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The Case for Using Stand-Level Analysis to Manage Timberland Investments

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I. Summary Report

This article summarizes the results and implications of a research analysis that was undertaken to more fully quantify and understand the impacts of stand-level management on the performance of large-scale timberland assets that are owned and managed as investments. The focus of the analysis was specifically on timberland holdings in the US-Southeast that are operated using intensive, plantation forestry techniques.

The key implication of this research is that most of the intensively-managed, pine plantation timberland assets owned by institutional investors are, in all likelihood, being operated sub-optimally from both a biological and financial standpoint because of the pervasive use of strata-level inventory techniques by TIMOs.

- The research was initiated to address a long-running debate within the timberland investment community about the relative benefits and drawbacks of using a stand-level sampling approach, as opposed to a strata-level sampling approach, to account for timber inventories and to develop subsequent forest management plans.
- The process of estimating timber inventories is a cornerstone of the financial analyses and decision support regimes that are required to optimize the performance of a timberland investment portfolio.
- Today, most timberland investment management organizations (TIMOs) operating in the US-Southeast routinely utilize strata-level inventory analysis, rather than stand-level analysis, to estimate and project timber volumes and values and to develop forest management plans for their clients' timberland properties.
- The key implication of this research is that most of the intensively-managed, pine plantation timberland assets owned by institutional investors are, in all likelihood, being operated sub-optimally from both a biological and financial standpoint because of the pervasive use of strata-level inventory techniques by TIMOs.

The figures on the next page describe strata-level and stand-level inventory management in more detail and demonstrate how they differ.

FIGURE 1: Visualizing Strata-Level Management

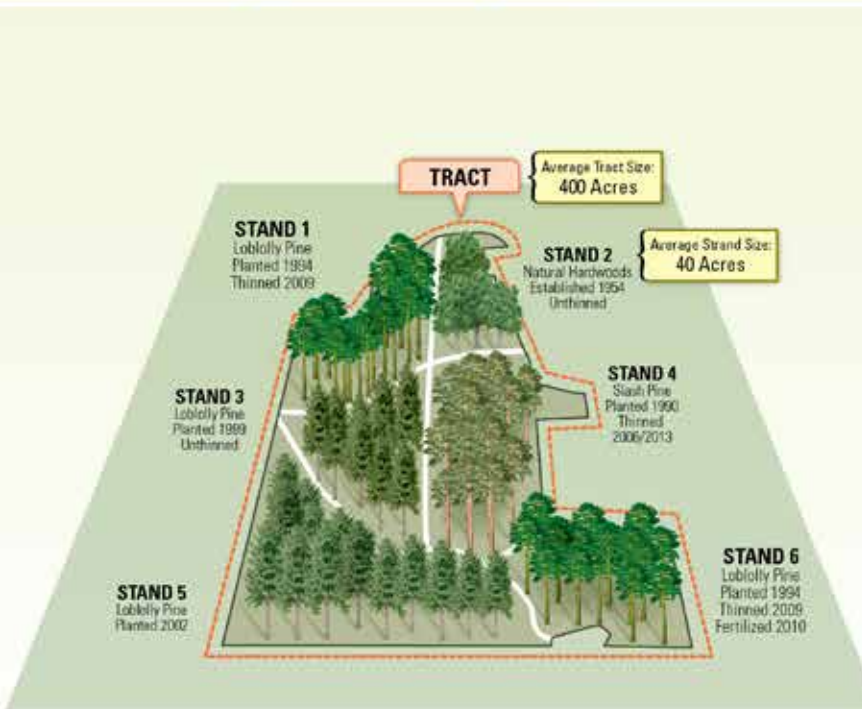
■ **TOP TEN LARGEST INVENTORY STRATA** at a Property Level



STRATA-LEVEL INVENTORY

MANAGEMENT entails classifying a timberland investment's assets into unique categories by their physical attributes. These unique categories are typically established based on species, age-class, management history (thinned or unthinned) and stand origin (e.g. natural, planted) characteristics. Large-scale timber investments can have as many as 30 to 60 individual stratum or more, depending on their geographic locations, their timber growing conditions and the manner in which the associated lands were previously managed. Using the strata-level management approach, each acre is assigned to a particular stratum, or "mega-stand," based on perceptions of its predominant stand characteristics. Once the strata-level data is available for each unique stratum, foresters develop and implement forest management plans that are designed to optimize timber productivity and financial performance of each stratum over the life of the investment.

FIGURE 2: Visualizing Stand-Level Management



STAND-LEVEL INVENTORY

MANAGEMENT entails accounting for the timber resources that comprise a timberland investment property using the individual timber stand as the management unit of interest. As with strata-level management, the timber composition and stocking characteristics of each stand are derived from forest-level surveys or inventories. However, these inventories entail capturing and synthesizing data from more field samples (plots) than are employed when a strata-level inventory is being deployed (typically by a factor of 3 to 5 times). This more intensive, more detailed, stand-based information is then used by foresters to develop site-specific forest management plans that are designed to optimize the biological growth and financial performance of each stand as a unique management unit over the investment period. The site-specific focus of a stand-based inventory, combined with the higher sampling intensity, results in a very accurate and precise estimate of the timber volume growing within each stand.

The primary and controlling difference between the two timber inventory approaches is that strata-level management organizes timber assets at the property level into “mega stands” (stratum), while stand-level management organizes those same assets into “mini investment units” that are identified by their unique characteristics and managed as separate entities.

The research that is the focus of this article was undertaken to evaluate the relative benefits and drawbacks of these two timber inventory management approaches. The study was performed by the nationally recognized forestry consulting firm, ForesTech International, which is based in Watkinsville, Georgia. The firm’s research was conducted on a 31,300-acre timberland property in Northern Florida that is owned by institutional investors.

Research Parameters

As the sponsor of the research, Timberland Investment Resources, LLC was interested in exploring the following questions:

- 1. Accuracy:** Do both inventory data collection processes produce accurate estimates of current and future total timber volumes and timber values?
- 2. Precision:** What tradeoffs, if any, must be recognized with regard to the statistical reliability or precision of the two inventory methods and how does this impact the property and stand-level estimates of timber volumes and values they each are attempting to produce?
- 3. Data Sufficiency:** To what extent do the two methods each generate site-specific timber inventory data that is sufficient for a forest manager to produce accurate future estimates of timber growth and stand development using sophisticated timber growth and yield models? In other words, do both approaches provide quality base inventory data that can be projected into the future to model stand development over time?
- 4. Optimality and Feasibility:** In a forest management planning context, to what extent does the data produced by the two methodologies enable a forest manager to develop a forest management plan that can be feasibly implemented and that will be capable of optimizing a timberland property’s biological and financial performance over the investment time frame?
- 5. Financial Impacts:** How do the costs associated with implementing the two approaches differ – to what extent are their associated returns on investment (ROI) different – and, how do they each influence the financial metrics used to measure timberland investment performance in a net present value (NPV) context?

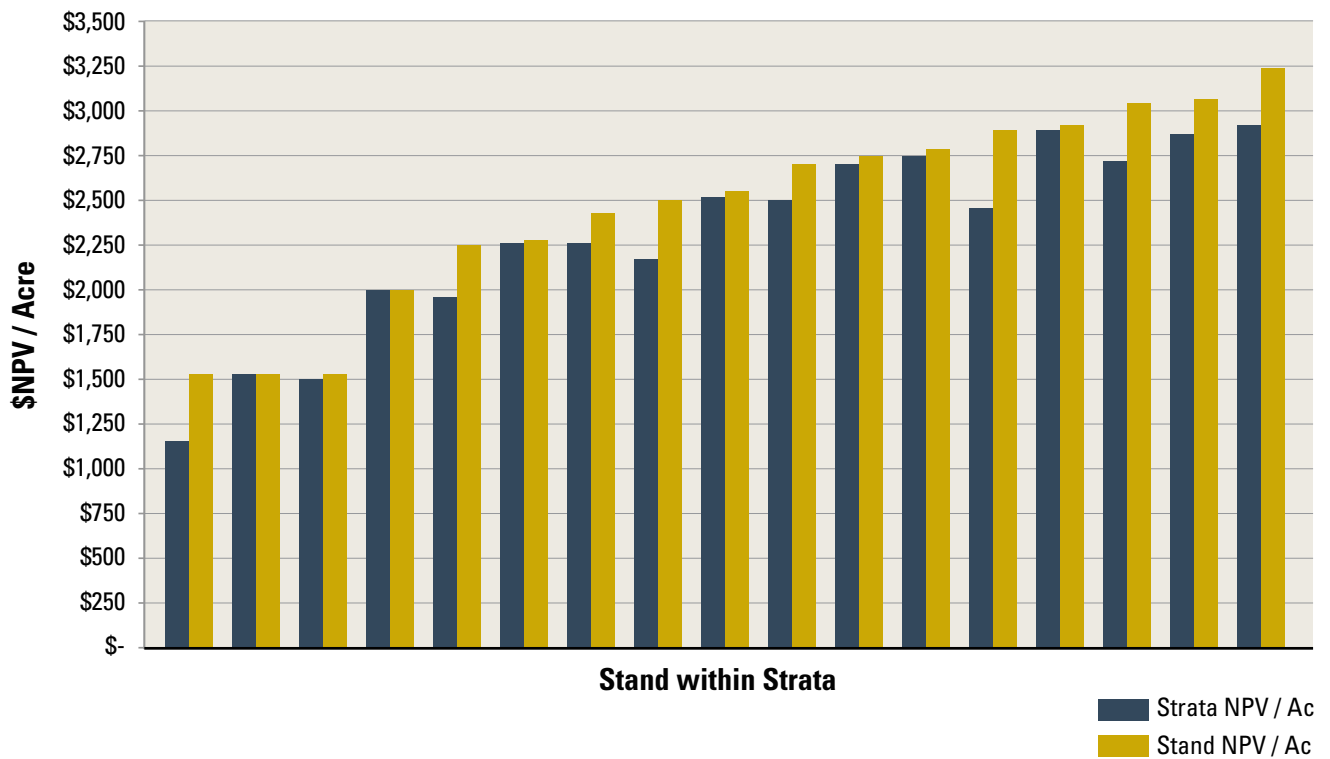
The property that was the subject of the study had recently undergone a comprehensive stand-level inventory. This data was then re-stratified to produce a corresponding strata-level inventory. One stratum identified during this process (10-year-old, planted and thinned loblolly pines) was selected by ForesTech for closer analysis. This stratum, and the 17 stands associated with it, were chosen because they represented a statistically meaningful sample and provided a typical forest management planning scenario for a timberland property that is being operated for investment purposes in the U.S. Southeast. ForesTech then developed 20-year forest management plans using the two data sets (the stand-level data and the aggregated strata-level data).

Research Findings

At a very high level, the ForesTech team reached the following conclusions upon completion of their research:

- 1. Accuracy:** With regard to their capacity to produce accurate estimates of a timberland property's total timber volumes and values, both stand and strata-level management techniques offered roughly equivalent results – providing comparable and acceptable estimates of the two metrics.
- 2. Precision:** With regard to precision (as measured by the statistical reliability of timber volume or value estimates produced for each acre), stand-level inventory management techniques generated far superior results, which led directly to more precise (narrower) estimates of timber volumes and values per acre for the same aggregation of assets.
- 3. Data Sufficiency:** Strata-level inventory techniques were not sufficient for ensuring that a forest manager's growth and yield modeling efforts would produce accurate estimates of future timber growth and stand development vs. the stand level inventory. In short, using the strata average vs. actual site-specific values for key forecasting variables, such as site productivity, stand history, stocking, level of hardwood competition, etc., caused the strata-level projections of stand development to be suboptimal when compared with the stand-level inventory results.
- 4. Optimality and Feasibility:** With regard to optimality and feasibility, the use of stand-level data always allowed a forest manager to establish forest management plans and prescriptions that were both optimal from a performance standpoint and feasible operationally. Conversely, the use of strata-level data offered far less certainty on both dimensions, especially selection of the optimal management regime.
- 5. Financial Impacts:** Finally, with regard to the financial impacts of the two inventory approaches, stand-level management is considerably more expensive to implement, but the additional costs associated with generating the more precise and detailed data it produces are more than offset by the additional investment value (improved investment performance) that can be captured over the life of a timberland investment by optimal decision-making.

Figure 3: Comparison of NPVs for Stratum vs. Stand Example



This bar chart illustrates the increased value per acre that is generated by employing stand-level timber inventory practices to guide ground-level forest management activities. It demonstrates that for each of the 17 stands measured in the ForesTech study, stand-level management techniques consistently produced stronger financial performance.

In short, the study compellingly demonstrated that under a variety of typical forest management scenarios, the use of stand-level inventory data consistently produced results that were superior to those produced when strata-level inventory data was employed. In fact, for purposes of this analysis, ForesTech found that while generating and utilizing stand-based inventory data cost from \$3 to \$5 more per acre, the beneficial impact, or ROI, of this additional cost was almost 40 times higher. This resulted in an estimated total NPV per acre that was 9 percent higher, and a total value per acre that was \$200 greater, as measured over the life of the investment.

Figure 4: Comparison of NPVs for Stratum vs. Stand Example

Summary of Results	Inventory Methodology	
Variable of Interest	Strata ("Mega Stand")	Stand
1. Unbiased Estimator of Merchantable Value (\$)	Yes	Yes
2. Statistical Precision of Estimated Value	Lower	2X Higher
3. Data Sufficiency (Future Projections)	No	Yes
4. Optimal Regime Assigned	Not Always	Yes (Always)
5. Operationally Feasible Results	Not Always	Yes
6. Financial Metrics	Lower	Higher
7. Estimated Composite NPV % Difference	0%	9%
8. NPV Value / Acre Difference (Benefit)	\$0	\$200.00
9. Three Year Inventory Cost per Acre	\$2.80	\$7.89
10. Inventory Cost / Acre Difference (\$/Acre)	N/A	\$5.09
11. Benefit / Cost Ratio Stand vs. Strata	N/A	39.3

The table above summarizes the key results produced by the analysis based on the survey design.

Again, the implications of these study findings are significant because pure stand-level management is NOT being consistently practiced on most of the timberland assets owned by institutional investors and high-net-worth investors in the US-Southeast. Theoretically, this suggests that the forest assets in these portfolios are significantly underperforming relative to their biological and financial potential.

The body of this article and the accompanying side bars provide considerable background on the ForesTech study and highlight the significance of its findings to timberland investors. To that end, we begin with an analogy that is meant to frame ForesTech's research in a familiar context.

II. Key Observations on the Strata vs. Stand-Level Management Study

Barry Shiver, Founding Partner and CEO, Ph.D., and Bruce Borders, Founding Partner, Ph.D. of ForesTech International.

The research study that is the focus of the companion article was conducted by Barry Shiver and Bruce Borders of ForesTech International. Their firm designs forest inventories and works with timberland owners and managers to insure that the timber stocking information collected from their holdings is accurate and sufficient for estimating current and future timber values.

During a recent interview, Shiver and Borders shared their personal assessments about their work and its implications for timberland investors. What follows is a summarized overview of their remarks and observations.

Q: What surprised you the most about the results of your research?

A: Barry Shiver... We have known for a long time that stand-level management and the data it produces provides a stronger foundation upon which to build forest management plans. It is just common sense that if you have more, and more precise, ground-level data and can make use of its detail to develop forestry regimes, you are likely to get better results. However, to some degree, the extent to which strata-level data was inadequate on a relative basis did surprise us. In every management situation we tested, the use of stand-level data led to better estimates of timber value, improved a forest manager's capacity to make better ground-level management decisions and produced better biological and financial results.

Q: Why is that?

A: Bruce Borders... The underlying presumption of strata-level management is that you randomly create hypothetical "mega-stands" consisting of numerous individual stands that supposedly share characteristics. However, the degree to which the stands that comprise a particular stratum actually have the characteristics that have been assigned to the stratum really depends on the intensity and randomness of the survey plots that have been used at a forest-level to paint the picture. In other words, the characteristics of these "mega-stands" are based on averages. For instance, one will seldom find an individual stand or a group of discrete stands that perfectly mirror the characteristics of the stratum to which they have been assigned. Consequently, when a forester uses such data to develop forestry prescriptions, those prescriptions are only calibrated to average, generalized conditions, not to the actual conditions on the ground. As you can imagine, this results in the sub-optimization of biological and financial performance.

Q: How is stand-level management different?

A: Barry Shiver... Stand-level management delivers a much higher level of data intensity. Far more inventory plots are taken. This allows a forester to have a much more informed perspective of what's growing in each stand. This has two important implications. First, it means a forester can estimate the amount and value of timber growing in each individual stand and across an entire property with much higher levels of precision and reliability. Second, it means he or she is in a better position to develop forest management plans and prescriptions that can help facilitate the optimized productivity and financial performance of each individual stand. When this kind of discipline can be applied across all of the stands that comprise an entire timberland property, the positive impacts simply multiply. In short, when intensive plantation forestry regimes are being employed, "stand-level" analysis empowers a forester to practice better forestry, which means better biological and financial performance.

Q: What are the not-so-obvious implications of using strata-level management?

A: Bruce Borders... Well, the poorly calibrated forest management activities that flow from the use of strata-level analysis also have a multiplier effect. Let's say, for instance, that the strata-level data that underlies a forester's management plan calls for him or her to thin all stands in the forest that comprise the 12-to-14-year-old loblolly pine stratum. The strata-level inventory data suggests that this should yield X tons of pulpwood, which will generate Y dollars of gross revenue in a given year. Well, if the forester goes out into the forest and observes that the number of stands that are assigned to this stratum are inadequate to produce the timber volumes that the annual budget says should be generated, a financial short-fall exists. What often happens in this scenario is that the short-fall is overcome by thinning adjacent or nearby stands that are younger or older than the designated stratum. As a result, over time, those stands end up being sub-optimized from a financial and biological productivity standpoint. This is analogous to the old adage: "Robbing Peter to pay Paul." In our study, we found, for instance, that when strata-level analysis was employed, about half of the stands our management plan said should be thinned were impossible to thin at the specified age because they were too immature. This inability to calibrate prescribed activities with actual, ground-level conditions is quite common with strata-level analysis.



Recently Thinned Pine Stand
Georgia



Mixed Hardwoods Stand
US-Northeast

A: Barry Shiver... Another example of this kind of sub-optimization takes place in relation to activities like fertilization and herbaceous competition control applications. When you use strata-level management data to design a chemical hardwood release application for a given stratum, you are likely to end up treating a lot of stands that may not need it. You also may fail to treat stands that would benefit from it — principally because they are inappropriately grouped within the wrong strata or masked by other stands in the strata. As a result, on the one hand, you waste money... and on the other, you don't spend money where you should on an activity that could have a real impact on both your near-term cash flows and your long-term total returns.

Q: If this is the case, why is strata-level management still being used?

A: Bruce Borders... For mixed hardwood and softwood forests, like those typically found in places like the Northeast and the Lake States, strata-level management is a perfectly acceptable and the most appropriate inventory method because the added cost associated with employing stand-level management techniques to extremely small or highly variable stands in such places simply cannot be justified. However, on lands that are managed and operated using intensive plantation silviculture, like many working forests owned by investors in the South and Pacific Northwest, the rationale for using stand-level management is compelling. As we said earlier, in every management scenario we tested during the research study, the financial results were better than those produced when strata-level management was employed. The net present values that were generated when stand-level inventory techniques were used were always as good or better than they were when strata-level management was employed.

Q: What about the intensity of your research... Is a detailed analysis of one particular stratum sufficient to draw conclusions about the relative superiority of stand-based inventory analysis?

A: Bruce Borders... Ideally, you always like to have the largest possible sample when you do an analysis like this. However, we're confident that if we were to apply the same research methodology to other strata, we would see the same types of results. That's because what we were doing here was

analyzing the underlying concepts of strata and stand-level management to understand how their application impacted data quality, forestry decision making and biological and financial performance. In light of that, it wouldn't matter if we were talking about 12-to-14-year-old un-thinned loblolly pines, which was the particular focus of this effort, or 18-to-20-year-old thinned slash pines. The actual numeric results would vary because of the differing species, ages and management histories of the two strata, but the overall quantification of those results would follow the same trend line and demonstrate that the use of stand-level analysis produces superior outcomes.



One-Year-Old Pine Seedlings
South Carolina

Q: Of the universe of TIMOs that are managing lands using intensive plantation techniques, what percentage are using stand-level management?

A: Barry Shiver... That's a hard question to answer, but I would say very, very few. Out of the universe of approximately 30 TIMOs operating in the marketplace, only about half say they are using stand-level inventory techniques. However, of those 15 or so firms that say they have embraced stand-level analysis, only a small number actually appear to be collecting and using the data appropriately. Ironically, we often encounter foresters who think they are employing stand-level management because their forest management plans are being implemented at a stand-level. However, in most cases, the inventory data that underlies their plans was generated using strata-level inventory techniques. Designing and implementing forestry plans at a stand level doesn't constitute stand-level management if the underlying data that is the foundation for those plans was produced using strata-level techniques.

Q: How would you explain the fundamental value proposition of stand-level analysis?

A: Bruce Borders... That's simple. Stand-level management is unquestionably more expensive to implement than strata-level management, but the return on investment it generates more than makes up for that additional cost. If it costs an average of an additional \$5.00 per acre to implement stand-level inventory techniques across a forestry property, and over the long term that investment produces \$35.00 of additional value per acre above and beyond what could have been achieved by using strata-level management techniques, that's significant – especially if you multiply that impact across all of the stands that comprise a timberland property. The cost-benefit argument is pretty compelling.

Q: If you could give investors and their TIMO managers one piece of advice in relation to this subject, what would it be?

A: Barry Shiver... To implement stand-level management and derive its full benefits, you need to have access to the right data models. It takes time and money to implement these models and to feed them with stand-based inventory data at an appropriate level of detail. However, as Bruce just explained, these are investments that pay off in the form of optimized biological and investment performance. In fact, they pay off in much the same way that Wal-Mart's investment in its supply-chain system has made it possible for the company to optimize the productivity and profit-generation potential of each square foot of retail space in its stores. It is all about having more information and more precise information so you can make good decisions about how to optimize the biological and financial potential of each timber stand.



Bruce E. Borders, Ph.D., is a professor of Forest Mensuration and Inventory at the Warnell School of Forestry and Natural Resources at the University of Georgia, where he is the Director of the Consortium for Accelerated Pine Production. During the past twenty years, Borders has been involved in forest research aimed at quantifying the effects of different silvicultural practices on growth and yield of southern pines.



Barry D. Shiver, Ph.D., is Emeritus professor of Forest Management with the Warnell School of Forestry and Natural Resources at the University of Georgia. Since his retirement in 2005, Shiver has focused on forestry consulting through his firm, ForesTech International, which he co-founded eight years ago. He also was director of the Plantation Management Research Cooperative (PMRC) at the University of Georgia for ten years and is widely recognized as an expert on southern pine responses to silvicultural treatments and growth and yield.

In addition to serving together on the faculty of the Warnell School of Forestry and Natural Resources at the University of Georgia and co-founding ForesTech International, Shiver and Borders co-wrote the forest inventory text, "Sampling Techniques for Forest Resource Inventory," which is widely used in university forestry curricula across the country.



Given the technical complexity of the stand-level vs. strata-level forest inventory discussion, it may be helpful to begin by exploring an analogy: How are a Wal-Mart store and a timberland investment alike and what parallels exist between their optimally efficient financial management?

The answer is that with both a Wal-Mart store and a timberland investment there is a critical need to ensure that the output capacity of a defined area of commercial space is optimized. In the case of the Wal-Mart store, that defined area is each square foot of retail space. In the case of the timberland investment, it is each acre dedicated to timber production.



To optimize the productivity and financial performance of its retail space, Wal-Mart manages its product inventory at the store level rather than at the company or regional levels. Since 1983, when it pioneered the use of satellite technology to link its stores with its corporate headquarters in Bentonville, Arkansas, Wal-Mart has invested hundreds of millions of dollars building and enhancing a supply-chain system that uses advanced technology and sophisticated analysis to determine what products, and in what amounts, to re-stock at each store every day. This investment in store-level efficiency and productivity has helped make Wal-Mart the envy of the retail world.

In the case of a working forest, even though the basic financial objective is the same, optimizing the productivity and financial performance of a defined area, in this case each timber stand, most timberland investments are not managed with a level of precision or sophistication that compares with Wal-Mart's store-driven supply-chain system.

Strata-Level Inventory Management Defined

As was explained in the Summary Report, timberland investment managers operating in the US-Southeast most often employ a technique for estimating and managing timber inventories that is based on a "strata-level" approach to forest management. This entails tracking the current inventory of timber on an entire property by pre-established categories, or strata, which are defined by differing physical characteristics.

An individual stratum is typically defined by a combination by tree species, age class and other physical attributes. During a strata-level inventory process, each acre of timber on a timberland property is assigned to a particular stratum based on an estimated perception of its physical attributes. Both individual stand-level detail and resolution are lost in the stratification process. An individual stand is simply aggregated with other stands into a single, larger sampling unit or “mega stand.” This aggregation is meant to classify the average, predominant timber stocking characteristics of the stands that have been aggregated. For instance, one of the many strata into which a timberland property’s timber assets might be aggregated could be 12-to-14-year-old, un-thinned loblolly pine. A second stratum might be all upland hardwood stands of natural origin that are older than age 25. A large working forest that has undergone a strata-level inventory process can have its timber assets aggregated into 30 to 60 unique stratum or more.



Once a working forest’s acres have each been assigned to a unique stratum, foresters develop and implement forest management plans based on their assessments of the types of forestry activities and prescriptive treatments (herbaceous control, fertilization, thinning, etc.) that will be required to cultivate and optimize the biological output of each stratum during the investment period. These forestry plans and activities are collectively referred to as the “management regime.” In the case of strata-level forest management, the “optimal management regime” for any stand of timber is the collective set of forest management treatments that should be prescribed and executed to maximize the biological and financial output of each stratum.

So, in the case of the stands designated by the strata-level inventory process as belonging to the 12-to-14-year-old un-thinned loblolly pine stratum, all would be subjected to roughly the same “optimal management regime” throughout the life of the investment. Although most timberland investments are only held by institutional investors for 10 to 15 years, planted pine stands in the US-Southeast that are being managed to produce timber that can be sold across the full spectrum of end-use product classes (pulpwood, chip-n-saw and sawtimber) normally undergo final harvests when their remaining trees are between 25-and-35-years-old. This means the “optimal management regime” for each stratum found on each property must be calibrated to the timberland investor’s risk and return expectations so ongoing cash flows and long-term asset appreciation potential can be maximized.

On a practical level, strata-level management would seem to be a highly efficient and cost effective way to manage a timberland investment. However, the research analysis that is the focus of this article has established that, when applied to timberland assets that are being operated with the intensive plantation forestry practices that are typically employed in the US-Southeast, strata-level management significantly sub-optimizes a working forest’s biological and financial return potential relative to the alternative approach, stand-level management.



...the ForesTech research demonstrated that strata-level management subverts sound forest-level decision-making because it aggregates characteristics of numerous timber stands and assigns them to a single sampling unit or “mega stand” based on average acre strata categories that are almost never fully descriptive of the actual ground-level conditions or underlying stand attributes.

According to ForesTech’s research analysis, the strata-level inventory approach generates base inventory data that is not only inadequate with respect to site-specific characteristics, but is often very imprecise when applied at the stand level. In short, it “masks” important attributes such as differences in site productivity, stand history and levels of hardwood competition. This loss of “sufficiency” not only undermines estimates of standing and future timber volumes and their values, it also compromises a forester’s ability to develop and implement forest management plans that optimize the biological and financial output of each stand over time. In other words, ForesTech’s research demonstrated that strata-level management subverts sound forest-level decision-making because it aggregates characteristics of numerous timber stands and assigns them to a single sampling unit or “mega stand” based on average acre stratum categories that are almost never fully descriptive of the actual ground-level conditions or underlying stand attributes.

Because of this effect of creating a mega stand with the attributes of the “average acre” and because of the resulting loss of sufficiency between the base inventory data and actual operating conditions, foresters who rely strictly on strata-level analysis are almost never able to calibrate their management activities to the true biological characteristics and potential of the timberlands upon which they are practicing forestry. According to the ForesTech research, in many cases, when strata-level methods are used, foresters find themselves attempting to apply ground-level forestry prescriptions to individual stands that are either inappropriate or poorly timed. In fact, in some cases, the recommended strata-level prescriptions are simply infeasible to implement. For instance, a forest management plan built on a strata-level inventory may prescribe the thinning of stands assigned to a certain stratum at a certain age. However, in reality, it is not uncommon for a forester to find that some, if not many, of the specific stands targeted for treatment at that age are understocked. This means they lack the timber volumes that are required to successfully execute the thinning operation that has been prescribed.

Our earlier analogy involving Wal-Mart offers a good way to think about the implications of this dislocation between data and actual operating conditions.

If Wal-Mart was to utilize an approach comparable to strata-level management to guide its supply-chain logistics — employing average company-wide or regional sales data to make decisions about how to re-stock individual stores — it would inevitably ship too much or too little of certain products to its retail outlets, which would result in the sub-optimization of its store space. For instance, if Wal-Mart’s regional data showed that the company sold more Panasonic flat-screen televisions than any other brand in its stores in the Midwest, and it used this data as the basis for shipping more Panasonic televisions to all of its stores in that region, individual stores in the Midwest that had traditionally sold more Sony flat screens would inevitably see that their retail floor space was being sub-optimized. As was explained earlier, Wal-Mart does not approach supply-chain logistics this way. It ships its individual stores higher concentrations of the products and brands they each sell the most.

Stand-Level Inventory Management Defined Parameter

In the world of timberland investing, the same principle of using data to concentrate assets, resources and activities in ways that produce optimized results can best be achieved through the use of stand-level timber inventory management.

Stand-level management entails collecting and tracking timber inventories stand by stand to obtain an accurate, site-specific profile of each stand's timber product volume, tree size distribution and stocking levels as well as other important physical attributes, including species mix, age-class characteristics and biological productivity potential.

The data produced from stand-level inventory management is more intensive and granular than the data generated by the strata-level inventory technique and this results in a more complete, more sufficient and more precise picture of the timber composition of each individual stand on a timberland property. This is not only superior for supporting current and long-term efforts to estimate timber volumes and values, it also allows foresters to better customize and target forest management prescriptions to the site-specific conditions present in each individual stand.

Comparing Strata- and Stand-Level Inventory Management

Unfortunately, the case for adopting stand-level management has largely been theoretical because little effort has been expended to rigorously prove its underlying value proposition. Timberland Investment Resources, LLC (TIR) engaged ForesTech International, a highly-regarded and widely recognized forestry consulting firm based in Georgia, to conduct the independent research analysis that is the basis for this article. The findings of this work, clearly demonstrated that the underlying theoretical assumptions about stand-level inventory methods have been correct — the capacity to gather and utilize more and better forest-level data does, in fact, lead to better overall forest-level management decision-making and financial performance.

The study was conducted on a 31,300-acre timberland property located in the Panhandle of Northern Florida. The property has been managed for intensive timber production on behalf of institutional investors for a number of years.

From a process standpoint, ForesTech extracted representative sample plot data from this property's recently completed stand-level inventory and stratified it to produce a corresponding strata-level inventory. The firm then chose to focus on a representative stratum. This stratum, or "mega stand," consisted of an aggregation of 17 un-thinned, planted, loblolly pine stands that had been established between 2000 and 2001. Collectively, these stands encompassed some 633 total acres. Other strata characterized by other attributes and conditions could have been chosen, but this particular stratum was selected because its age, management history and species composition provided ForesTech with the best opportunity to develop 20-year management plans. As a result, the firm determined that this approach would facilitate its efforts to produce a meaningful and analytically-rigorous comparison of the relative merits and drawbacks of the two inventory approaches from an investment standpoint.

The baseline stand-level inventory for these stands was produced from data generated from 192 inventory plots — a concentration of approximately one plot for every three acres (an average of approximately 11 plots per stand). By comparison, the strata-level inventory ForesTech produced was based on data generated from installing and measuring one inventory plot for every 25 acres. Both of these survey plot concentrations were consistent with standard industry practice for each inventory technique.

The data generated from the two inventory approaches was then used to develop 20-year optimal management regimes to forecast future stand development over time. Multiple management treatment scenarios were then developed and analyzed using the sets of data. Among other things, these scenarios considered the timing of mid-rotation thinnings, the use of hardwood competition control, the application of fertilizer and the timing of final harvests. The goal in both cases was to optimize the biological and financial performance of the subject strata and stands to maximize their NPVs over the 20-year planning horizon.

In comparing the results produced at the property level from the two data sets, ForesTech found that the estimates of total timber inventory that the two methodologies each produced for the targeted stratum (un-thinned, loblolly pine in 2000-2001) were roughly comparable. This finding was consistent with prior analytical work that had been undertaken by others to study the relative accuracy of the two approaches at an overall property level.

ForesTech's most compelling finding, however, was that there was a significant difference in the levels of precision or inherent reliability between the stand and strata-level data sets as pertained to actual, stand-based stocking conditions. In other words, even though the total inventory estimates of volume by product class generated by the two approaches were very similar at a property level, they were not comparable at a stand level in terms of statistical precision.

The composite inventory estimate of total volume or value painted by the stand-level inventory was far more detailed, far more precise and statistically less variable than the one painted by the strata-level analysis for the same aggregation of stands. Moreover, when these data were projected into the future, the resulting management plans for each approach were also significantly different. ForesTech attributed this disparity to the fact that the strata-level inventory approach was insufficient for capturing the inherent site-specific differences between the individual stands in the stratum. Consequently, when the “average acre” conditions represented by the stratum were projected into the future, important details were lost. For example, key site-specific information associated with site productivity, initial stocking levels, levels of hardwood competition and past stand histories were averaged or lost in the future projection of the stratum’s productivity. This resulted in sub-optimal management plans and a lower overall NPV when applied back to individual stands in the stratum. According to ForesTech, these results suggest that:

“When developing management plans to maximize timber value, stand-level plans developed with stand level-timber inventory data will always meet or exceed the value generation potential of management plans developed over time using strata-level timber inventory data. This is because the average conditions represented by the strata-level inventory simply do not apply to any specific stand but to the average conditions of a group of stands in the stratum. Consequently, strata-level plans will always result in less total timber value coming from a given property.”

The table on the next page provides evidence of ForesTech’s conclusion in this regard. It illustrates that, under the study’s conditions, a stand-level approach to forest management beats a strata-level approach in all cases. This conclusion is based on optimum Net Present Value (NPV) criteria and on the application of associated forest management prescriptions and expectations of future stand development. Again, ForesTech found that the optimum assigned management NPV for each individual stand was always greater than, or equal to (never less than), the stratum assigned optimum NPV for the same stand. In addition, because of the intensity and precision of the data generated by the stand-level inventory techniques, using stand-level data for growth and yield modeling and forest management planning resulted in cash flows being realized sooner, mid-rotation thinnings being executed at optimal times from both a biological and financial return standpoint, and final harvests being scheduled and completed sooner.

Figure 5: Comparison of NPVs for Stratum vs. Stand Example

Stand and Sizes (In Acres)	Strata-Level NPV / Acre	Stand-Level NPV / Acre	Stand-Level NPV / Acre Positive Differential
1. 27.42	\$1,172	\$1,545	\$373
2. 54.56	\$1,560	\$1,567	\$7
3. 39.7	\$1,524	\$1,572	\$48
4. 50.51	\$1,985	\$2,018	\$33
5. 89.78	\$1,958	\$2,255	\$297
6. 14.03	\$2,277	\$2,289	\$12
7. 28.76	\$2,263	\$2,395	\$132
8. 72.61	\$2,169	\$2,511	\$342
9. 15.66	\$2,559	\$2,589	\$30
10. 35.42	\$2,501	\$2,682	\$181
11. 18.78	\$2,690	\$2,758	\$68
12. 16.78	\$2,756	\$2,793	\$37
13. 13.77	\$2,417	\$2,889	\$472
14. 22.3	\$2,888	\$2,919	\$31
15. 89.82	\$2,718	\$3,044	\$326
16. 20.86	\$2,879	\$3,086	\$207
17. 22.21	\$2,919	\$3,240	\$321
Totals/Averages: 632.97	\$ 2,213	\$ 2,412 (109.0%)	\$ 200 (9.0%)

This table further demonstrates that using strata-level inventory techniques to guide forestry activities is sub-optimal when compared to using stand-level techniques because of the inherent data insufficiencies that result with regard to key management and measurement variables like site productivity, levels of herbaceous competition, diameter and height distributions, prior silvicultural history and product quality forecasts.

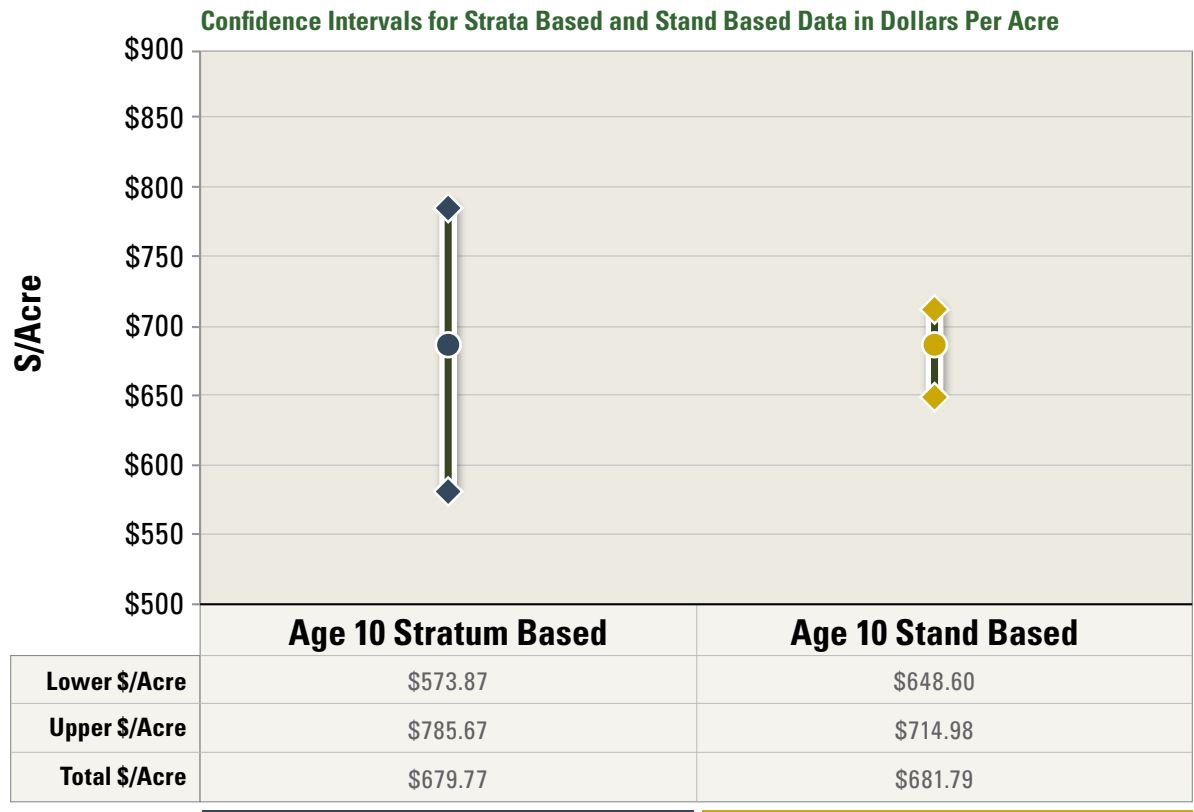
This lack of insight influences the ability of a TIMO or forest manager to design and implement optimized, stand-specific forestry prescriptions. It also compromises one's ability to accurately project per acre timber growth rates, yields and values. The key finding is that the use of stand-based inventory techniques produced an NPV that was 9 percent higher.

With respect to the relative inventory costs of the two methodologies, ForesTech's findings also suggest that it is more expensive to implement a stand-level inventory approach because of the number of survey plots that are required. However, these costs appear to be more than offset by the increased financial performance that can be generated by subsequently using stand-level data to develop customized, stand-by-stand timber treatment prescriptions. Moreover, the marginal increase in cost per acre of about \$5 per acre is much smaller than the marginal cost of making poor or sub-optimal management decisions, where treatment costs ranging from \$35 to \$150 per acre are the norm. Using these marginal differences as examples, the resulting benefit to cost ratios (ROI) would range from 7 to 50 times higher using a stand based inventory approach. In addition, ForesTech also found that because of the aggregated averaging of inventory data that is used to estimate stand-based timber volumes, strata-level management can produce a much wider range of timber values because it can significantly under or over-estimate timber volumes at the stand level. This can have valuation implications, especially in a land transaction scenario when a partial sale or purchase of a larger property is being executed using these statistically less precise estimates of volume and value. The inability to precisely assess the timber stocking levels of the individual stands involved in such a sale while employing strata-based inventory approach can result in the loss or capture of value by either the buyer or seller.

Figure 6: Comparison of Key Management and Output Variables

Variables of Interest	Strata-Level Inventory	Stand-Level Inventory
Acres in Merchantable Planted Pine	633	633
Sampling Intensity: Acres Per Plot	25	3.3
Number of Inventory Plots Collected	25	192
Cost Per Inventory Plot	\$30	\$20
Total Initial Inventory Cost per acre	\$1.40	\$6.07
Annual Maintenance Cost per acre per year	0	\$0.61
Estimated Three-Year Inventory Update Cost per acre	\$1.40	\$1.82
Total Three-Year Inventory Cost Per Acre	\$2.80	\$7.89
Merchantable Timber Value Per Acre	\$680	\$682
Merchantable Timber Coefficient of Variation (Planted Pine Only)	39%	33%
Standard Error of Estimate @ 95% Confidence Level	7.8%	2.4%
Merchantable Timber Value for All Stands	(\$680/ac)	(\$682/ac)
Lower Limit of Merchantable Timber Value	(\$574/ac)	(\$649/ac)
Upper Limit of Value of Merchantable Timber	(\$786/ac)	(\$715/ac)
NPV \$ Total and \$NPV Per Acre	\$ 2,213/acre	\$2,412/acre
	Difference: \$200 Per Acre 9.0% Improvement	

This table demonstrates some of the key variables used to track inventory process costs and outputs. One other significant finding of the ForesTech study can be found in the last few rows of the table, which illustrate the wide degree to which strata-level inventory practices can over and under estimate the upper and lower ranges of timber values on a property.

Figure 7: Comparison of Data Accuracy and Sufficiency

This chart demonstrates the relative confidence intervals between stand and strata-level management estimates within the ForesTech study. It illustrates that the study's stand-level management data set produced output that was determined to be approximately 95 percent accurate – considerably higher than the accuracy of the strata-level data.

According to ForesTech, the industry standard for stand-level inventory data collection is one survey plot for every 2 to 4 acres within each stand that is being measured. The average cost of each of these samples is typically in the range of \$20 to \$30, depending on stand composition and other factors. Conversely, as was referenced earlier, strata-level inventories usually employ a sample intensity of one plot per every 15 to 25 acres. Because of the distances between survey plots, the cost of each sample is higher for a strata-level inventory than for a stand-level inventory, but when spread over an entire property, the total cost of a strata-level survey is much lower because fewer sample plots are utilized.

For purposes of the research referenced in this article, ForesTech made some reasonable assumptions about the number of survey plots that would be required to conduct both stand and strata-level inventory analyses on the property in Northern Florida that was the subject of the study. Again, it was determined that to conduct a stand-based inventory for the targeted stratum, 192 sample plots would be required, while 25 plots would be necessary to produce a comparably-scaled strata-level inventory. As Figure 6 illustrates above, the cost of the initial stand-level inventory for those stands containing the targeted “mega stand” was \$6.07 per acre. The cost of the strata-level inventory for the same stratum was \$1.40 per acre – a difference of approximately \$4.67 per acre. The estimated three-year costs of each approach, including the initial inventory and subsequent annual updates for the stand-based approach, was \$7.89 per acre. The comparable three-year costs of the stratum-based approach, including an initial inventory and new inventory at the end of year three, was \$2.80 per acre – a difference of \$5.09 per acre.

As was explained earlier, this inventory cost differential is a product of the more intensive and more precise data collected for individual stands during a stand-level inventory. However, as Exhibit 4 demonstrates, the quality and depth (accuracy and sufficiency) of a stand-level inventory provides the means to implement optimized stand-by-stand forest management prescriptions, which, in turn, produce beneficial results in the form of financial performance that is 40-times higher than the performance projected from using strata-level management data.

This not only means when stand-level analysis is used, each stand will receive the forest management attention it needs to ensure optimal timber productivity, it also means that forest management expenditures will not be wasted. For instance, a management plan built off of a strata-level inventory may produce a forest management prescription that calls for fertilizing all stands on a property that contain a particular timber stratum — including stands within that strata that may not need fertilization or benefit from it. In such a scenario, the additional costs of treating those stands are wasted (at a rate of \$150, or more, per acre at current fertilizer prices). Furthermore, this unnecessary expenditure of working capital means that funds may not be available to pay for other forestry practices (like controlling woody competition or invasive species) that might prove more impactful to those stands not requiring fertilization. Again, the “masking” of site-specific attributes, like levels of woody competition, at the stratum level make management treatments difficult or inefficient to apply operationally, whereas these differences are readily apparent when stand-level data is collected and used as the foundation for a management plan.

In closing, the ForesTech research clearly establishes that when stand-level inventory analysis is used to manage timberland investments, especially those that are being intensively cultivated using plantation silvicultural regimes, the end result is stronger biological and financial performance. In short, for investment-oriented landowners, stand-level management offers a far more compelling value proposition than strata-level management and is highly supportive of their objectives, which emphasize optimizing their investment returns for each acre and each timber stand they own.

For questions or more information, including a more detailed synopsis of the ForesTech International study, please contact Steve Smith, Managing Director of Forest Management, Timberland Investment Resources, LLC at smith@tirllc.com.

Maturing Slash Pine Stand
Florida



Different Performance Objectives Require Different Inventory Approaches

Strata-level management is often described as a vestige of industrial forestry — an approach that migrated into the timberland investment world as institutional investors became the dominant owners of large-scale timberland properties.

When most of the investment-grade timberland in the United States was owned and operated by paper, packaging and solid wood products companies, their lands were often managed with a narrow product orientation. For instance, many paper and packaging companies managed their forests as pulpwood farms — growing trees to their minimum merchantable sizes over short periods of time (often 10 to 15 years), harvesting them for use in the paper and pulp production process and then re-planting the lands to start the cycle all over again. Likewise, companies that produced solid wood products, like lumber and plywood, and that wanted to maximize return on investment (ROI) from their primary capital assets, their saw mills and panel mills, tended to manage their timberlands with an emphasis on producing large quantities of chip-n-saw and sawtimber-grade logs.

In short, the objectives for owning timberland were different for many paper and forest products companies than they are for today's timberland investors. Industrial timberland owners were less interested in maximizing their financial returns from each individual acre or stand. Rather than growing trees on their lands in accordance with the unique productivity characteristics of those lands, or in response to the needs of the open market, more often than not they were focused on maximizing the output of each forest as a whole with an emphasis on producing log grades that met their own processing specifications.

Under these circumstances, strata-level management was a perfect fit. However, as the paper and forest products industry began to consolidate in the late 1980s, and companies began to divest of non-strategic assets, more and more timberland

came under the ownership of institutional investors. Strata-level management techniques migrated with these lands and were adopted as the inventory standard of choice by most TIMOs. In time, however, some in the TIMO community began to recognize that this inherited propensity was actually inconsistent with the needs of financially-oriented investors, whose focus was more like that of Wal-Mart — centered on optimizing and hopefully maximizing the financial performance of the asset. This realization triggered increased interest in stand-level management, which, in turn, spurred demand for new technologies and statistical tools that could be used to generate more precise inventory data at a stand level. The task was to provide forest managers with more precise data with which to estimate timber stocking at both the stand and property levels so they could more accurately estimate timber values and develop customized, stand-based management plans that would facilitate the optimized management of a timberland property by optimizing the performance of its component stands.

During the last 15 years, the forestry consulting and technology communities have responded to these needs by developing advanced data models and forest management applications, which have increasingly enabled the cost effective adoption of stand-level management by some TIMOs. However, the biggest challenge with the growing interest in stand-level management has been the inability of its proponents to simply demonstrate and quantify its actual impact on timberland investment performance relative to the use of traditional strata-level management techniques. As was explained in the other companion pieces to this article, this challenge has been compounded by the fact that while most TIMOs now recognize the intrinsic benefits of stand-level management, there are still slow-adopters within the sector. Furthermore, some appear to describe their strata-level management practices in ways that obscure the actual differences between the two approaches.



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