Panther Creek, OR Collaborative Research Project
Leaf-On versus Leaf-Off Comparison

Introduction

The Panther Creek watershed, located in the Oregon Coast Range northwest of McMinnville, OR, is an experimental landscape (or 'forest') for research on LiDAR applications in Pacific Northwest Forests. The Panther Creek Project is a collaborative research effort lead by the US Bureau of Land Management (BLM) in partnership with US EPA, NRCS, Weyerhaeuser Company, USFS PNW Research Station, Oregon DOGAMI, City of Carlton, McMinnville Water and Light, Oregon State University, University of Washington, and Seattle Biometrics.


Panther Creek Watershed, OR

Panther Creek Research Objectives:

- Develop and refine LiDAR stand level inventory methods
- Conduct a systematic soil sample
- Develop methods to predict distribution of soil carbon
- Characterize Panther Creek slope stability
- Characterize Panther Creek soil chemistry
- Assess effects of forest / land use management on carbon storage

The Panther Creek Project is a time-series of discrete return LiDAR data collected during a succession of leaf-on and leaf-off seasons extending from summer 2007 through spring 2011. In order to provide a consistent comparison between seasons, each LiDAR dataset has been acquired using the same specifications and instrumentation. All data collection specifications (Table 1) have matched those used by the Oregon LiDAR Consortium, the Puget Sound LiDAR Consortium, and other multi-use LiDAR projects in the Pacific Northwest.

Table 1 – LiDAR Collection Specifications for Panther Creek Project, NW Oregon.

Scan Angle	28^{o} ($\pm 14^{o}$ from Nadir)
Returns Collected Per Laser Pulse	Up to 4
Multi-Swath Pulse Density	≥8 pulses/m^2
Slope Elevation RMSE (1σ) Open Bare Earth	at 0 degrees ≤ 15 cm at 20 degrees ≤ 35 cm at 50 degrees ≤ 100 cm

Objectives

This time series provides the unique opportunity to assess the impact of leaf-off versus leaf-on data acquisition in a typical Western Oregon/Washington watershed. In the Pacific Northwest (PNW), snow levels at higher elevations and notoriously poor winter weather can delay or preclude airborne data acquisition during an entire leaf-off season. Thus, of particular importance is the question of ground model quality in a predominantly conifer landscape during the leaf-on season.

Our first priority was to compare derived ground models from the most recent leaf-on (July 2010) and leaf-off (March 2010) data acquisitions. The data are assessed with regard to ground return density and the resulting bare earth ground models at the standard 8 pulse/m^2 specification. To provide context for the comparison with respect to native pulse density, the leaf-off/leaf-on comparison is further made for high vs low resolution data. For low density LiDAR, we chose the commonly specified the USGS Version 13 LiDAR specification of 1 pulse/m^2.

Panther Creek Watershed

The Panther Creek research site (~5,000 acres) is typical of terrain and land-cover types found in the forested Coastal and Western Cascade Mountains of Oregon and Washington. Ownership is mixed between public (federal and local) and private (primarily forest resource companies). The forest consists primarily of mixed aged stands of conifers (Douglas Fir, Red Cedar, and Western Hemlock) with some deciduous/broad leaf trees (Red Alder, Broad Leaf Maple) in the valley bottoms.

70-80 year Douglas Fir Stand in the Panther Creek Research Site

LiDAR System

The LiDAR survey utilized a Leica ALS60 sensor mounted in a Cessna Caravan 208B. The LiDAR system was set to acquire ≥105,000 laser pulses per second (i.e., 105 kHz pulse rate) and flown at 900 m above ground level (AGL), capturing a scan angle of ±14° from nadir[1]. The survey implemented opposing flight lines with side-lap of ≥50% (≥100% overlap) to reduce laser shadowing and increase surface laser painting. To solve for laser point position, an accurate description of aircraft position and attitude is vital. Aircraft position is described as x, y, and z and was measured twice per second (2 Hz) by an onboard differential GPS unit. Aircraft attitude is described as pitch, roll, and yaw (heading) and was measured 200 times per second (200 Hz) from an onboard inertial measurement unit (IMU).

[1] Nadir refers to a vector perpendicular to the ground directly below the aircraft. Nadir is commonly used to measure the angle from the vector and is referred to as "degrees from nadir".

Methodology

Leaf-on and Leaf-off comparisons were made on the Panther Creek research areas by looking for differences between the ratio of native pulse density and ground classified return density for each condition. Summary statistics were calculated to quantify the differences in ground density compared to native pulse densities for both the leaf-on and leaf-off condition. As stated, LiDAR data were collected at a native 8 pulses/ m^2. To enable comparisons to lower pulse densities, WSI performed a point thinning process which removes every other point to simulate a 1 pulse/m^2 native density.

Results

The following figures are meant to illustrate differences between leaf-on and leaf-off conditions with a specific focus on resulting ground return densities and accuracy of the resulting bare earth models. The results of the density comparisons for the overall study area (~5,000 acres) are shown in **Table 2**.

For the native 8 pulse/m^2 data set, the ratio of ground classified returns versus total returns was 14% for the leaf-off condition. In addition, the ground return density for leaf-on 8 pulse/m^2 data has five times the classified ground density when compared to the standard leaf-off 1 pulse/m^2 data.

Table 2: Native and Ground Density values calculated from the Panther Creek survey site

	1st Return Pulse Density	Ground Classified Density
OLC Standard 8 pulse/m^2	**Leaf Off:** 8.78 pts/ m^2	**Leaf Off:** 0.54 pts/ m^2
	Leaf On: 7.41 pts/ m^2	**Leaf On:** 0.33 pts/ m^2
USGS Standard* 1 pulse/ m^2	**Leaf Off:** 1.10 pts/ m^2	**Leaf Off:** 0.07 pts/ m^2
	Leaf On: 0.93 pts/ m^2	**Leaf On:** 0.02 pts/ m^2

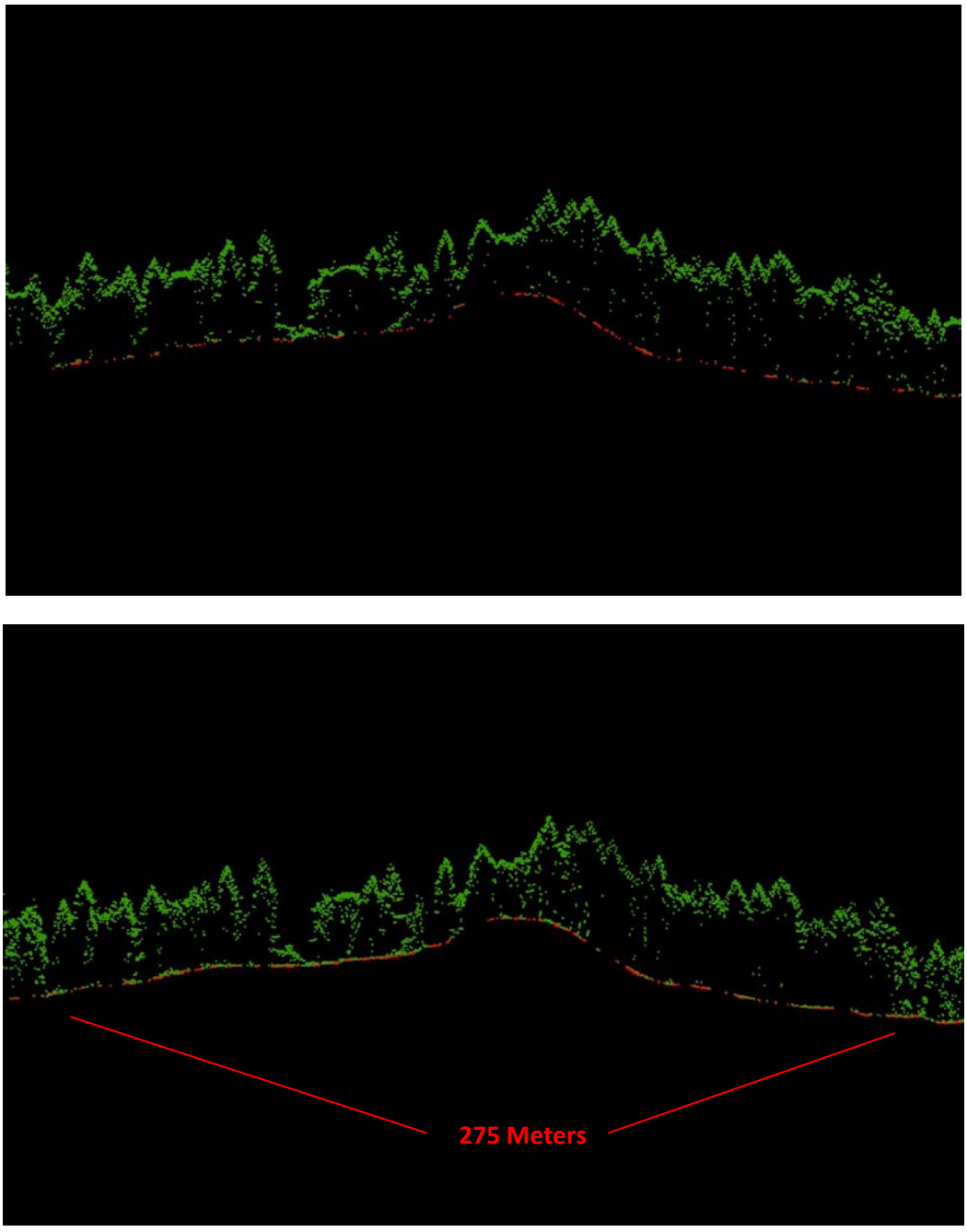
**Based on USGS Version 13 Specifications*

Point cross sections (1 meter width) shown in **Figure 1** provide a graphical illustration of the point densities in both the 8-pulse/m^2 and 1-pulse/m^2 scenarios. The ground classified returns are shown in red while above ground turns are displayed as green. The figures illustrate how the ground classified returns in 8 pulse/m^2 leaf-on data provides improved definition of the ground plane when compared to either the leaf-on or leaf-off 1 pulse/m^2 data set.

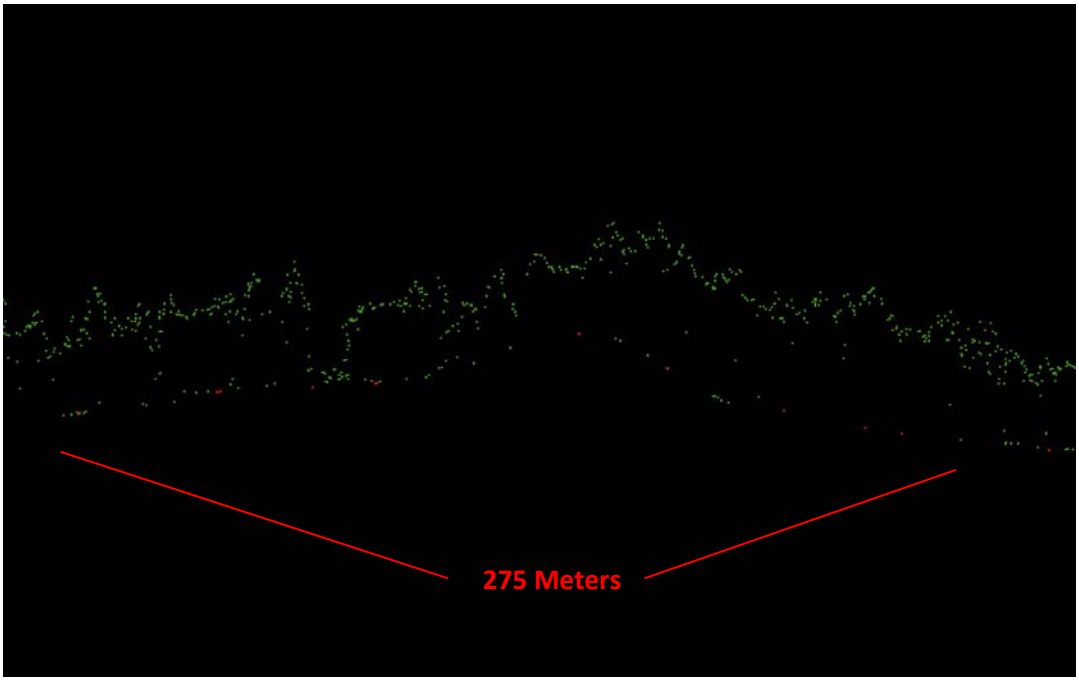
Figure 2 provides a visual comparison of the bare earth ground model leaf-on and leaf-off data sets for native pulse densities ranging from 8 pulses/m^2 to 1 pulse/m^2.

Figure 1: Compares the same cross section (1 meter width) of a ridge in both leaf-on and leaf-off conditions.

8 pulse/ m^2: Leaf-on Conditions on July 15th, 2010 (top) and Leaf-off Conditions on March 1st, 2010 (bottom).



1 **pulse/ m^2** : Leaf-on Conditions on July 15th, 2010 (top) and Leaf-off Conditions on March 1st, 2010 (bottom)



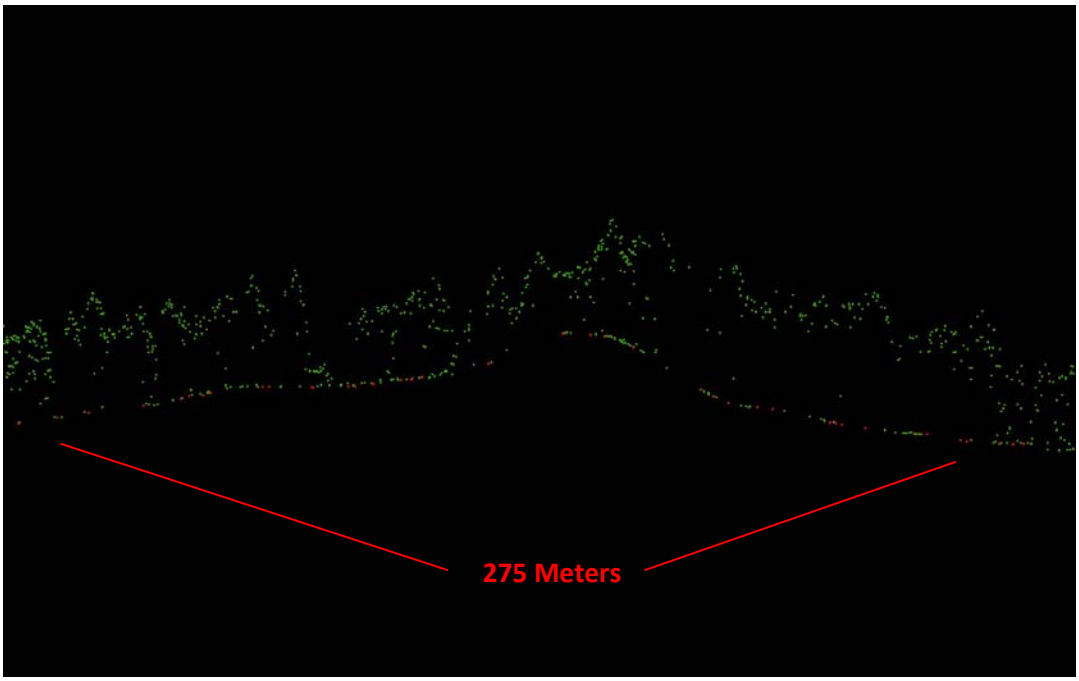
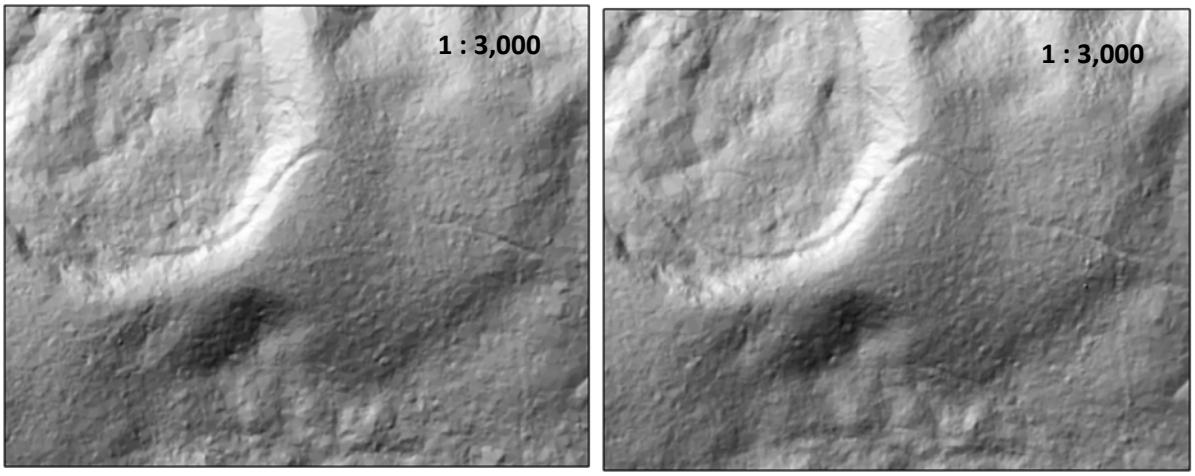
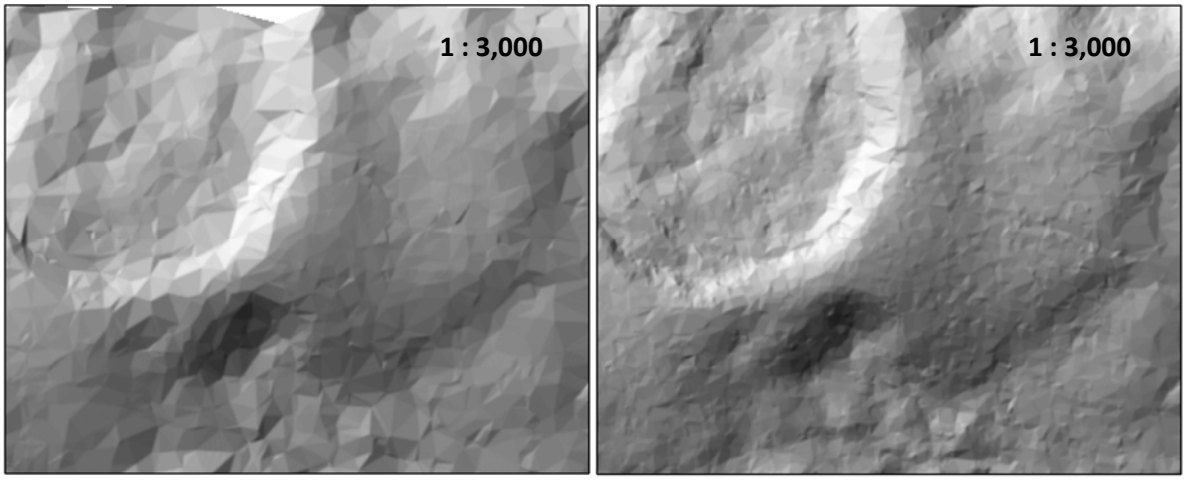


Figure 2: Visual comparison of DEM hillshades of the same area in both leaf-on and leaf-off conditions.

8 pulses/ m^2 : Leaf-on (left) on July 15th, 2010 and Leaf-off (right) on March 1st, 2010.



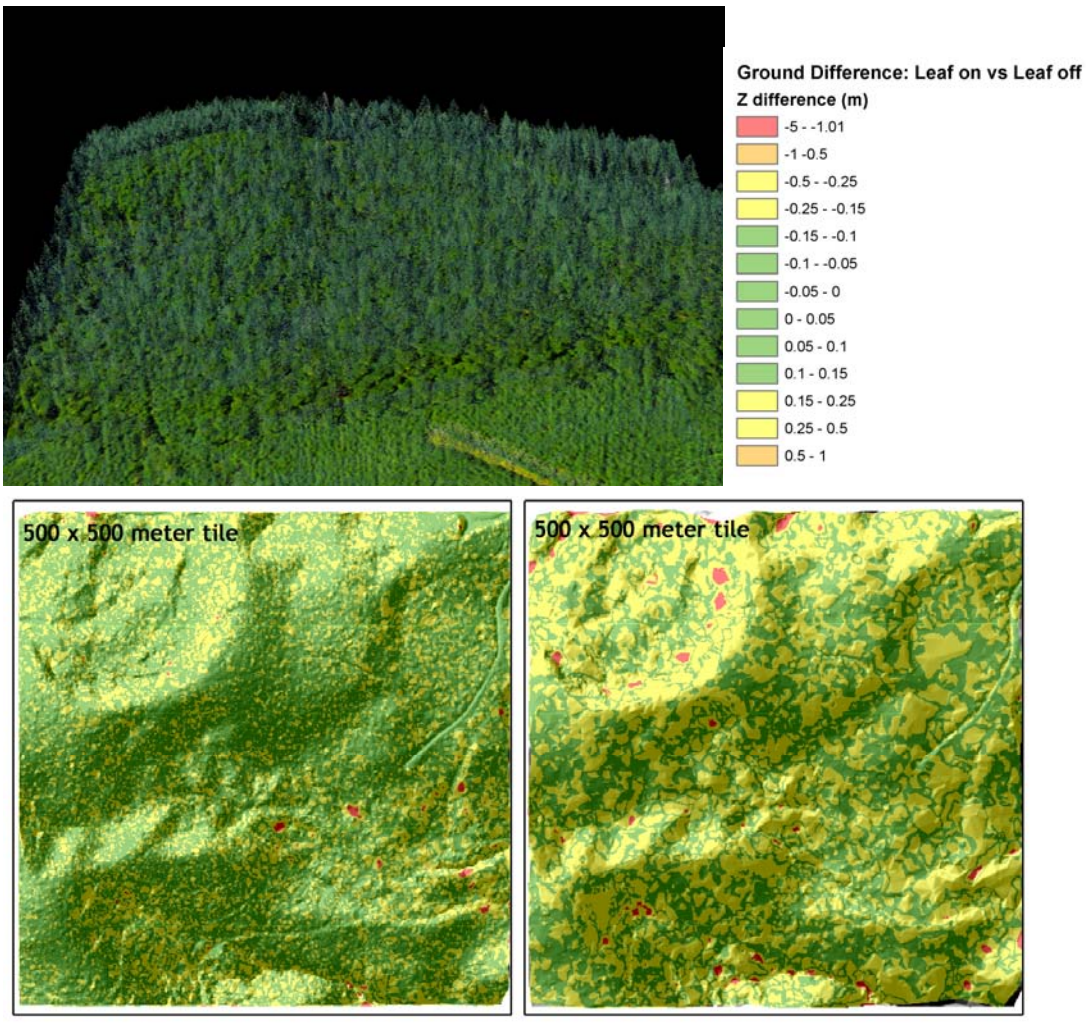
1 pulse/ m^2 : Leaf-on (left) on July 15th, 2010 and Leaf-off (right) on March 1st, 2010.



Accuracy Comparison

In order to look examine how leaf-on conditions influence the ground model accuracy under conifer dominated landscapes, we computed the difference between the leaf-off DEM and the leaf-on DEM to create a "difference" raster for both the collected 8 pulse/m^2 and the simulated 1 pulse/m^2 condition. While some variability in the ground models is expected, the general differences should be within the expected vertical accuracy tolerances for airborne LiDAR given land cover and slope. The results showed that with the 8 pulse/m^2 data the majority of the area fell within ±15 cm difference, which was well within expected tolerance. Only a few sites fell within the 50 cm to 100 cm range. In contrast, the 1 pulse/m^2 data exhibited the largest area within the difference range of 25cm to 50 cm, with a higher frequency of area within the 50-100cm range.

Figure 3: The 3D figure illustrated on the top left shows an all return point cloud for the 500x500 meter area used to compare bare earth differences between the leaf-off and leaf-on condition. The bottom images show "Difference" rasters for the 8 pulse/m^2 data set (left) and the 1 pulse/m^2 data set (right).



For the purposes of the overall project goals, the BLM has spatially distributed 42 forest research plots throughout the Panther Creek study areas (Figure 4). The center points of these plots were accurately located using Cadastral Survey techniques. These points were surveyed independent of the shallow slope, bare earth checkpoints used for common LiDAR accuracy assessments. These independently collected survey points are located under various forest canopy densities and terrain slopes and are ideal for assessing accuracy under both leaf-on and leaf-off condition for conifer dominated landscapes.

Table 3 provides standard accuracy statistics computed based on elevation differences between the forest survey plots and the derived ground model for both leaf-on and leaf-off conditions. The results show that there was an 8.5 cm difference (defined by 1^{st} σ) between the leaf-on and leaf-off conditions.

Figure 4: Distribution of surveyed Forest Research plots in the Panther Creek study area. The surveyed plot centers provide an independent check for DEM accuracy under various forest canopies and terrain slopes.

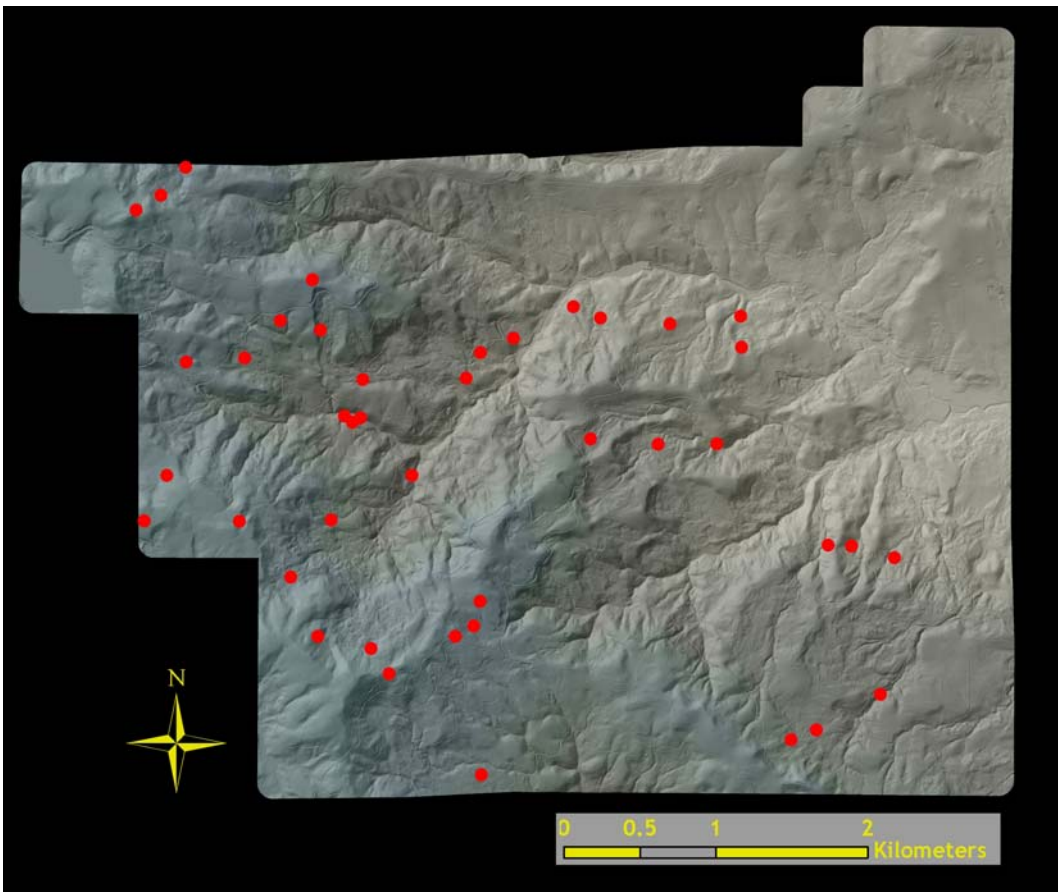


Table 3: DEM accuracy for both Leaf-on and Leaf-off conditions based on comparison to surveyed forest research plots in the Panther Creek study area based on 42 spatially distributed points.

Leaf-On 8 pulse/m^2: PC Plot compared to LiDAR DEM

Average Dz	-0.163 meters
Minimum Dz	-2.05 meters
Maximum Dz	0.556 meters
1 Sigma	0.397 meters
1.96 Sigma	0.779 meters

Leaf-Off 8 pulse/m^2: PC Plot compared to LiDAR DEM

Average Dz	-0.164 meters
Minimum Dz	-1.060 meters
Maximum Dz	0.9560 meters
1 Sigma	0.3119 meters
1.96 Sigma	0.6113 meters

Digital image taken skyward within a 70yr old Douglas Fir stand in the Panther Creek watershed. The image illustrates typically canopy density within a conifer forest regardless of season.

Conclusions

While this analysis was limited to a relatively small study area, the results indicate the following for LiDAR data under conifer dominated landscapes:

- An 8 pulse/m^2 native pulse density under leaf-on conditions results in a higher ground classified return density than a traditional 1 pulse/m^2 data set under leaf-off conditions.
- The vertical "difference" between bare-earth models derived for an 8 pulse/m^2 leaf-off/leaf-on data set was generally between ± 15 cm with only a very small percentage of the area exceeding 50 cm.
- Considering the various land-cover and slopes, the differences in absolute accuracy between the leaf-on (0.397 m 1σ) and leaf-off (0.312m 1 σ) were considered minimal and within expected tolerances for forested environments.