PRICING INTERMEDIATE-AGED TIMBER IN A MARKET WITH DERIVATIVES

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ABSTRACT

Derivative contracts can be used by timber investors to establish the selling price as of the end of an anticipated holding period. By introducing the use of such contracts into valuation exercises, an analyst is able to value intermediate-aged timber without either forecasting the selling price or estimating a risk-adjusted discount rate. An application to a southern hardwood stand demonstrates that values estimated with the derivative-based approach can imply substantially different management regimes than ones based on discounted cash flow valuations.

INTRODUCTION

Even for a stand of timber that is merchantable, the estimated present value of a future timber sale can differ substantially from the stand’s immediate harvest value. A common situation in which the differential is quite pronounced is a stand on the verge of experiencing dramatic merchantability-class ingrowth—that is, moving out of one class (say, pulpwood) to a more valuable one (say, sawtimber). In order to capture the benefits to be derived from the larger trees, the timber owner must be willing to delay the receipt of net timber sale revenue and to confront certain risks—with the future level of timber prices generally representing the primary nondiversifiable risk. Thus, the discounted cash flow-based valuation of this delayed harvest is sensitive to both the selected discount rate and the estimated level of future timber prices.

Given the availability of appropriate derivative contracts, the timber investor could synthetically "lock in" the price per volumetric unit for a delayed timber sale by adding a combination of such contracts to ownership of the standing timber. A derivative contract is one with a value contingent upon the price of some underlying asset price (see Zinkhan 1994, 1995). If the investor’s opportunity is to be
devoid of arbitrage profits, then the value of the price-hedged position as of the date of a future resale must equal the accumulated value (as of the same future date) achieved by immediately executing a timber sale for future harvest and investing the proceeds in an investment vehicle with a risk level matching that of the hedged position. The purpose of this paper is to propose, apply, and investigate an approach for valuing timber—especially intermediate-aged timber—when timber-derivative contracts are available. This proposed valuation approach is most appropriate in those cases in which there is a lack of confidence regarding estimates of either future timber prices or the level of risk-adjusted discount rate to utilize.

A THEORETICAL FRAMEWORK

Consider numerous investors contemplating the purchase at time \( t_0 \) of standing timber, all categorized within a single merchantability class (CLASSA), from a landowner. Assume frictionless markets with neither income taxes nor transaction costs; homogeneous expectations regarding the price distribution of timber; and an informationally efficient timber market where two structures of timber-purchase contracts are under consideration:

CON1: Landowner sells \( Y \) volumetric units, representing all of the currently merchantable timber, to an investor for immediate resale.

CON2: Landowner again sells \( Y \) volumetric units to an investor, but in this case resale is delayed until time \( t^* \), where \( t^* > 0 \) and represents the perceived value-maximizing contract maturity, for all \( t > 0 \). By time \( t^* \), the timber is projected to mature into \( Z \) volumetric units of CLASSB timber.

Given assumptions of an absence of taxes and transaction costs and an opportunity for arbitrage profits to be achieved when prices deviate from the equilibrium, the value of CON1 (VALCON1) at time \( t_0 \) would approach:

\[ \text{VALCON1} = Y \cdot \text{PRICECLASSA}_{t_0} \quad [1] \]

where:

\[ \text{PRICECLASSA}_{t_0} = \text{market price}, \text{per unit of volume}, \text{of CLASSA timber at time } t_0 \]

Private contracts between an investor and a dealer in derivatives enable the investor to establish a price floor, a
price range, or perhaps to "lock in" a price of some commodity, all for a time period of \( t^* \). A cash-settlement European put option contract (for a unit of volume of CLASSB timber) between the investor and a derivatives' dealer would obligate the seller of the contract to pay the buyer the difference between the exercise price \( X \) and the price per unit of CLASSB timber at time \( t^* \) (i.e., \( X - \text{PRICECLASSB}_{t^*} \)), when \( \text{PRICECLASSB}_{t^*} < X \) at time \( t^* \). When \( \text{PRICECLASSB}_{t^*} \geq X \) at time \( t^* \), the seller of the contract would not be required to make a payment to the buyer. For assuming the potential obligation, the seller receives an upfront premium, \( \text{PUTPREM} \) per unit, from the buyer.

In contrast to the put option, a cash-settlement European call option would obligate the seller of the contract to pay the buyer the difference between the price per unit of CLASSB timber at time \( t^* \) and \( X \) (i.e., \( \text{PRICECLASSB}_{t^*} - X \)), when \( \text{PRICECLASSB}_{t^*} > X \) at time \( t^* \). When \( \text{PRICECLASSB}_{t^*} \leq X \) at time \( t^* \), the seller would not be required to make a payment to the buyer. For assuming the potential obligation, the seller receives an upfront premium, \( \text{CALLPREM} \) per unit, from the buyer.

Consider a long forward contract on CLASSB timber, a cash-settlement European call option on CLASSB timber with maturity \( t^* \) and exercise price \( X \), and a cash-settlement European put option on CLASSB timber with maturity \( t^* \) and exercise price \( X \). Assume no carrying costs associated with the underlying asset, CLASSB timber. At time \( t^* \), the forward-contract is structured so that the investor’s account is credited for \( \text{PRICECLASSB}_{t^*} \). Based upon the basic option conversion equation (see Brealey and Myers 1991, p. 488-494), at time \( t^* \) the sum of \( \text{PRICECLASSB}_{t^*} \) and the value of the put option should equal the sum of \( X \) and the value of the call option:

\[
\text{PRICECLASSB}_{t^*} + \text{PUTPREM}_{t^*} = X + \text{CALLPREM}_{t^*} \tag{2}
\]

The investor in CON2 could fix the effective price, at \( X \), for one volumetric unit of CLASSB timber as of time \( t^* \) by purchasing one put option and selling one call option:

\[
X = \text{PRICECLASSB}_{t^*} + \text{PUTPREM}_{t^*} - \text{CALLPREM}_{t^*} \tag{3}
\]

For this equation, a positive sign indicates a long position in the associated asset; a negative sign indicates a short position.

Given a contract structure in which the investor (1) is responsible for all holding period expenses, such as forest management expenses, property taxes, and custodial costs, and (2) compensates the landowner for use of the bare land, the value of CON2 (VALCON2) at time \( t_0 \) would approach:
VALCON2 = PV\{Z \times X\} - Z \times \text{PUTPREM}_{t_0} + Z \times \text{CALLPREM}_{t_0} \tag{4} \\
\text{PV}\{\text{CUSTEXPENSE}_t\}_t^{t*} - \text{PV}\{\text{LEASEPMTS}_t\}_t^{t*} \quad \text{where:} \\
\text{PV}\{\} = \text{present value, as of } t_0, \text{ of contents} \\
\text{CUSTEXPENSE}_t = \text{anticipated custodial expenses, forest management expenses, and property taxes during period } t^* \\
\text{LEASEPMTS}_t = \text{lease payments sufficient to compensate landowner for use of bare land which supports subject timber, during period } t^* \\

Here, a positive sign indicates a cash inflow whereas a negative sign indicates a cash outflow from the perspective of the investor. Equation \([4]\) describes a situation in which the timber investor has locked in the effective future price at \(X\) by combining the purchase of timber price insurance (i.e., the put option) with the sale of the upside timber price potential (i.e., the call option).

Importantly, the risk-free rate of interest is appropriate for discounting the exercise price in equation \([4]\), since it is contractually fixed. Furthermore, standard option pricing models (such as those that might be applied to the valuation of \(\text{PUTPREM}_{t_0}\) and \(\text{CALLPREM}_{t_0}\)) do not require the estimation of a risk-adjusted interest rate as an input.

Even if a derivatives' dealer does not quote a price for either the call or put option positions described in equation \([4]\), decomposing the value of the delayed timber sale into its financial components offers certain benefits. First, unlike a traditional discounted cash flow approach, a forecast of the future timber price is not required. Instead, specification of the future shape of the timber price changes and an estimation of the associated periodic standard deviation are sufficient. Second, given the structure of equation \([4]\), VALCON2 is not very sensitive to the selection of risk-adjusted discount rate; the selection of such a rate is a controversial issue in forestry (e.g., Cubbage and Redmond 1985; Zinkhan 1988). Application of an option pricing model to the valuation of the put and call option positions does not involve the estimation of a risk-adjusted discount rate. Although estimation of the level of the lease payments in equation \([4]\) will sometimes necessitate the selection of a forestry-related, risk-adjusted rate, the overall valuation of CON2 will be much less sensitive to the selection than a traditional discounted cash flow approach. Third, the derivative-based approach enables the investor to establish values for both the downside price risk and the upside price potential.
Finally, the maximum bid, \( \text{MAXBID}_{t0} \), to be offered by an investor for the timber at time \( t_0 \) is:

\[
\text{MAXBID}_{t0} = \text{MAX}(\text{VALCON1}, \text{VALCON2})
\]  

[5]

APPLICATION TO A CASE OF SOUTHERN HARDWOODS

Consider an investor that is evaluating the purchase of an acre of standing 40-year-old southern hardwood timber. The investor intends to use a contract similar to either CON1 or CON2 (described in the last section). Resale of the purchased timber within a 10-year window of opportunity is to be investigated. Detailed assumptions associated with this stand and its valuation are listed in Appendix 1.

The value under contract structure CON1—that is, the current-use value of the standing pulpwood, oak sawtimber, and mixed-hardwood sawtimber—is $1,200.

Both traditional discounted cash flow analysis and an approach relying on the use of timber derivative contracts can be adopted to value the investment under contract structure CON2. Using traditional discounted cash flow analysis with an assumption of no real increase in timber prices, the expected present value of buying, holding, and selling the timber is maximized if a five-year holding period is anticipated (see Table 1). The maximum value of the timber purchase with delayed resale is $1,301, 8.4% greater than the value estimated if the timber is immediately resold by the investor.

Adopting the derivative-based approach described in equation [4], value-maximization necessitates a delay in reselling the timber until at least year 10 (see Table 1). The associated value of CON2, $2,076, is substantially greater than the levels estimated with a discounted cash flow value using either a 5- or 10-year holding period. Of course, since a price forecast is not included among the valuation inputs when the derivative-based approach is adopted, an increase in the assumed rate of real appreciation in timber prices mitigates the gap between the results estimated using the two approaches. Equality of the estimates is not reached until the annual rate of real appreciation is increased to almost 5% (not shown in Table 1).

Given the 10-year-horizon limitation for this study, the maximum bid that would be made by the investor for this stand of timber is (based on equation [5]):
TABLE 1
Selected Valuation Estimates for the Southern Hardwood Timber Case

<table>
<thead>
<tr>
<th>Age (Years)</th>
<th>Call Values</th>
<th>Put Values</th>
<th>Derivative-Based Valuea</th>
<th>DCF Valueb</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$104</td>
<td>$51</td>
<td>$1,271</td>
<td>$1,217</td>
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<td>2</td>
<td>178</td>
<td>60</td>
<td>1,353</td>
<td>1,233</td>
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<td>3</td>
<td>254</td>
<td>61</td>
<td>1,444</td>
<td>1,249</td>
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<tr>
<td>4</td>
<td>332</td>
<td>61</td>
<td>1,547</td>
<td>1,273</td>
</tr>
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<td>5</td>
<td>416</td>
<td>59</td>
<td>1,662</td>
<td>1,301</td>
</tr>
<tr>
<td>6</td>
<td>493</td>
<td>53</td>
<td>1,732</td>
<td>1,288</td>
</tr>
<tr>
<td>7</td>
<td>575</td>
<td>45</td>
<td>1,809</td>
<td>1,274</td>
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<td>8</td>
<td>659</td>
<td>37</td>
<td>1,892</td>
<td>1,264</td>
</tr>
<tr>
<td>9</td>
<td>752</td>
<td>26</td>
<td>1,981</td>
<td>1,250</td>
</tr>
<tr>
<td>10</td>
<td>848</td>
<td>19</td>
<td>2,076</td>
<td>1,242</td>
</tr>
</tbody>
</table>

a Estimated using equation [4].
b This discounted cash flow approach reflects an assumed real rate of appreciation in timber prices of 0%.

\[
\text{MAXBID}_{t_0} = \text{MAX}($1,200, $2076) = $2,076
\]

Further investigation of the valuation of the derivatives' components of CON2 may be instructive. Consider, for instance, the valuation of the call options associated with the pulpwood. In order to apply the binomial option pricing model (see Hull 1991, p. 308-327), five inputs are needed: current price of pulpwood ($11.83 per cord), annualized standard deviation of the continuously compounded change in pulpwood prices (15.5\%, based on the Timber Mart-South quarterly price series from 1977-1994), the exercise price of the contract ($15.90, based arbitrarily on the current price plus the assumed inflation rate over the contract's duration), the risk-free rate of interest (7.6\%, based on the continuously compounded form of the rate on U.S. Treasury strips with a maturity equal to the contract's duration), and the contract's duration (10 years). Applying Stand-Alone software (McGraw-Hill, 1988), the value per contract is $4.55. That is, the investor should be compensated with $4.55 per cord in return for selling, beyond the assumed rate of inflation, the upside price potential of pulpwood. Since the estimated volume of pulpwood in year 10...
is 39.59 cords, the total value received for selling pulpwood call options is $180.13 (i.e., 39.59 contracts x $4.55 per contract).

Notice that neither a timber price forecast nor a risk-adjusted discount rate is included among the inputs needed to value the call option (see Brealey and Myers 1991, p. 502). This represents a potential advantage of the approach versus a traditional discounted cash flow approach.

Using equation [2], the cost to the investor of buying insurance against pulpwood prices falling short of current prices plus expected inflation over the next 10 years can be estimated. The estimated cost of $.13 per cord (or contract) is reflective of the low probability of this outcome as well as the reduction in the present value of the exercise price as the option's time to expiration lengthens. The cost of 39.59 contracts is $5.15 (i.e., 39.59 contracts x $.13 per contract).

Having sold the upside pulpwood price appreciation and having purchased insurance against price depreciation, the investor establishes the year 10 pulpwood price at X, or $15.90 per cord.

IMPLICATIONS OF A DERIVATIVE-BASED APPROACH FOR PERFORMANCE INDICATORS

Due the absence of a longstanding series of continuous prices for a broad sample of timberland, historical timberland performance indicators are sometimes constructed by periodically revaluing the components of the timberland investment—namely the merchantable timber, the premerchantable timber, and the bare land. For example, the annual version of the Southern Hardwood Forestland Index and the underlying assumptions used in its construction are shown in Appendix 2. Given the lack of associated regular data, notice that no value was assigned to premerchantable timber and the timber values reflected only current-use merchantability classes.

The results of the last section suggest that the intrinsic value of an intermediate-aged hardwood stand can substantially exceed its immediate harvest value. If the timberland market recognizes only timber's immediate harvest value, then investors should be able to frequently capture excess value by purchasing such tracts, selling the timber at some optimal age, and then selling the land and any residual timber. In the absence of offsetting incremental pricing factors (such as illiquidity), this opportunity would
certainly suggest a market inefficiency. In contrast, if the market fully recognizes the present value of the timber within some optimal harvest regime, then expected rates of return should approach the appropriate risk-adjusted discount rate.

Potential investors may have an interest in the performance of timberland investments when the standing timber’s value is fully reflected in acquisition and disposition prices. The forecasting of timber prices as part of the process of estimating the periodic, historical values of standing is inappropriate for an ex post performance indicator. However, this step would be necessary if a discounted cash flow value were used to periodically value all standing timber. An alternative would be the utilization of the derivative-based approach. Although an estimate of future timber price volatility would be required to implement the latter approach, it is likely that ex post volatilities—used to estimate ex ante volatilities—are more stable than ex post absolute price levels. The volatilities of southern mixed-hardwood and oak sawtimber were rather stable during the 72 quarters ending in year-end 1994. The annualized standard deviations of the continuously compounded changes in mixed-hardwood sawtimber prices ranged from 13.2% to 15.2% when the study period was divided into three 24-quarter sub-periods. For oak sawtimber, the comparable range was 14.7% to 17.7%. There was greater instability within the hardwood pulpwood price series; its comparable range was 9.3% to 19.7%. Additional empirical research is needed to investigate the use of the derivative-based approach for helping to construct timberland performance indicators.

CONCLUSIONS

Financially engineered timber portfolios enable the investor to modify the structure of future payoffs. Through the trading of timber price derivatives, timber investors can change their level of exposure to future timber price fluctuations. One alternative is the use of derivatives to establish the future timber price at a given level. Recognition and investigation of this alternative can provide insights into the valuation of standing timber.

While adoption of the derivative-based approach can overcome certain disadvantages associated with discounted cash flow approaches, other problems are introduced. First, an active market for timber derivatives has not been developed. Thus, derivative prices cannot be observed in the marketplace; instead, the values of rather complex options must be estimated from various inputs in order to implement
the derivative-based approach. Second, much of the available data regarding timber sales are for sales with rather short-term harvesting requirements. This may be problematic if such data are used to value long-term timber derivatives, since timber derivatives are a form of contingent security. As such, their value is contingent upon the price of these timber sales. If the timber sale prices do not reflect the opportunity for long-term delayed harvests, then their prices only reflect current timber demand and supply conditions. The likely approach for addressing this shortcoming is the use of timber allocation estimates from timberland transaction data in the process of estimating the value of long-term timber derivatives. Additional investigation of this issue is needed.

Empirical testing of the derivative-based valuation approach is needed. Initial testing should be transaction oriented. Investigations of the gaps between actual and predicted prices for intermediate-aged timber should provide investors with a better understanding of the markets for such timber. Of special concern is the degree to which this timber's relative illiquidity influences its pricing.

LITERATURE CITED


APPENDIX 1--ADDITIONAL ASSUMPTIONS

Additional assumptions used in the generation of the output in Table 1:


2. As of year 0, the age of the dominant trees was 40 years. Age 40 characteristics of the forest: height of dominant trees--90 feet; basal area per acre of merchantable timber--130 square feet. Of the timber, 32.5 cords is classified as pulpwood and 5.962 mbf (Doyle rule) is sawtimber. Of the basal area, 15% is oak and the remainder is mixed hardwoods. Volumes were projected for the next 10 years using the tables developed by Roeder and Gardner.

3. Year 0 stumpage prices (using the Southeast State averages reported in the fourth quarter, 1994 Timber Mart-South): $192/mbf (Doyle rule) for oak sawtimber, $127/mbf (Doyle rule) for mixed-hardwood sawtimber, and $11.83/cord for hardwood pulpwood.

4. Annual custodial costs of $3.72, fluctuating with the assumed annual rate of inflation.

5. Annual compensation of $16.32 paid by the timber investor to the landowner for use of the bare land.
6. In addition to the contract's maturity and the level of current stumpage prices, three other variables are required to value timber call and put options: the standard deviation of the continuously compounded change in timber prices, the continuously compounded rate on a risk-free investment, and the contract’s exercise price. Oak sawtimber, mixed-hardwood sawtimber, and hardwood pulpwood prices are anticipated to have volatilities of 16.1%, 14.5%, and 15.5%, respectively. These annualized levels reflect the historical volatilities of these timber price series, reported quarterly, for the period 1977-1994. The risk-free rates used for the various contracts reflect the term structure of interest rates of U.S. Treasury strips. With a base equal to the year 0 stumpage price, the exercise price of each timber option contract is equal to the base plus an increment reflecting the assumed inflation rate.

7. An annual inflation rate of 3%.

8. The discount rates used to estimate the discounted cash flow values reflect a capital asset pricing model beta of 0.11, a market premium of 6.58%, and the term structure of interest rates for U.S. Treasury strips. The beta was estimated using the quarterly version of the Southern Hardwood Forestland Index (see Appendix 2) and the S&P 500 Index for the period 1978-1994.

9. The binomial option pricing model was adopted to value the options. The options' lifetimes were divided into 10 intervals for the valuation exercises.

APPENDIX 2--THE SOUTHERN HARDWOOD FORESTLAND INDEX (SHFI)

The SHFI was created to provide a broad benchmark for the historical investment performance of southern hardwood forestland. Annual returns reflect net income from periodic timber sales and net appreciation in the value of a residual synthetic forest. The synthetic forest and the estimated annual returns can be described as follows:

1. The overall synthetic forest consists of equal acreages of seven types of southern hardwood forests: Black River Bottom; Bottomland; Branch Bottom; Coves, Gulfs, and Lower Slopes; Muck Swamp; Red River Bottom; and Wet Flat. These representative forests grow in areas ranging from poorly drained portions of the Coastal Plain to segments of the upper Piedmont and Mountains. Each of these seven components is divided into 20 units of equal acreage, in which grow stands of homogeneous age classes ranging from
20 to 39 years (at the beginning of each year).

2. The forest is the product of natural regeneration.

3. Growth and yield data for the seven forest types were compiled by North Carolina State University (Gardner et al. 1982; Roeder and Gardner 1984).

4. Throughout each year, timber volume equal to the annual growth of the overall forest is sold and harvested from the oldest stand. Thus, the total volume of timber remains constant from year to year. At the end of each year, the residual sawtimber and pulpwood volumes of the cutover units are equal to that of the age-class 20 stands; the cutover units are then swapped for age-class 20 stands. The swap permits the maintenance of a relatively even-aged character for each unit of the forest.

5. Merchantable volumes of stands ranging in age from 20 to 30 years are based upon the stand characteristics described by Gardner et al. The characteristics of the 30-year stands were used to estimate the growth over the subsequent 10 years—in two five-year increments (Roeder and Gardner).

6. Timber Mart-South is the source of timber price information. For the purpose of valuing standing timber and timber sales, the following three timber product categories are recognized: woods-run oak sawtimber, woods-run mixed hardwood sawtimber, and hardwood pulpwood. Southeastern State average prices are applied to the three timber product categories. When valuing the sawtimber, the distribution of oak versus mixed-hardwood sawtimber is based upon the species' respective shares of basal area (see Gardner et al.)

7. Bare land associated with six of the forest types—Black River Bottom, Bottomland, Branch Bottom, Muck Swamp, Red River Bottom, and Wet Flat was priced at the rate of $127 per acre as of year-end 1988. Using Washburn's (1988) analysis of bottomland versus cutover pine land prices, this price represented 60.4% of the value of cutover Mississippi pine land (Timber Mart-South region 2). Bare land associated with the other forest type—Coves, Gulfs, and Lower Slopes—was priced at the rate of $157 per acre as of year-end 1988. Using Washburn's analysis of hardwood versus cutover pine land prices, this price was 74.6% of the value of cutover Mississippi pine land (Timber Mart-South region 2). The annual price of land is assumed to fluctuate with the rate of change in the eight-quarter weighted moving average of timber prices (see Hancock Timber Resource Group (1993) for a justification). For the first year of the index, 1977, a
five-quarter weighted average of timber prices was used as the foundation for estimating the annual change in bare land prices. Mixed-hardwood sawtimber prices serve as the basis for estimating the annual changes in bare land prices.

8. The value of the overall forest equals the value of the merchantable standing timber plus the value of the bare land. No value is assigned to premerchantable timber.

9. Timber sale administration expenses are 7% of annual timber sale revenues.

10. Annual custodial costs (including property taxes) associated with all acreage and costs associated with modest regeneration-enhancing activities on the cutover units were $2.62 and $20.00 per acre, respectively, as of year-end 1984 (Thomson 1992). These levels fluctuate with the CPI. The site regeneration costs are incurred before the cutover units are swapped.
### SOUTHERN HARDWOOD FORESTLAND INDEX (SHFI)

(Not Adjusted Through the Use of Timber Derivatives)

<table>
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<tr>
<th>YEAR</th>
<th>INDEX</th>
<th>INDEX INCOME</th>
<th>% INCOME</th>
<th>% APPRECIATION</th>
<th>% RETURN</th>
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#### Mean Income: 4.49%

#### Mean Appreciation Rate: 6.79%

#### Mean Annual Rate of Return: 11.28%

#### Compound Annual Rate of Return (With Reinvested Income): 10.79%

#### Standard Deviation: 10.30%

Note: An investment of $100.00 at the end of 1977 in a forest mimicked by the SHFI would have yielded net cash flows of $5.38, $5.13, $4.42 ... $11.99 during the years of 1978 to 1994. At the end of 1994, the residual forest would have been worth $283.58. With reinvestment of income, an investment of $100.00 at the end of 1977 would have been worth $571.20 by the end of 1994.