit over a 50-year period, the price of timber per MBF at a 2002 base is \$87. Compared to the current saw log price, this price is quite small. However, an advantage of uneven-aged management is that selling timber in several different market periods significantly reduces market risk to the landowner by making it possible to avoid selling all of the timber at the lowest price. By selling timber regularly, expected sales price is closer to actual average price, and variance of sales, the range of money you can earn from one sale, is less than it would be from fewer timber sales. Selling most of the timber in the 1950s would have led to lost opportunity for higher incomes because of high prices over the last 20 years. However, the range in price of saw logs was from \$20 to \$170 (2002 base), indicating that by selling timber regularly, Pioneer Forest avoided selling significant volumes of timber at a lower price. Uneven-aged management has proven to be an excellent method of avoiding market risk because landowners can harvest multiple times, thus avoiding risks of price fluctuation over time.

## MANAGEMENT COSTS AND PROFITS

Table 2 shows incomes and expenses from 1996 to 2001. The figures cited do not include certain sale expenses such as miscellaneous and consulting fees; rather, most are sales from saw log timber.<sup>11</sup>

Over the last 6 years, Pioneer Forest has netted profit constantly at an average of 57 percent of the total expenses. The largest portion of annual expenses is labor-related, which accounts for 70 percent to 80 percent of the annual costs. The second largest cost is taxes, with property tax the highest, at 10 to 20 percent of the annual costs.

**Table 2— Incomes and expenses of Pioneer Forest**

Year	Nominal		Ratio (incomes: expenses)
	Incomes	Expenses	
	----- dollars -----		
1996	499,391.19	360,873.43	1.38
1997	651,860.91	393,089.17	1.66
1998	700,890.23	398,466.46	1.76
1999	766,041.26	456,050.14	1.68
2000	784,299.67	470,014.35	1.67
2001	645,897.21	490,205.54	1.32
2002	731,525.75	490,878.21	1.49
Average			1.57

### FINANCIAL CONSIDERATIONS FOR SMALL LANDHOLDINGS

Having developed an understanding of the methods, benefits, and drawbacks of single-tree selection on Pioneer Forest, it is possible to draw some inferences about the economic potential for single-tree selection in general, and particularly on private land. There are a number of components to consider in the differences between a large landholding such as Pioneer Forest and smaller private landholdings that do not employ full-time foresters. First, it is important to note that because of overhead costs, it is not always economically feasible for a logger to enter a small acreage; whereas there are possible solutions to this problem, namely landowner cooperatives, they are beyond the scope of this paper. Additionally, because most landowners do not employ or need to employ a full time forester, the associated costs include fees charged by consulting foresters.

The charges that a landowner will incur from a forester usually include a flat rate for a stewardship management plan, a per-hour fee for appraisal, boundary marking, and other nonsale services, and a percentage of any timber sale. These fees approximate the costs to Pioneer Forest, which average approximately 12 percent of income and will account for fixed costs and salary, which will not need to be calculated separately. Based on this, it is possible to estimate the potential income for an individual private landowner using the approximate per-acre per-year income earned by Pioneer Forest, which was \$4 for the past 25 years. This means that if a landowner harvests 40 acres on a 20-year cycle, each harvest will gross \$3,200.

This is likely to be an underestimate since it is based on the entirety of Pioneer Forest's acreage although not all of their land is harvested. One potential source of additional income from forestland that is not addressed is nontimber products. Individual private landowners might consider such activities as annual hunting leases, growing other commodities such as mushrooms or, depending on the size and location of the forest, ecotourism.

In addition to costs, landowners face a number of obstacles when managing their forests using single-tree selection. The most noteworthy of these is the difficulty of finding a forester who is knowledgeable about single-tree selection and a logger who is willing to harvest in this manner. However, it is possible to ask a forester for references from previous clients and to look into the types of management he or she has utilized. Additionally, consulting foresters work directly for landowners, not logging companies, and are typically able to find an appropriate logger and manage the sale to ensure that all recommendations are followed.

### COMPARISON OF UNEVEN-AGED MANAGEMENT WITH EVEN-AGED MANAGEMENT<sup>12</sup>

To determine whether uneven-aged management is economically competitive with even-aged management, it is necessary to determine the volume of harvested trees. Assuming that approximately 6,000 board feet per acre can be harvested out of one clearcut, what volume of standing trees per acre is required to harvest an equal amount from uneven-aged forests?<sup>13</sup> The clearcut rotation in the Missouri Ozarks is estimated as roughly 80 years for oaks, although no forested tract in Missouri has been regrown through that suggested rotation period, and it may possibly be longer. However, during that period, uneven-aged management allows Pioneer Forest to harvest 40 percent of total volume at four different periods.

The CFI data reveal that on the whole, the harvests on Pioneer Forest compare quite favorably to those of even-aged management. On average, about 2,700 board feet per acre have been harvested, and, at this rate, it is possible to harvest 4,333 board feet per acre over 80 years<sup>14</sup> while still retaining an average standing volume of 3,700 board feet per acre. The last 50 years have been, in part, a transition period, during which time the volume of standing trees has been increasing. However, if all of the trees on Pioneer Forest were cut now,

<sup>12</sup> This comparison is hypothetical because Pioneer Forest has no areas managed using even-aged management. However, another study offers a direct comparison of low-impact methods and clearcutting methods. A 45-year study undertaken in New Brunswick by the New Brunswick Federation of Woodlot Owners and the University of New Brunswick compared three similar stands, two managed using low-impact, selection forestry and the other managed through clearcutting (<http://www.lowimpactforestry.com/doesitpay/study2.htm>). The results show that low impact forestry provided an average of 74 hours per acre of employment, whereas clearcutting provided 35 hours per acre. The sites managed using selection forestry yielded an average of 35 cords per acre, and the clearcut sites yielded 22 cords per acre. The total stumpage value, in 1996 dollars, averaged \$1,350 per acre from the low-impact site and \$550 per acre from the clearcut site. In addition, the site managed using low-impact methods had twice the standing volume of the clearcut site when the study was published in 1996, with a wood of higher value, red spruce, than the clearcut site, poplar.

<sup>13</sup> Clinton E. Trammel, Personal Communication, 1310 Hillview Drive, Rolla, MO 65401

<sup>14</sup> 4,333 board feet per acre is calculated simply by multiplying 2,708 by 1.6 (80 years/50 years). The amount of harvest for the 80 years will exceed 4,333, because volume of standing volume now is higher than 2,708 board feet per acre.

the harvest would be 6,400 board feet for 50 years; the volume of timber that has been produced for 50 years, on average, is 5,270 board feet. In an 80-year rotation, 8,480 board feet would be produced assuming that the volume of standing trees increased at the same rate. If the volume of standing trees does not increase, a conservative estimate, the amount of harvested trees will be 2,700 board feet multiplied by 80/50 years. The volume produced would be 6,920 board feet; therefore, even the conservative case is competitive with even-aged management. Another important consideration is that when a landowner clearcuts, land costs have to be carried 60 to 80 years with little or no revenue from that land.

The principal economic advantages of uneven-aged management, compared to even-aged management, are (1) financial diversification, (2) annual value added, (3) constant income, (4) continuous forest cover, and (5) a long-standing relationship with sawmills. As explained through this paper, uneven-aged management enables diversification in two ways. One is diversification by more sales opportunities, and the other is diversification by holding several different investments. This combination allows landowners to be exposed to less risk. Second, as shown previously in table 2, annual growth of standing volume on Pioneer Forest has increased under uneven-aged management, and annual average volume growth per acre is 106 board feet for 50 years compared to 75 board feet under even-aged management.<sup>15</sup> This shows that the value added annually for uneven-aged management is greater than that of even-aged management. Of course, these numbers are averages, and trees do not grow at the same rate all the time, although overall, if landowners keep forest in uneven-aged management and even-aged management for the same period, forests in uneven-aged management produce more timber.

Third, uneven-aged management provides landowners with an income from their land every 20 years rather than once every 80 years. Consider a hypothetical example of two identical sites; one is managed using even-aged management, the other using uneven-aged management. On both sites, 6,000 board feet can

be harvested for 80 years, and the price of timber is constant at \$170 (real) per MBF. Table 3 shows the schedule of harvests. Based on both stumpage values and nominal values, uneven-aged management yields a higher profit than even-aged management over the duration of the 80-year cycle. In the case of high inflation or an increase in expected timber price, nominal values for uneven-aged management would be even higher. How the cash flow is ranked depends on individual preference, and some prefer the constant cash flow and value provided by uneven-aged management. Additionally, the maximum yield for even-aged management on Pioneer Forest has not yet been determined. Furthermore, in uneven-aged forests, multiple uses such as hunting, camping, and hiking are continuously possible, and landowners may derive some income from these activities.

Finally, since there are more opportunities to sell timber using uneven-aged management, it could be possible to have long-term relationships with sawmills. These relationships help to establish trust between landowners and sawmills because they offer a more continuous timber transaction for both the buyer as well as the seller. Actually, Pioneer Forest has such long-term relationships with sawmills extending over generations of mill owners, which helps the business of Pioneer Forest to run smoothly.

## CONCLUSION

It is clear that there are both advantages and disadvantages to uneven-aged management, particularly for small, nonindustrial private forest landowners. However, it is also clear that single-tree selection is profitable for landowners and may even compete financially with even-aged management. Whereas the economic aspects of uneven-aged management are primarily addressed in this paper, there are numerous ecological factors that should be considered for a complete comparison to even-aged management. Ultimately, the combination of ecological benefits, continuous forest cover, and economic incentives make single-tree selection a valuable tool.

<sup>15</sup>  $[2,600(\text{an increase in standing trees per acre})+2,700(\text{average harvest per acre})]/50 \text{ years}=106.$

**Table 3—Investment value of even-aged and uneven-aged management**

Year		Tract 1—Even-aged management			Tract 2—Uneven-aged management		
		Volume/acre	Stumpage	Nominal	Volume/acre	Stumpage	Nominal
		----- dollars -----			----- dollars -----		
0	Original volume	6,000 bd ft			6,000 bd ft		
	Harvest, <sup>a</sup> bd ft	6,000 @\$6/mbf	36.00	343.61	2,900 <sup>b</sup> @\$6/mbf	17.40	166.06
	Retained volume	0			3,100		
	Bd ft growth	0			2,900 <sup>c</sup>		
20	Volume, bd ft	0			6,000		
	Harvest, bd ft	0			2,900 @\$6/mbf	17.40	201.32
	Retained volume	0			3,100		
	Bd ft growth	800			2,900		
40	Volume, bd ft	800			6,000		
	Harvest, bd ft	0			2,900 @11/mbf	31.90	181.64
	Retained volume	800			3,100		
	Bd ft growth	1,000			2,900		
60	Volume, bd ft	1,800			6,000		
	Harvest, bd ft	800 @ \$72/mbf	57.60	107.74	2,900 @\$57/mbf	165.30	309.20
	Retained volume	1,000			3,100		
	Bd ft growth	2,000			2,900		
70	Volume, bd ft	3,000					
	Harvest, bd ft	1,000 @\$100/mbf	100	124.87			
	Retained volume	2,000					
	Bd ft growth	2,900					
79	Volume, bd ft	4,900			6,000		
	Harvest, bd ft						
	Retained volume	4,900			6,000		
	Volume	4,900 @\$170/mbf	833.00	833.00	6,000@\$170/mbf	1,020.00	1,020.00
	Total harvested volume	7,800			11,600		
	Total residual volume	4,900			6,000		
	Total volume	12,700			17,600		
	Total value of harvested and remaining volume		1,026.60			1,252.00	
	Nominal dollars reinvested using CPI <sup>d</sup>			1,409.22			1,878.22

<sup>a</sup> Harvests begin immediately and assume 80 year investment.

<sup>b</sup> Harvest no more than the annual growth.

<sup>c</sup> 145 board feet annual growth per acre per year.

<sup>d</sup> Consumer Price Index of 2.86.

