Investigating the 3% Growth Rate Assumption

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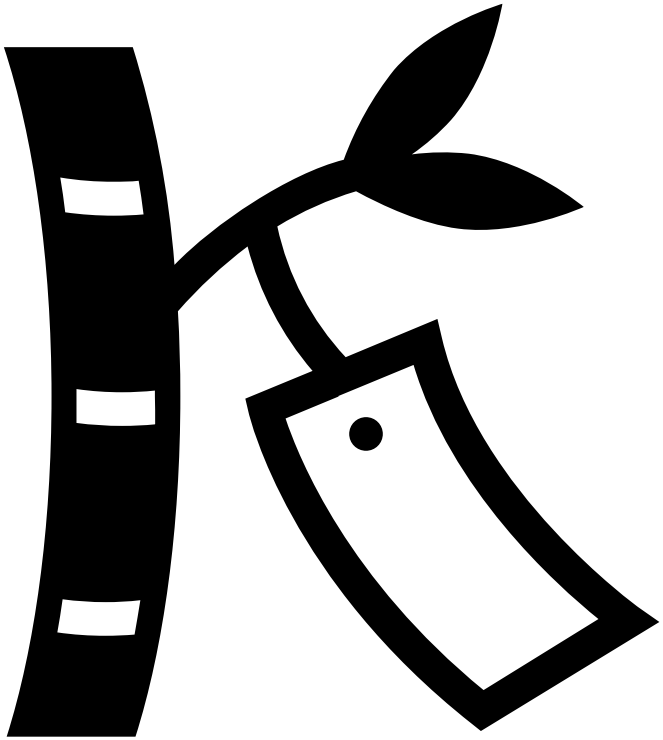
Topics Covered…

1. Background of 3% Growth
2. USFS FIA and rFIA
3. USFS FIA Growth Analysis
4. Empirical Yield Table and FVS Growth Comparison



Background of 3% Growth Rate

- **How is the 3% growth rate used?**
  - Applied in the form of simple interest
  - Typically, not applied to primary forest type of property
    - Bottomland hardwoods in SE holding pine plantations together
    - Areas of lower value and/or low intensity management
    - Seen applied to many forest types in NE, SE, Lake States, and Appalachia
  - Stand level growth projections from inventory data
    - Total and Product Volume and Weight, BA, TPA
  - Same rate applied to all merchantable stands
  - Data management systems
    - Reporting to investors and fiduciaries
    - Used to make management decisions
    - Evaluations, Appraisals, and Transactions
- **Growth projections of 3% are still in use**
  - Widely used but waning
  - Myself and some AFM systems included

Background 3% Growth Rate

- **Why is a growth rate of 3% widely used and accepted?**
  - **I am not sure!**
  - **Let's speculate…**
    - **A constant growth rate is easy to apply**
    - **"It is what has always been used!"**
    - **No complaints or motivation to change**
    - **Applied to low value forest types represented by sparse inventory data**
    - **Lack of growth models for natural forest types**
    - **It is not 2% or 5%, 3% seems about right**
    - **Stands are growing at 3%**

Background 3% Growth Rate

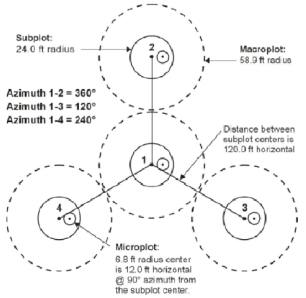
- **Issues with 3% Growth**
  - **No Product Shift**
    - Estimates by product only increase, never grow into large product
    - Unable to realize substantial shift in stands value
    - Ok for older mature stands, not so much for younger developing stands
  - **Favors high estimates**
    - In absolute terms, small values stay small and big values get bigger
    - After 10 years, 10 → 13, 100 → 130, 1000 → 1300
    - Implications for young and mature fully stocked stands
  - **Straight line Growth with no Asymptote**
    - Simple interest formulation increases linearly forever
    - Biological growth is not linear or perpetual
  - **Longer projections compound inherent issues**
    - Typically used on Forest Types with infrequent inventory collection
    - 10+ years not uncommon

Background of the 3% Growth Rate

- **No more time to speculate…but why?**
  - Investigating 3% growth on my to do list for a long time
  - Carbon
    - Increased value of natural forest types → Motivation → Prove it
- **Tools needed for analysis are readily available**
  - USFS FIA data
    - National forestland dataset.
  - R software and RStudio
    - Statistical computing software and IDE
  - rFIA R Package
    - Open-source set of functions to query USFS FIA data

USFS FIA and rFIA

- **Forest Inventory and Analysis (FIA) Background**
  - Established in 1930 with mission to:
    - *"make and keep current a comprehensive inventory and analysis of the present and prospective conditions of and requirements for the renewable resources of the forest and rangelands of the US."*
  - Annual data collection since 1999 with state and regional reporting varying from 5-10+ years
  - Repeated measurements
  - Cluster plot design comprised of 4 sub-plots
  - Include standard tree and plot measurements



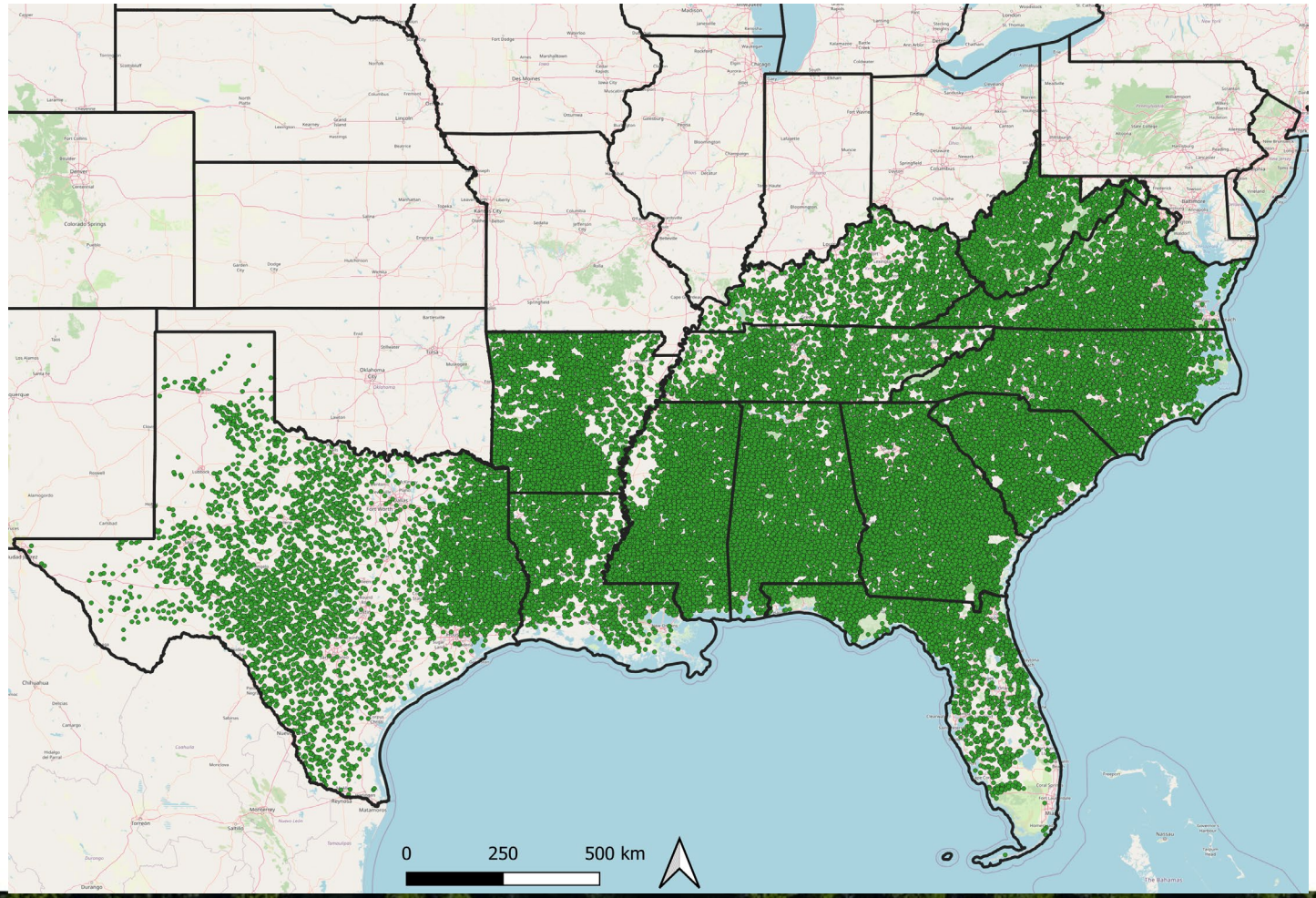
- **FIA data**
  - Hundreds of tables and millions of tree measurements
  - South Carolina alone:
    - **104 unique tables with hundreds of fields**
    - **Relationships between all tables**
    - **Conservatively more than 100k unique tree records**
- **Complexity and size are barriers to use of the FIA data**
- **Enter rFIA Package!**

USFS FIA and rFIA

- **rFIA Background**
  - Developed at Michigan State by Hunter Stanke and Andrew Finley
  - Open-source R package
  - Consists of a series of functions that enable interaction with FIA data
  - Flattens the learning curve needed to work with FIA data
  - Validated against FIA's EVALIDator estimates
- **rFIA Uses**
  - Process and perform analysis directly in R environment
  - Query Plots and Trees
  - Able to pair Time 1 and Time 2 measurements
  - Create "custom" tables and calculations

FIA Plot Locations

FIA Plot Locations – Private Forestland 2015-2022



USFS FIA and rFIA Growth Analysis

- **rFIA used to query FIA dataset**
  - 11 Southeast States – AL, AR, FL, GA, LA, MS, NC, SC, TN,TX, VA, + WV
  - Queried Plot and Tree data
  - Formatted and Calculated Data needed for Analysis
  - Developed methods to leverage rFIA functions to use in house per acre weight estimates by product
    - Consistent product specs across Southeast
    - Pine – Pulp, Chip-N-Saw, Sawtimber and Topwood
    - HW – Pulp, Sawtimber, and Topwood
  - Additional Plot and Tree data include
    - Previous and Current DBH, HT, BA, TPA, Net Volume, Saw BF, Total and Product Tons, and Above Ground Biomass/Carbon
    - Change and Growth Calculations
    - Percent Change and Growth– Growth/Previous Growth
  - Excluded "outlier" measurements and growth

USFS FIA and rFIA Growth Analysis

- **Summarized Plot Data**
  - Provide Per Acre Estimates like Stand Inventory Estimates used in 3% growth projections
  - Noise of Tree data is reduced
- **Refining the Test Dataset**
  - Natural Plots Only with Proportion of Forest >= 90%
  - Dominant Species is a Hardwood
  - Only Merchantable Plots, Age >= 25
- **Further filtering…**
  - No Change in Forest Type between re-measurement cycle
  - No harvesting or change in condition code
  - Bin into Mountains, Piedmont, and Coastal Plain
- **1,329 plots met all these criteria out of ~72,790 (<2%)**

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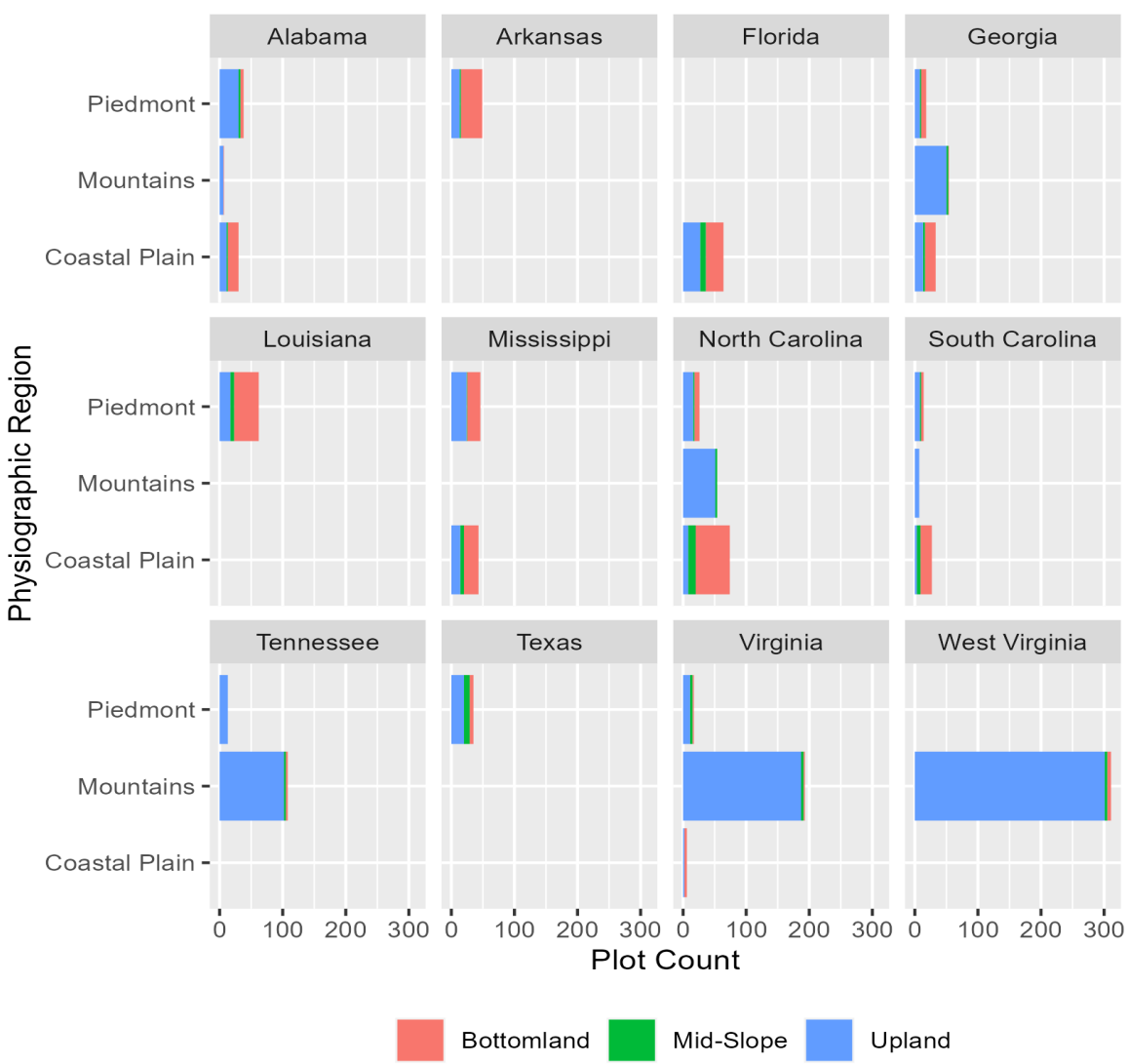
USFS FIA and rFIA Growth Analysis



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FIA Growth Rates - Numbers

		Annual Per Acre % Growth					
Mean Age	Number of Plots	Basal Area	Mortality	Net Volume	Total Tons	Sawtimber BDFT	Biomass
71	1329	2.15%	0.03%	3.16%	3.18%	5.11%	2.98%

			Annual Per Acre % Growth					
Physiographic Region	Mean Age	Number of Plots	Basal Area	Mortality	Net Volume	Total Tons	Sawtimber BDFT	Biomass
Coastal Plain	59	277	2.55%	0.03%	4.04%	4.27%	5.48%	3.74%
Mountains	81	734	1.84%	0.01%	2.56%	2.69%	4.72%	2.45%
Piedmont	59	318	2.51%	0.08%	3.80%	3.34%	5.66%	3.56%

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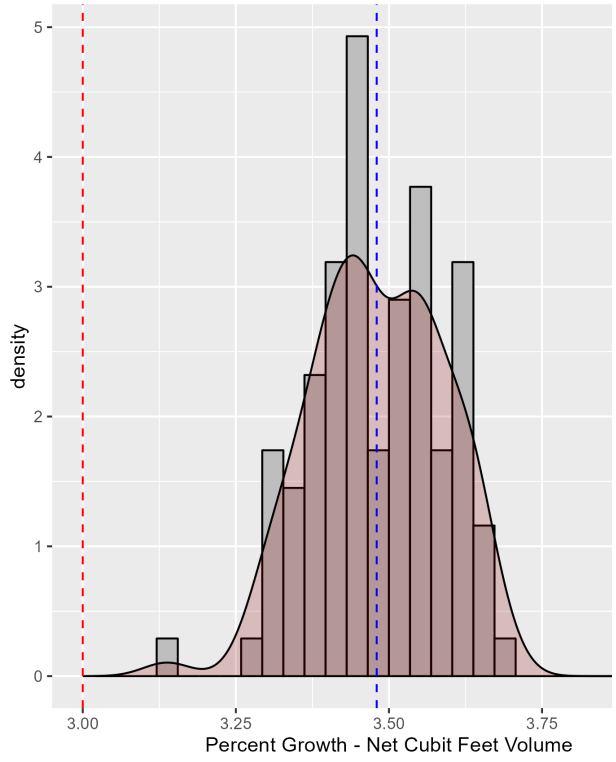

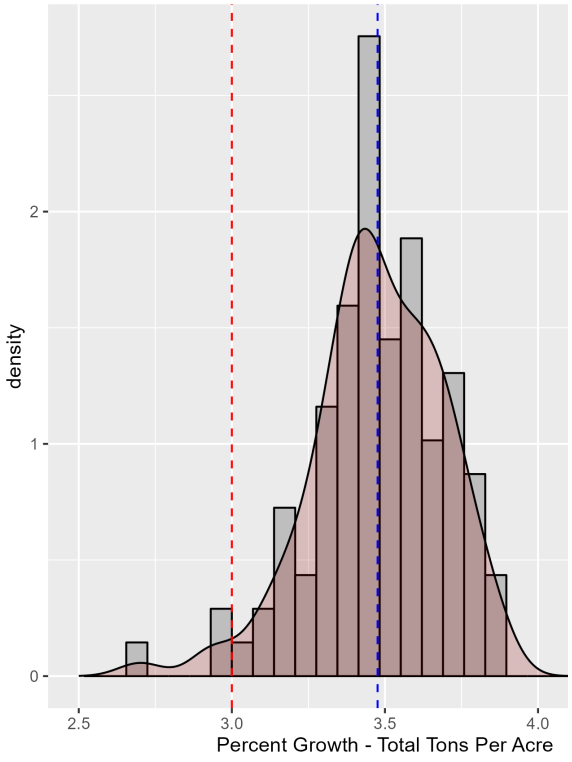

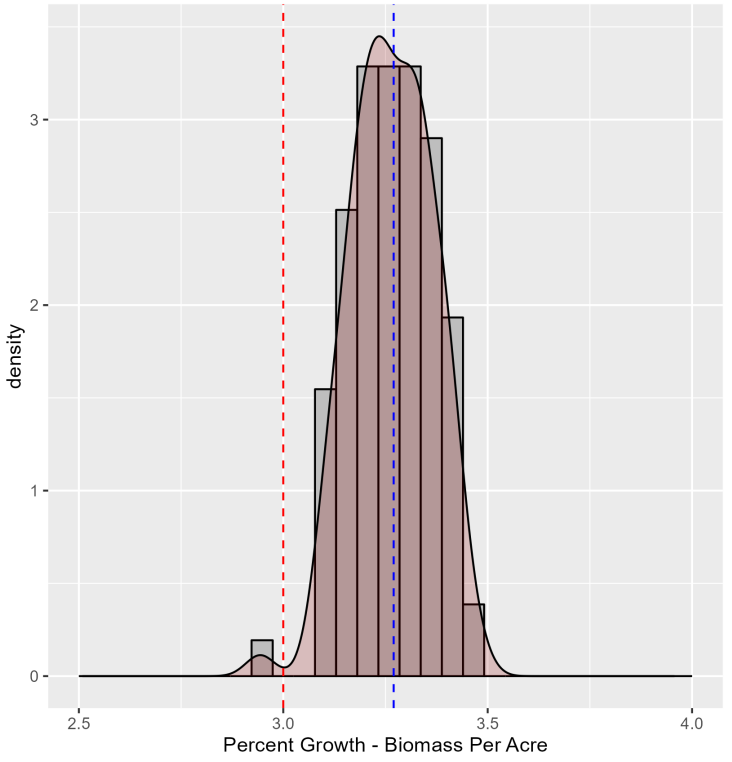

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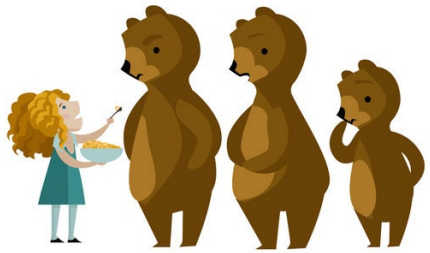
				Annual Per Acre % Growth					
Physiographic Region	Ownership	Mean Age	Number of Plots	Basal Area	Mortality	Net Volume	Total Tons	Sawtimber BDFT	Biomass
Coastal Plain	NIPF	57	194	2.76%	0.08%	4.23%	4.46%	5.36%	3.92%
Coastal Plain	PUBLIC	65	83	2.06%	-0.11%	3.59%	3.81%	5.76%	3.31%
Mountains	NIPF	74	316	2.25%	0.05%	3.10%	3.58%	4.95%	2.95%
Mountains	PUBLIC	86	418	1.52%	-0.02%	2.14%	2.02%	4.55%	2.07%
Piedmont	NIPF	58	248	2.52%	0.03%	3.80%	3.48%	5.47%	3.59%
Piedmont	PUBLIC	66	70	2.47%	0.25%	3.80%	2.85%	6.34%	3.49%

FIA Growth Rates - Words

- **Regionwide**
  - Volume, Weight, and Biomass ~ 3.5%
  - BA ~ 2%, Mortality ~ 0%, and Saw BF ~ 5%
- **Physiographic Region**
  - Vol., Wgt, Bio. Growth decreases from coast to mountains
    - **Mountains (~2.5%) → Piedmont (~3.5%) → Coastal Plain (~4.0%)**
  - BA ~2.5%,~2%, Mortality ~ 0%, Saw BF ~ 5.5%, ~4.75%
- **Physiographic Region by Ownership**
  - Private has higher growth rate than Public
  - Private and Public Piedmont growth similar

FIA Growth Rates - Conclusions

- **Southeast Regionwide**
  - Annual 3% growth for volume, weight, and biomass is OK
    - 3% is conservative but that's kind of a good thing
  - Not so much for BA and especially for mortality
    - Implications for stand table projection and similar projection systems
- **Physiographic Region**
  - Goldilocks and the not 3% Bears
  - 3% just does not seem the right fit



- **Physiographic Region by Ownership**
  - Big deal in the Mountains region, less in Coastal Plain, Piedmont not at all
  - At smaller scale, state, number of plots an issue

FIA Growth Rates - Conclusions

- **Sawtimber Board-feet**
  - Exceeds 3% in all cases, ~5% to ~5.5%
  - Product shift within merchantable stands
    - DBH and merchantable height exceeds sawtimber threshold
    - Jump or steps in sawtimber volume
- **Mortality**
  - Almost none at the plot level
  - Trees die right?
    - Ingrowth from trees less than 5”
    - Merchantable mature stands are stable
- **Final thoughts for the Southeast**
  - We can do better than assuming 3% growth for natural stands
    - Scrutiny of carbon projects, length of projection, differences in growth rates for BA, total volume and weight, and sawtimber board-feet
  - Physiographic region and ownership should be considered
- **How do commonly used growth models compare to 3%?**

Growth Model Comparison

- **Forest Vegetation Simulator Southern Variant (FVS-SN)**
  - USFS "family" of individual-tree distance-independent growth and yield models that covers forest types of the US
  - Widely used publicly and privately for research, harvest planning and reporting and carbon projects

- **USFS SE regionwide yields by forest type**
  - McClure and Knight, *Empirical Yields of Timber and Forest Biomass in the Southeast*, RP-SE-245, 1984
  - Developed from 24,775 Forest Survey (FIA) randomly distributed plots across the southeast in fully stocked stands
  - Yield tables of green tons by d-classes and sawtimber volume

Growth Model Comparison

- **Growth Inputs**
  - Randomly selected FIA plots and associated tree data from 1329 plots analyzed for growth
    - **Mountains 32, Piedmont 31, and Coastal Plain 30**
- **FVS-SN Set-up**
  - Default settings
- **Empirical Yields**
  - Regression fit to each forest type, site, and product
    - **Mountains – Oak-Hickory all sites**
    - **Piedmont – Oak-Pine all sites**
    - **Coastal Plain – Oak-Gum-Cypress all sites**
- **Growth Projection**
  - Consistent time 0 estimates determined from FVS-SN
  - Projected for 5 years

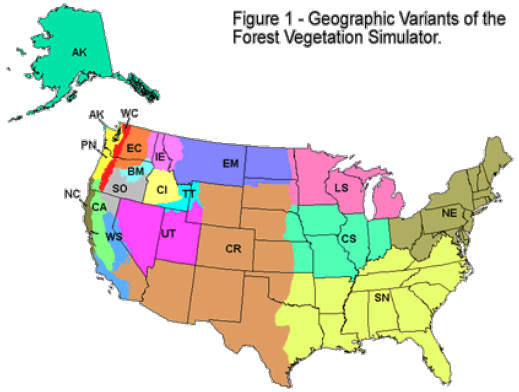


Figure 1 - Geographic Variants of the Forest Vegetation Simulator.

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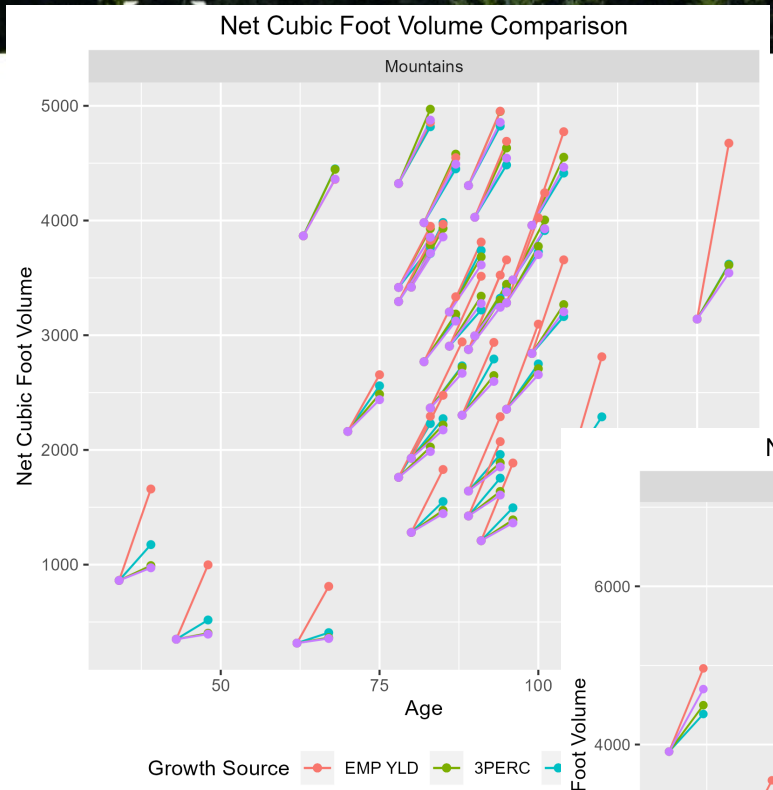
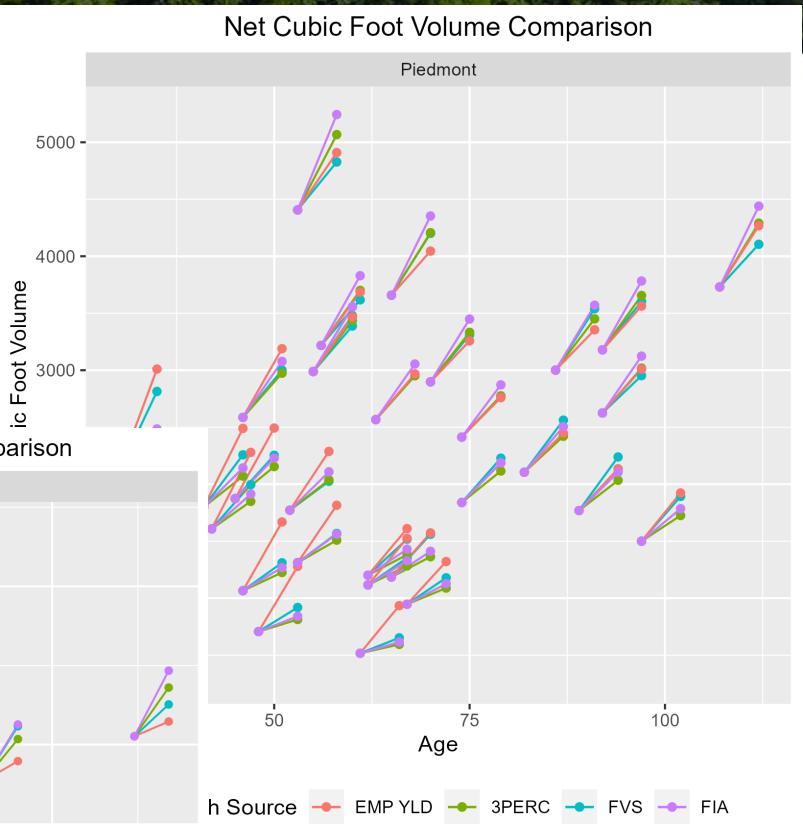
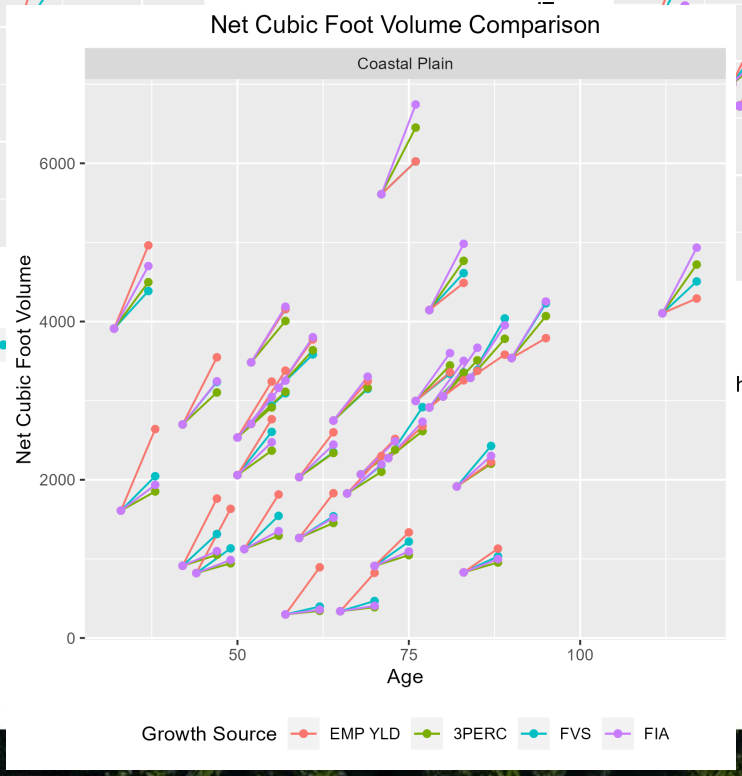
Growth Comparison – Net Volume







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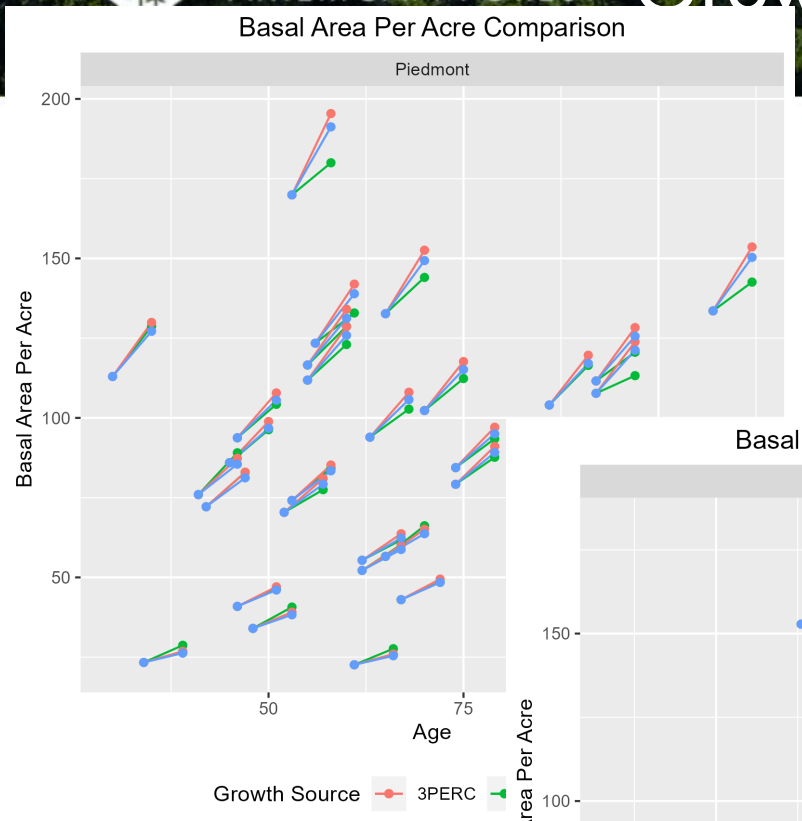
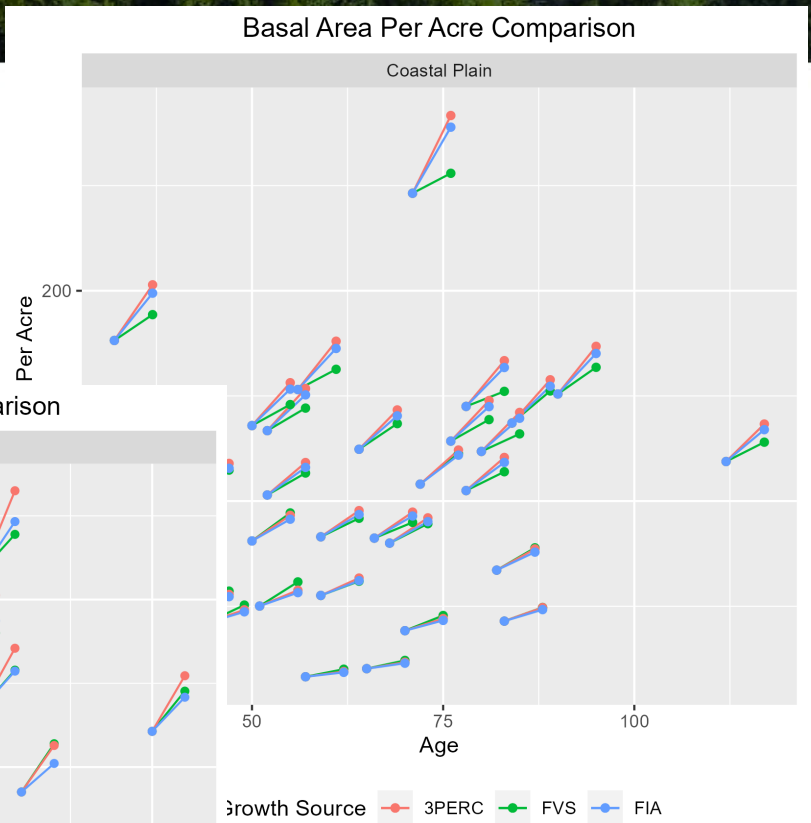
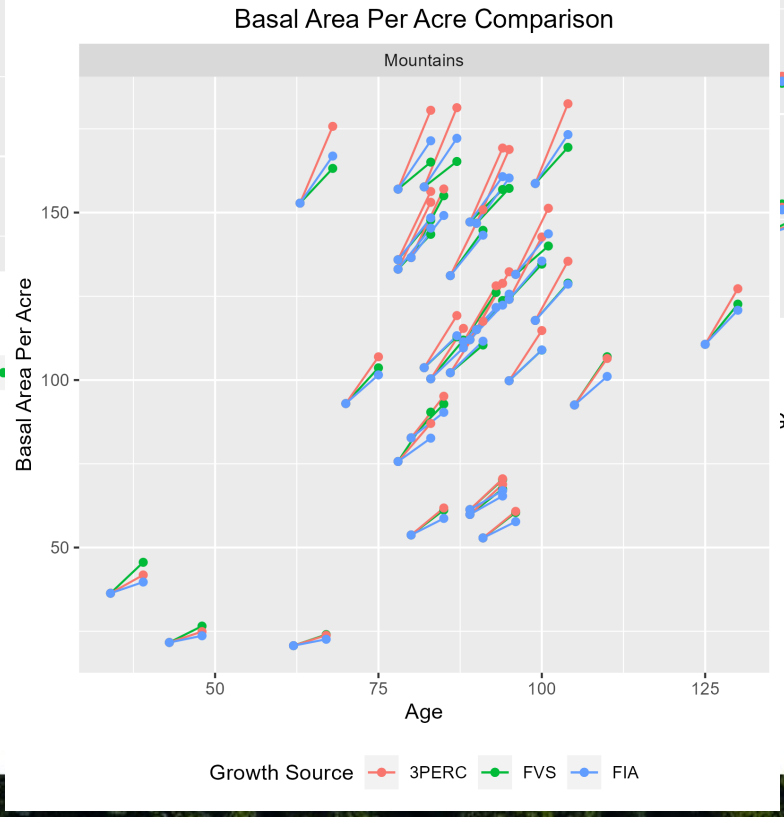
Growth Model Comparison - BA







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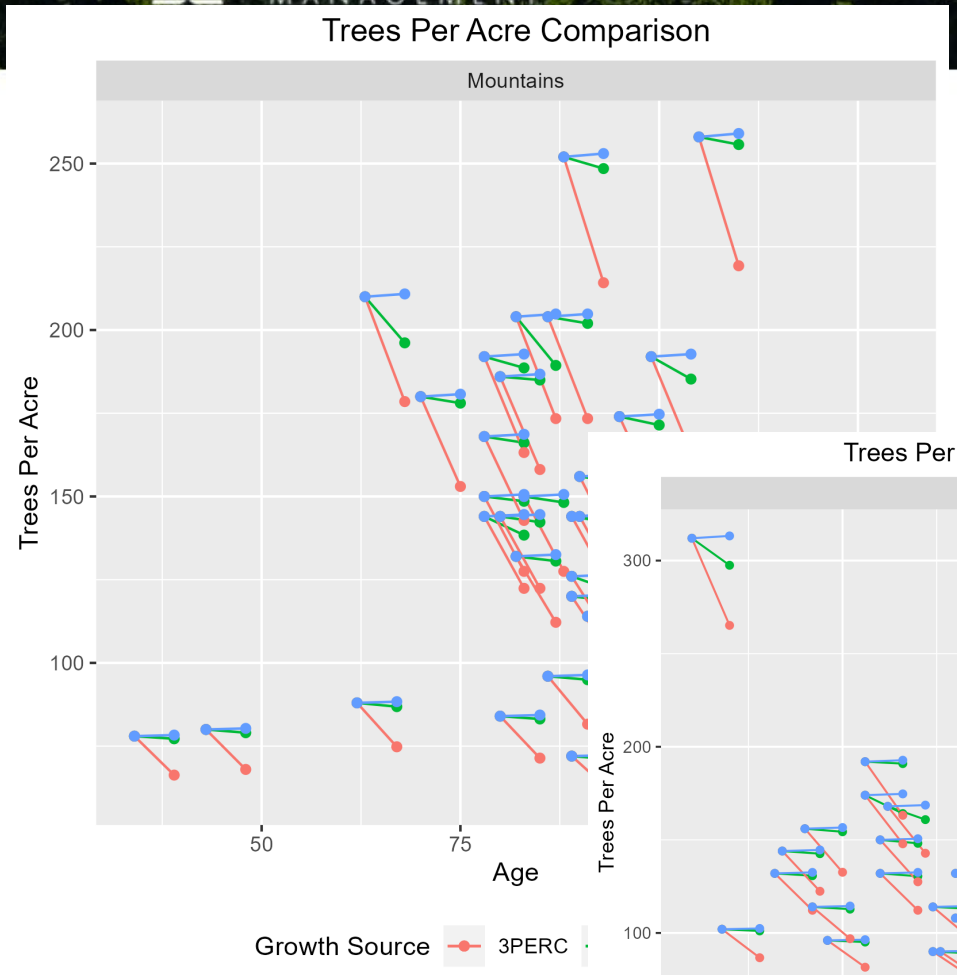
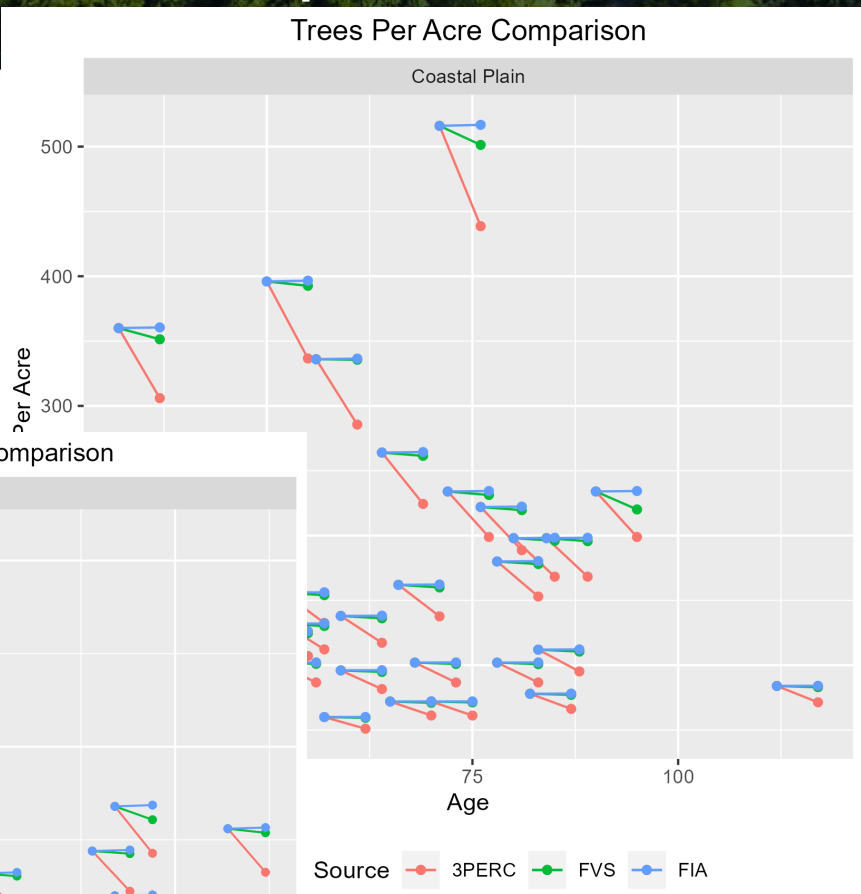
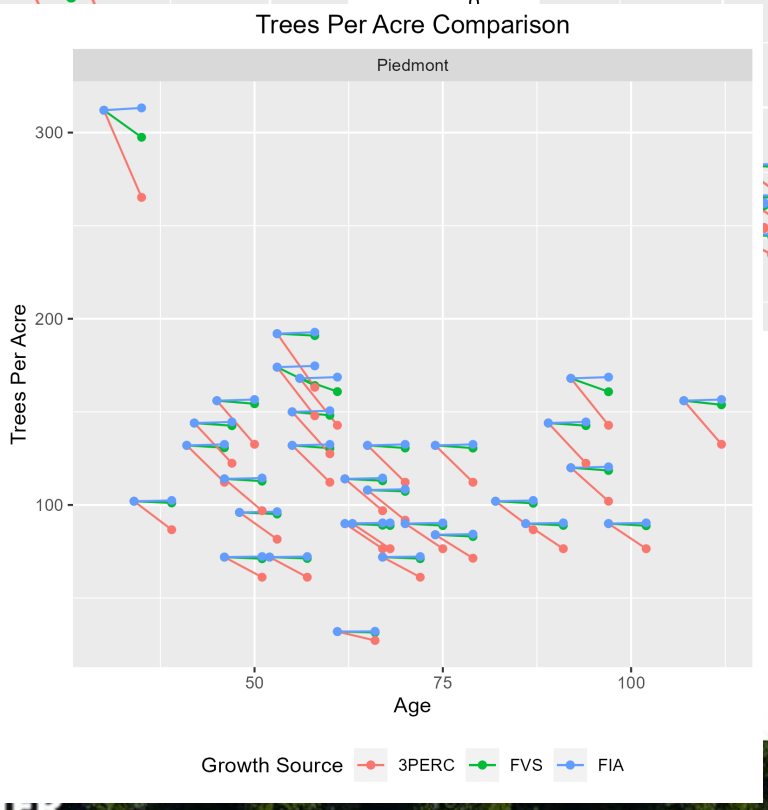
Growth Model Comparison – TPA







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Growth Model Comparison - Conclusions

- **Overall trends**
  - Largest differences at the "tails" – ages, values
  - 3% → FIA → FVS → Empirical Yields
- **FVS-SN**
  - Default projections compared favorably to FIA growth rates
  - Slightly higher growth, Mountains higher, but tracked FIA rates
  - Encouraging results
- **USFS Empirical Yields**
  - Much higher than other growth models or calculated rates
  - Consider low sites or different forest types? Or why bother?

Physiographic Region	Mean Age	Number of Plots	Trees Per Acre			Basal Area Per Acre			Net Volume CF			
			FVS	3PERC	FIA	FVS	3PERC	FIA	FVS	3PERC	YLD	FIA
Coastal Plain	69	30	-0.27%	-3.00%	0.03%	2.40%	3.00%	2.55%	4.35%	3.00%	7.80%	4.04%
Mountains	89	32	-0.35%	-3.00%	0.01%	2.25%	3.00%	1.84%	3.60%	3.00%	7.50%	2.56%
Piedmont	68	31	-0.31%	-3.00%	0.08%	2.49%	3.00%	2.51%	4.18%	3.00%	7.21%	3.80%

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In Summary…

- **Southeast regionwide 3% rate validated by FIA, but..**
  - As growth and yield practitioners we can do better
  - Goldilocks and not 3% Bears – 3% is not just right
  - Increased importance (value) of natural hardwood stands demands more robust growth modeling methods
  - Current computing, data bases, GIS, software, etc no longer are limitations
- **FVS-SN is viable alternative, even with the default settings**
  - Proceed with caution!
- **What do about input data constraints for natural stands?**
  - Phase out old data collection methods – collect data on par with the increasing importance (value) of natural stands
  - Leverage all the available resources to best model resource

The End

Special Thanks to Clara Clark and Scott Hillard

Questions?