Improving Site Index Resolution with Lidar and Satellite Imagery to Refine Growth Model Predictions

Tom Baribault, Mark Rasmussen,
Donald Gagliasso
April 6, 2022

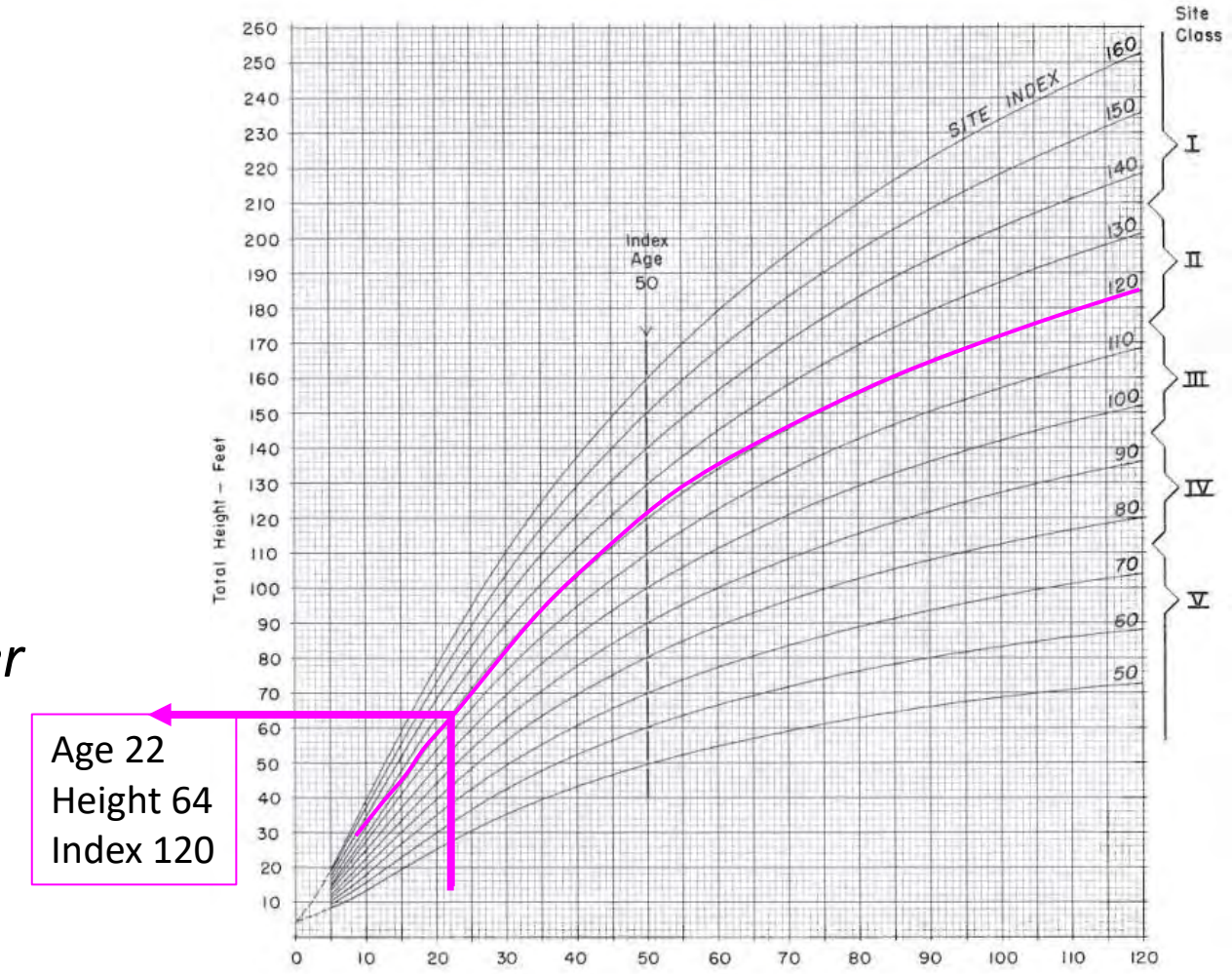
Background

- Purpose: calculate site index using known stand age and Lidar
- Data: public sources/zero-cost; 2009-2014; ~2 ppm
- Useful where:
  - New Lidar acquisitions are impractical or too expensive
  - Field-based site index unavailable or incomplete
  - Growth model results inform important decisions
- Applications:
  - Forest management, harvest scheduling
  - Due diligence, acquisitions, valuation
- Limitations:
  - No capacity for ground verification
  - Partial coverage, single species, requires stand age, ….

Abbreviations: Forest Vegetation Simulator (FVS); Site Index (SI); Douglas-fir (DF)

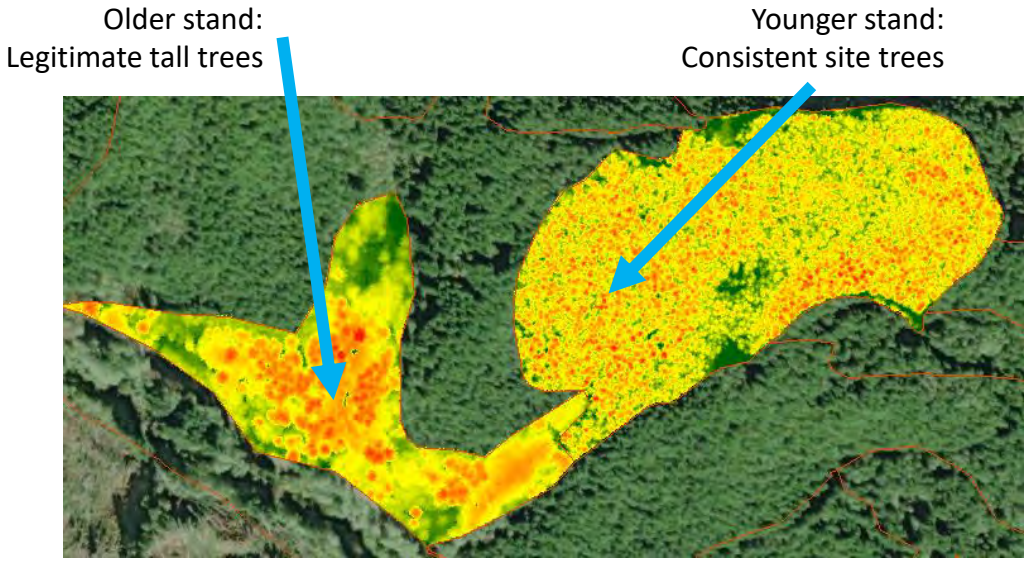
Site index review

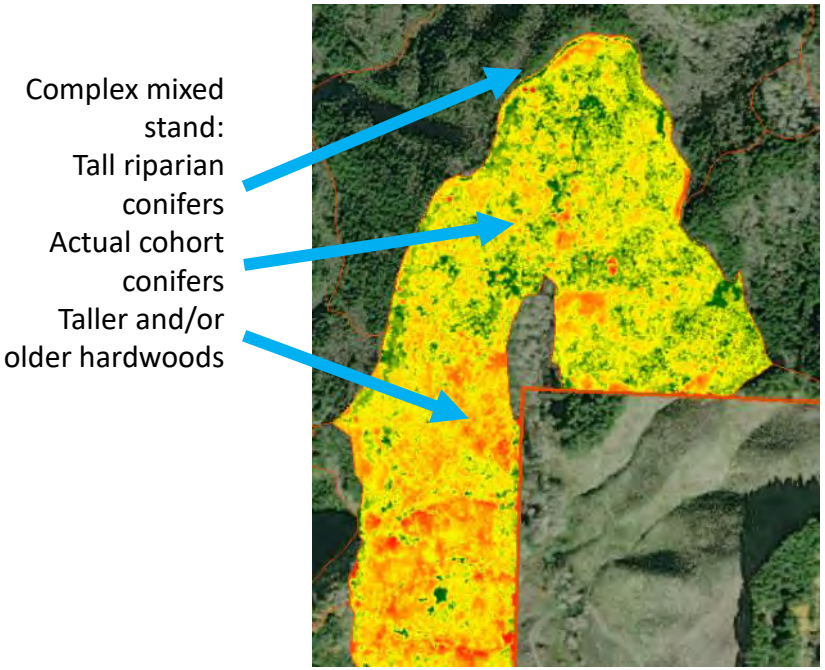
- Measure of productivity
- Important growth driver in FVS
- King SI for DF plantation
  - Defined for groups of 50 trees
  - Height of largest 20% of trees *by diameter*
  - Index age 50



Prototype

- Problem: received a uniform site index for >70% of stands in a due diligence project
- New site index:
  - Stand age, Lidar date, dominant tree height
  - King 50 DF site index for all trees
  - Stand-level average SI of top 20% trees by height
- Drawbacks:
  - Stand average ≠ King's 50-tree group method
  - Mixed species composition conflates RA, DF



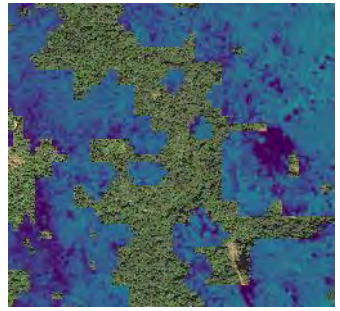


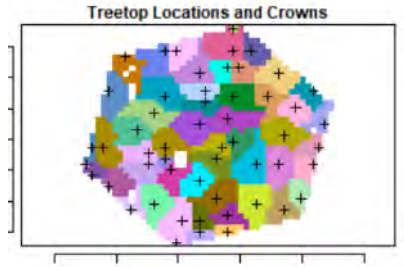
Update

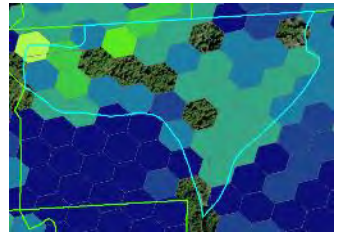
- Problem: inventory has historic site index groups or a cruise-derived site index
  - ~30% derived from cruise data
  - ~70% H, M, L from historic tax records
- New site index:
  - Stand age, Lidar-derived individual tree height
  - Species composition
  - King 50 DF site index for DF-class cover in 1-acre grid cell groups
  - Stand-level site index as acre-weighted average of component cells
  - Integrated with FVS calibration and growth projections
- Remaining drawbacks:
  - Dominant trees visible in Lidar over-represent large trees in sample
  - Uses average of top 20% trees in group *by height*
  - Relevant to ~100% DF plantation

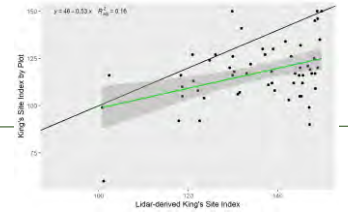
Overview of Lidar SI method

1. Lidar Canopy Height Map with acquisition date
2. Devise sampling units that replicate King's method
3. Detect tree top heights in all sampling units, subsample 20%
4. Species cover classification, conifer (DF) or deciduous
5. Compute $King_{50}$ DF SI if DF cover type
6. Calculate stand-level Lidar SI
7. Recalibrate FVS for use with stands that have new Lidar SI
8. Apply suitable FVS calibration for inventory updates or harvest planning corresponding to site index source



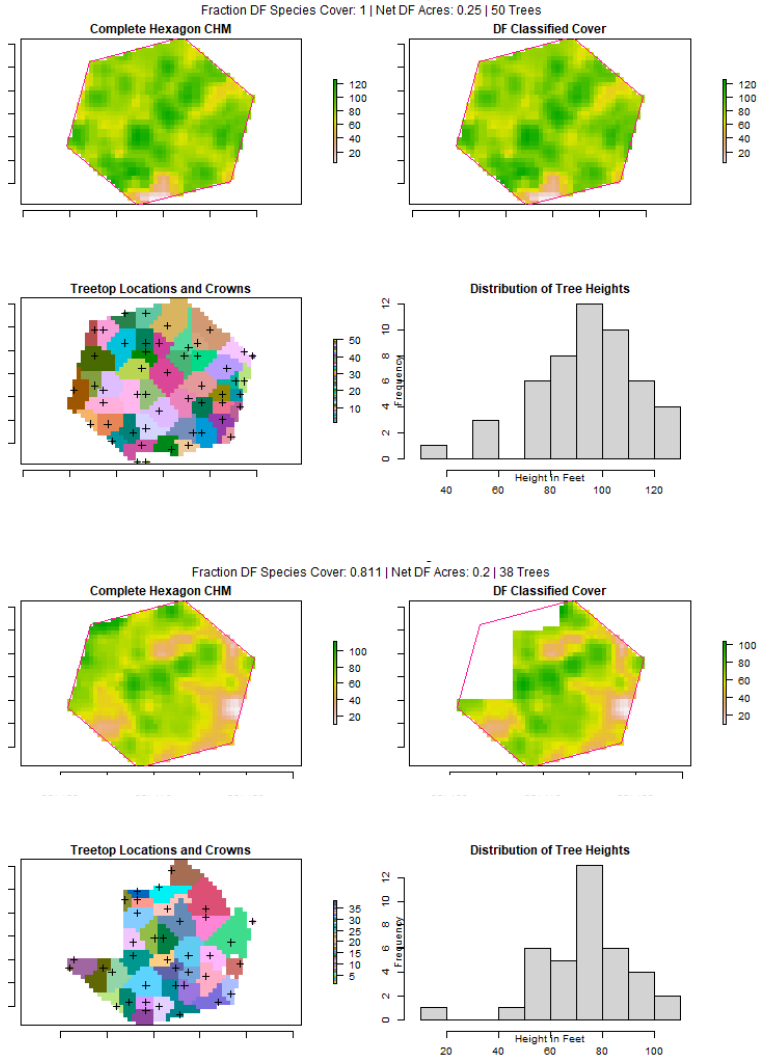






Replicating King's SI method

- Required a plot containing at least 50 DF trees
- Samples the largest 20% of trees by diameter
- Unknown how many trees per plot in CHM
  - Tested 0.25, 0.5, 1.0, and 2.0-acre hexagon plots
  - Trees per plot ranged from 40 to 300
  - No substantive difference in 0.25 to 1.0 acre
- Overlay species cover classification on hexagons
- Balance sampling with computational efficiency
  - King opted for 50 trees per plot for ease of fieldwork
  - 0.25-ac needs 8x more computer time than 2-ac
  - 1-ac cells work well



Area sensitivity

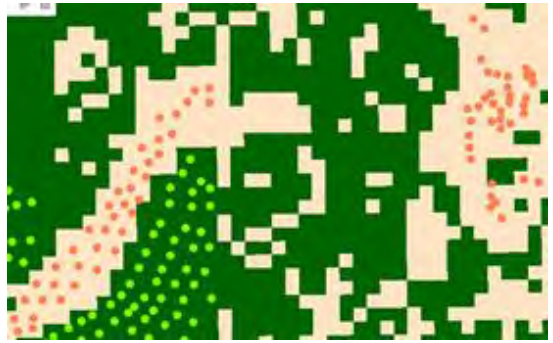
- 0.25-acre hexagons most reliably capture 50-tree groups
- Larger groups are acceptable, to a point

MASON, BRUCE & GIRARD
Insights. Ideas. Integrity.

Species cover classification

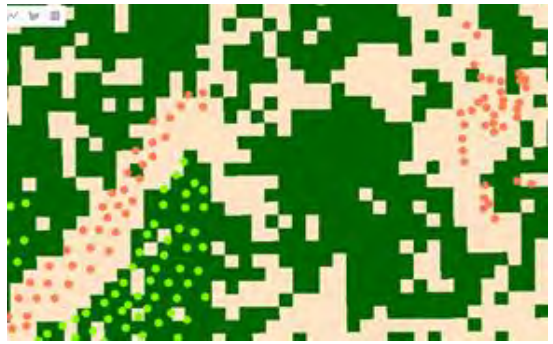
- CART in Google Earth Engine using LANDSAT 8 imagery
- Training points manually selected using contemporary mosaic imagery
- Classification by majority through 10 quarters preceding training set

Classification 2018, Q1



…

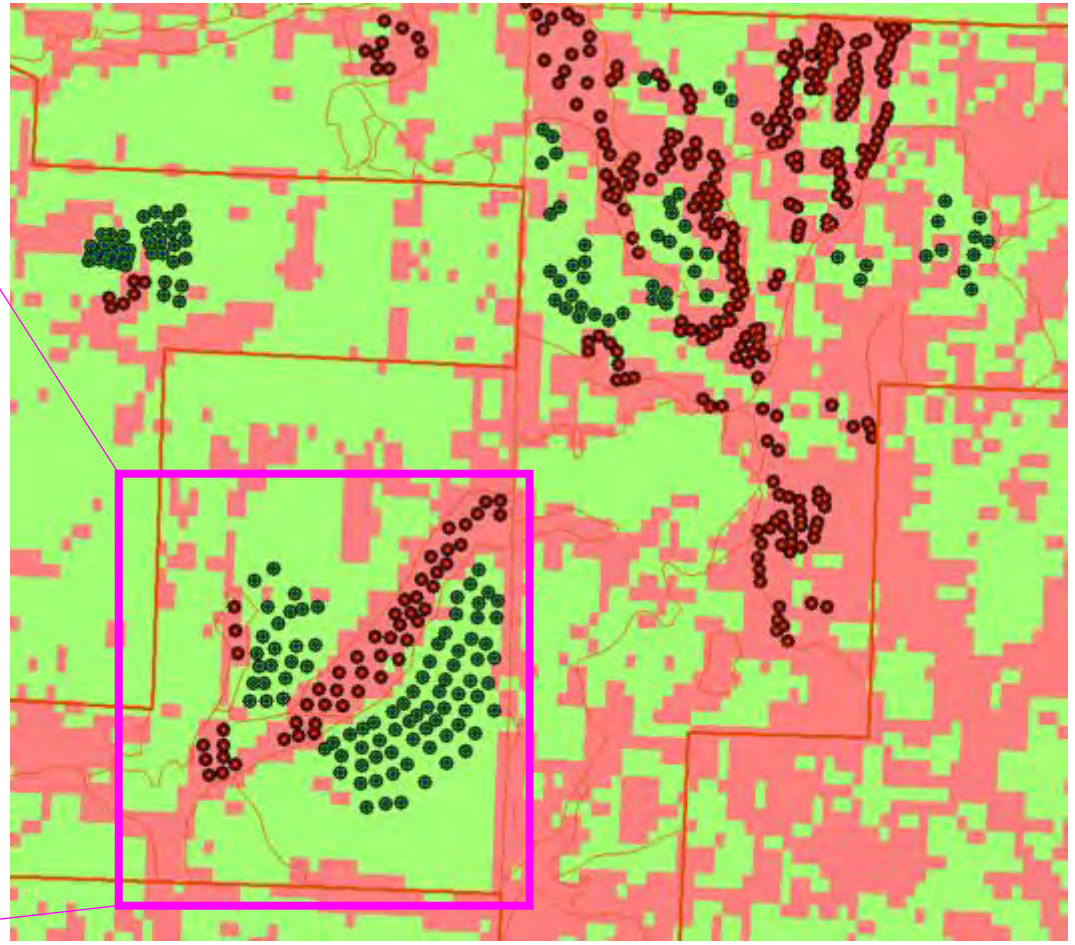
Classification 2021, Q3



Species cover classified

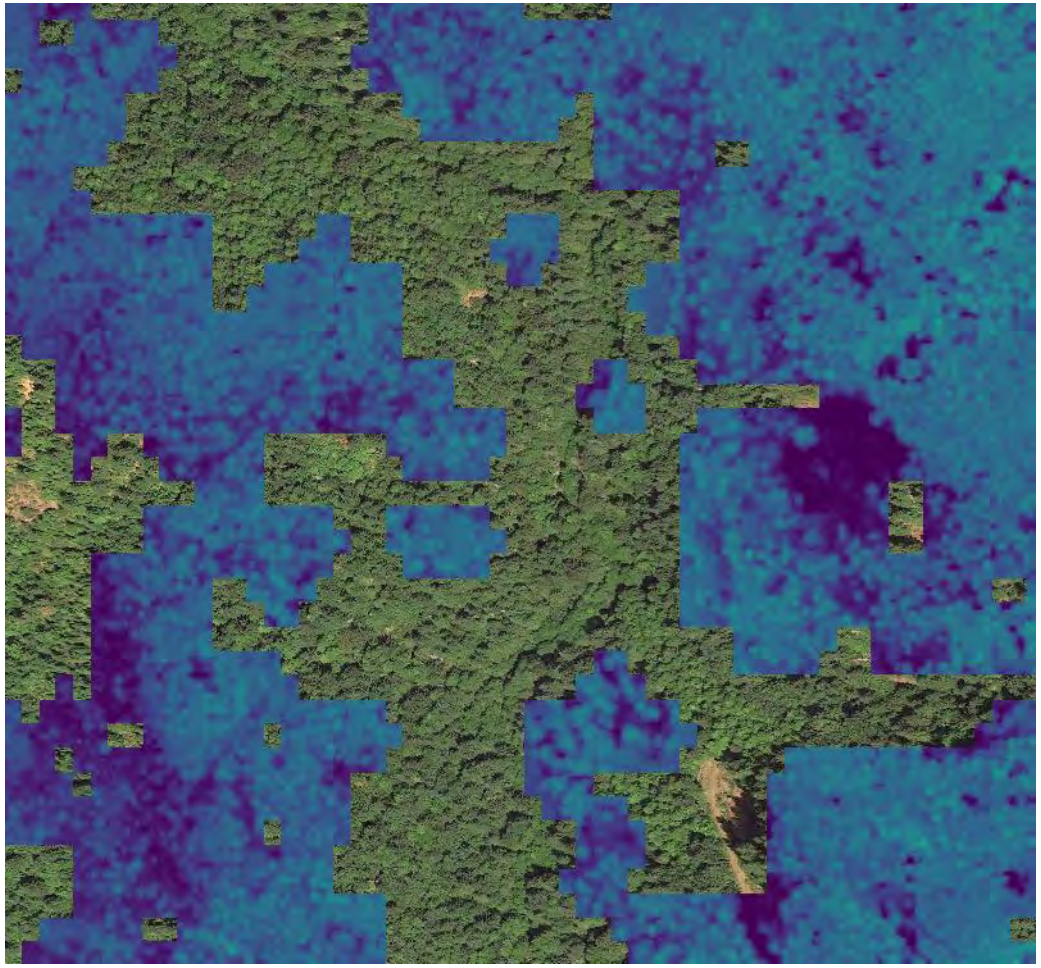
Contemporary satellite mosaic (ESRI basemap *ca*. 2019), **deciduous training points**, **DF training points**

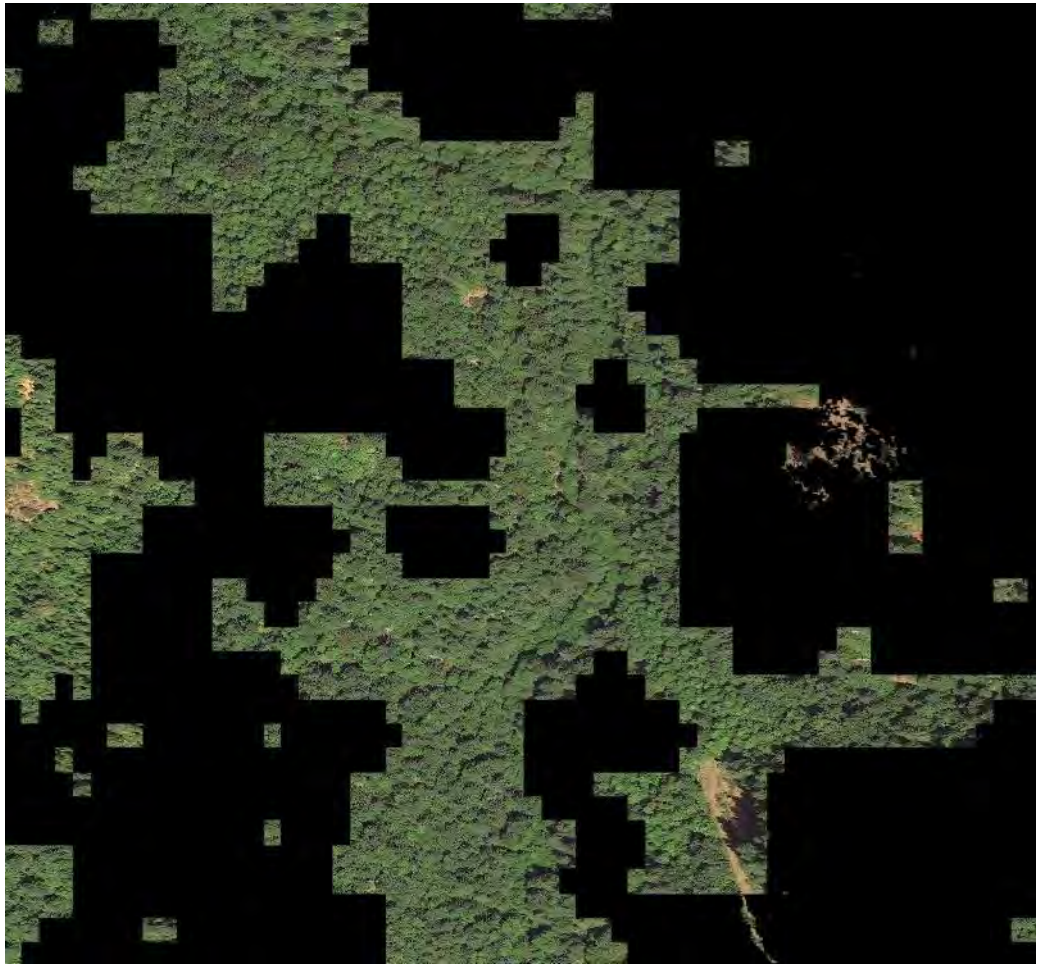
Classified result, DF cover, deciduous cover, with training points overlay



Mask Lidar with cover class

- Binary classification of Lidar CHM: DF will receive SI calculation

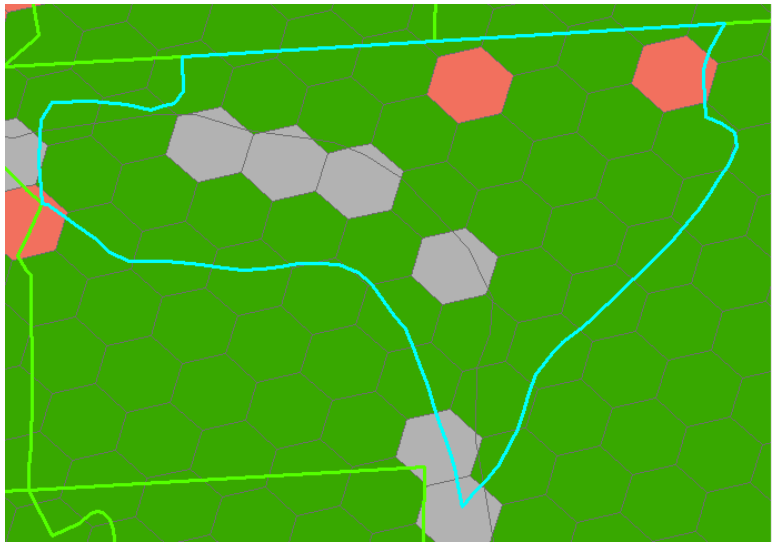




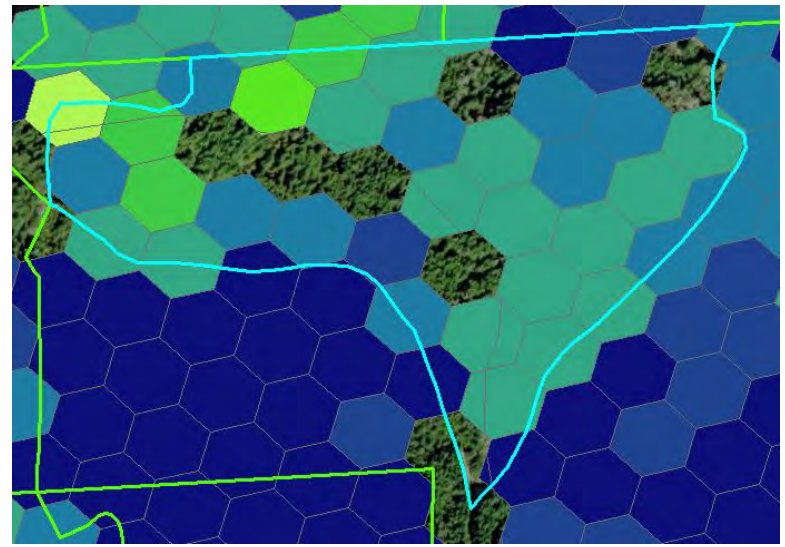
Stand SI

Satellite Image → cover class

Site index for DF cover class

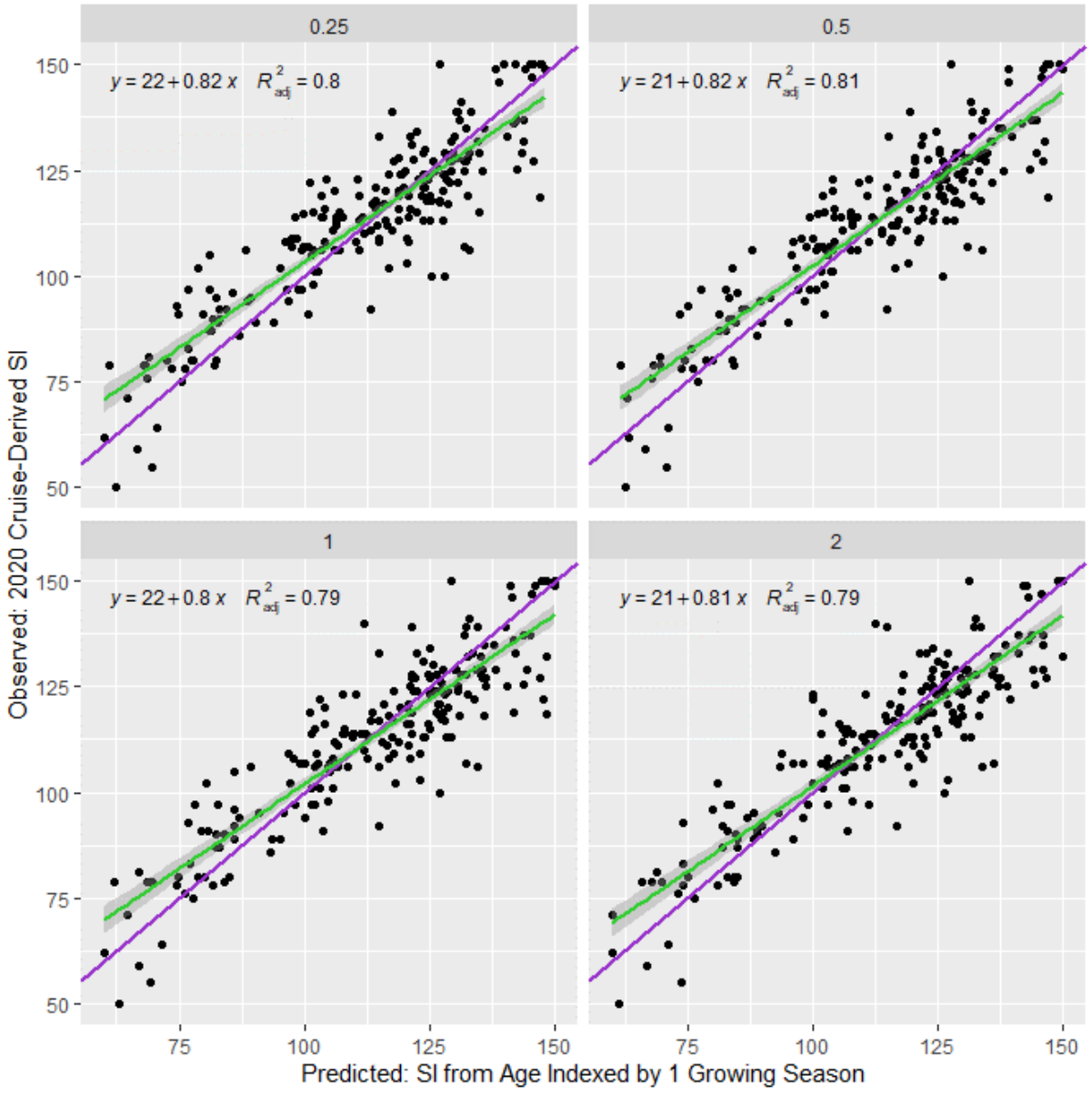


Stand-level SI weighted average



Cruise vs Lidar SI

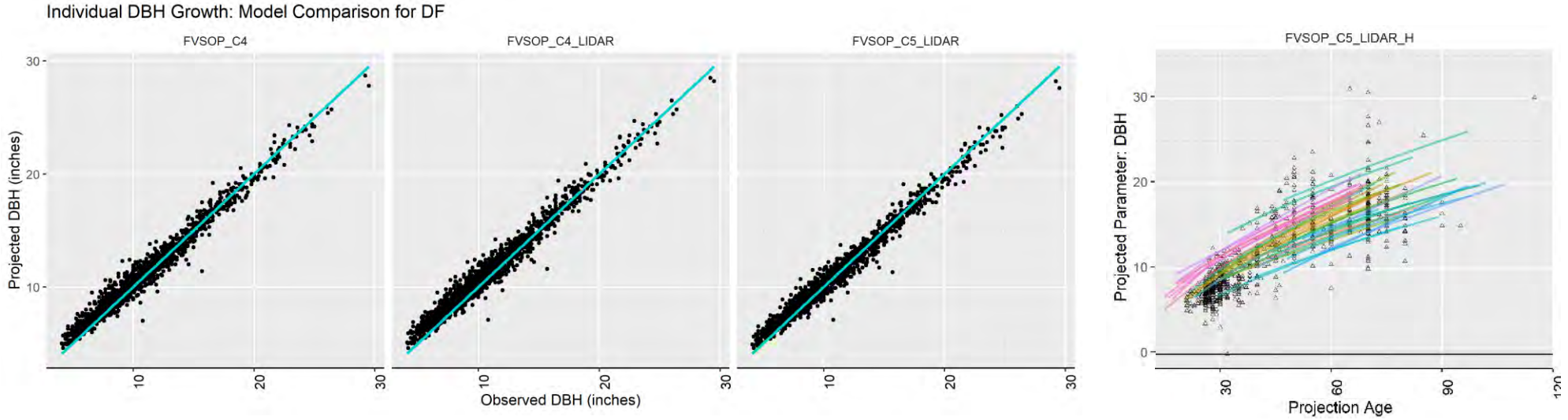
- Reasonable correlation
  - 79% at 2-acre AU
  - 80% at 0.25-acre AU
- Limited bias
  - Slight under-prediction at lower SI
  - Slight over-prediction at higher SI
  - Could be explained by CHM detection limitations—only canopy emergent trees



MASON, BRUCE & GIRARD
Insights. Ideas. Integrity.

FVS calibration

- SI does not need to be correct—it must consistent
- Lidar SI typically > cruise SI
- Would over-predict if used with cruise-calibrated FVS
- Maintain separate FVS calibrations for each SI source
- Keyword-based calibration



MASON, BRUCE & GIRARD
Insights. Ideas. Integrity.

Lessons and conclusions

- Site index from Lidar CHM is strongly correlated with cruise-based SI
- A 1-acre grid cell efficiently balances sampling with computation
- Including edge cells does not alter stand-level results
- Example property, originally 30% cruise / 70% historic SI:
  - Updated 40% of property to Lidar SI
  - Increased property-level average SI by 10 feet
  - Changed individual stand volume by -16% to +11%
  - <1% volume change in property-wide annual inventory update
- Potential for large changes at the stand level
- Impacts harvest schedules and property valuation

Future

- Measure impacts on planning and value
- Improve species classification with higher resolution satellite imagery and more capable classification method
- Seek paired plot-Lidar data to model over-prediction of SI
- Monitor stability of SI over time as new CHM coverages released
- Extend SI calculation to other species, higher-diversity areas
- Maintain FVS calibration library and expand geographic coverage