

An Evaluation of Lidar Inventory Growth Projections

Western Mensurationists

2023 Annual Meeting

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R&D things forest sampling, estimation, modeling, mapping, GNSS, remote sensing. Likes travel and outdoor family adventures.

PhD, MSc Forestry, Stats Oregon State University
BS, MS Forestry, University of Washingtons

Peter Gould



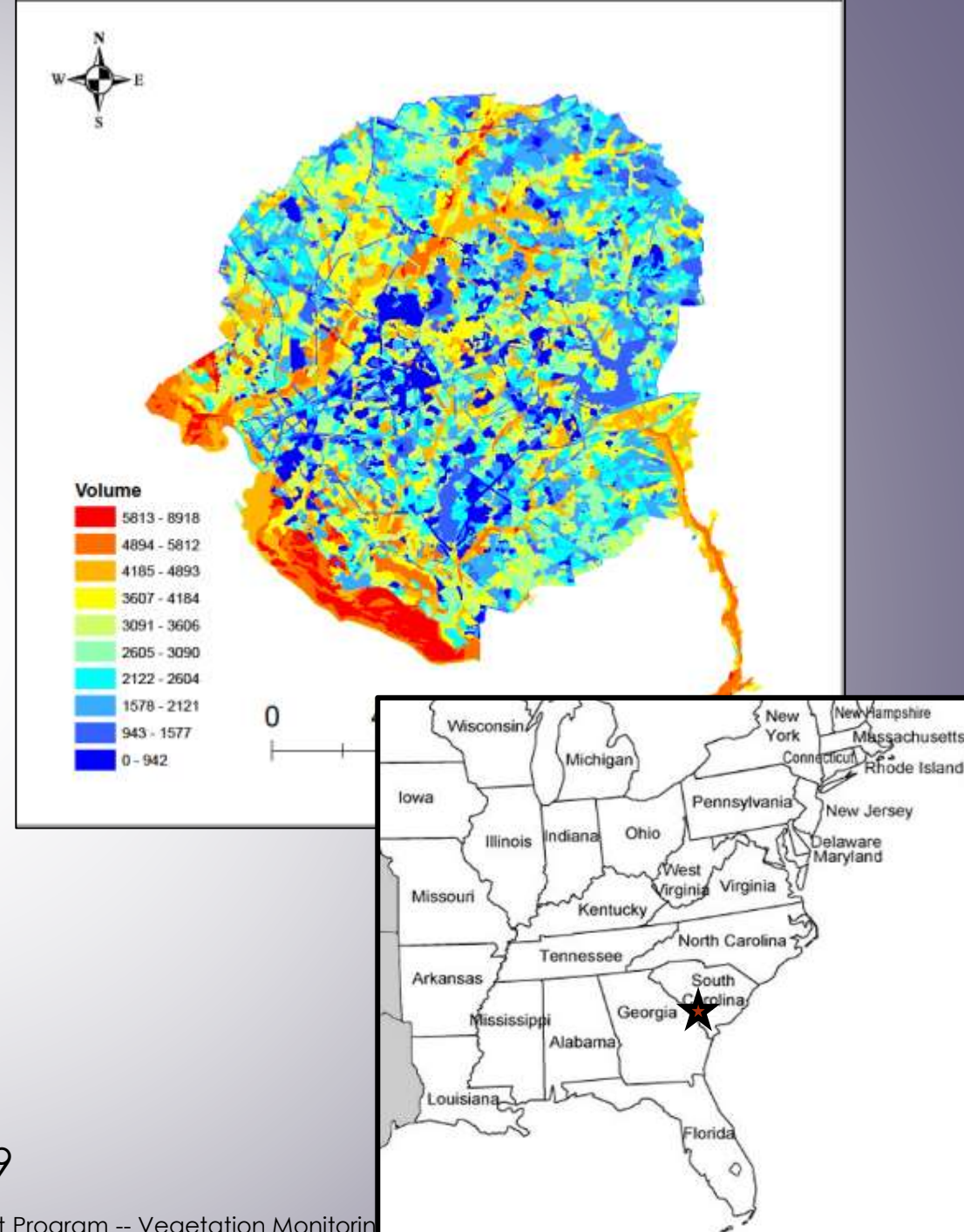
Peter is a great resource for all things technical! Forest biometrics, growth and yield, remote sensing, coding, visualization, software development, design circuit boards or data loggers, drones,

PhD Penn State
BS Northern AZ University

Savannah River Site in South Carolina

- 1) 200k ac total, 170k ac forest
- 2) Wood production & Conservation
~50 / 50 split
- 3) kNN Lidar inventory, 2019*
 - A. Tract-wide
 - B. Stand-level
 - C. Rasters (30 m)

*A Lidar inventory was also performed by VMaRS in 2009



Lidar Inventory

Good for Current conditions!

1) Strategic & Tactical Inventory today

Tactical: Jacob L. Strunk and Robert J. McGaughey. 2023. Stand validation of lidar forest inventory modeling for a managed southern pine forest. *Canadian Journal of Forest Research*. **53**(2): 71-89. <https://doi.org/10.1139/cjfr-2022-0032>

2) Wall-to-wall, consistent, fine-scale, single-date forest inventory

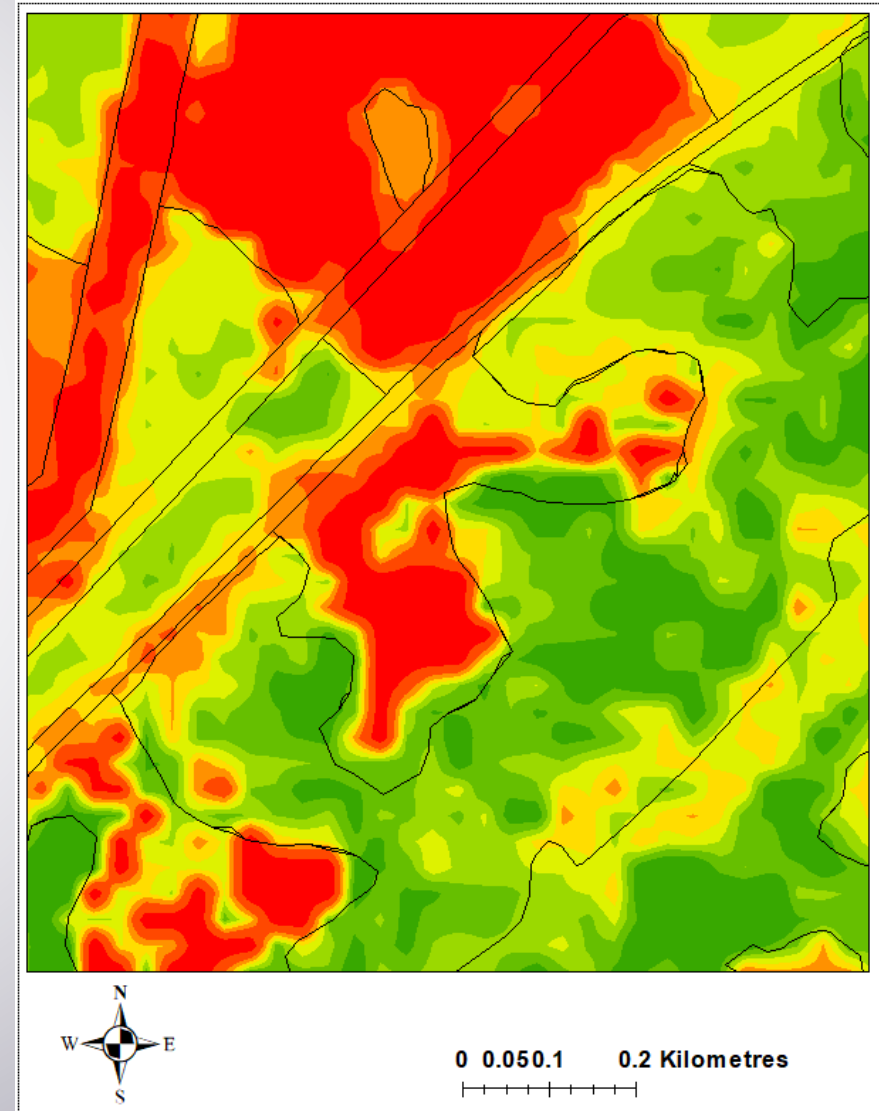
3) Cost Efficient (for stand-level+ detail)

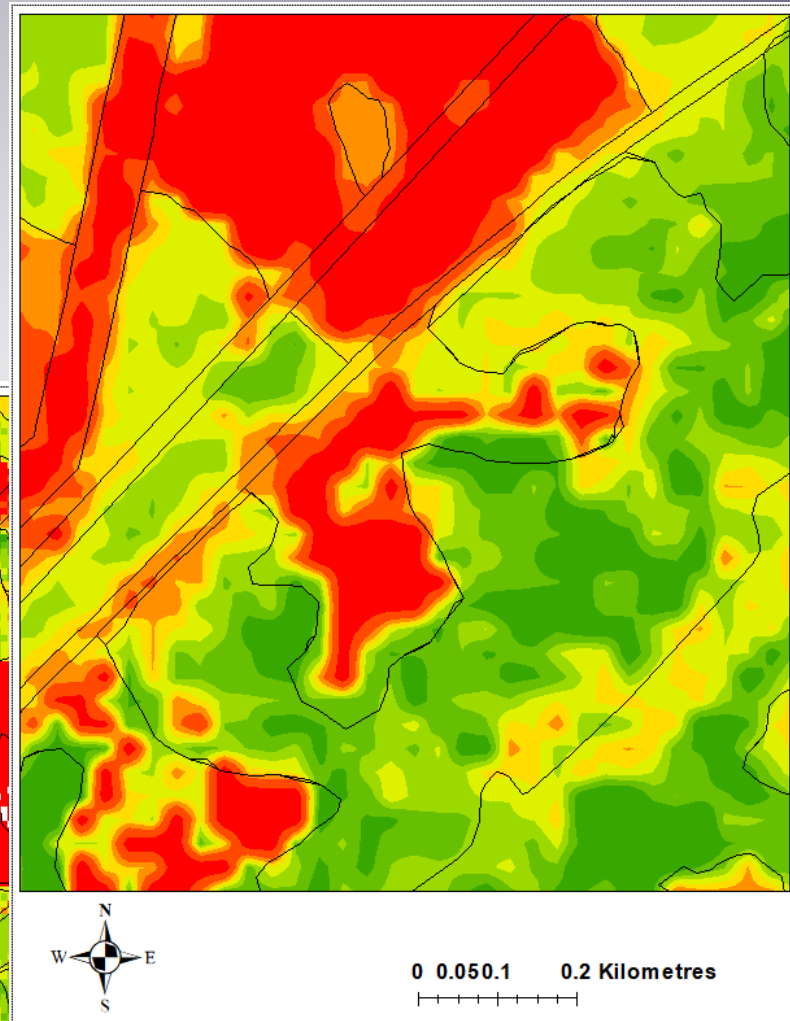
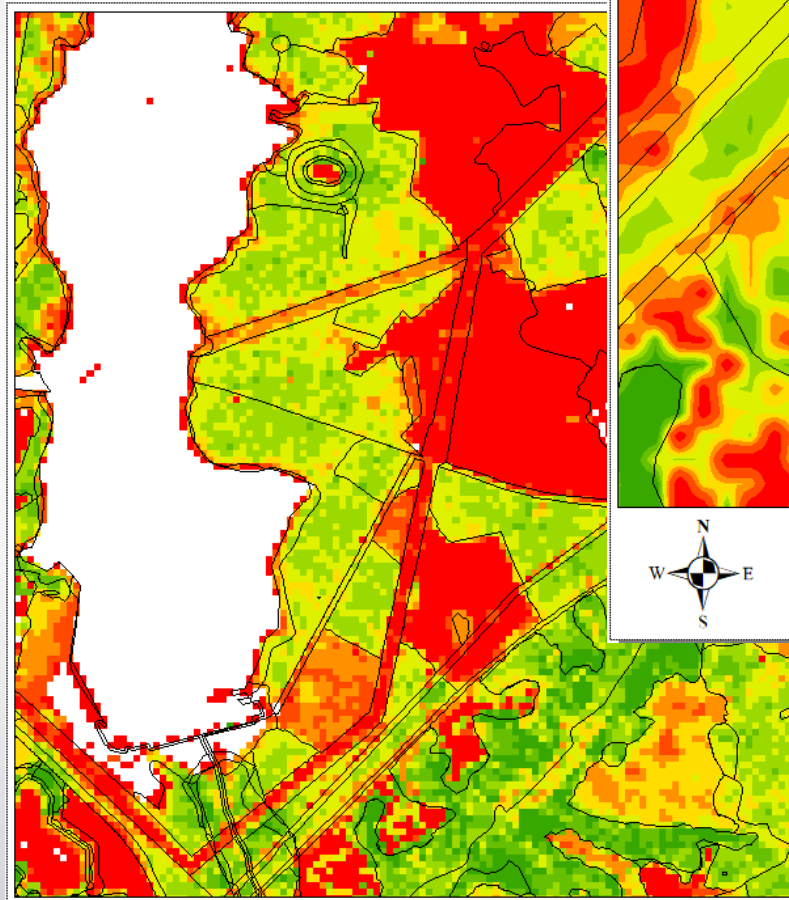
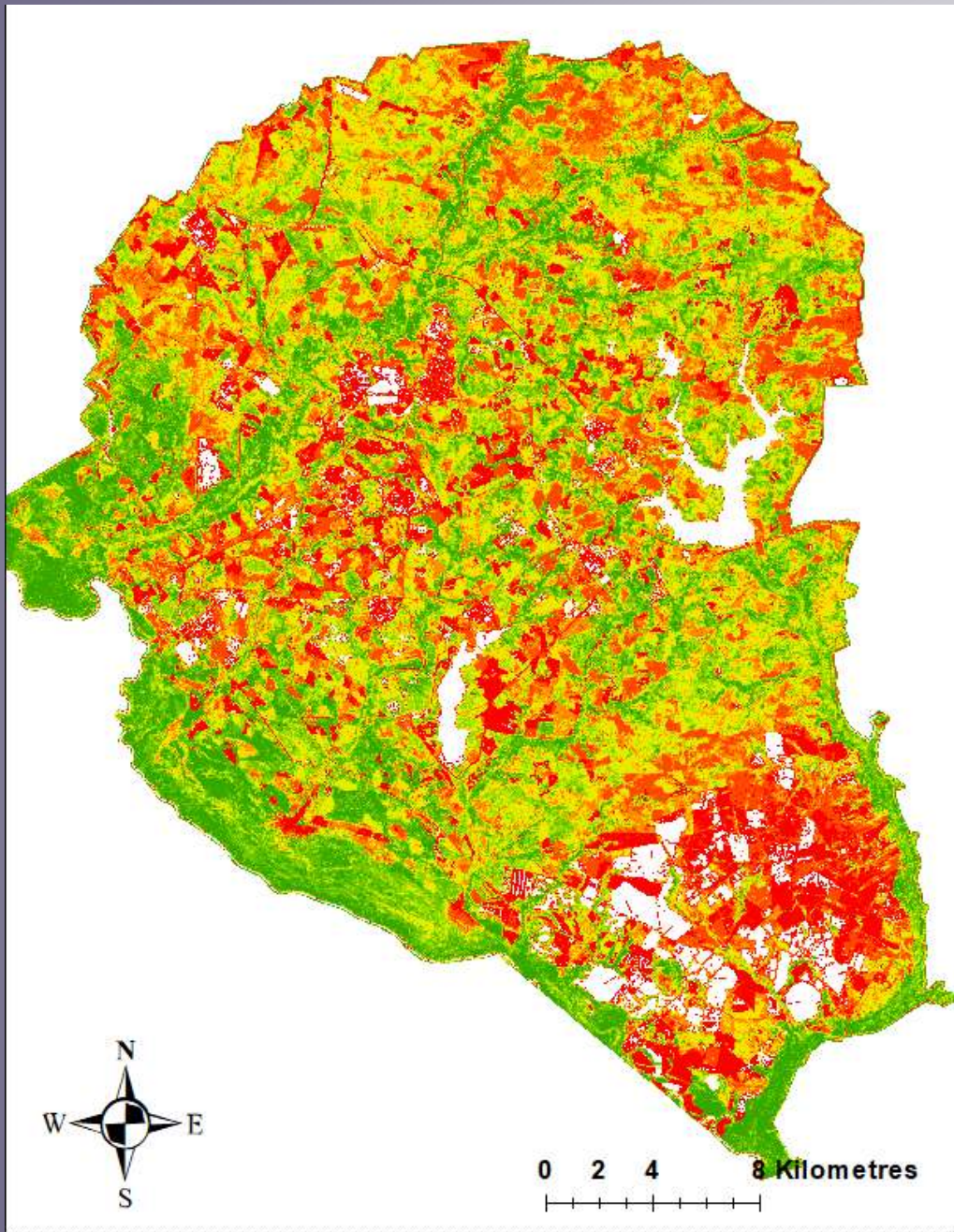
A. ≈\$250k for 200k acres

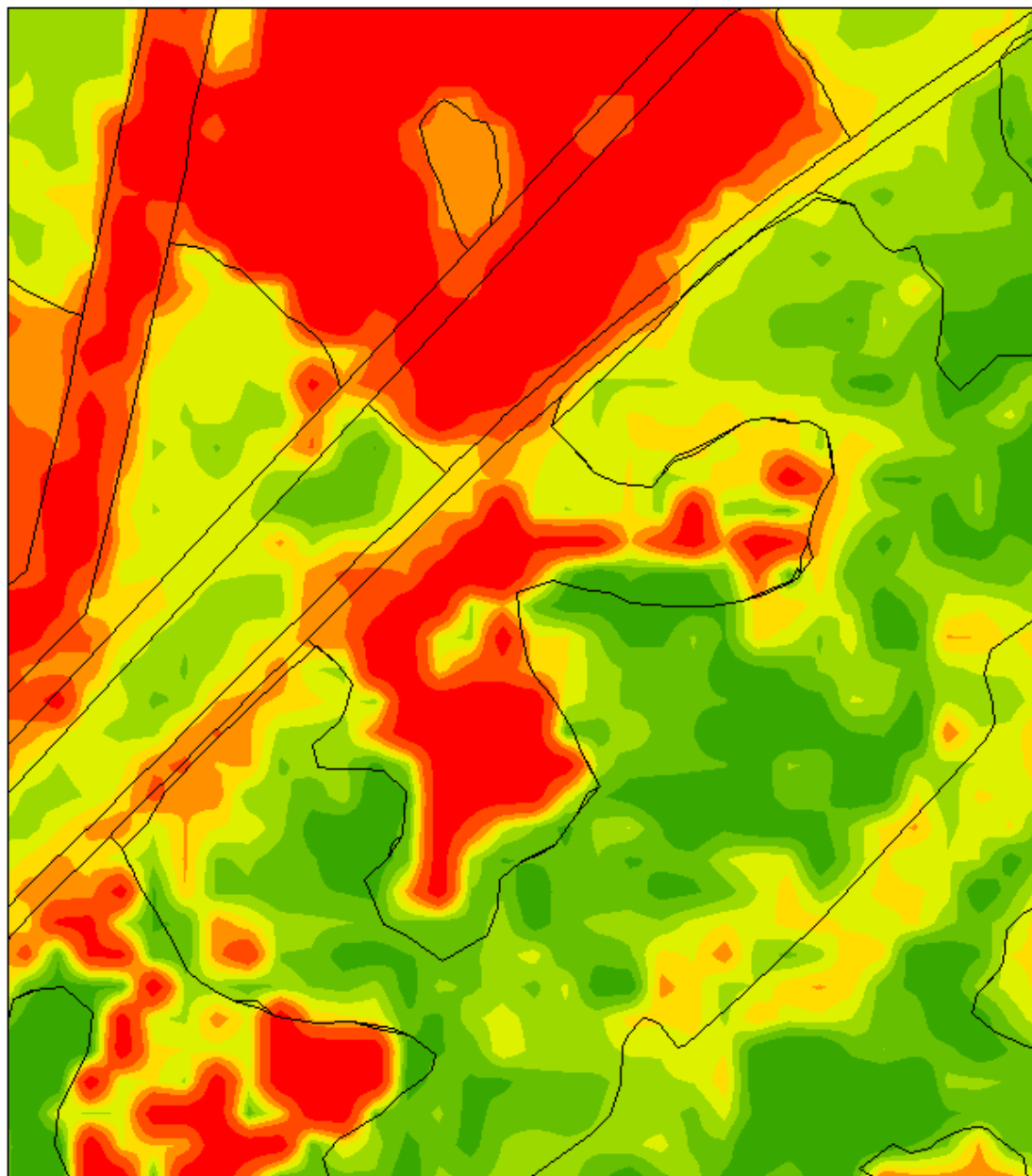
B. 550 plots (\$75k)

C. Lidar (\$60k)

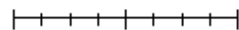
D. Analysis (\$115k)







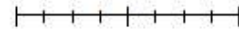
0 0.050.1 0.2 Kilometres



Source: Data, Ministry of Agriculture, Fisheries and Forestry, © 2008/Mapas-2008, 5 de A. 2008, 2008, 2008, and 2008 5 de A. 2008



0 0.050.1 0.2 Kilometres



Is Lidar any Good for Growth Projections?

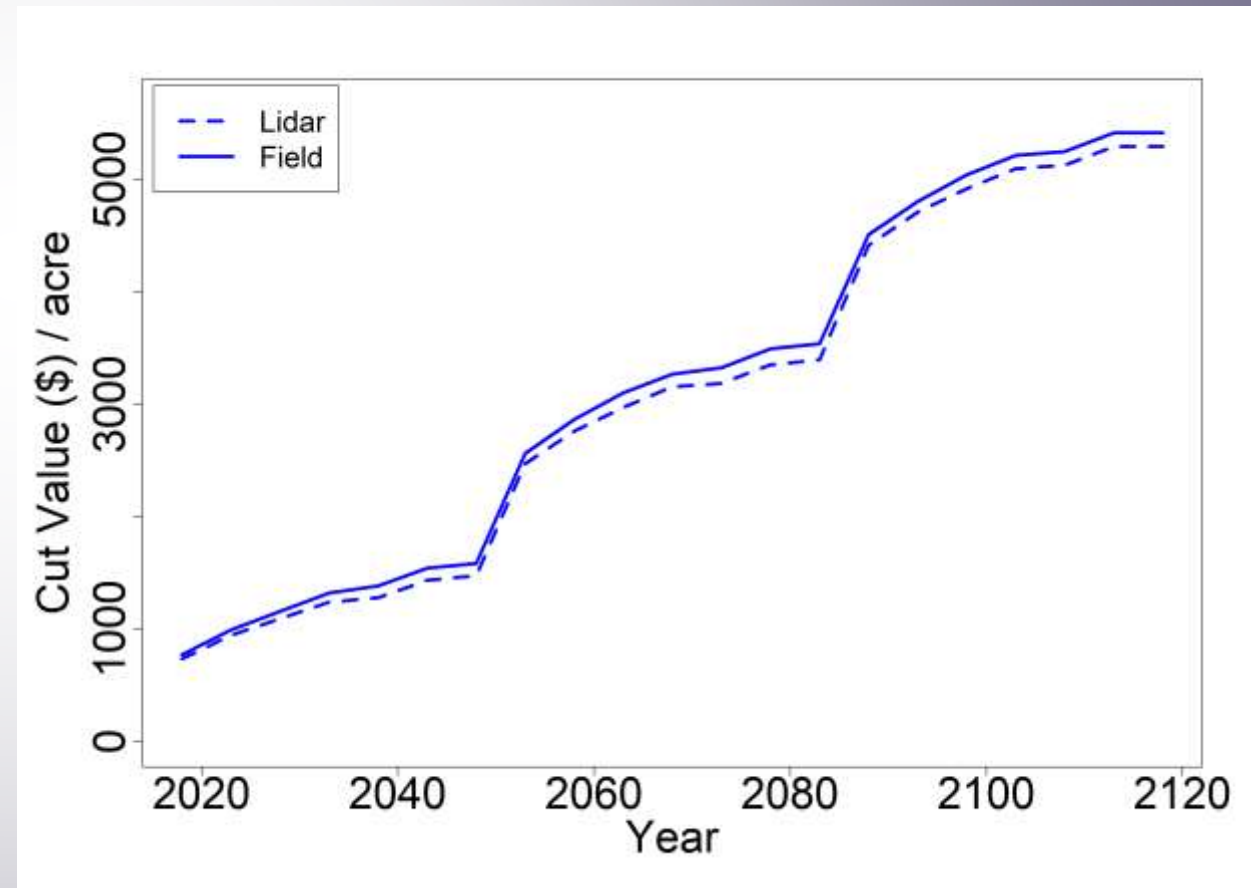
1) Grow and compare stand-level inventories

A. Lidar

B. Field

2) 6 Scenarios (high to low intensity)

3) “Tract” vs Stand performance



Analysis

- **USFS Forest Vegetation Simulator (FVS)**

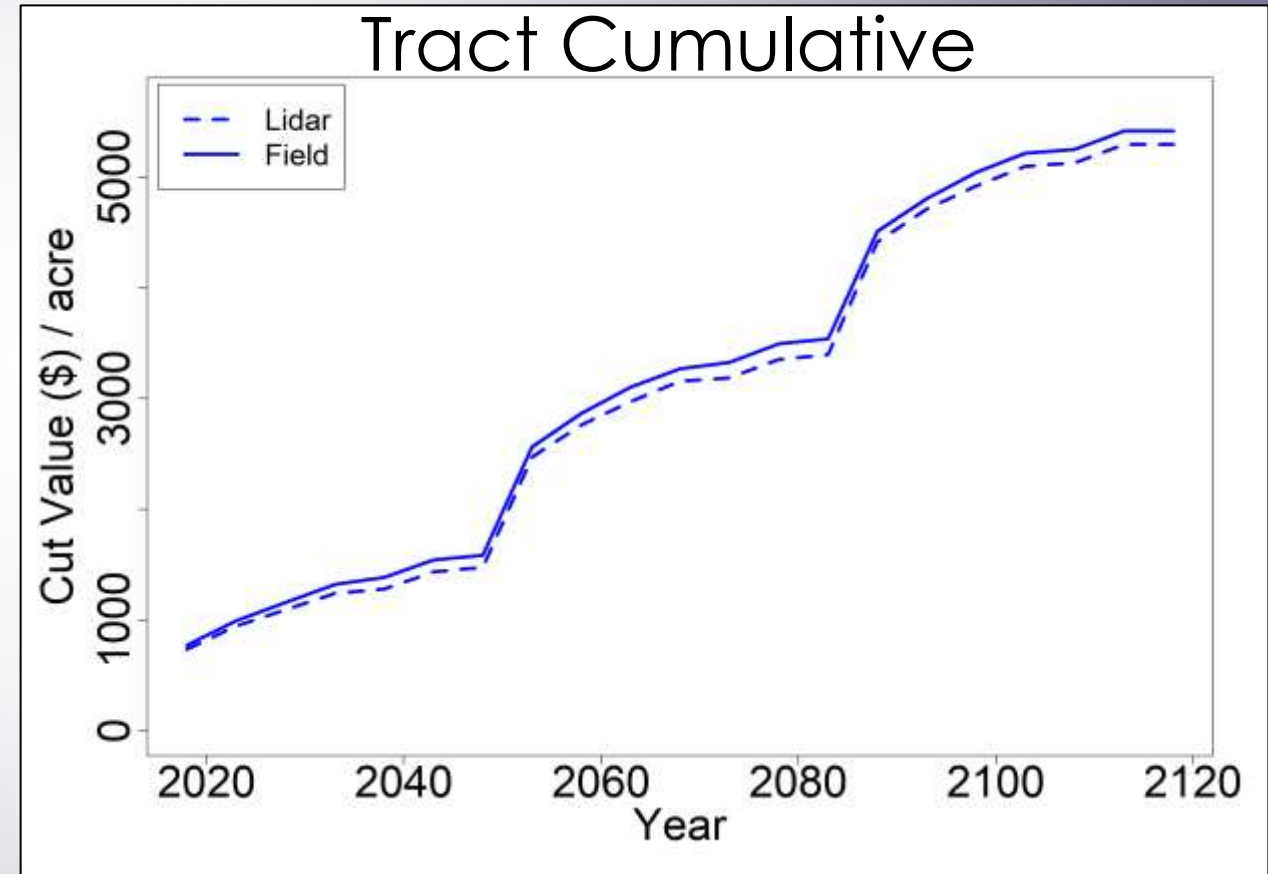
- SN Variant
- 5 year periods
- 100 years

- **Scales**

- Tract
- Stand
- (Plot/Pixel)

- **Metrics**

- Volume
- Carbon
- Value
- Net present value (NPV)
- Temporal Agreement



FVS Growth Projections

Individual Tree based growth model

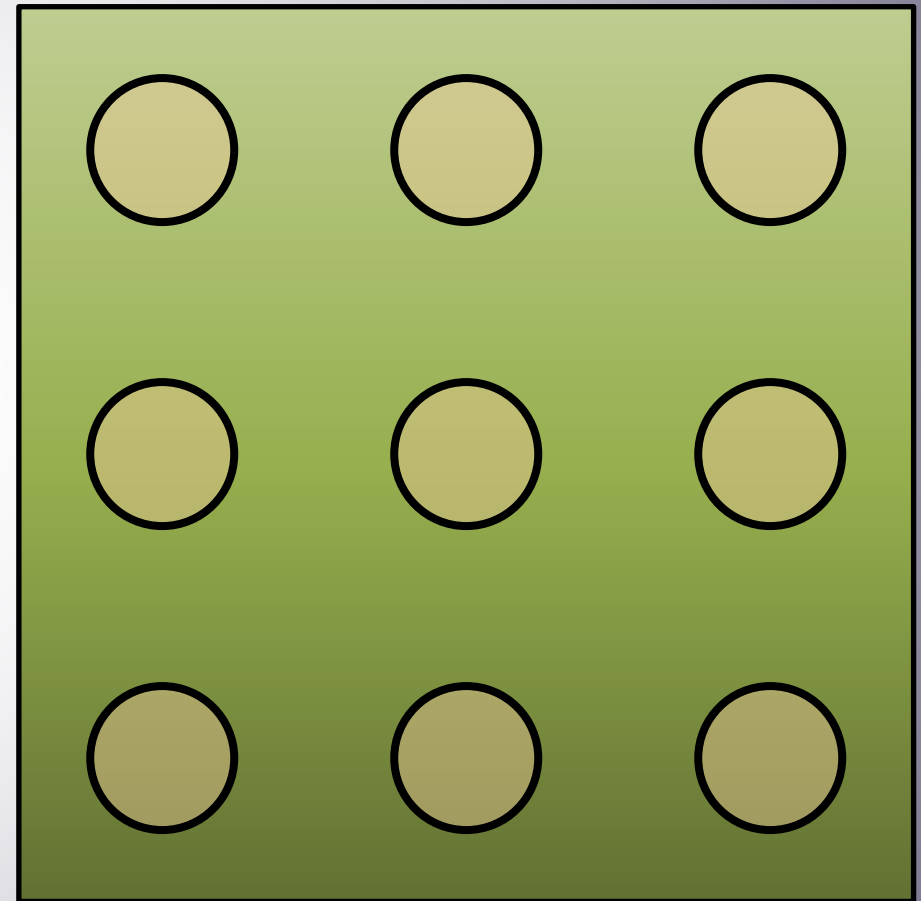
1. Plant (375 vs 550)
2. Thin to 70 sq ft / acre (0,1,2 x thins)
3. Harvest rotation (35, 50, 60, never)

Management scenarios

- A. 375 plant / acre, No Thin, 35 yr harvest
- B. 550 plant / acre, No Thin, 35 yr harvest
- C. 550 plant / acre, 1 Thin, 35 yr harvest
- D. 550 plant / acre, 2 Thin, 50 yr harvest
- E. 550 plant / acre, 2 Thin, 60 yr harvest
- F. No management (let grow)

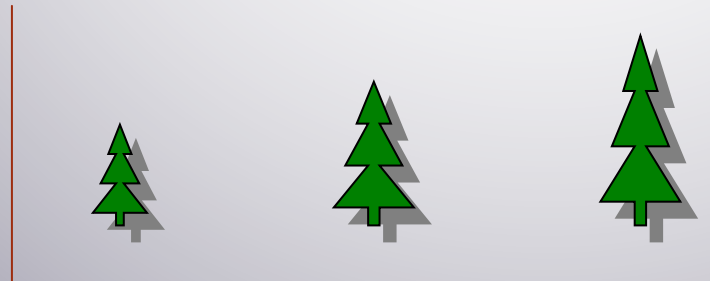
50 x Validation Stands

- 5 acres / stand
- 9 x plots / stand
 - 1/10th acre plots



Strategic (Tract-level) Inventory:

1. Growth projections: Lidar VS Field
2. Differences by management strategy

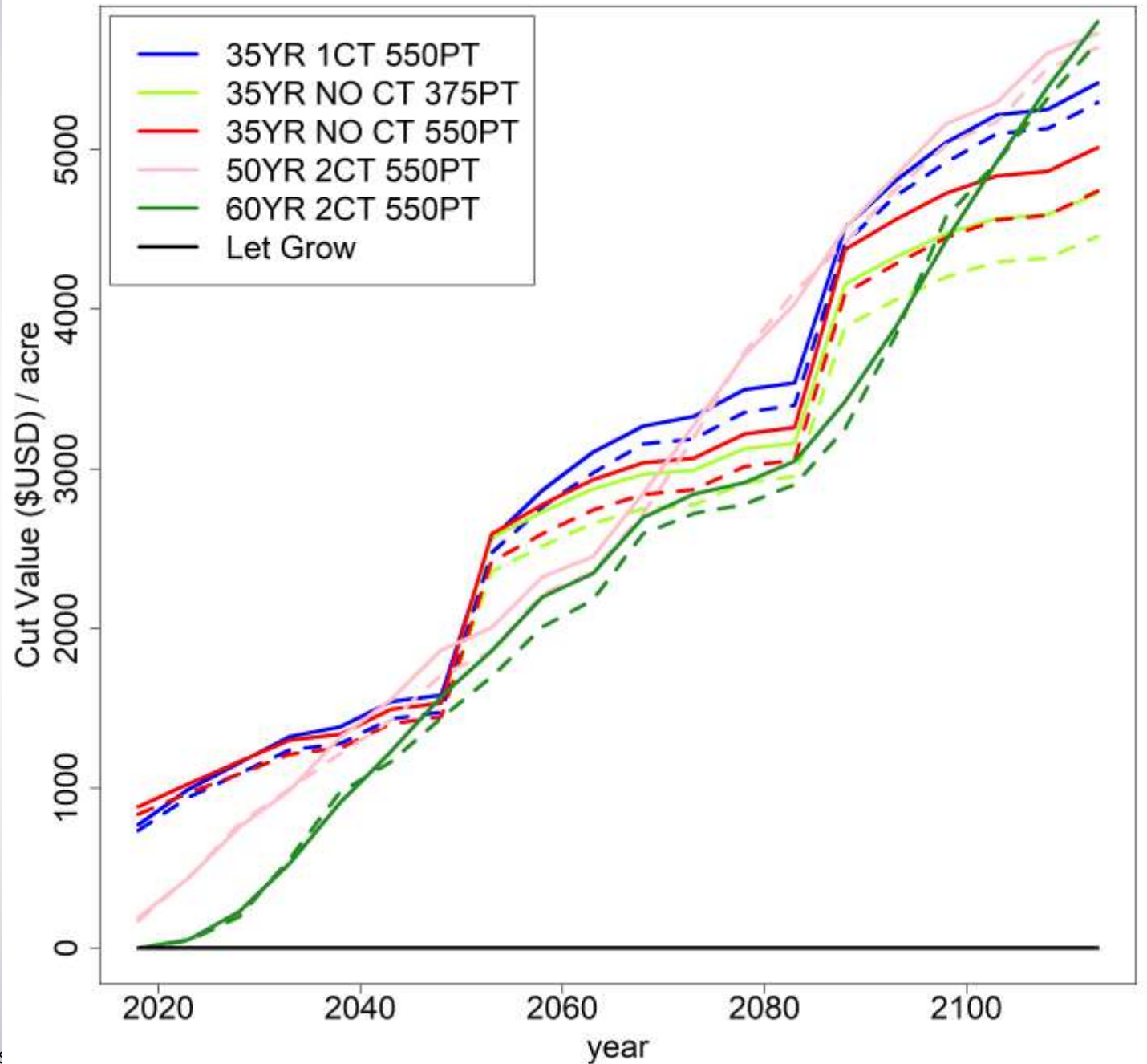


Lidar and Field: ≈ Exact match

Cyclic – no clear winner

- 35YR 1CT?
- 50 or 60 yr?

35YR NO CT - worst

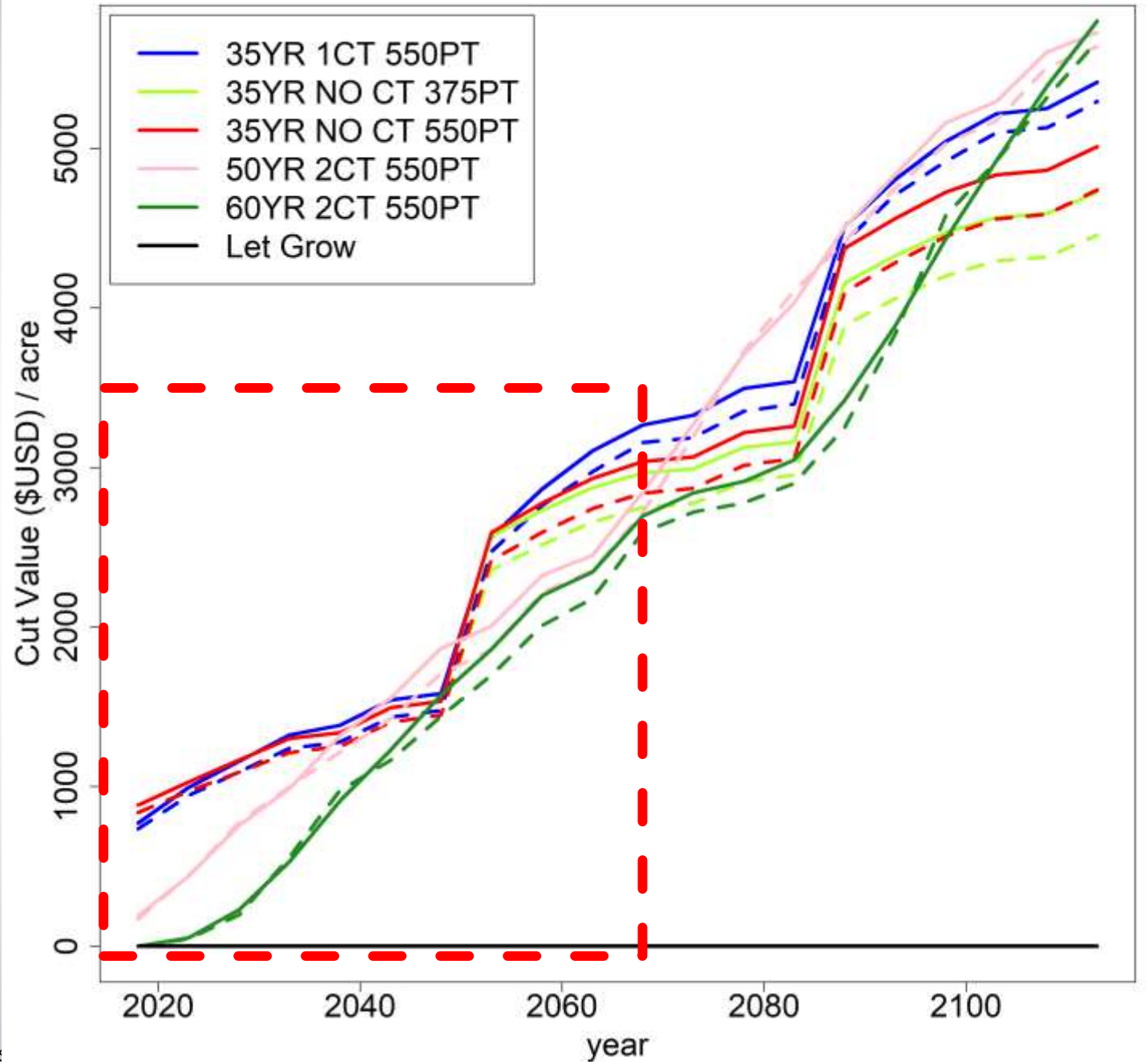


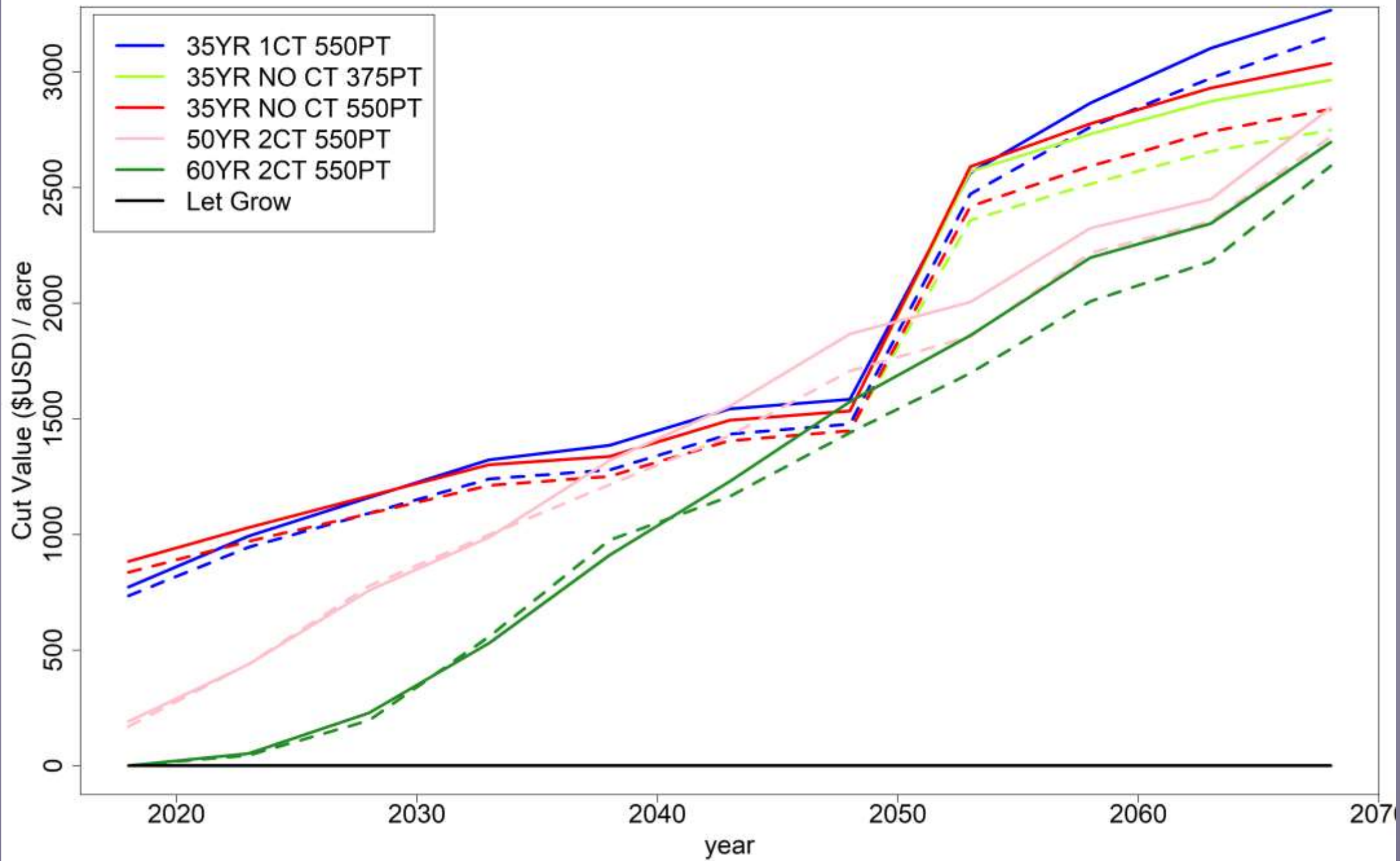
Lidar and Field: ≈ Exact match

Cyclic – no clear winner

- 35YR 1CT?
- 50 or 60 yr?

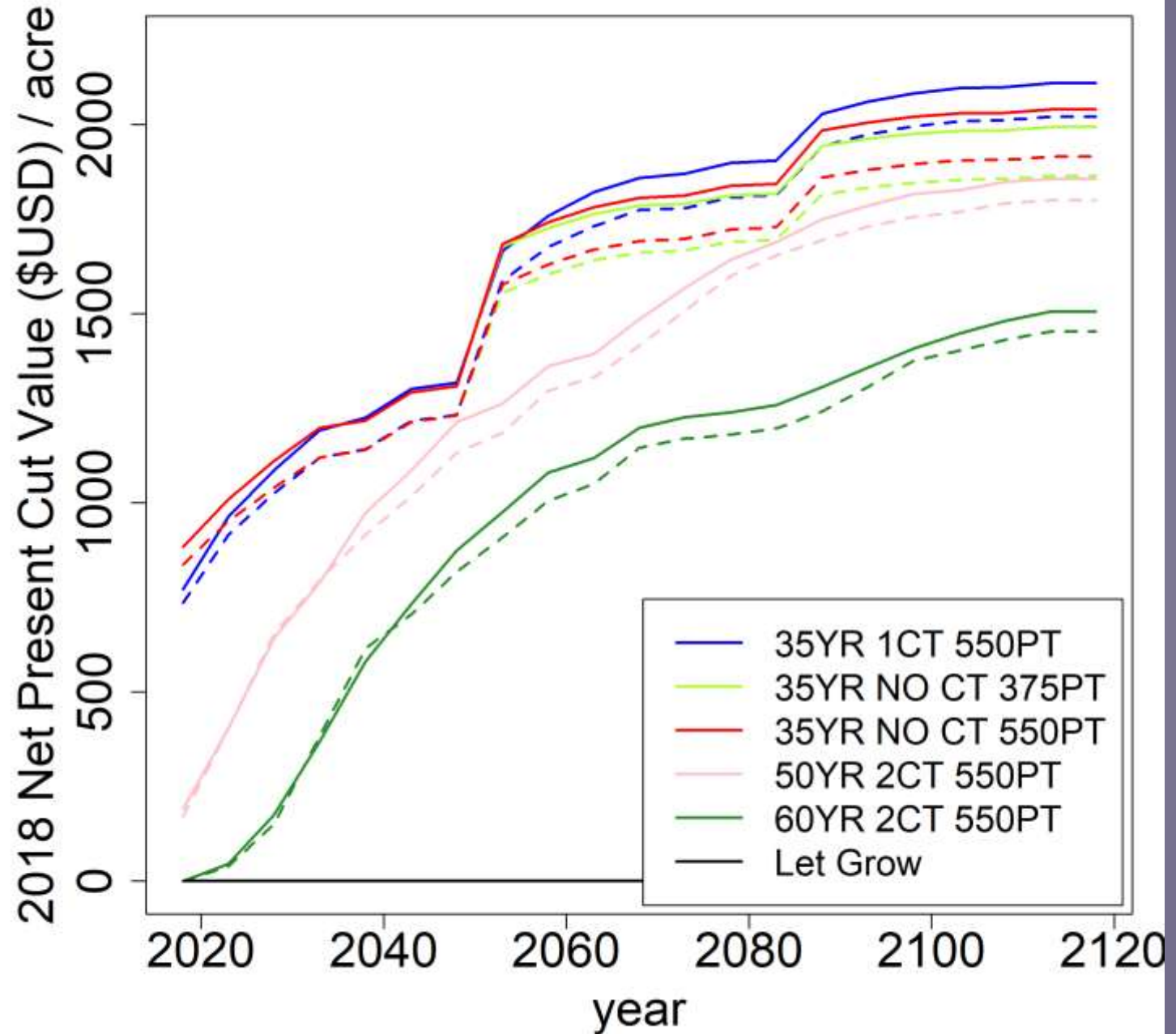
35YR NO CT - Losers





NPV (3%, 2018): More Interesting

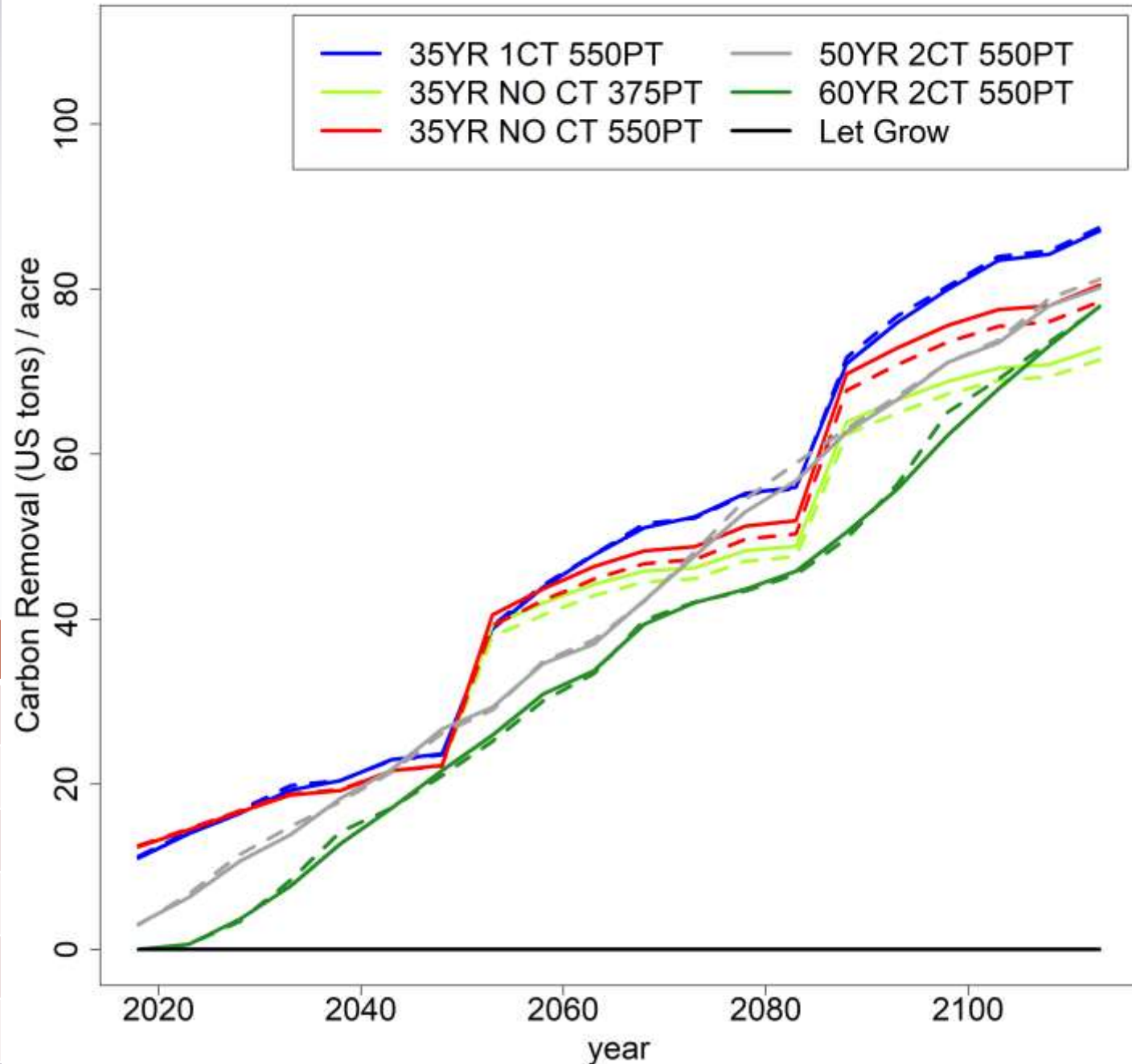
- Shorter rotations win ...
- CT / no thin, planting density effects minimal



Carbon Removals as wood timber

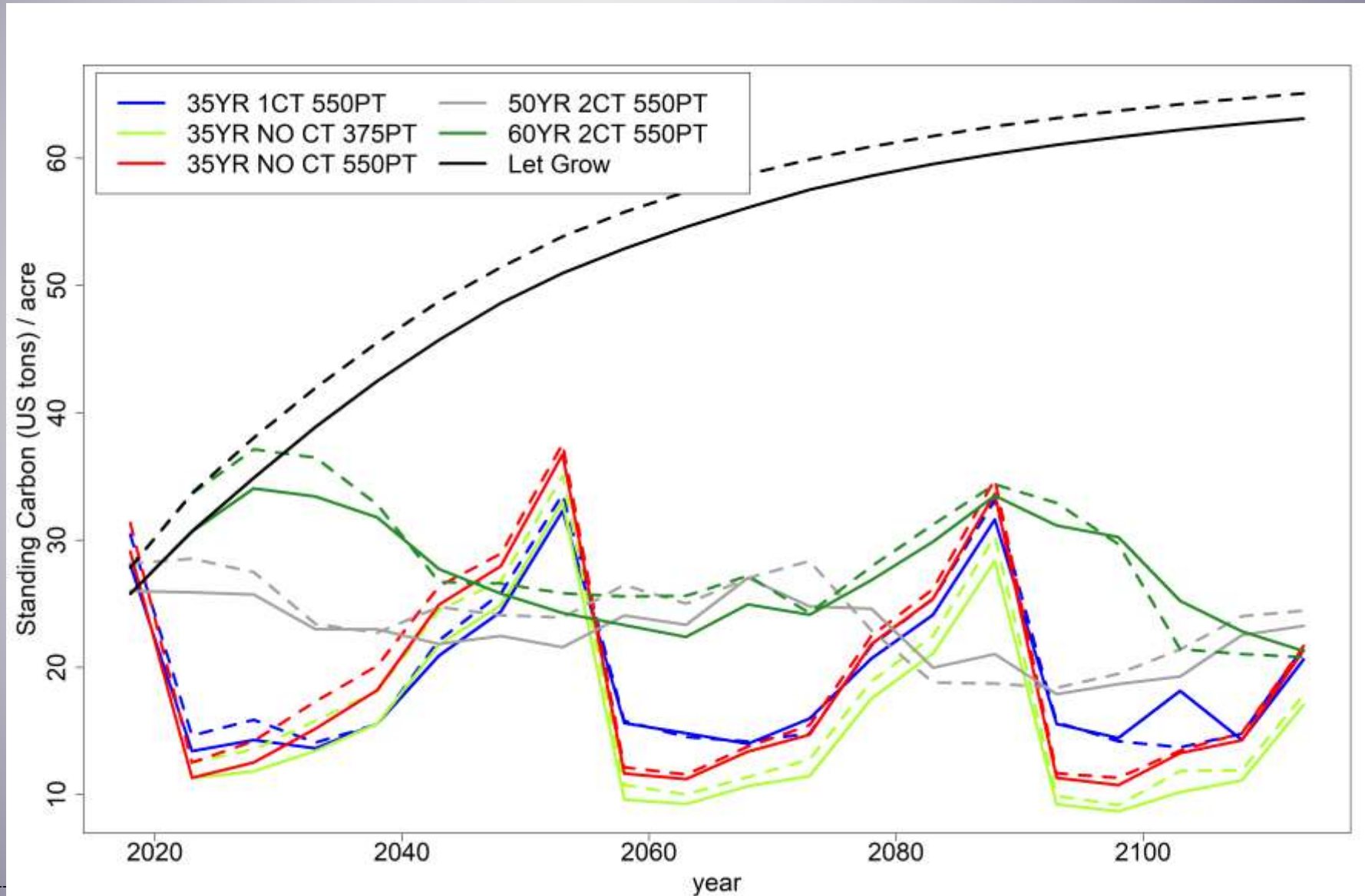
- Shorter rotations win ...
- CT / no thin, planting density effects minimal

	lidar	field
35yr_1thin_550	0.92	0.92
35yr_no_thin_375	0.75	0.77
35yr_no_thin_550	0.83	0.85
50yr_2thin_550	0.85	0.84
60yr_2thin_550	0.82	0.82
let_grow	0.00	0.00

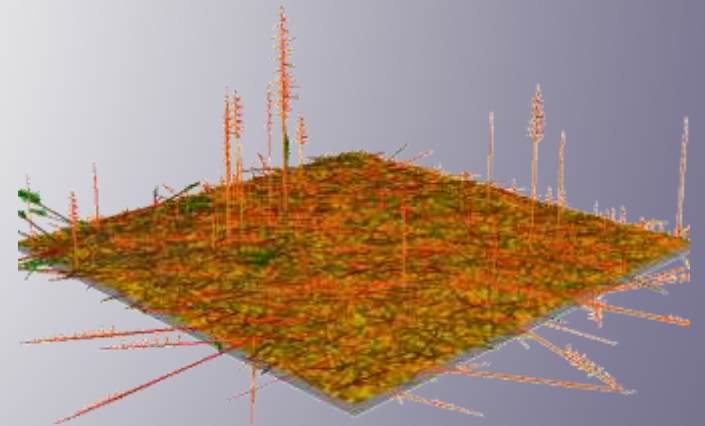
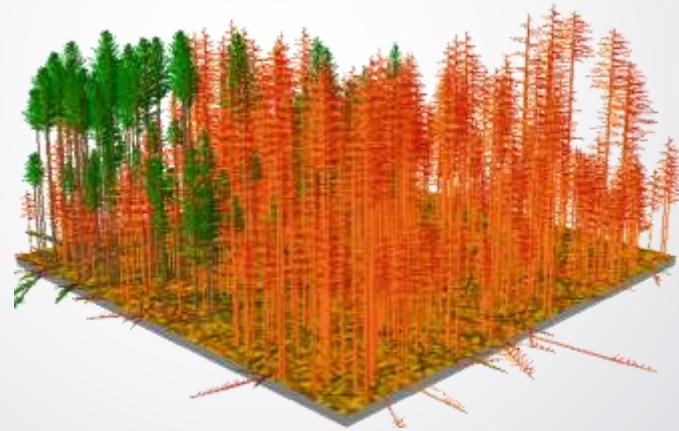
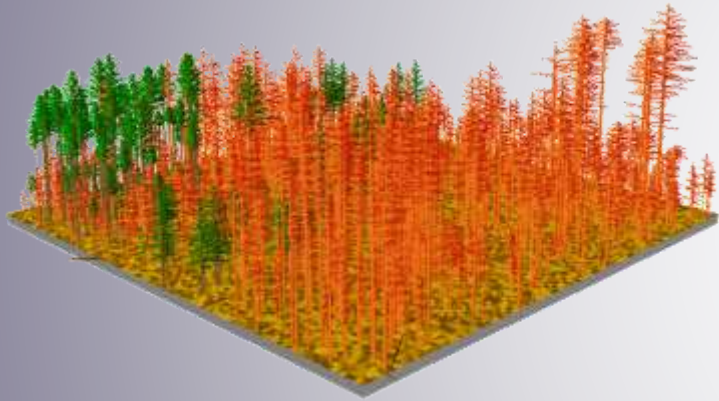


Standing Carbon

Lidar and Field: *Close Match*



Tactical (Stand-Level) Inventory



*Visualizations from SVS Software made by Robert J McGaughey

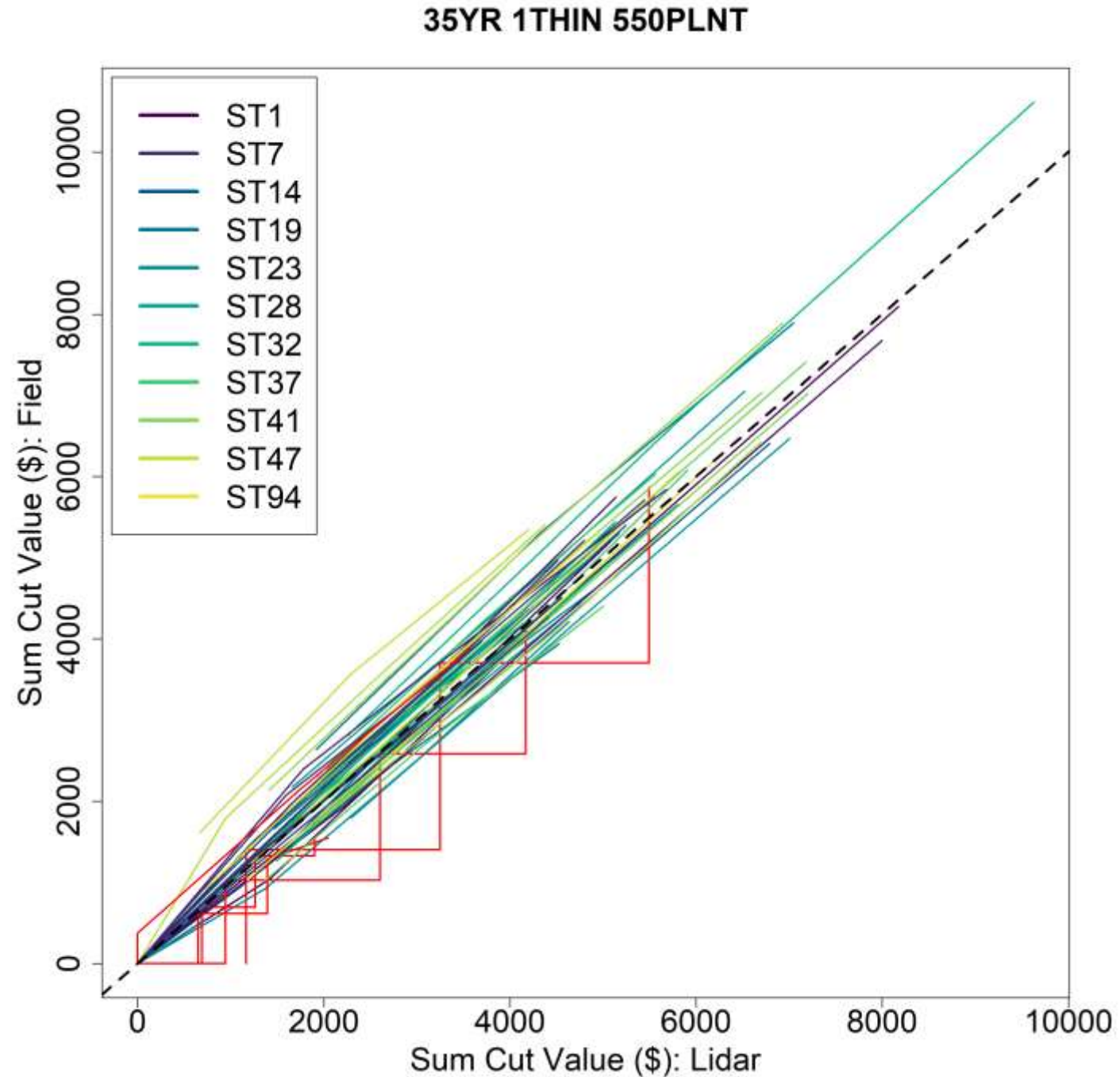
Example: Temporal Trends by Stand

RED = Mgmt YR Mismatch

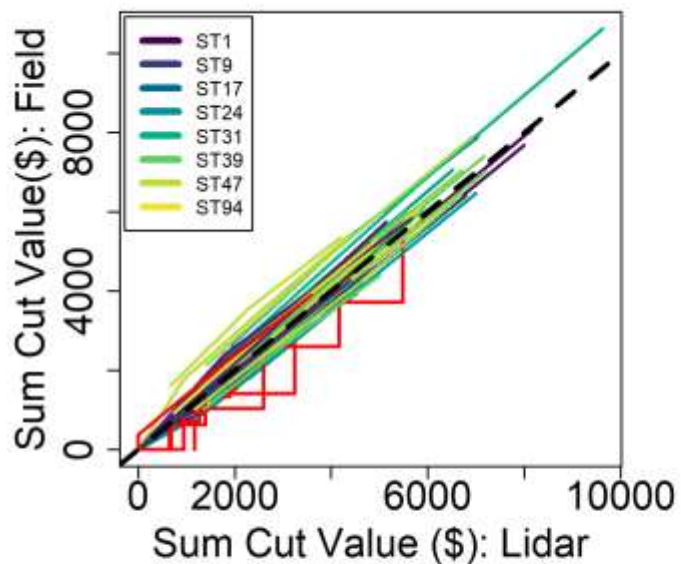
Example:

Lidar thinned 2023

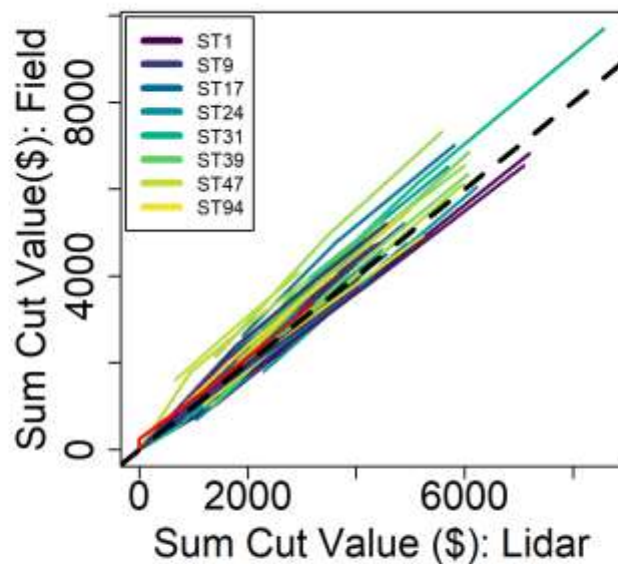
Field thinned 2025



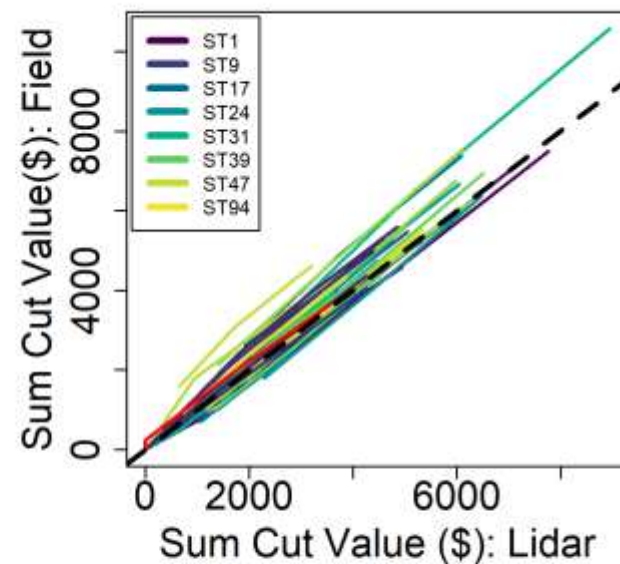
35YR 1THIN 550PLNT



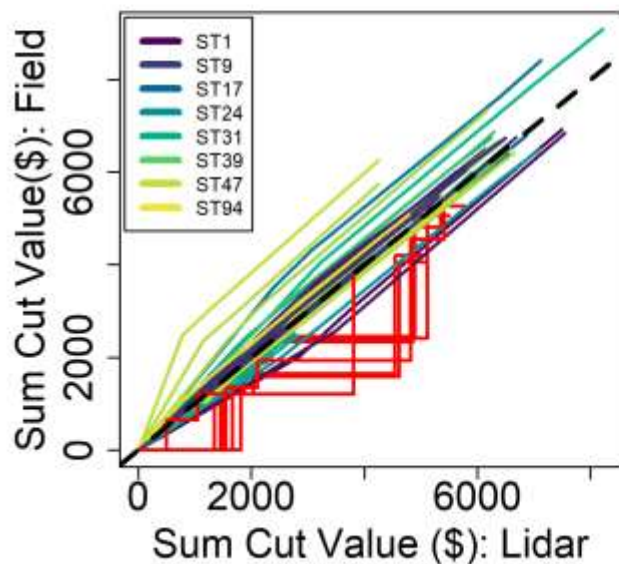
35YR NO THIN 375PLNT



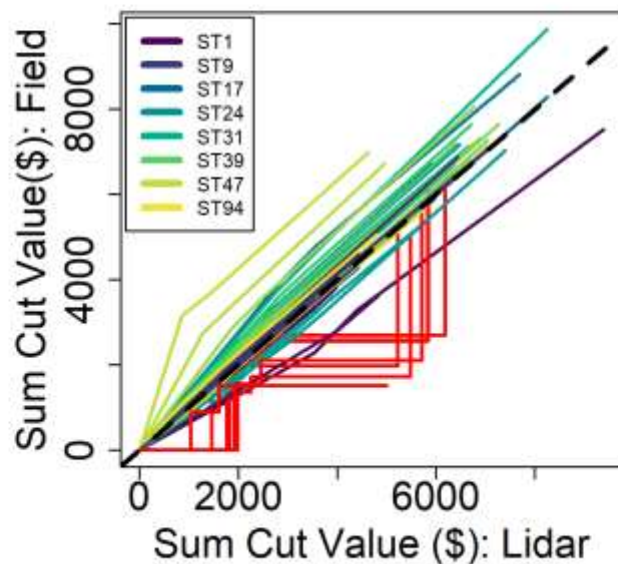
35YR NO THIN 550PLNT



50YR 2THIN 550PLNT



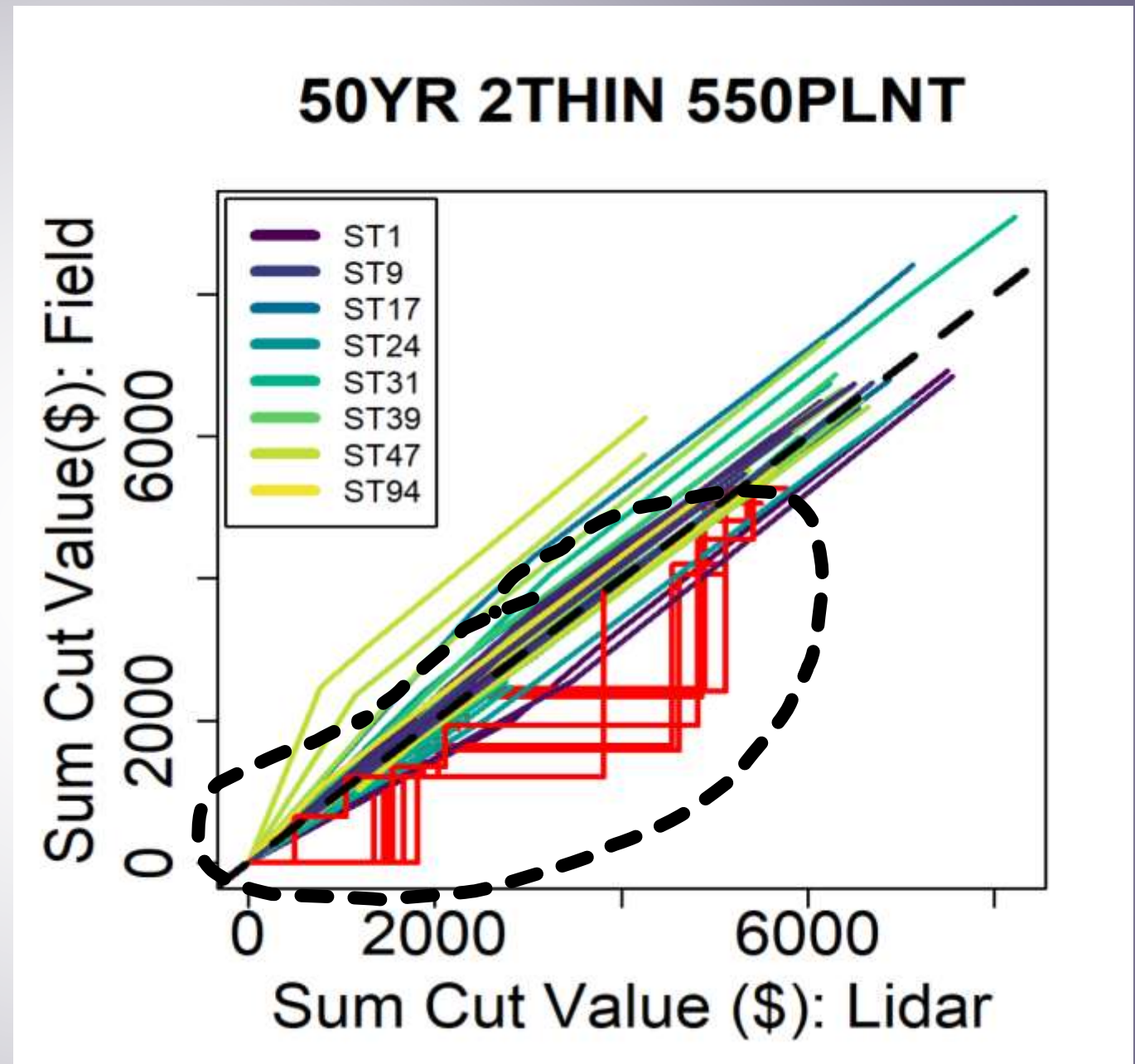
60YR 2THIN 550PLNT



1) Initial Divergence

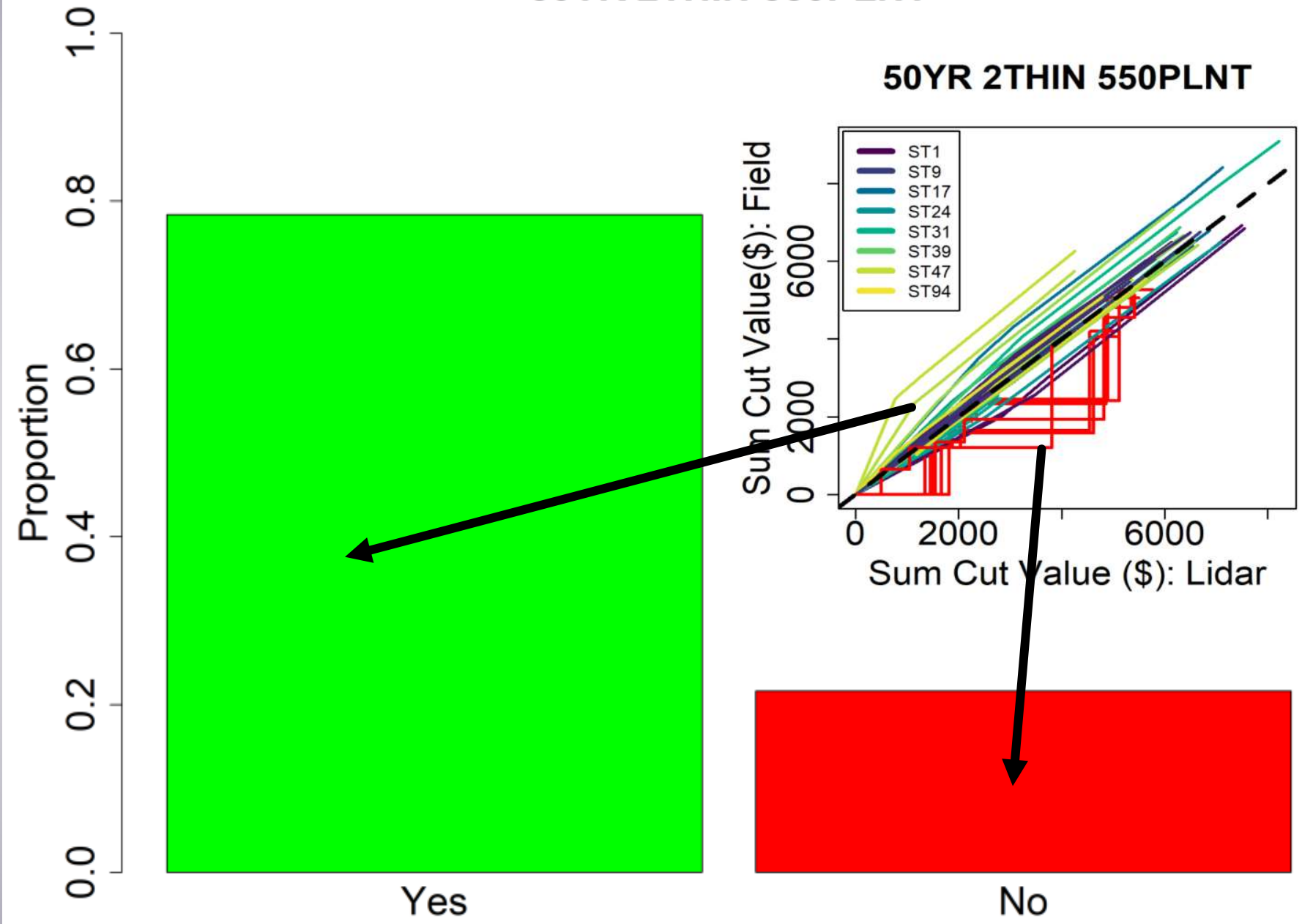
BUT

2) Reverts back to trend lines



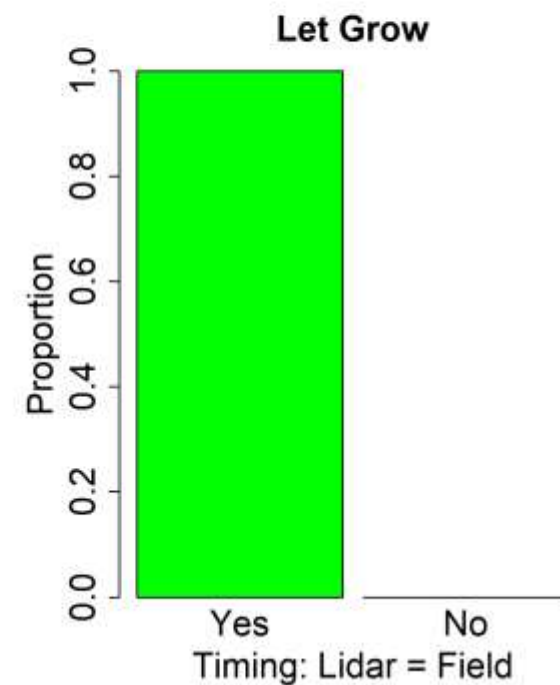
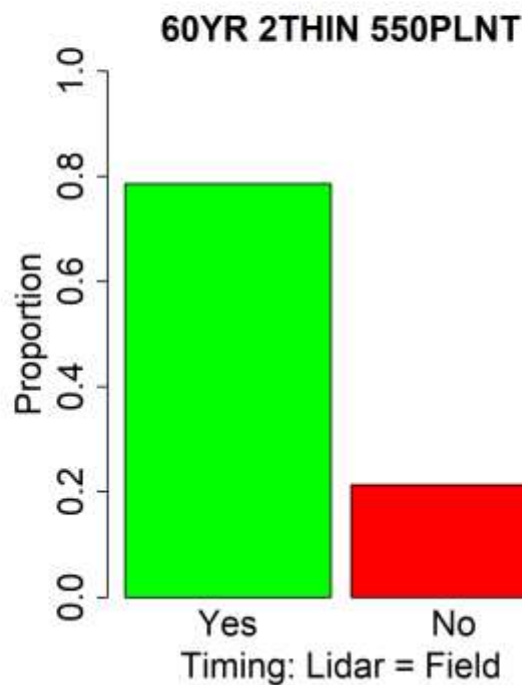
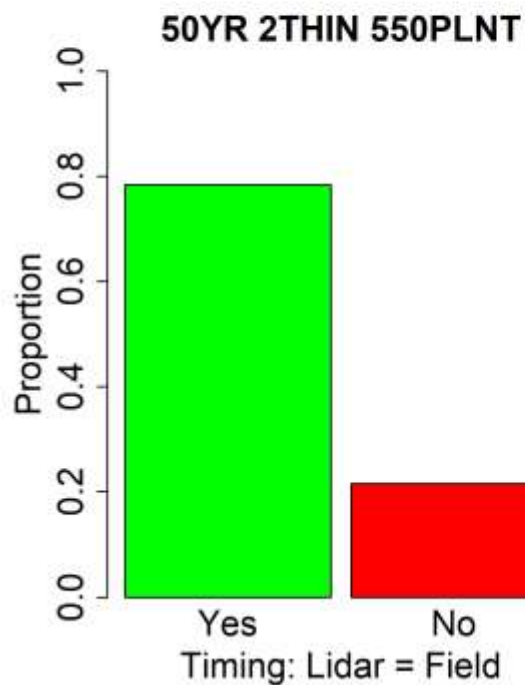
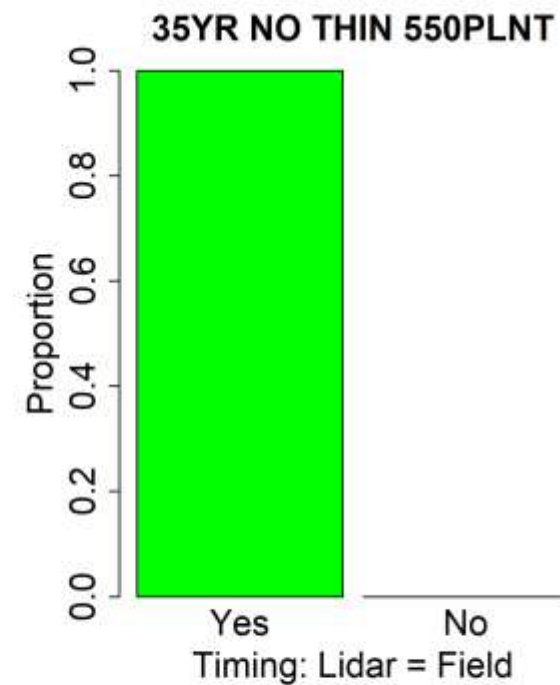
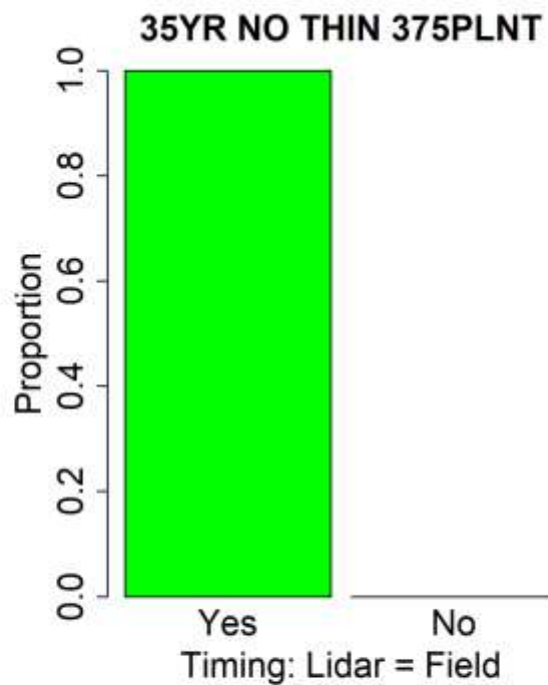
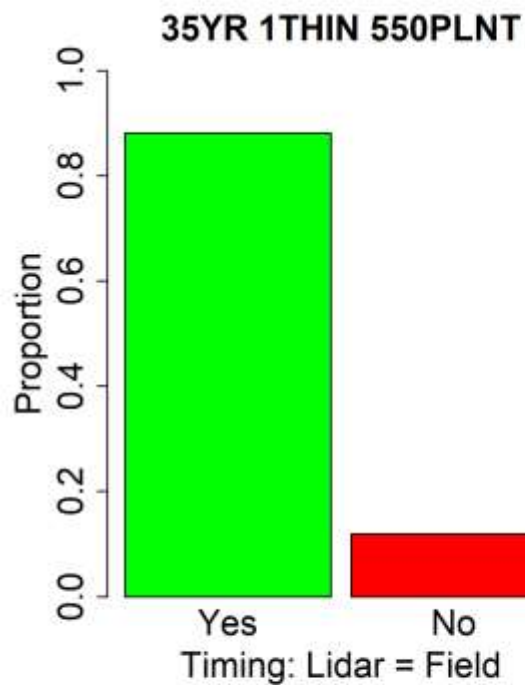
Timing Agreement

50YR 2THIN 550PLNT



Timing: Lidar = Field

Timing Agreement

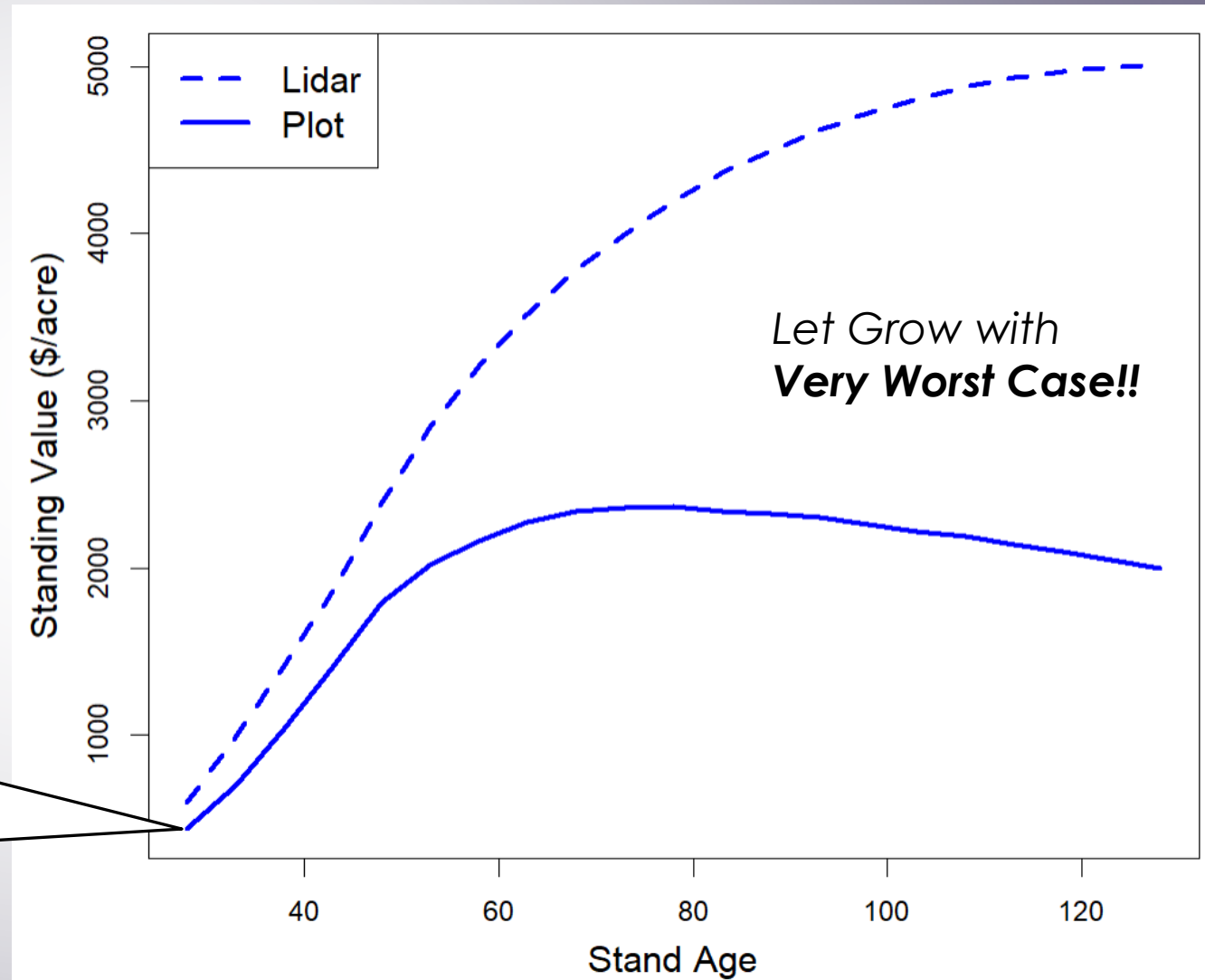


Diagnostics

Which factors in the **initial** tree lists cause projections to diverge over time?

- 1) QMD has a moderate influence on basal area and trees per acre
- 2) Hardwood proportion has a strong influence on volume and value over time

Example Stand MS1:
Lidar inventory 17% HWD
Plot inventory 63% HWD



Conclusions

1) Lidar and Field projections VERY similar!

- A. Tract
- B. Stand

2) Stand-level mismatch

- A. Exists
- B. Temporary** divergence...

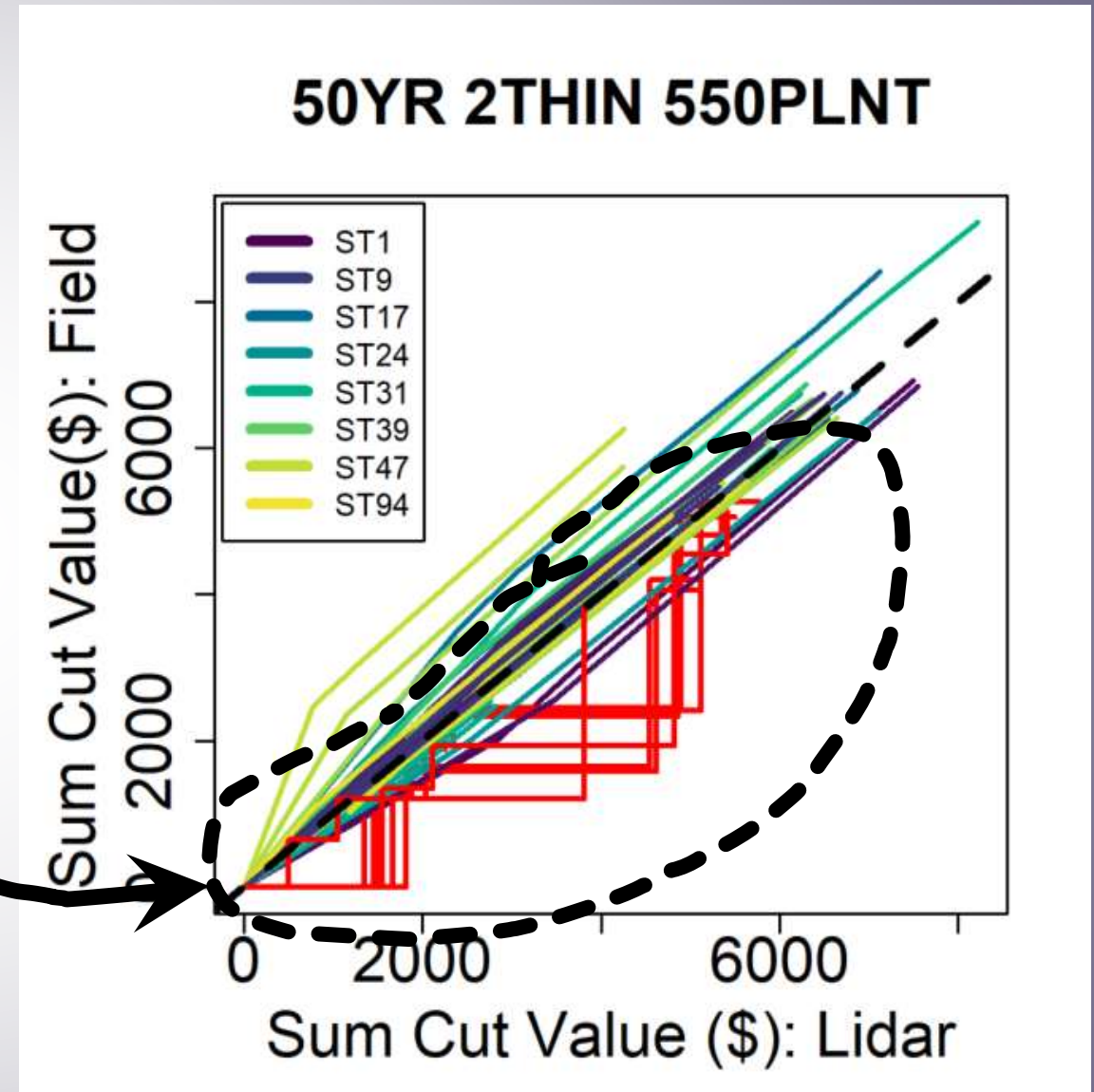
3) Muddy inference: "best" mgmt strategy

- A. No clear winner in total dollars
- B. Shorter rotation have higher NPV
- C. Longer rotations less cyclic*

4) HW Proportion

- A. Biggest indicator of errors
- B. Focus on species predictions (lidar) !

5) *Plan is to look at forest estate models next



END

Questions?

Growth Projections

- 1) FVS Software - FVSsn.exe
- 2) Management scenarios
 - A. 375 plant / acre, No Thin, 35 yr harvest
 - B. 550 plant / acre, No Thin, 35 yr harvest
 - C. 550 plant / acre, 1 Thin, 35 yr harvest
 - D. 550 plant / acre, 2 Thin, 50 yr harvest
 - E. 550 plant / acre, 2 Thin, 60 yr harvest
 - F. No management (let grow)
- 3) Comparison Metrics (lidar versus field)
 - A. Annual standing C and vol , standing vol x product class
 - B. Annual volume growth, cutout, cut vol x product class , value
 - C. NPV

Evaluation

1) Lidar vs Field

- A. Tract
- B. Stand

2) Attributes

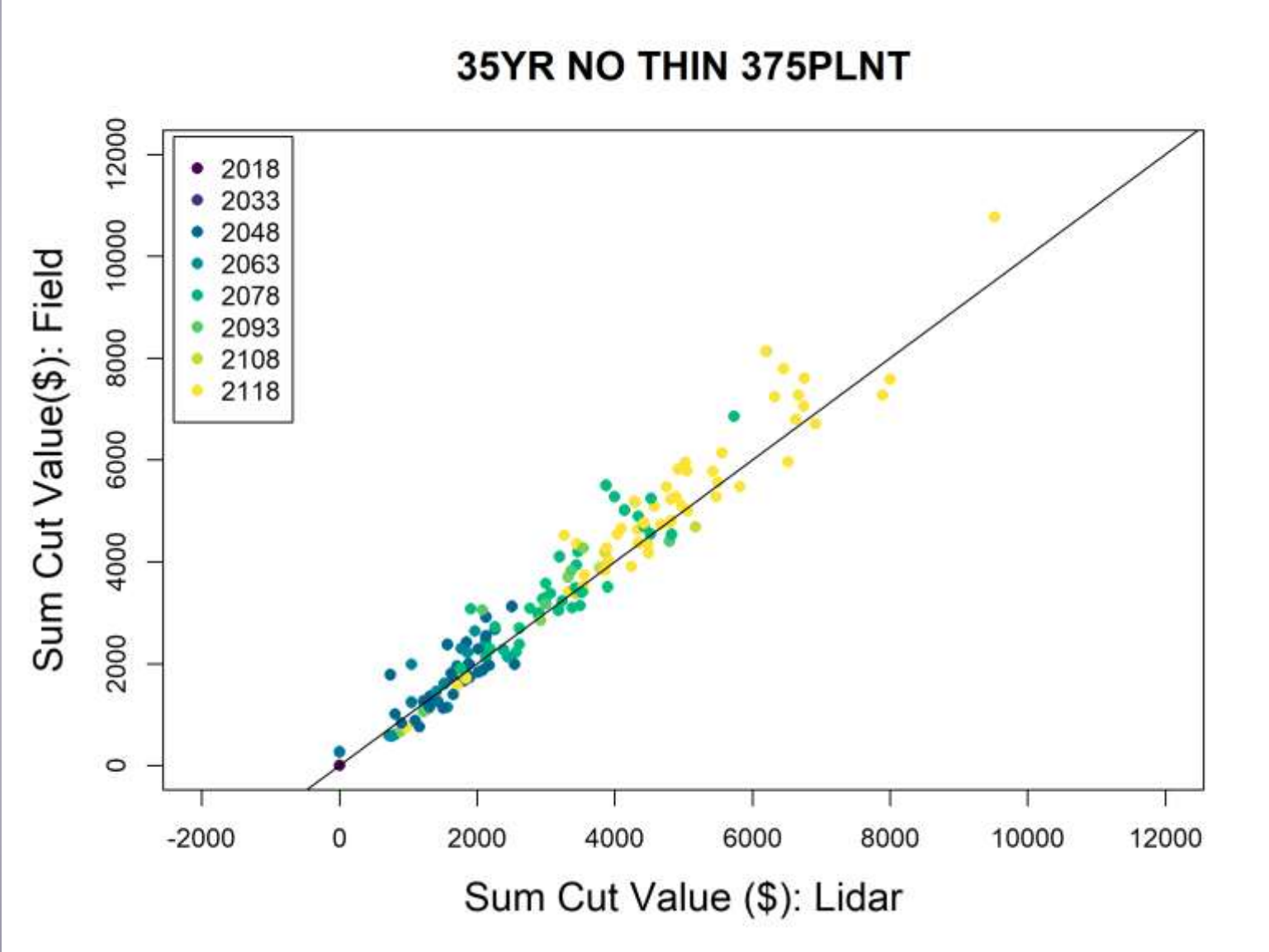
- A. Annual standing C, Value, Vol x product
- B. Annual volume growth, cutout, cut vol x product class , value
- C. NPV

3) Metrics

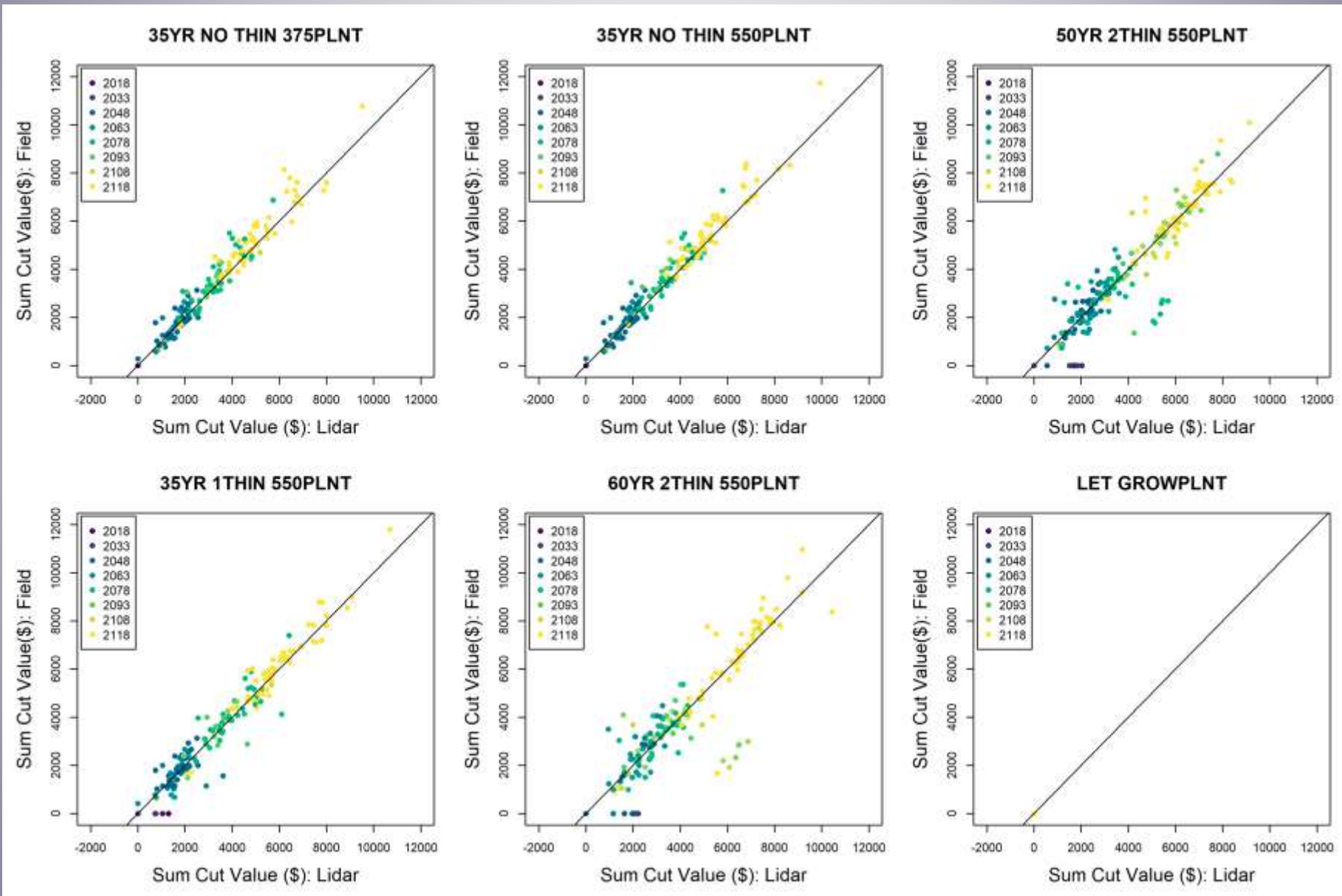
- A. Bias, RMSE, Correlation
- B. Coefficient of determination

OLD SLIDES

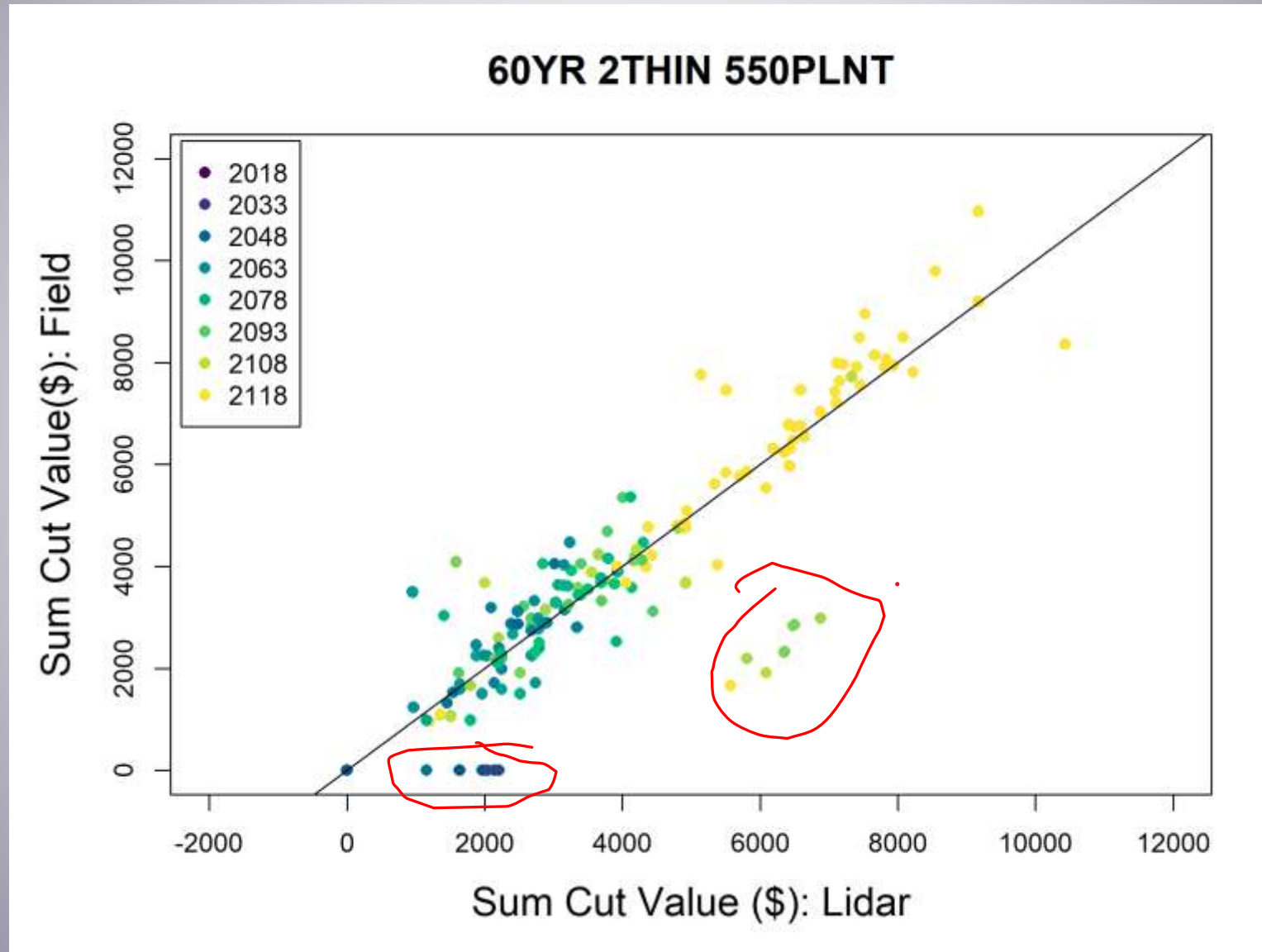
100 Years, Lidar VS Field: Cut Values Match



6 Scenarios: Cut Values (\$) Match

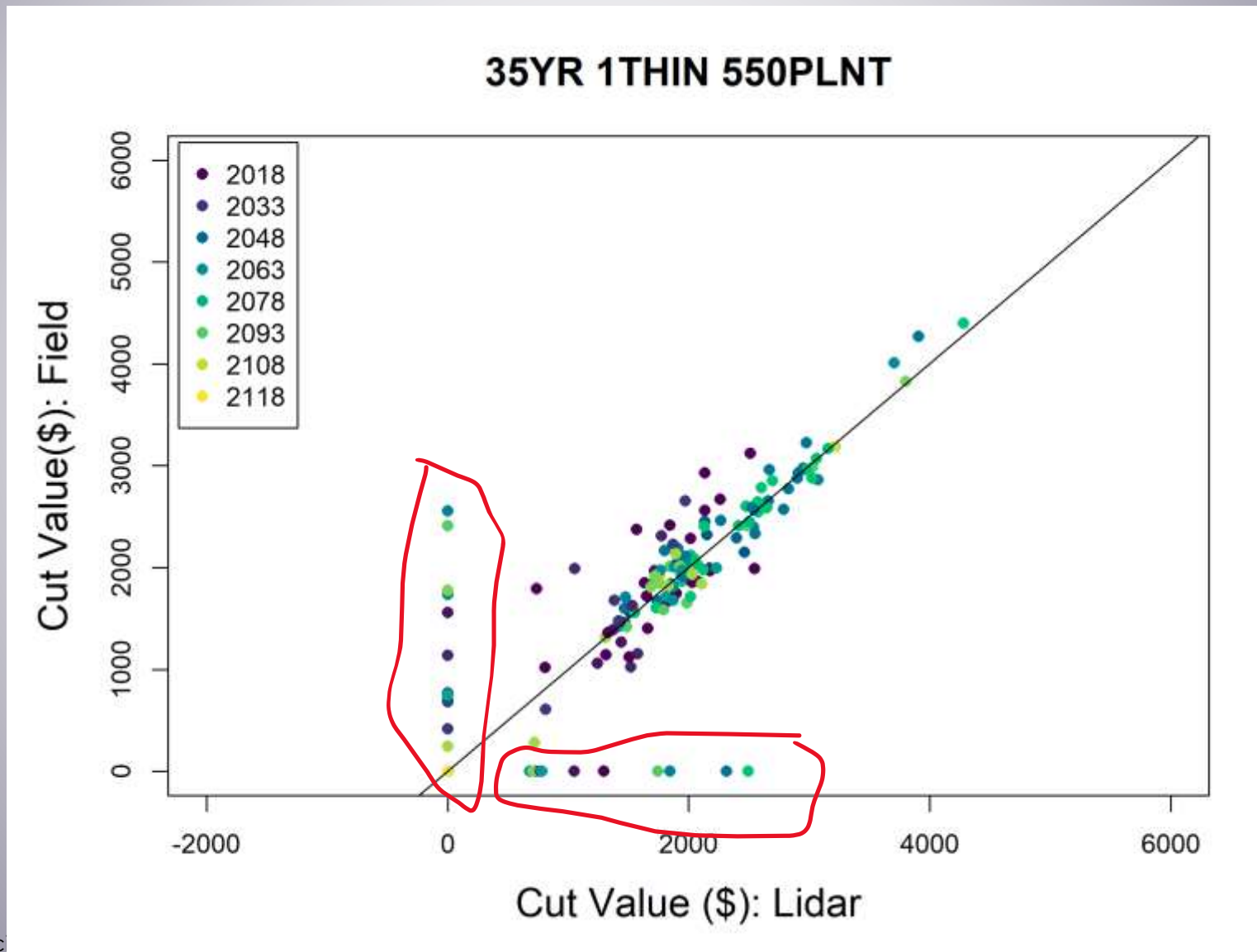


Temporal Mismatch – More Complex Mgmt

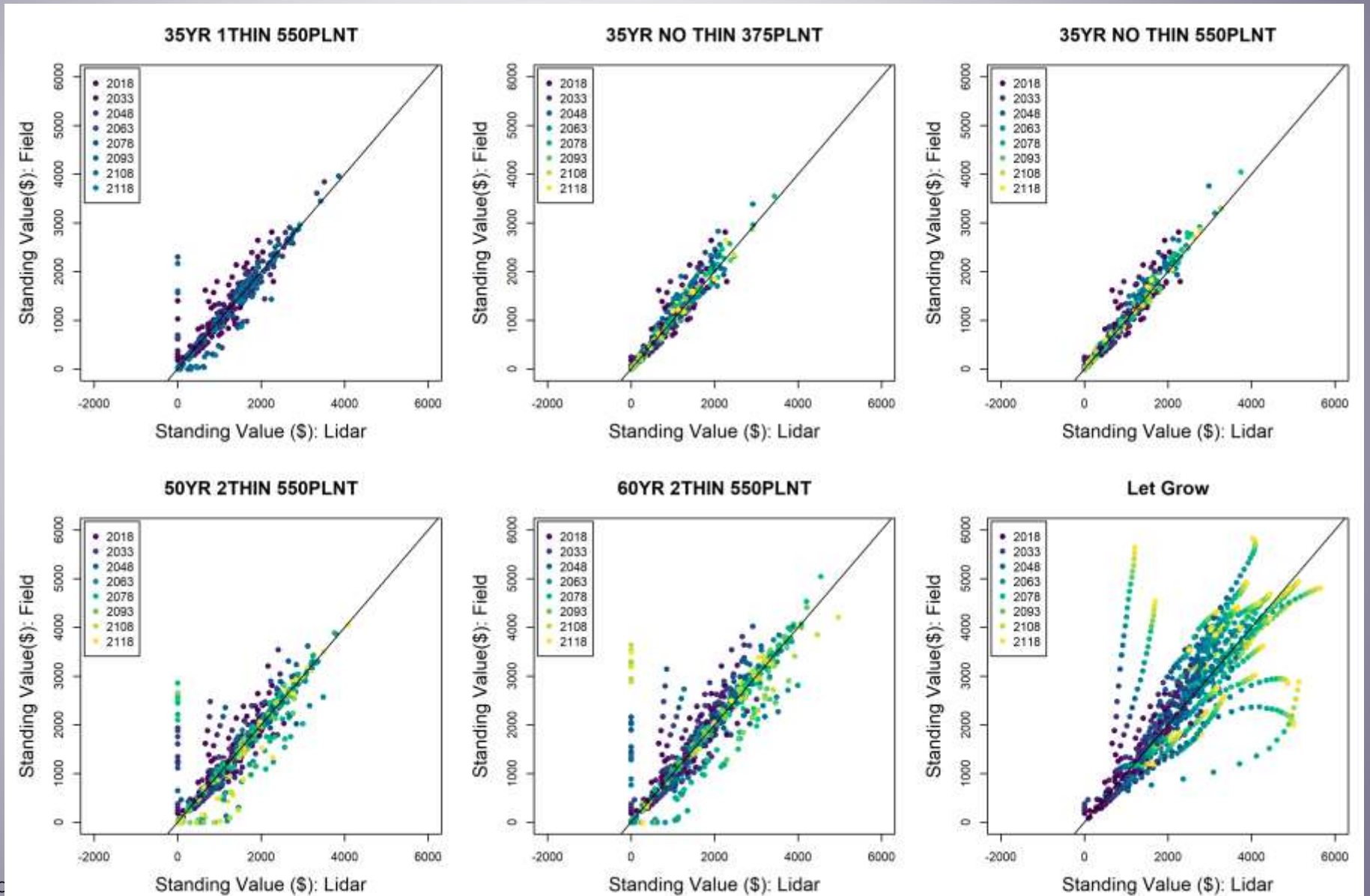


Annual (periodic) Cut Values

Approx. 1-period timing mismatch



Standing Value



Two More Questions

1) How to run the data

- A. As plots?
- B. As stands?

2) Effect of height predictions (e.g., add height errors)

- A. Distribution of heights compressed
- B. Volume residuals upward biased?

The screenshot shows the Forest Vegetation Simulator (FVS) web interface. At the top, it displays the project name 'Project_1', the last accessed date 'Mon Apr 04 16:06:00 2022', and the release date '20220311'. Below this, there are navigation links for 'Simulate', 'View Outputs', 'Visualize', 'View On Maps', 'Manage Projects', and 'Help'. A table titled 'FVS_StandInit' is displayed, showing 20 rows of data. The table has columns for 'Delete', 'STAND_CN', 'STAND_ID', 'VARIANT', 'INV_YEAR', and 'GROUPS'. The data rows show various stand identifiers and their corresponding attributes. Below the table, there are controls for 'Number display rows' (set to 20), 'Variables to consider' (a list of variables including STAND_CN, STAND_ID, VARIANT, INV_YEAR, GROUPS, ADDFILES, FVSKEYWORDS, LATITUDE, LONGITUDE, REGION), and a 'Find stand (ID)' search box. At the bottom, there are buttons for 'Remove all rows and commit' and 'Commit edits or new rows'.

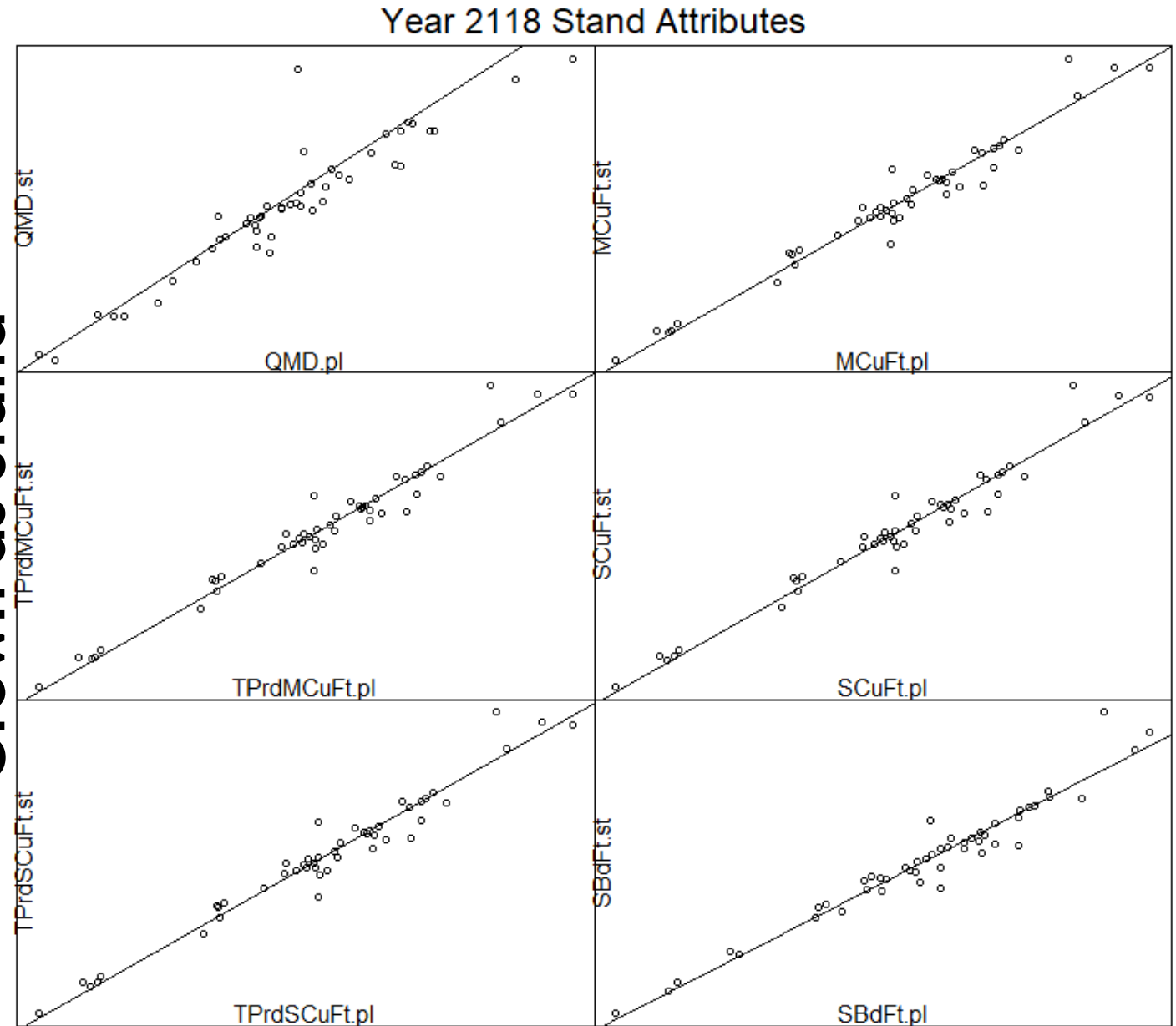
	Delete	STAND_CN	STAND_ID	VARIANT	INV_YEAR	GROUPS
1	<input type="checkbox"/>	3315584010602	090521000330002	cs	2015	All_Stands Project-inventory Forest_Type=501 Variant=c
2	<input type="checkbox"/>	3315588010602	090521000330007	cs	2015	All_Stands Project-inventory Forest_Type=503 Variant=c
3	<input type="checkbox"/>	3315591010602	090521000330010	cs	2015	All_Stands Project-inventory Forest_Type=402 Variant=c
4	<input type="checkbox"/>	3315594010602	090521000330011	cs	2015	All_Stands Project-inventory Forest_Type=402 Variant=c
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6	<input type="checkbox"/>	3315600010602	090521000330031	cs	2015	All_Stands Project-inventory Forest_Type=503 Variant=c
7	<input type="checkbox"/>	3315604010602	090521000330033	cs	2015	All_Stands Project-inventory Forest_Type=503 Variant=c
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13	<input type="checkbox"/>	3315625010602	090521000330124	cs	2015	All_Stands Project-inventory Forest_Type=503 Variant=c
14	<input type="checkbox"/>	3315629010602	090521000330135	cs	2015	All_Stands Project-inventory Forest_Type=501 Variant=c
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20	<input type="checkbox"/>	3315651010602	090521000330175	cs	2015	All_Stands Project-inventory Forest_Type=404 Variant=c

FVS

Effect of Stand vs Plot

- 1) Grow tree
 - A. 100 years
 - B. As plots (+error)
 - C. As stands
- 2) Yes: Stand level differences
- 3) ~Unbiased at 100 years
- 4) No effect from ht errors
- 5) Results same at 2038

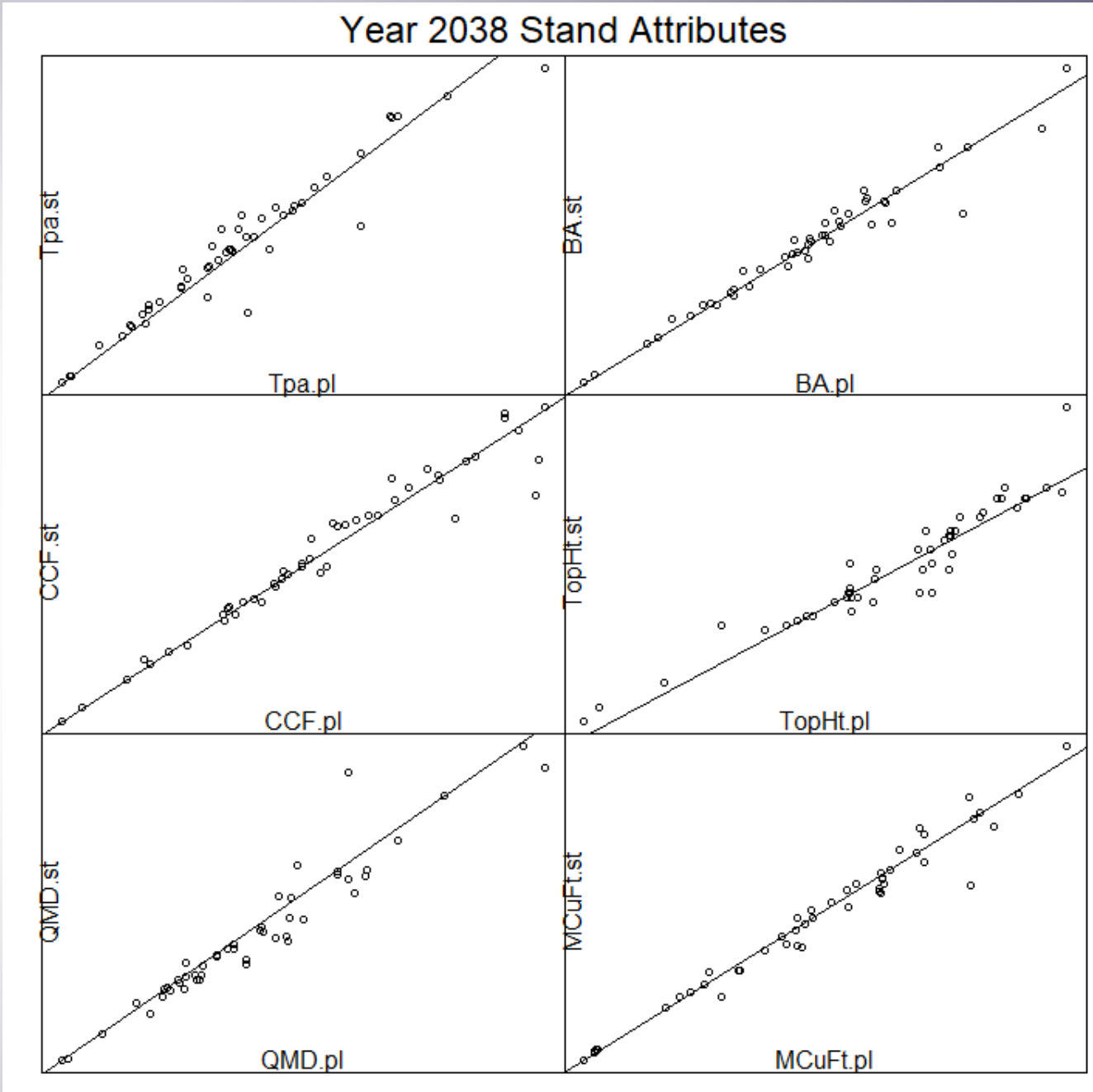
Grown as Stand



Grown as Plot (+ Ht error)

Year	mcft_Bias%	mcft_CV%
2018	-0.12	0.59
2038	-1.06	5.00
2058	-5.46	8.28
2078	-0.24	4.51
2098	-0.38	4.64
2118	-0.41	4.85

Grown as Stand



Grown as Plot (No Ht error)

Plot Grid (550 plots)

