FOREST BIOMASS ESTIMATES USING AIMS PROFILING LIDAR AND IMAGERY

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Mount Holyoke College
Honors Thesis Research
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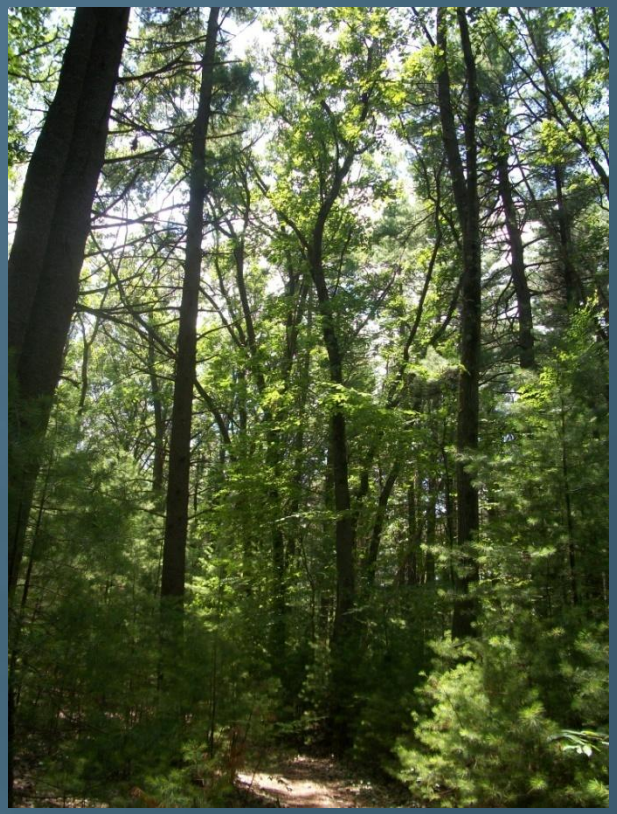
Outline



- Objective
- Background
- Height
- Biomass
- Conclusion

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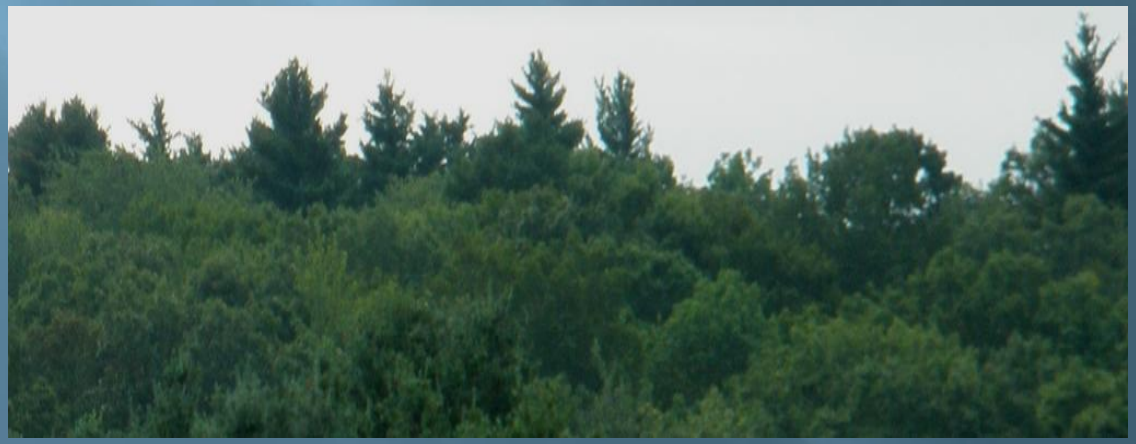
Project Objective

- **Estimate**
  - **Stand-level biomass:**
    - **Remote sensing**
    - **Ground data**
- **Compare results**



Why?

Biomass

Allometric equations

Red Oak **aboveground biomass(Mg)=**

((EXP(-2.972+-0.017*dbh+2.873*(LN(dbh^1))))*0.001)*1.05

⟶Remote data as surrogates

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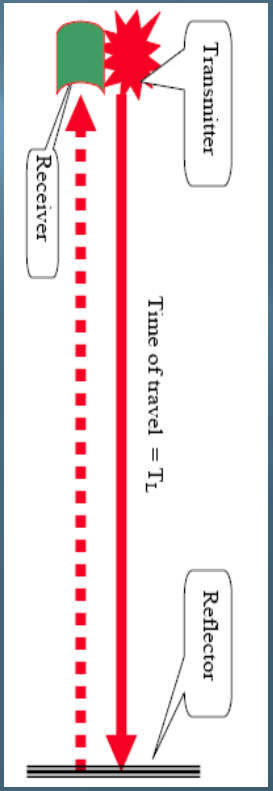
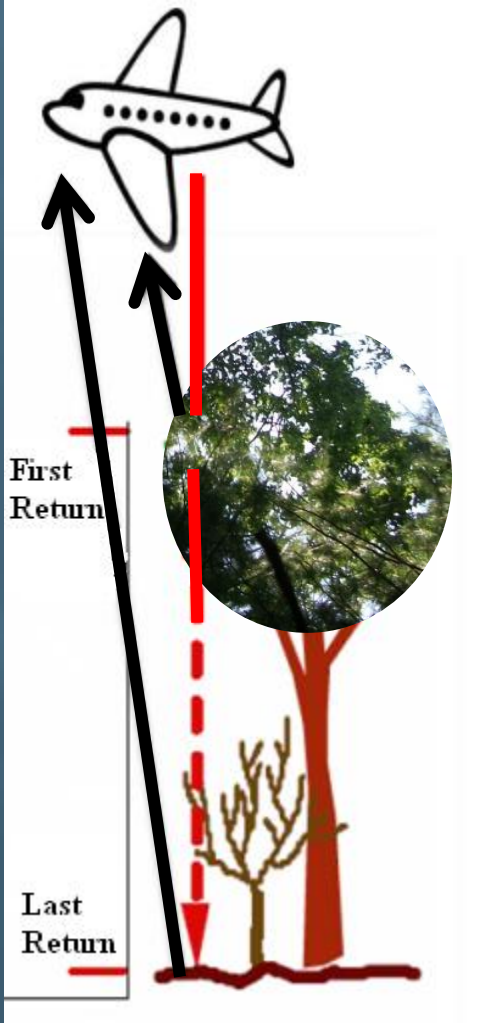
What is Lidar?

An acronym: Light Detection And Ranging

- **Measures distances**
  - **Laser pulse travels at the speed of light**
  - **Time is converted to distance D=ct/2**





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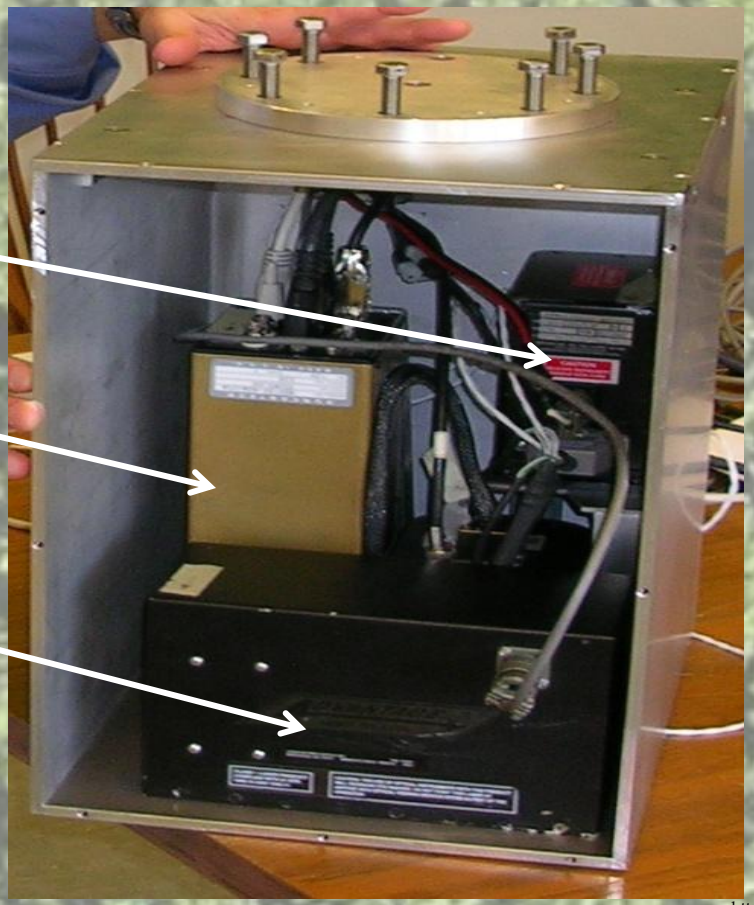
AIMS Sensor

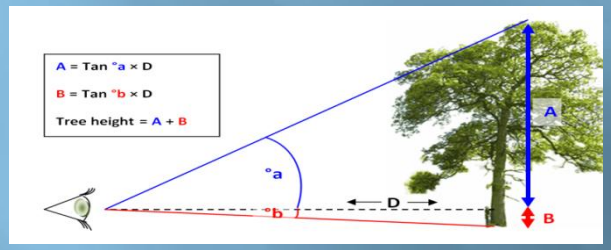
Airborne Imaging and Multispectral System

- AHRS
- High resolution camera
- Lidar
- GPS
- Computer



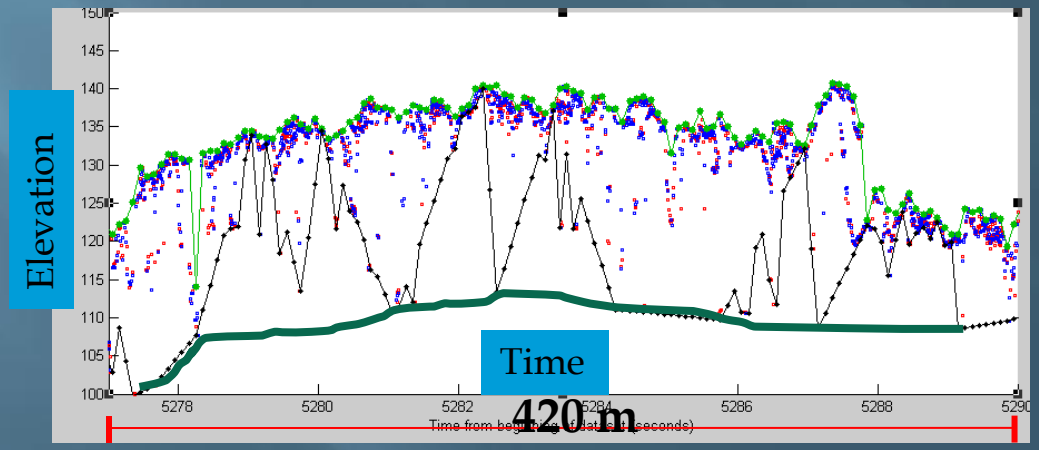
http://pugetsoundlidar.ess.washington.edu/laser_altimetry_in_brief.pdf

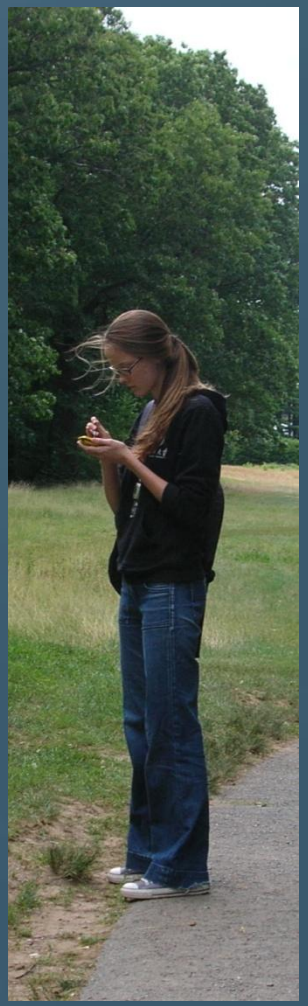
2010 Summer Research Project



http://sylva.org.uk/oneoak/images/trigonometry.PNG

- **Estimate transect heights**
  - **Lidar measurements**
- **Verify with ground data**





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Remote Measurements

- Flew AIMS over 5 transects
  - Cessna 172
  - ~300m elevation
  - ~145km/h
    - Heights
    - Images

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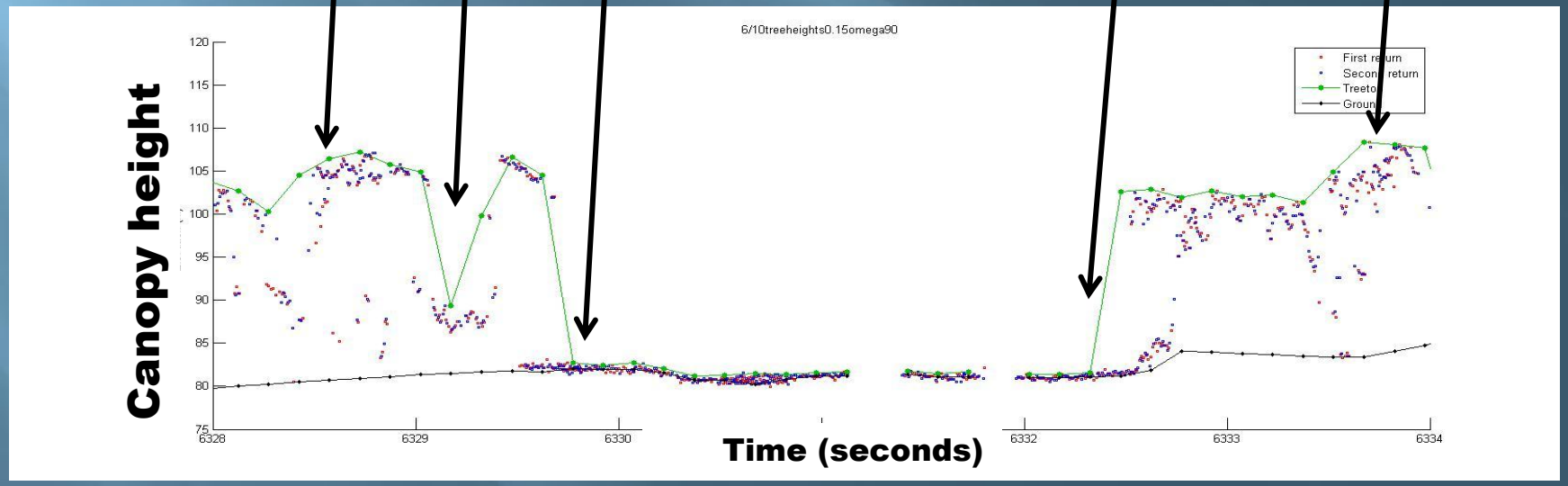
www.syntap.com

Height: Lidar processing



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Profiling lidar processed using MatLab Scripts

Ground Measurements

- Systematic sampling
- 5 transects-366 trees
  - Species
  - Canopy
  - Height
  - DBH
    - Distance & azimuth

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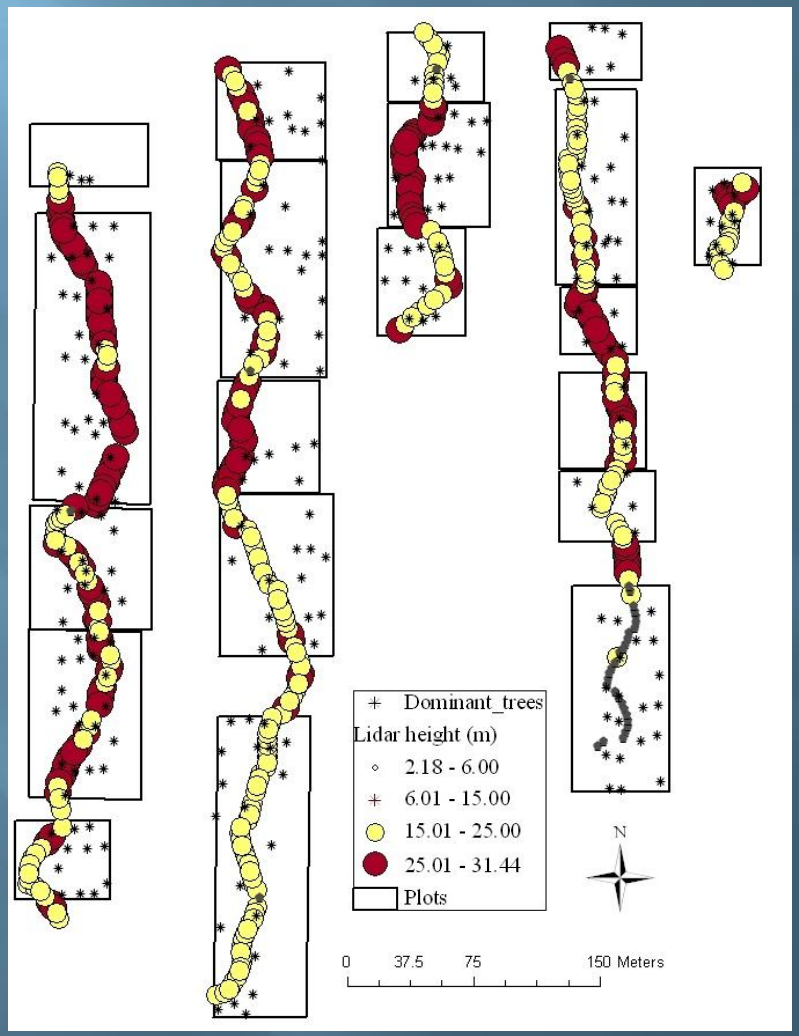
Plots



Subdivide

- 20 plots

Filter

- 236 canopy trees

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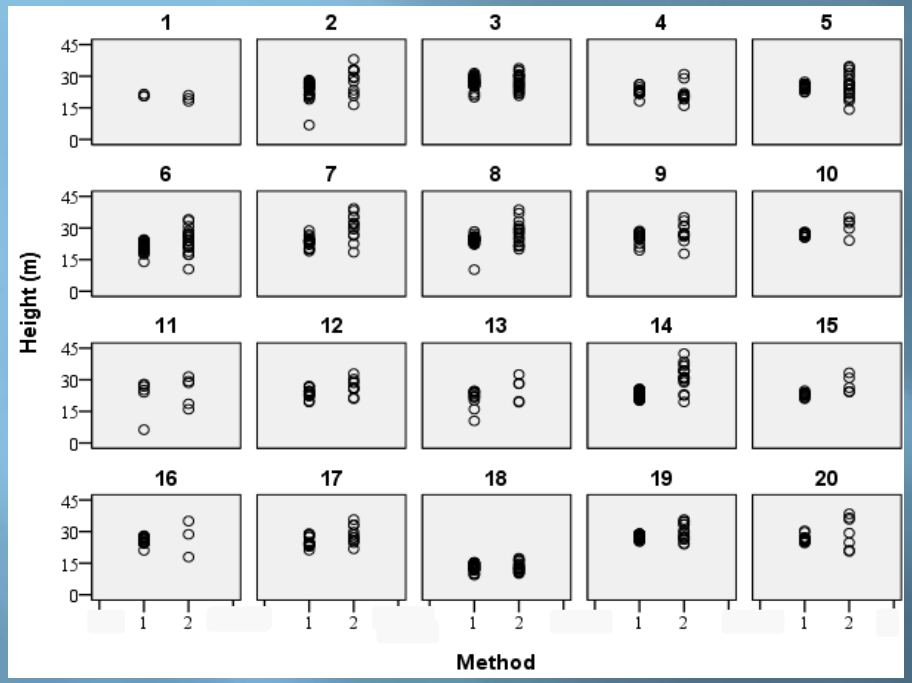
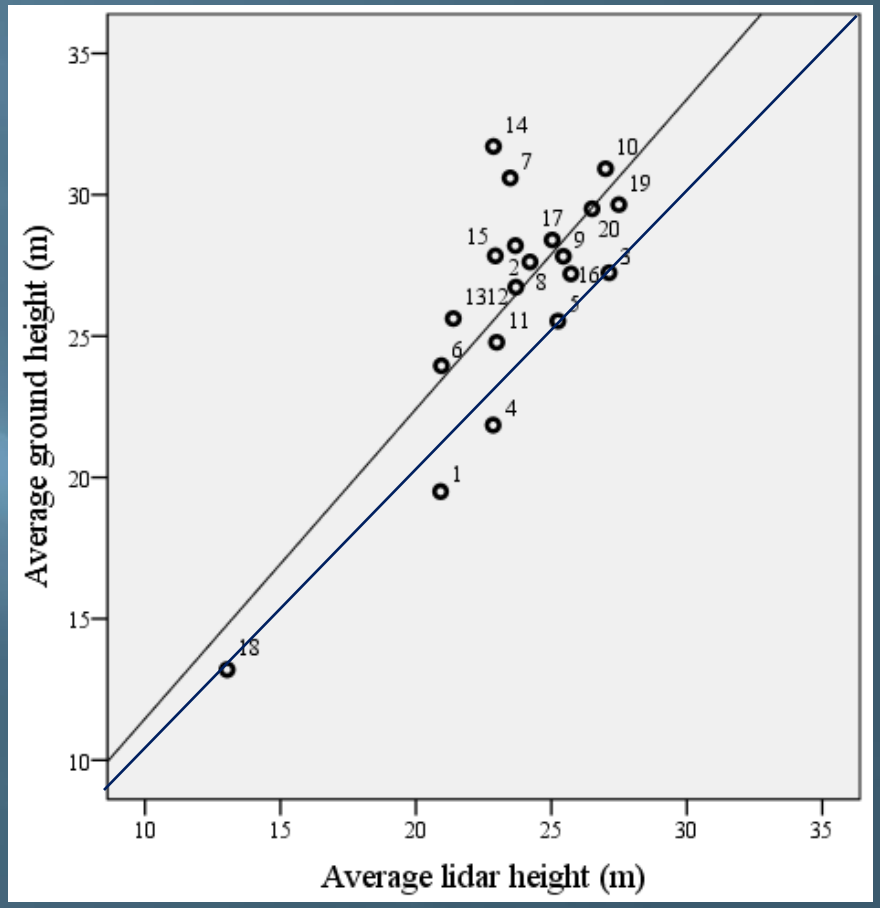
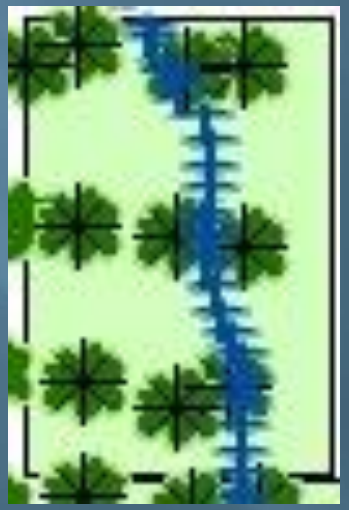
Canopy height data





1=lidar

2=ground (canopy-level trees)



Average ground height= 0.511+(1.096*Lidar height)

R^2=0.658, p<0.001

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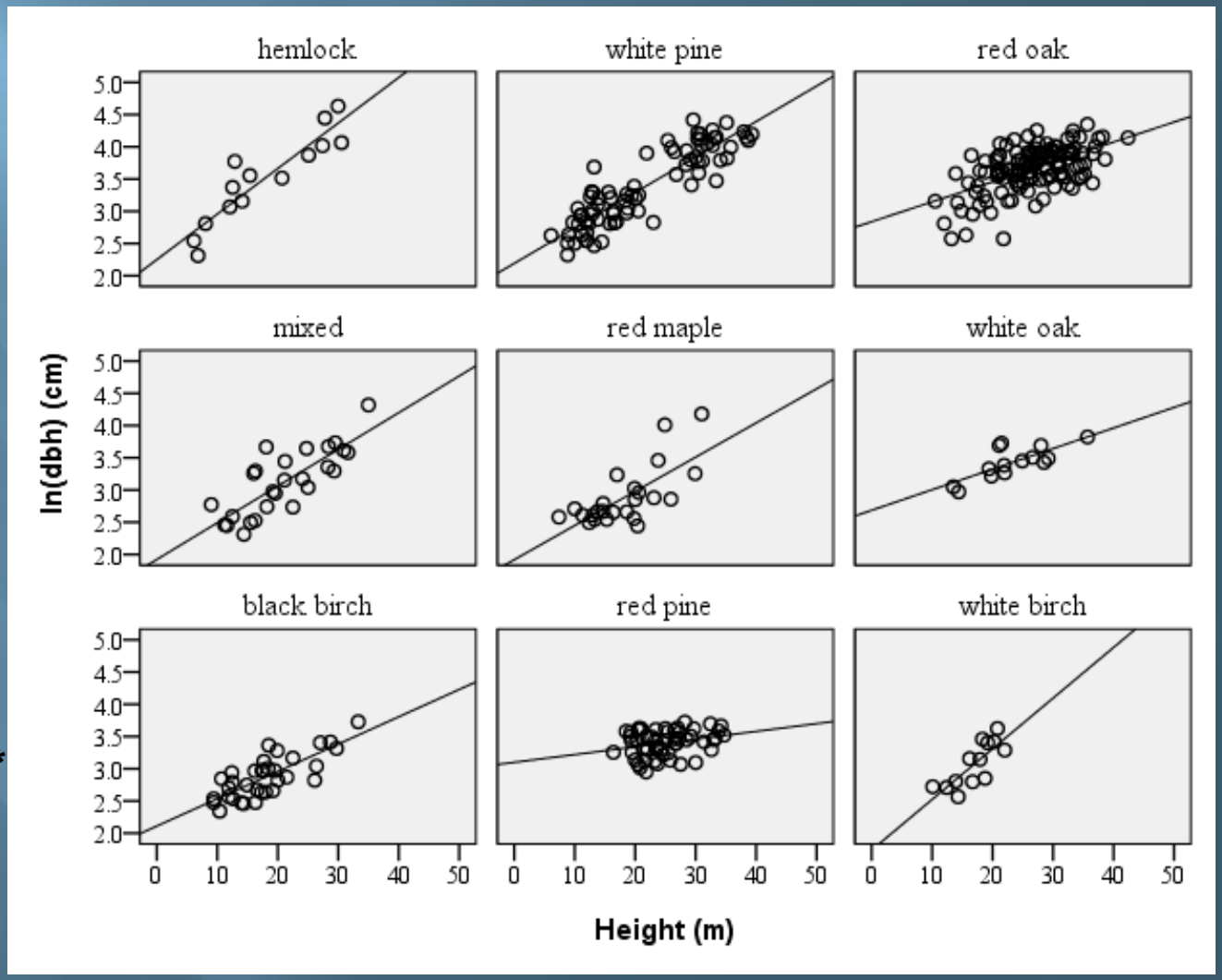
Height to Estimate ln(dbh)

R^2 by species

White pine =0.782**
Hemlock =0.701**
White birch=0.620*
Black birch=0.600**
White oak =0.572**
Red maple =0.507**
Red oak =0.318**
Red pine =0.078*

Mixed hardwood=.60**



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Stand-level biomass

ten 30m*30m subplots- scaled to hectare

Ground calculations

Species
Dbh

Remote calculations

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Calculating Biomass From Ground Data

Identify species

DBH of each tree

Calculate biomass

Total plot biomass

Scale to hectare

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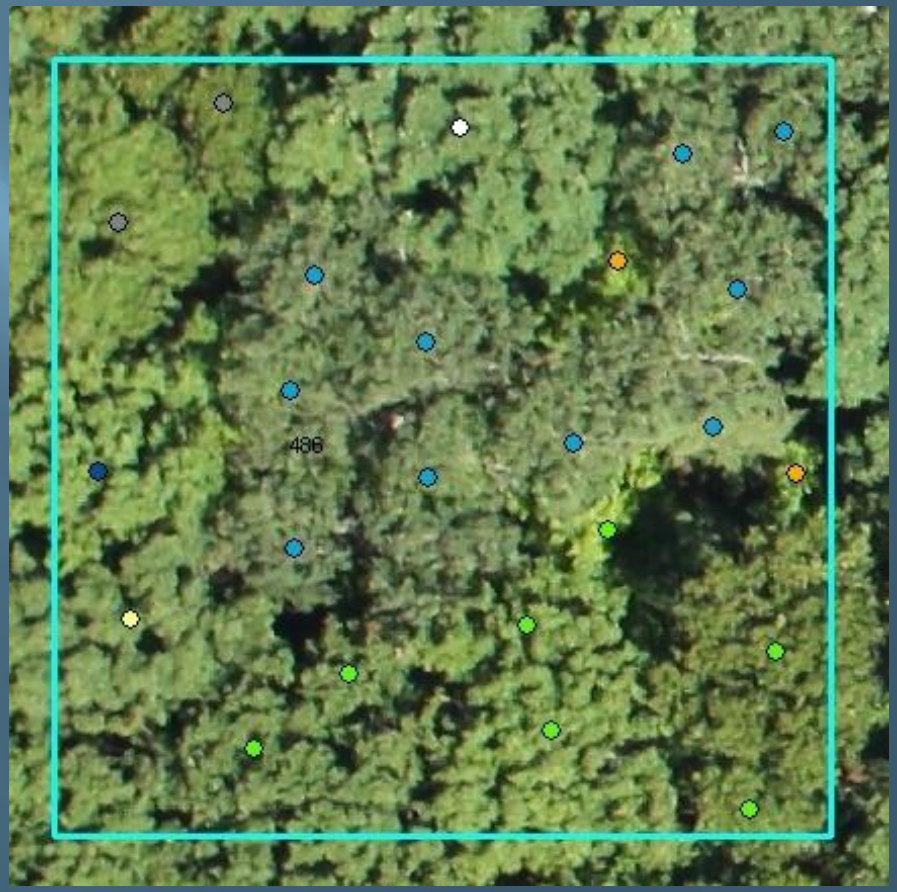
Remote Methodology
Photointerpretation

- Identify species
  - Texture
  - Color
- Count stems
  - Measure crowns
  - Growth patterns



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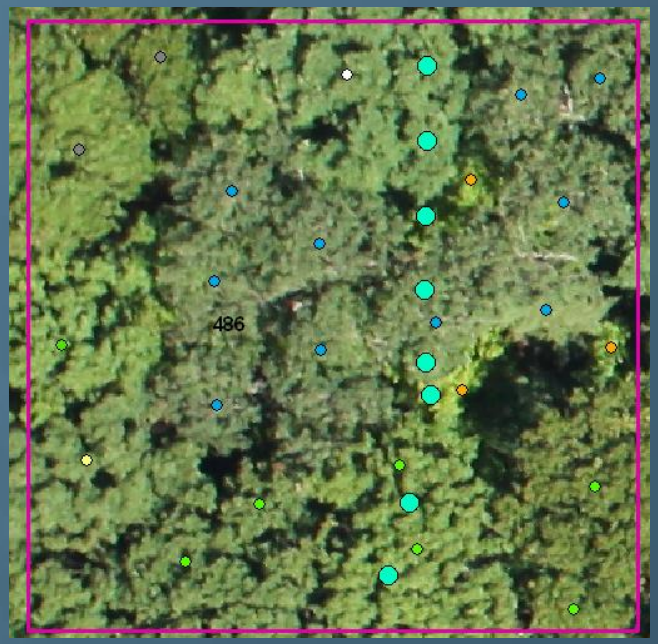
Remote biomass

Plot 486



1 lidar height

lidar height	pred. height	sp	#trees/ sp	stems/ 30x30	trees/ha	reg lndbh	dbh	biomass	HA sp ttl biomass	total bio/ HA
23.4	26.1	bb	2	24	22.2	3.208	**24.7**	**0.360**	8.001	
23.4	26.1	ro	7	24	77.8	3.649	**38.4**	**1.000**	77.742	
23.4	26.1	sm	1	24	11.1	3.396	**29.8**	**0.738**	8.195	
23.4	26.1	mh	0	24	0.0	3.412	**30.3**	**0.401**	0.000	
23.4	26.1	wo	1	24	11.1	3.522	**33.9**	**0.551**	6.126	
23.4	26.1	hi	3	24	33.3	3.410	**30.3**	**0.585**	19.485	
23.4	26.1	bta	10	24	111.1	3.396	**29.8**	**0.318**	35.304	**162.602**

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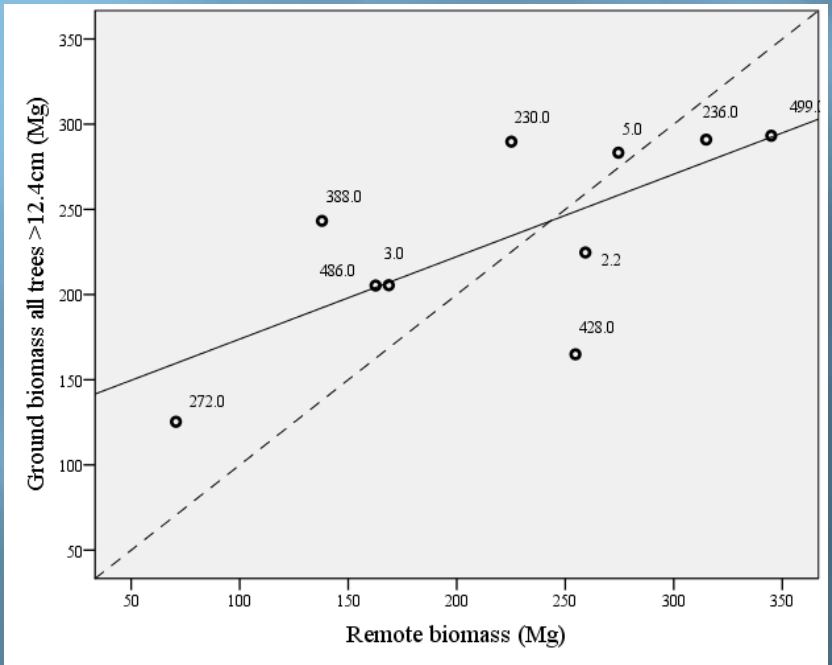
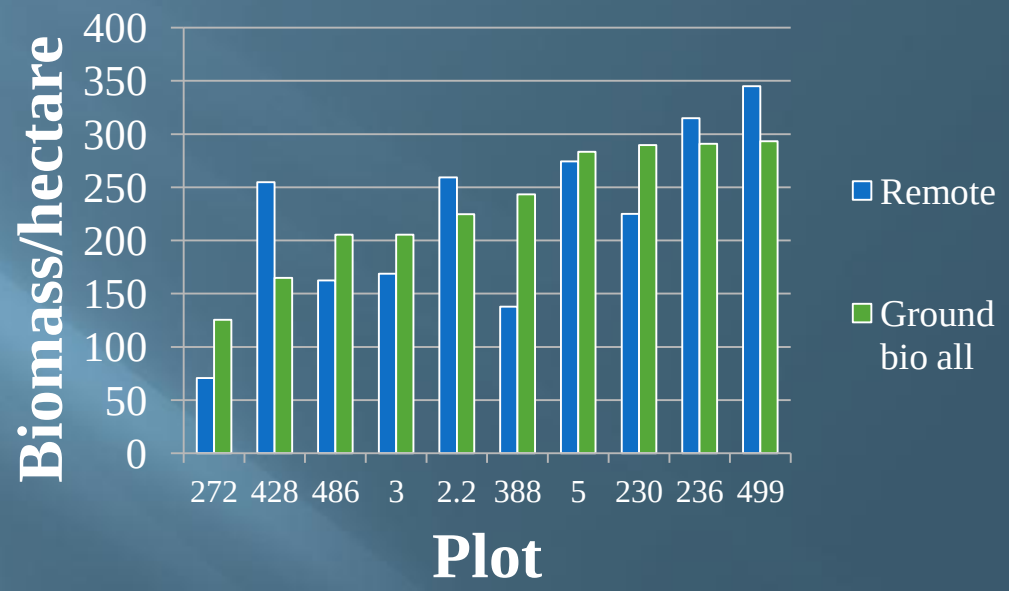
Biomass





biomass= 125.492+(0.484*remote biomass estimation)

R^2=0.499, p=0.022

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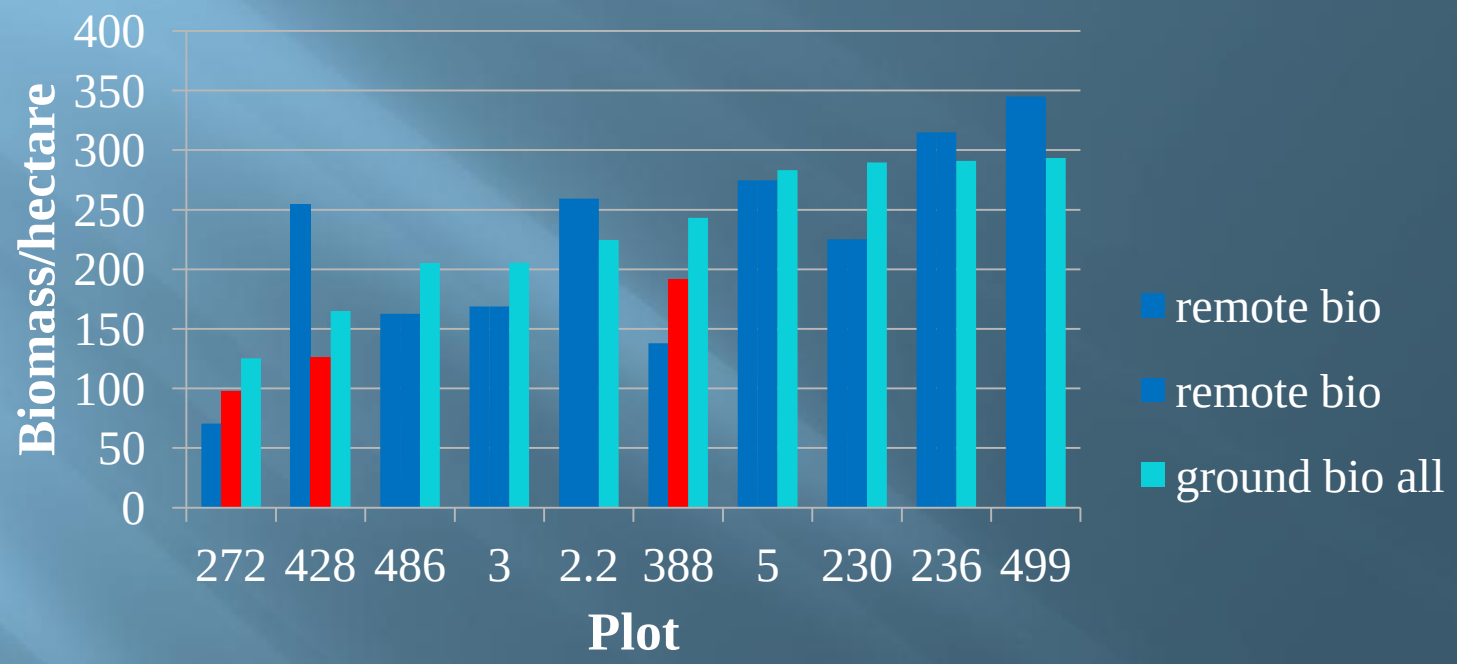
Methodology test



- **Red bars = data that reflects actual stem density or %red oak (R^2=0.74)**

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Conclusions

- **We can:**
  - **Use lidar to estimate stand height**
  - **Estimate dbh from height (For most species)**

- **To estimate biomass**
  - **We need:**
    - **More data**
    - **Improve consistency**

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References

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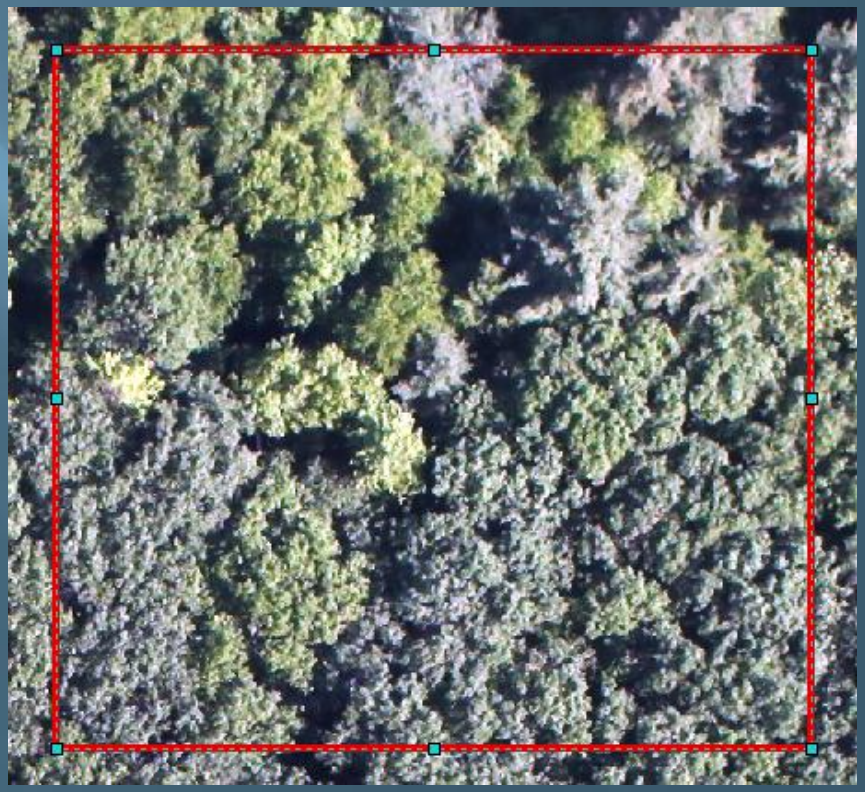
Determine individual trees

NATURAL COLOR

STANDARD DEVIATION STRETCH



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Sampling density

Sampling scheme grid pattern over tree ~20-30m tall tree canopy. Dominant canopy stem density ~240 trees/ha. (21 trees)

Sampling scheme grid pattern over ~14m tall tree canopy. Dominant canopy stem density >1000 trees/ha. (131 trees)

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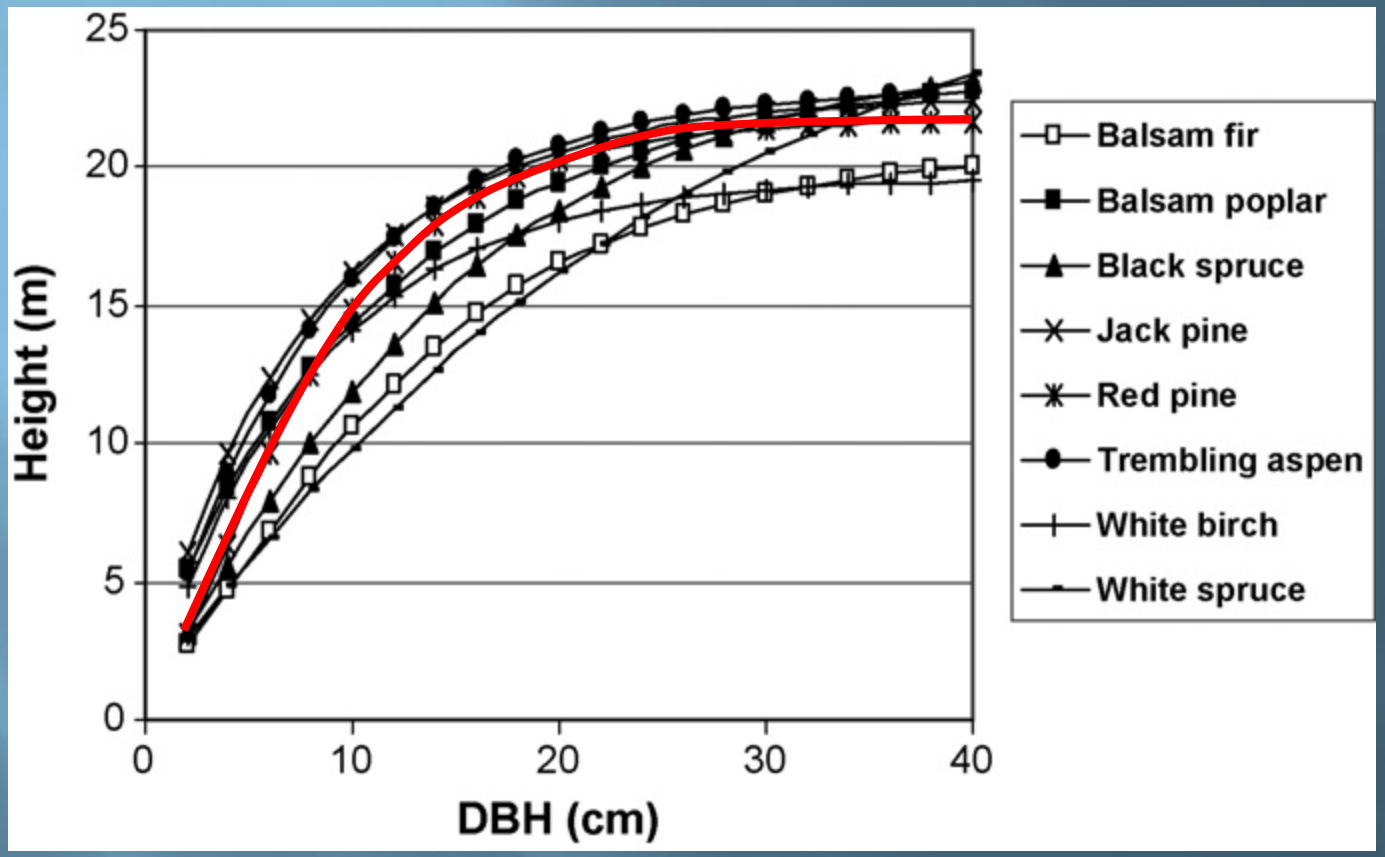
Red pine height to dbh relationship



My trees range from 16-34m tall and 19-41cm dbh *Normally, mature red pines are about 21 to 24m tall, with d.b.h. up to 91 cm* silvi manual

Shama, M. and J. Parton. 2007. Height-diameter equations for boreal tree species in Ontario using a mixed-effects modeling approach. Forest Ecology and Management 249:187-198.

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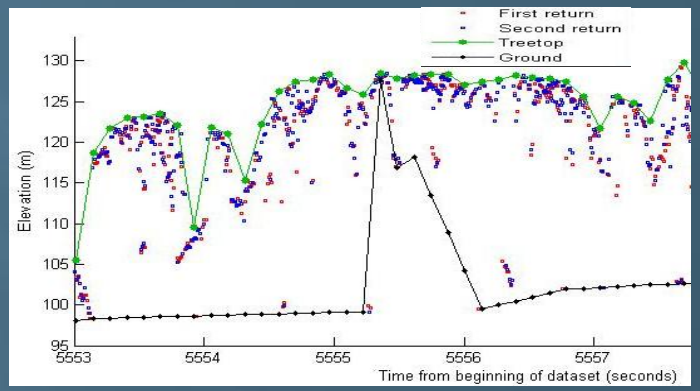
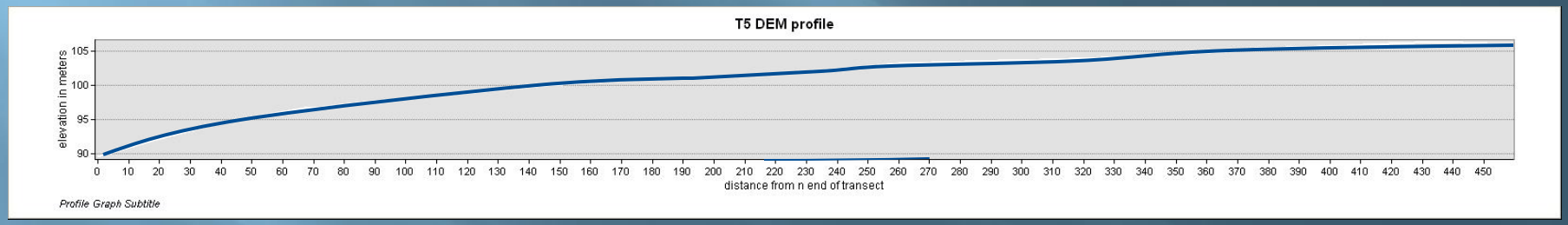
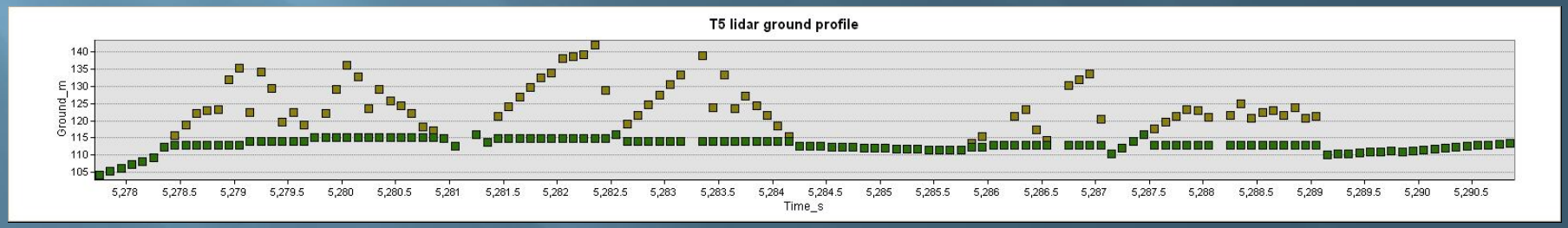
Lidar Groundline ArcGIS 3-D Analyst

- MatLab Scripts
- DEM profile
- Fix ground error
- Recalculate canopy height







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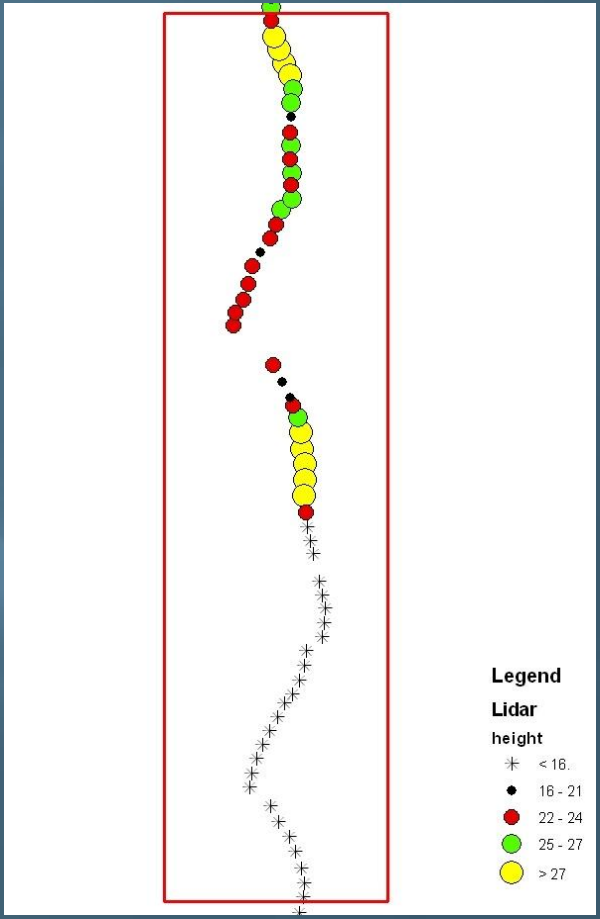
Within plot height variation

Biomass estimation due to lowered average height

Plot	Average lidar height (m)	Estimated biomass (Mg/0.5ha)	Estimated biomass (Mg/1.0ha)
7 N + S	19.49	na	96.63
7 N	25.77	103.11	206.22
7 S	14.74	64.79	129.59
Sum of 7N + 7S biomass		169.90	



1-ha plot is 200m*50m

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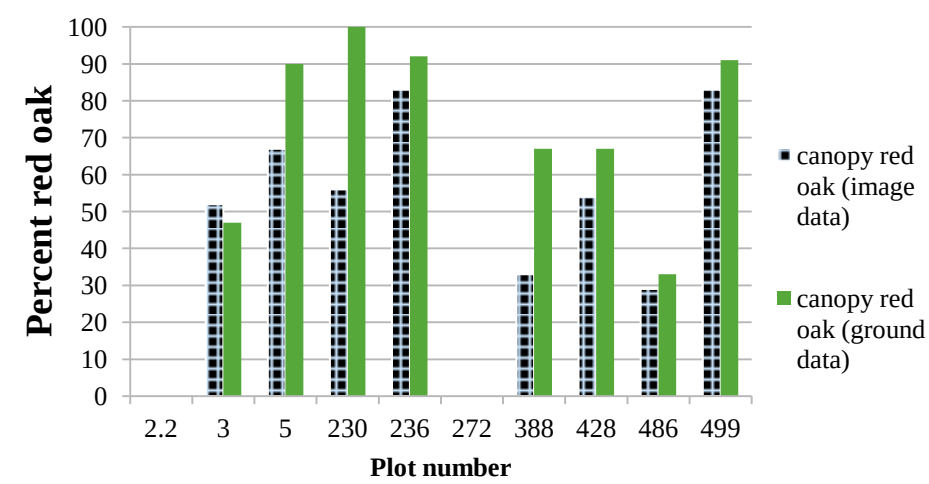
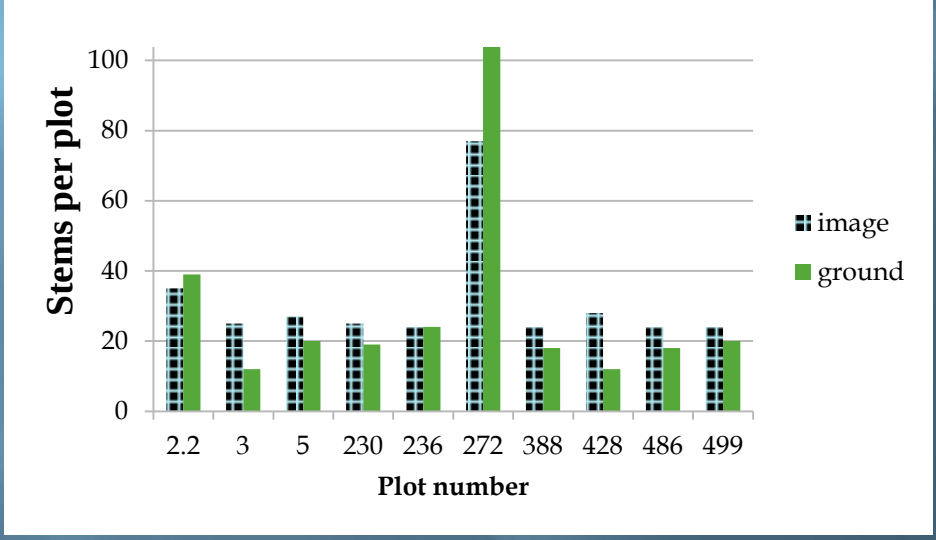
Two sources of error





Plot	Remote error
2.2	0.15
3	-0.18
5	-0.03
230	-0.22
236	0.08
272	-0.44
388	-0.43
428	0.54
486	-0.21
499	0.18

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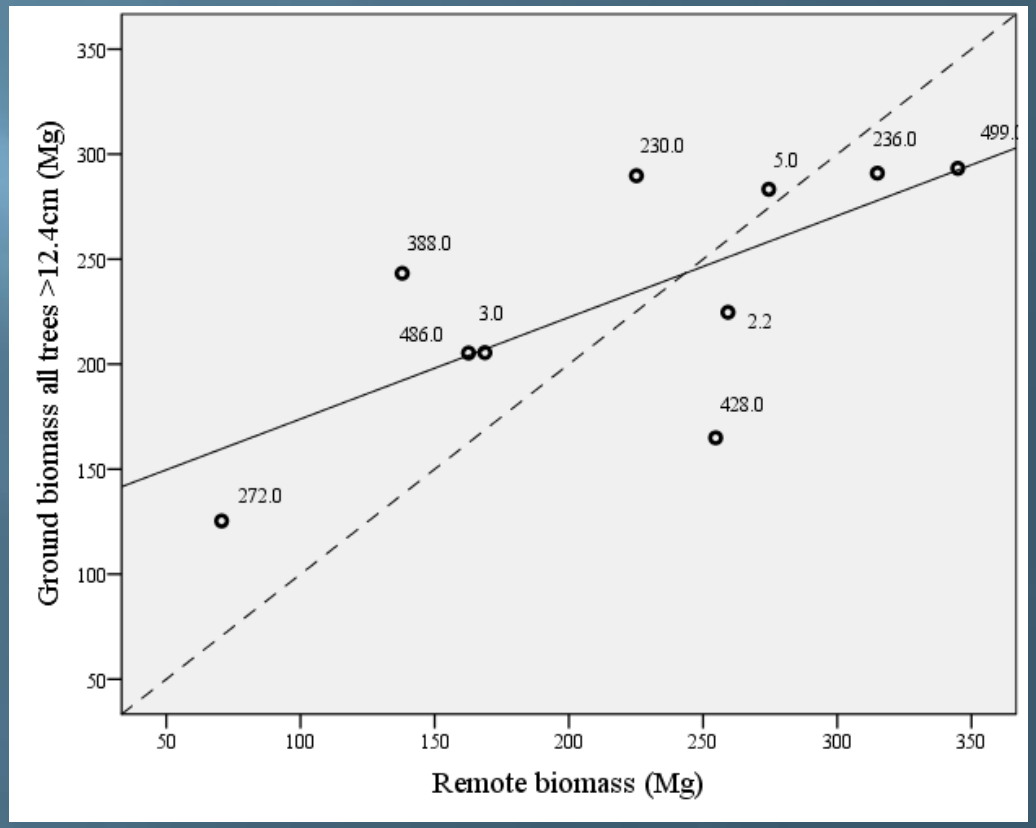
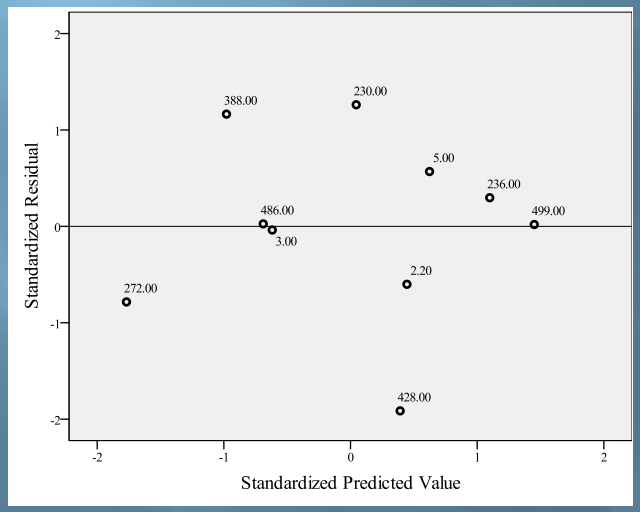
Biomass regression

biomass=125.492+(0.484*remote biomass estimation)

R^2=0.499, p=0.022



Standardized residuals



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Calculating Biomass From Lidar and Image Data

Identified tree

Predicted height

Lidar height

Stem density/ species

Ln(dbh)

Total stem density

dbh

Species average biomass

Species total biomass

Total plot biomass

Scale to hectare

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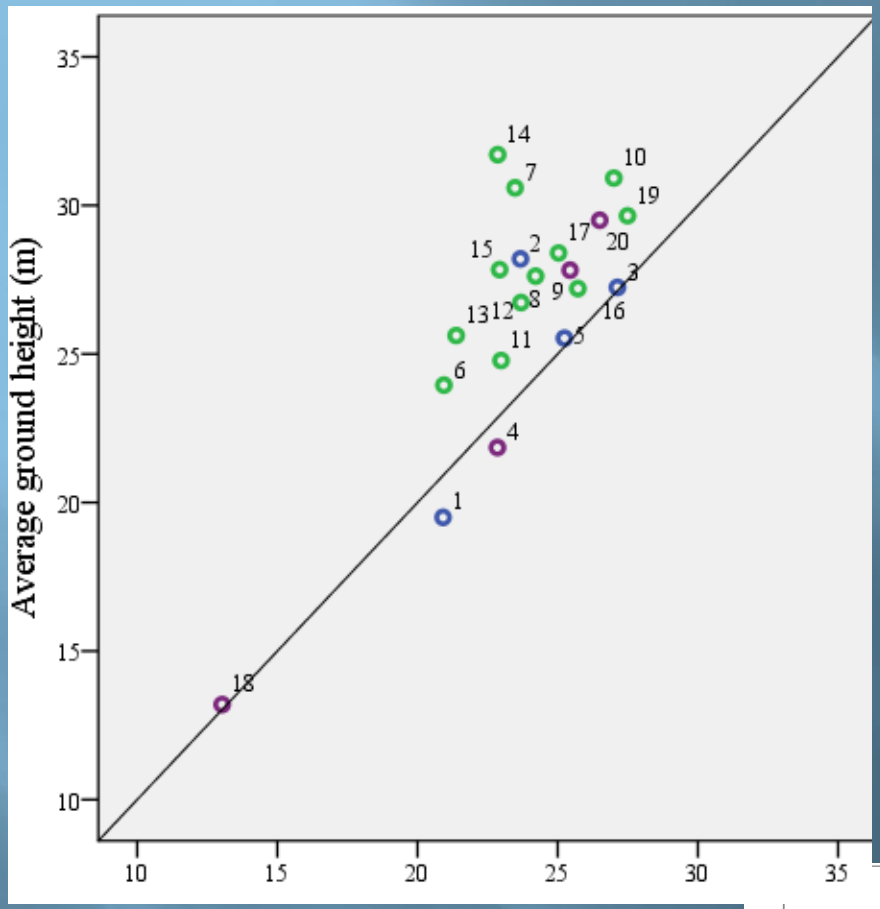
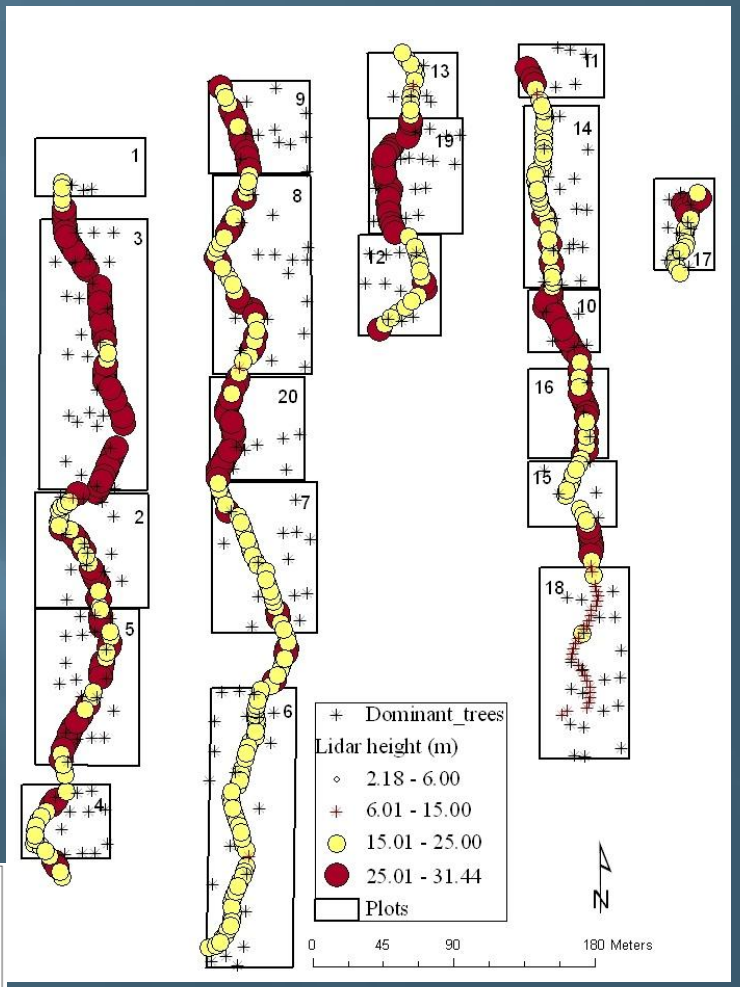
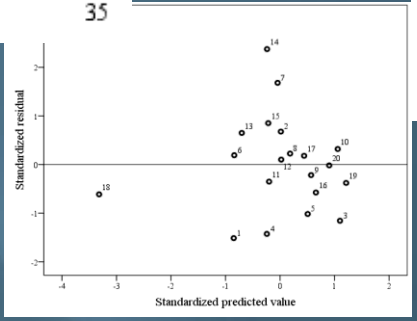
Lidar canopy underestimation







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Biomass differences

Table 3. Comparison of remotely calculated biomass with ground biomass.

Plot	Remote	Ground bio all	Difference ground-remote	*Lidar plot height average*
2.2	259.27	224.66	34.61	*30.14*
3	168.69	205.48	-36.79	*24.05*
5	274.47	283.25	-8.78	*28.03*
230	225.15	289.72	-64.57	*27.24*
236	314.95	290.94	24.01	*29.88*
272	70.62	125.34	-54.72	*14.22*
388	137.90	243.24	-105.34	*24.98*
428	254.70	164.92	89.78	*27.77*
486	162.60	205.32	-42.72	*26.13*
499	344.90	293.26	51.64	*31.22*
Sum	2213.25	2326.13	-112.88	

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Lidar underestimation gradient

lidar height	height*slope	+constant	difference
5	5.48	5.991	-0.991
10	10.96	11.471	-1.471
15	16.44	16.951	-1.951
20	21.92	22.431	-2.431
25	27.4	27.911	-2.911
30	32.88	33.391	-3.391
35	38.36	38.871	-3.871

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Pearson's Correlation

	Dominant Stem Density (ground)	%Canopy	% Vis Image	Act. dom canopy %RO	Remote bio	Ground bio all
Dominant StemDen	1					
pctCanopy	.545	1				
pctVis Image	-.593	-.149	1			
Actual dom. can %RO	-.632*	-.134	.595	1		
remote_bio	-.529	.208	.560	.600	1	
ground_bio_all	-.569	.198	.262	.769**	.707*	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).N=10 for all cases.

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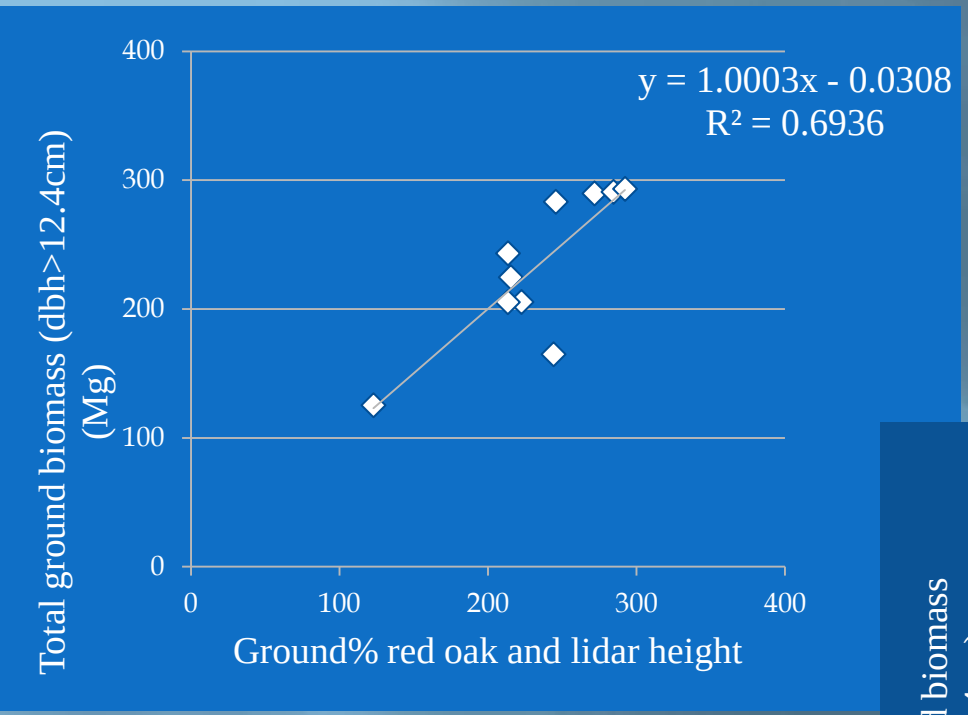
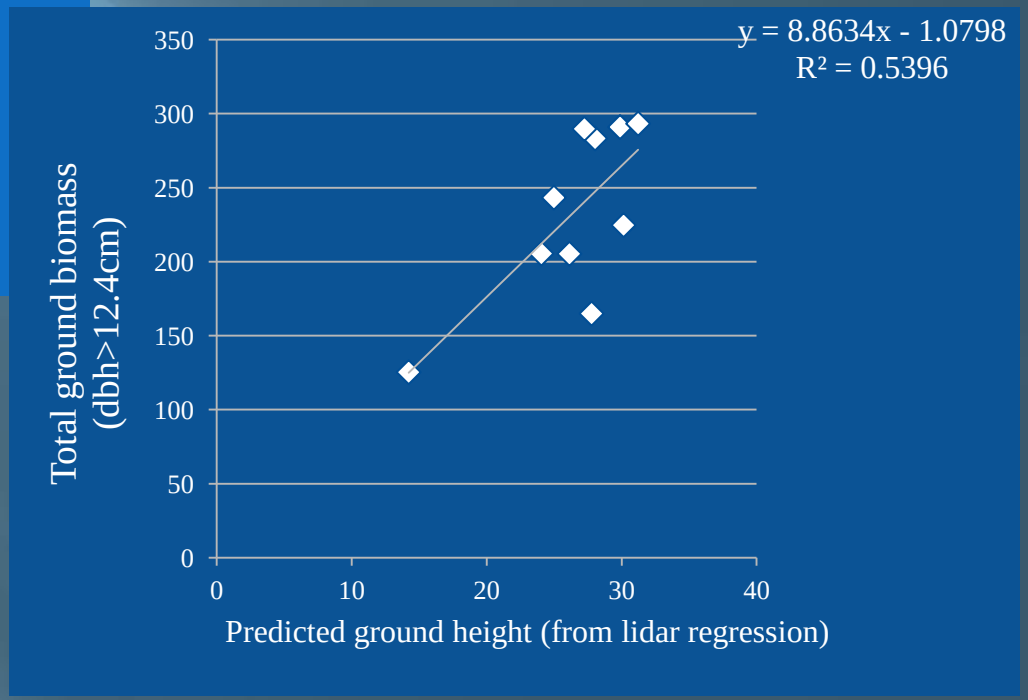
Other tentative estimations



p=0.016 (individual coefficients are not significant)

Removing 428 gives an R2 =0.91



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