An Evaluation of Lidar Inventory Growth Projections

Western Mensurationists

2023 Annual Meeting

Jacob Strunk

Peter Gould

USDA Forest Service -- Pacific Northwest Research Station – Forest Monitoring and Assessment Program -- Vegetation Monitoring and Assessment Team

Jacob Strunk

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

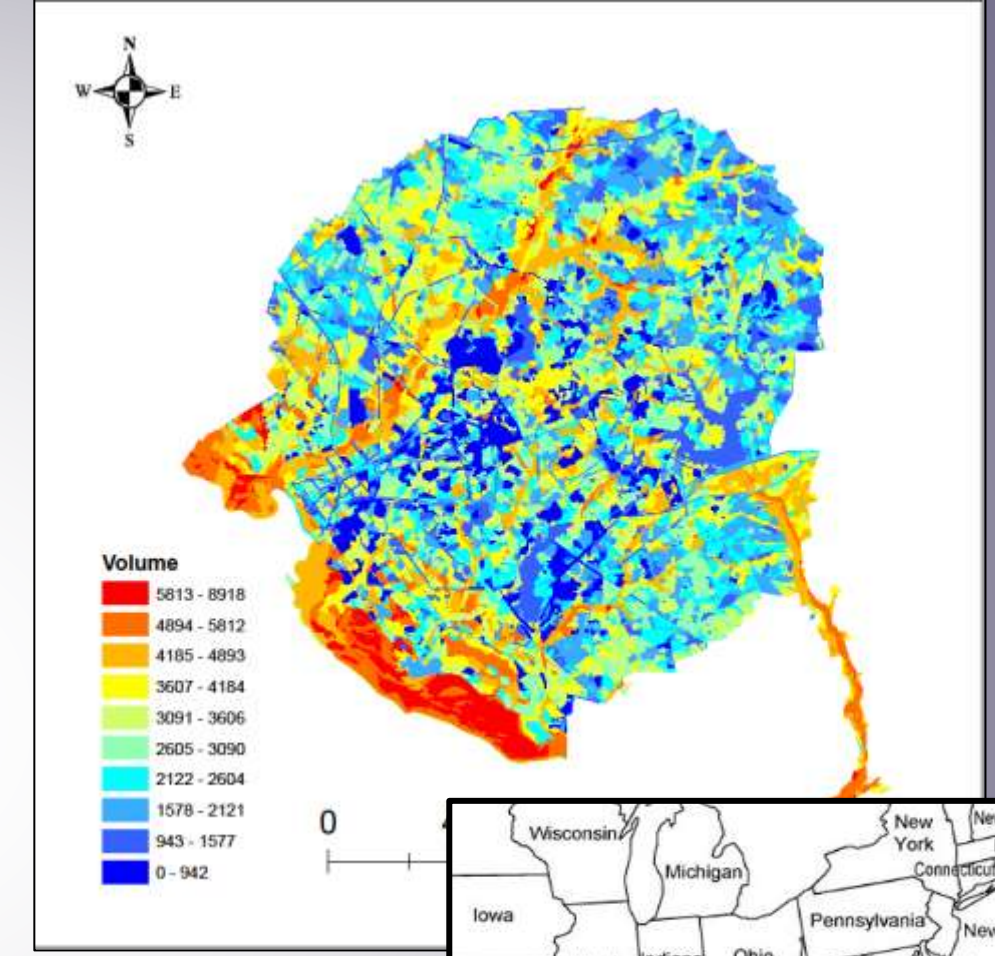
BS Northern AZ University

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

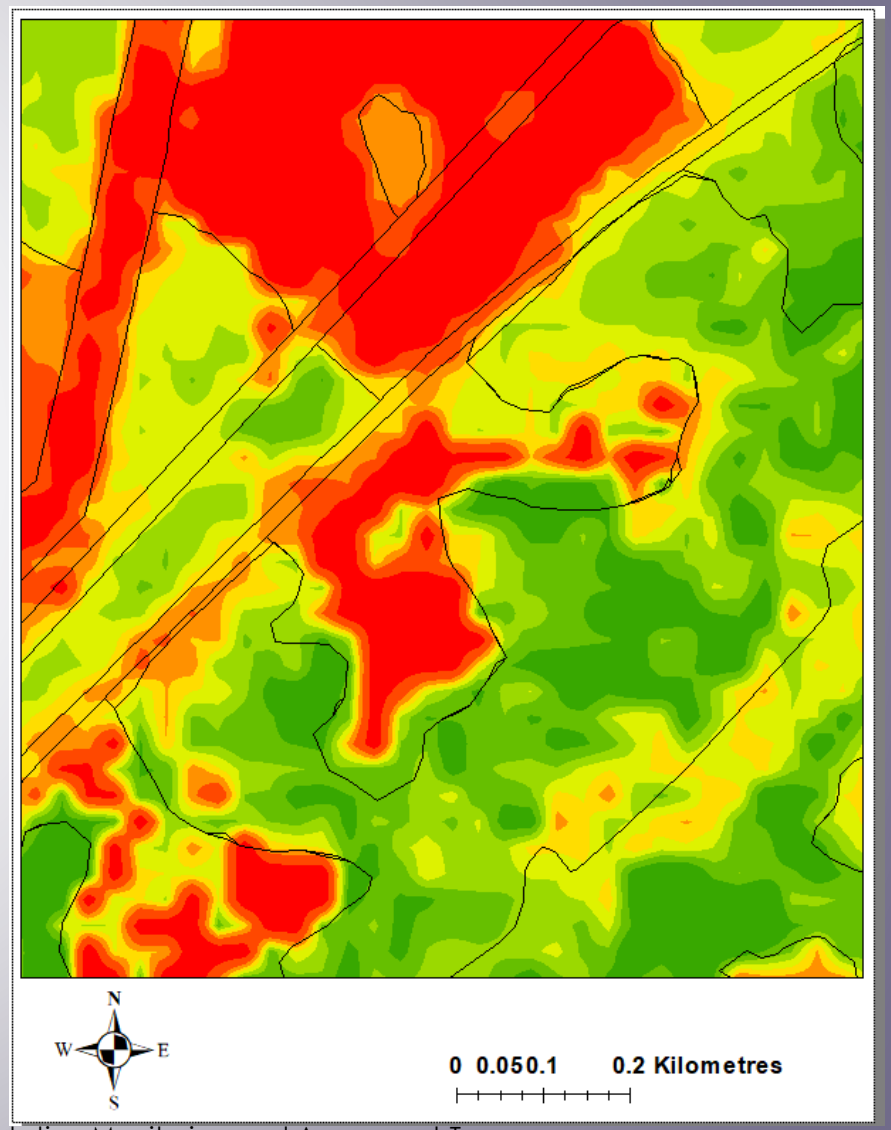
3) Cost Efficient (for stand-level+ detail)

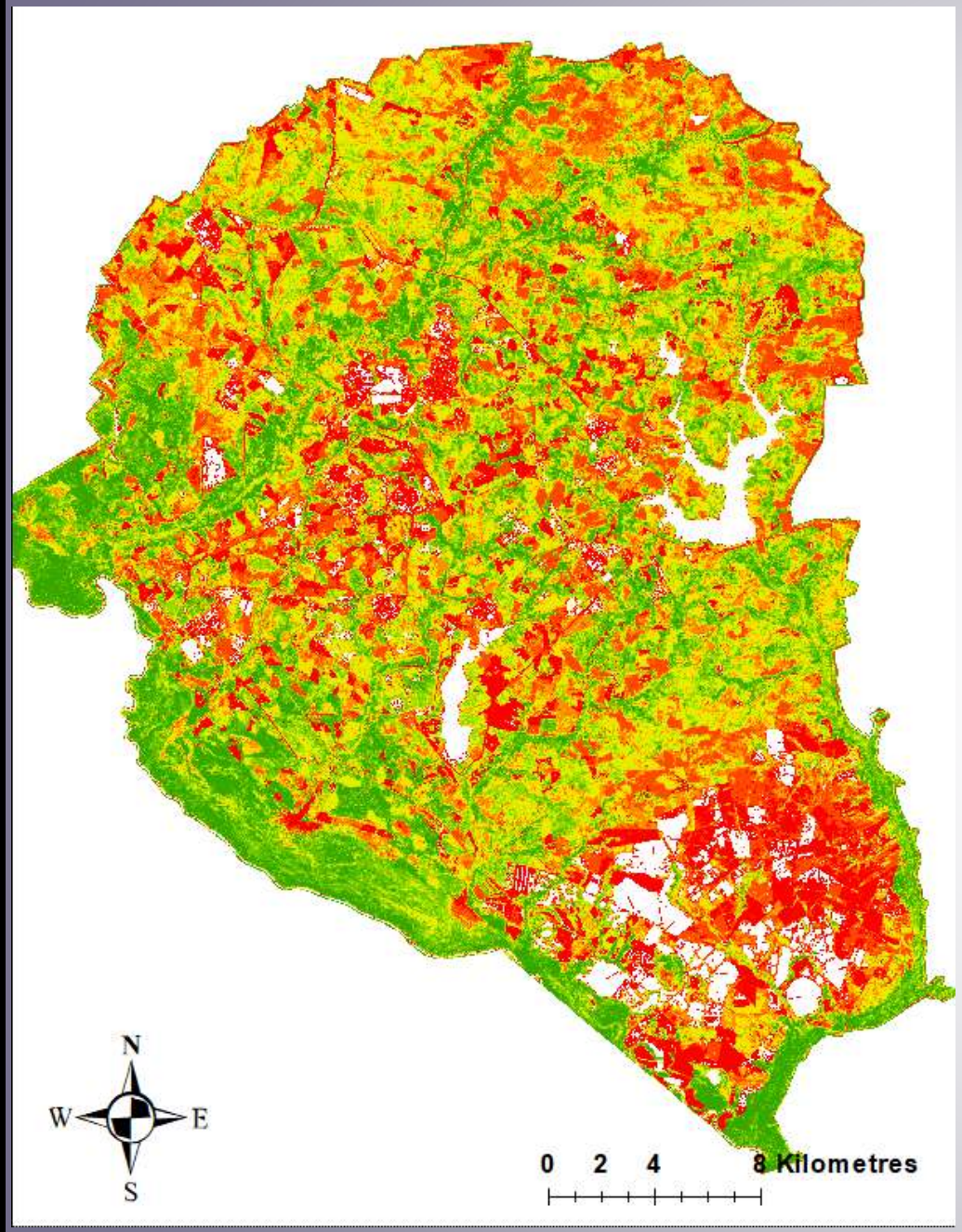
   A. ≈$250k for 200k acres

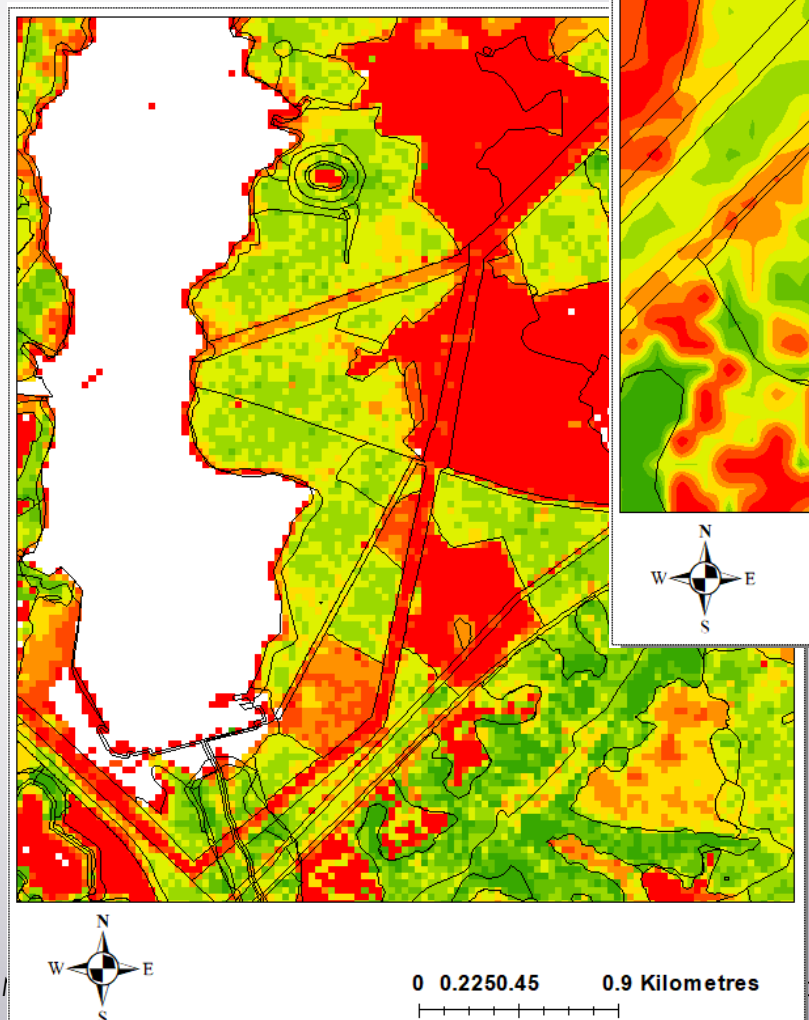
   B. 550 plots ($75k)

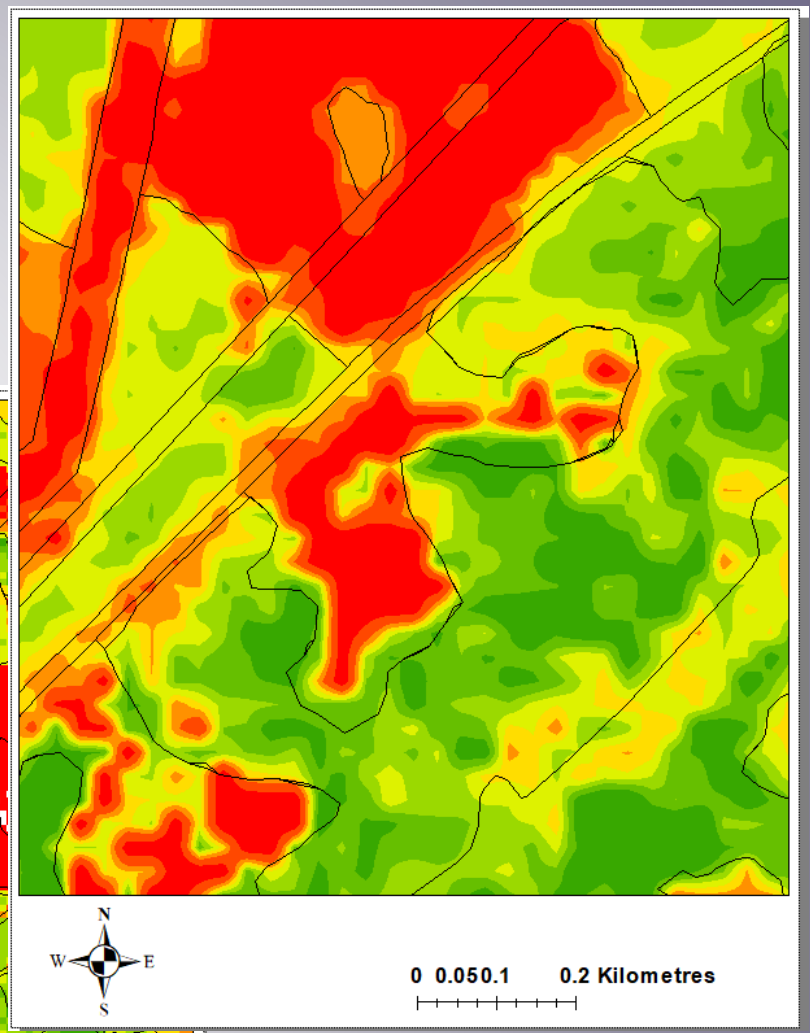
   C. Lidar ($60k)

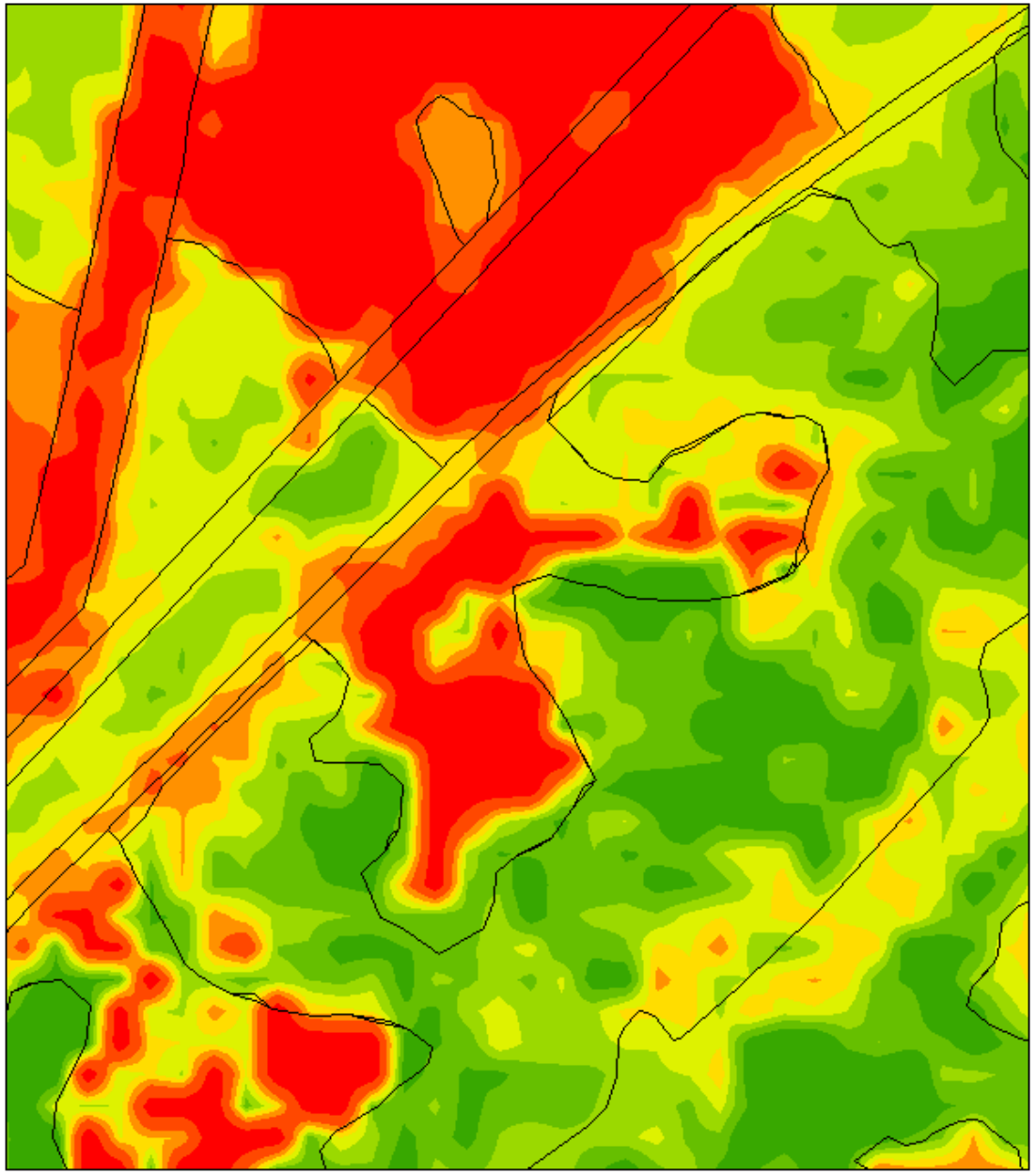
   D. Analysis ($115k)




N
W
E
S
0 2 4 8 Kilometres


N
W
E
S
0 0.2250.45 0.9 Kilometres


N
W
E
S
0 0.050.1 0.2 Kilometres

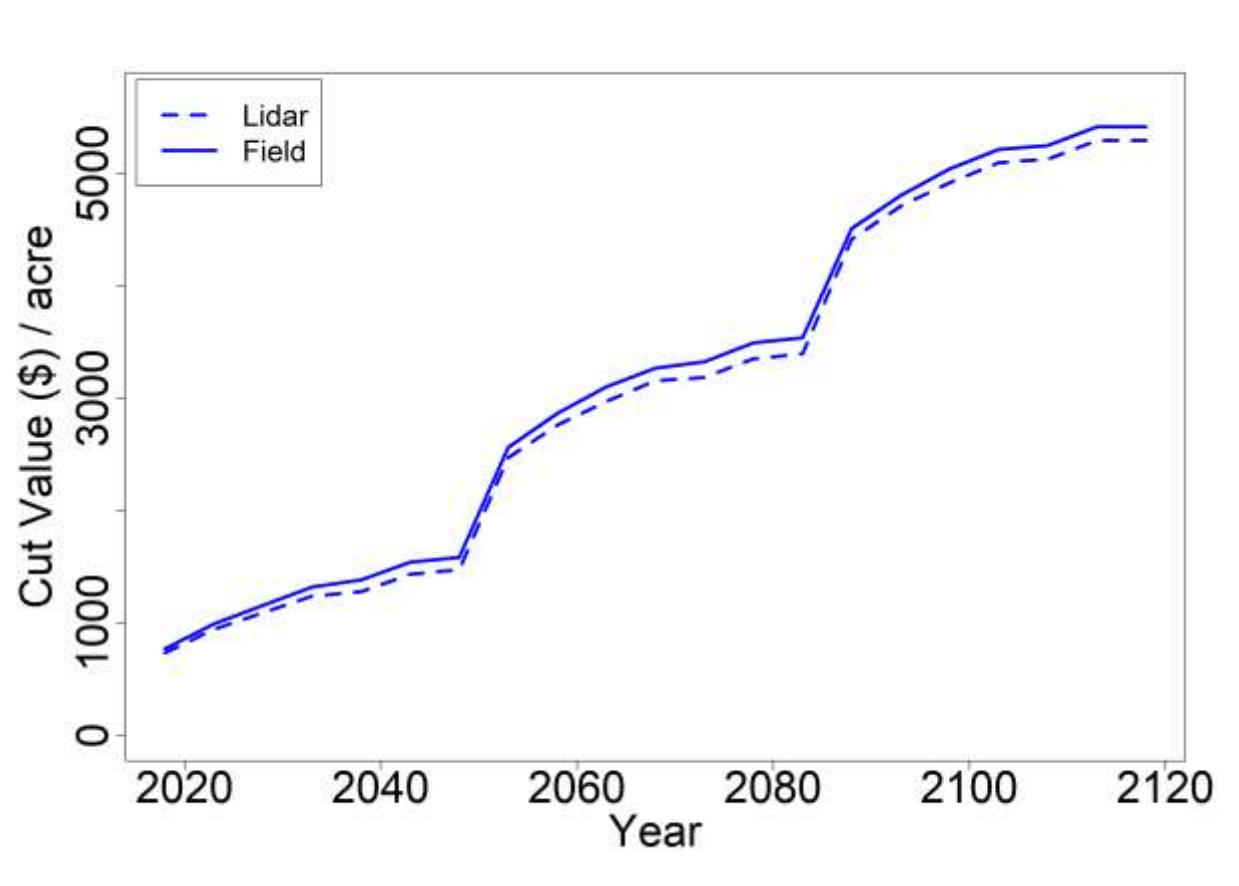


0 0.050.1 0.2 Kilometres

0 0.050.1 0.2 Kilometres

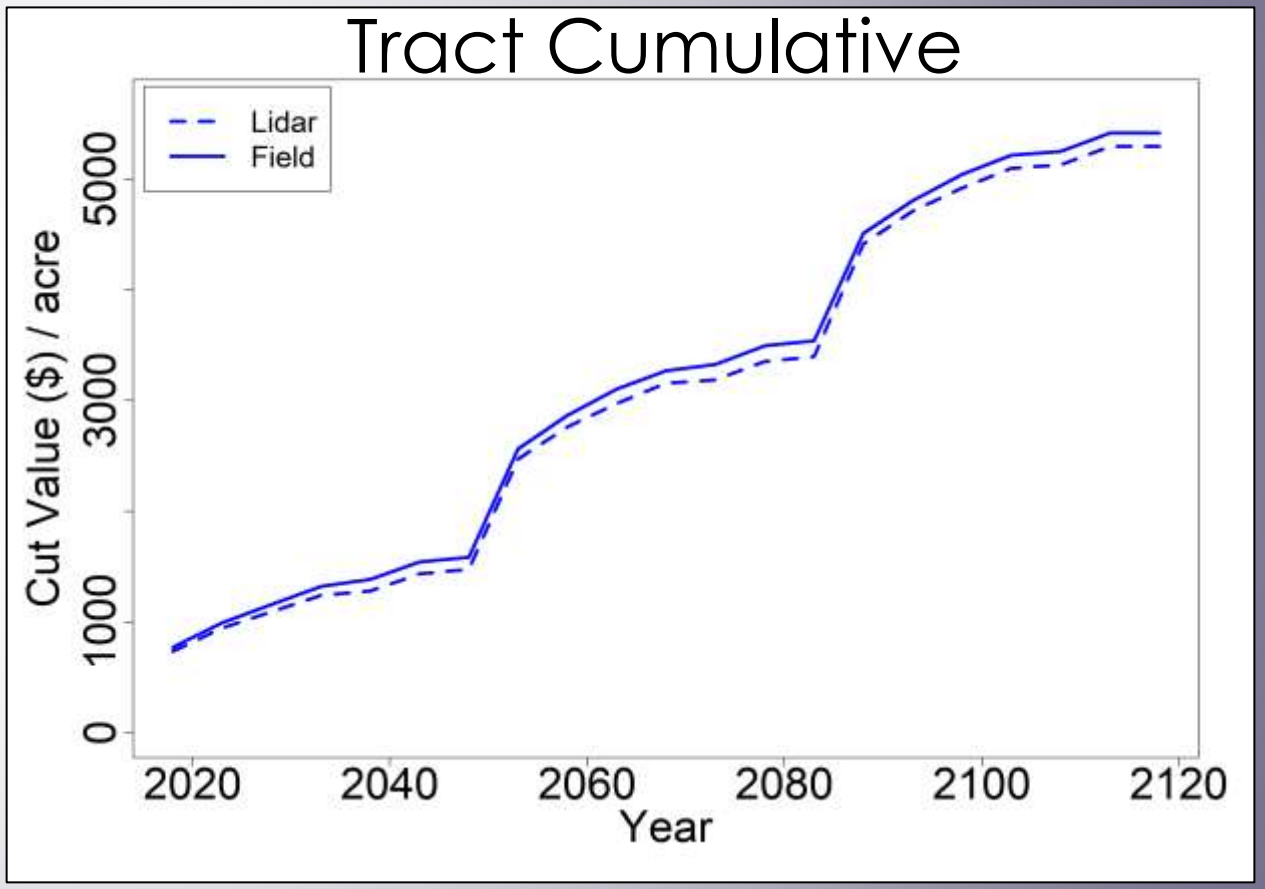
Is Lidar any Good for Growth Projections?

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

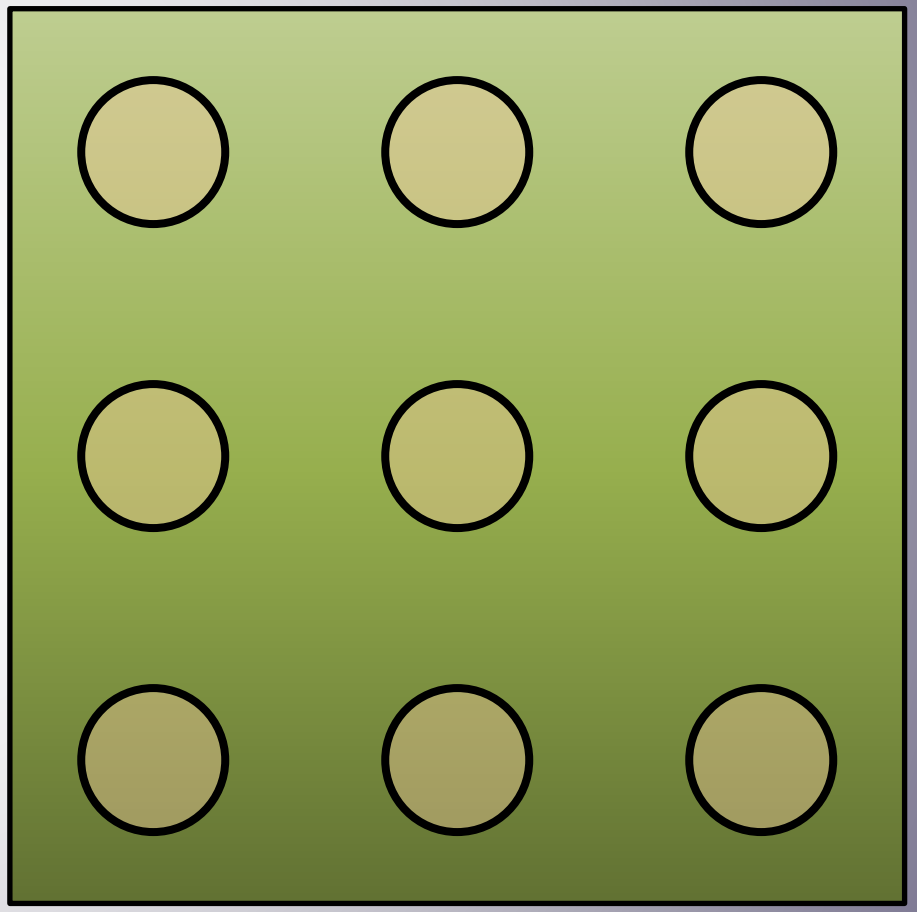
1. Plant (375 vs 550)
2. Thin to 70 sq ft / acre (0,1,2 x thins)
3. Harvest rotation (35, 50, 60, never)

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:

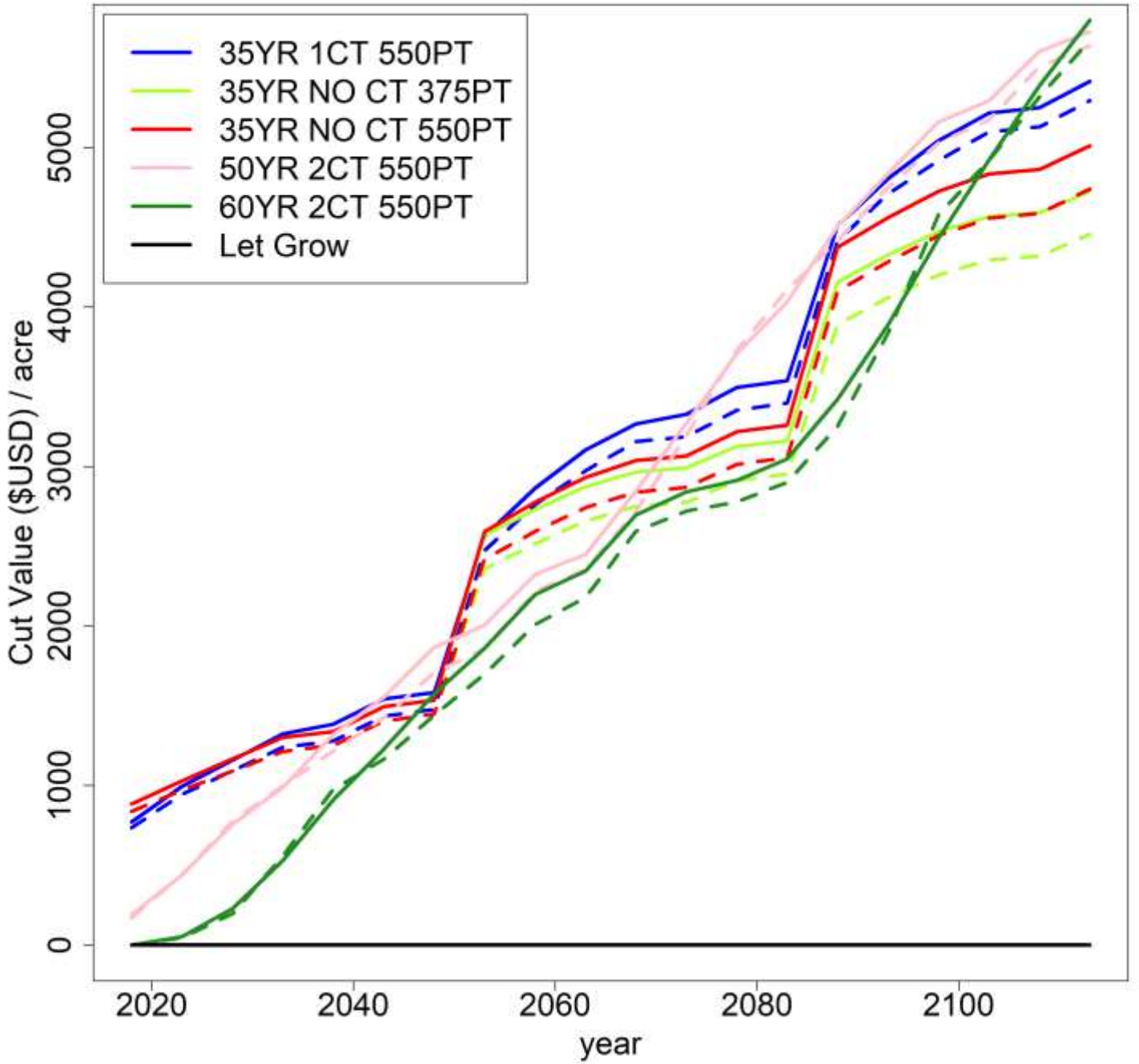
1. Growth projections: Lidar VS Field
2. Differences by management strategy

Lidar and Field: ≈Exact match

Cyclic – no clear winner

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

35YR NO CT - worst

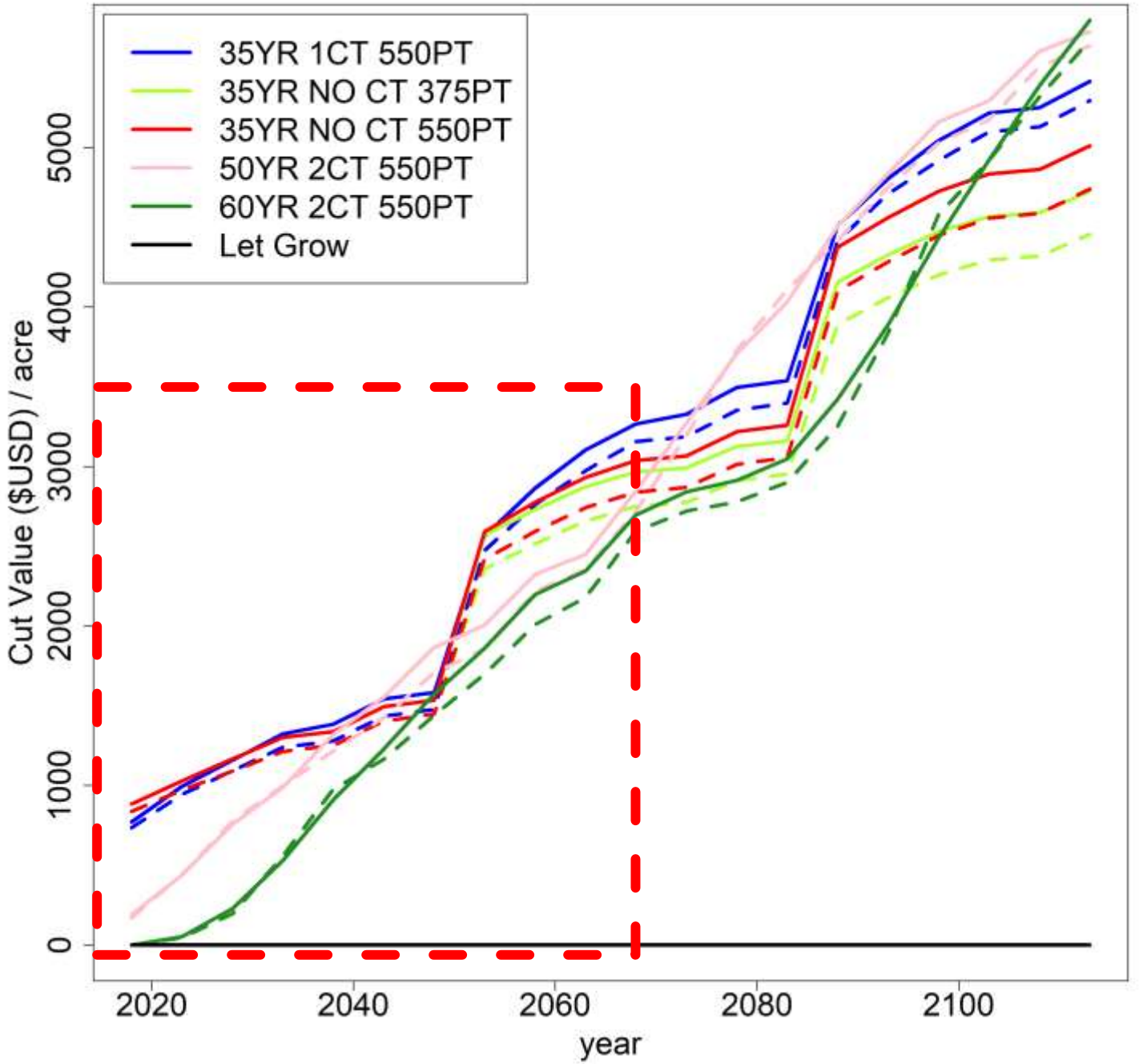


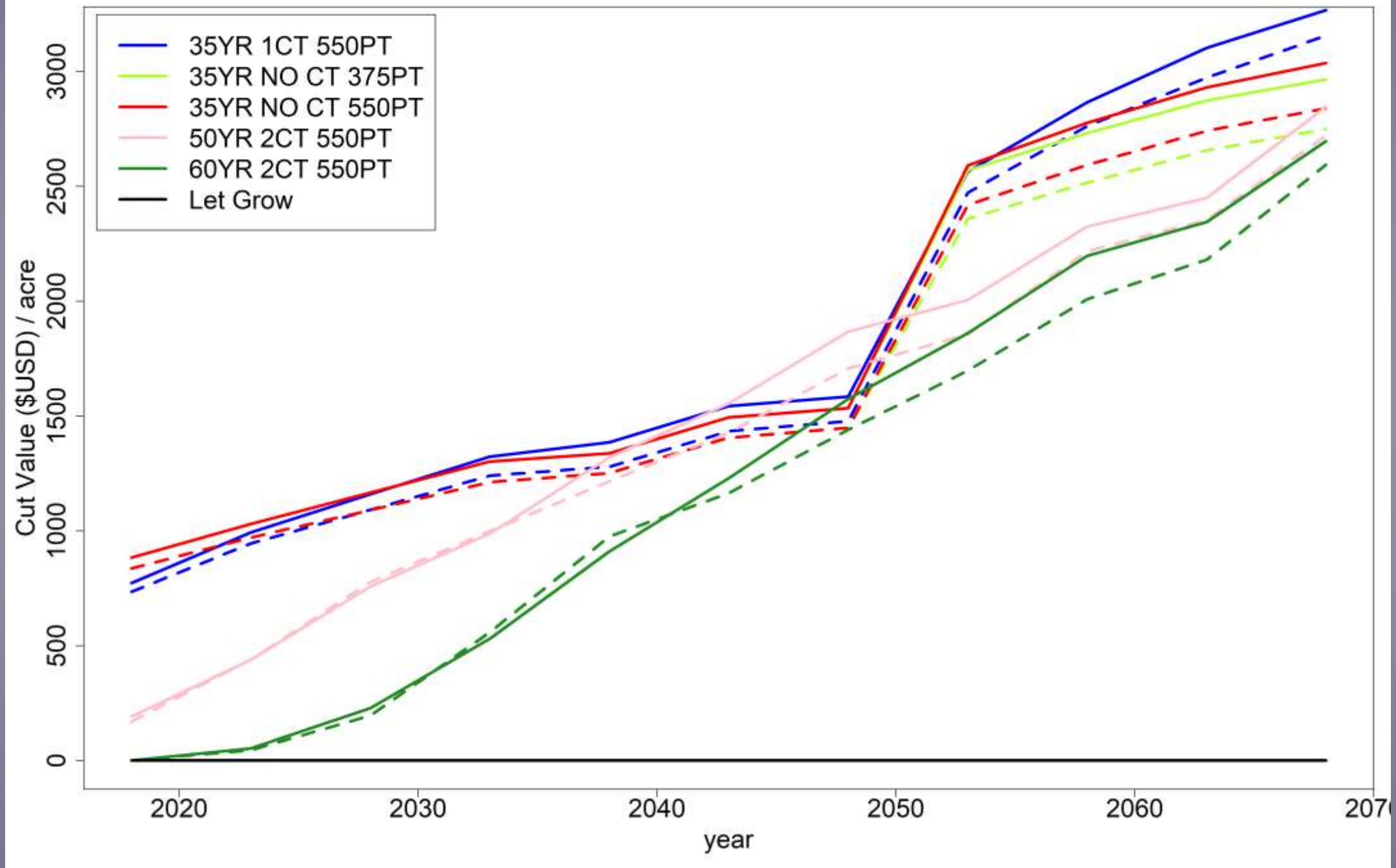
Lidar and Field: ≈Exact match

Cyclic – no clear winner

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

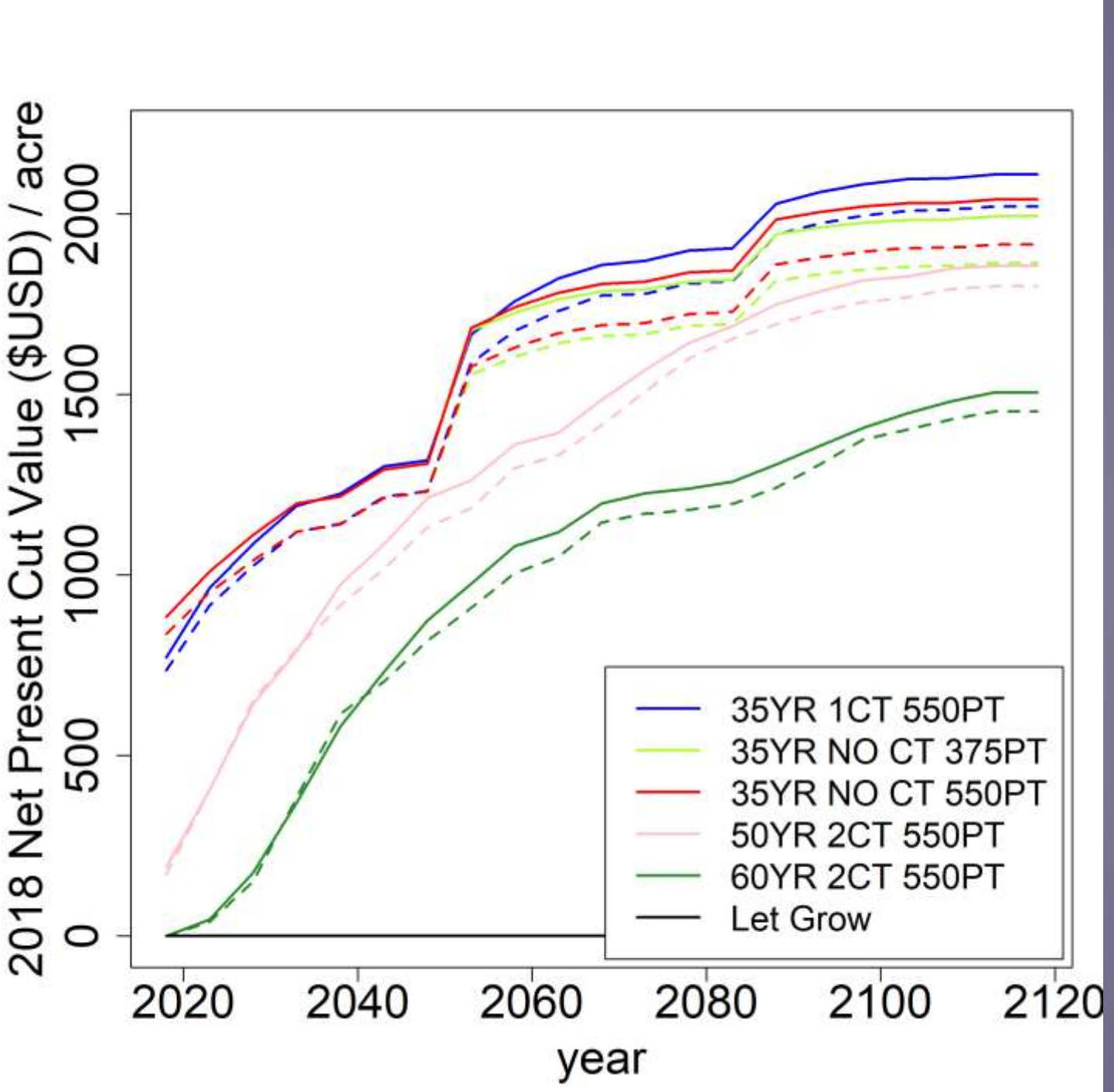
35YR NO CT - Losers




35YR 1CT 550PT
35YR NO CT 375PT
35YR NO CT 550PT
50YR 2CT 550PT
60YR 2CT 550PT
Let Grow
Cut Value ($USD) / acre
0
500
1000
1500
2000
2500
3000
2020
2030
2040
2050
2060
year

NPV (3%, 2018): More Interesting

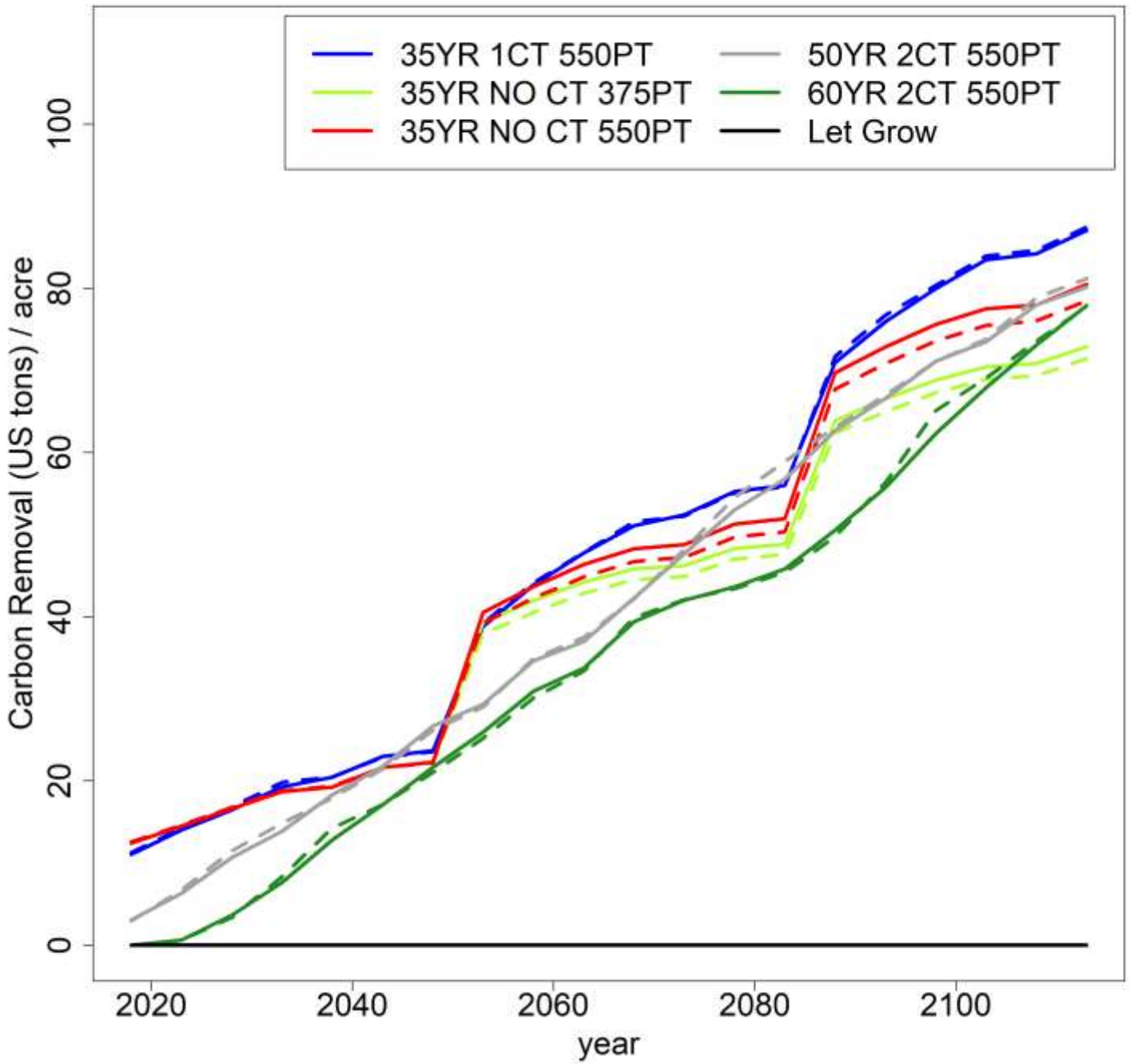
- Shorter rotations win …
- CT / no thin, planting density effects minimal



Carbon Removals as wood timber

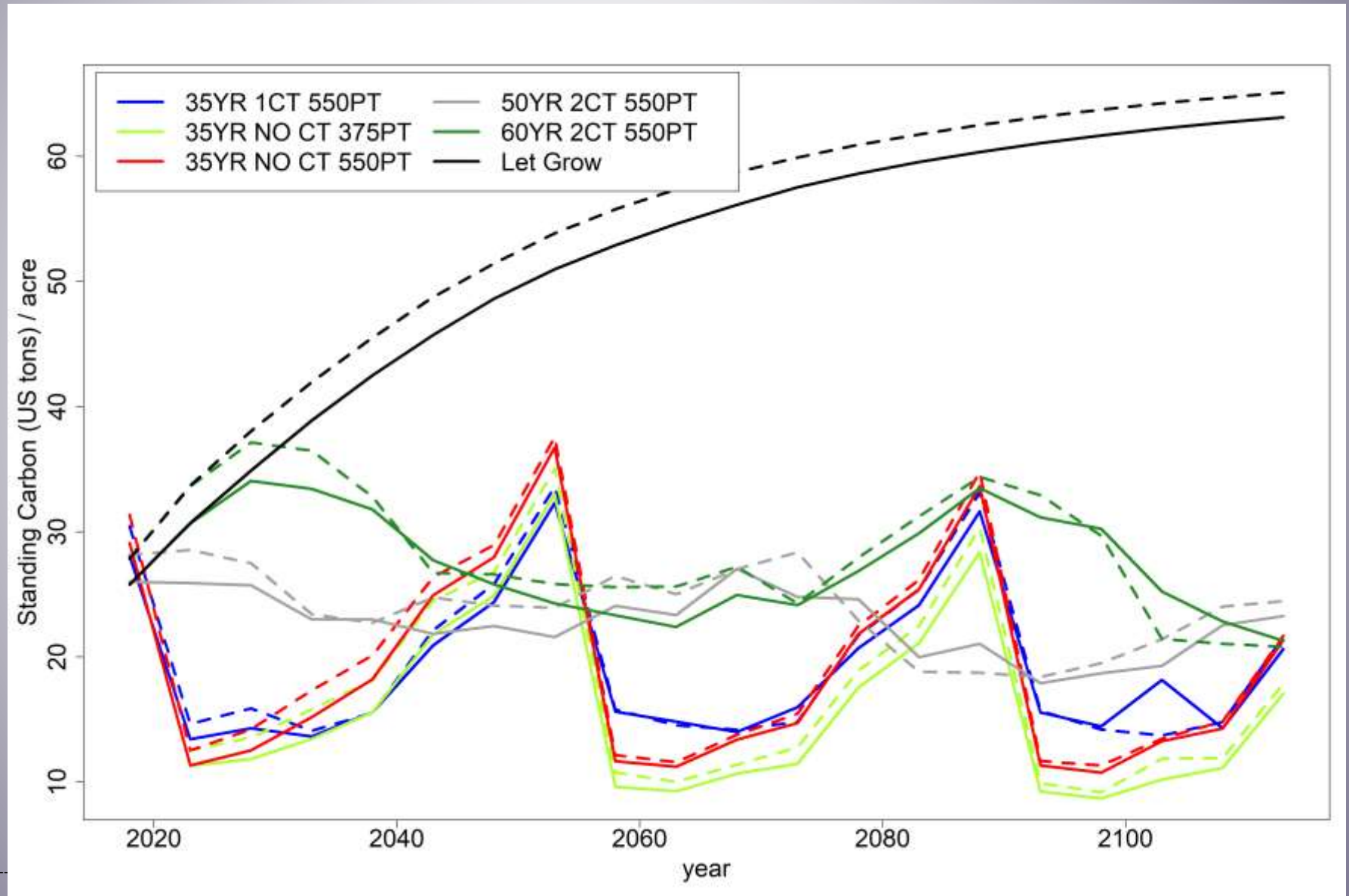
- Shorter rotations win …
- CT / no thin, planting density effects minimal

	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

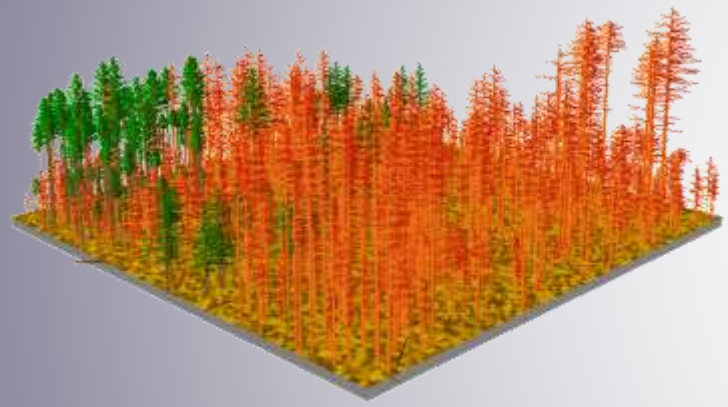


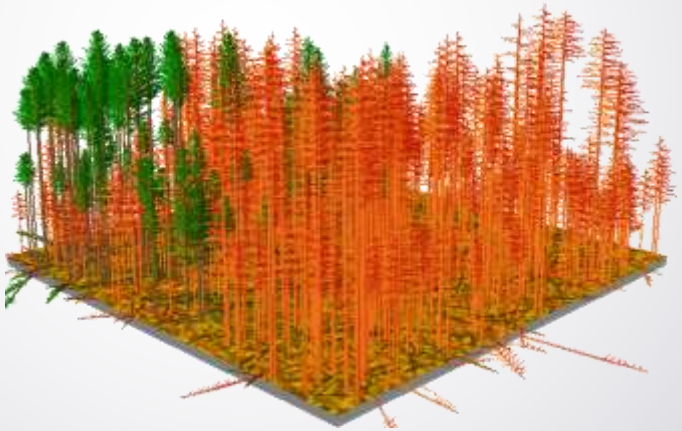
Standing Carbon

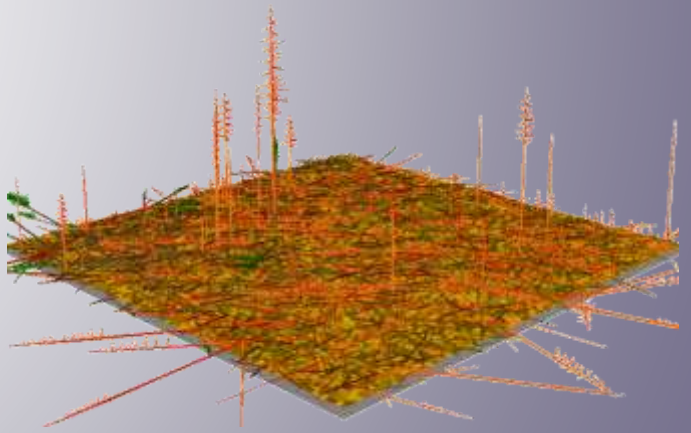
Lidar and Field: *Close Match*



Tactical (Stand-Level) Inventory







*Visualizations from SVS Software made by Robert J McGaughey

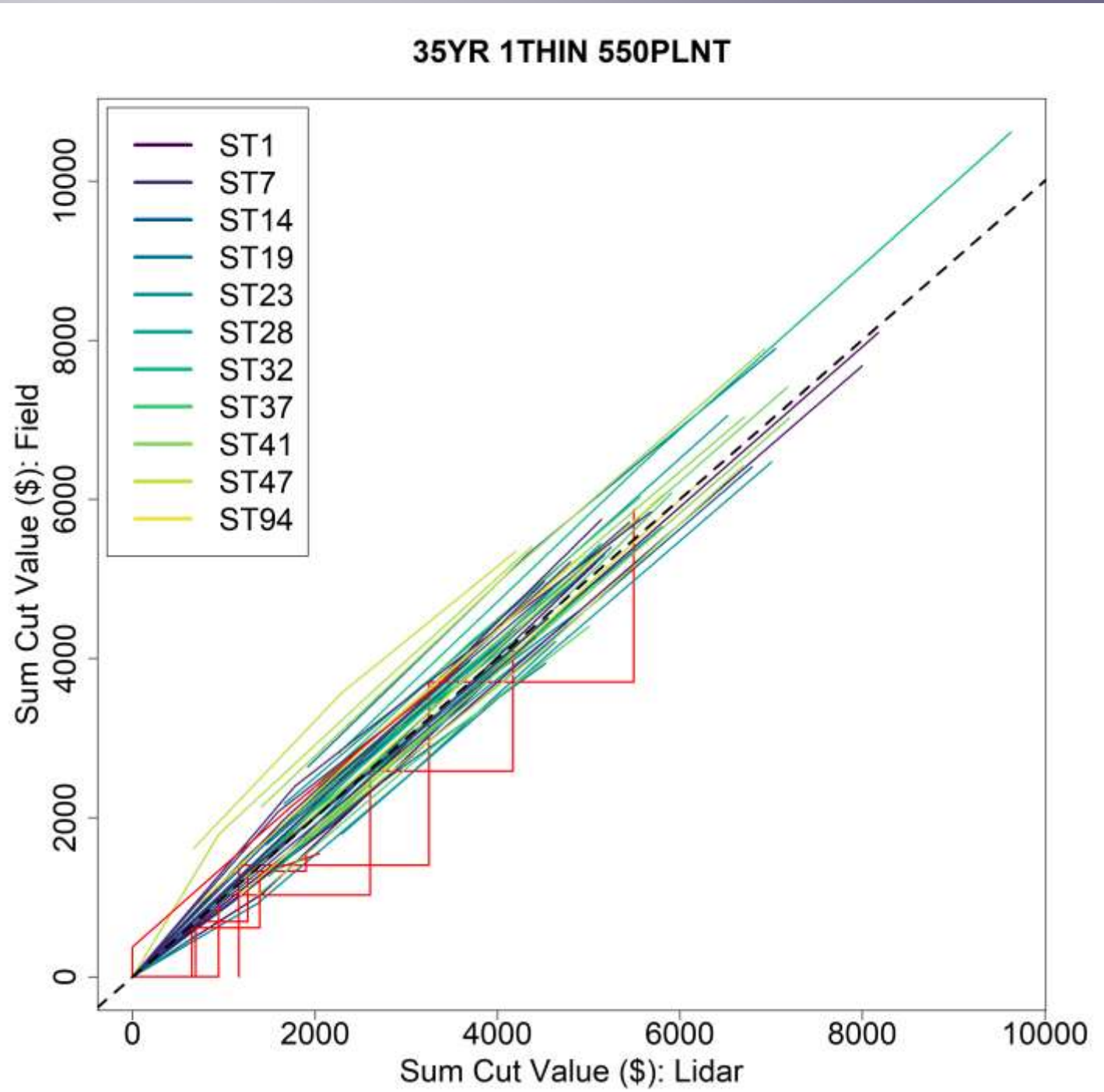
Example:
Temporal Trends by Stand

RED = Mgmt YR Mismatch

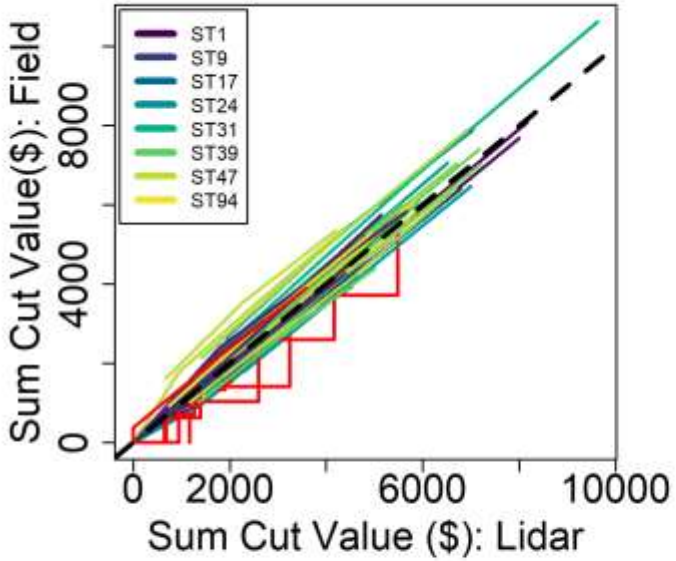
Example:

Lidar thinned 2023

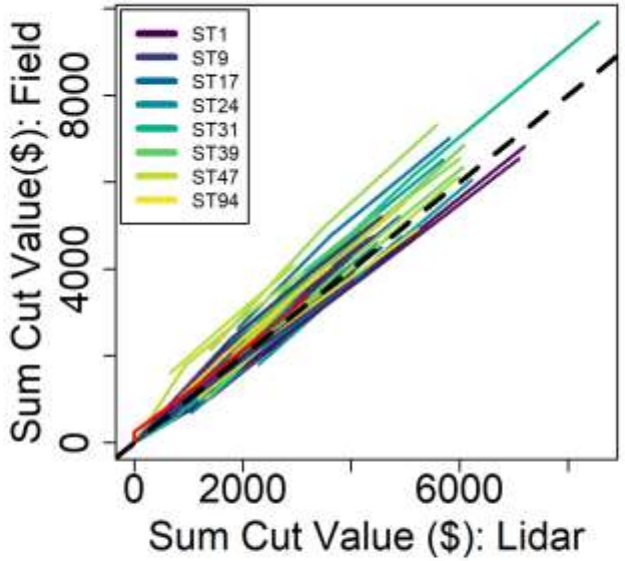
Field thinned 2025



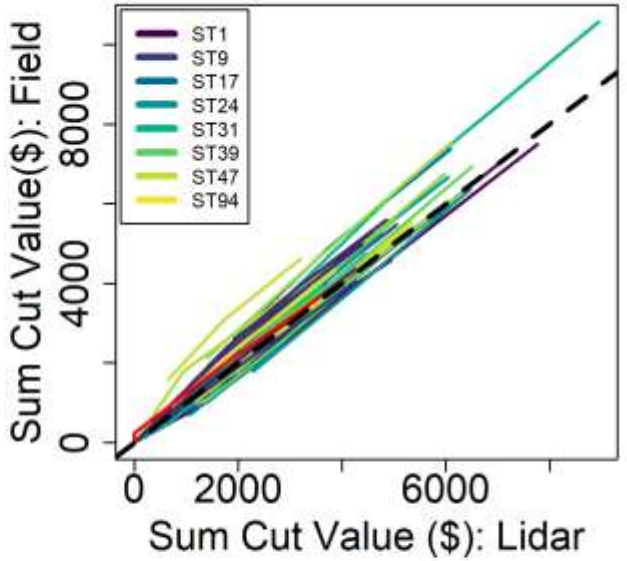
35YR 1THIN 550PLNT



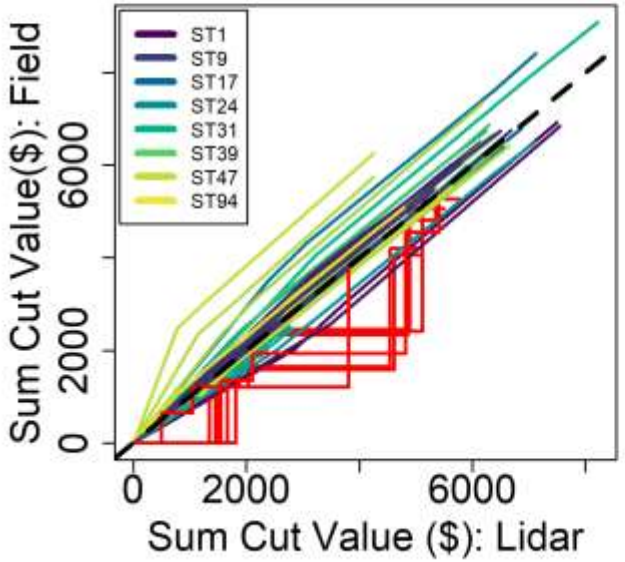
35YR NO THIN 375PLNT



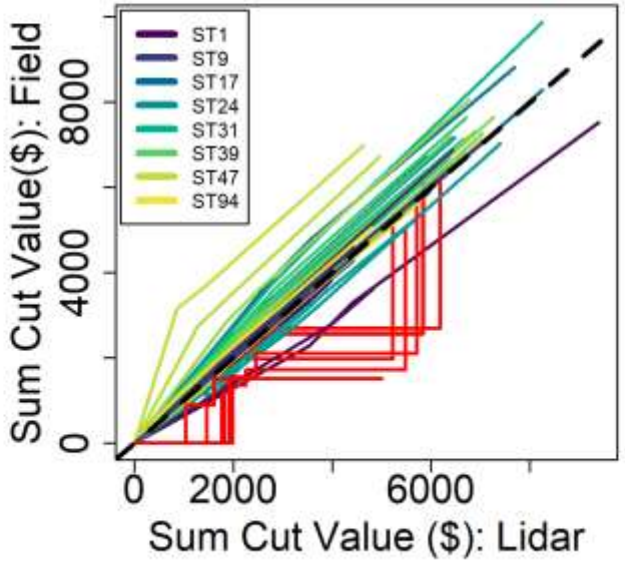
35YR NO THIN 550PLNT



50YR 2THIN 550PLNT



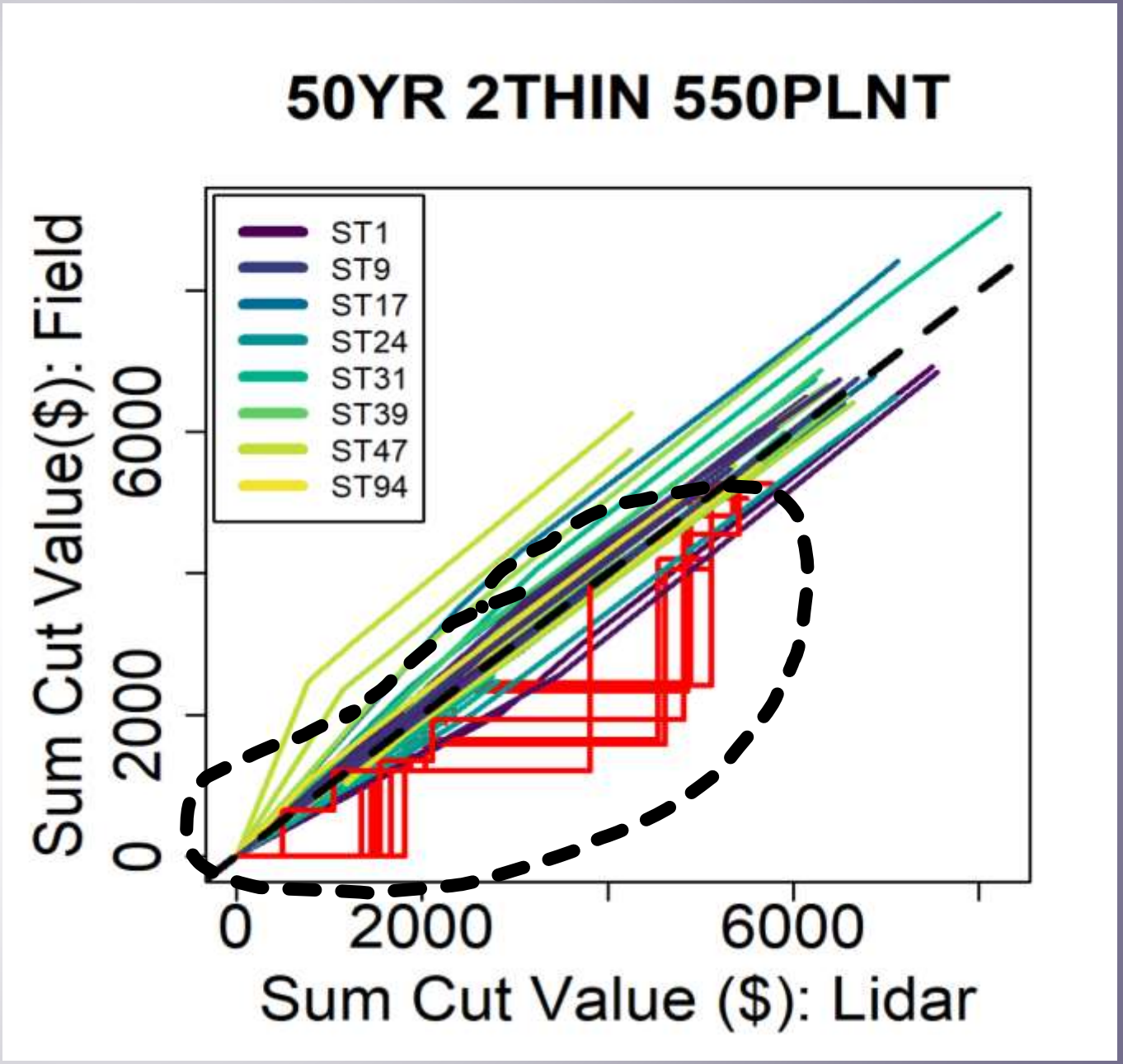
60YR 2THIN 550PLNT



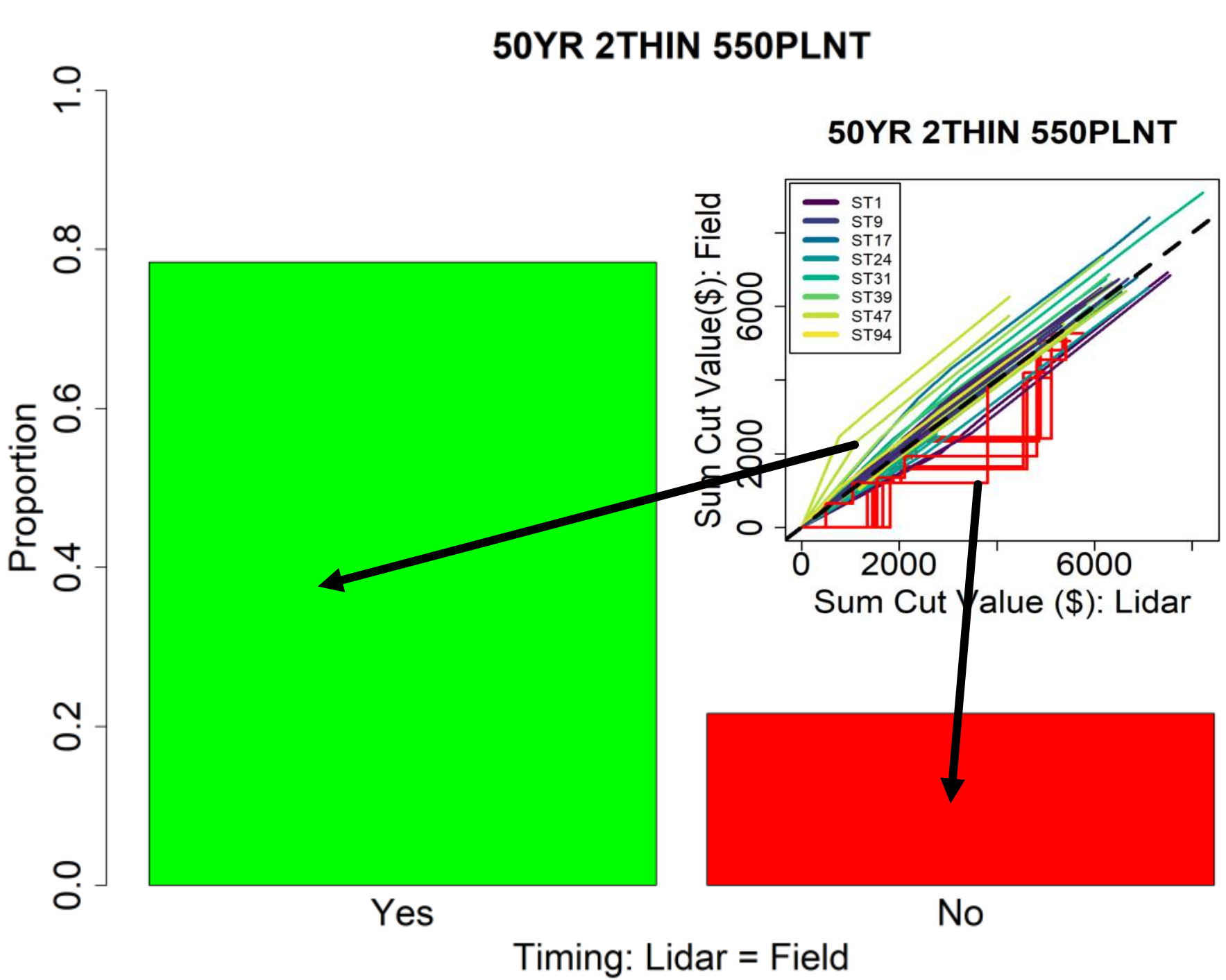
1) Initial Divergence

BUT

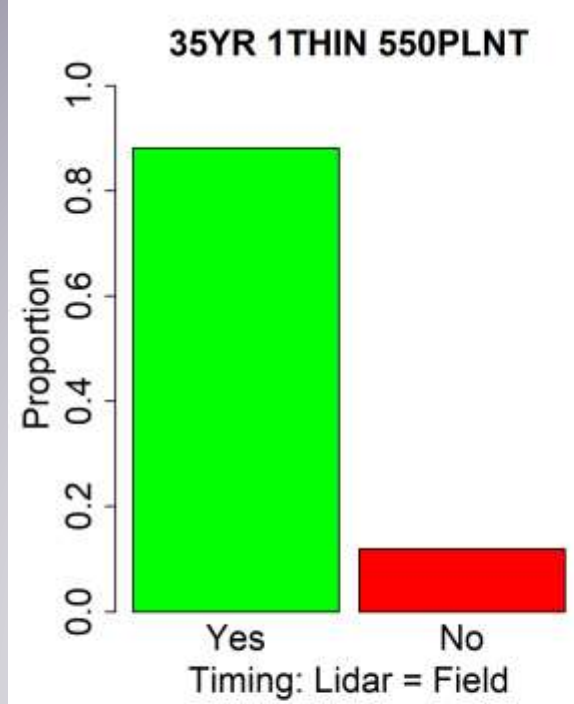
2) Reverts back to trend lines

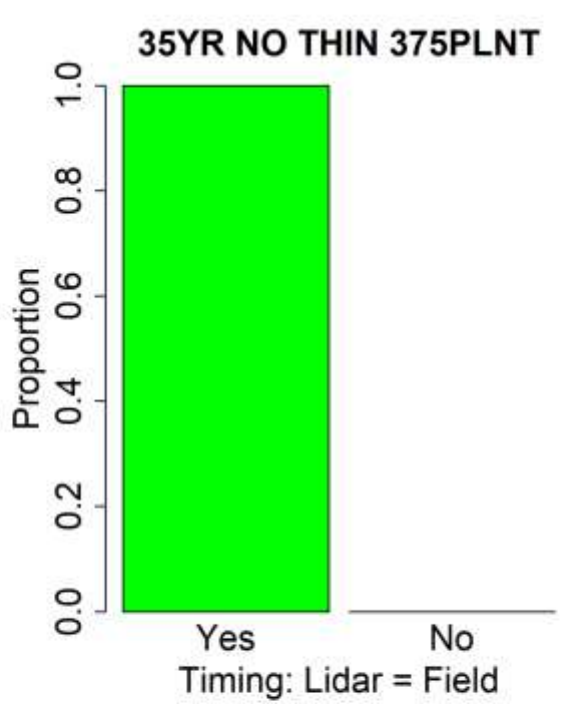


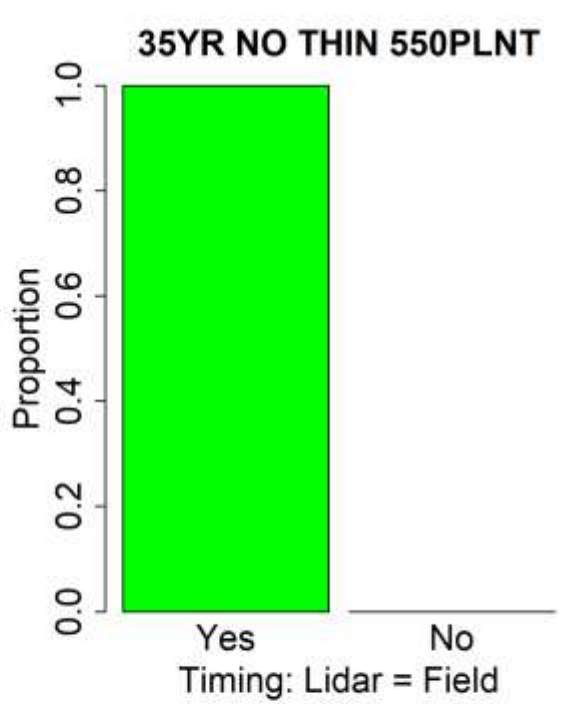
Timing Agreement

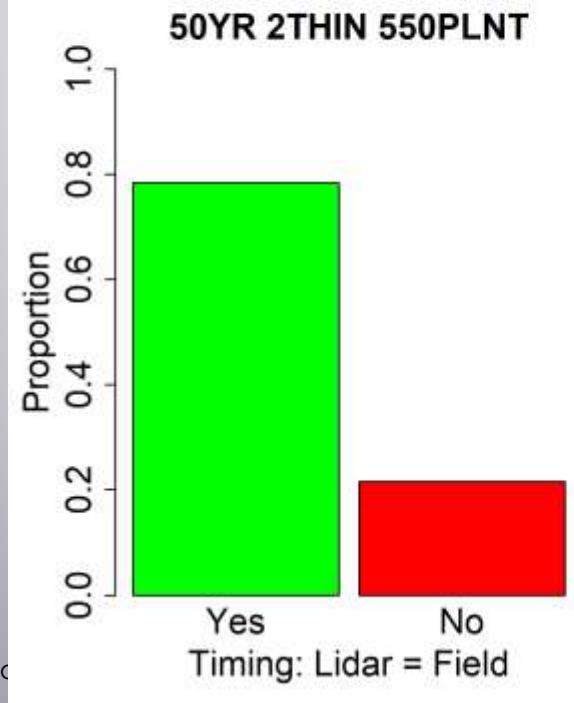


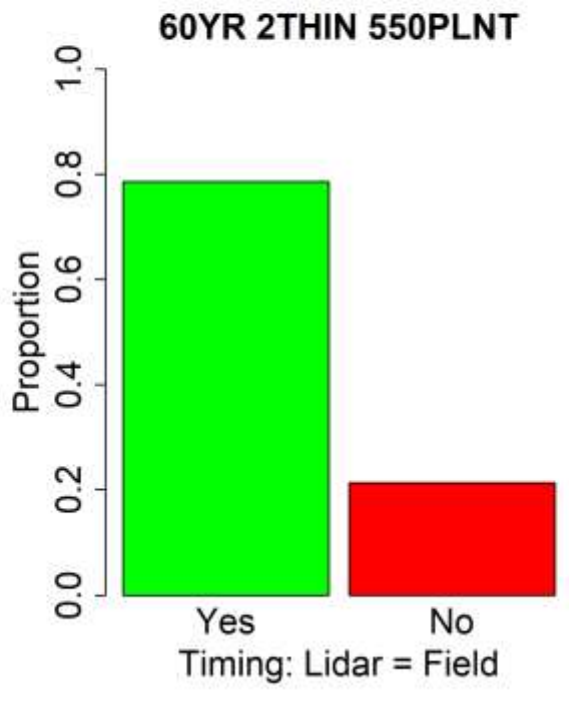
Timing Agreement

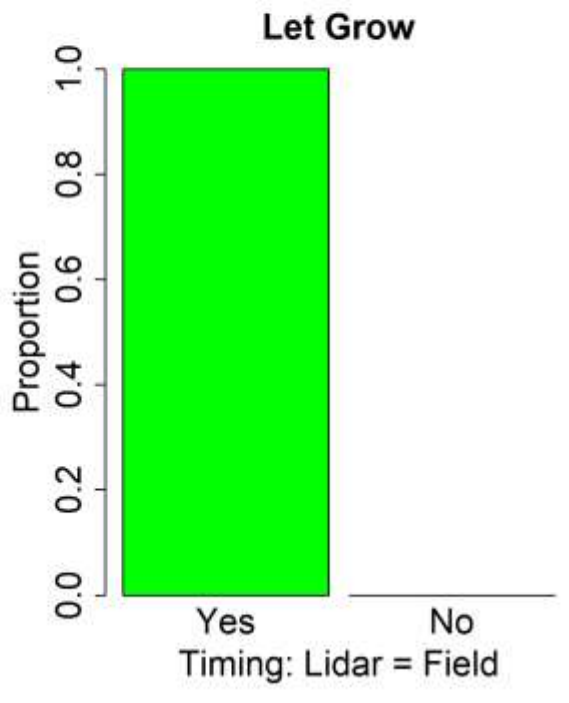








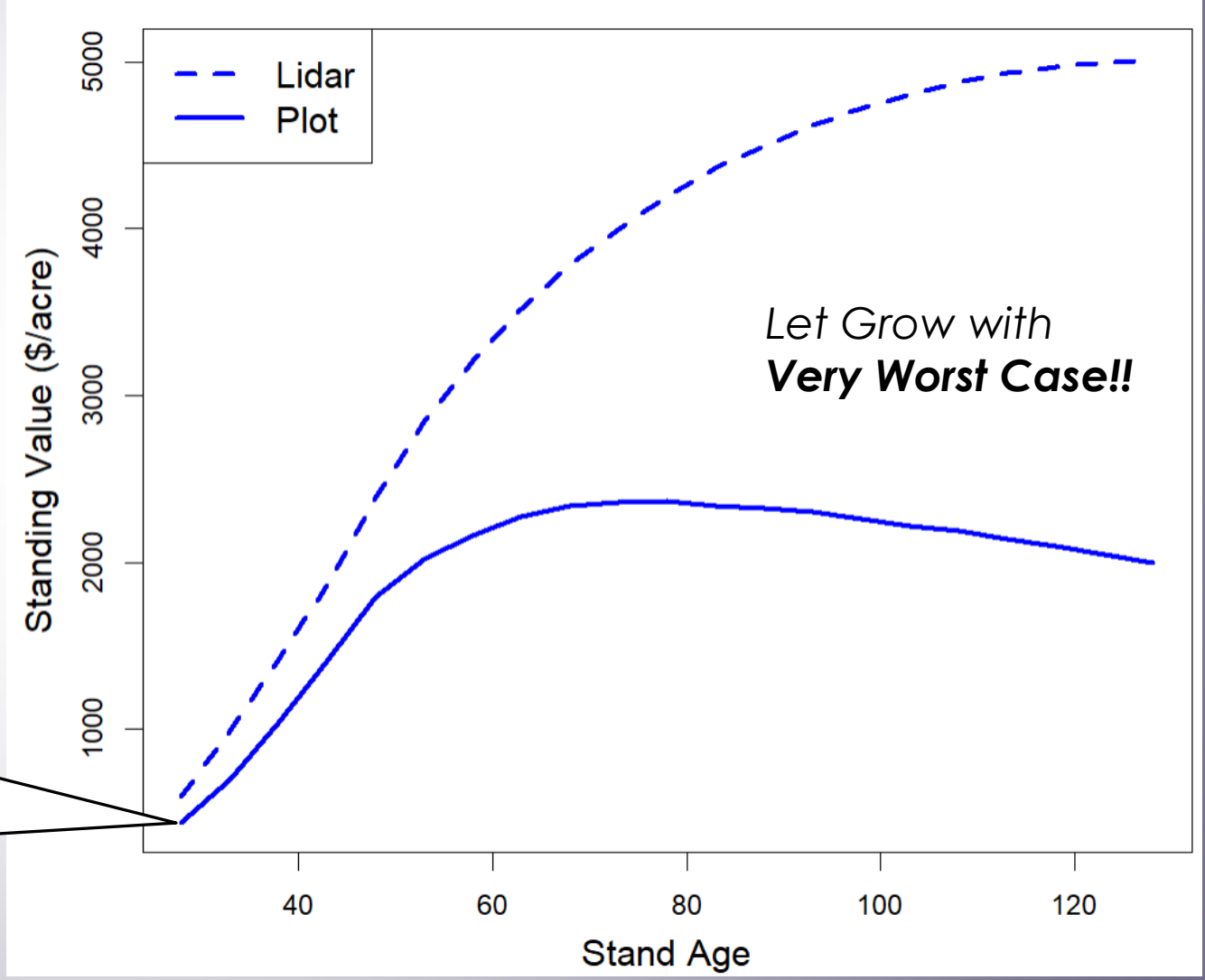




Diagnostics

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

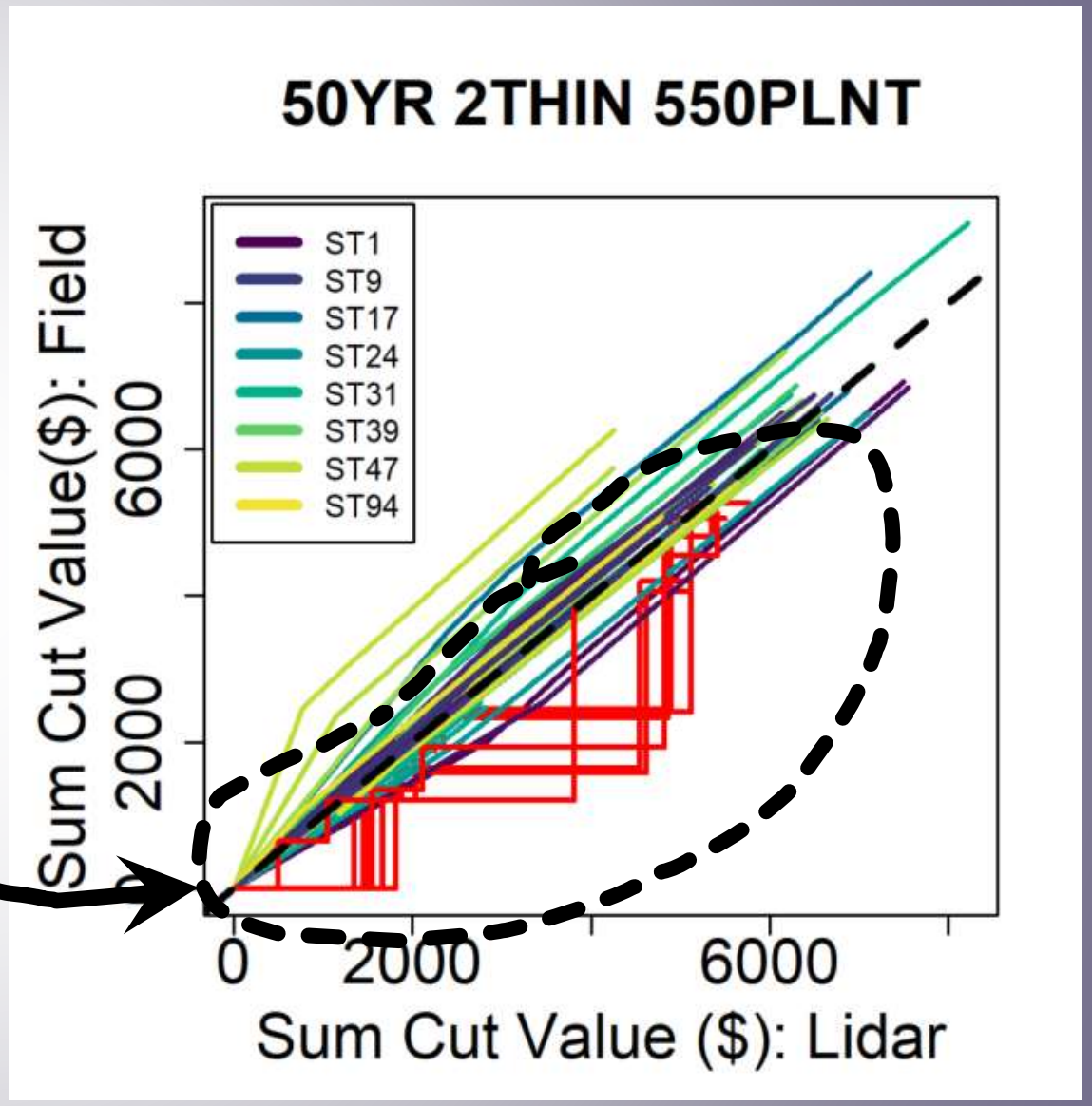
1) QMD has a moderate influence on basal area and trees per acre
2) Hardwood proportion has a strong influence on volume and value over time



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) **<u>*Plan is to look at forest estate models next</u>**



END

Questions?

Growth Projections

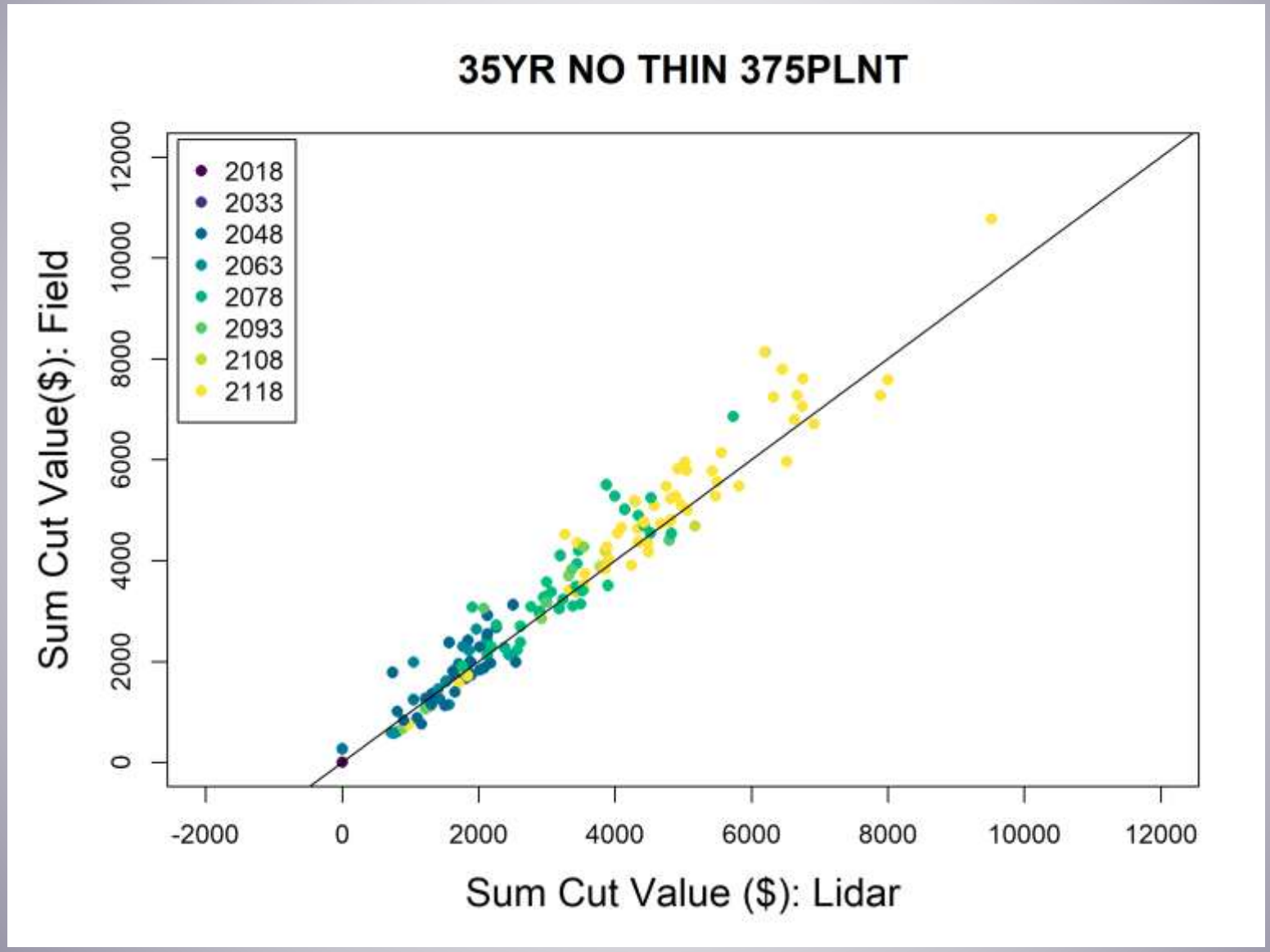
1) FVS Software - FVSsn.exe
2) Management scenarios
    A. 375 plant / acre, No Thin, 35 yr harvest
    B. 550 plant / acre, No Thin, 35 yr harvest
    C. 550 plant / acre, 1 Thin, 35 yr harvest
    D. 550 plant / acre, 2 Thin, 50 yr harvest
    E. 550 plant / acre, 2 Thin, 60 yr harvest
    F. No management (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

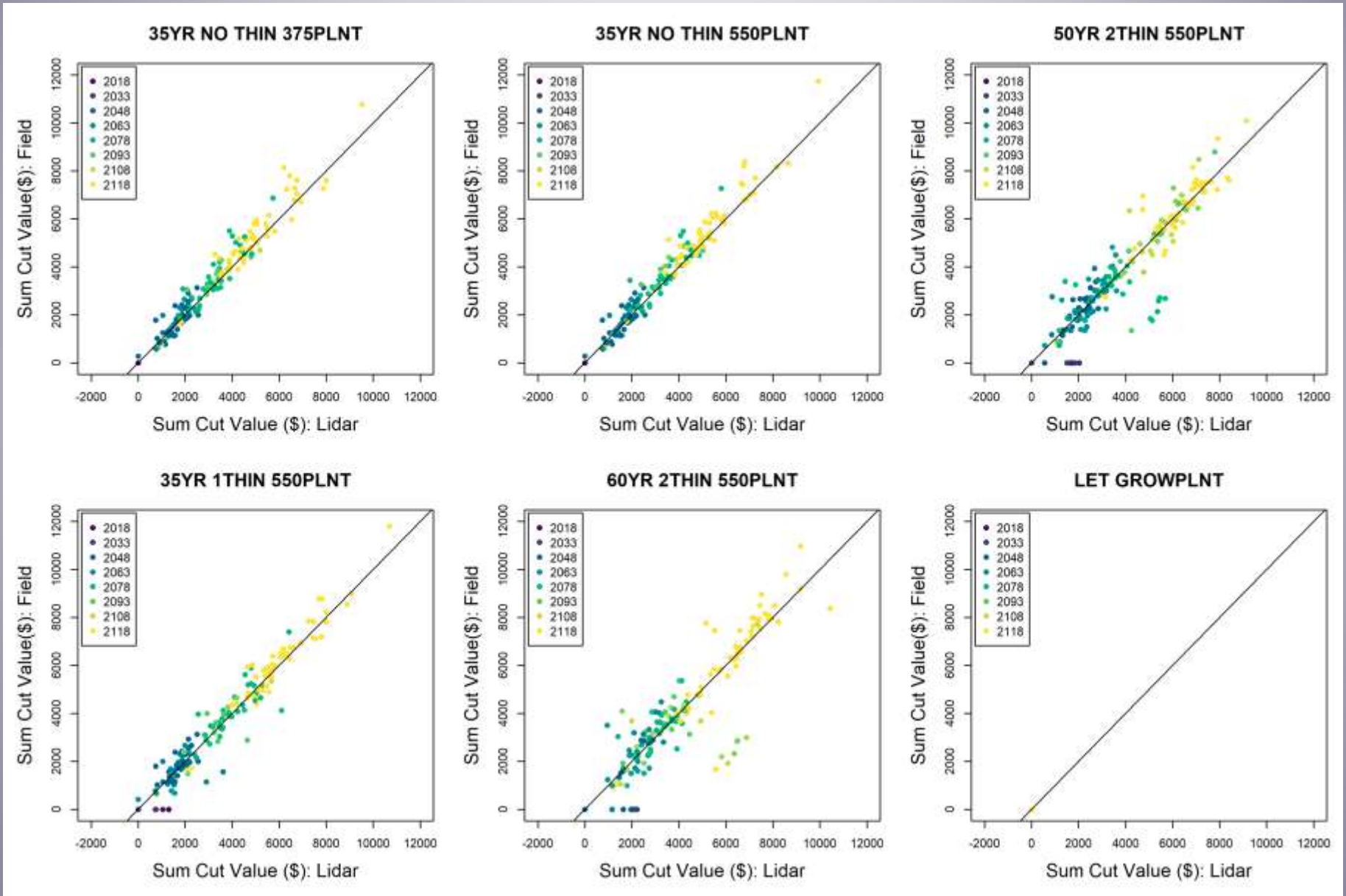
1) Lidar vs Field
    A. Tract
    B. Stand
2) Attributes
    A. Annual standing C, Value, Vol x product
    B. Annual volume growth, cutout, cut vol x product class , value
    C. NPV
3) Metrics
    A. Bias, RMSE, Correlation
    B. Coefficient of determination

OLD SLIDES

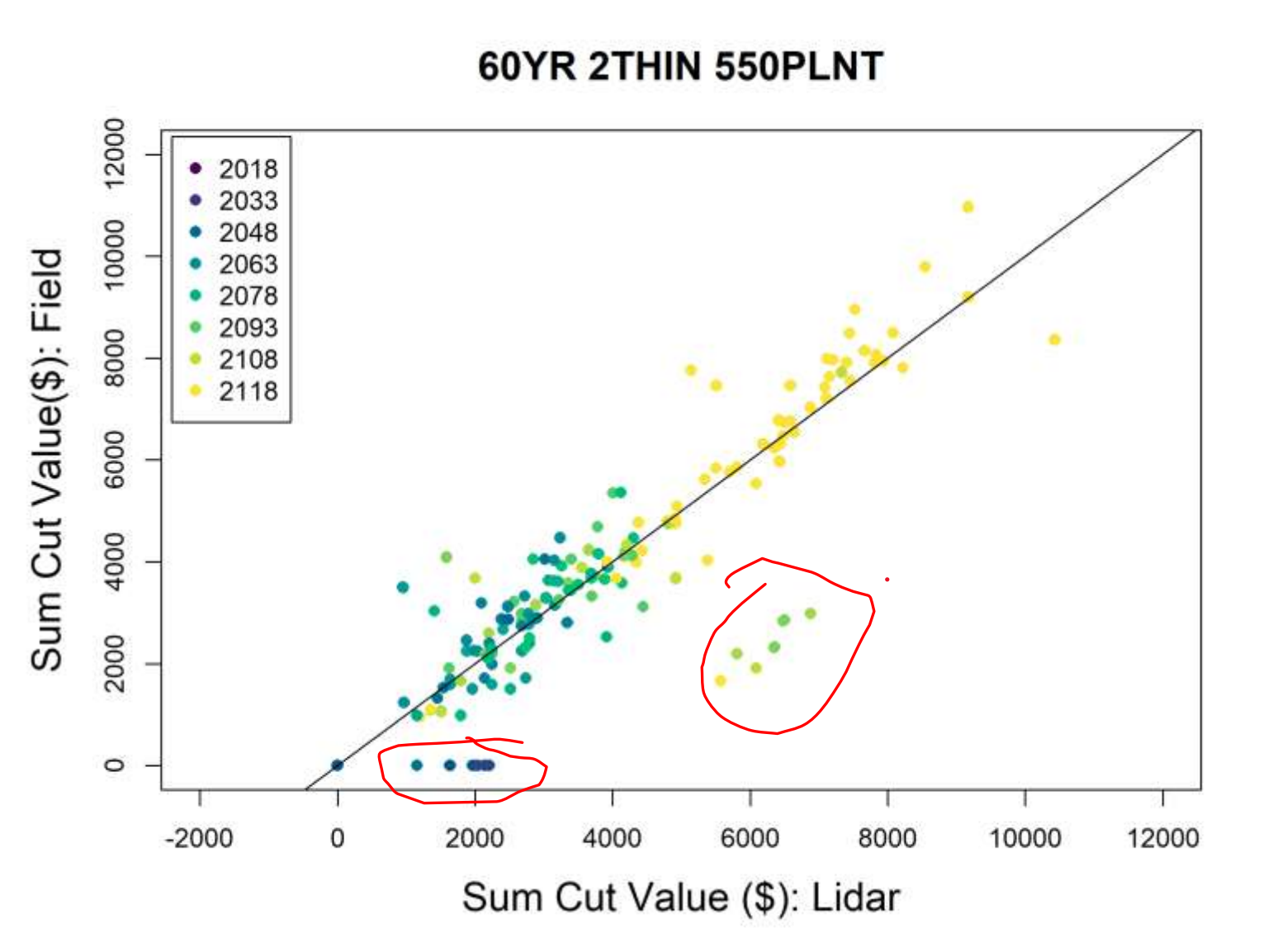
100 Years, Lidar VS Field: **Cut Values Match**



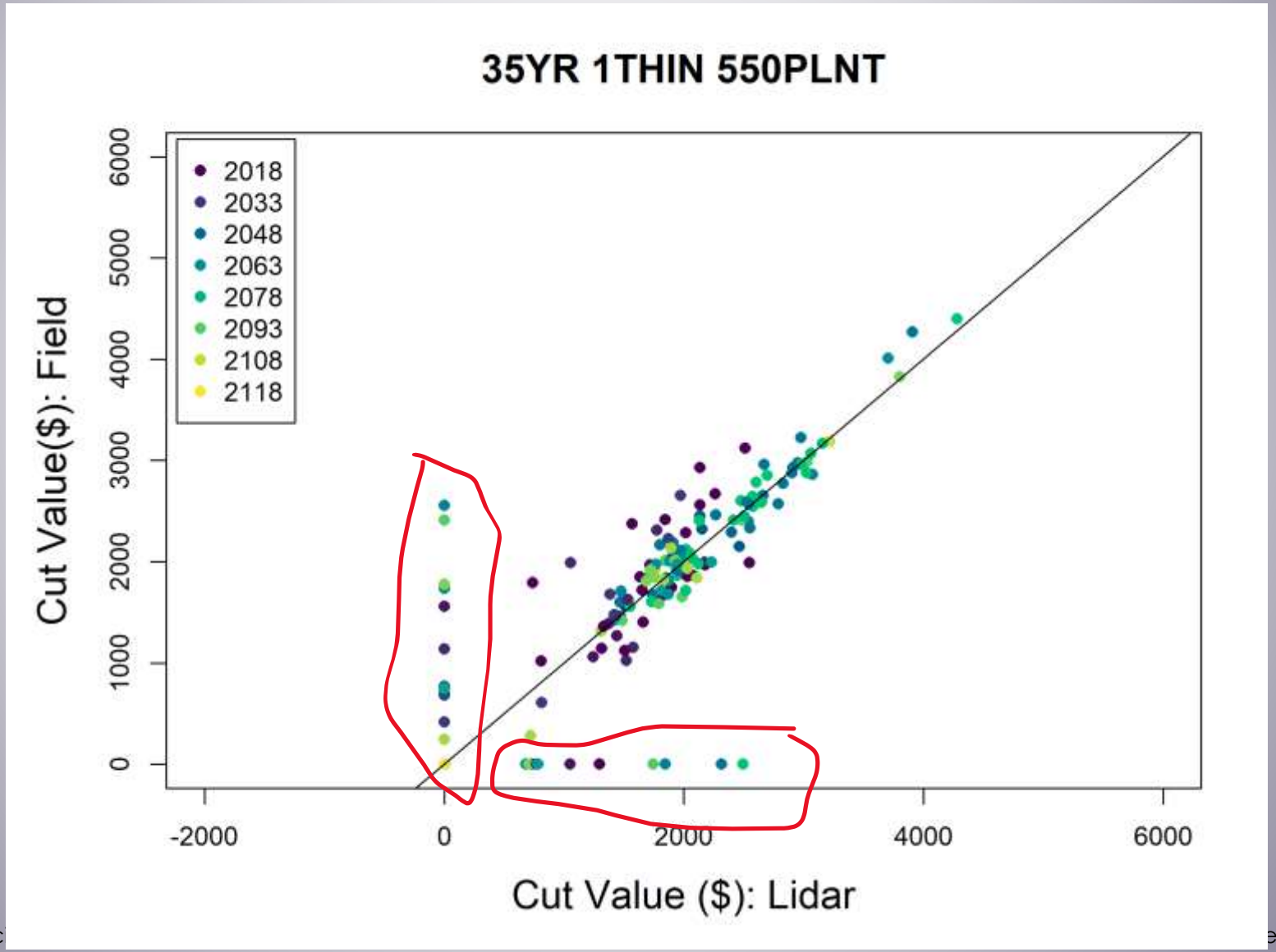
6 Scenarios: **Cut Values ($) Match**



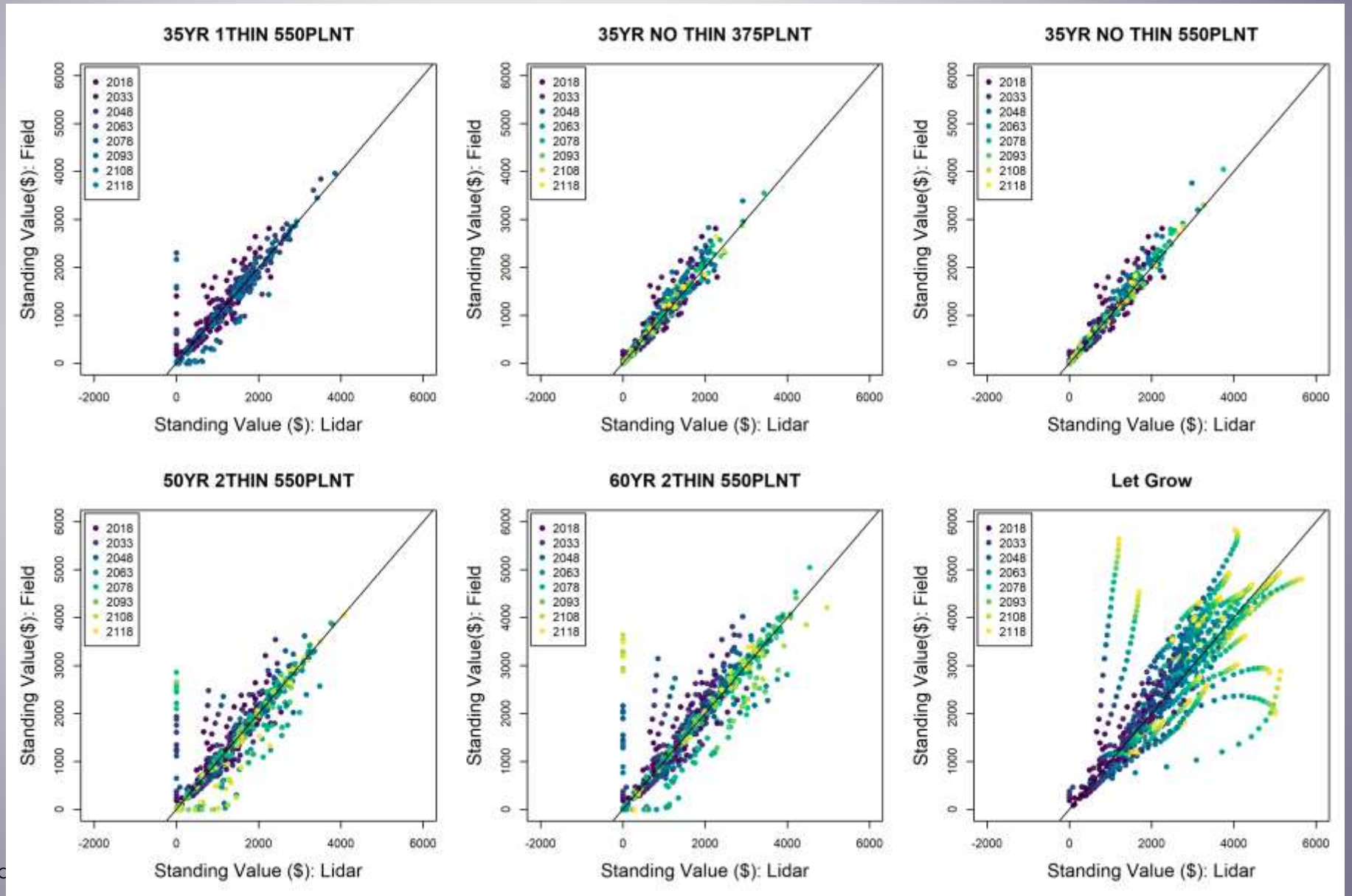
Temporal Mismatch – More Complex Mgmt



Annual (periodic) Cut Values
Approx. 1-period timing mismatch



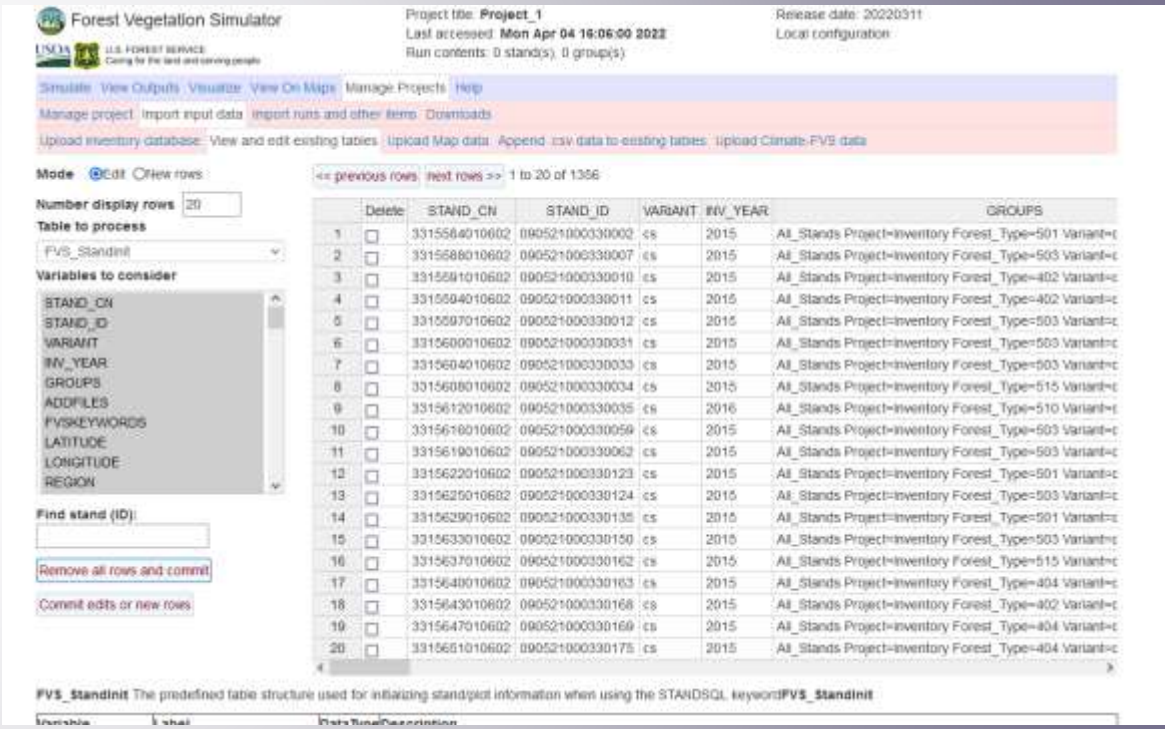
Standing Value



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?



FVS
Effect of Stand vs Plot

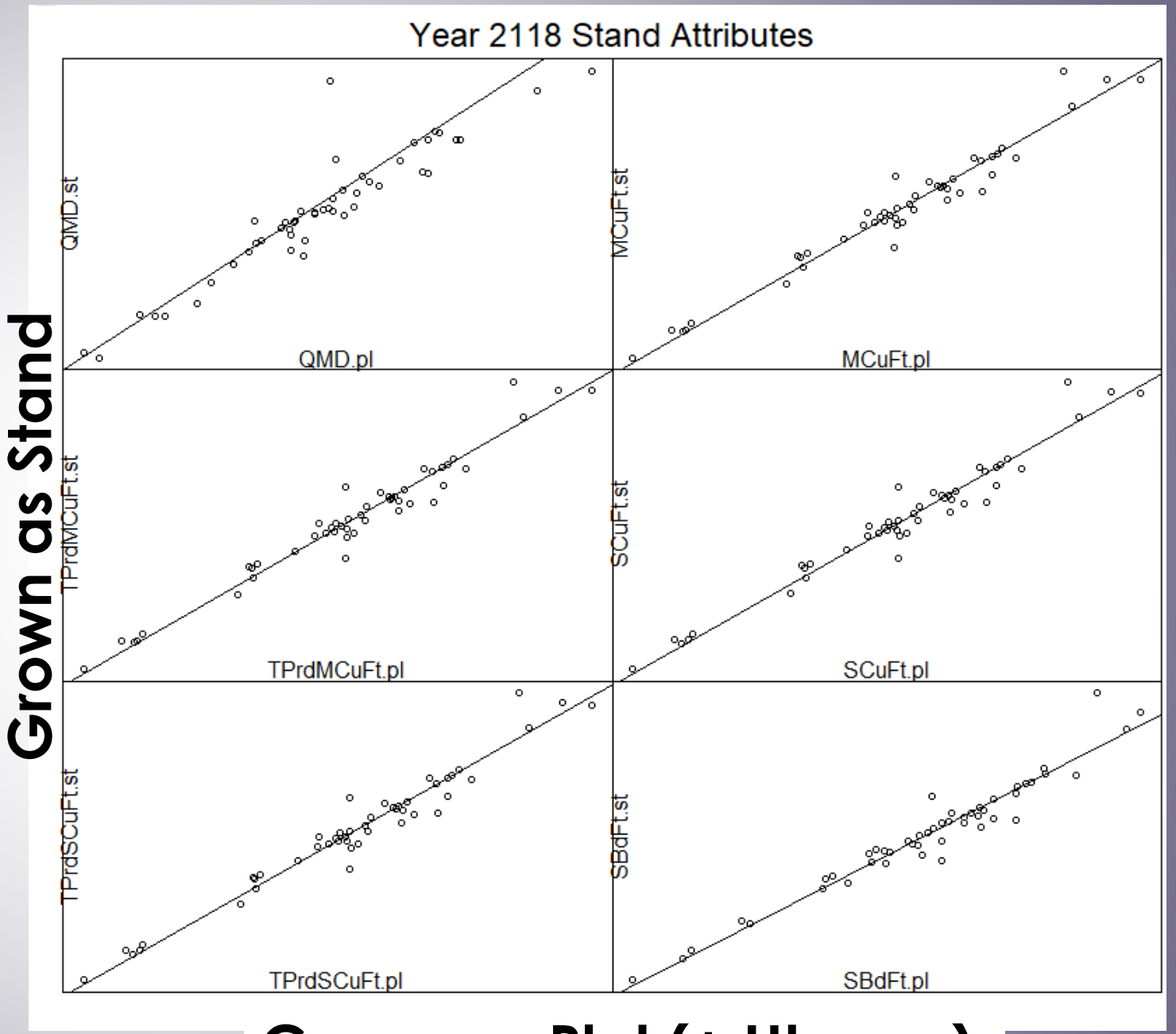
1) Grow tree
   A. 100 years
   B. As plots (+error)
   C. As stands

2) Yes: Stand level differences

3) ~Unbiased at 100 years

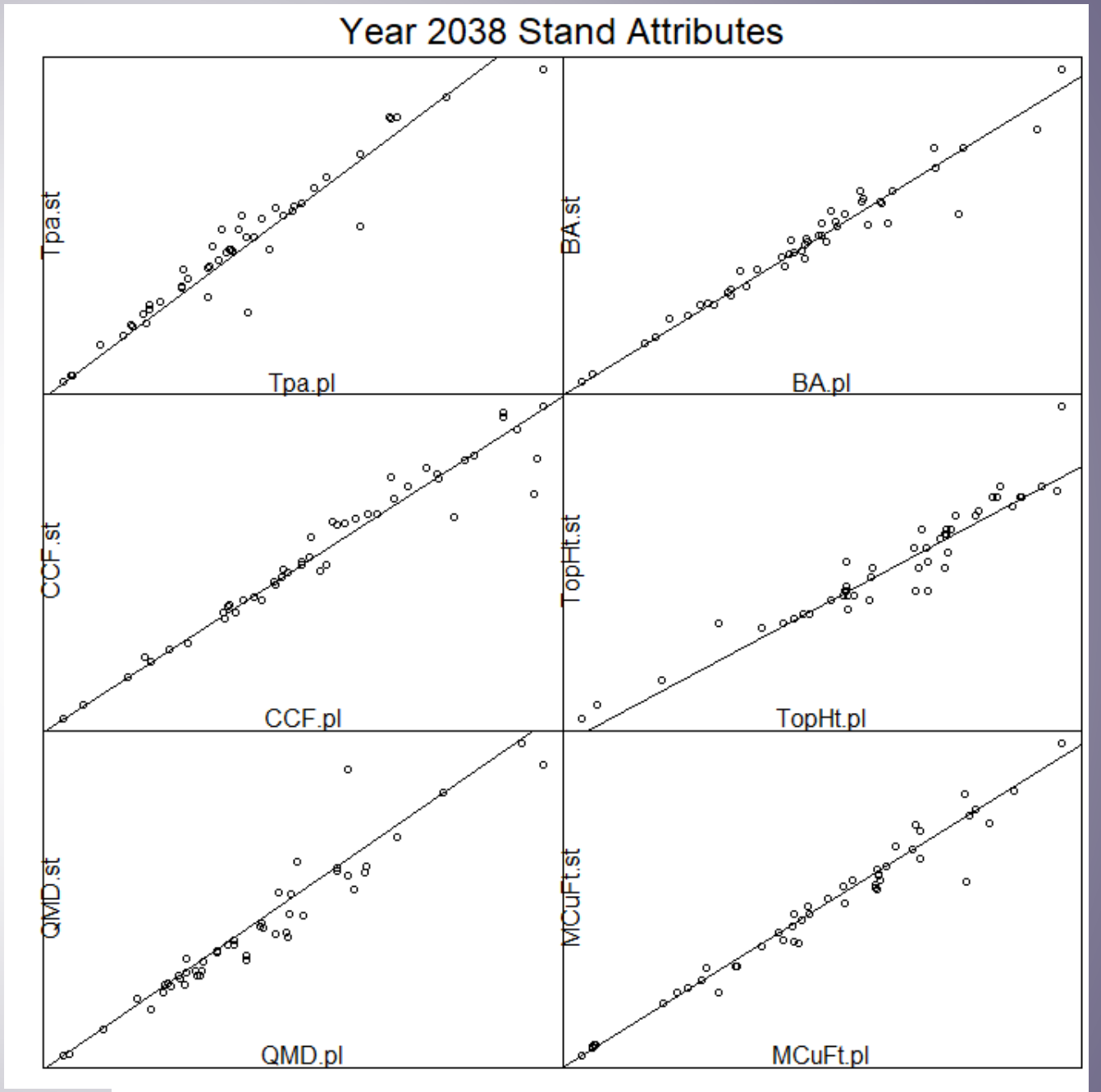
4) No effect from ht errors

5) Results same at 2038



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)