Quantitative Timber Management Planning: Growth & Yield Models and Timber Inventory Data

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Walmart – World’s Leading Retailer
What Makes Walmart So Successful?
What Makes Walmart So Successful?

Walmart is the world’s leading retailer because they are the world’s leading retail inventory/logistics managers (decision support systems).
What Makes Walmart So Successful?
Decision Support/Planning

- I am going to present a brief review of decision support/planning in timber management
- Don’t worry – it will be VERY BRIEF – no sleeping!!
Quantitative Decision Making

• Recognize the Problem
  – Our problem is to develop timber management plans at *stand* (management unit) and/or forest level that help us achieve our objectives (usually a financial objective in my world)

• Develop and specify alternative strategies that will (hopefully) meet our objectives
  – Alternative management strategies that will allow us to achieve our objectives and satisfy any constraints we may have

• Identify an appropriate Decision Criterion (most likely NPV in my financial context) with which to rank our alternatives (management plans) & *calculate its value for each alternative*

• Select the ‘optimum’ strategy that achieves our objective(s), satisfies our constraints and maximizes the value of the Decision Criterion
Decision Support/Planning

- We all know - or we all work with people who know - how to develop alternative management regimes, calculate their NPV and rank them from low to high (stand level management) or identify the regime that satisfies forest level constraints and contributes to the overall forest NPV (forest level management)
Decision Support/Planning

• So what’s the problem????
  – Why are our plans so often at variance with the reality on the ground?

• When your foresters go to a stand/area in search of what you claim to be there (based on your inventory/management plan) and they don’t find it – AND this happens time and time again:
  – YOU SHOULD BE WORRIED, YOU SHOULD BE VERY WORRIED
Decision Support/Planning

• What is a typical response to such problems?

• A typical response I hear is something like:
  – ‘That quantitative stuff is nice theoretically but - it just doesn’t work in the real world.’ OR
  – ‘I believe this theoretical stuff should work and help us make better decisions but - those @#$* growth and yield models just don’t work well. I sure wish those guys at Georgia or VT (substitute MT, OSU, etc) would make some models that actually represent what happens in the real world.’
Decision Support/Planning

• What I never hear is something like the following:
  – Harvest Scheduling/Planning is useful; growth and yield models perform pretty well
  – Maybe our timber inventory data does not represent conditions on the ground
    • After all – our inventory gives us an error of +X% (at some level of resolution)
  – Maybe we need to improve our timber inventory information and obtain/store more detail in our timber inventory system to help improve performance of growth models.

• This may imply that we can’t continue to carry out timber inventory using our ‘business as usual’ approach and we may actually have to spend more money on our timber inventory to help improve our bottom-line profitability
Decision Support/Planning

• Requisite Information and Tools
  – Inventory information that **actually represents** the standing timber conditions within each management unit (this is different than having inventory information that shows a certain level of sampling error)
  – Growth and yield models that can project timber inventory information forward in a **realistic** fashion under a wide array of conditions
  – Realistic estimates of expected costs (taxes, management and silvicultural related costs)
  – Realistic estimates of current and expected future stumpage values
Decision Support/Planning

• Inventory information that actually represents the standing timber conditions within each management unit
• Different groups have their own approach to developing this type of information as well
  – Most organizations view timber inventory work as a necessary cost to be minimized
  – This leads to timber inventory estimates that are not often representative of actual standing timber conditions
  – For profit oriented firms in the southern US we have shown this can reduce bottom line profitability from timber growing by >10%
Decision Support/Planning

• Confessions of a Timber Inventory Instructor
  – I learned the theory of sampling and timber inventory methods as a student
  – I learned how to properly apply timber inventory methods operationally by working with many of the present and past timberland management groups that have managed timberlands throughout the world
  – I have been teaching proper theory and application of timber inventory methods for more than 25 years
  – I continue to be astonished that my students who have been well taught and have shown a thorough understanding of timber inventory methods/application seem to forget everything they learned at school when they go to work in the ‘real world.’
Decision Support/Planning

- Confessions of a Timber Inventory Instructor
  - I have actually thought about this quite a bit and have come to the conclusion that some conversation like the following must happen when a well educated undergraduate or graduate student goes to work with many timberland management groups:

**Billy the Recent Graduate:** Mr. Jones I have been thinking about how we are doing timber inventory here at _______ company and thought we could improve it a bit if we did a few things that I learned at school.
Mr. Jones: Billy don’t worry about all that crap you learned at school, you’re in the real world now. We have been doing this stuff for a long time and we know what works in the real world. Just learn our system (side note – a system that is likely been in place for decades and no one currently working at the company actually knows why it is done the way it is done) and do it the way we do it here in the ‘real world.’
Decision Support/Planning

• Some groups have their own models and some groups use off the shelf models (e.g. SiMS 2009, FASTLOB, TAUYIELD, GaPPS, etc – It goes without saying that SiMS 2009 is superior!!)
  – When such models are fed poor quality data and inadequate data to characterize your stands (management units) well we often hear cries of frustration from operational folks that we need ‘new models’
  – So ONE MORE TIME WITH FEELING – the models available in the southern US are likely not the primary problem.
    • There is always room for improvement in any mathematical model
    • However – refusal to accept that it is the data that actually drives the results blinds you to the opportunity to truly optimize the value of your timberland holdings
Decision Support/Planning

• Nelson 2003
  – “… our ability to formulate and run large-scale, long-term forecasting models often exceeds the scientific credibility of the data, especially for complex forest ecosystems. In the absence of critical thinking, such powerful models can become dangerous weapons.”

• Garbage In = Garbage Out is a Truism we can not avoid!
Timber Inventory for Decision Support/Planning

• Timber inventory for timber management planning is not the same as timber inventory for estimating current standing timber value

• When estimating current standing timber value our major concern is our estimate of standing merchantable tons by product within our management unit
Timber Inventory for Quantitative Timber Management

• When the objective for a timber inventory is to develop a timber management plan using G&Y models/financial analysis we must design the inventory strategy to develop realistic estimates of current standing timber conditions that can then be fed into the model we intend to use for projections

• SO – the inventory for management planning is designed to develop realistic estimates of necessary model inputs

• Consequently, you must know what information your growth model requires to make realistic growth projections
Inputs to Growth and Yield Models

• This information will vary by specific model and the software system the model is implemented in.
• My comments apply to the architecture of models as implemented in the SiMS 2009 software system.
Inputs to SiMS

- Inputs for a given stand type/species (e.g. cutover loblolly, cutover slash, natural loblolly, etc.)
  - Site Index
  - Dominant Height (HD) – Age Pair (from a cruise past crown closure)
  - Stand Age (A)
  - Surviving Trees/Acre (TPA)
  - Basal Area/Acre (BA)
  - Detailed stand table or individual tree list with all quality information available (i.e. always pulpwood, sawtimber stoppers, broken tops, etc)
  - Historical silvicultural management is known and available as input into the model (plantations only)
Growth and Yield

• Loblolly Pine Stand
  – Age 20, TPA=293, SI=65, Medium Hardwood Level
  – History
    • 1st Generation,
    • Burn/Brown – Low Hardwood Level,
    • HWC Banded year of planting
    • DAP 125 lbs/acre first growing season
    • Thinned at Age 15
  – HD at Age 20 = 60 feet
  – BA = 109.9 ft^2/acre
# Growth and Yield

## Cruise Stand Table

<table>
<thead>
<tr>
<th>Dbh Class</th>
<th>Trees per Acre</th>
<th>Average Height</th>
<th>Basal Area</th>
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**Totals**

|                      | 293.30 | 109.52 |

## Yield Unit:

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<th>Dbh Class</th>
<th>Trees per Acre</th>
<th>Average Height</th>
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</table>

**Totals**

| 293.30 | 109.52 | 0.00 |
Growth and Yield

• Run this stand with various types of inventory input:
  • S, A, TPA
  • S, HD, A, TPA
  • S, A, TPA, History
  • S, A, TPA, History, Stand Table
  • S, A, TPA, History, Stand Table with TQI
## Growth and Yield

<table>
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<tr>
<th>Input</th>
<th>BLV ($)</th>
<th>R Age</th>
<th>PW Tons</th>
<th>CNS Tons</th>
<th>Saw Tons</th>
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Growth and Yield

• This can go on and on
• You get the point – same models different input = different results
• More information about your stand (management unit) makes your plan more realistic
Timber Inventory for Decision Support/Planning

• Several Points in the Life of a Timber Stand when we should obtain timber inventory information:
  – Post regeneration/pre-crown closure
  – Post crown closure/pre-first thin
  – Post first, second, etc. thin(s)
  – Pre-final harvest

• NOTE – periodic inventories taken across an entire property (typically stratified into rather coarse strata) are not useful for planning if your objective is to truly identify optimal decisions
Post Regeneration/Pre-Crown Closure

• When? – Planted stands – end of first growing season; Natural stands – 3 to 5 years following regeneration cut

• Purpose 1 – Determine if regeneration has been successful

• Purpose 2 – provide information to G&Y system for inventory updates and preliminary management planning
Post Regeneration/Pre-Crown Closure

• Methods (sample size adequate to characterize stand variation)
  – Natural Regeneration – small (1/50, 1/40 acre) circular sample plots
  – Planted Stands –
    • Rectangular sample plots - 1/40 or larger
    • Row plots used with row sampling strategy
    • NOTE – avoid smaller circular sample plots
Post Regeneration/Pre-Crown Closure

• Desired Information for G&Y System:
  – Number of surviving trees/acre
  – For plantations – estimates of hardwood/waxy leaf woody competition and herbaceous competition (if your G&Y system uses this information to improve growth projections)
  • HOW? – have cruisers make a call (low, medium, high) for each type of competition – use modal value for stand
  – Site Index Estimate – where from?, base?, expressed?
Post Crown Closure/Pre-First Thin

• When?
  – Planted stands – will vary between age 8 and 12 years depending on site quality/management
  – Natural stands – will vary a lot depending on site quality, number of trees/acre and competition levels

• Purpose 1 – First ‘good’ look at the stand since post regeneration cruise. Ensure stand is vigorous and in tact.

• Purpose 2 – provide information to G&Y system for inventory updates and management planning
Post Crown Closure/Pre-First Thin

• Methods (sample size adequate to characterize stand variation AND minimize Coverage Error)
  – Natural Regeneration – small (1/40, 1/30 acre) circular sample plots
    • DO NOT use point sampling
  – Planted Stands –
    • Rectangular sample plots (circular ok but not preferred) - 1/40, 1/30 acre or larger
    • Row plots used with row sampling strategy
    • DO NOT use point sampling
Post Crown Closure/Pre-First Thin

• Desired Information for G&Y System:
  – Number of surviving trees/acre, basal area/acre, average height of dominants/co-dominants
  – **Stand Table** – number of trees/acre by 1 inch dbh class or tree list with dbh measured to nearest 0.1 inch (2 inch dbh classes should NEVER be used)

• Tree Quality Information – pulpwood always, sawtimber; stopper heights

– Plantations – estimate of hardwood/waxy leaf woody competition (if your G&Y system uses this information to improve growth projections)
Side Note – Point Sampling and Young Stands

• Point Sampling is a probability proportional to size (PPS) sampling design that:
  – Works very well for estimation of current total standing timber volume/value in stands that large range of tree sizes and we are primarily interested in current volume
  – Small sample sizes in lower diameter classes leads to poor characterization of stand tables in young/uniform stands (e.g. plantations, natural regen areas)
Post Thin Inventory

• When?
  – Should be done within a year or two of most recent thinning
  – If it has been longer than 7 or 8 years since last thinning, a new inventory should be carried out to update the system with improved information

• Purpose 1 – Obtain current standing tons by product for merchantable timber

• Purpose 2 – provide information to G&Y system for inventory updates and management planning
Post Thin Inventory

• Methods (sample size adequate to characterize stand variation)

• Row Thinned Planted Stands –
  • Rectangular sample plots (circular ok but not preferred) - 1/40, 1/30 acre or larger
  • Plots established so as to represent area of take out row and leave rows
  • Row plots used with row sampling strategy

• Natural Stands
  – Fixed area circular plots or point sampling (once majority of stems > 5” DBH) (BAF chosen so average number of sample trees is 6 to 8)
Post Thin Inventory

• Desired Information for G&Y System:
  – Number of surviving trees/acre, basal area/acre, average height of dominants/co-dominants
  – **Stand Table** – number of trees/acre by 1 inch dbh class or tree list with dbh measured to nearest 0.1 inch (NEVER use 2 inch classes)
    • Tree Quality Information – pulpwood always, sawtimber; stopper heights
  – Plantations – estimate of hardwood/waxy leaf woody competition (if your G&Y system uses this information to improve growth projections)
Various Timber Inventory Comments

• Row thinned stands – present a very unique and difficult problem if you go about this work without using your common sense

• Must insure that sample represents the area of take rows and leave rows appropriately

• Using typical grids (1 plot per 2 to 5 acres) that permit sample plots to fall without regard to take/leave row can result in very POOR numbers (even though precision estimates look good)
Various Timber Inventory Comments

• Row Thinned Stands

• Solution 1 (preferred): use rectangular sample plots with two sides running perpendicular to sample rows and corners established so as to include the area of the take and leave rows (best with well defined rows)
Various Timber Inventory Comments

• Row Thinned Stands

• Solution 2: use circular plots or point samples established by systematically forcing plot/point to fall in take row, 1\textsuperscript{st} leave row, 2\textsuperscript{nd} leave row, 3\textsuperscript{rd} leave row, take row....
EXAMPLE 30TH ACRE RECTANGULAR PLOT INSTALLATION

Start Plot at first row and stretch plot across all leave rows across. Take row.

1st Measurement (W)

\[ \frac{43560}{\text{Plot Size}} \times \frac{1}{W} \times \frac{1}{10} = L \ (\text{to tenth}) \]

\[ \frac{43560}{20} \times \frac{1}{52.2} (W) = 27.8 \ (L) \]

Double flag 1st tree on corner.

Measure calculated distance to create fixed area plot.

2nd Measurement (L)

Flag height trees.

Only measure trees in this section.

Measure trees are contained within plot corners marked with red stars.
Various Timber Inventory Comments

• Measure trees – the majority of timber inventory expense is travel to the area

• Once the cruiser is on the ground your objective is to obtain a representative sample using an appropriate design/strategy – this includes having cruisers measure tree characteristics not ‘ocularly estimate’ tree characteristics
Various Timber Inventory Comments

• Timberland Managers (TIMO, REIT, Private Owner, Government Agencies, etc)
  – You may have to pay more per sample plot to have useful information, you may need to pay for more sample plots per unit area
  – You should institute rigorous sample plot audit procedures and audit all information (including proper sample unit placement) for all cruisers on a routine basis
  – Hold cruising organizations accountable for their errors
  – Do not allow cruising contractors to dictate what is done – you dictate what is done
Various Timber Inventory Comments

• Timberland field consultants (i.e. cruisers)
  – You have to realize that your daily production rates are going to fall
  – You must also realize that business as usual is not going to cut it
  – You work for landowners – some are well informed, some are not – when you cut corners with a landowner that is well informed and you are not held to account that is their problem as well as yours
  – When you cut corners with a landowner that is not well informed you are operating unethically
Various Timber Inventory Comments

• Don’t get overly excited about precision estimates for cruises

• In my experience the more reliance a group has on meeting a given error estimate for a cruise the less they know about the true nature of sampling and samples (ignorance is bliss)

• If it sounds too good to be true – IT IS!
Various Timber Inventory Comments

• Sampling error – one class of error samples are exposed to
  – For probability samples we can estimate this error for a given sample design/sample data

• Non-sampling error (bias) – the second class of error samples are exposed to
  – Specifically concerned with ‘Coverage’ Error
  – In application, this error is usually more problematic than sampling error
  – Receives less attention because it can not be estimated from our data
Various Timber Inventory Comments

• When I am asked to review the quality of a timber inventory – the last thing I am concerned with is the estimate of precision

• WHY? – because this estimate is totally dependent on the nature of data we obtained – we can have a very impressive (i.e. small) estimate of error for very poor quality information
Various Timber Inventory Points

• I am most interested in:
  – What is the purpose of the inventory?
  – What type/size of sample units (plots, points, rows, etc) were used?
  – How is the timber distributed on the ground (i.e. natural stands at random, planted in rows, row thinned, etc) – how were sample units distributed?
  – Does type of sample unit comport with the purpose?
Various Timber Inventory Points

• I am most interested in:
  – Were trees measured or ‘ocularly estimated’?
  – Were cruisers audited in a rigorous fashion?
  – What is quality of your area estimates?? (spatial info)
  – How is tree volume or weight calculated?
Summary

• Timber Inventory for planning purposes is not the same as timber inventory for estimation of current standing tons

• Modern day timber management requires detailed information to optimize the value of the timberland investment
Summary

• It is necessary to have high quality timber inventory information as well as high quality growth and yield systems available.

• Growth and yield models in the Southern US are likely adequate for providing decision makers with useful information to guide their decisions – *IF realistic, appropriate data are available.*
Questions & Comments
All Welcome!