Classification of canopy structure in the Cedar River Municipal Watershed using LiDAR and permanent sample plots

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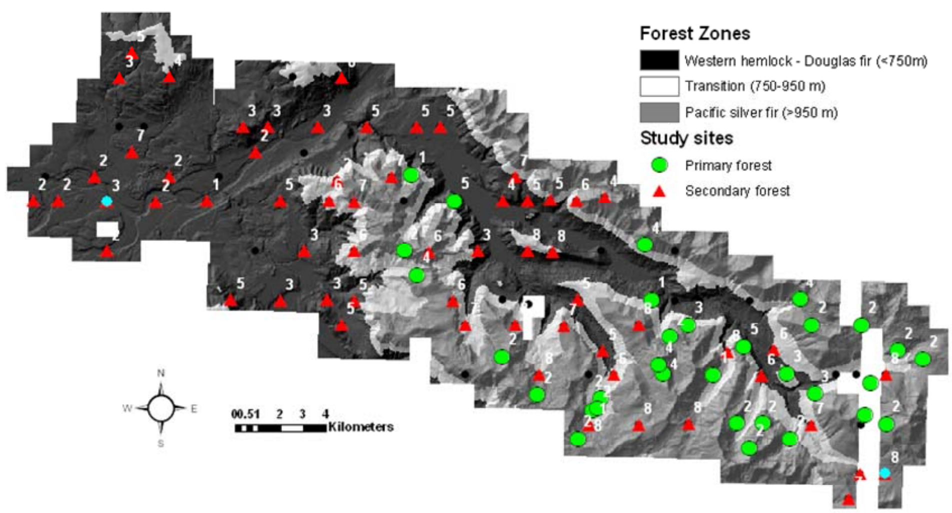
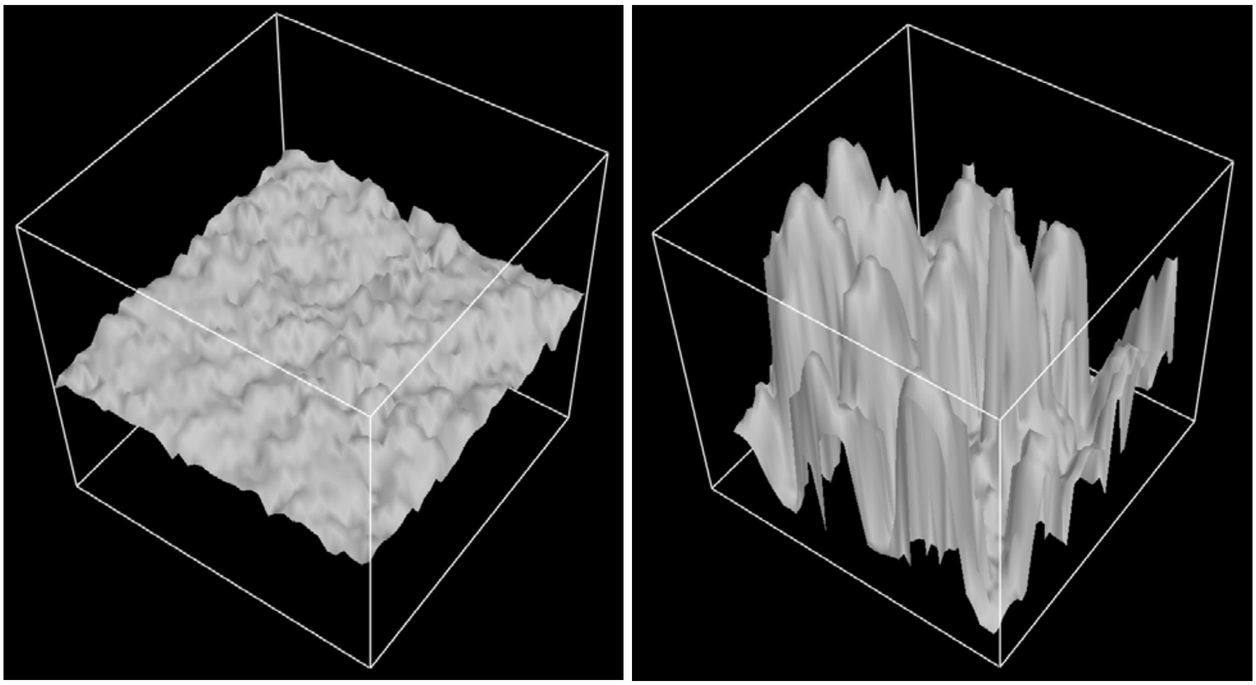
Forest habitat value is one ecosystem function that is well correlated with structural complexity of the forest canopy. This project developed a classification of forest canopies using remotely sensed LiDAR (Light Detection And Ranging) data and information from 105 permanent sample plots (PSP) distributed throughout different forest types in the watershed (Figure 1).

Figure 1: Map of the study sites in the Cedar River Municipal Watershed used in developing forest classes based on Lidar canopy surface data.



Young second-growth forests recovering from disturbance (harvesting) can be characterized by homogeneous, dense canopies with little structural complexity. Habitat value for species that depend on late-successional forest structures (large trees, decadence, canopy layering) is low. Old forests that have undergone disturbance mortality and have developed multiple canopy layers are characterized by a rough canopy surface, greater depth of the canopy, and lower density. Habitat value for species of concern in the CRMW is high in these forests.

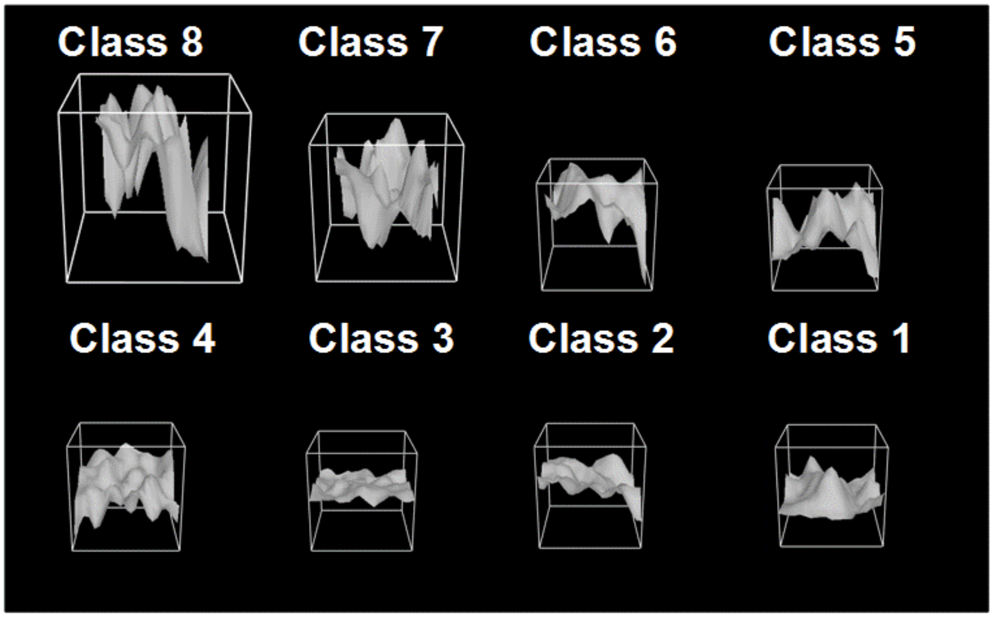
Figure 2: Visualization of canopy roughness (Rumple) of a young second-growth forest (left) and an old primary forest (right); LiDAR data was processed using the FUSION software.



To characterize the distribution of forest habitat over the landscape, we analyzed LiDAR data and developed metrics for canopy tree height, canopy density, and canopy surface roughness (Rumple Index, ratio of canopy surface over ground surface). Other forest metrics (tree size, age, variability) were correlated with canopy metrics using PSP data throughout the watershed and across vegetation zones.

We used multi-variant analyses to determine an appropriate combination of LiDAR derived variables and to group forest plots with similar canopy structure. LiDAR variables used in the classification were Rumple, canopy density, and the 95th percentile of LiDAR first return heights. Figure 3 shows examples of PSP canopies typical for the eight classes of canopy complexity (1 = least complex, 8 = most complex) separated by the analysis.

Figure 3: Illustration of the eight classes of forest canopy complexity developed from LiDAR canopy data; class means for rumple and tree height are given in the table below.



Class	8	7	6	5	4	3	2	1
Height*	49.7	42.8	41.1	27.1	28.6	24	12.3	12
Rumple	4.05	3.31	1.98	2.33	1.72	1.24	1.19	1.49

*95th percentile height (m)

While the classification of canopy structural complexity is useful for landscape scale analysis of forest habitat, the development of canopy structure occurs over a continuum from low to high complexity and can take different developmental pathways. The eight classes developed in this analysis are possible structure types that may occur depending on establishment conditions, stand age, species composition, site quality, and disturbance interaction.

The variables used in this analysis are inter-related and indicate community processes during forest stand development (Figure 4). One of the driving factors in canopy development is the increase with tree height (95^{th} percentile height) which is a function of age. Forest stands with increasing height can develop greater values of canopy roughness (Rumple, upper graph). While canopy density initially increases with canopy height (Arrow 1) and reaches a maximum (lower graph), canopy height continues to increase (Arrow 2). At greater canopy height, stands can take on a wide range of canopy roughness caused by disturbance (Arrow 3), often associated with loss of canopy density (lower graph).

These developmental patterns agree well with processes observed during forest vegetation dynamics in similar forest types. The possible pathways of development provide restoration mangers with indicators for structural development following restoration treatments and small scale disturbances.

Figure 4: Relationship of canopy tree height with Rumple Index and canopy density for the eight forest classes; arrows indicate increase in canopy density (1), canopy height (2), and canopy roughness (3).