forestry & natural resources
WOODLAND MANAGEMENT

The Economics of Timber Stand Improvement

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Silvicultural Goals

Timber stand improvement (TSI) is a conscious woodland management investment which encompasses a number of different silvicultural treatments. TSI includes improvement cutting, cleaning, weeding, and liberation cutting and thinning. In Indiana, the two major activities conducted under the term TSI are 1) improvement cuttings and 2) thinnings.

Improvement cuttings are generally made in previously unmanaged stands and take the form of removing cull trees or low-value species. The goal of such an operation is to increase future stand value by removing trees of little or no economic value and by providing space in which higher quality and high-value species can develop. Secondary goals may be removal of poor seed sources and vine control.

Thinnings to control density are the second major activity associated with TSI. The goal is to lower the density to an optimum level so that the growth potential is redistributed to the most desirable trees. In thinning, all the trees remaining are assumed to be left for a specific reason. An uncut tree may be left to become a crop tree, a trainer for a crop tree, or to act as a "spacer" in the stand.

Crop tree release is a special application of thinning. In this case, the trees to be removed are determined by proximity to preselected crop trees. Crop trees are selected on the basis of their quality or potential quality from species having above average market prices, such as black walnut, yellow poplar, and white oak. The purpose of this activity is to reduce the cost of thinning the whole stand while still gaining the benefits of increased growth on selected high-value trees. Occasionally, trees of lesser quality potential are selected as crop trees if they are members of the high-value species group. Release may save them from being suppressed and killed by dominating less-valuable trees which overtop them.

The goal of any TSI project is the concentration of diameter growth on high-value, vigorously growing trees. The degree to which this goal can be satisfied for any individual woodland will depend, in large part, on the stands' condition before TSI. Obviously, stands which need only small amounts of TSI are going to respond the least. Stands where the residual stand will be less than 35 to 50 percent of desirable trees might be more efficiently managed by a regeneration cut and possibly supplemental planting. Stands of intermediate quality will have the greatest potential for response from TSI when the desirable trees form 50 to 80 percent of the residual stocking.

Characteristics of the TSI Investment

Costs

The costs incurred in a TSI investment are:

- Paid professional services used in evaluating the woodlands
- Paid professional service used in the designation of trees to be saved or removed
- Expense of removing or killing trees designated for removal
- Capitalization of the investment over time.

The expense of removing or killing trees comprises the cost of labor and overhead, including supervision, supplies and equipment, insurance, and transportation. Capitalization is the implicit interest cost of holding an investment over time. It is the required rate of return necessary to maintain the funds in the investment. The investment analysis suggested herein calculates the capitalization (interest) costs, and it is not necessary to enter them explicitly. As the length of the investment period increases, the capitalization costs will increase as well.

Benefits

The economic benefits stemming from TSI are:

- Increased stand value through improved tree quality
- Faster diameter growth on the crop trees, which may reduce the investment period.

Increased stand value results from diameter growth being concentrated on higher-valued, faster-growing trees. Usually, overall tree quality will increase. Since the trees are growing faster, the investment period may be shortened, and the capitalization cost may be reduced. Together, this results in larger trees of higher quality, which means more volume per tree at higher per board foot prices.

The greatest single problem in the analysis of TSI is the estimation of the benefits. The anticipated benefits are difficult to quantify. Foresters familiar with local conditions can utilize their professional experience and judgement in making these estimates.

TSI Investment Analysis

The TSI investment analysis procedure presented here will determine if the cost of the investment is equal to or less than the benefit gained from the investment. Only those costs and benefits which are attributable to the TSI activity are pertinent. Past costs and revenues do not affect the analysis. *The benefit measured is the difference in future value between untreated and treated woodlands, not the difference between present stand value and future stand value of the treated stand.* This is an important consideration because it reduces the benefit which is sometimes erroneously attributed to TSI, the difference between present and future value of the treated stand.

Current prices are used to evaluate the worth of the timber to remove the influence of inflation. Since the value of the TSI operation is being examined and inclusion of the price changes will mask the true affect of TSI, current prices must be used in this analysis. This does not imply constant prices, since current price varies with quality.

Tax impacts on the TSI investment are complex. Depending on the degree of sophistication desired, the analysis can be done before or after taxes. The examples below are before taxes. To obtain an after tax analysis, the costs and benefits must be net of the tax imposed on them.[1]

The availability of federal cost sharing funds can also reduce the out-of-pocket cost to forest owners. This means that two analyses may be performed, one for the rate of return on the woodland owner's out-of-pocket costs, and one for the total cost of the investment to evaluate the overall effectiveness of the cost sharing program.

A Step By Step Procedure For Analyzing TSI Investments

STEP 1 Obtain an inventory of present stand conditions. This includes the percentage of cull and other undesirable trees by volume basal area and/or number of trees, total merchantable volume, a measure of stocking level of desirable trees, and projected growth.

STEP 2 Using the projected growth, calculate[2] the future stand condition including all the above stand parameters. To the volume information, apply current prices to determine the future value of the stand with TSI.

STEP 3 Using the above calculated growth rate and anticipated increase in growth, estimate the future value of the stand if TSI is completed. The anticipated increases are crucial, and yet, there is little definitive information available. This is where an experienced professional forester is most valuable. With a knowledge of current published research and his knowledge of local condition, the forester can estimate the increased growth. Again using present prices, calculate the value of the future stand with TSI.

STEP 4 Calculate the net gain from the TSI by subtracting the value found in STEP 2 from the value found in STEP 3. If this net gain is negative, it is obvious that TSI will not pay. If the net gain is positive, go on to STEP 5.

STEP 5 In this step, three ways of assessing the rate of return on the TSI investment are described. It is first necessary to select the rate of return (interest rate) which you "demand" from an investment of this type. Then perform any one of the following.

Method A. In Appendix I select the graph which represents your chosen rate of return. Then find the dollar return on the Y axis, that is, the net gain calculated in STEP 4.

From that point, project a horizontal line across the graph until it reaches the length in years of the

[1] *A Guide to Federal Income Tax for Timber Owners.* Agricultural Handbook 596, USDA Forest Service. 1982. U.S. Government Printing Office. 74 pages.

[2] Stand growth projections can be made using a number of different methods. See Husch, B., C.I. Miller, and T.W. Beers. 1982. *Forest Mensuration,* 3rd Ed., New York, The Roland Press Company, Chapter 16 or Moser, J.W., Jr. 1972. *Purdue Forest Data Processing Service Program Documentation.* Purdue University Agricultural Experiment Station Research Bull. No. 891, 48p.

investment period. Now, interpolate between the various investment curves to estimate the maximum outlay which will yield the given return in the specified investment period. If the cost of TSI is less, accept the TSI project; if the cost is greater, reject TSI.

Method B. A second way to evaluate the investment is, again, by selecting the appropriate graph from Appendix 1. Find the number of years equaling the investment period on the X axis. Next, project a vertical line upward until it reaches the investment curve corresponding to your estimated cost of TSI. (Interpolation between investment curves will probably be required). From this point on the vertical line, project a line horizontally to the Y axis, and read the required dollar return. Compare this dollar return with the net gain of STEP 4. If the value from the graph exceeds the net gain, the TSI investment will not pay at that interest rate. If the dollar return for the graph is equal to or less than the net gain, the TSI investment is acceptable at that interest rate.

Method C. A third and more general method is to calculate an internal rate of return[3] directly using the following formula:

$$(1+i)^n = \frac{NG}{C} \quad \text{or} \quad i = \left(\sqrt[n]{\frac{NG}{C}}\right) - 1.$$

where i= internal rate of return
n= number of years in the investment period
NG= net gain calculated in STEP 4
C= total cost of TSI

In most situations, average per acre value should be used to enter the graphs in Appendix I, while total net gain and total cost can be used in method C.

SAMPLE ANALYSIS.

Even-aged Example[4]

Present Age - 40 years	Site Index 75 (50 years)
Rotation Age - 65 years	Investment Period 25 years

STEP 1 - Calculate present stand conditions per acre for all trees 2.6 inches DBH and greater.

Basal Area	101
Volume (BDFT Doyle, DBH - 8.5 inches)	731
Percent Cull	20
Number of trees	400
Average DBH	6.8
Age	40

STEP 2 - Estimate the future stand conditions per acre without TSI.

Basal Area	115
Volume	3845
Percent Cull	20
Number of trees	249
Average DBH	9.2
Age	65
Value ($160/M stumpage)	$492

STEP 3 - Estimate the future stand condition per acre with 20% TSI.

Basal Area	106
Volume	4021
Percent Cull	5
Number of trees	210
Average DBH	9.6
Age	65
Value ($180/M stumpage[5])	$724

STEP 4 - Calculate the net gain.

Net gain (NG) = Value estimated in STEP 3 Value estimated in STEP 2

NG = $724 - $492

NG = $232

STEP 5 - Using method C, calculate the internal rate of return.

$$(1+i)^n = \frac{NG}{C}$$

let C = $28
NG = 232
n = 25

$$(1+i)^{25} = \frac{232}{28}$$

$$i = \left(\sqrt[25]{\frac{232}{28}}\right) - 1$$

$i = 0.0888$ or 8.8%

If the required return on investment is greater than 8.8% reject the investment. If the required return on investment is less than 8.8% accept the investment.

Uneven-aged

The analysis of TSI in uneven-aged management is somewhat more complicated. This stems from the fact that each tree has a rotation length and, in theory, establishment costs and harvest revenues are occurring simultaneously. In practice, harvests normally occur at regular intervals in time, and the cost of TSI can be capitalized until the next harvest.

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[3]Internal rate of return is the interest rate which equates the NG with the cost of the TSI operation, plus the capitalization costs.

[4]Data from Dale, Martin, 1972. *Growth and Yield Prediction Program for Upland Oak*, USDA Forest Service Research Paper NE - 241, 21p.

[5]Board foot value increase is due to overall quality increase and not a change in price due to inflation or other factors.

The benefits accruing to uneven-aged stands can be measured as described earlier; however, special consideration should be taken in evaluating the residual or growing stock's value. TSI should continually increase the value of this growing stock even if the same stand parameter, (i.e., basal area) limit is used in the management plan. Figure A displays this idea graphically. The upper graph simulates stand development while the lower graph simulates monetary value for the same stand, with and without TSI. Without forest management and continuous harvesting, it is likely that the value of the growing stock will decline rather than remain stable. Figure A assumes equal forest management practices except in the use of TSI. Some of the value of TSI in uneven-aged stands will be in this increase in value of the growing stock.

A word of caution concerning the relations depicted in Figure A. These relationships are based upon theory. There is very little empirical evidence showing whether or not these events will actually occur as depicted. Again, local knowledge should allow a forester to interpret these relationships for the landowner's situation.

Uneven -aged Example [6]

Investment Period	15 years
Estimated Site Index	85
	(50 years, dominate oaks)

STEP 1 - Calculate present stand conditions per acre for all trees 11.0" DBH and larger.

Basal Area	64
Volume (BDFT, Doyle)	3712
Percent Cull	16
Number of trees	46
Average DBH	15.9

STEP 2- estimate future stand conditions per acre without TSI.

Basal Area	65
Volume	5212
Percent Cull	16
Number of trees	42
Average DBH	16.8
Value (assorted stumpage prices according to species)	$504

STEP 3 - Estimate future stand conditions with 16% TSI.

Basal Area	60
Volume	6019
Percent Cull	3
Number of trees	37
Average DBH	17.1
Value (determined as above)	$596

STEP 4 - Calculculate net gain.

Net gain = Value estimate in STEP 3 minus Value estimate in STEP 2

NG = $596 — $504

NG = $92

STEP 5 - Using method A, assume than an 8% return on investment is required. Find Figure 4, Appendix I. On the graph, find the point equal to $92 on the Y-axis. Next, project a line to the right across the graph, stopping at 15 years on the x-axis. This is shown on Figure B. Now, by interpolating between the investment cost curves of $20 and $30, a cost of $29 is estimated. This means that an investment of $29 in TSI will yield an 8% return on investment in 15 years. If the actual cost of TSI is below $29, the investment in TSI will be returning at least 8%, and the project is acceptable. If the TSI will cost more than $29, the rate of return on investment will be less than 8%, and the project should be rejected.

Conclusion

The paper suggests an investment analysis procedure for TSI, as well as discussing the motivation for use of TSI. No attempt was made to provide widespread prescriptions or recommendations for the use of TSI. The purpose was to encourage foresters and other woodland managers to consciously and objectively examine the economics of TSI. TSI, for the sake of TSI, is not a justifiable silvicultural operation. If all TSI investments are analyzed with only acceptable investments undertaken, TSI operations will result in improved returns to the woodland owners and an efficient allocation of resources for the production of timber.

[6]Data was taken from demonstration woods inventories, Department of Forestry and Natural Resources, Purdue University.

Figure A. Expected changes in an uneven-aged stand with and without TSI.

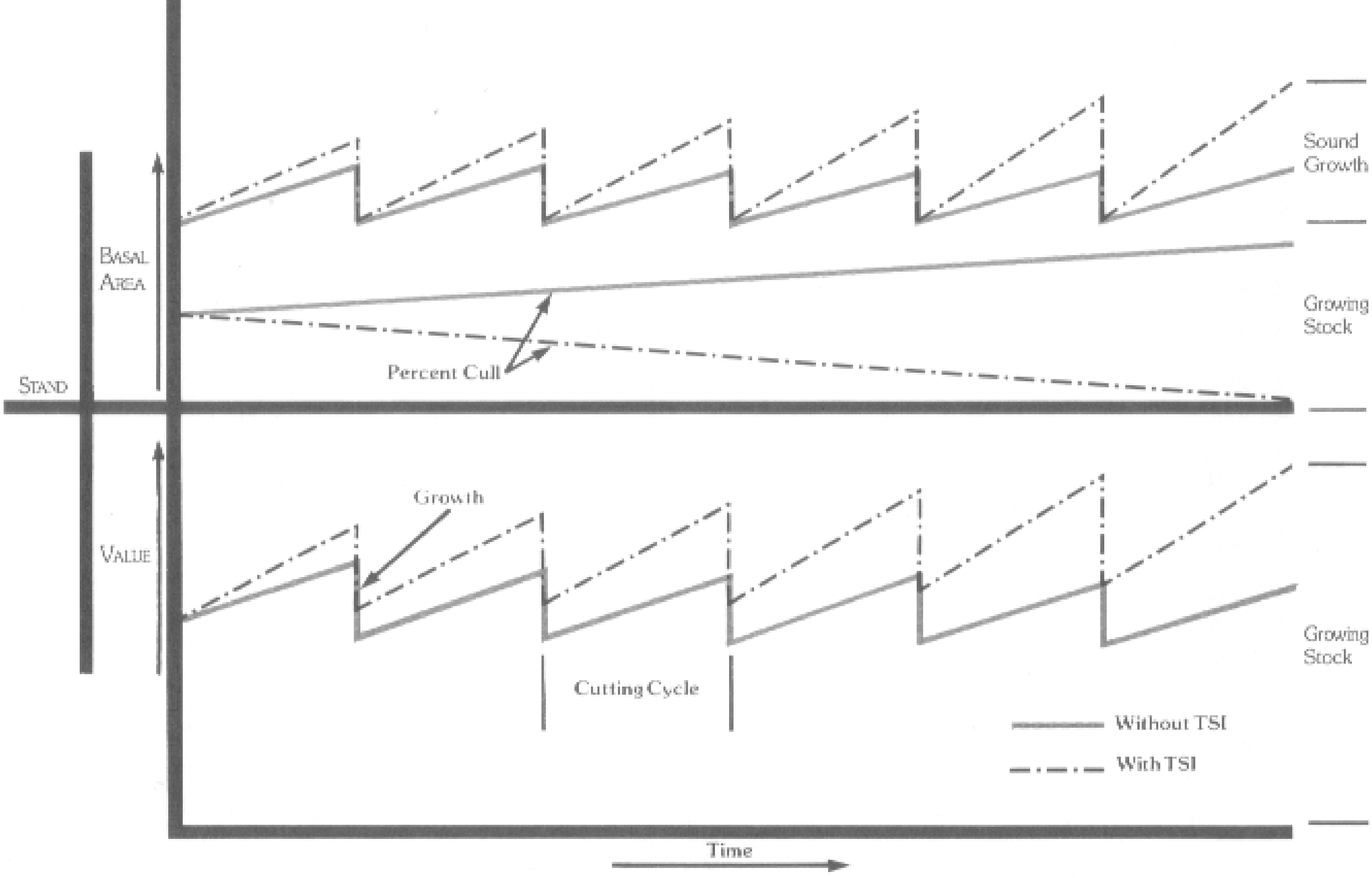


Figure B. Method A Using data from the uneven-aged example.

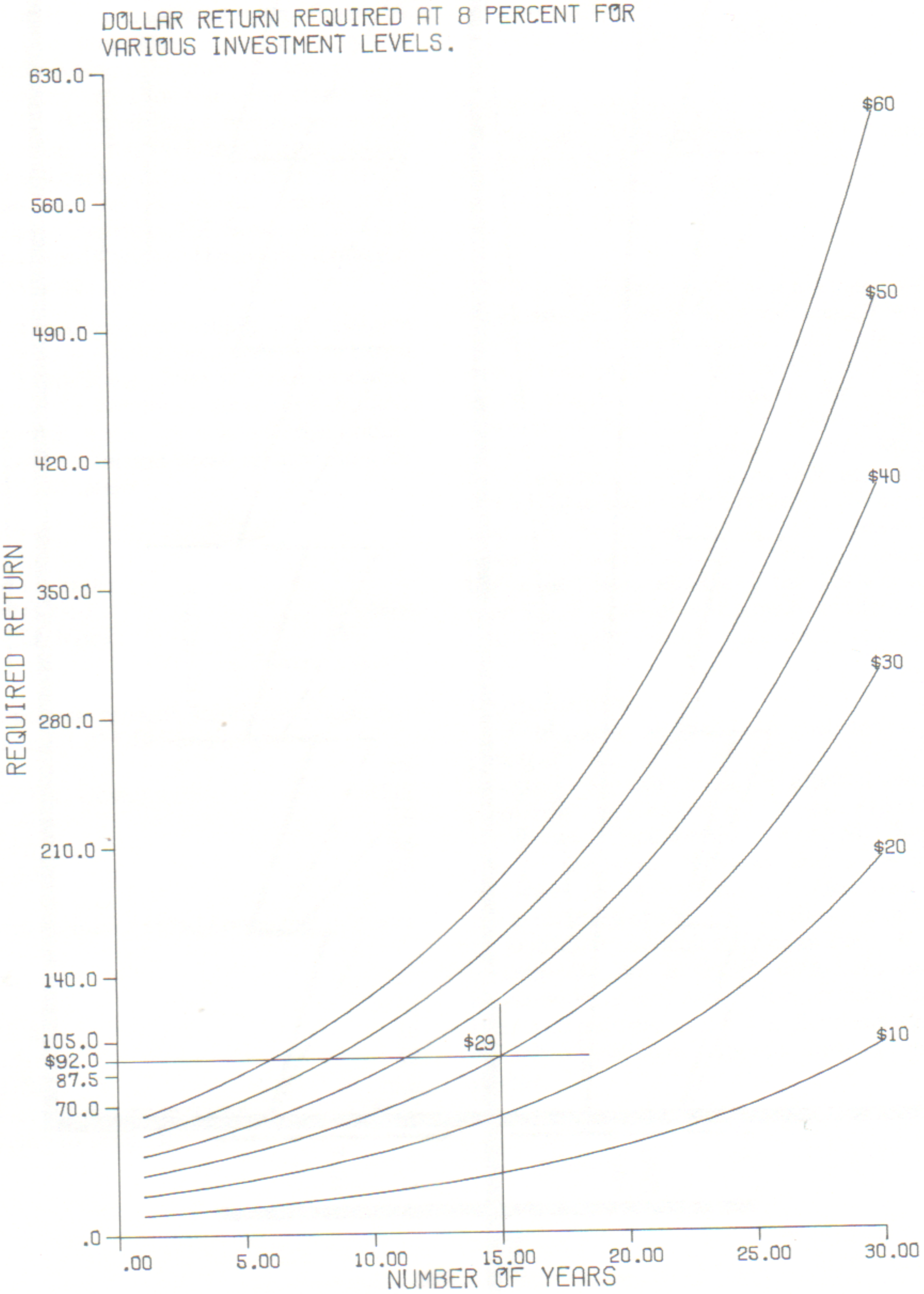


FIG.1 DOLLAR RETURN REQUIRED AT 5 PERCENT FOR VARIOUS INVESTMENT LEVELS.

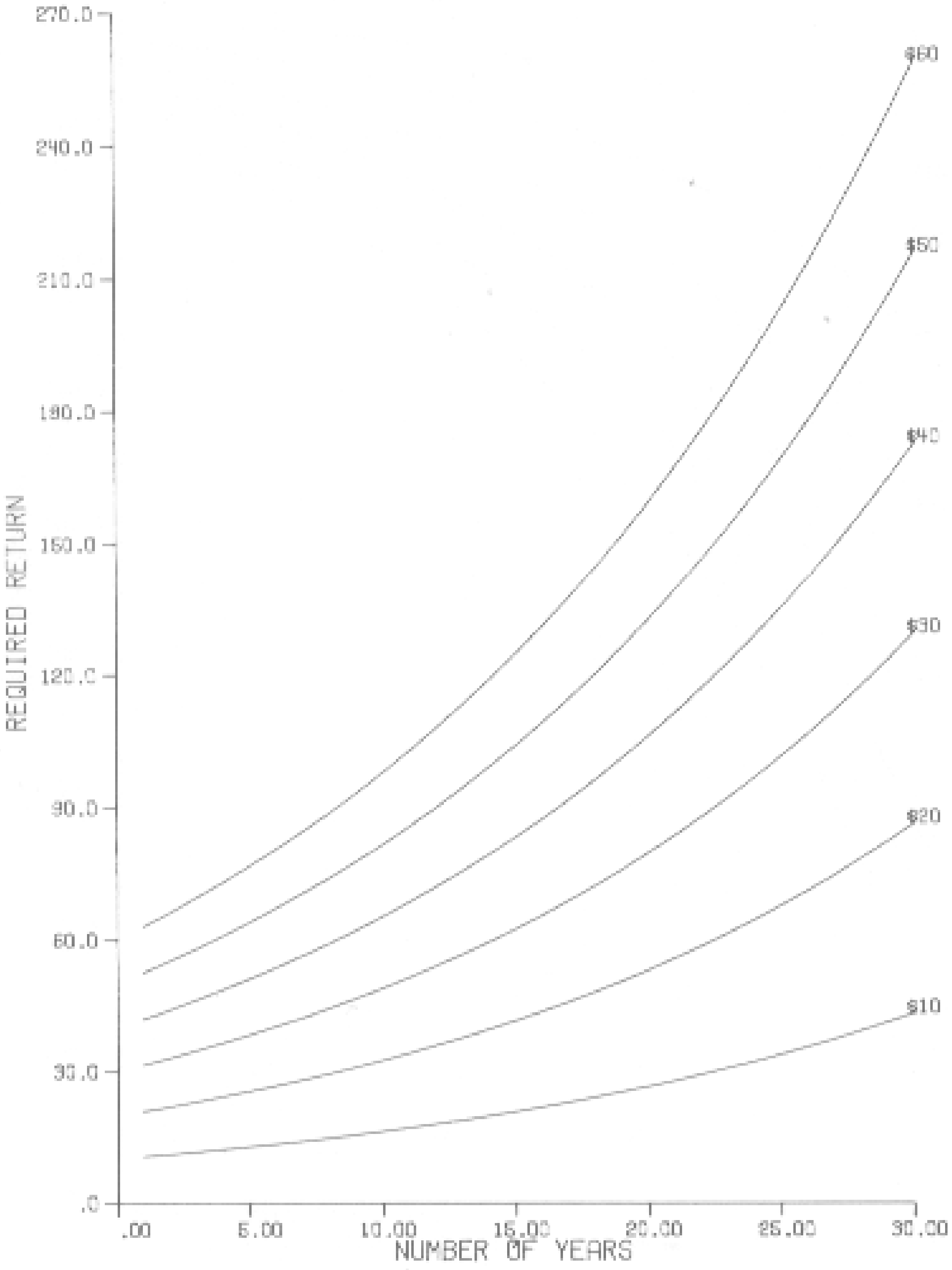


FIG.2 DOLLAR RETURN REQUIRED AT 6 PERCENT FOR VARIOUS INVESTMENT LEVELS.

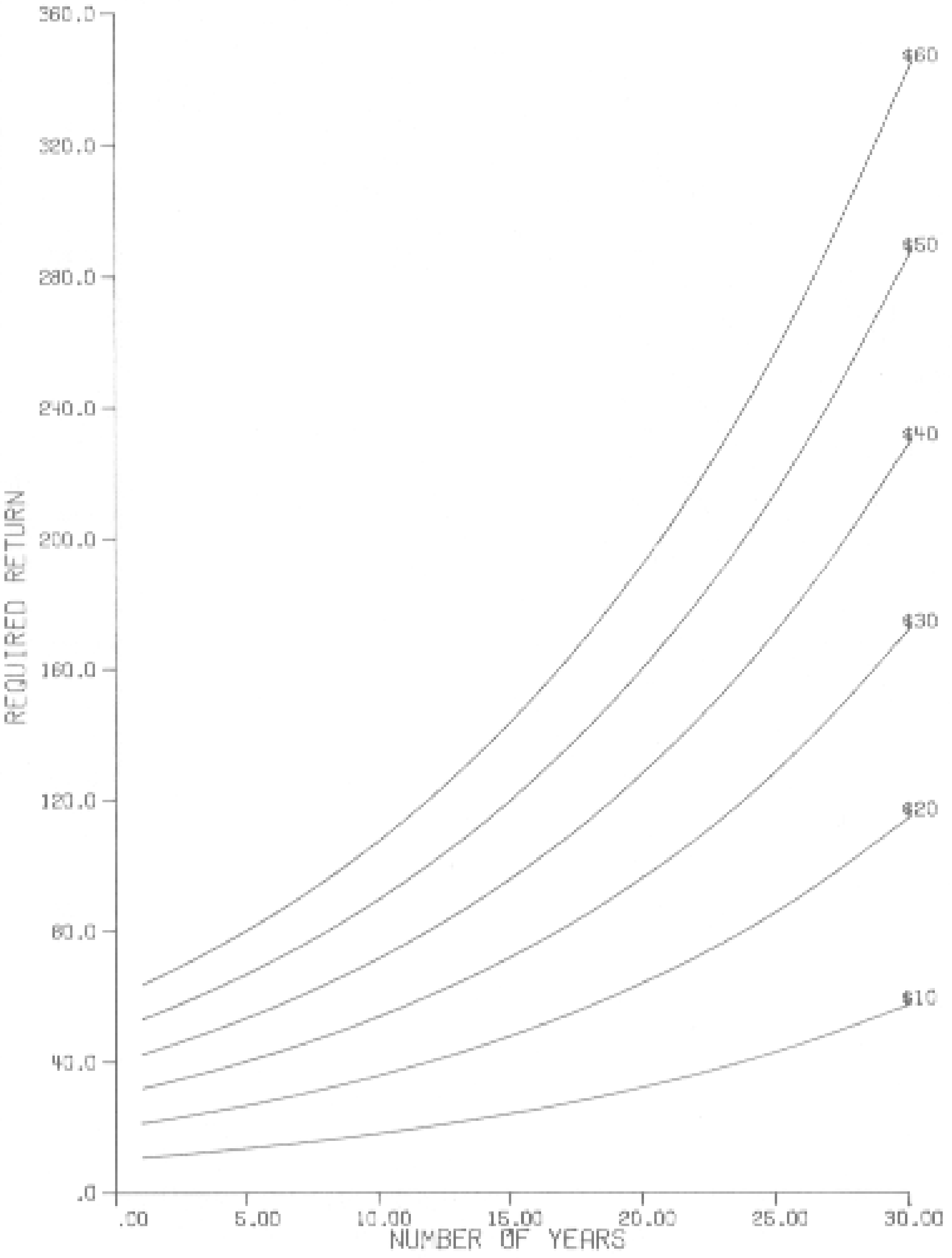


FIG.3 DOLLAR RETURN REQUIRED AT 7 PERCENT FOR VARIOUS INVESTMENT LEVELS.

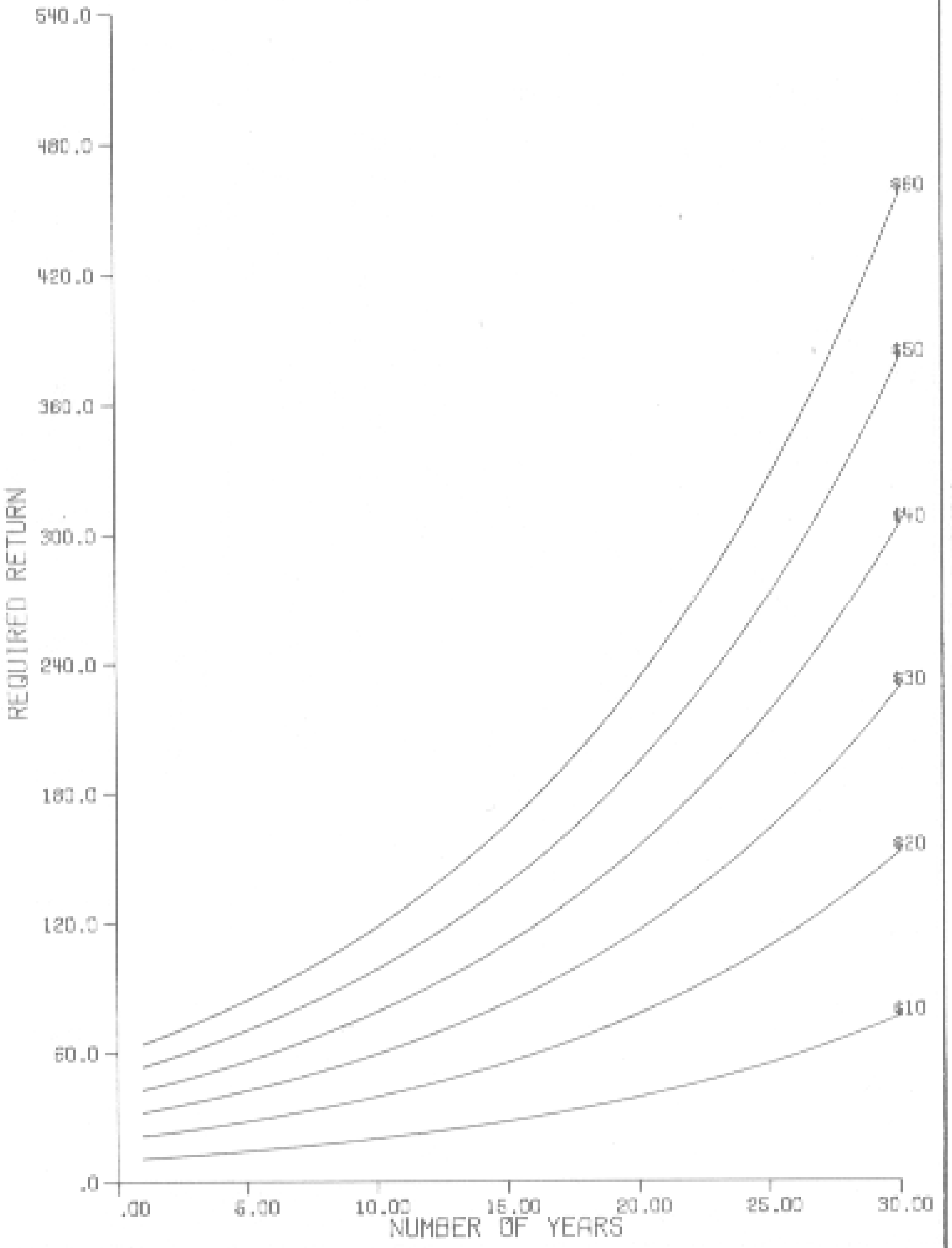


FIG.4 DOLLAR RETURN REQUIRED AT 8 PERCENT FOR VARIOUS INVESTMENT LEVELS.

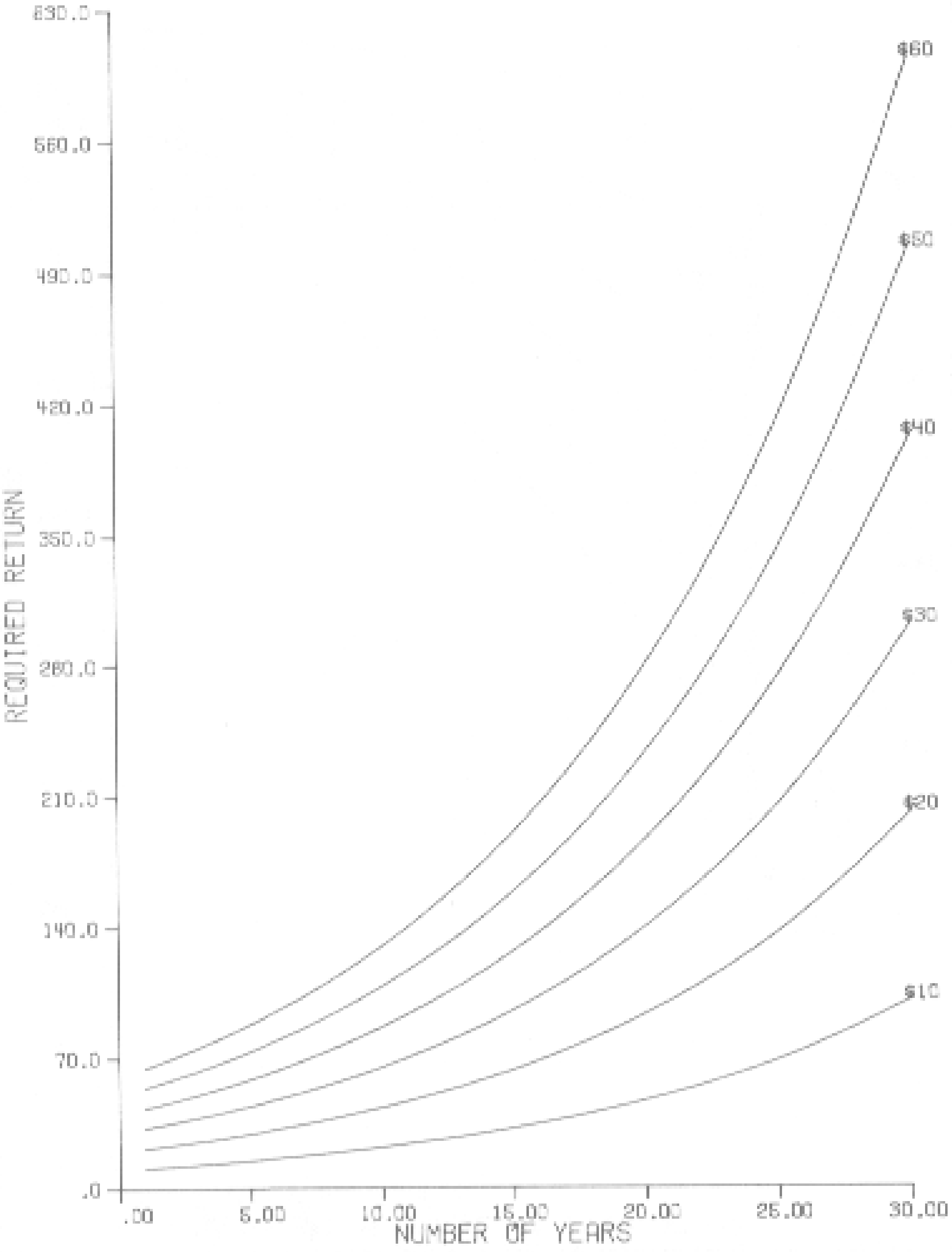


FIG.5 DOLLAR RETURN REQUIRED AT 9 PERCENT FOR VARIOUS INVESTMENT LEVELS.

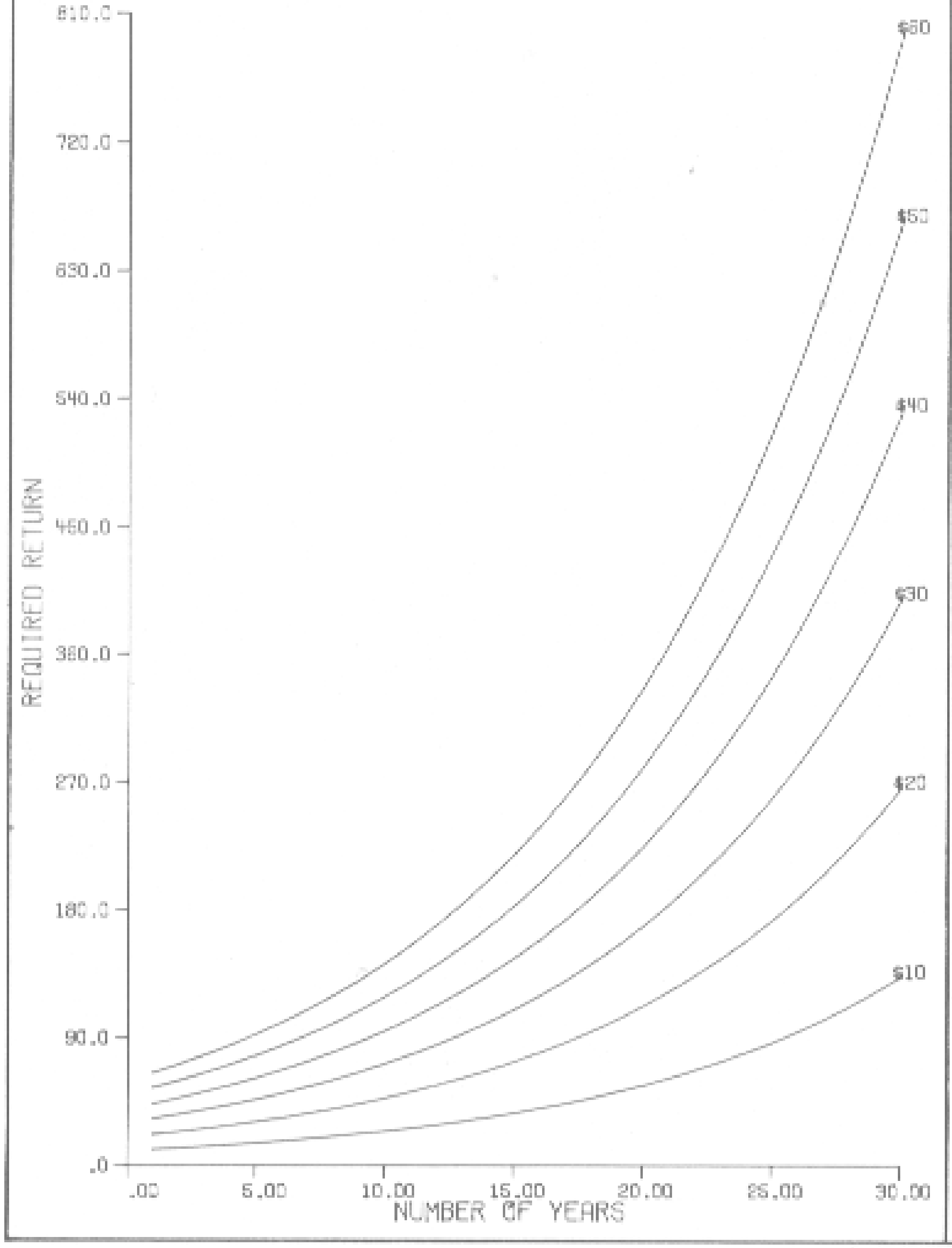
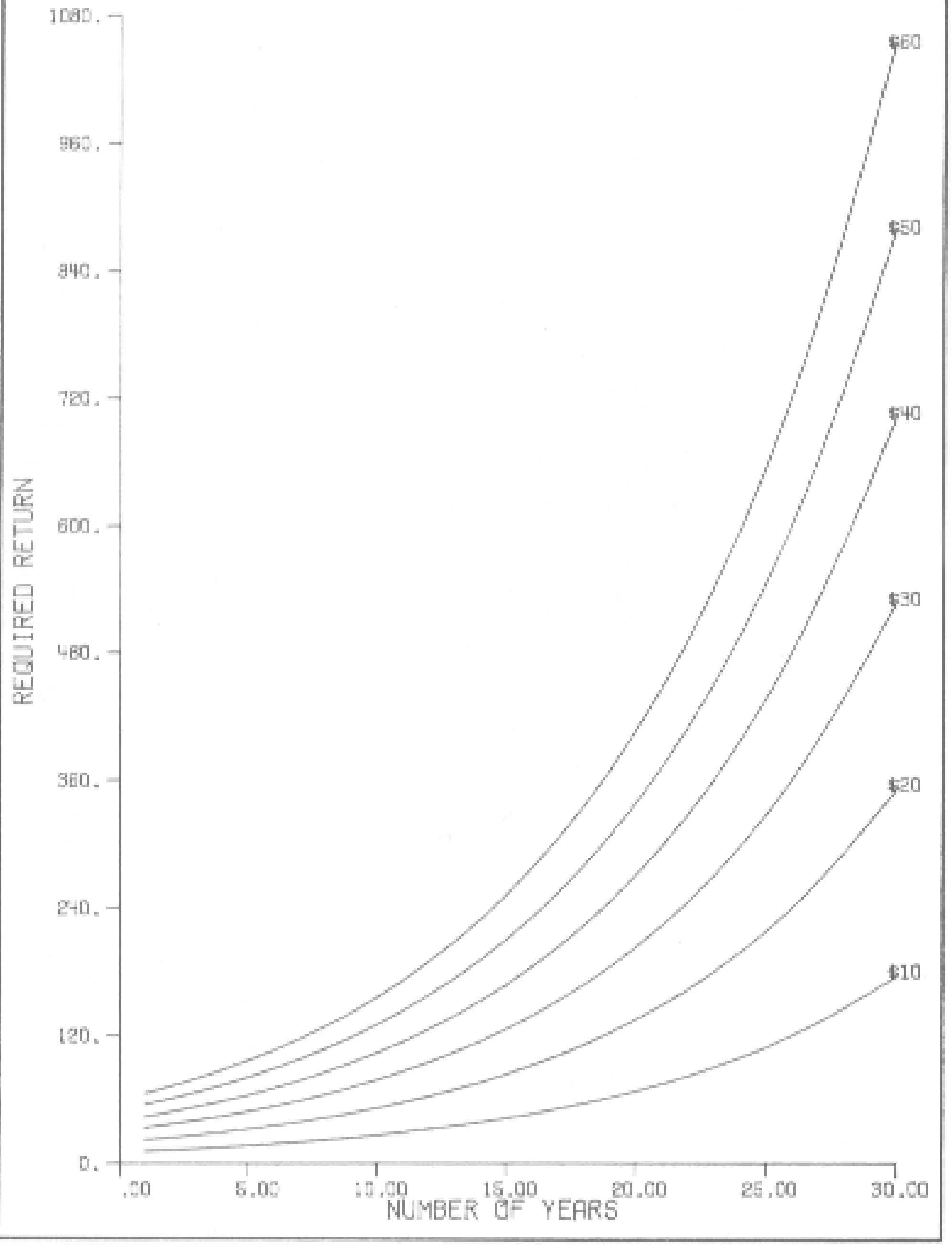


FIG.6 DOLLAR RETURN REQUIRED AT 10 PERCENT FOR VARIOUS INVESTMENT LEVELS.



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