BG4.9

Regional Mapping, Modelling, and Monitoring of Tree Aboveground Biomass Carbon

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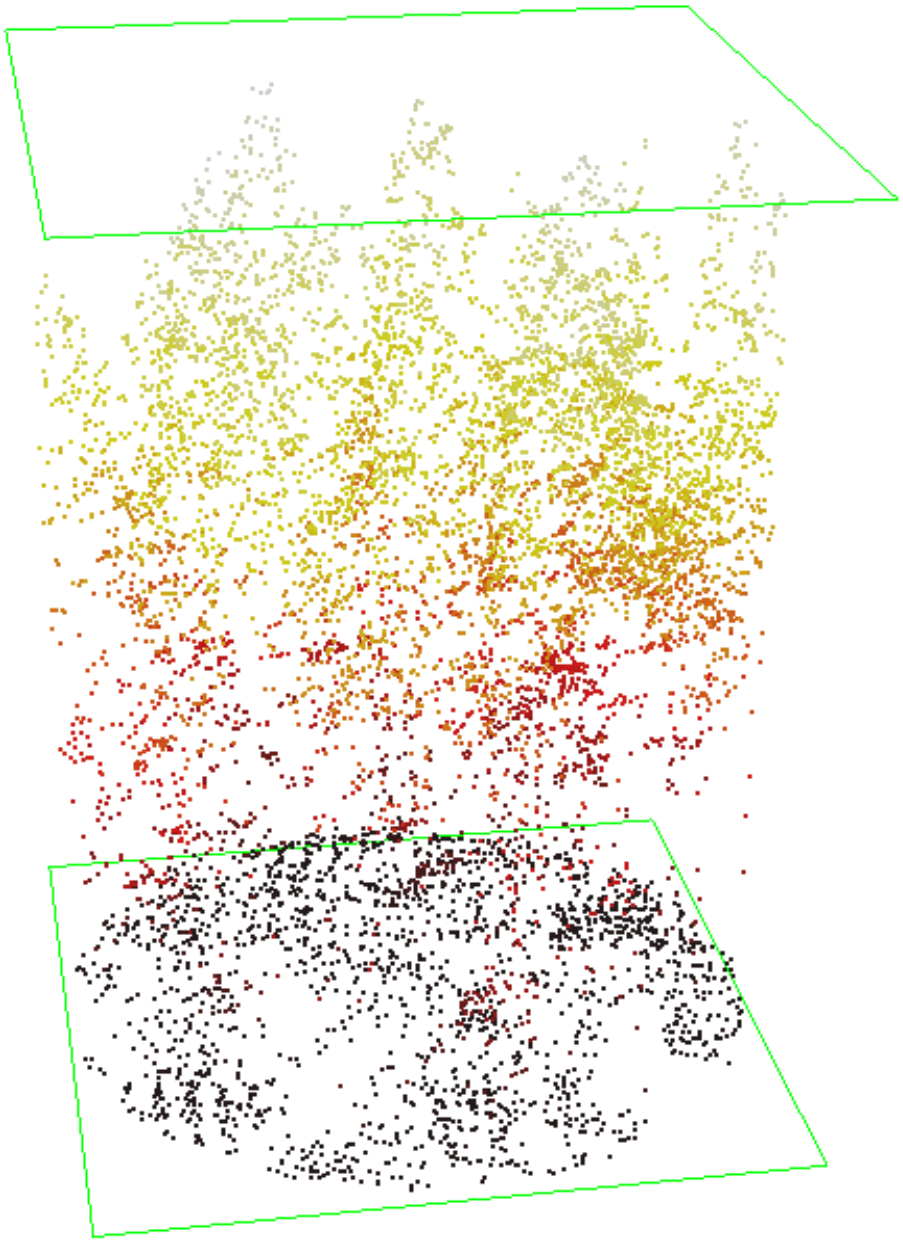
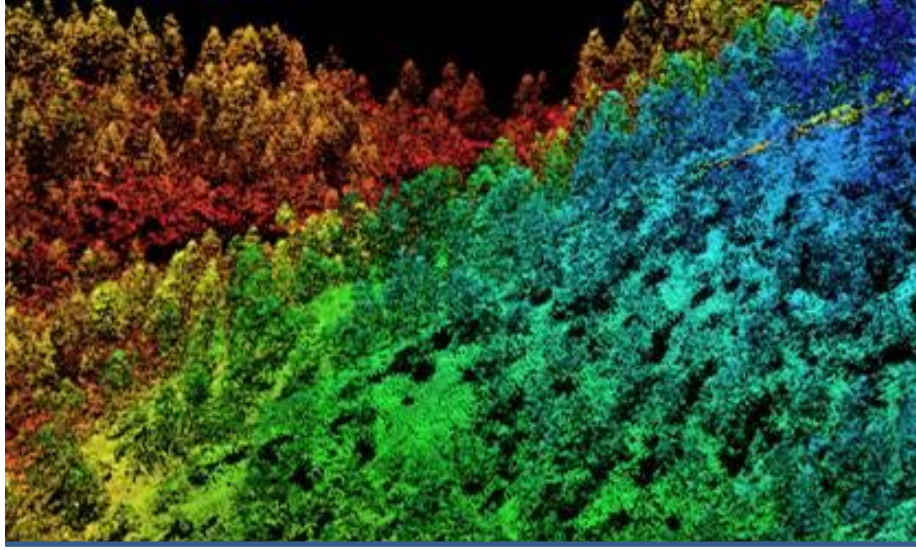
Objectives and Overview of Approach

- Develop a Carbon Monitoring System (CMS) that uses Random Forests (RF) to map aboveground biomass (AGB) at two scales:
  - Landscape level, with following input data:
    - Field plot measures of AGB
    - Light Detection and Ranging (LiDAR) metrics
  - Regional level, annually, with following input data:
    - Landscape-level AGB maps
    - Landsat based detection of trends in disturbance and recovery (LandTrendr) metrics
    - Shuttle Radar Topography Mission (SRTM) 30-m topographic metrics
      - » Except elevation
    - Physiologically relevant climate variables
- Develop a Validation Protocol for Monitoring, Reporting, and Verification (MRV)
  - Aggregate annual, regional AGB maps to county level
  - Compare against annual, county-level Forest Inventory and Analysis (FIA) estimates of AGB available nationally, calculate biases

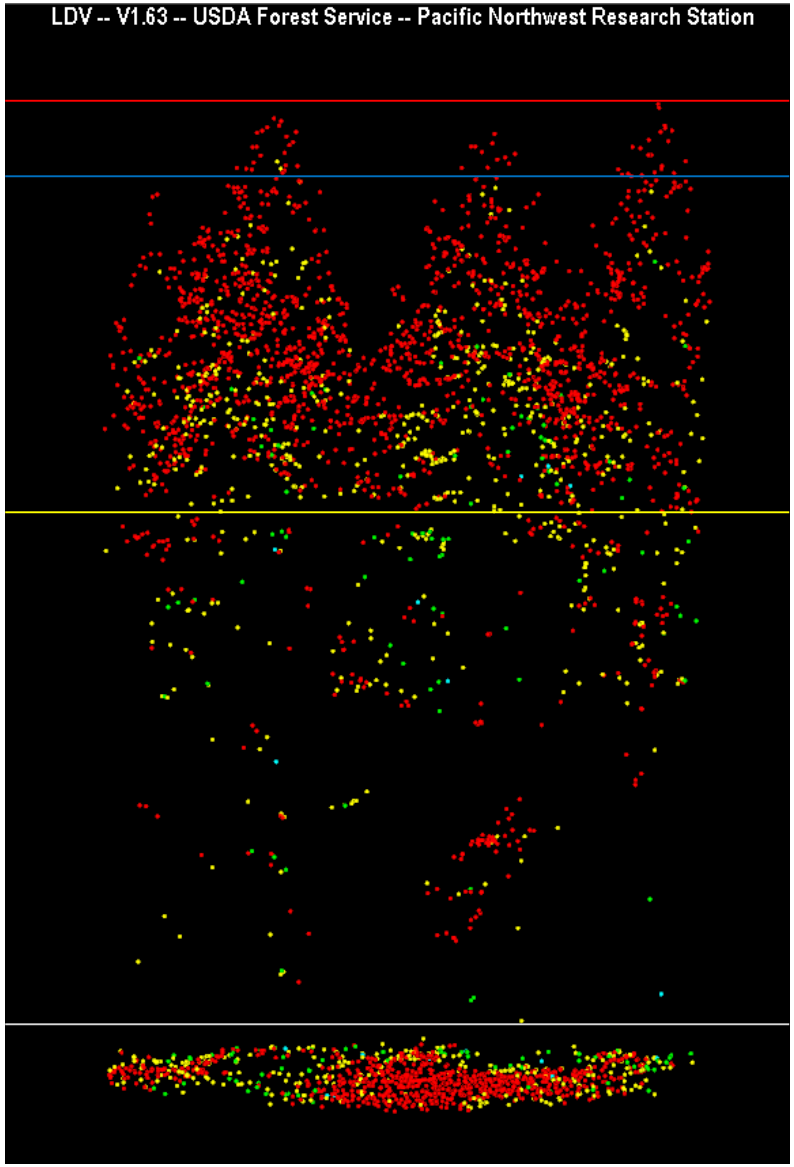


Light Detection and Ranging (LiDAR) point cloud at the scale of a 400 m^2 forest inventory plot in northern Idaho



Field photo of same plot as depicted on the left

Height Metrics



Maximum Canopy Height

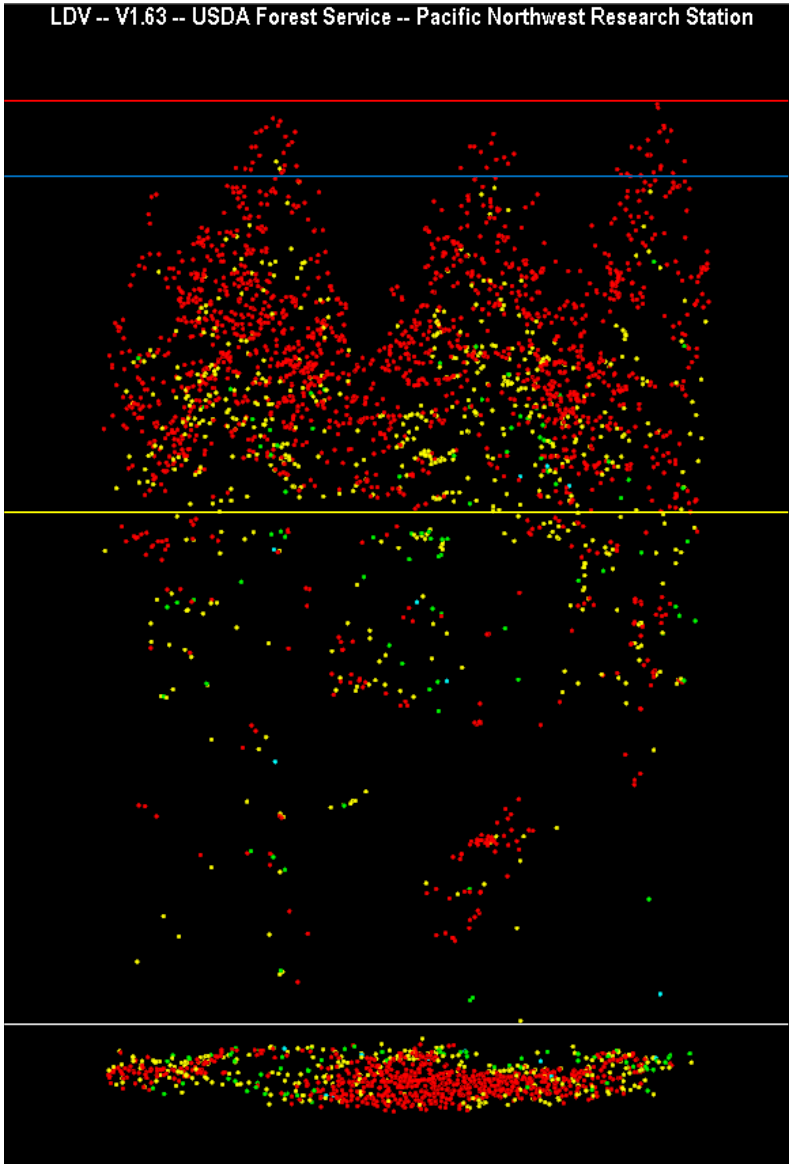
95th percentile

Mean Canopy Height

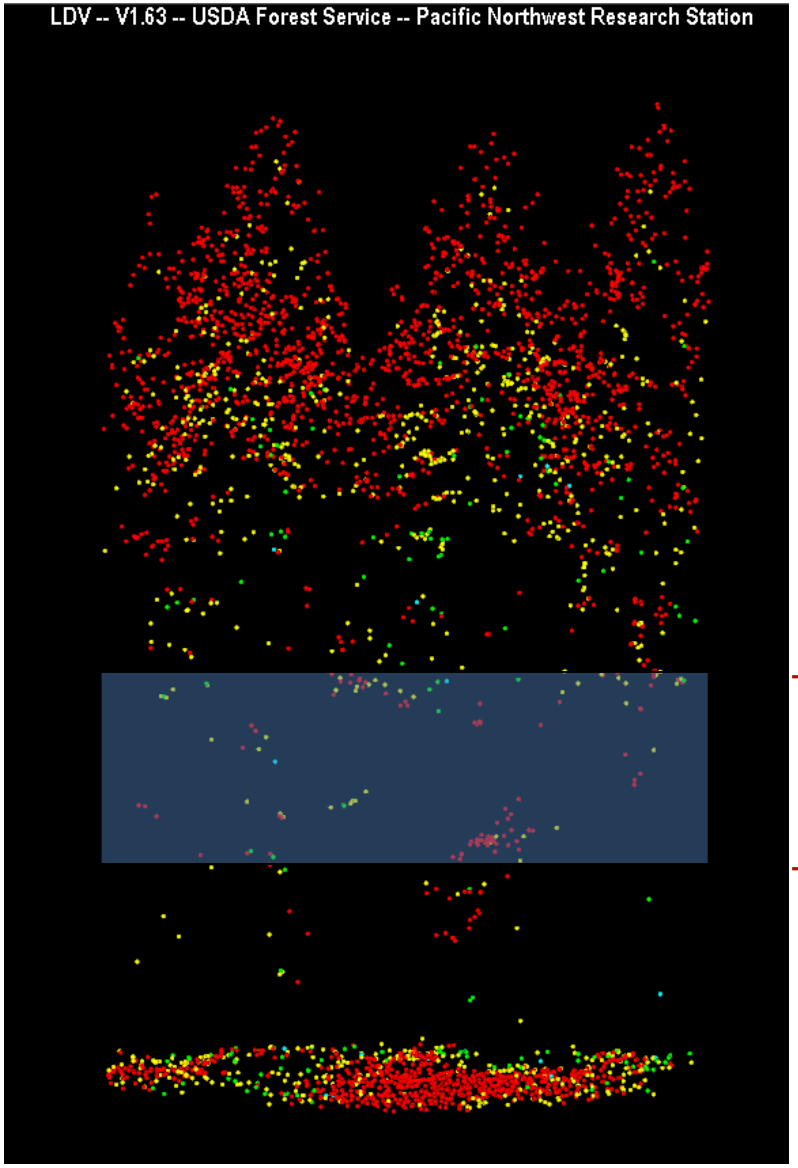
Height Cutoff (1.37 m)

USDA Forest Service, Remote Sensing Applications Center, http://fsweb.rsac.fs.fed.us

Height Metrics



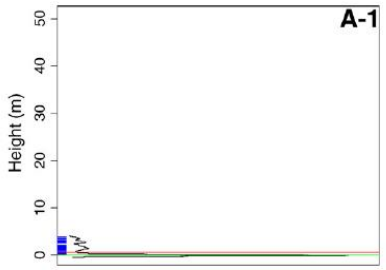
Density Metrics

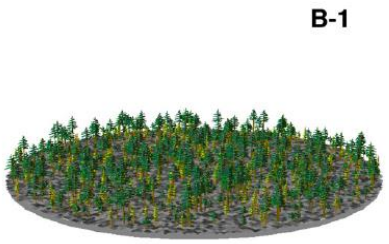


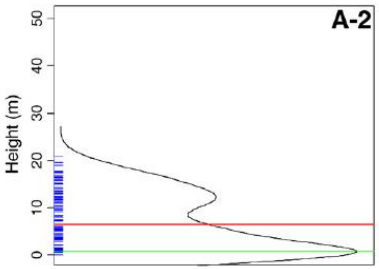
$$\frac{\text{Returns in stratum s}}{\text{Total returns}} \times 100$$

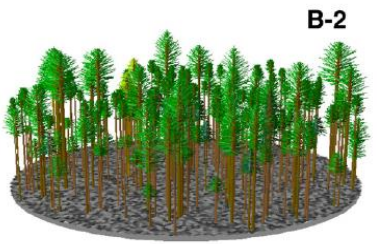
USDA Forest Service, Remote Sensing Applications Center, http://fsweb.rsac.fs.fed.us

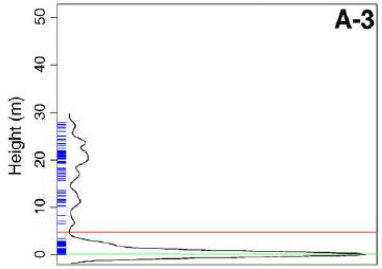
“Living” Database of Project-Level Reference Plots

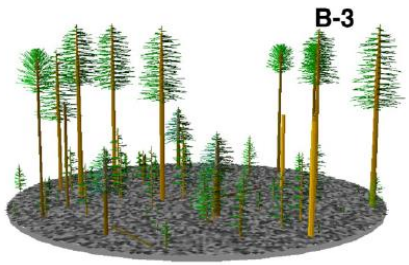


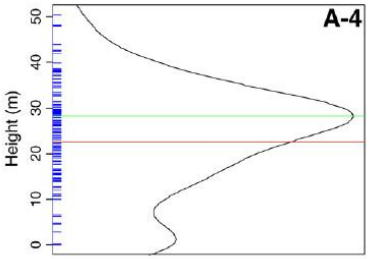


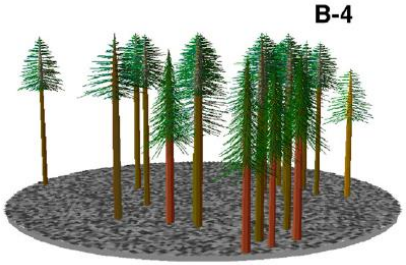






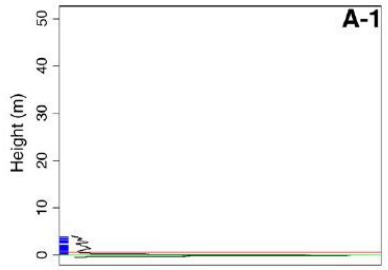


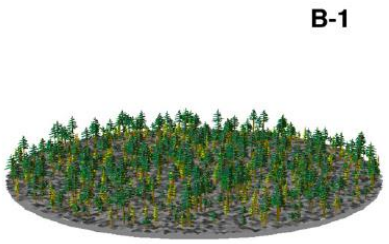


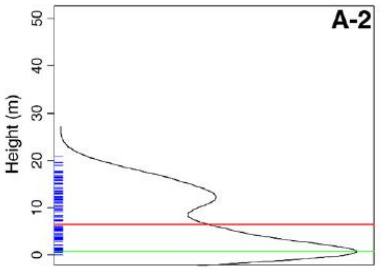


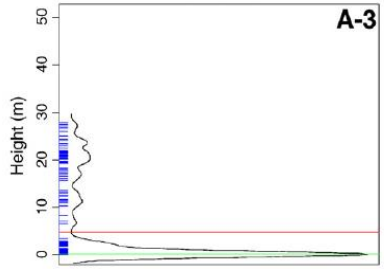
P. A. Fekety

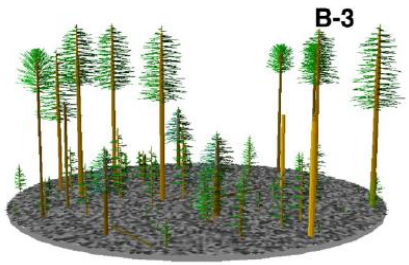
Predict Attributes at Unsampled Locations

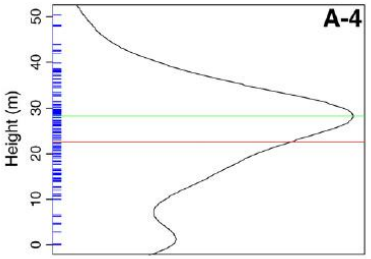


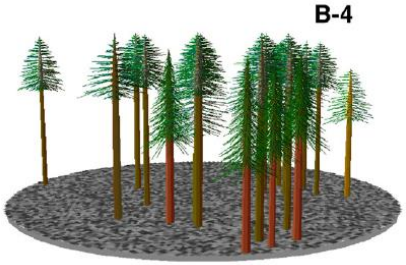


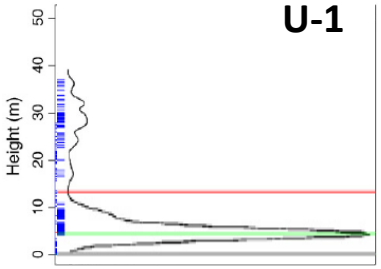












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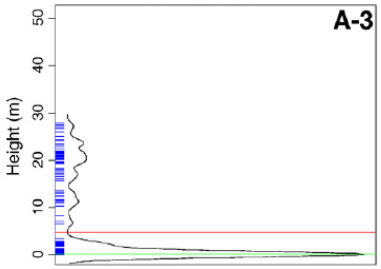
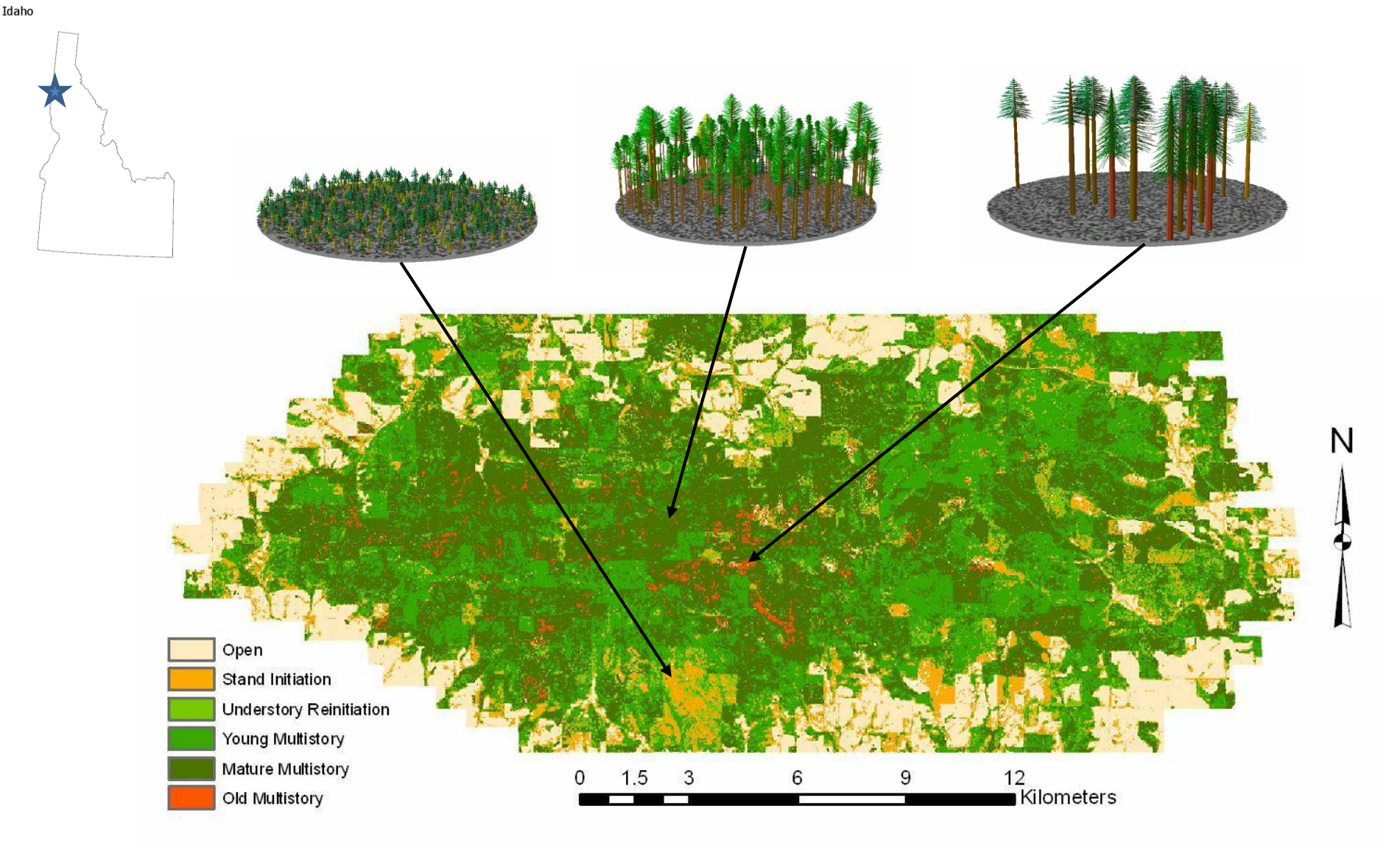


$\therefore$ U-1 $\Rightarrow$ A-3

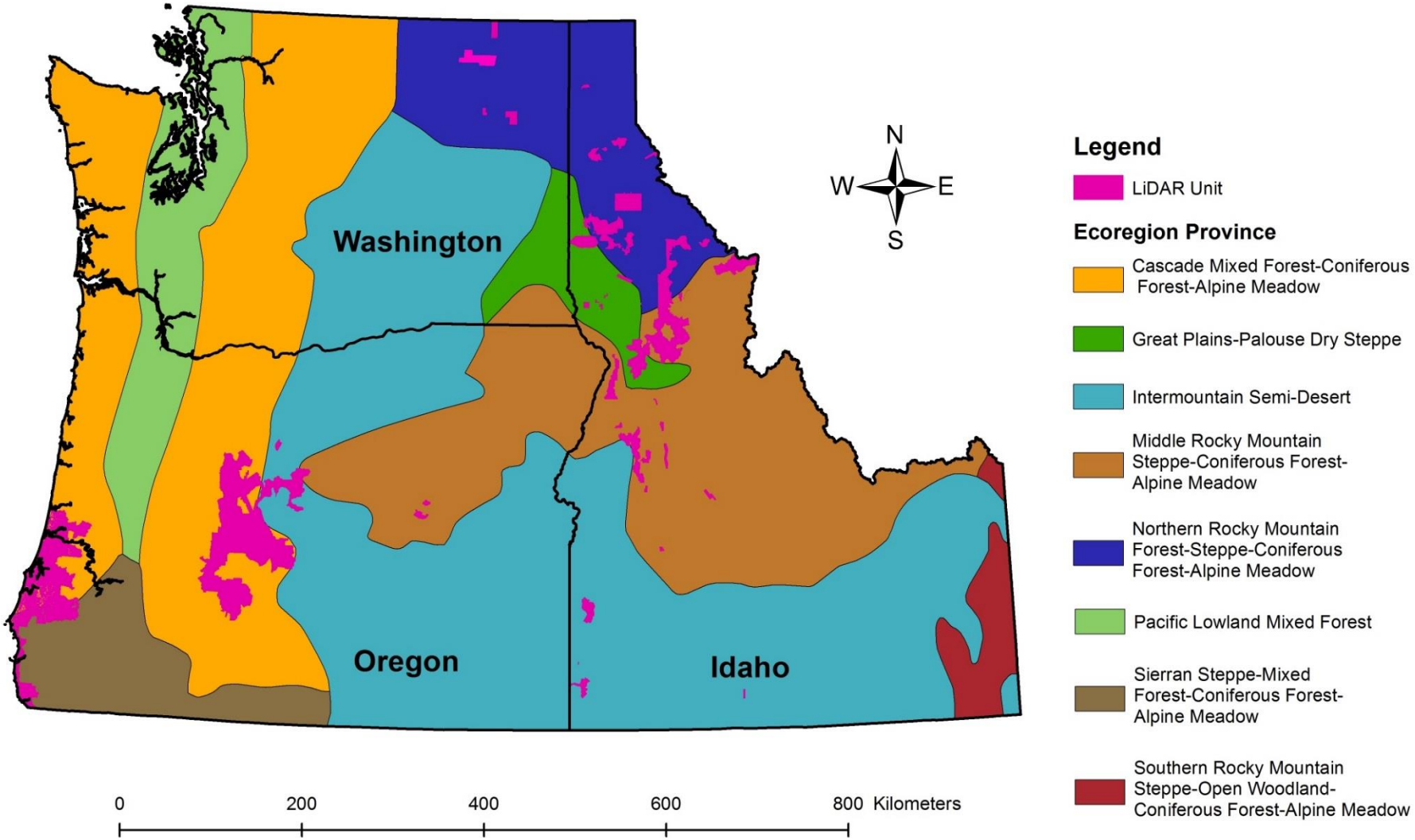
M. J. Falkowski, P. A. Fekety

Landscape-Level Approach



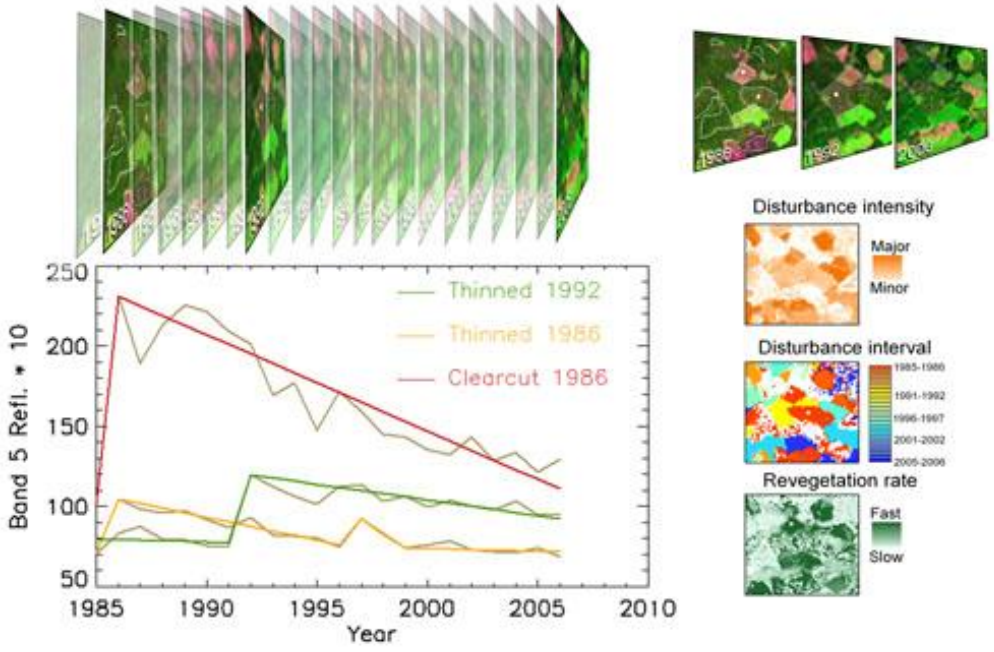
Falkowski et al. (2009) *Remote Sensing of Environment* 113: 946-956.

Regional-Level Approach



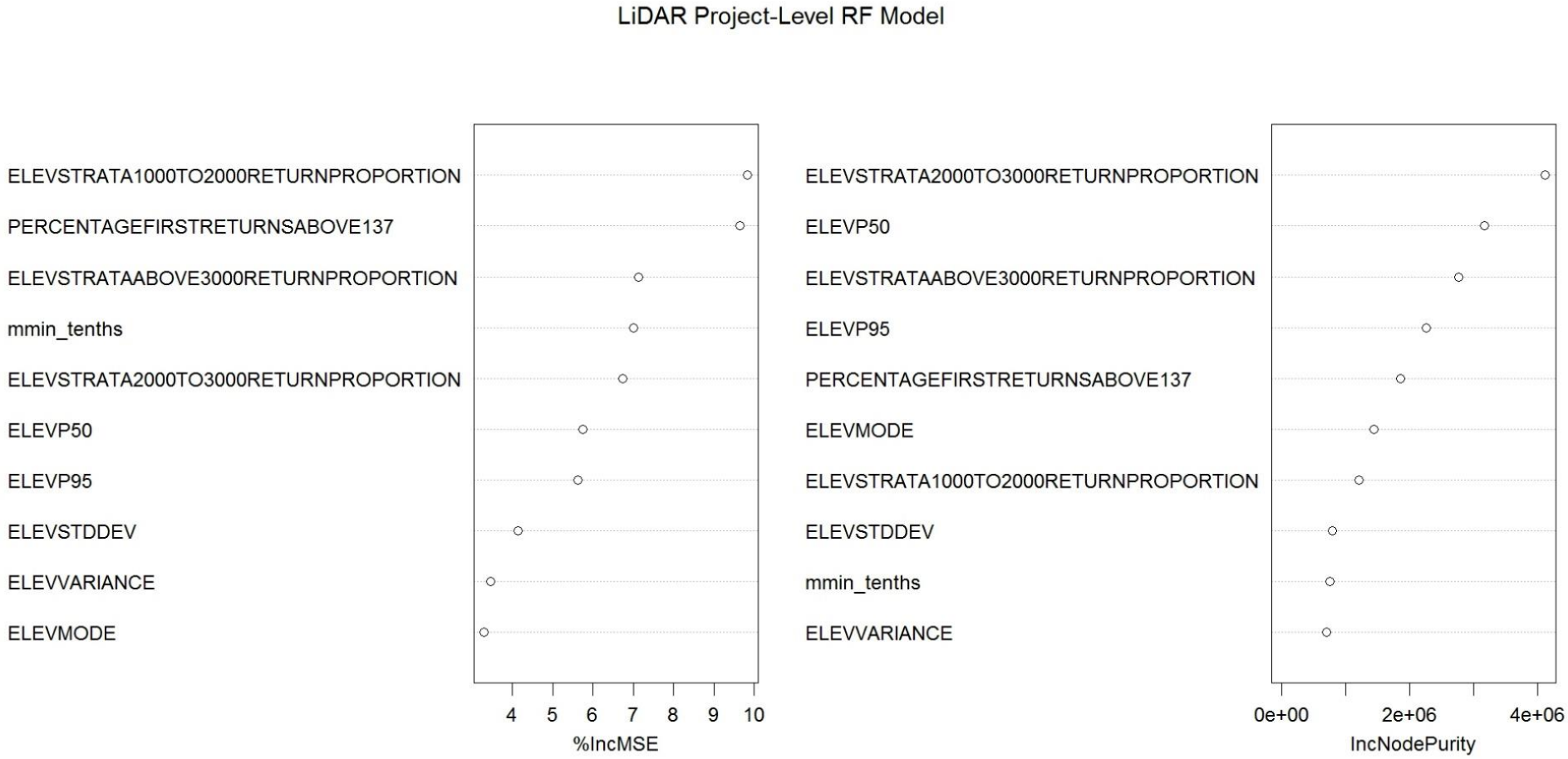
LandTrendr (LT) data

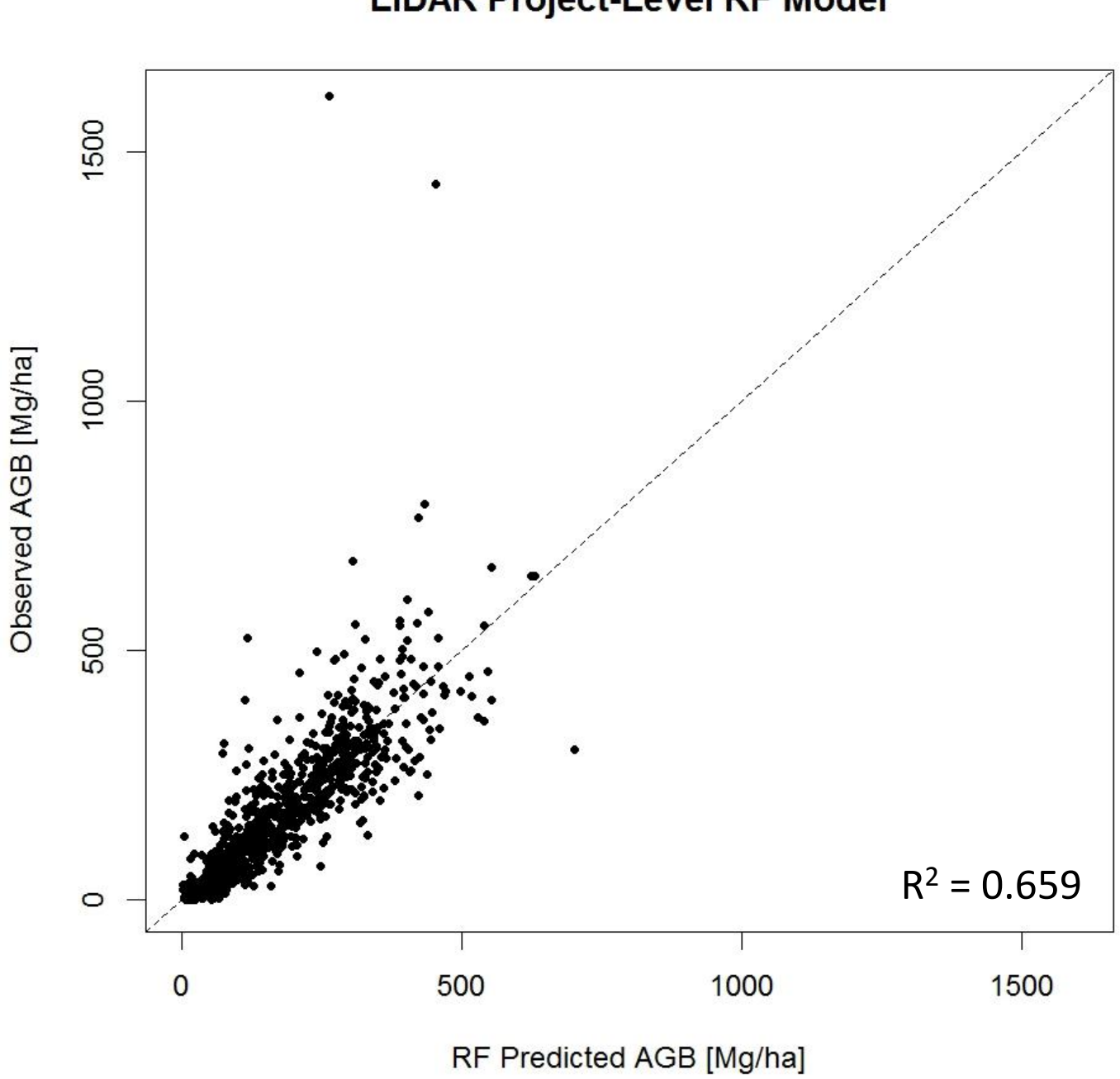
- LandTrendr - Landsat based detection of trends in disturbance and recovery algorithm (Kennedy et al., 2010)
- Input: Annual Landsat images stacked from 1984-2012
- Output: Trajectories describing trends for each 30-m pixel from multiple spectral variables
- Primary predictors we are using for annual AGB prediction are the tasselled cap indices:
  - Brightness
  - Greenness
  - Wetness
- Other important LT metrics:
  - Magnitude of greatest disturbance
  - Time since disturbance

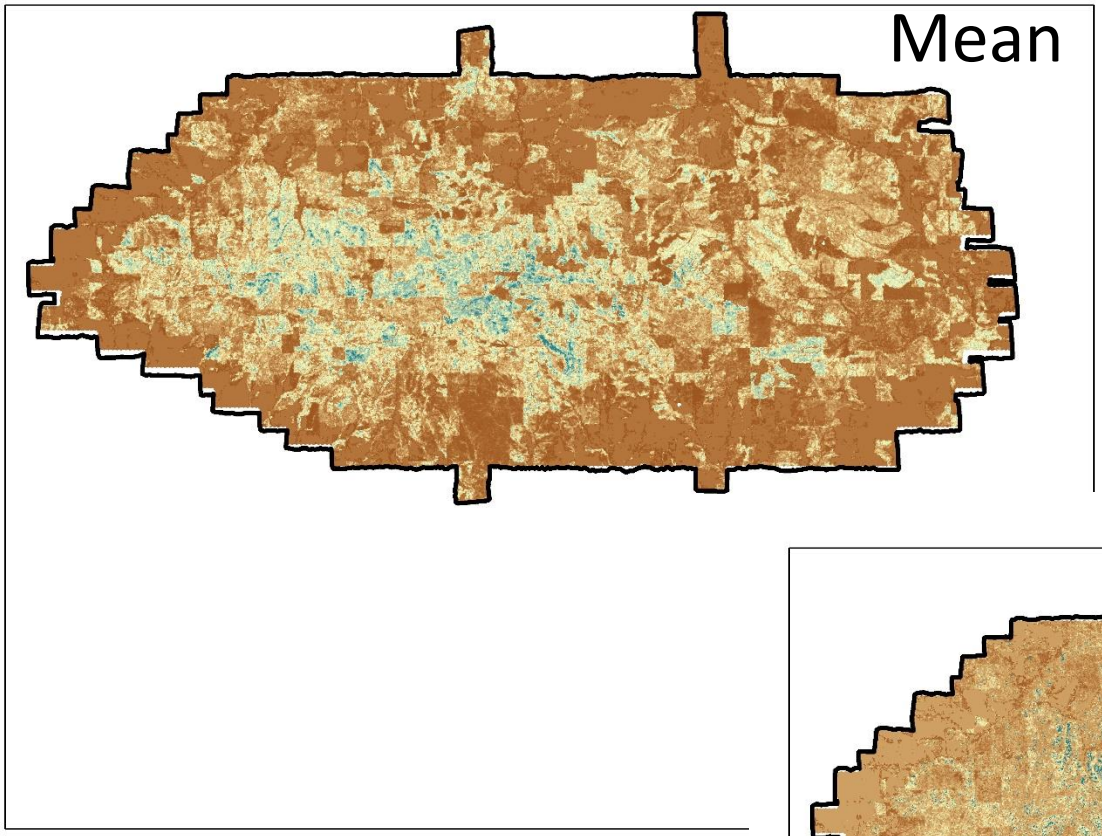


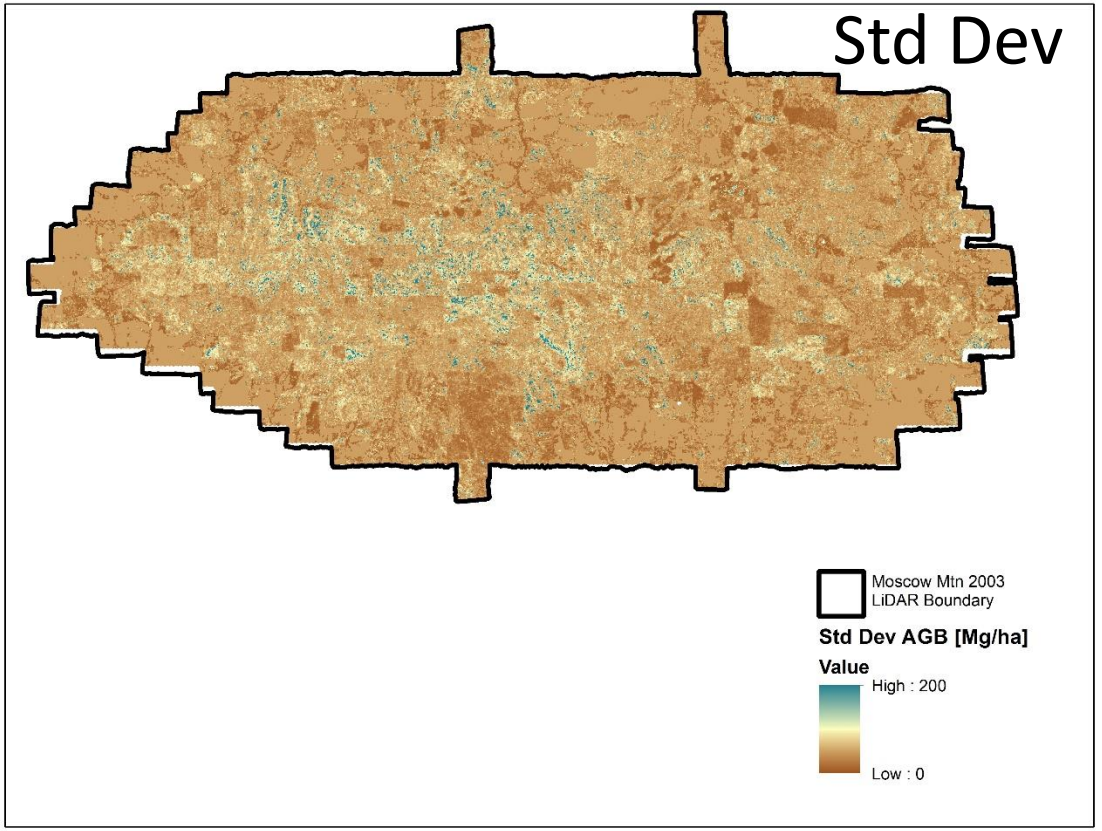
http://landtrendr.forestry.oregonstate.edu/content/how-landtrendr-works

Landscape-Level Random Forests (RF) Model



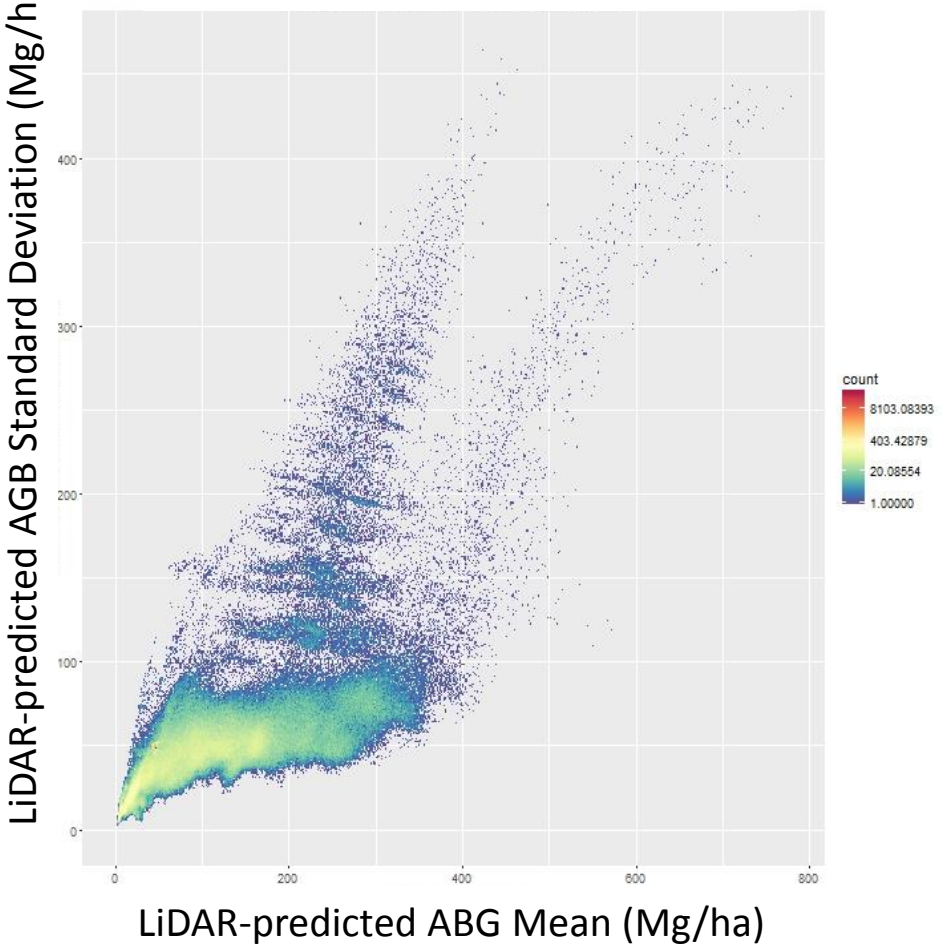

LiDAR Project-Level RF Model
Observed AGB [Mg/ha]
RF Predicted AGB [Mg/ha]
0
500
1000
1500
R^2 = 0.659


Mean

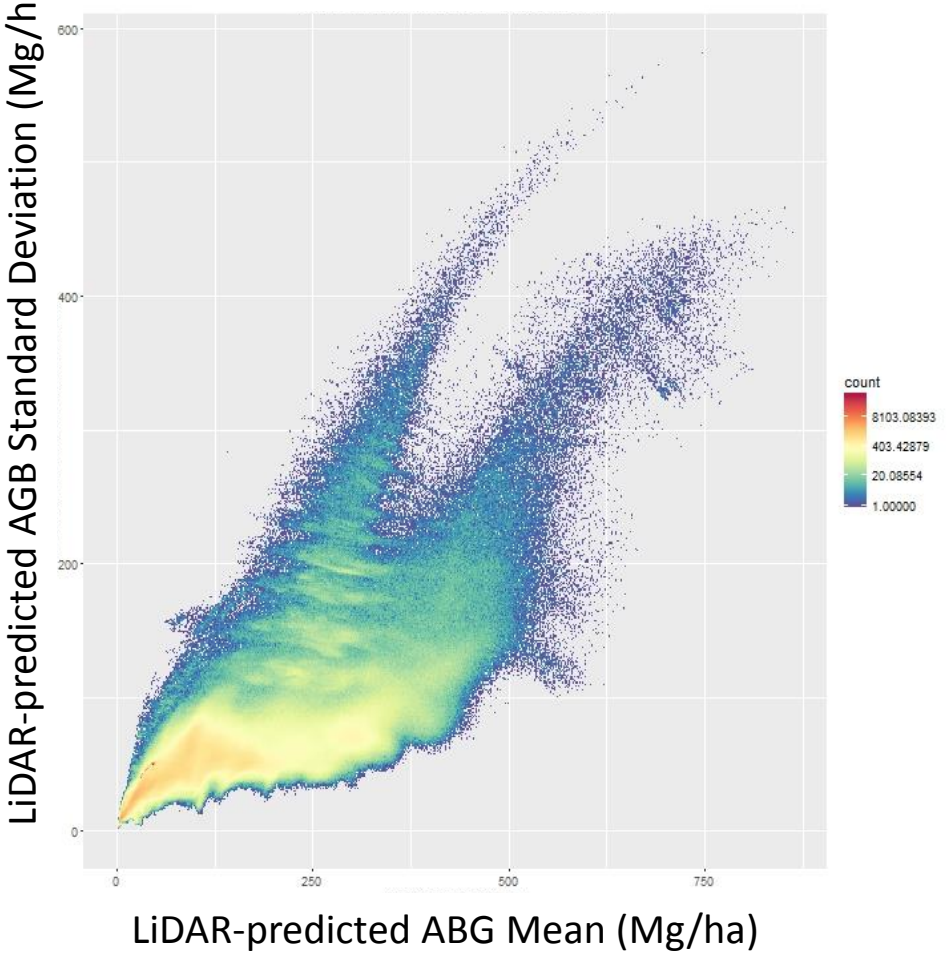

Std Dev
Moscow Mtn 2003
LiDAR Boundary
Std Dev AGB [Mg/ha]
Value
High : 200
Low : 0

Uncertainty in 30-m ABG (Mg/ha) Map Cells Predicted from LiDAR

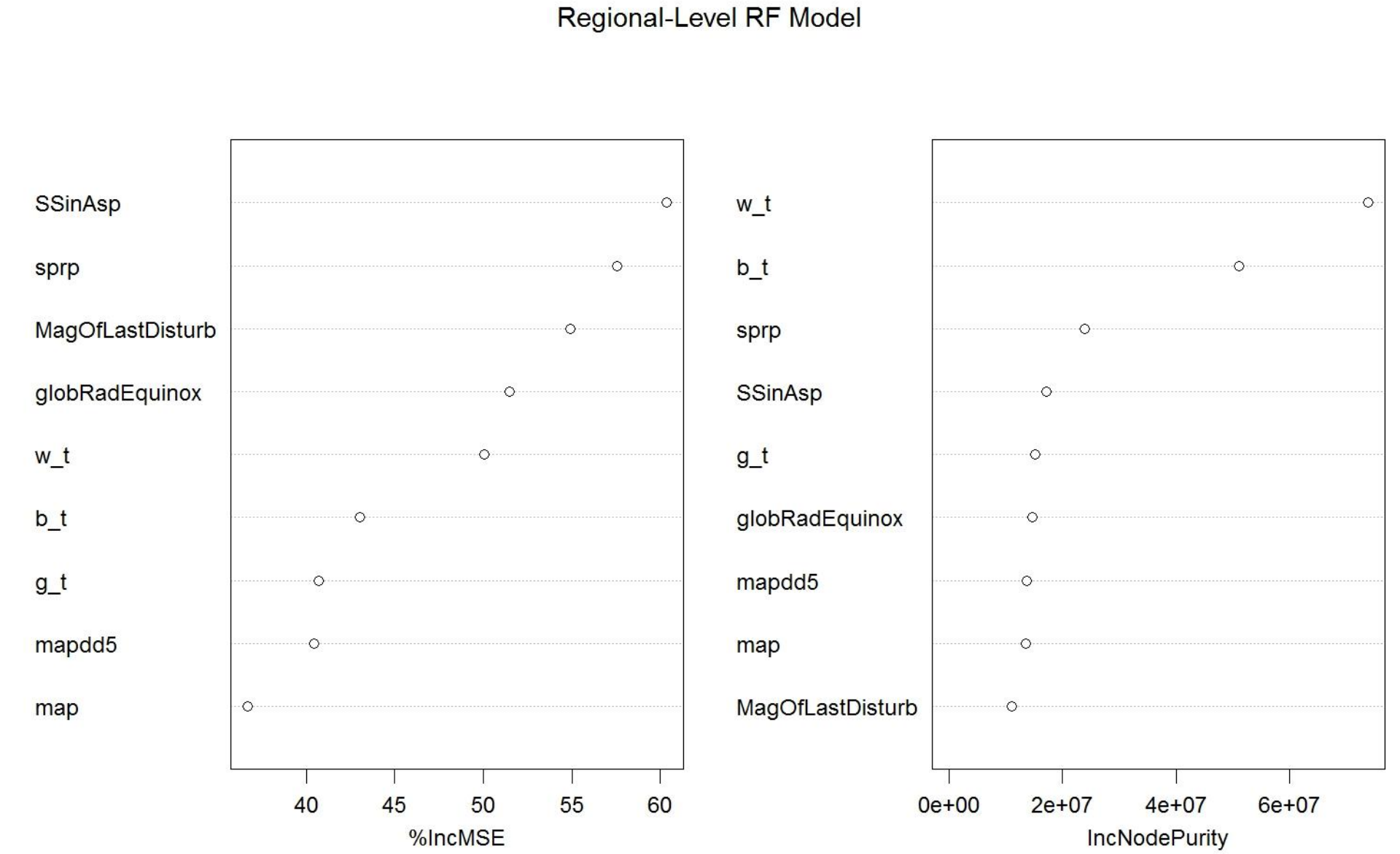
One Landscape (Moscow Mt.)

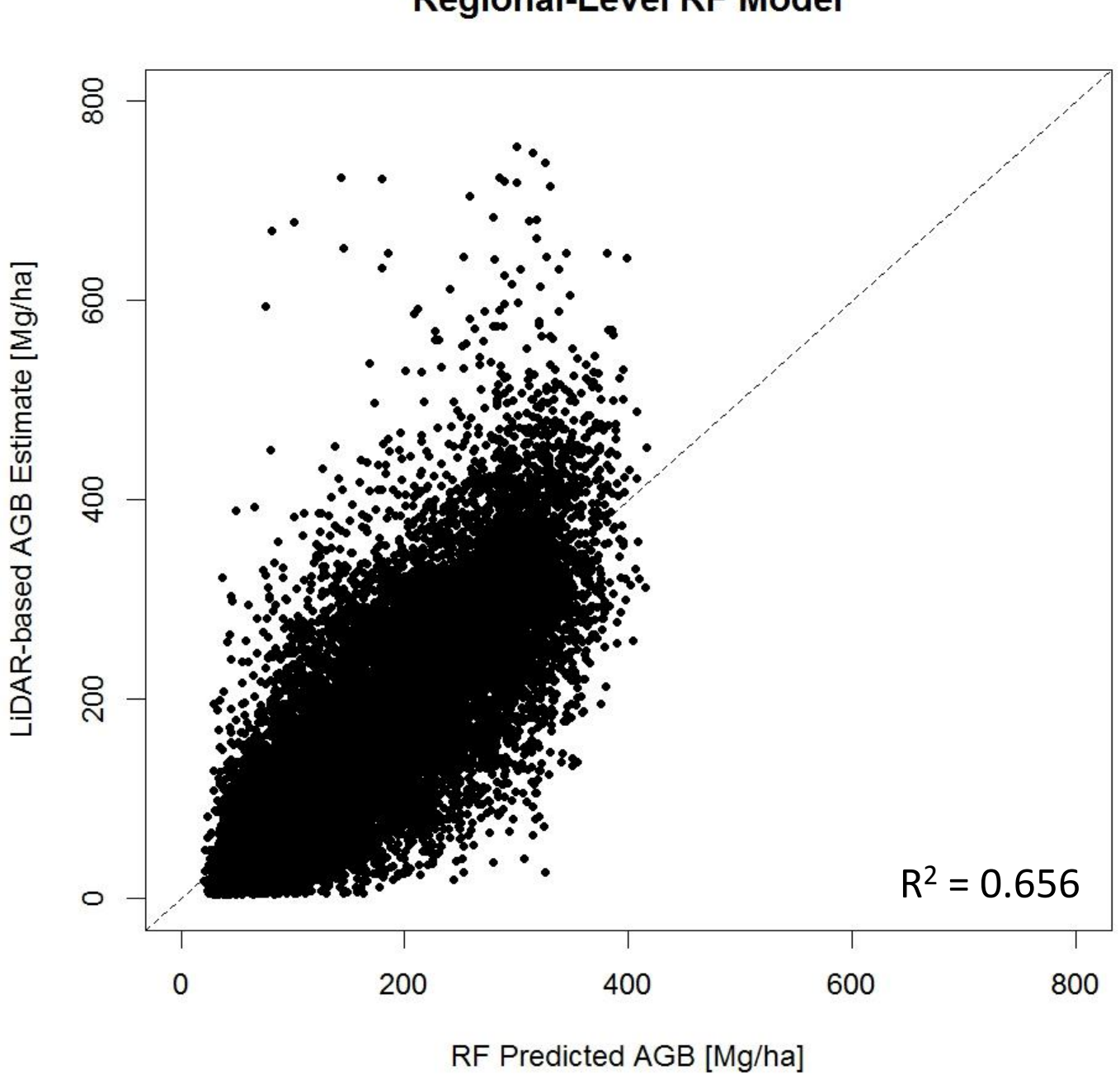


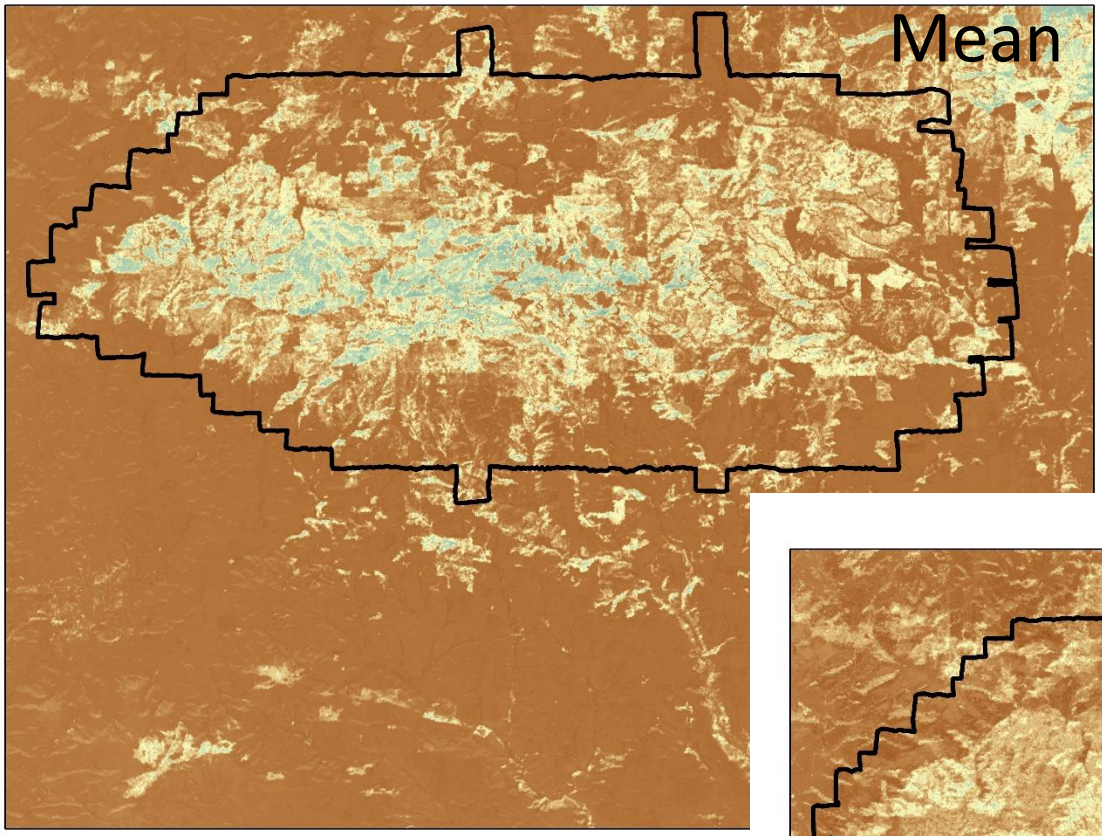
All N. Idaho Landscapes

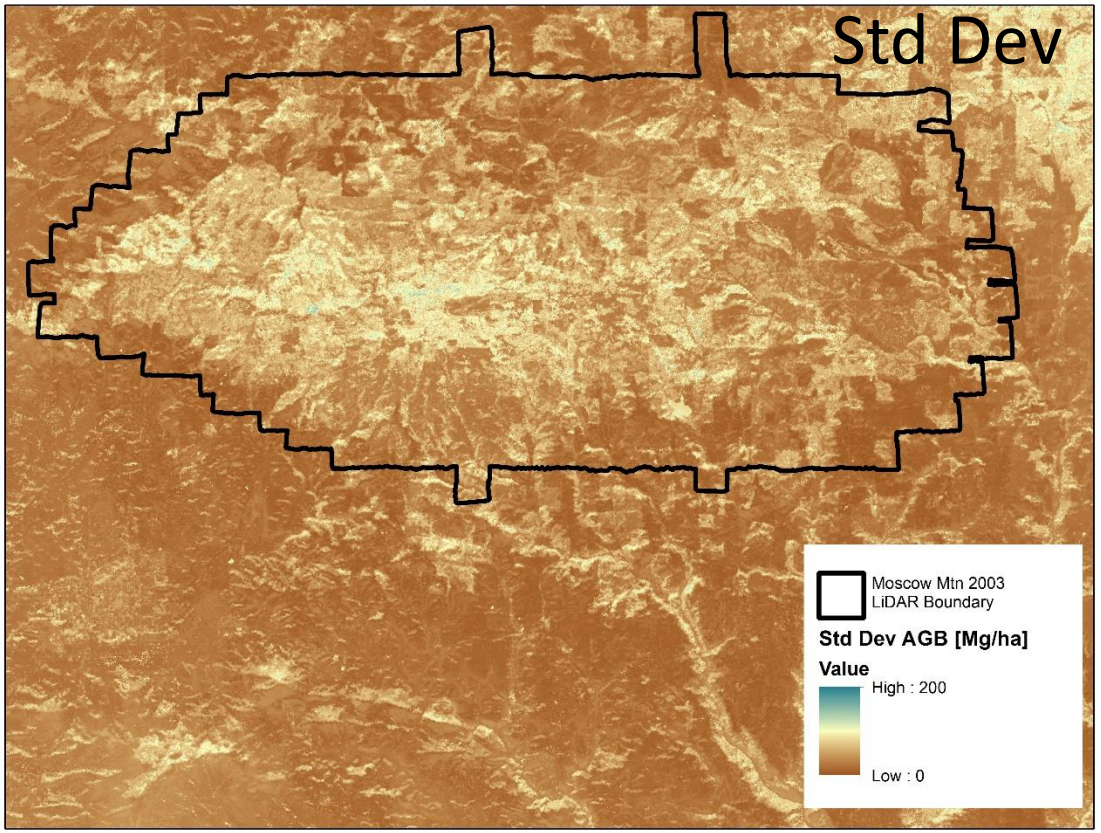


Regional-Level Random Forests (RF) Model

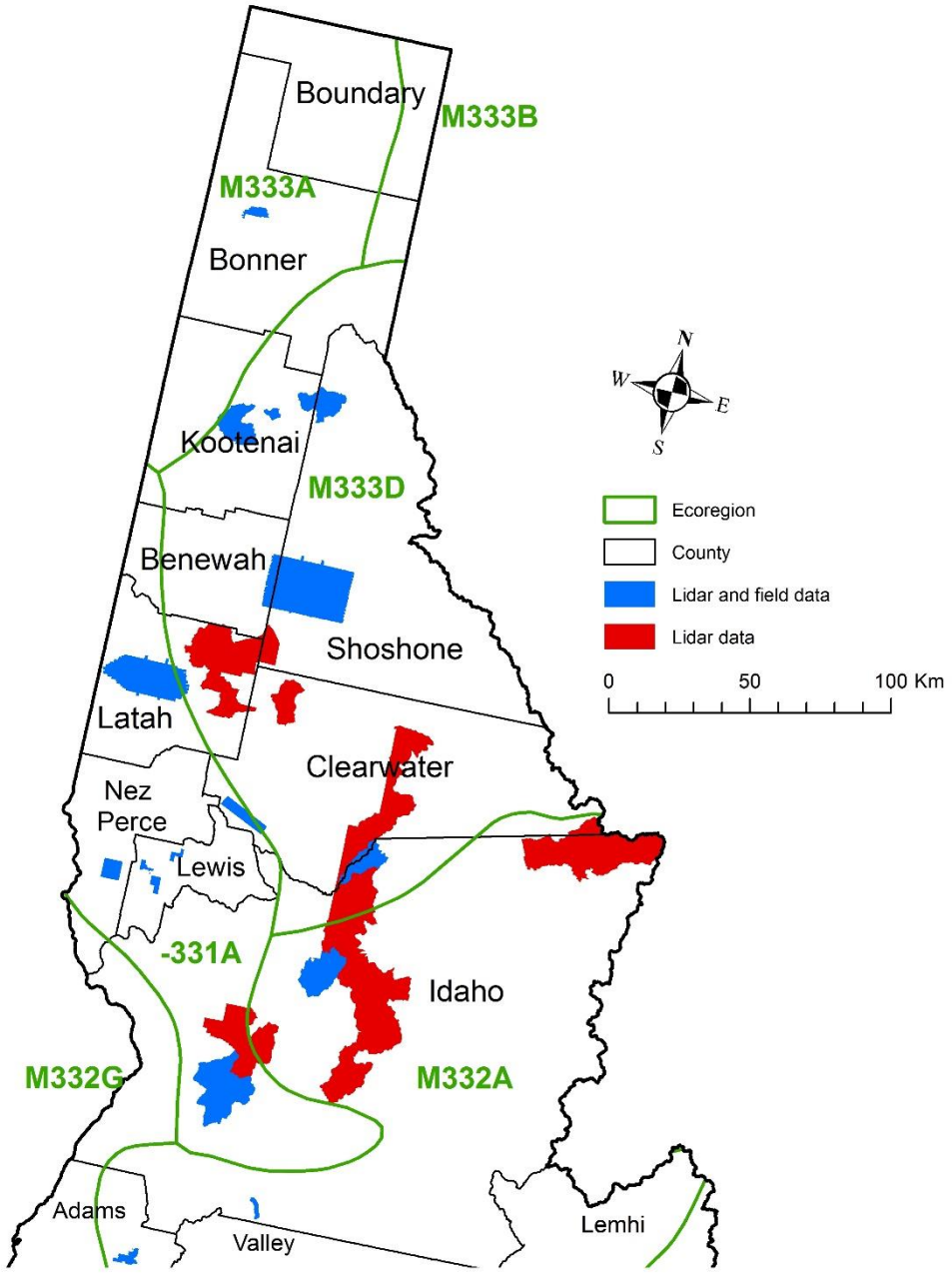



Regional-Level RF Model
LiDAR-based AGB Estimate [Mg/ha]
RF Predicted AGB [Mg/ha]
0
200
400
600
800
R2 = 0.656


Mean


Std Dev
Moscow Mtn 2003
LiDAR Boundary
Std Dev AGB [Mg/ha]
Value
High : 200
Low : 0

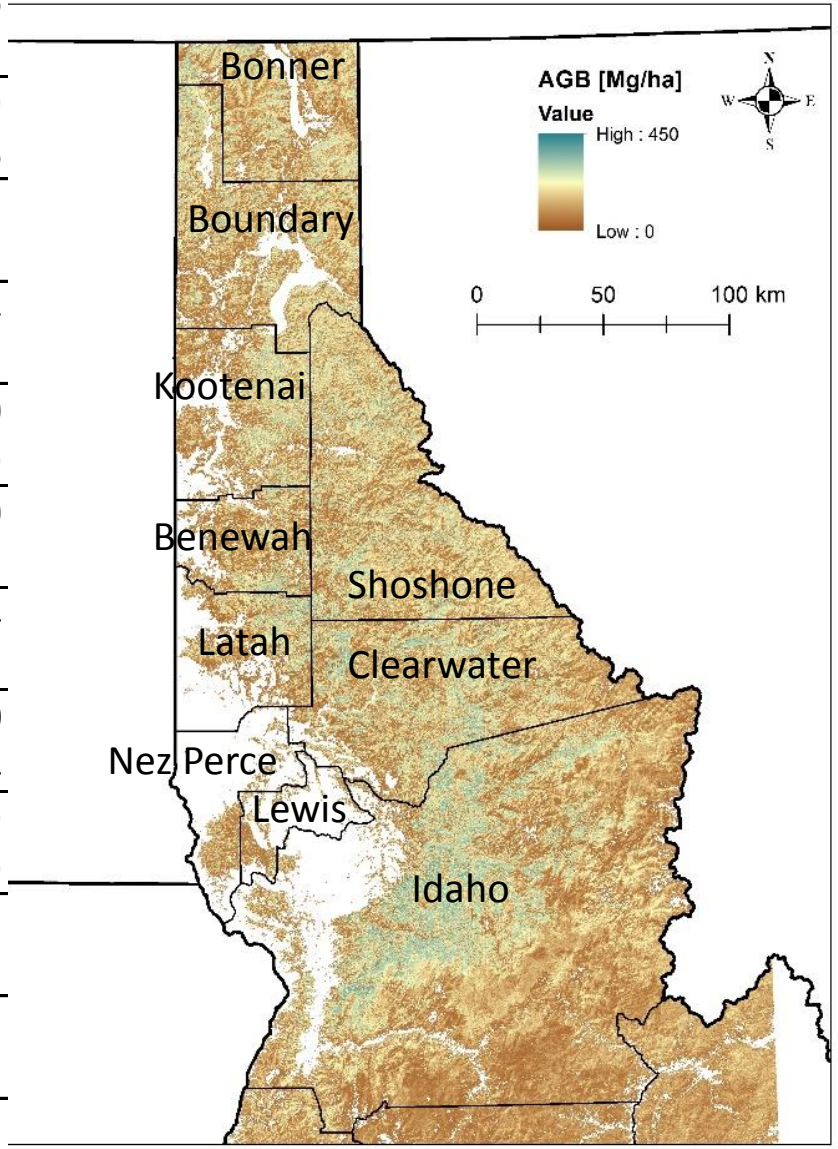
Carbon Monitoring
Systems Program



Note: Green labels are ecoregion identifiers

County	Year	AGB [Mg / ha] FIA	AGB [Mg / ha] Predictions	%Bias
ID-Benewah	2010	111.6	138.5	24
	2011	117.6	136.5	16
ID-Bonner	2010	119.1	149.7	26
	2011	123.3	149.9	22
ID-Boundary	2010	128.6	152.8	19
	2011	131.7	153.3	16
ID-Clearwater	2010	129.4	159.5	23
	2011	131.6	159.8	21
ID-Idaho	2010	78.6	144.3	84
	2011	78.6	144.0	83
ID-Kootenai	2010	122.1	146.6	20
	2011	122.1	145.6	19
ID-Latah	2010	111.6	145.3	30
	2011	115.0	143.4	25
ID-Lewis	2010	52.7	107.6	104
	2011	51.5	108.7	111
ID-Nez Perce	2010	52.9	111.2	110
	2011	52.2	111.8	114
ID-Shoshone	2010	149.9	163.7	9
	2011	149.7	163.8	9
WA-Asotin	2010	-	122.3	
	2011	91.9	122.5	33
WA-Garfield	2010	-	126.4	
	2011	87.7	125.3	43
WA-Pend Oreille	2010	-	149.4	
	2011	140.9	150.5	7

AGB 2011



Conclusions, Next Steps

- Workflow has been developed to predict AGB across large spatial extents from historical Landsat images, using LiDAR-mapped 30-m AGB pixels as reference observations, and 30m pixels without lidar as target observations
- Current annual predictions are higher than annual county-level FIA reports. Why?
  - Disturbance dynamics
    - Include LandTrendr time-since-last disturbance metric, delta metrics
  - What is “forest” vs “non-forest”?
    - Include tree cover mapped from high resolution airborne imagery
    - Landsat-based National Land Cover Database (NLCD) map has local inaccuracies
      - Gaps within forest matrix (commission errors)
      - Tree islands within non-forest matrix (omission errors)
  - FIA doesn’t inventory non-forest trees… but they’re out there!

Acknowledgements

NASA Carbon Monitoring Systems Program

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USFS Rocky Mountain Research Station