TIMBERLAND INVESTMENT RESOURCES LLC

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TIR

MODERN FOREST MANAGEMENT PRACTICES

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Forest Management

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Introduction

Modern forest management is at the very core of TIR's business. The introduction of intensive management of tree plantations in recent years has brought about an historic transformation in the commercial production of timber, especially in the U.S. South, and has resulted in appreciable increases in biological growth and volume yields.

Even with the dramatic advances evident in fast-growing plantations, the definition of forest management as practiced by TIR extends beyond the science of growing and harvesting timber. Our experienced professionals integrate the biology of growing forests with financial management to achieve the highest economic return for investors. Aside from our continued commitment to the principles of forest stewardship and sustainability, there are three areas of forest management where TIR distinguishes itself as a leader. They are Forest Inventory, the Growth and Yield of Intensively Managed Plantations, and Harvest Scheduling. This paper describes these modern practices in greater detail, furnishes evidence of their efficiency in comparison to standard techniques and highlights the corresponding financial benefit to the client.

Forest Inventory

Figure 1. A stand in a forest plantation contains trees of the same species, age, and site quality.

A fundamental component of forest management is the determination of standing timber volume, timber growth potential, and the assignment of these attributes to individual timber stands. As displayed in **Figure 1**, a timber stand is a group of trees that is growing under similar conditions and with homogenous growth potential.

TIR conducts thorough inventories of timberland prior to any acquisition. After acquisition, the initial inventory is updated every three years. The timber inventory contains vital information at the stand level such as site productivity, number of trees per acre, and timber product by category (i.e., pulpwood, chip-and-saw, and sawtimber). Key events in the stand history, such as fertilization and control of competing vegetation, can have a significant effect on growth and the future value of the forest. This information is collected to refine the precision of timber volume projections.

Double Point Sampling Efficiency

Basal area is quickly and inexpensively measured on all plots, and volume estimates are obtained on a smaller sub-sample. A definition of basal area is provided in **Figure 2.** What is important to note is that basal area is quickly and inexpensively measured. Fortunately, basal area is also highly correlated to volume per acre. Double sampling is efficient because it pools two sources of information; the inexpensive measurement of basal area from many plots, and the precise measurement of volume from a sub-sample of inventory plots.

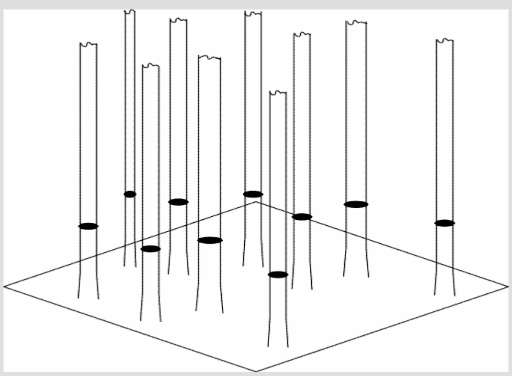

Figure 2. Basal area per acre is a measure of absolute density and is computed by summing the area of all trees at the height of 4.5 feet (demonstrated by black ellipses)

Fortunately, it is possible to quantify the gains from double point sampling. Using the example depicted in **Figure 3**, the inventory compilation program fits a regression between volume per acre and basal area per acre from data of the yellow sample plots. The better the fit statistics or R_2 from the regression, the higher the gain in precision obtained from adopting double point sampling when compared to simple random sampling. Typically in southern pine plantations, we can anticipate a coefficient of determination or R_2 of 0.8 between volume and basal area per acre for an individual stand.

TIR uses a variety of sampling designs for achieving a cost-effective and statistically efficient inventory of each forest stand. Traditionally, simple random sampling has been used for timber inventories. However, the same statistical precision can be achieved at a lower cost by employing double point sampling. Double sampling is a technique that replaces measurements of a costly variable with a supplementary variable that is cheaply observed.

In addition, TIR employs Global Positioning System (GPS) units to aid in the unbiased location of plot centers, decrease the time needed to navigate from plot to plot, and mark plot location for improved inventory audits.

Finally, TIR inventories obtain high precision and correlation between volume and basal area per acre because the inventory computations are stand specific. As a routine policy, TIR does not employ strata based sampling, which typically combines all stands of the same age into an average group or strata. Pooling young forest stands together into one stratum is a dangerous generalization when making long-term growth projections and financial analysis. Foresters who pool stands into strata are likely to adopt the same management prescription regardless of other important stand attributes such as site quality, basal area, or trees per acre, resulting in suboptimal management outcomes.

Computing the gain from the example in **Figure 3**, we should expect the variance of double point sampling to be 48% lower than the variance obtained from employing the traditional approach of simple random sampling.[1]

Figure 3. A timber inventory is conducted by visiting each sample plot in the field. The location of each plot is determined with the aid of a GPS unit attached to a PDA unit which contains the distance and bearing from the position of the observer to the plot. At the red plots, only basal area is recorded. At the yellow plots, both basal area and volume are measured.

The Growth and Yield of Intensively Managed Plantations

Intensive forest management, which incorporates a wide array of silvicultural practices such as genetically improved seedlings, advanced site preparation methods, competition control, and fertilization, have resulted in remarkable increases in the growth of tree plantations, particularly southern pine.[2] Intensive management

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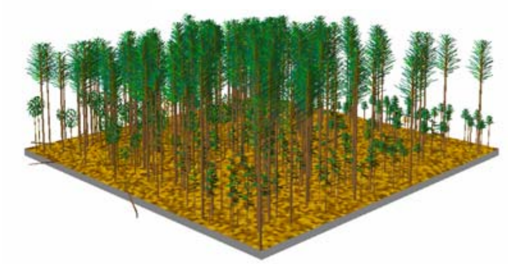
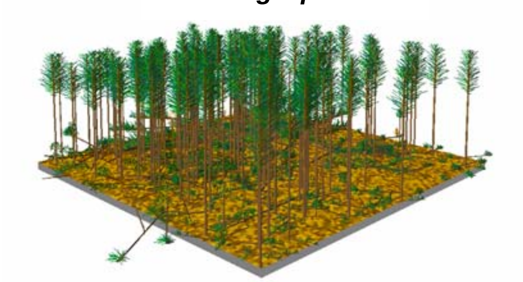
1 The variance of double sampling can be approximated as: $v(\bar{y}_{lr.ds}) = \frac{S_y}{n}\left(1-\frac{n'-n}{n'}R^2\right)$
where n = number of yellow plots, n' = number of red and yellow plots, S_y/n is the variance of simple random sampling, and R^2 is the coefficient of determination from the regression of volume and basal area per acre of the yellow plots.

2 Silviculture is defined as the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society on a sustainable basis.

Before Thinning



Thinning Operation



Residual Stand After Thinning

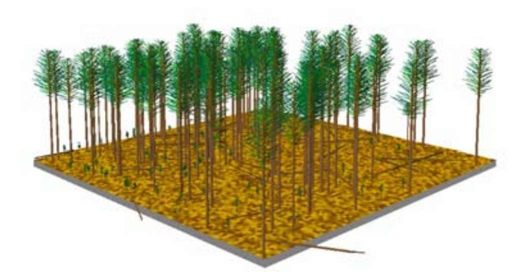


Figure 4. Thinning is a management tool used to enhance value by increasing the size and quality of residual trees. The thinning operation removes smaller and defective stems, allowing additional growing room for high value trees. The residual stand after growth contains fewer albeit larger size and higher value trees.

techniques, such as the thinning operation displayed in **Figure 4**, can accelerate tree diameter growth, thereby shifting trees from lower to higher value products at an earlier age.

A forest “prescription” - as foresters frequently call a grouping of silviculture practices - contains unique and detailed information about activities, treatments, and standing volumes for a forest stand from establishment to the completion of the rotation at harvest. The development of forest stand prescriptions is virtually impossible without the aid of growth-and-yield computer models that predict stand dynamics over long periods. An example of several forest prescriptions is presented in **Figure 5**. TIR is committed to using the best available growth and yield models to make stand projections for the stand level attributes of tree survival, dominant tree height, and basal area. When selecting among an array of available growth and yield algorithms, TIR prefers those that display the sigmoid S shape and possess sound biological behavior with respect to growth rates and final size.

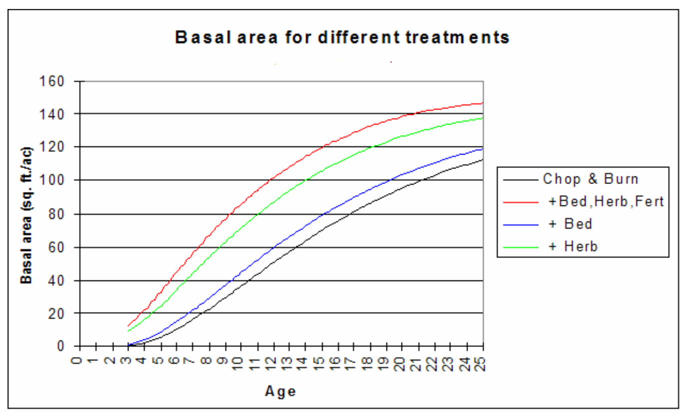


Figure 5. The growth of several forest prescriptions is depicted for a typical rotation length. The forest prescription drawn with the red line calls for the additional site preparation treatment of bedding, followed by herbaceous weed control and fertilization.

TIR is among a few forest management organizations with a staff capable of developing statistical models for predicting the gain in growth and yield from intensive management practices. While an industry standard off-the-shelf software program may resolve ad-hoc investment questions on an individual stand basis, the modern growth and yield models at TIR are integrated among all applications of decision making analysis, providing superior information flow and decision outcomes. An example of this capability is demonstrated by TIR's unique response to recent chemical site preparation treatment literature.

Chemical Site Preparation Treatments

The current model used for chemical site preparation treatments, *R* = *f(yst)*, where *R* equals the (treated – untreated) response in ft. or ft^2/ac, is a function of years since treatment (*yst*).

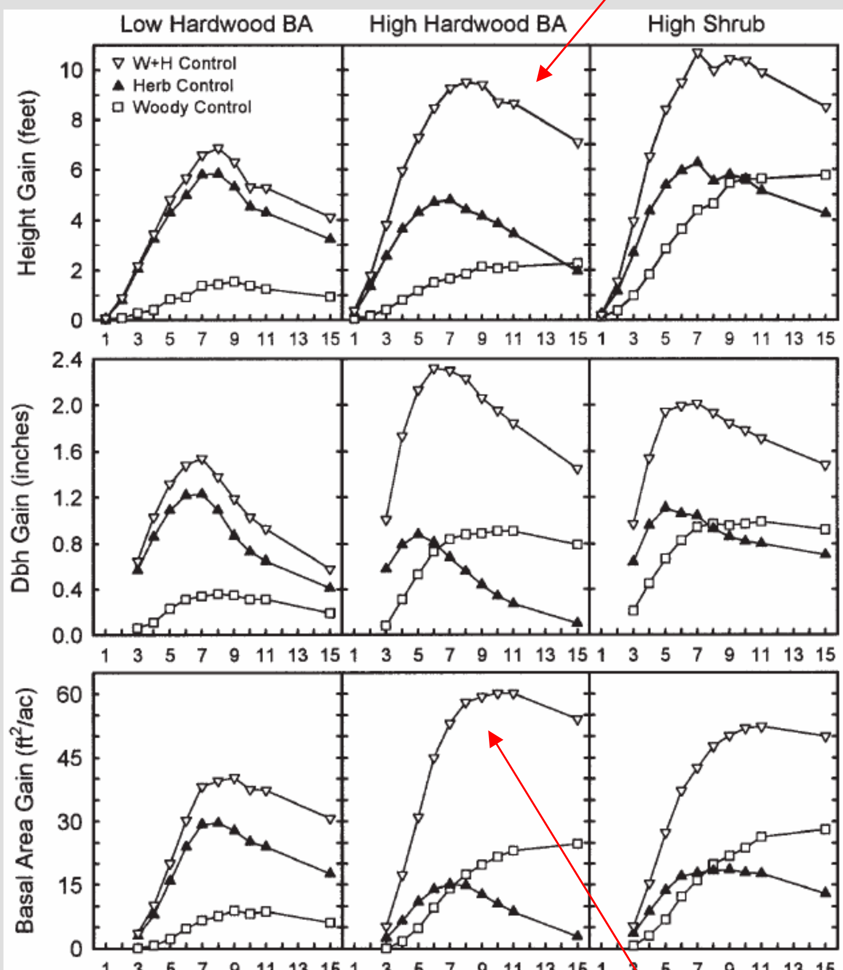
New literature by Miller et al. (2003) indicates that growth response is also a function of the competing vegetation, and herbaceous and/or woody chemical treatment. The new research results have been presented in summary tabular and graphical form; however, it could be years, if ever, before university growth and yield research cooperatives statistically analyze the data and publish new chemical site preparation response models. TIR has the internal capacity to construct these new response models without relying on university or consulting experts. As demonstrated in **Figure 6**, TIR has already developed response models for loblolly pine stands with the large component of competing hardwood trees that are chemically treated.

Growth and yield is computed with a sequential system of equations for dominant height (H), stand basal area (B), and stand volume (V). Additive response terms, R_H and R_B, are used to adjust the dominant height and basal area respectively:

$$H = f(Age(A), Site\ Index) + R_H \qquad B = f(A, H, N) + R_B$$

where N = trees per acre. Expert knowledge is needed to construct the R_B equation, since unlike the image portrayed in **Figure 6**, the R_B term must exclude the gain allocated to B that is already explained by R_H.

$$R_H = 3.058(yst)e^{-0.125(yst)}$$



$$R_H = 3.058(yst)e^{-0.125(yst)}$$

Figure 6. Using the graphs above, TIR constructed new response models for dominant height, R_H, and basal area, R_B.

After the inclusion of R_H and R_B in the system of equations, experience has demonstrated that no special response term in needed for V. The system of equations is complete with the following symbolic equation:

$$V = f(A, H, N, B)$$

Financial Impact

Growth and yield projections that measure the response to intensive treatments are extremely important. They provide the foundation for TIR's economic analysis and decision-making on the timber tracts it manages for its investors. In the example described below, an intensive management prescription was found to generate an IRR improvement of 4.9% over the conventional management prescription.

Case Study – TIR Intensive Management Prescription

The following case study employs TIR's proprietary growth and yields models and response functions to intensive treatments. The case study involves a 12 year old stand that is managed for 15 years. Starting conditions for the 12 year old stand are described in Appendix A.

Two prescription options are analyzed for management. Prescription option 1 calls for 15 years of conventional management and growing the stand until age 27 with no thinning, no fertilization, and no hardwood release. Prescription option 2 entails a chemical hardwood release at age 12, thinning followed by fertilization at ages 16 and 23, and growing the residual stand until age 27. Details of the two management prescriptions or regimes are provided in **Table 1**. The growth and simulated cutting of both prescriptions were performed using TIR models.

Table 1. Description of intermediate cultural treatments for Prescriptions 1 and 2.

Prescription	Release	Thin	% Row	Res. BA	Fertilize	Final Age
1	-	-	-	-	-	27
2	Age 12	Age 16 Age 23	20 -	70 65	Age 16 Age 23	27

Release = chemical hardwood release with effectiveness of 1.0; % Row = removal of stems by mechanical row thinning; Res. BA = target residual basal area of a thinned stand in ft^2/ac; Fertilize = application of 200 lbs/ac of elemental nitrogen and 50 lbs/ac of elemental phosphorus.

As displayed in **Figure 7**, the intensive management prescription (R_x 2) yields more wood production and furnishes an improvement of 4.9% in internal rate of return (IRR) over that of the conventional management prescription (R_x 1). The rapid departure in growth between the two prescriptions at ages 12-16 is a reflection of the chemical hardwood release treatment.

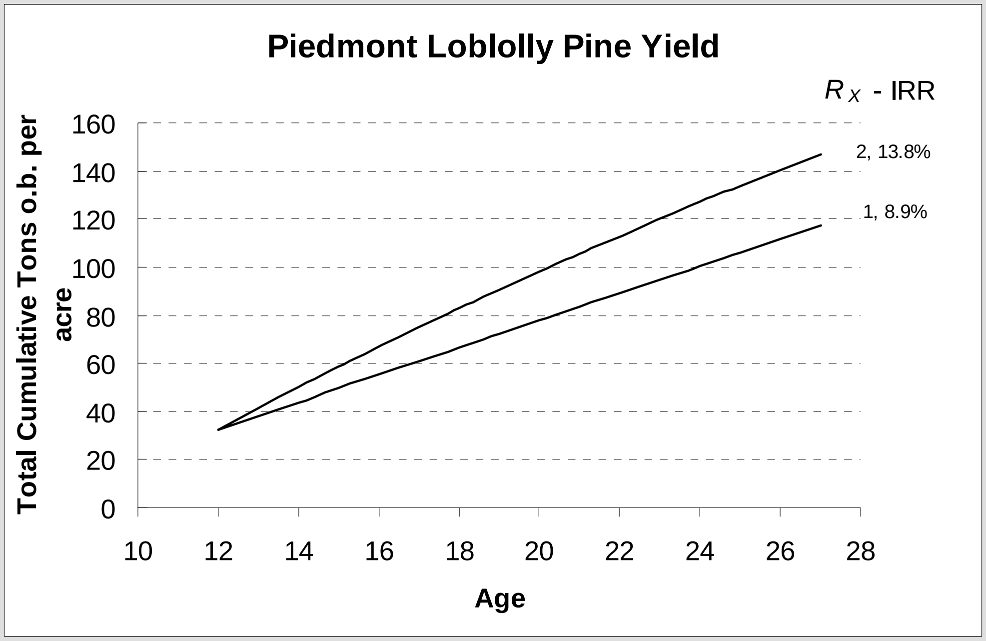


Figure 7. Total cumulative production and internal rate of return (IRR) by prescription (Rx) option.

A decomposition of the total cumulative biomass production into merchantable products discloses more information about valuation of the two prescription options. **Table 2** contains the merchantable production by prescription and age (cutting operation). Clearly, the large sawtimber production of Prescription 2 at age 27 is a reflection of the benefits derived from repeated thinning and fertilization.

Table 2. Merchantable production by prescription and age. The production figures are for each product class before degrade to pulpwood with the default defect percentages. The yellow highlight compares the high-value sawtimber production of Prescriptions 1 and 2.

Prescription	Age	tons per acre outside bark		
		Pulpwood	Chip-n-saw	Sawtimber
1	27	55.8	57.7	0
2	16	20.8	0.4	0
	23	18.8	22.7	0
	27	7.6	15.7	55.8

Stand Level Economics and Harvest Scheduling

Optimal Rotation Age

Useful guides are available for describing the optimal rotation age (clearcut age) for managing a specific forest stand of interest. Should the focus rest solely on maximizing biological growth, it is possible to estimate the age corresponding to maximum volume production based on an infinite series of rotations (harvests and replantings) by finding the point of maximum mean annual increment (MAI). In the example depicted in **Figure 8**, the optimal rotation age equals 25 years. While this simplistic approach ignores prices and the distinction in multiple products (pulpwood, chip-n-saw, and sawtimber), it does establish an interesting upper bound on the optimal rotation age. Using almost any discounted economic analysis with prices, costs, and interest rates, the optimal economic rotation length is to the left of the vertical line displayed in **Figure 8**. Foresters frequently analyze the economic performance of management alternatives by comparing the discounted net revenue of an infinite series of rotations. This index, called bare land value (BLV), was introduced in 1849 by Martin Faustmann. Internal Rate of Return (IRR) is considered an appropriate performance measurement for a timberland investment. Several interesting publications are available that compare indices for determining the optimal rotation age.[3]

Forest trees may be distinguished from many other assets in that they are both the biological growth mechanism and the final wood product. Unless the extraction of the product is carefully managed, the biological factory is at risk of producing far below capacity. With the exception of fast-growing conditions in southeastern United States, forestry in the United States is also characterized by long production periods. Many management choices are available in terms of inputs, investment duration, and product outputs. Forest economics is concerned with the determination of the optimal allocation of input resources and the maximization of investor benefit.

Forest Level Economics

A forest stand is often considered a candidate for final harvest when the value growth equals the minimum acceptable return. Generally defined, this occurs when the holding value equals the liquidation value. Beyond this value the forest stand is considered to be financially mature. An important variable under the control of the forester for achieving optimal timberland returns is the selection of the rotation age.

There are instances when it may be prudent to depart from the optimal financial rule for determining rotation age. A forest quite frequently contains a heterogeneous collection of stands of different species, ages, and productive capabilities. It is not unusual to acquire a forest that contains a shortfall of forest acres in a certain age class, while experiencing a significant surplus of forest acres in another age class. This particular situation describes a forest that is not 'fully regulated' and where the annual harvest volume is unbalanced with respect to the annual growth of the forest. When confronted with operational restrictions, it may be impractical to manage each individual stand according to the optimal financial rule. Several of the following

[3] Samuelson, P. A. 1976. Economics of forestry in an evolving society. Economic Inquiry. XIV, Dec.: 466-492 and Newman, D.H. 1988. The optimal forest rotation: a discussion and annotated bibliography. USDA For. Serv. Gen. Tech. Rpt. SE-48.

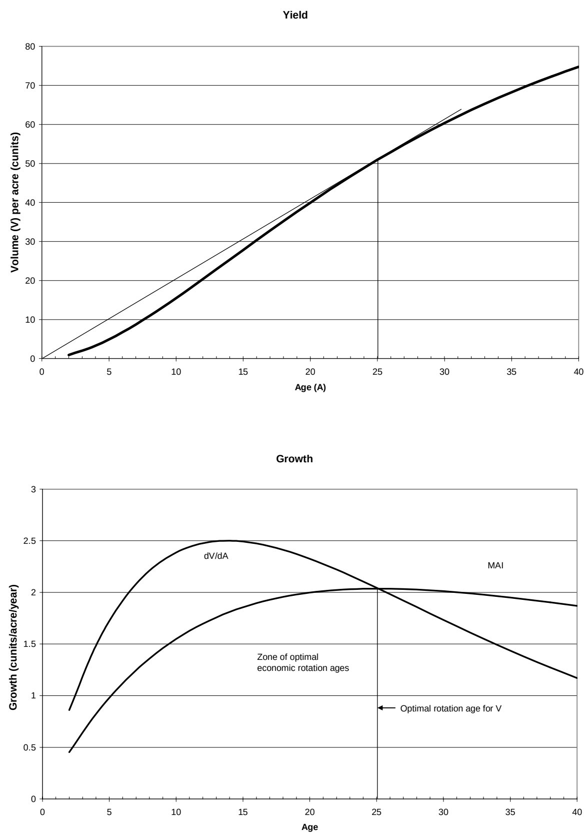


Figure 8. In the top panel, the point of tangency with a ray from the origin and the yield curve defines the age of maximum volume production (V). The MAI curve in the bottom panel equals of quotient of volume and age or V/A. The optimal age of the top panel corresponds to the age in the bottom panel of maximum MAI and where the first derivative of the yield curve (dV/dA) equals MAI.

constraints are quite common when managing large forest properties:

1. The time horizon of project may not coincide with the optimal rotation age. For example, a stand that is 22 years of age may be clearcut in the last year of the investment, even though age 25 represents the optimal rotation age
2. The client may have some constrained minimum annual cash flow requirements
3. The real estate development potential of the residual stand may call for a special cutting pattern
4. The visual and multi-resource stewardship objectives may curtail clearcutting adjacent stands.

TIR utilizes a mathematical programming model with spatial resolution for harvest scheduling that maximizes overall investment performance and meets additional client needs. Our constrained optimization tool is called Habplan. It was developed by the National Council for Air and Stream Improvement (NCASI), an independent, non-profit research institute that focuses on environmental topics of interest to the forest resources sector. We typically use the harvest scheduling model to address several operational concerns:

- Fulfillment of annual quota in Fiber Supply Agreement (FSA)
- Employment of intensive management prescriptions to accelerate number of candidate stands for final harvest
- Use of management prescriptions that enhance scenic beauty
- Introduction of spatial features that will maximize spatial continuity for a compartment (ie. minimize creation of islands)

Neoclassical Wood Supply Models

Not all timber investment management organizations rely upon modern harvest scheduling tools, such as Habplan, to determine their long term cutting budgets. Although relatively uncommon in the US South, neoclassical methods or binary search models, have been used to solve wood supply schedules for large forest properties in western and northern timber types (Johnson and Tedder, 1983; Jamnick, 1990). Binary search models are easier to formulate; however, they typically can not evaluate multiple candidate silvicultural prescriptions for each stand. Jamnick (1990) found that constrained optimization techniques, such as linear programming, consistently harvested more wood than the sequential binary search approach. When Walters (1993) described the binary search and linear programming features of the Woodstock model, he stated that future extensions were to be made exclusively to the linear programming model. Walters and Feunekes (1994) reported that the linear programming model produced strategic allowable cuts that were 9-22% higher than previous schedules made with a sequential binary search model.

Departure from the Optimal Solution

Tests using Habplan and the linear programming harvest scheduling models have demonstrated almost identical results for spatially unconstrained problems. An independent test conducted by Turner et al. (2002) concluded that the advantage of Habplan over linear programming is that it took far less time to converge. The effect of spatial constraints on the unconstrained optimal solution is dependent on the spatial arrangement of a specific property, but it is possible to depress the unconstrained NPV value by 18% and higher (Carter et al. 1997). Since linear programming can not deal with spatial constraints, there exists a real danger that the user will attempt to modify the unconstrained linear programming solution by hand to meet the spatial constraints.

When conducting a harvest schedule with Habplan, the user typically will track several model outputs simultaneously. These outputs include, the project net present value (NPV), annual cut volumes for pulpwood, chip-n-saw, and sawtimber, residual or standing volumes for pulpwood, chip-n-saw, and sawtimber, and spatial configuration of the optimal silvicultural prescriptions.

Harvest Plan Implementation and Planning Feedback

Successful implementation of the harvest schedule can only occur if there is ample exchange of suggestions, information input, and observations between the Planning and Operational groups of TIR during the drafting of the plan, actual deployment, and annual evaluation period. While some departures from the plan are fully justified as savvy judgments that are timed to match dynamic external market events, an annual evaluation of planned events versus the actual performance can uncover some performance issues that require immediate attention.

TIR conducts a new harvest scheduling analysis for each property every year. An annual analysis is fully justified when changes in prices, product specifications, and the clients' constraints occur. Rare and localized catastrophic events, such as fires, insect outbreaks, or local ice damage, also warrant a complete re-evaluation of long term harvesting plans.

The outcome of these efforts is the simultaneous development of strategic and tactical cutting plans that are current and operational.

Financial Impact

Implementation of a suboptimal harvest schedule can significantly impact investor returns. Recent literature by The Carroll et al. (2006) has demonstrated that reliance upon traditional 'rules-of-thumb' for forest management can have undesirable consequences. This study revealed a loss of 2.6% or 6 million dollars over 25 years, compared to the optimal solution, when foresters rigorously imposed silvicultural prescriptions that called for a thinning age of 16-18 years and a clearcut age of 26-28 years.

Conclusion

In the context of an increasingly crowded and competitive timberland investment landscape, forest management activities have emerged as primary drivers of investor returns. TIR's commitment to industry leadership in the essential forest management disciplines of Forest Inventory, the Growth and Yield of Intensively Managed Plantations, and Harvest Scheduling, provide a unique platform for achieving industry leading investor returns. The disciplines described here are essential to unlocking the management potential of higher value accumulation from timberland assets.

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Appendix A

This forested stand is assumed to be located in the Piedmont physiographic region on land of average site quality (site index = 63 and dominant height of 37.1 feet). The stand possesses initially 493 pine trees per acre and a pine basal area of 74 ft^2/ac. Interspersed among and competing with the pine component is 7.4 ft^2/ac of hardwood basal area. The hardwoods are assumed to have no commercial value. Using the Weibull probability density function, the growth and yield program assigns an initial stand table for the pine component by diameter class (**Table A1**). Stand and stock tables beyond age 12 are computed using stand table projection methods rather than relying upon values derived from a probability density function.

Table A1. Initial stand and stock table for age 12 stand.

Age = 12		Hd = 37.1			Green weight in tons outside bark				
	DBH	TPA	BA	HT	Total	Pulp Wd	C-n-S	Sawtbr	Top Wd
	2	2.2	0	23	0	0	0	0	0
	3	19.5	1	28.5	0.3	0	0	0	0
	4	86.3	7.5	32.6	3	0	0	0	0
	5	195.8	26.7	35.5	11.5	9.8	0	0	0
Dq = 5.3	6	163.3	32.1	37.7	14.6	13.3	0	0	0
	7	25.8	6.9	39.3	3.2	3.1	0	0	0
	TOTAL	492.9	74.2		32.6	26.2	0	0	0

Hd = dominant height in feet; Dq = quadratic mean diameter in inches; DBH = tree diameters in inches at 4.5 ft.; TPA = trees per acre; BA = tree basal areas in ft^2/ace; HT = tree heights in feet; Total = tree green weight in tons outside bark to a 0 inch top. Pulp Wd = merchantable tree green weight in tons outside bark to a 3.1 inch top outside bark. Note: when discrete 1-inch classes are used for the density function, small round-off errors occur with the total TPA and BA.