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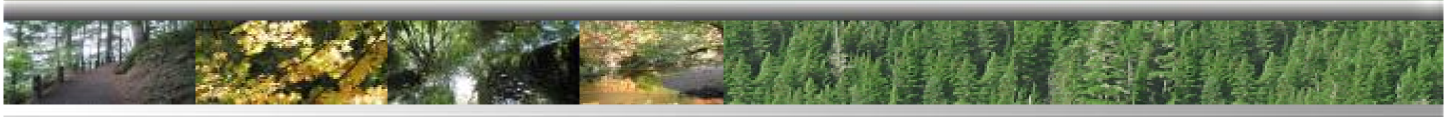


The FORSight Resource

Volume 4, Issue 4 Q4 2007

Upcoming Events...

SOFEW 2008
Annual Meeting
March 9-11, 2008
Savannah, GA

6th Southern Forestry and Natural Resource Management GIS
(SOFOR GIS 2008)
March 24-26, 2008
Orlando Florida
http://soforgis.net/2008

Brazil Forestry Study Tour
March 30 - April 6, 2008
April 6 - April 13, 2008

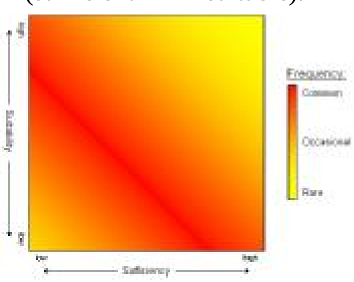
http://www.worldforestinvestment.com

Western Forest Economists
Annual Meeting
May 5-7, 2008
Welches, OR

Inside this issue:

Is Your Inventory Up To The Task? Part II

In the last newsletter, we discussed at some length the concepts of sufficiency and suitability of inventory databases. Hopefully, you will have had the opportunity to assess your own situation and think about ways to address any shortcomings and move toward the upper right quadrant (sufficient AND suitable).



For those of you who are still struggling in the other three quadrants, we will now present some different strategies for making your inventory work in a forest planning context.

Option 1. Project all stands

In this case, sufficient inventory data are available for projecting all stands (i.e., tree-list or stand summary data exist for running either an individual tree or stand-level model, respectively). All data are first checked for errors. The clean and we'll now assume suitable data are then formatted for input into the growth model and then brought forward to a common time period. Each stand is then grown forward using alternative management regimes.

There are obvious and compelling advantages to growing each stand separately. There is no need for identifying stratification criteria and then placing each stand into a specific stratum. In addition, there is no loss of precision with regards to representing the overall range of variability on the ownership. All stand conditions existing in the forest are represented in the data. Growth models are not run with data that have been averaged, thereby representing conditions that might not actually exist. And finally, the selection of candidate regimes for each stand can be done more judiciously than if stands are grouped into strata.

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Barber Revisited: On the Aggregation of Age Classes in Harvest Schedule Models

One of the most important yet commonly overlooked issues in harvest schedule modeling is age class aggregation. Planners often take for granted the inherent assumptions associated with aggregated age classes. In doing this, they fail to recognize the bias that may be introduced. Bias may be further exaggerated by failing to fully understand calculations and assumptions made by growth-and-yield and planning software. A landmark paper by Richard L. Barber addresses these assumptions. This article serves as an introduction and overview of Barber's work and provides justification for revisiting the topic.

There are several reasons to formulate a periodic model using aggregated age classes. First, inventory data resolution may be poor. Exact ages may be unavailable or unreliable, leaving the planner with age class data only. A model con-

(Continued on page 4)

Barber, Richard L. 1985. The Aggregation of Age Classes in Timber Resource Scheduling Models: Its Effect and Bias. For. Sci. 31:73-82

Growth Model Review–FORSim LPGS

	PARTICULARS
Authors	Mark L. Hanus, Charles T. Stiff , and Bruce L. Carroll
Species	Even-aged stands of naturally regenerated longleaf pine
Region	Southeastern United States
Silviculture	Commercial thinning and assessment of RCW foraging habitat
Model Type	Stand/tree-level model
Add'l Info	http://www.FORSightResources.com/forsim.htm

FORSim is a suite of regional growth and yield applications designed to put the functionality of powerful growth models at the fingertips of inventory foresters and biometricians. FORSight's latest release, the Longleaf Pine Growth Simulator (LPGS), integrates a user-friendly, Excel-based interface with a longleaf pine growth engine. The dynamic link library (dll) which incorporates the longleaf pine growth functions also provides for alternative thinning treatments, and calculates scores for assessing foraging habitat for the endangered red-cockaded woodpecker (RCW).

FORSim LPGS was developed using models for predicting and/or projecting stand- and tree-level attributes available from previously reported studies. Those models were developed by researchers using plot data from even-aged stands of naturally regenerated longleaf pine installed and re-measured by the USDA Forest Service Regional Longleaf Growth Study (RLGS). These models were combined in a unique way with FORSight's proprietary growth functions to create a robust platform for predicting the development of longleaf pine. Growth in young stands (1–19 years) can be either predicted or projected annually using stand-level models, while growth in older stands is based on projected tree list data. Tree list data are either input by the user or initially generated at age 20 using the 3-parameter Weibull probability density function.

Required inputs to the model include total stand age, site index (range 30-110 feet, base age 50 years), stand stocking (trees/acre), projection length (number of 1 year projection periods), product merchandising specifications, and a choice between using either stand-level prediction or projection models. Optional inputs to the model include stand density (basal area/acre), dominant height (feet), number of years to reach breast height, tree list data, and specifications for up to five thinning treatments.

FORSim LPGS simulates commercial row thinning, thinning from above, thinning from below, and a combination row and below thinning using stand age, residual basal area/acre or trees/acre, and the minimum and maximum DBH removed. Up to five thinning treatments and thinning types can be specified. Stand- and tree-level removals and product volumes are reported in spreadsheet tables by DBH class. The user can specify the reporting frequency of grown tree lists (every projection period, or only following thinning treatments).

Multiple-product (saw-timber, chip-n-saw, and pulpwood) volumes (green tons/acre outside bark) are predicted using stem taper functions and user-specified values for minimum DBH, minimum top diameter, and average stump height. For larger trees, top volumes are removed after removing the primary saw-timber or chip-n-saw products. The pre-merchantable volume category includes all standing trees with DBH less than the minimum pulpwood specification, while debris includes the remaining un-merchantable tops, branches, and foliage.

Spreadsheet tables are output for annual stand-level projections, grown and cut tree lists, and habitat scores. The habitat scores can be used for evaluating alternative management regimes with respect to achieving and maintaining desirable RCW foraging habitat. Graphical outputs include dominant height, trees/acre, basal area/acre, total ft3/acre volume, Curtis relative density, relative spacing, quadratic mean DBH, percent maximum Reineke stand density index, current and mean annual increment (ft3/acre/year), product volume (tons/acre), and RCW habitat score plotted against stand age.

FORSim LPGS is a versatile tool that provides biometricians and inventory foresters with the functionality of the longleaf pine growth engine in an easy-to-use, excel-based interface. It provides a means for quickly analyzing and comparing stand-level treatments through graphical and tabular outputs. Users will find this to be a valuable addition to the FORSight Resources' FORSim product suite.

Inventory collection in longleaf pine plantation. Sand Hills State Forest, South Carolina. Photo courtesy, S. Phillips.

Up To The Task?...

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The major disadvantage of this approach is that inventory data are required for all stands. Due to budget and time constraints as well as a common failure to save old data, this approach is often not possible. In addition to the time and expense associated with collecting data, the data must be checked for errors. The more stand data present, the more time will be spent checking and fixing errors in the data. Growth model processing time will also be increased due to the increased number of runs required to simulate all stands using alternative management regimes. And finally, it is possible that the resulting linear programming (LP) matrix arising from a stand-based model may exceed the capacity of available LP solvers.

Option 2. Stratification

When cruise data are not present for all stands, an alternative approach must be taken to get growth and yield information for those stands lacking sufficient data to run them through the growth model. Commonly, this is when stratification comes into play. Stratification allows stands without sufficient data to be represented by a stand considered as approximately the same biologically and with respect to future management, and for which enough data are present to run the growth model (sufficient).

For stratification to be done accurately, all stands must be brought to the same point in time. Enough data must be present to grow each stand forward to the current day. If enough data are not present for this, the age of data must be a factor in the stratification. This can greatly increase the resulting number of strata. Along with needing to support the growth model, enough data need to be present to place the stands into strata. Stratification can be done without this, but its effectiveness is questionable and therefore it is not recommended.

Theoretically, homogeneity exists across the stands within a stratum with respect to cover type, age, site quality, stand density, and any other important variables upon which the stratification is based. Variability between stands within a stratum should be at a minimum. In reality, some stands are grouped together for convenience, to ensure a minimum number of acres per stratum, to reduce the overall number of strata, because of a lack of data, or because there is no where else to put them and they don't merit their own stratum*. Regardless of the methods used to develop strata, the variability across stands within a stratum is often higher, and in some cases much higher, than desired.

Option 2a. Project the average stand

A common method projects the average stand using average data from all stands in the stratum with at least sufficient data for running the growth model. For a stand-level model, basal area/acre, trees/acre, total or breast height age, site index, along with other important stand attributes would be averaged across all stands within each stratum. The average stand attributes are then projected for each stratum. For a tree-level model, averaging is typically done using the tree expansion factors in the cruised tree-lists. All the tree-lists are then aggregated, resulting in one large tree-list with a total stand TPA equivalent to the average of the individual cruise plot TPA values.

Projecting the average stand requires less time formatting and projecting data. Thus, the method also reduces the size of the planning problem, resulting in less processing time and an increased likelihood of a solvable model. Additionally, if strata are truly homogeneous, then the averaged values will accu-

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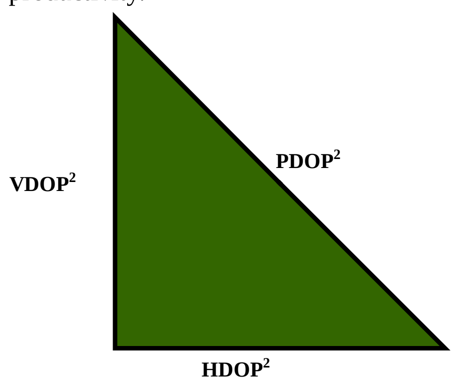
*****_A rule of thumb for determining whether to recognize a particular stratum might be a 1% / 1000 acre rule: If the stratum is greater in size than 1% of the total forest acreage, keep it. Alternatively, if the stratum is greater than 1000 ac in size, keep it, otherwise combine it with another similar stratum._

How it works: Positional Dilution of Precision (PDOP) in GPS

Global Positioning System (GPS) units are a widely used within the forest industry, but not everyone understands the technical particulars of the technology. One of the acronyms used for predicting GPS accuracy is PDOP (Position Dilution of Precision). PDOP is a unitless value derived using a mathematical formula which predicts relative GPS accuracy based on the number of the visible satellites and the relative geometry of the visible GPS constellation. Since satellite positions are very predictable, PDOP can be calculated at any given time.

Basically, the more clustered together the visible satellites are, the higher the PDOP value and the less accurate the GPS position. Conversely, the more "spread out" the visible satellites are, the lower the PDOP value and the more accurate the GPS position. A low PDOP value represents an increased confidence of obtaining an accurate position due to favorable satellite positioning; however, since GPS accuracy is based on many other factors, an accurate position cannot be guaranteed by looking at PDOP values alone.

PDOP is composed of 2 components - HDOP or Horizontal Dilution of Precision and VDOP or Vertical Dilution of Precision. For most forestry uses, GPS is used for horizontal measurements such as area and distance as opposed to vertical measurements such as elevation and height. If the user is concerned mainly with area or distance measurements, a HDOP mask can be used instead of a PDOP mask to improve field productivity.



$$PDOP^2 = HDOP^2 + VDOP^2$$

Most GPS vendors recommend setting a PDOP mask of 6 (this means the receiver will not collect a position if the PDOP is > 6). To obtain the same horizontal accuracy, you can use a HDOP mask of 4. In the field, it is easier to stay below HDOP=4 than it is a PDOP=6; thus, decreasing the amount of time needed at each point collected in the field.

One more way to improve field productivity is to use mission planning. Mission planning software allows a user to plan field work around the times of the day with the lowest HDOP values and highest number of visible satellites. Some mapping grade GPS receivers have mission planning software preloaded. Trimble offers a free desktop mission planning application (http://www.trimble.com/planningsoftware_ts.asp) for those without it loaded on their handheld units.

Forester's workloads seem to be ever increasing. By switching to a HDOP mask and utilizing mission planning, you can increase GPS productivity in the field. These are two steps that do not take a lot of time to implement but can save you precious time in the field.

If you have any questions or need additional help with GPS or field data collection, give FORSight a call.

Barber Revisited...

(Continued from page 1)

forming to the aggregated age classes is thus the only option. In the past, an inability to generate annual models with suitably long planning horizons forced the use of periodic models. It is widely accepted that planning horizons two or more rotations in length are necessary to fully model the harvest scheduling problem. Long planning horizons translate into large models that may be difficult to structure and solve. In response, many past models used 5- or 10-year age classes with equally long planning periods.

When Barber's work was published in 1985, mainframe computers had substantially less computing power than today's desktop PCs. Improved computer power has allowed planners to generate annual models for forests that previously required aggregated age classes. In some regions, however, rotation age of 60-100 years still mean long planning horizons, pointing towards the use of periodic models. Finally, the detail provided by an annual model may not outweigh increases in model complexity and size for some forests, pointing planners towards a periodic model.

Two important yet distinct concepts, age class width and planning period width, must be understood before moving further into a discussion of age class aggregation. Age class width describes the number of ages combined into a single age class. Any number of ages can be aggregated, and the width need not be fixed. As an example, models formulated in the northeastern US may use ten-year age classes (1-10, 11-20,…) while a southern pine models may use annual age classes for younger stands and aggregate older-aged stands into wider classes (1,2,…,30,31-35,36-40,41+). Planning period width describes the length of time each planning period represents.

Like age class width, planning period width need not be constant. Because the first ten years of a model are often viewed as the most critical, a model may be formulated with ten annual periods followed by a series of wider periods. Although the convention in much of the harvest scheduling literature is age classes and planning periods of equal width, in practice this is often not the case. As a result, this article generalizes the work of Barber, who dealt with the specific case of equal age class and planning period widths.

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Barber Revisited...

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The use of periodic models requires the acceptance of several underlying assumptions. A thorough understanding of them is critical as they directly affect model development and can introduce bias in projected harvest volume. A common assumption is that acreage is randomly distributed according to a uniform distribution within each age class. In other words, it is assumed that there are an equal number of acres at each age within the class (equal to the total acres in the class divided by the width of the class). Somewhat counter to this is an assumption that all acreage within the class is harvested simultaneously. Although it is understood that some acreage will be harvested annually (assumed to be equal to the total harvest divided by the class width), from a modeling perspective each period must be treated as having a single discrete harvest. As a result, a uniform harvest age is required for yield calculations. The assumed harvest age is a function of harvest timing within the period and the initial age of the class.

Harvest timing within a period is also important because it dictates the appropriate discounting. These issues lead to the most critical question when using aggregated age classes – what harvest age minimizes yield bias?

There are two common assumptions for harvest timing within a period, period mid-point and period end-point. By assuming equal annual harvest, one can see that on average, acres will be harvested at the period mid-point. Alternately, some planners extend the assumption of period end-point harvest used in annual models to periodic models. There are also two common assumptions regarding initial age class age: age equal to age class mid-point or age equal to age-class end-point.

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Up To The Task?...

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rately reflect stand attributes and very little information will be lost.

A recurring problem using average data is how to go about averaging non-numeric stand and/or tree data. For nominal (i.e., non-ordered classification) data, the median or mode could be used instead of an average. However, projecting a stand with median or mode slope type (e.g., concave versus toe ridge) could produce much different yield curves. In many cases, numeric values are assigned to ordinal (i.e., ordered) data and an average is calculated. If the ordinal data are crown ratios (10 = 0-14%, 20 = 15-24%, etc), the average retains most of the information. However, projections using averages based on unequal interval ordinal data could produce unexpected yield curves.

Before any averaging can be done, the stands must first be placed into strata. This requires a certain amount of current information for each stand. While not as demanding of the inventory as growing each stand separately, this can also be considered a disadvantage because the data must be available for putting the stands into strata. Another disadvantage comes in the form of the question, what does it mean to be the average stand?

In the case of stand-level growth models, averaging of the stand parameters may result in a combination of stand parameters that does not actually exist in nature, let alone in the particular stratum. With tree-level models averaging the cruise data results in a tree-list with a record for every tree cruised in the stratum. The question must be asked whether this averaged tree-list containing records for all the species present in the stratum represents a condition that can or does exist, and whether growing this aggregated condition forward will give an accurate representation of the collective future growth of the stands within the stratum.

Option 2b. Project the representative stand

A second method projects the stand within the stratum which best represents the average condition of all stands within the stratum. The method for selecting the representative stand depends on the stratification criteria and goals of the planning model. Data availability for each stand within a stratum can also play a roll in selection. As with the average stand method, this method will work better if the stands within a stratum are more homogeneous.

Similar to projecting the average stand, this method reduces the size of the planning problem, resulting in less processing time and increasing the likelihood of solving the model. Unlike the average stand method however, the stand being grown is actually present in the ownership. There is no averaging, and therefore, data being grown are from an actual existing stand within the stratum. Also, like the average stand method, if strata are truly homogeneous, the selected stand will accurately represent the full acreage within the stratum, and more between-stratum variability will be retained

A disadvantage of this method can be the difficulty in finding a representative stand within each stratum that has sufficient data to run the growth model. Lack of homogeneity within the stratum further complicates the choice of the most representative stand. Similar to the average stand method, differences can and likely will exist between the yield curves for the chosen stand and the average for all stands within the stratum. Stands should be carefully selected to minimize both current and future differences as much as possible.

Option 2c. Project all stands within the stratum and average the output

A third method grows all stands within each stratum and then averages the yields by stratum at each time period. Ideally, sufficient data are present to stratify and grow all stands. If data are missing for some stands, then only those stands within a stratum having enough data are grown and averaged.

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Barber Revisited...

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Using the uniform distribution assumption discussed earlier, it is easily seen that on average, the age of acres within each class are equal to the age class mid-point. Barber, however, views the apparent age of acres within each class as being equal to the class end-point. Given these alternate assumptions, several possible harvest ages emerge.

Consider the four examples illustrated in Table 1: age class width greater than planning period width, equal to planning period width, and less than planning period width and annual age classes. In all cases a five-year planning period width is assumed. The table reveals that underlying assumptions have substantial impact on the apparent harvest age for a given class.

The yields which minimize bias and produce the most accurate harvest volumes remain at question. Barber attempted to provide an answer by comparing volume outputs from annual and periodic models using age class mid-point or age class end-point yields. He examines uniform and skewed age class distributions using both area and volume control models. His results, cited by many planners, indicate that age class end-point yields minimize bias, with age class mid-point yields often leading to harvest volume underestimates. Several key issues, however, point towards revisiting the topic.

Although still used for some planning, area and volume control models have fallen out of favor with most planners. They have been replaced with comprehensive linear programming tools that not only schedule harvests but also address a variety of concerns such as wildlife habitat and cultural resources. This shift leads to the question of whether results from linear programming models would mimic those of Barber.

Barber's use of area and volume control models meant that harvest schedules were generally fixed, although some variation could occur with volume control models. Altering volume inputs in linear programming models may translate into altered harvest schedules. These shifts may be further exaggerated in the presence of constraints on harvest volume and/or area, commonly used in today's models. Finally, Barber only examined the case where age class and planning period widths were equal. Table 1 illustrates that importance of considering all cases in the analysis.

A final point is that annual models are not free of bias, an issue exaggerated by our increasing ability to generate annual models. Despite producing annual yields, some growth and yield models remain periodic. Annual results are generated through interpolation of periodic values. In addition, popular harvest schedule software allows development of annual models using linear interpolation of periodic yields. The bias that may be introduced through the use of interpolated yields is unclear, but demands further study.

Some planners remain unaware of these issues and the impacts they may have on model results. This brief article serves as an introduction for a more detailed investigation that will be carried out by FORSight Resources staff. We will update and expand upon the work of Barber, re-examining past issues and addressing questions raised by improved modeling abilities. As with all modeling, assumptions must be made. Violating assumptions can lead to errors that range from inaccurate harvest volumes to sub-optimal solutions. Managers must recognize and understand these critical issues, making decisions that will minimize bias and produce the most accurate insights. Look to a future issue of the FORSight Resource for the results of this study and what they mean for the resource planner.

Table 1. Apparent harvest ages for four age classes given assumed initial age class ages and harvest timings (five-year planning period width).

Age Class	Assumed Initial Age	Assumed Harvest Timing	Apparent Harvest Age
21-30	25	Mid-Point	30
21-30	25	End-Point	35
21-30	30	Mid-Point	35
21-30	30	End-Point	40
26-30	27.5	Mid-Point	30
26-30	27.5	End-Point	32.5
26-30	30	Mid-Point	32.5
26-30	30	End-Point	35
21-23	22	Mid-Point	24.5
21-23	22	End-Point	27
21-23	23	Mid-Point	25.5
21-23	23	End-Point	28
30	30	Mid-Point	32.5
30	30	End-Point	35

Jewels in the December snow. Southwestern Ontario, Canada. Photo courtesy, K. Walters.

Up To The Task?...

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Unlike the average stand method, all stands are projected using the actual measured rather than averaged stratum data. The method thus preserves stand-to-stand variability and both within- and between-stratum heterogeneity further into the process than if averaging had been done prior to growth. It can be argued that accounting for the variability not just at the start but also in the growth trajectory between stands within a stratum creates a more representative average yield curve. As with the other methods involving stratification, the planning model size is reduced. Runtime will be less and solvability will be more likely.

An obvious disadvantage with this method is the amount of data necessary for each stand and the additional time required to generate yield curves for all stands and average yield curves for each stratum. Similar to the average stand method, there are also questions about the validity of resulting average yield curves. If strata are not homogeneous due to stand-to-stand variability in projected growth, then averaging at each time step could lead to averaged yield curves with illogical behavior. Finally, if data are not available for all stands, then the benefits of this method are significantly reduced.

Quite often, especially using tree-level models, sufficient data are not available for projecting all or even a large percentage of stands through the growth model. One important take-home message from the above discussion is to collect and save data. Remember, old data is better than no data at all.

All of the alternatives discussed in this paper assume a high degree of completeness and suitability in your inventory data. Otherwise you have to accept the limitations of your data, which include a reduced ability to derive meaningful results from your analysis. The difference between using averaged data versus projecting a representative stand, or using a unsuitable stratification scheme could have serious consequences on your analysis results. Only careful analysis of data for sufficiency and suitability, then selection of further analysis methods that match the findings will help to ensure that your inventory data and analysis methods are up to the task.

FORSight Resources provides world-class expertise to companies and agencies facing critical natural resource decisions. The company's offerings include forest planning, acquisition due diligence, forest inventory & biometrics, GIS & data services, custom system/application development and hardware/software sales.

FORSight Resources Contacts:

Office Locations:

Southern Office
(Corporate Headquarters)
8761 Dorchester Rd., Suite 102
North Charleston, SC 29420
Phone 843.552.0717

Western Office
3813 H Street
Vancouver, WA 98663
Phone 360.882.9030

Lake States Office
350 Northside Dr
Milton, WI 53563-1370
Phone 608.868.2799

Northern Office
272 West Broadway
Bangor, ME 04401
Phone 207.945.3302

FORSight Resources LLC

Bruce Carroll - President & CEO
843.552.0717

Greg Day - VP-GIS & Data Services
843.552.0715

Karl Walters - VP-Planning Services
360.882.9030

William Boswell - Product Sales
843.552.0715

Trimble

http://FORSightResources.com
info@FORSightResources.com

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An Adjacency Formulation Overcoming Modeling Limitations Imposed by Shelterwood Treatments

Steven D. Mills and Marc E. McDill. 2007

Abstract– Policy guidelines limiting the size of forest openings reinforce the need for spatially explicit forest planning. These policies are modeled with adjacency constraints. The two basic types of exact adjacency constraint formulations fail to provide a framework for accurately modeling shelterwood silvicultural treatments.

A new adjacency formulation overcoming the limitations of current models is presented. Extensions to other areas of harvest schedule modeling are discussed.

KEYWORDS: Spatial forest planning, adjacency, optimization, constraints, harvest schedule, shelterwood, forest planning.

For a copy of this slide presentation, visit our website: http://FORSightResources.com/library.htm#presentations

Give a man a fish, and you'll feed him for a day.
Teach a man to fish, and he'll buy a funny hat.
Talk to a hungry man about fish, and you're a consultant.
- Scott Adams