# FINANCIAL RATES OF RETURN ON THINNED AND UNTHINNED STANDS, USING LARGE-SCALE FOREST INVENTORY DATA IN MISSISSIPPI AND ARKANSAS, 1977 TO 1995

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**Abstract**—Providing landowners and natural resource managers information on financial rates of return (ROR) plays a vital role in providing and promoting forest management. I combined Timber Mart-South stumpage price data with forest inventory data spanning 17 years from the Southern Research Station, Forest Inventory and Analysis work unit for the States of Arkansas and Mississippi. This dataset was used to compute simple and adjusted financial ROR. The study area encompassed 63.4 million acres of which 37.4 million acres were in timberland. A total of 11 325 sample plots, of which 6 416 were classified as forest, made up the initial dataset. The study's timeframe spanned three decades, with MS surveys conducted in 1977, 1987, and 1994, while AR were in 1978, 1988, and 1995. Of these 6 416 plots, 245 were classified as sapling-seedling sized stands 1977 to 1978, sawtimber size 1994 to 1995, and having no harvesting or disturbance (< 5 percent all live removals or mortality) occurring on them at any time during the survey time span. Another 41 plots where classified as sapling-seedling sized stands in 1977 and had 20 to 50 percent of their all live volume removed during the 1987 to 1988 survey. These 41 plots had no harvesting, mortality, or disturbance during any other forest inventory and were classified as sawtimber size by the mid-1990s. I studied the annual rate of change (both monetary and volume) from the point which harvesting occurred on the thinned stands. Therefore, these preliminary results pertain to changes that occurred between the 1987 to 1988 and 1994 to 1995 surveys. The average annual volume growth of all live trees on the undisturbed plots was 2.2 percent per year, while the 41 thinned stands' volume growth was 4.6 percent per year. The average real ROR on the undisturbed stands was 15.7 percent per year using a simple financial maturity model, and 8.6 percent per year using an adjusted financial maturity model. The thinned stands grew at a higher rate, as their real rate of value change was 19.9 percent and 10.1 percent per year for the simple and adjusted financial maturity models, respectively. All volume and value change differences between undisturbed and thinned stands proved to be statistically significant. Combining long-term/large-scale forest inventories with price data has the potential to guide landowner decisions by offering insights into forest management dynamics.

## INTRODUCTION

Duerr and others (1956) developed the concept of financial maturity, which is comparing the growth rate in timber values with an alternative rate of return. This idea can be adapted to any species and silvicultural system. Financial maturity is attained when the cost of holding an appreciating asset exceeds the expected monetary gains (Mills and Callahan 1979). Recently, data from the Southern Research Station (SRS), Forest Inventory and Analysis (FIA) unit have been used to calculate historical rates of return (ROR) on undisturbed forests across the South. These rates were compared to alternative investment options available to natural resource managers during the study timeframe (Hartsell 1999).

The next logical step in the process is to study the impacts of intermediate silvicultural practices, such as thinnings, using similar methodology. This paper investigates the financial impacts of thinnings using financial maturity concepts by combining FIA data with Timber Mart-South (TMS) stumpage prices. Two distinct datasets and time phases are analyzed. Comparisons will be made between thinned and unthinned stands over post treatment and rotation phases. Post treatment ROR compare thinned and unthinned stands for the survey period after the thinnings occurred, while the rotation ROR compare the rates of these for the entire study period.

## STUDY AREA

The study area consists of all timberlands in the States of Arkansas and Mississippi. Timberland is defined as land that is at least 10 percent stocked by trees of any size, or formerly having such tree cover, and not currently developed for nonforest uses. Minimum area considered for FIA classification and measurement is one acre. The study area encompassed 63.4 million acres, of which 37.4 million acres were in timberland. A total of 11,325 sample plots, of which 6,416 where classified as forest, made up the initial dataset.

## TIMEFRAME

The study's timeframe spanned three decades, with MS surveys conducted in 1977, 1987, and 1994, while AR were in 1978, 1988, and 1995. The study investigates two phases, posttreatment and rotation. Posttreatment ROR pertain to the change that occurred from the 1980s surveys to the 1990s. For thinned stands, this represents the change in value that occurred to the residual trees. The rotation ROR reflects the change that occurred between the initial stand and the terminal inventory.

## METHODS

The data came from forest surveys of AR in 1978, 1988, and 1994, and MS in 1977, 1987, and 1994. The sample design utilized a two-phase method: dot counts for estimating timberland area and tree measurements on sample plots for determining stand and tree attributes. Sample plots were located on a 3-mile square grid. Each sample plot consisted of a 10-point satellite system covering about 1 acre. At each satellite point, trees were tallied by species along with diameter breast height (d.b.h.), height, and other tree-character variables for the determination of volume and biomass. Additionally, for each plot, stand level attributes

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were determined by computer algorithm for stand size and forest type.

## PLOT SELECTION

All plots must be classified as forested for all survey periods in question. All 1970s plots had to be classified as poletimber size or smaller. All plots had to be sawtimber size and have at least 5 000 board feet per acre (International ¼-inch rule) in the 1990 surveys. Plots classified as unthinned had to have zero evidence of harvesting, management, or man-caused disturbance in either of the last two survey periods. This resulted in a sample size of 245 plots classified as unthinned (table 1). Plots classified as thinned had 20 to 50 percent of their all live volume removed between the 1970 and 1980 surveys, and no harvesting or management between the 1980s and 1990s surveys. Forty-one plots met the conditions for thinned stands. The distribution of these plots is illustrated in figure 1.

## TREE SELECTION

All live trees ≥ 5 inches d.b.h. were included in the sample set, except rotten cull trees. Rough cull tree volumes were given pulpwood value. No cull trees were used in sawtimber computations. Tree selection was performed by variable radius sampling (37.5 basal area factor [BAF]). Since tree selection was performed by variable radius sampling, new trees appear over time. These new trees were included in all computations and therefore affect growth and value changes. Trees that died between survey periods were included only in the survey year(s) in which they were alive. This has the potential to create negative biological and economic value growth between surveys.

## TIMBER MART-SOUTH DATA

This study uses TMS price data to calculate individual tree values. TMS has been collecting delivered prices and stumpage prices for 11 Southern states since December 1976. All TMS price data are nominal. Real prices were calculated using the U.S. Bureau of Labor Statistics all commodities producer price index. As 1987 was the midpoint of the study period, all TMS prices were inflated or deflated to 1987 levels.

## TREE PRODUCTS AND VALUES

The algorithm used for determining tree products was: 1) all poletimber-size trees are used for pulpwood, 2) the entire volume of rough-cull trees, even sawtimber-size trees, is used for pulpwood, 3) the saw-log section of sawtimber-size trees is used for sawtimber, and 4) the section between the saw-log top and 4-inch diameter outside bark pole top is used for pulp and often referred to as topwood. Poletimber-size trees are softwoods 5.0 to 8.9 inches d.b.h. and hardwoods 5.0 to 10.9 inches d.b.h. Sawtimber-size trees are all softwoods that are

**Table 1—Number of plots, average annual growth percent, real timber value growth, and real forest value growth percent of unthinned and thinned stands, post treatment period, in Arkansas and Mississippi, 1988 to 1995**

| Model | Number | Average | Std.dev. | Maximum | Minimum |
|---|---|---|---|---|---|
| | | *unthinned stands (percent)* | | | |
| BGP[a] | 245 | 2.17 | 3.86 | 13.23 | -44.72 |
| TVG[b] | 245 | 15.66 | 7.38 | 38.80 | -55.67 |
| FVG 250[c] | 245 | 10.87 | 4.44 | 21.35 | -19.94 |
| FVG 500[d] | 245 | 8.62 | 3.72 | 18.75 | -14.25 |
| FVG 750[e] | 245 | 7.22 | 3.28 | 16.75 | -11.27 |
| | | *thinned stands (percent)* | | | |
| BGP[a] | 41 | 4.60 | 3.27 | 13.20 | -2.66 |
| TVG[b] | 41 | 19.86 | 6.98 | 36.68 | 8.33 |
| FVG 250[c] | 41 | 12.98 | 4.87 | 22.02 | 2.20 |
| FVG 500[d] | 41 | 10.10 | 4.31 | 19.97 | 1.27 |
| FVG 750[e] | 41 | 8.38 | 3.94 | 18.32 | 0.89 |

[a] BGP = the average annual change in volume expressed as a percentage.
[b] TVG = the unadjusted annual real rate of return.
[c] FVG = the adjusted annual real rate of return with land value = $250 per acre.
[d] FVG = the adjusted annual real rate of return with land value = $500 per acre.
[e] FVG = the adjusted annual real rate of return with land value = $750 per acre.

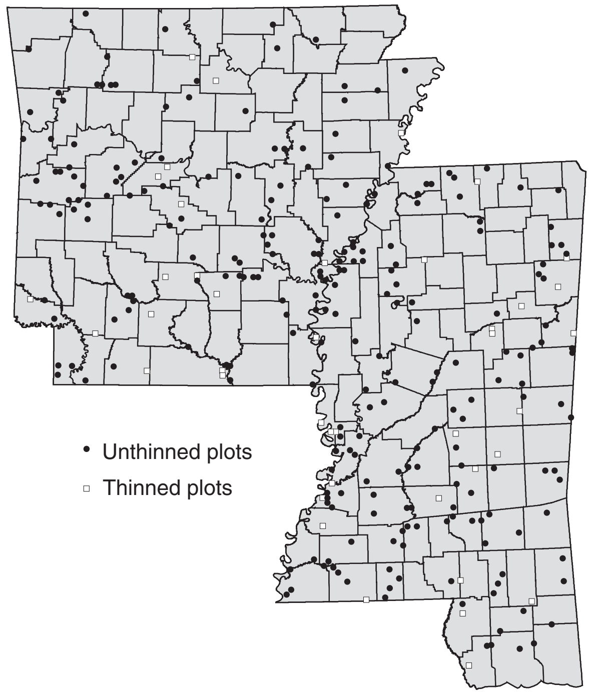


Figure 1—Distribution of unthinned and thinned sample plots in Arkansas and Mississippi.

at least 9.0 inches d.b.h. and hardwoods that are at least 11.0 inches. Cull trees are any tree that is less than one-third sound.

In 1981, TMS began to report southern pine chip-n-saw prices. Therefore, the two survey periods after this time included a third product, southern pine chip-n-saw. Chip-n-saw trees are southern pines 9.0 to 12.9 inches d.b.h. All trees < 9.0 inches are still treated as pulpwood and trees ≥ 13.0 inches d.b.h. are treated as sawtimber trees. This modification was made for the 1988 and 1995 survey periods.

FIA traditionally computes all board foot volumes in International ¼-inch log rule. Most of the TMS price data is in Doyle log rule. To accommodate the price data, all FIA tree volumes were recalculated using the Doyle formula. There are a few instances where prices are reported in Scribner log rule. To accommodate this, the Doyle prices for these few instances were converted to Scribner prices by multiplying the Doyle price by 0.75 (Timber Mart-South 1996).

The TMS reports include a low, high, and average price for standing timber for various products. This report does not consider peeler logs or poles and piling as possible products because determining these products from FIA data is questionable. Omitting these classes allows for a slightly conservative approach to estimating tree and stand value. FIA data has information on species, product size (poletimber or sawtimber), and quality (tree class and tree grade). Prices for each section of the tree were assigned based on these factors. These prices were then applied to the different sections of a tree.

## GROWTH MODELS

Timber volumes and values are summed for each plot. These totals are then used as inputs for the growth models. Three growth models were used in this study. Each is based on the formula used in determining average annual change.

Timber value growth (TVG) is a simple financial maturity model that considers only the actual change in value for a plot for the survey period in question. Incomes derived from future stands are ignored (Hartsell 1999). The basic formula for TVG is:

$$FVG = \left[\left(\frac{TVF + LVF}{TVP + LVP}\right)^{1/t} - 1\right] \times 100 \qquad (1)$$

where

TVG = timber value growth percent
TVF = ending sum of tree value on the plot at time 2
TVP = beginning sum of tree value on the plot at time 1
t = number of years between surveys.

Forest value growth (FVG) includes the value of land in the computation of economic value change (Hartsell 1999). The formula for FVG is:

$$FVG = \left[\left(\frac{TVF + LVF}{TVP + LVP}\right)^{1/t} - 1\right] \times 100 \qquad (2)$$

where

FVG = forest value growth percent
TVF = ending sum of tree value on the plot at time 2
LVF = ending land value
TVP = beginning sum of tree value on the plot at time 1
LVP = beginning land value
t = number of years between surveys

FVG is an adjusted financial maturity model. Adjusted financial maturity concepts account for all implicit costs associated with holding timber. These are sometimes referred to as opportunity costs. In doing so, revenues from future stands are accounted for. One method of adjusting the model is to include bare-land value (LV) in the equation, because bare-LV accounts for future incomes and the inclusion of LV adjusts the simple financial maturity model. Further discussion on implicit and explicit costs, as well as the results of these studies, can be found in other studies by the author (Hartsell 1999).

Biological growth percent (BGP) is similar to TVG, except it uses timber volumes instead of timber values. The BGP model accounts for the actual annual change in tree volume for a plot over a survey period. The BGP model is the same as the TVG model, except it uses the sum of tree volumes on the plot instead of the sum of tree values (Hartsell 1999).

## RESULTS AND DISCUSSION

Comparing posttreatment volume and value change rates between thinned and unthinned stands yields predictable results. Stands that had 20 to 50 percent of their all live volume removed in the 1970s grew more than twice as much as unmanaged stands between the last two surveys (mid-1980s to mid-1990s). Unthinned stands increased in total volume at a rate of 2.2 percent per year, while stands that where thinned in the prior survey grew at a rate of 4.6 percent per year. This indicates that the thinning produced an increased growth response, or release, for the remaining trees (table 1).

Financial ROR also favored thinned stands. The simple financial maturity model (TVG) shows that between the last two survey periods, thinned stands earned 19.9 percent per year, compared to 15.7 percent for unmanaged stands. These rates appear high for several reasons. The first is that there was a dramatic increase in real stumpage values that occurred in the late 1980s and early 1990s. Another is that the simple model fails to account for many of the implicit and explicit costs of holding timberlands. The adjusted models (FVG) account for these costs. FVG was computed for three different per acre bare-LV; $250, $500, and $750. Increasing bare-LV has a moderating effect of ROR. The adjusted ROR on thinned stands ranges from 13.0 percent per year to 8.38 percent per year depending on the value of land. All of these are higher than the adjusted ROR found on unthinned stands, which have ROR ranging from 10.9 percent per year to 7.2 percent. Additionally, all thinned stands produced a positive financial ROR, that is, no managed stand lost money. Conversely, at least one unthinned stand lost anywhere from 11.3 percent to 19.9 percent per year, depending on LV.

Stratifying the plots by forest type reveals that pine stands responded to the thinning, the greatest in terms of biological growth (table 2). Thinned pine stands accrued 5.8 percent per year in volume, compared to 4.0 percent per year for unthinned stands of the same type. Again, all thinned forest types outperformed their same type in the unthinned dataset. One would assume that due to this increase in growth, pine would outperform the other types in terms of financial growth as well. But this is not the case. Managed mixed and oak-gum-cypress stands had higher unadjusted ROR than thinned pine due to the dramatic increase in the stumpage prices of hardwoods that occurred during this time period.

Adjusting the simple model with $750 per acre yields different results, as pine stands are now ranked first in terms of ROR, earning 10.6 percent per year. This is significantly higher than mixed-stands' 8.5 percent per year. Oak-gum-cypress or oak-hickory stands (7.7 and 4.7 percent per year respectively) are the lowest earning types (table 2). The reason these pine stands earn more after the adjustment is simple. Pine stands in general had higher per acre values in the mid-1980s than hardwood stands. Over the next 10 years, hardwood stumpage prices rose faster than pine. This produced higher simple returns for hardwoods, as the starting value for these stands was low. However, adjusting the model had a greater moderating effect on hardwood stands due to this low initial stand value.

Tables 1 and 2 clearly illustrate the post-thinning response of forested stands in AR and MS. This raises the question: what is the economic impact of thinning for the entire "rotation," with rotation being the timeframe of the study (mid-1970s to

**Table 2—Number of plots, average annual growth percent, real timber value growth, and real forest value growth percent of unthinned and thinned stands, post treatment period, by forest type, in Arkansas and Mississippi, 1988 to 1995**

| Forest type | Number | BGP[a] | Std. dev. | TVG[b] | Std. dev. | FVG 750[c] | Std. dev. |
|---|---|---|---|---|---|---|---|
| | | | *unthinned stands (percent)* | | | | |
| Pine | 32 | 3.97 | 2.58 | 16.41 | 4.63 | 8.59 | 3.21 |
| Mixed | 26 | 2.53 | 2.34 | 16.85 | 6.29 | 8.27 | 2.74 |
| Oak-hickory | 62 | 1.19 | 6.36 | 14.90 | 11.19 | 6.54 | 3.94 |
| Oak-gum-cypress | 117 | 2.09 | 2.40 | 15.83 | 5.74 | 7.01 | 3.00 |
| Elm-ash-cottonwood | 8 | 2.84 | 1.40 | 12.49 | 2.83 | 6.86 | 1.93 |
| | | | *thinned stands (percent)* | | | | |
| Pine | 15 | 5.80 | 2.32 | 19.89 | 4.41 | 10.64 | 4.52 |
| Mixed | 5 | 3.29 | 3.11 | 20.34 | 6.63 | 8.49 | 2.05 |
| Oak-hickory | 7 | 3.85 | 3.89 | 17.59 | 11.37 | 4.72 | 3.17 |
| Oak-gum-cypress | 14 | 4.16 | 3.90 | 20.79 | 7.48 | 7.75 | 2.76 |

[a] BGP = the average annual change in volume expressed as a percentage.
[b] TVG = the unadjusted annual real rate of return.
[c] FVG = the adjusted annual real rate of return with land value = $750 per acre.

**Table 3—Number of plots, average annual growth percent, real timber value growth, and real forest value growth percent of unthinned and thinned stands, entire study period, in Arkansas and Mississippi, 1988 to 1995**

| Model | Number | Average | Std.dev. | Maximum | Minimum |
|---|---|---|---|---|---|
| | | *unthinned stands (percent)* | | | |
| BGP[a] | 245 | 3.15 | 3.33 | 28.21 | -22.29 |
| TVG[b] | 245 | 9.27 | 5.94 | 33.92 | -28.47 |
| FVG 250[c] | 245 | 5.57 | 2.64 | 11.66 | -7.46 |
| FVG 500[d] | 245 | 4.27 | 2.02 | 9.58 | -4.96 |
| FVG 750[e] | 245 | 3.52 | 1.70 | 8.21 | -3.76 |
| | | *thinned stands (percent)* | | | |
| BGP[a] | 41 | 2.14 | 2.56 | 9.34 | -3.31 |
| TVG[b] | 41 | 8.01 | 4.21 | 16.30 | -1.09 |
| FVG 250[c] | 41 | 4.97 | 2.57 | 10.20 | -0.94 |
| FVG 500[d] | 41 | 3.81 | 2.06 | 7.87 | -0.83 |
| FVG 750[e] | 41 | 3.14 | 1.76 | 6.77 | -0.75 |

[a] BGP = the average annual change in volume expressed as a percentage.
[b] TVG = the unadjusted annual real rate of return.
[c] FVG = the adjusted annual real rate of return with land value = $250 per acre.
[d] FVG = the adjusted annual real rate of return with land value = $500 per acre.
[e] FVG = the adjusted annual real rate of return with land value = $750 per acre.

mid-1990s)? These results were surprising and confounding. Initial post treatment period results indicated that unthinned stands grew more and earned more than thinned stands. Unthinned stands grew 3.1 percent per year versus 2.1 for thinned stands (table 3). Likewise, all economic ROR were higher for unthinned stands. The unadjusted ROR for managed stands was 9.3 percent, compared to 8.0 percent for managed forests. Adjusting the model with LV with $250, $500, and $750 per acre produced similar results.

ROR by forest type were then computed to determine if these results where due to species. This was not the case, as unthinned stands again outperformed thinned in every type group. Unthinned pine stands grew 5.2 percent per year, compared to only 3.5 percent for unthinned (table 4). The unadjusted model indicates that unthinned stands earned more than their counterparts for every type except mixed, which where statistically insignificant. Only after the model is adjusted with $750 per acre do thinned pine and mixed stands begin to compare to those that were undisturbed. Unthinned pine stands earned 4.4 percent per year (adjusted model with $750 per acre) which is comparable to 4.2 percent for the thinned stands.

The results from tables 3 and 4 caused a review of the methodology and models. It is quickly apparent that the models do not account for any tree volume and value that was removed during the thinning. Thus, the current models are reliable for studying the post management response to stands (tables 1 and 2), but lacking when dealing with entire rotations (tables 3 and 4). Therefore, conclusions drawn from the first two tables, thinning produces more growth and economic returns immediately after thinning, are correct. Tables 3 and 4 underestimate the returns from thinned stands, as incomes derived from the silvicultural operations are excluded. This is particularly revealing, because the adjusted ROR for pine and mixed stands were statistically

**Table 4—Number of plots, average annual growth percent, real timber value growth, and real forest value growth percent of unthinned and thinned stands, entire study period, by forest type, in Arkansas and Mississippi, 1988 to 1995**

| Forest type | Number | BGP[a] | Std. dev. | TVG[b] | Std. dev. | FVG 750[c] | Std. dev. |
|---|---|---|---|---|---|---|---|
| | | | *unthinned stands (percent)* | | | | |
| Pine | 32 | 5.21 | 5.06 | 11.56 | 7.25 | 4.37 | 1.70 |
| Mixed | 26 | 3.42 | 2.59 | 9.73 | 4.99 | 4.07 | 1.51 |
| Oak-hickory | 62 | 2.27 | 3.74 | 8.14 | 7.08 | 3.07 | 1.95 |
| Oak-gum-cypress | 117 | 2.92 | 2.41 | 9.18 | 5.04 | 3.41 | 1.53 |
| Elm-ash-cottonwood | 8 | 4.23 | 1.87 | 8.60 | 4.65 | 3.58 | 1.44 |
| | | | *thinned stands (percent)* | | | | |
| Pine | 15 | 3.49 | 2.83 | 9.35 | 3.95 | 4.22 | 1.78 |
| Mixed | 5 | 1.80 | 2.00 | 10.01 | 3.56 | 4.02 | 1.03 |
| Oak-hickory | 7 | 1.85 | 3.00 | 8.79 | 4.67 | 2.12 | 1.44 |
| Oak-gum-cypress | 14 | 0.97 | 1.77 | 5.48 | 3.80 | 2.17 | 1.37 |

[a] BGP = the average annual change in volume expressed as a percentage.
[b] TVG = the unadjusted annual real rate of return.
[c] FVG = the adjusted annual real rate of return with land value = $750 per acre.

insignificant to the unmanaged stands when higher bare-LV are used to adjust the models. To fully examine the long-term ROR on managed stands, the current models need to be modified to account for these revenues. Future studies will incorporate these factors.

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