Derived LiDAR Products and Forestry Applications: Crawford Study Area—White Mountain National Forest

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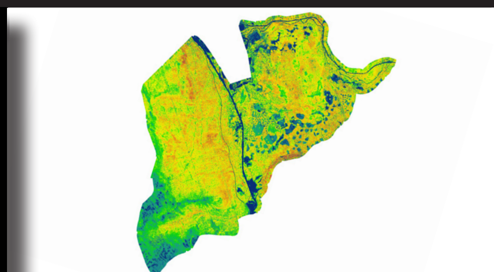
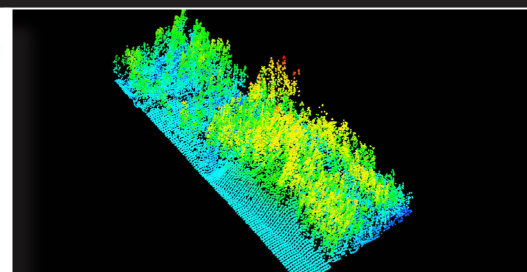
RSAC-0999-BRIEF3

United States Department of Agriculture

Forest Service

Remote Sensing Applications Center

Abstract

In May of 2007, multiple-return LiDAR (light detection and ranging) data was acquired over the Crawford study area on the White Mountain National Forest New Hampshire. In this report we will outline products produced from this data set using Fusion, software produced by the Forest Service from the Pacific Northwest research Station. Products useful to Forestry are included here as well as a table report on the data set itself.

Key Words

LiDAR, Forestry, New Hampshire, White Mountain National Forest, Digital Terrain Model, Percentiles, Intensity Image

Authors

Haans Fisk is a remote sensing/GIS specialist at the Remote Sensing Applications Center in Salt Lake City, Utah.

Paul Maus is a remote sensing/GIS analyst working at the Remote Sensing Applications Center and is a principal of RedCastle Resources.

Steven Dale is a remote sensing/GIS analyst working at the Remote Sensing Applications Center and employed by RedCastle Resources.

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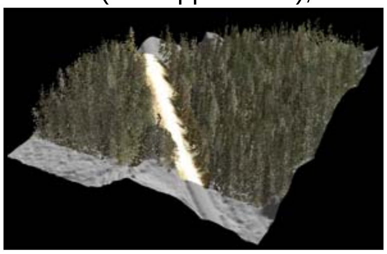
Overview

In May of 2007, multiple-return LiDAR (light detection and ranging) data was acquired over the Crawford study area on the White Mountain National Forest. This report describes that data set and provides several interesting and useful products pertaining to terrain and forestry applications. It includes a brief overview of the technical specifications as provided in the metadata, summarizes key characteristics of the data set (see Appendix A), and introduces several LiDAR derived products including:



- Digital Terrain Model (DTM)
- LiDAR Intensity Image
- Canopy Surface Model (CSM)
- Canopy Height Model (CHM)
- Canopy Cover Model (CCM)
- Vertical Structure Percentiles
- Site-Specific Visualizations

LiDAR is an active remote sensing system that uses laser light to accurately determine the elevation of objects. This technology can penetrate vegetation canopy and be used to produce high-resolution images of the ground surface (figure 1). It can also be used to generate vegetation structural layers including canopy cover and vegetation height. If analyzed in conjunction with suitable field data, a variety of forest metrics can be modeled such as tree size class, basal area, forest biomass, and volume. Obtaining information about vegetation composition, structure, and pattern can benefit a variety of natural-resource planning and monitoring activities, including assessing fuel loads and fire risk, wildlife habitat, and impact from recreational activities.

The LiDAR derived products introduced in this report were prepared using Fusion. Fusion is a LiDAR viewing and visualization software suite developed by the Silviculture and Forest Models Team of the Pacific Northwest Research Station. Fusion is readily installed and will run on FS corporate hardware without the need to obtain administrator privileges – and it's provided free. It is available at: http://forsys.cfr.washington.edu/fusion/fusionlatest.html.

In addition, the Forest Service Remote Sensing Applications Center (RSAC) has prepared an on-line tutorial to help resource staff better understand LiDAR data and the use of Fusion software through interactive display, visualization, and measurements. The tutorial is available on the FS Geotraining website at: http://fsweb.geotraining.fs.fed.us/tutorials/fusion/. Furthermore, if staff on the White Mountain National Forest needs to follow up with the information provided in this report, please contact Haans Fisk at the Remote Sensing Application Center, (801)-975-3750.

Technical Data Summary

Data Package:
- Data Format: LAS files
- Number of Tiles: 24 tiles
- Data size: 1.15 GB

Acquisition Date: May 5, 2007 & May 7, 2007
Area Coverage: 13,900 acres
Wavelength: Near Infrared (~0.75-1.4 µm)
Accuracy:
- Horizontal: 17 cm RMSE
- Vertical: 7 cm RMSE

Return Density (per 1 sq. meter):
- Average: 2.4

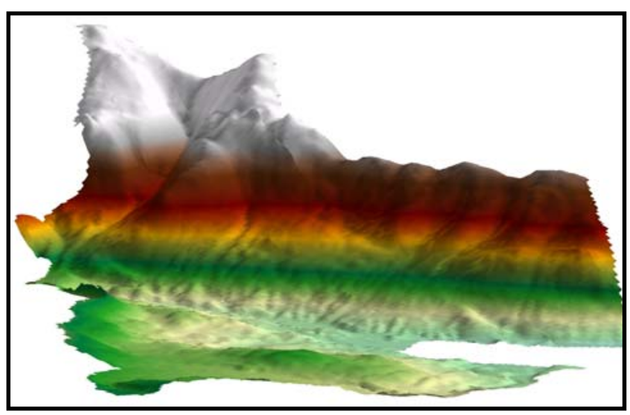


Figure 1. Perspective view of LIDAR elevation data draped over DTM, Crawford study area.

Digital Terrain Model (DTM)

The Digital Terrain Model (DTM), sometimes called bare earth model, is derived from the LiDAR point cloud data (raw x, y, and z), which penetrates tree canopy. Fusion was used to produced a DTM for the Crawford study area at a 3 meter spatial resolution. This model is useful for a number of terrain analyses that include mapping stream channels, debris slides, and fine-scale surface features.

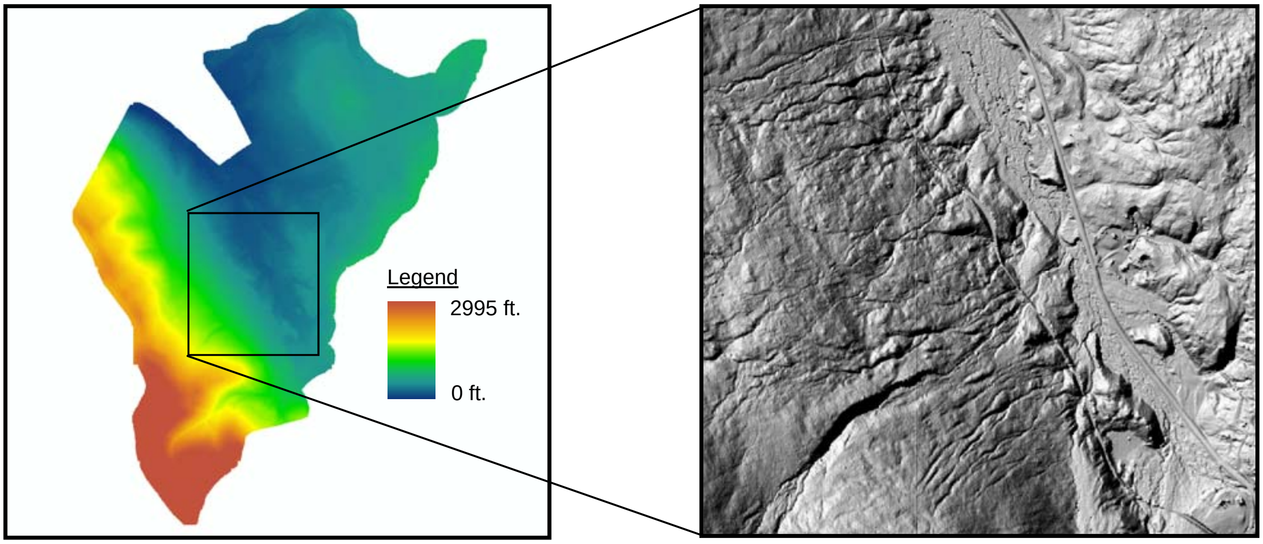


Figure 2. Left is a Digital Terrain Model (3m) of the Crawford study area. On the right is a DTM hillshade that clearly depicts geomorphic landscape features.

LIDAR Intensity Return Image

The LiDAR intensity return image represents surface reflectivity similar to an orthophotograph image. During LiDAR acquisition, an intensity value is collected for each LiDAR point. An index and catalog executable within Fusion uses this value to produce the reflectivity surface. The Intensity image shown below was created at 3 meters and may be useful in discriminating ground elements.

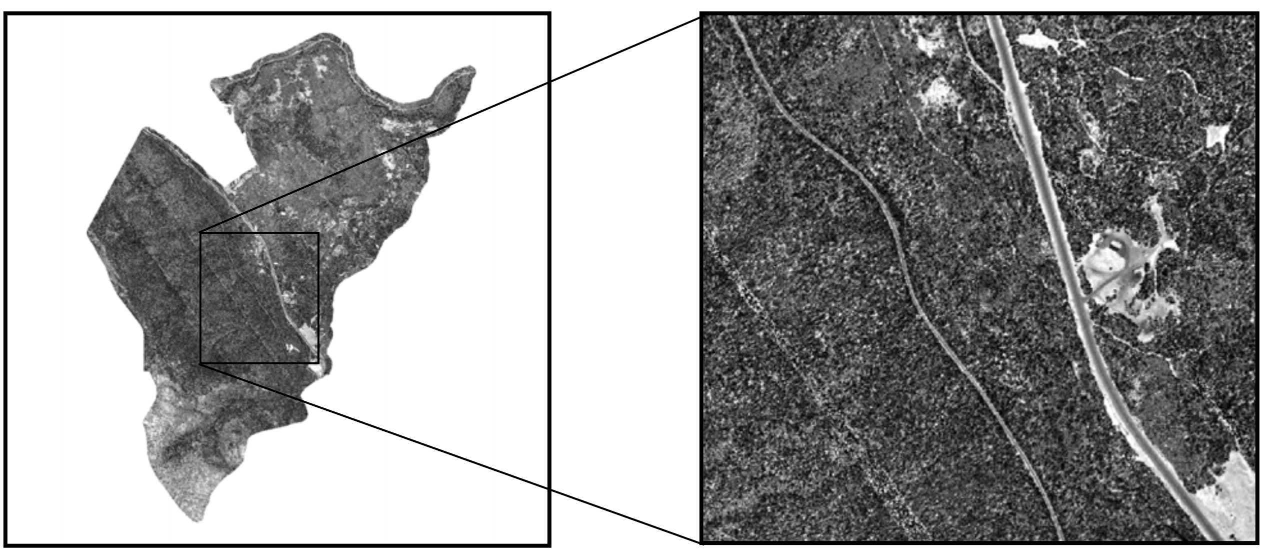


Figure 3. Left is a LiDAR intensity image (3m) of the Crawford study area. On the right is a close up view of the intensity image which looks similar to a panchromatic Digital Orthophoto Quadrangle (DOQ).

Canopy Surface Model (CSM)

The Canopy Surface Model (CSM) is a direct measure from the LiDAR point cloud data (first return). The surface model can be generated using Fusion and as in the example below was produced with a 3 meters resolution. The layer is useful for displaying canopy surface texture and is integral to calculating other derivatives such as canopy height.

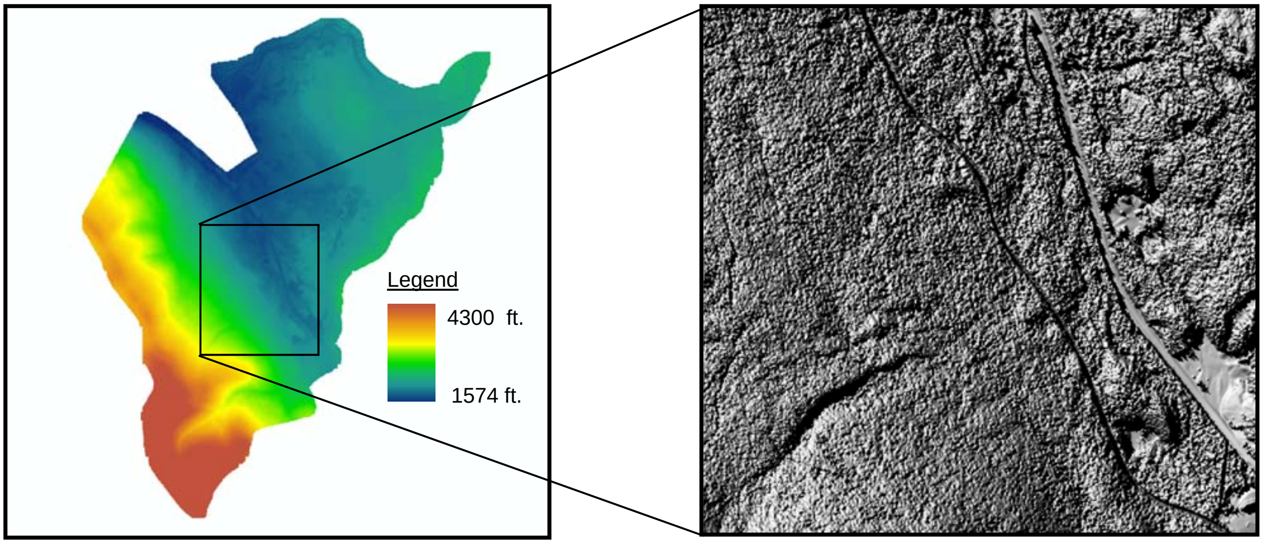


Figure 4. Left is a Canopy Surface Model (3m) of the Crawford study area. On the right is a CSM hill-shade which shows the texture and shadowing effects of canopy surface structure.

Canopy Height Model (CHM)

The Canopy Height Model (CHM) is derived by taking the difference between the bare earth and canopy surface model. It provides a useful measurement of tree heights and can help derive other forest metrics such as tree density, basal area, crown cover, and biomass. This layer was created using Fusion which normalized the highest LiDAR returns to the DTM.

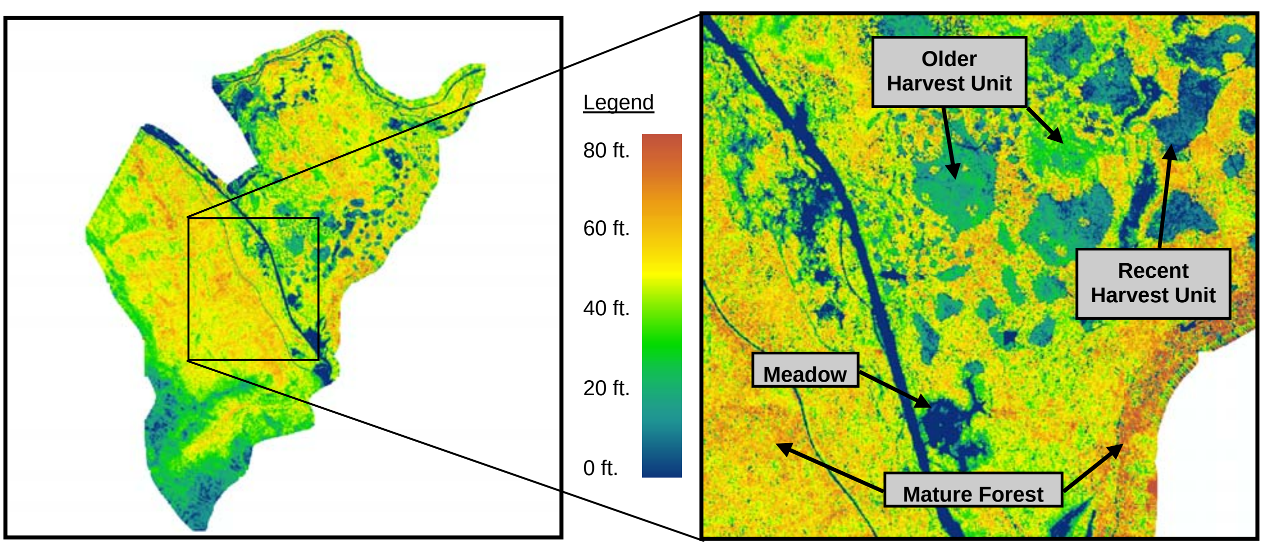


Figure 5. Left is a Canopy Height Model (3m) of the Crawford study area. On the right is a close up view of the CHM showing the distribution and concentration of vegetation canopy height.

Canopy Cover Model (CCM)

The Canopy Cover Model (CCM) provides a reasonable estimate of overstory canopy. Fusion divides the number of LiDAR pulses above some threshold value (elevation above ground) by the total number of LiDAR pulses for a specified area. The canopy cover layer created for the Crawford area, shown below, specified a 20-meter grid spacing and a threshold height break of 6ft. The resulting grid shows the patchiness and patterns of vegetation density.

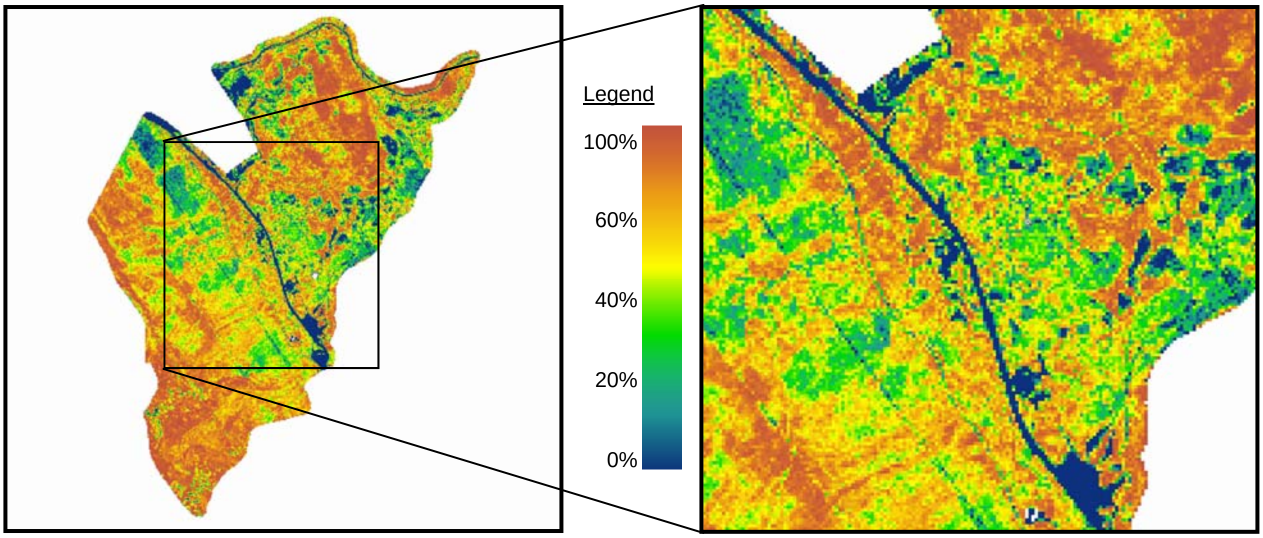


Figure 6. Left is a Canopy Cover Model (20m) of the Crawford study area. On the right is close up view of the CCM showing the distribution of vegetation density.

Vertical Structure Percentiles

Percentile metrics provide information about the vertical profile of stand structure. Fusion was used to generate the layer below, which is a single percentile metric at the 75th percentile. Generating additional height metrics at the 25th and 50th percentile could be used together to help differentiate forest types.

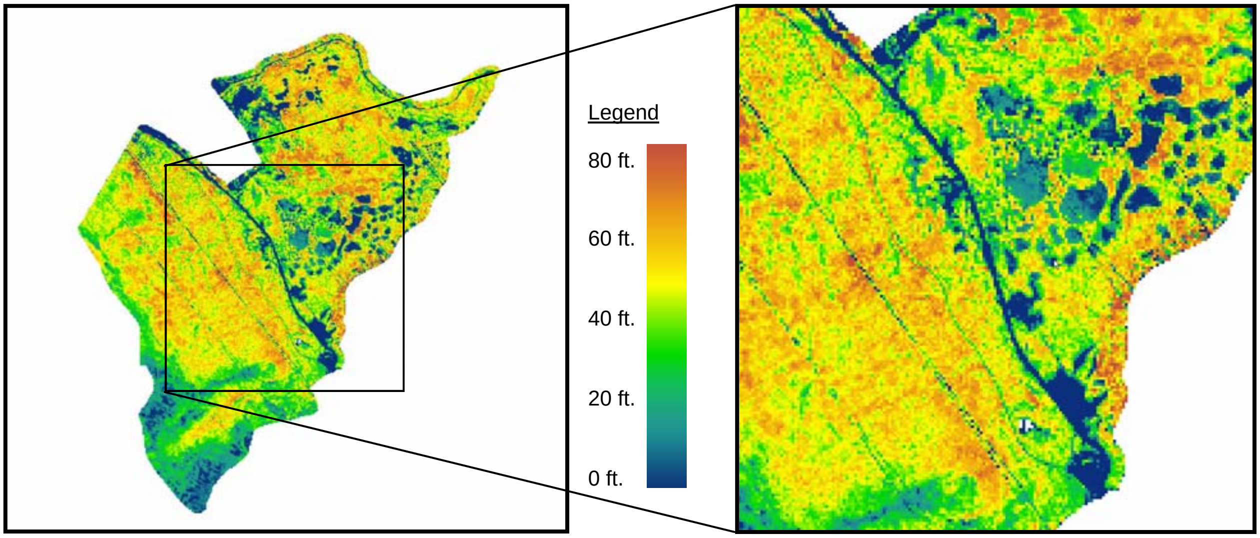


Figure 7. Left is an example of the 75th percentile surface height values (20m) of the Crawford study area. On the right is a close up view showing the height values along vertical profile.

Visualization 1

LiDAR point cloud data captures three-dimensional patterns of surface vegetation. These patterns can be exploited to distinguish vegetation types with contrasting structural characteristics. Fusion offers a way to explore the point cloud, visualize vegetation patterns, take measurements, and establish a method for differentiating forest types (figure 8).

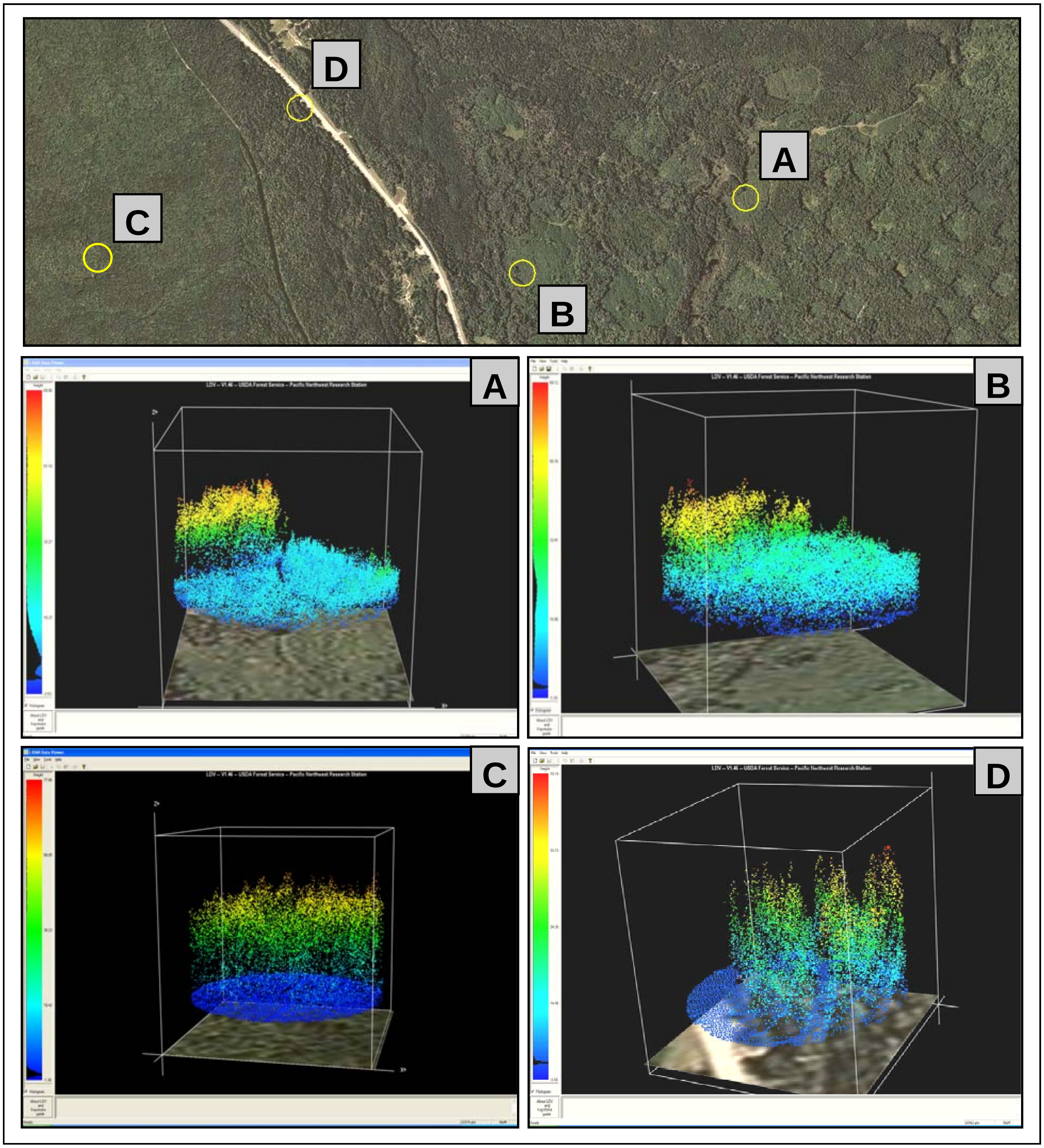


Figure 8. The NAIP image, displayed above, shows locations of four contrasting stands depicting differences in forest structure: A) regeneration; B) sapling; C) young even-aged; and D) mature stand. These illustrate contrasting stand attributes such as crown density, vertical canopy distribution, and tree height (note the histogram displayed along the left side of each visualization).

Visualization 2

Combining the three-dimensional surfaces of LiDAR point cloud data with high-resolution optical imagery simulates existing vegetation patterns (figure 8). These visualizations provide effective tools to communicate existing resource conditions with other specialists, managers, and external partners.

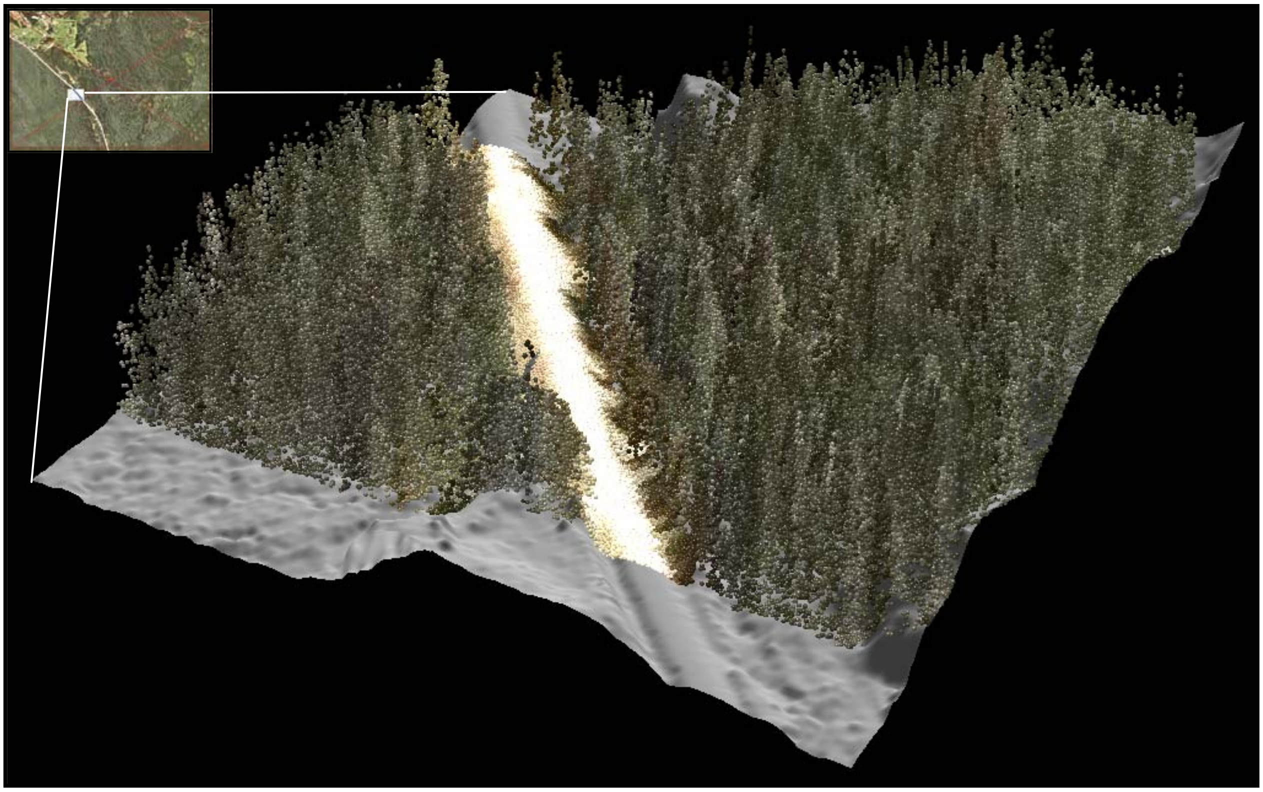


Figure 9. NAIP imagery fused with the LiDAR point cloud and rendered over a hillshade of the digital terrain model (DTM). This visualization provides a realistic perspective of the existing conditions.

Summary

The White Mountain National Forest is fortunate to have this LiDAR data. This data can be used to inform resource managers about existing topography and vegetation conditions. Obtaining accurate information about vegetation height, canopy cover, and other LiDAR-derived metrics would be useful in assessing resource conditions and enhancing project-level planning. Hopefully, the information presented in this report increases awareness about the LiDAR data available to the White Mountain National Forest.

Additional References:

Fusion software: http://forsys.cfr.washington.edu/fusion/fusionlatest.html
Fusion on-line tutorial: http://fsweb.geotraining.fs.fed.us/tutorials/fusion/
RSAC LiDAR publications: http://fsweb.rsac.fs.fed.us/search.php?searchstring=lidar%20lutefisk

Also, as mentioned earlier, if there is a need to follow up with any of the information presented here, please contact Haans Fisk at the Remote Sensing Application Center, (801)-975-3750.

Appendix: Fusion LIDAR Data Coverage Report

The report below was generated using Fusion's Catalog function and summarizes LiDAR data tiles available on the Crawford study area. It states the nominal return density of each LAS tile and provides some useful visuals of the data coverage, return density, and intensity.

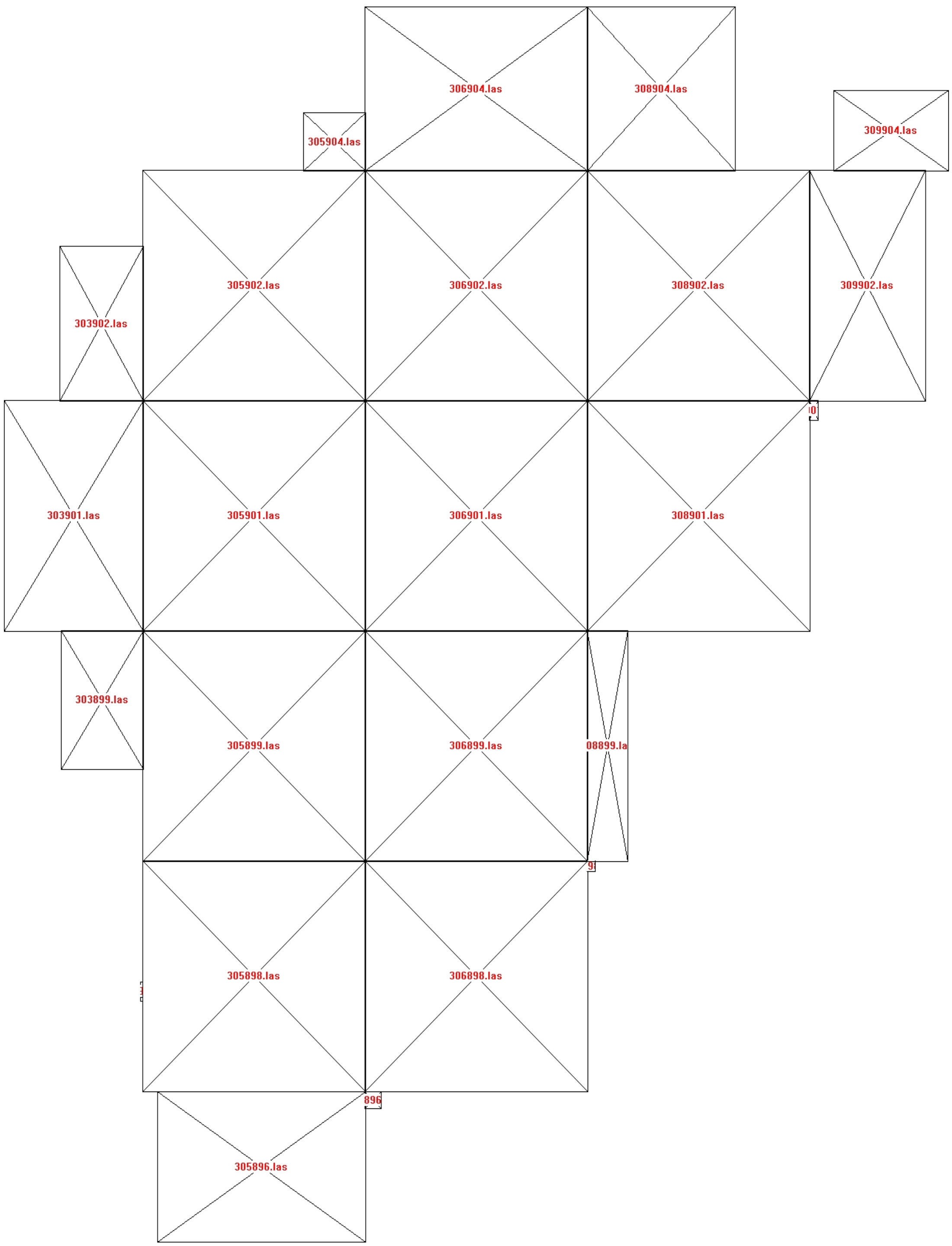
LIDAR Data Coverage Report

Command line: Catalog /index /density:1,2,4 /image /coverage /intensity:25,0,255 *.las

Filename	Minimum X	Minimum Y	Minimum Elevation	Maximum X	Maximum Y	Maximum Elevation	Total Returns	Nominal Return Density
303898.las	304482.69	4898085.34	3920.83	304499.72	4898210.87	4054.32	1,172	0.55
303899.las	303945.88	4899599.87	2690.22	304500.30	4900500.02	3115.91	607,603	1.22
303901.las	303561.84	4900499.93	2259.08	304500.31	4902000.01	3099.99	2,288,500	1.63
303902.las	303937.49	4901999.96	1573.23	304500.31	4903008.08	2664.14	566,841	1.00
305896.las	304597.46	4896518.01	3314.82	306000.28	4897499.99	4300.68	639,065	0.46
305898.las	304499.72	4897499.94	2459.05	306000.30	4899000.06	4070.17	3,400,117	1.51
305899.las	304499.65	4898999.94	1877.78	306000.31	4900500.05	3383.72	4,817,546	2.14
305901.las	304499.64	4900499.92	1607.05	306000.34	4902000.07	2739.86	4,642,155	2.06
305902.las	304499.63	4901999.93	1529.79	306000.32	4903500.05	2306.82	1,393,136	0.62
305904.las	305582.34	4903499.95	1614.76	306000.28	4903877.32	1757.31	149,842	0.95
306896.las	305999.66	4897386.98	3307.57	306106.53	4897499.99	3417.25	11,334	0.94
306898.las	305999.68	4897500.00	1886.32	307500.23	4899000.05	3469.38	2,298,539	1.02
306899.las	305999.63	4898999.92	1695.01	307500.32	4900500.07	2715.94	4,425,450	1.97
306901.las	305999.67	4900499.94	1589.69	307500.34	4902000.07	1967.29	4,062,972	1.80
306902.las	305999.67	4901999.92	1612.69	307500.33	4903500.07	1995.37	3,723,706	1.65
306904.las	305999.69	4903499.91	1628.80	307500.35	4904566.63	2559.87	1,889,480	1.18
308898.las	307499.70	4898930.85	1886.64	307553.99	4899000.05	1966.07	3,813	1.01
308899.las	307499.67	4898999.99	1895.34	307770.69	4900500.03	2183.07	282,590	0.70
308901.las	307499.68	4900499.92	1736.84	309000.27	4902000.06	2183.00	2,972,360	1.32
308902.las	307499.66	4901999.92	1749.60	309000.34	4903500.07	2140.09	3,950,622	1.75
308904.las	307499.67	4903499.95	1715.02	308498.08	4904566.09	2017.25	1,098,543	1.03
309901.las	308999.72	4901872.71	2072.83	309057.01	4902000.06	2168.93	6,548	0.90
309902.las	308999.65	4902000.00	1900.85	309780.51	4903500.07	3043.20	911,215	0.78
309904.las	309163.62	4903499.92	1976.05	309939.09	4904022.25	2146.09	325,871	0.80
Overall (24 files)	**303561.84**	**4896518.01**	**1529.79**	**309939.09**	**4904566.63**	**4300.68**	**44,469,020**	**0.87**

Nominal Data Coverage

Nominal coverage image is 1611 rows by 1276 columns: Catalog_overall_coverage.jpg



Return Density

Density computed using a cell that is 1.00w by 1.00h units (1.00 square units)
Density image is 8049 rows by 6379 columns: Catalog_return_density.jpg

Minimum return density (returns per square unit)	1.00
Maximum return density (returns per square unit)	377.00
Average return density (returns per square unit)	2.40

	Description	% of Area with Data	% of Total
	Cells with no points (could be outside coverage area)	NA	63.89
	Density less than minimum specification (less than 2.00 points per square unit)	40.78	14.73
	Density within specification (2.00 to 4.00 points per square unit)	50.40	18.20
	Density exceeds specification (more than 4.00 points per square unit)	8.81	3.18

Intensity Image