Comparison of Canopy Height Models Derived from UAV and ALS LiDAR Data

GGS 622 Drone Remote Sensing

Final Project

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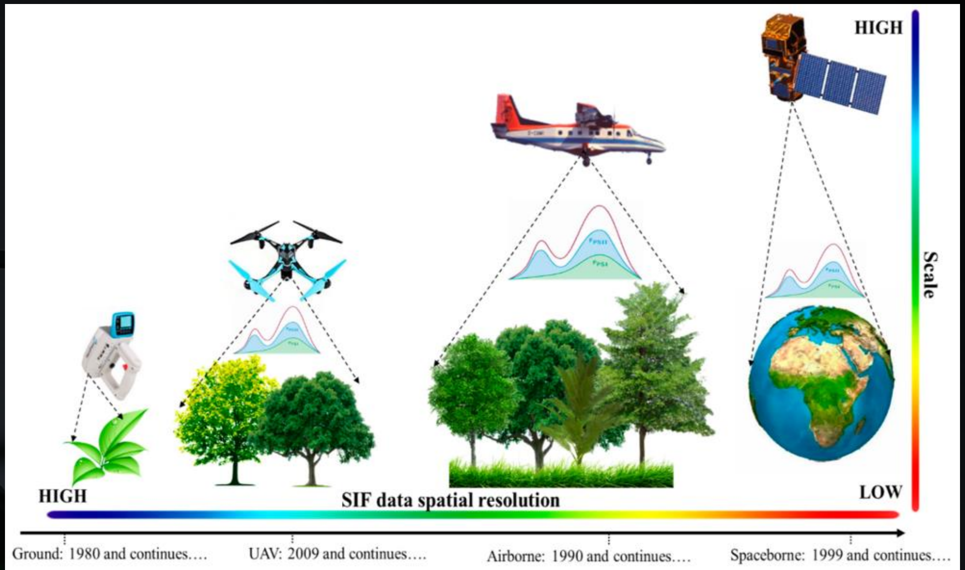
Motivation:

As part of my PhD dissertation, it is interesting to see how well the Canopy Height Models (CHMs) derived from Airborne Laser Scanning (ALS) can perform compared to those from Unmanned Aerial Vehicle (UAV)?



Hypothesis:

- UAV CHMs can provide more details in comparison to ALS CHMs. A pit-filling algorithm should be applied to make CHM datasets comparable.
- The linear relationship between ALS and UAV datasets is strong.

Objective:

- Derive comparable pit-free CHMs from both ALS and UAV LiDAR data products.
- Implement statistical analysis to examine the relationship between ALS and UAV derived CHMs.
- Discuss results and potential errors.

Background

1. Bruggisser, M., Hollaus, M., Kükenbrink, D., & Pfeifer, N. (2019). Comparison of Forest Structure Metrics Derived from Uav Lidar and Als Data. *Proceedings of the ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 325-332.

- compare the scene coverage between ULS and ALS
- Examine the relationship between forest structure metrics and point cloud attributes

2. Resop, J. P., Lehmann, L., & Hession, W. C. (2019). Drone Laser Scanning for Modeling Riverscape Topography and Vegetation: Comparison with Traditional Aerial Lidar. *Drones*, *3*(2), 35.

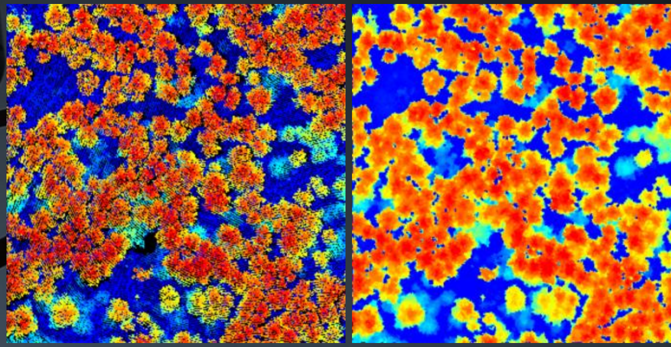
- Developed automating lidar data processing tool for standard ALS data workflows.
- Compare classified point cloud from DLS and ALS to measure riverscape terrain and vegetation features;
- Compare DTMs and CHMs derived from DLS and ALS.

3. Thiel, C., & Schmullius, C. (2017). Comparison of UAV photograph-based and airborne lidar-based point clouds over forest from a forestry application perspective. *International Journal of Remote Sensing*, *38*(8-10), 2411-2426.

- Develop multi-level tree canopy detection algorithms based on UAV and ALS LiDARs.

4. Roussel, J. R., Auty, D., Coops, N. C., Tompalski, P., Goodbody, T. R., Meador, A. S., ... & Achim, A. (2020). lidR: An R package for analysis of Airborne Laser Scanning (ALS) data. Remote Sensing of Environment, 251, 112061.

- Implement pit-filling algorithms in LAStools to maximize the performance of CHMs.



Isenburg et. al (2014)

Method

Study area

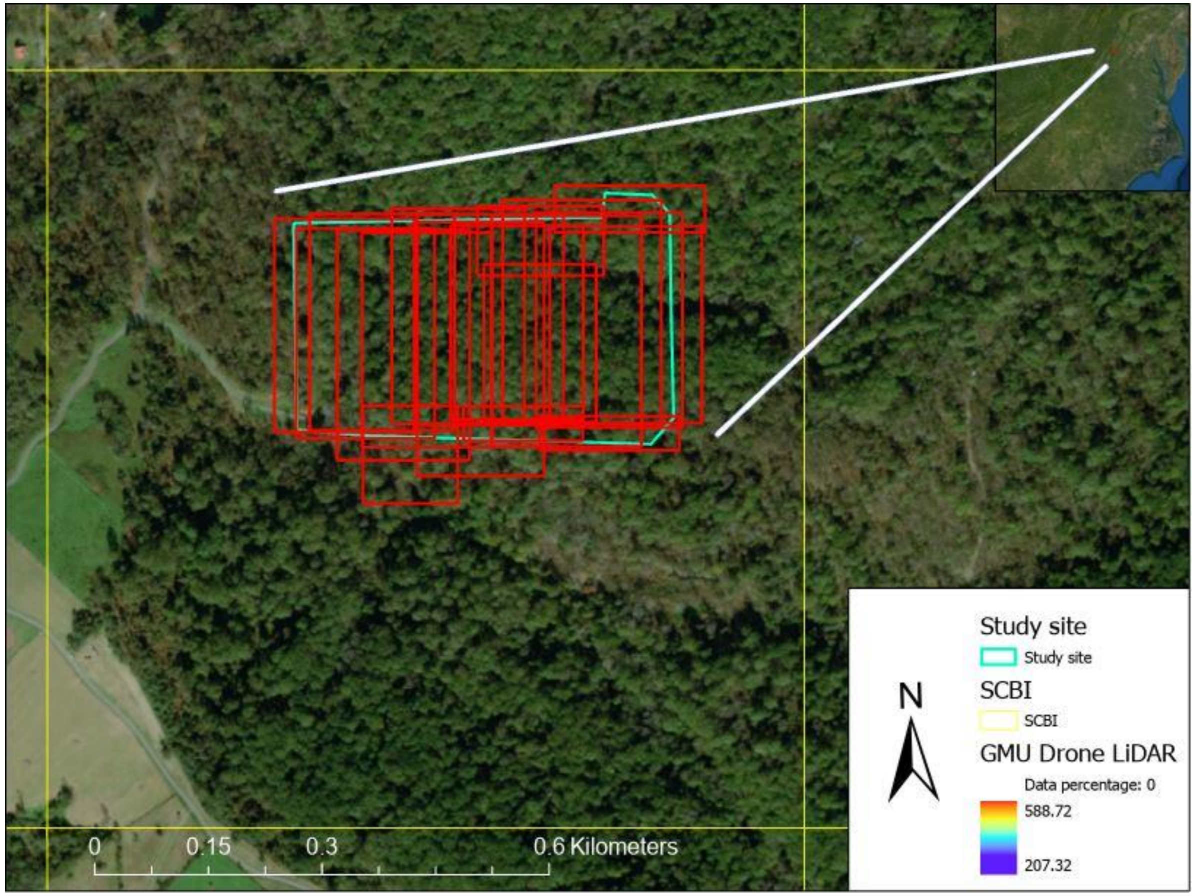


Figure 1. Study site (cyan) in the east of Smithsonian Conservation Biology Institute (SCBI), NEON LiDAR data tiles (yellow), and GMU UAV LiDAR data tiles (red)

Data

GMU UAV LiDAR
Data collection date: March 19, 2020
Data tiles: 19
Point density: 50~300 pt/m^2

NEON (SCBI) ALS LiDAR
Data collection date: June 2019
Data tile: (747000, 4308000)
Point density: 1.7 pt/m^2

Method

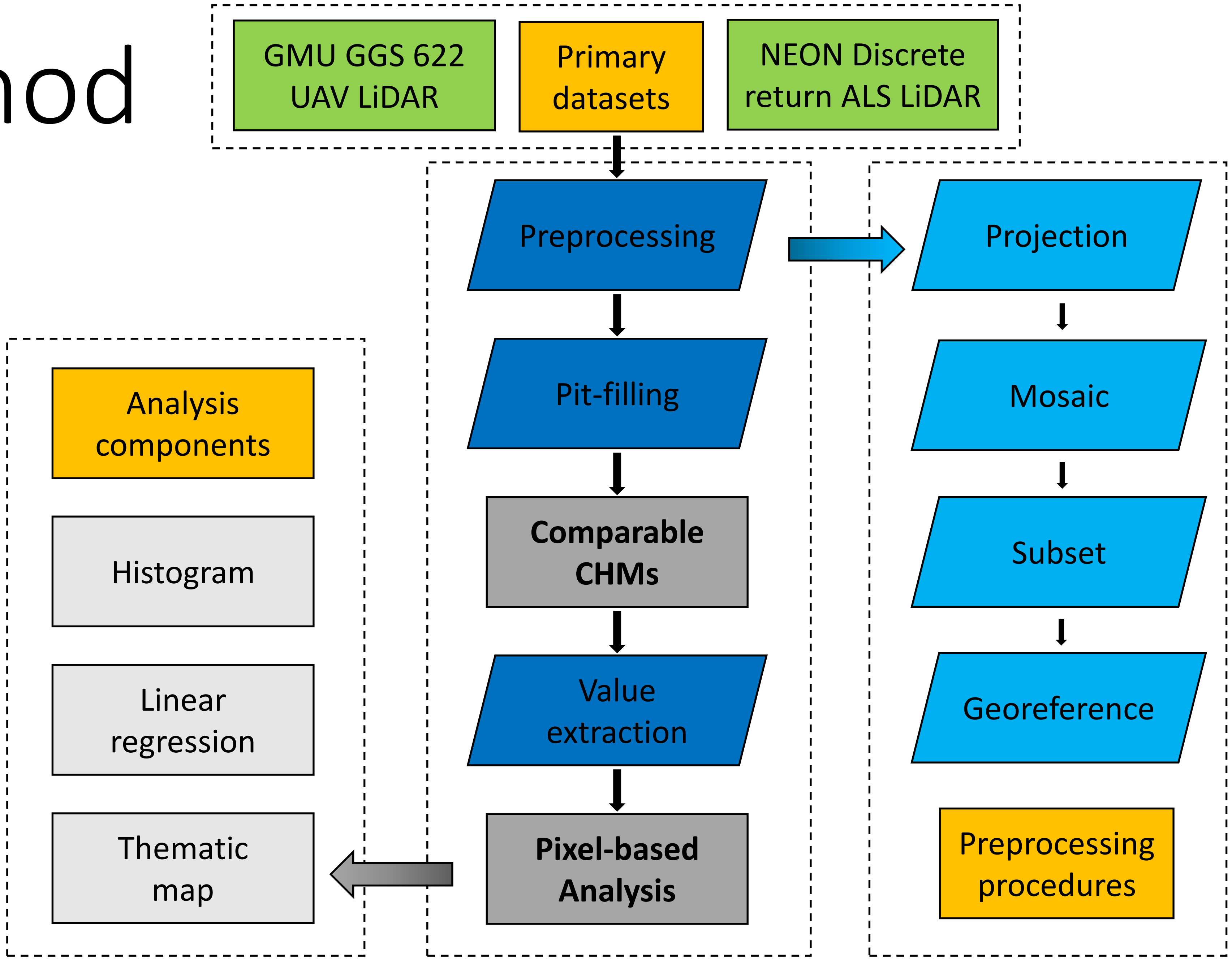


Figure 2. Project workflow

Results

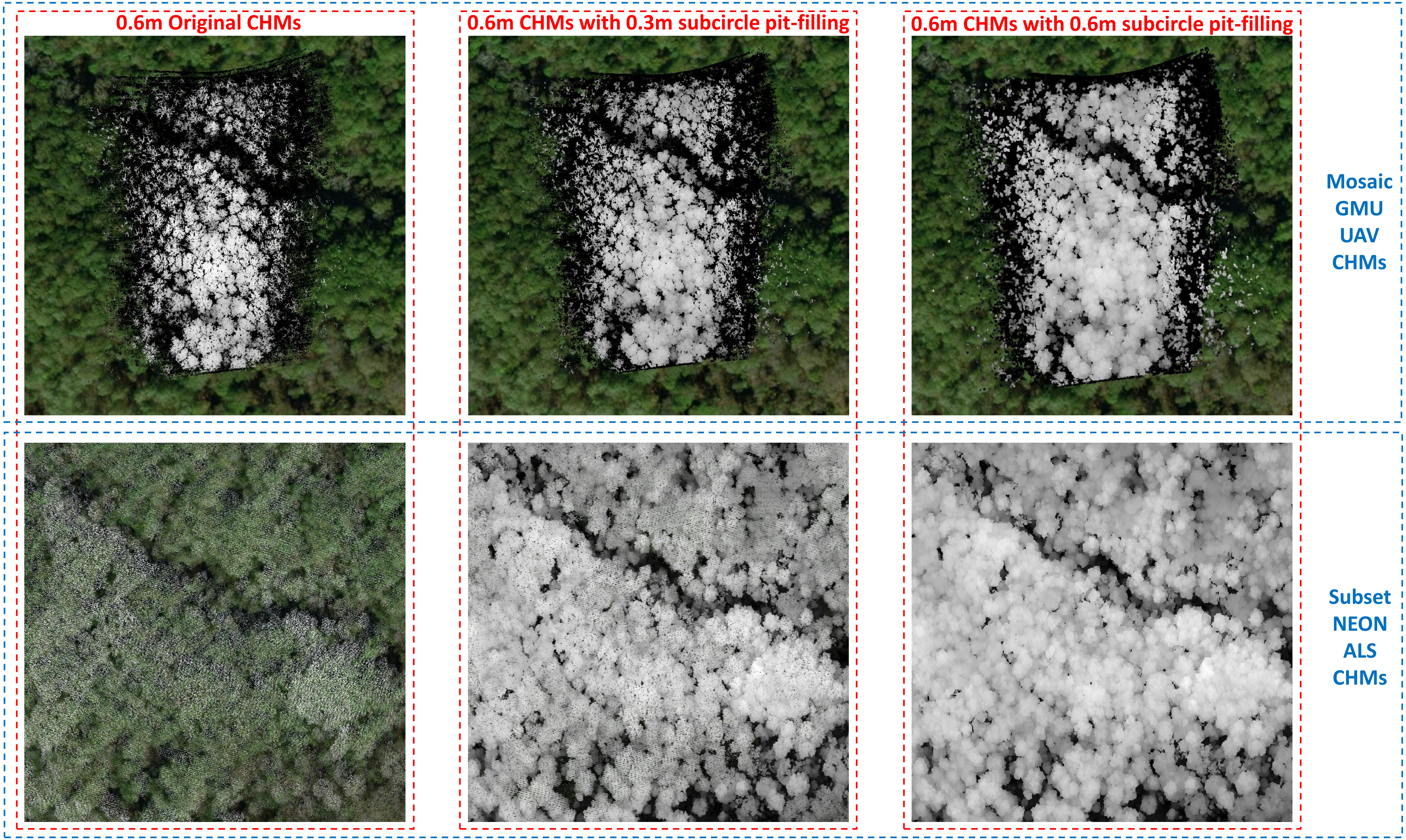


Figure 3. Preprocessed CHMs derived from GMU UAV LiDAR and NEON ALS LiDAR

Results

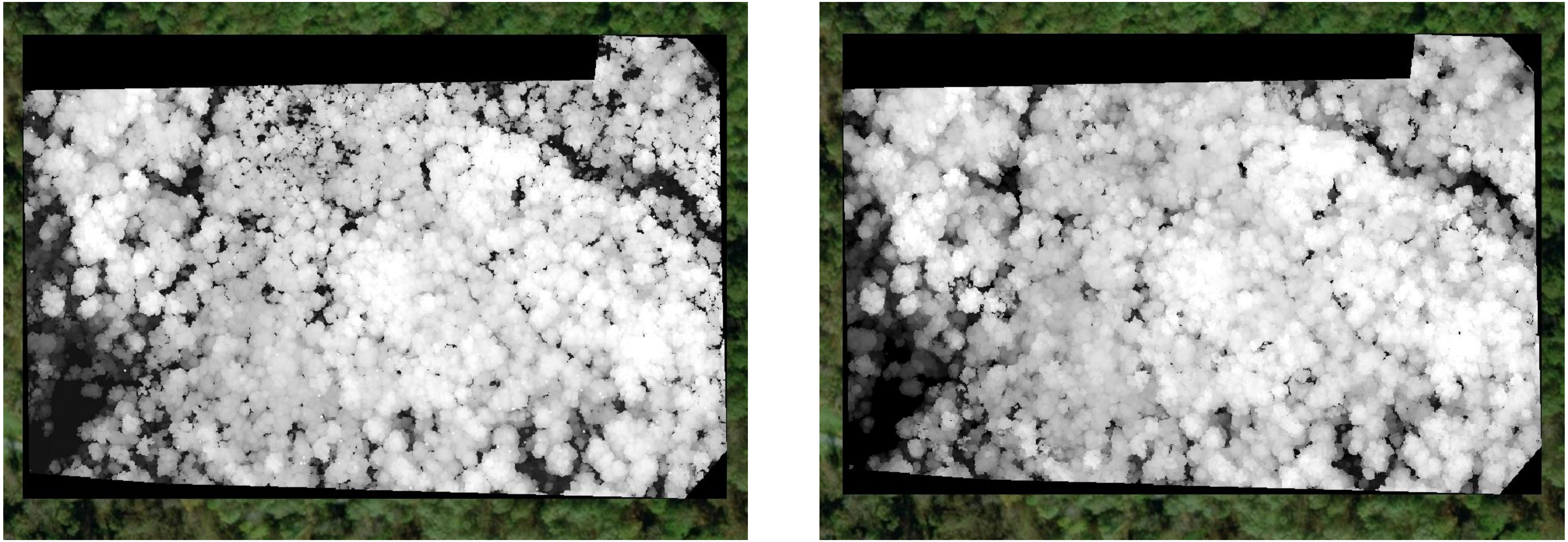
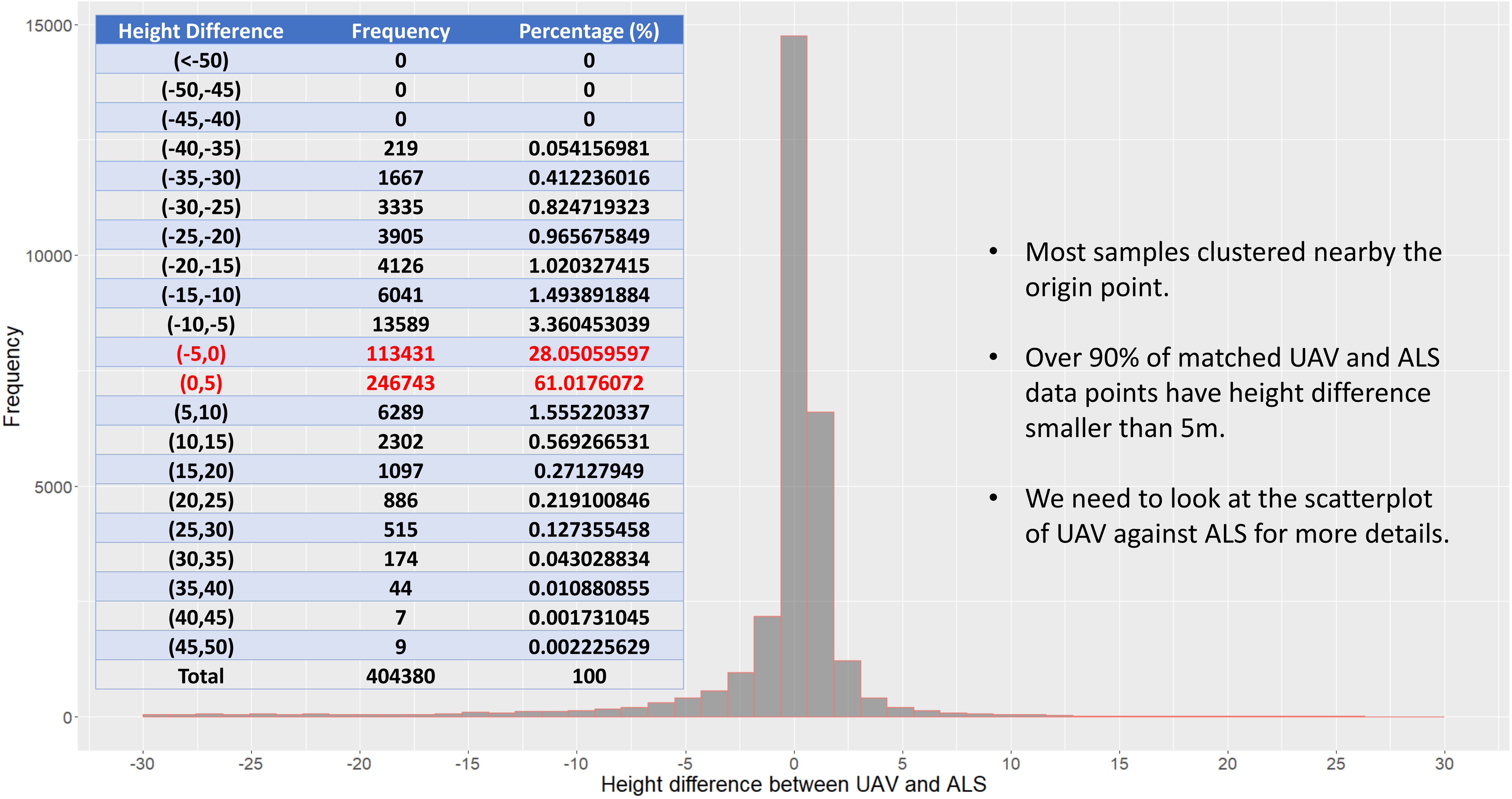


Figure 4. Pit-filling CHMs derived from GMU UAV LiDAR (left) and NEON ALS LiDAR (right).

Results

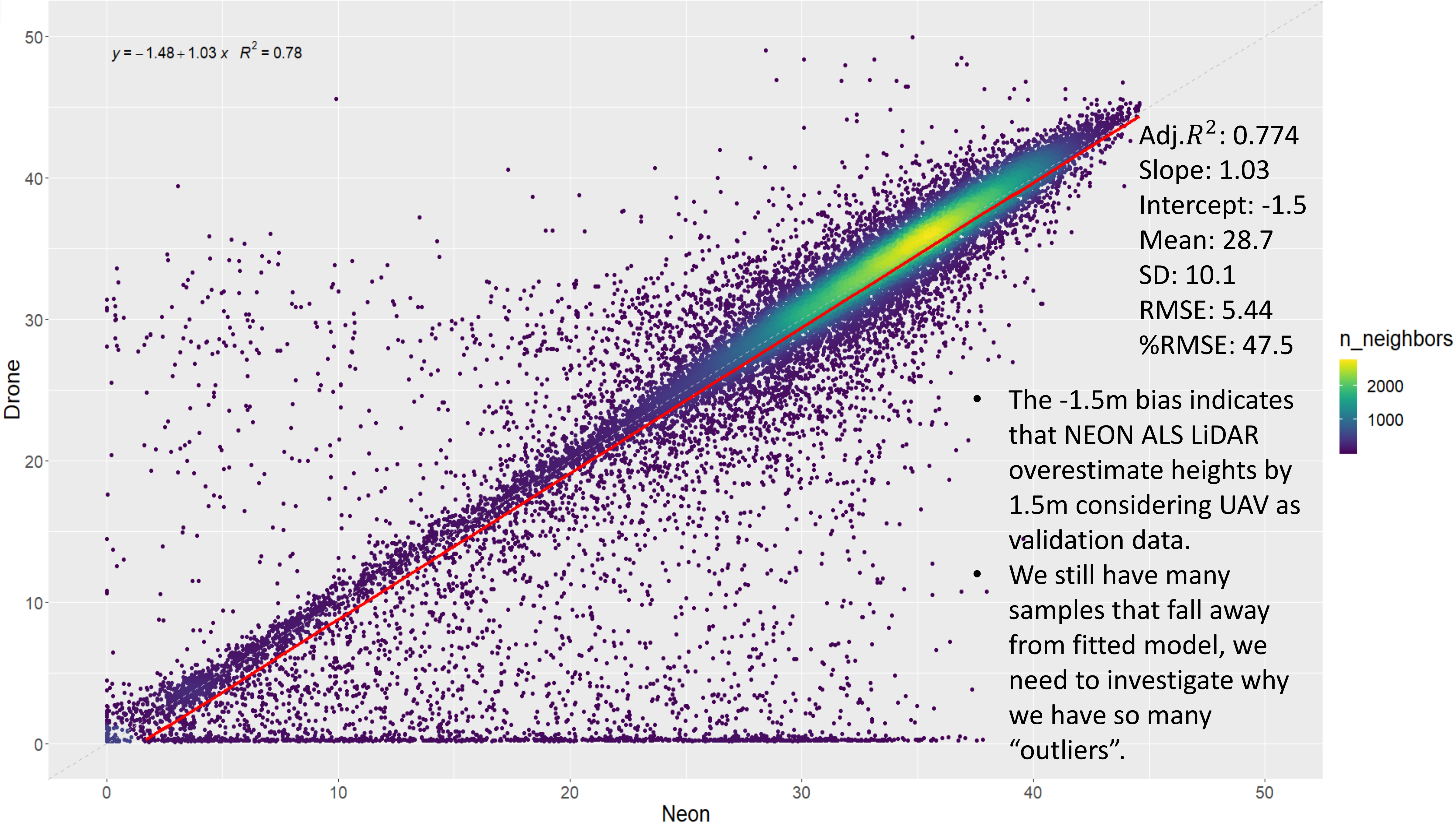


Height Difference	Frequency	Percentage (%)
(<-50)	0	0
(-50,-45)	0	0
(-45,-40)	0	0
(-40,-35)	219	0.054156981
(-35,-30)	1667	0.412236016
(-30,-25)	3335	0.824719323
(-25,-20)	3905	0.965675849
(-20,-15)	4126	1.020327415
(-15,-10)	6041	1.493891884
(-10,-5)	13589	3.360453039
(-5,0)	113431	28.05059597
(0,5)	246743	61.0176072
(5,10)	6289	1.555220337
(10,15)	2302	0.569266531
(15,20)	1097	0.27127949
(20,25)	886	0.219100846
(25,30)	515	0.127355458
(30,35)	174	0.043028834
(35,40)	44	0.010880855
(40,45)	7	0.001731045
(45,50)	9	0.002225629
Total	404380	100

- Most samples clustered nearby the origin point.
- Over 90% of matched UAV and ALS data points have height difference smaller than 5m.
- We need to look at the scatterplot of UAV against ALS for more details.

Figure 5. Histogram of height difference between GMU UAV LiDAR and NEON ALS LiDAR

Results



- The -1.5m bias indicates that NEON ALS LiDAR overestimate heights by 1.5m considering UAV as validation data.
- We still have many samples that fall away from fitted model, we need to investigate why we have so many “outliers”.

Figure 6. Pixel-based linear model of CHMs derived from GMU UAV LiDAR and NEON ALS LiDAR

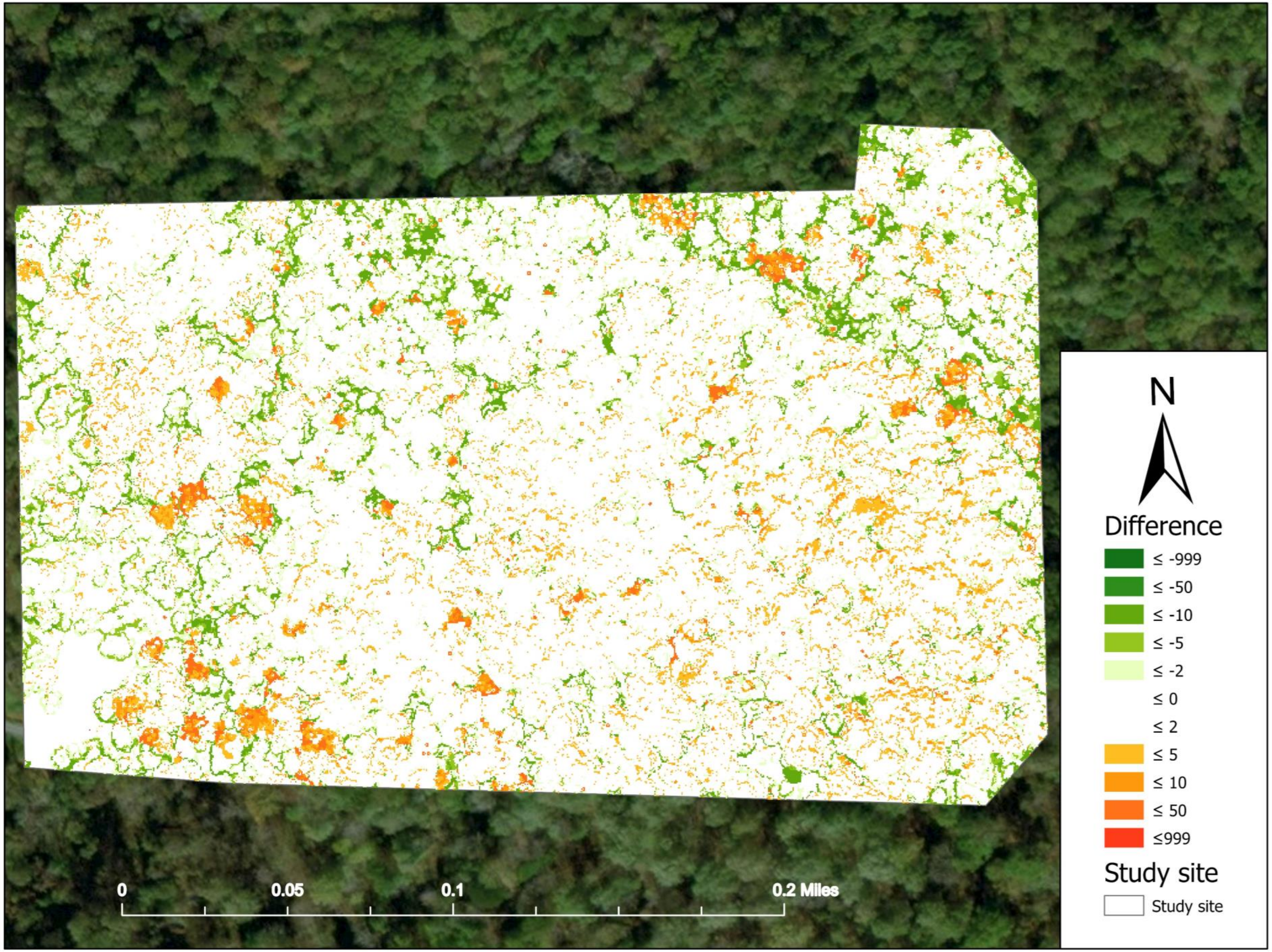
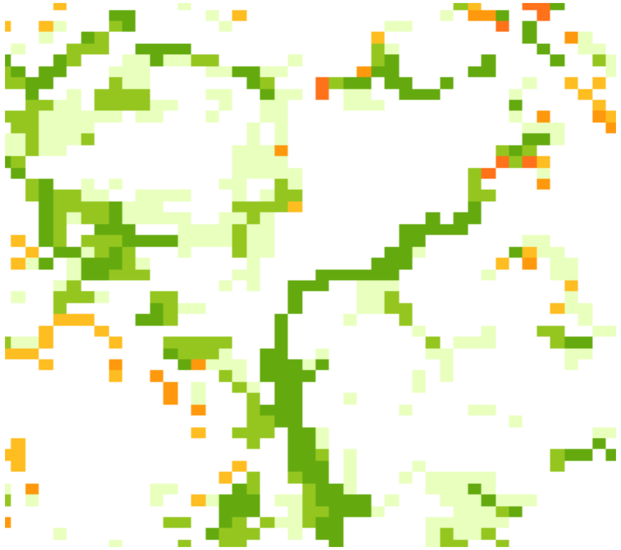
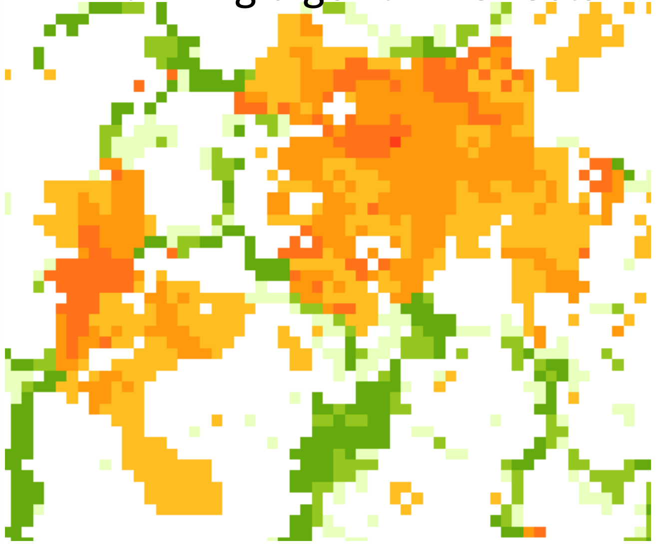


Figure 7. Difference map between GMU UAV LiDAR and NEON ALS LiDAR



Boundaries in **green**:

- Gereferencing?
- Pit-filling algorithm effects?



Clusters in **red**/**orange**:

- ALS point density limitation
- Potential vegetation change

Conclusion

- UAV LiDAR provides billions of point cloud samples with extremely high point density, demonstrating excellent performance for topography measurement and ALS data validation. The results show that UAV derived CHMs are able to provide more feature details compared to ALS data.
- There is a strong relationship between UAV and ALS derived CHMs, with a R^2 of 0.77 and a bias of -1.5m. However, the variance of test samples is still kind of large. Possible reasons are pit-filling effects, georeferencing issues, ALS point density limitation, and potential vegetation change. Overall, the results suggest that UAV dataset is useful for validating ALS LiDAR.

Future work

- Include spaceborne LiDAR missions (GEDI, ICESat2) into the analysis. Investigate the potential capability of using ALS/UAV datasets to validate large footprint spaceborne LiDAR data products.
- Another GMU Drone LiDAR dataset collected in Sep 2020 is also expected to have promising statistical results. Further analysis will be focusing on using such existing high point density LiDAR datasets to validate global or country-level LiDAR products.
- To avoid boundary effects, pit-filling algorithms are expected to be carefully developed based on different circumstances.

Reference

- Bruggisser, M., Hollaus, M., Kükenbrink, D., & Pfeifer, N. (2019). Comparison of Forest Structure Metrics Derived from Uav Lidar and Als Data. *Proceedings of the ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 325-332.

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- Isenburg, M. (2014). Rasterizing perfect canopy height models from LiDAR.