LONG-TERM ECOLOGICAL RESEARCH IN FOREST PARK: TRACKING URBAN IMPACTS TO FOREST STRUCTURE AND PRODUCTIVITY

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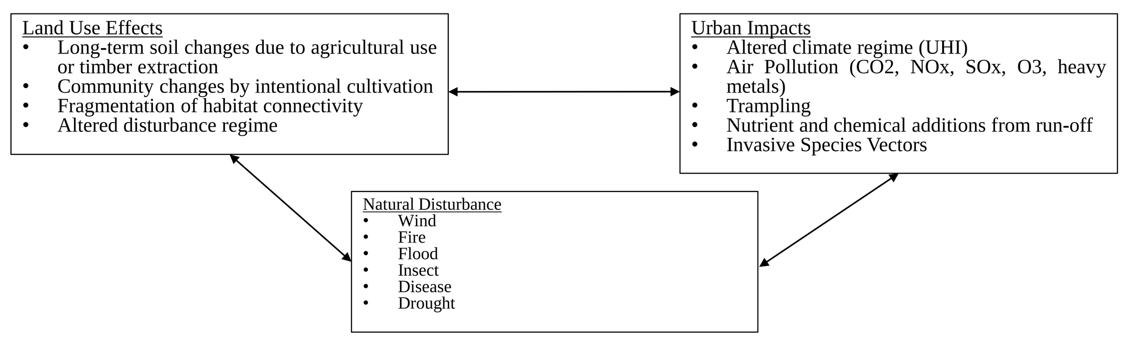
General Background

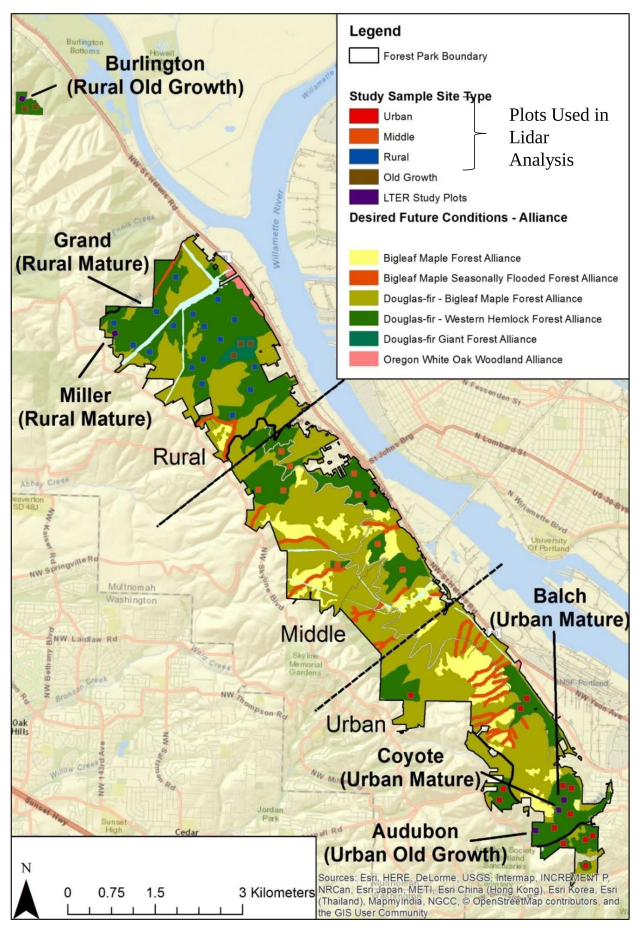
Past land use history, such as clear-cut logging, as well as chronic anthropogenically driven stresses to ecosystem processes through climate change, air pollution, and introduction of exotic species provide novel sets of conditions that tests the resilience of forest ecosystems, especially in urban areas[1-4]. Urban forests can serve as an early indicator for how global climate changes associated with higher temperatures, increased CO2 levels, and nitrogen and pollution deposition may affect forest ecosystems worldwide[5].

Interaction of Impacts on Urban Forests



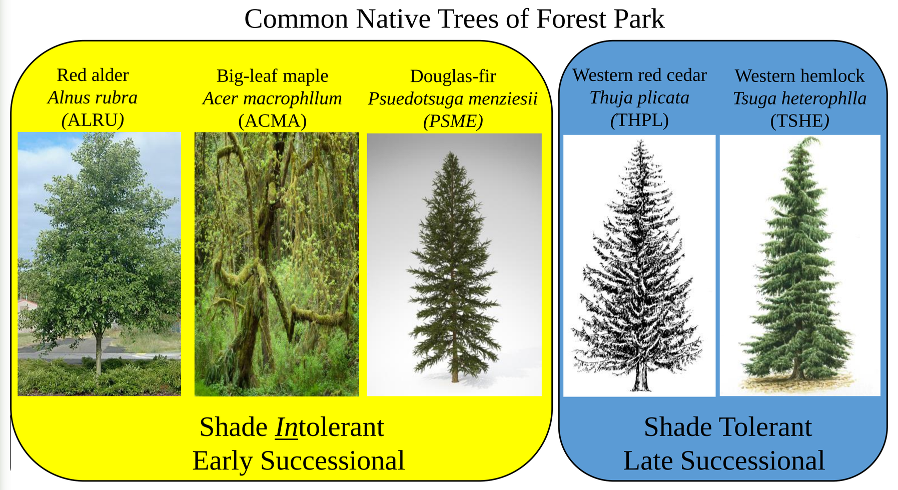
Forest Park is a 2,000 hectare forested park located northwest of downtown Portland, Oregon. It is the largest forested park within an urban boundary in the contiguous U.S. and serves as an ecological corridor from the Coast range biome to the Portland metro area and Willamette Valley[6].

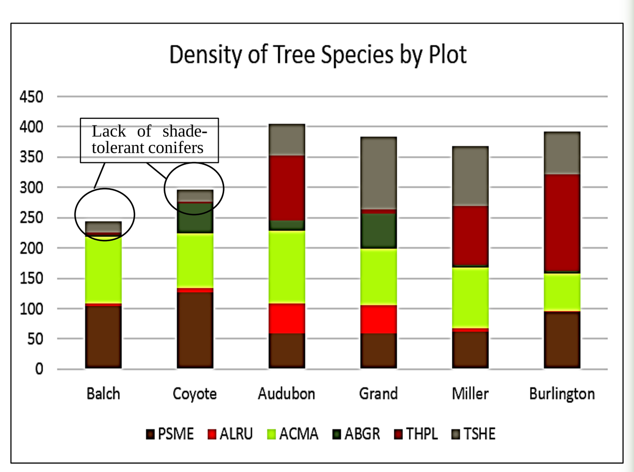
Researchers from Portland State University have established six 1-hectare long-term ecological research (LTER) plots throughout Forest Park. There are 2 urban mature plots and 2 rural mature plots with Douglas-fir dominant mixed-conifer stands, and canopy trees aged 80-100 years old[7]. There are also 2 old-growth reference plots (1 urban and 1 rural) that contain a few very old trees (150-350 years old) and show more structural characteristics of old- growth Douglas-fir – Western Hemlock forests[8]. Plots are closely matched in elevation, aspect, soil type and other abiotic factors.

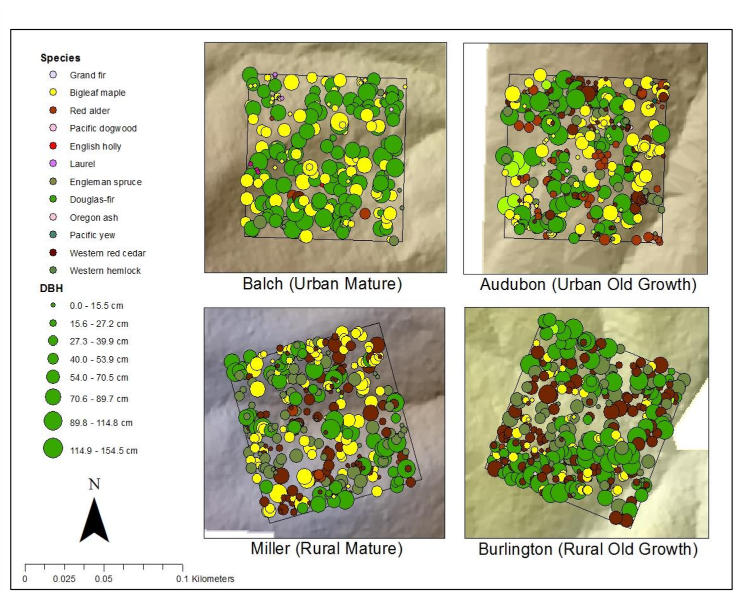


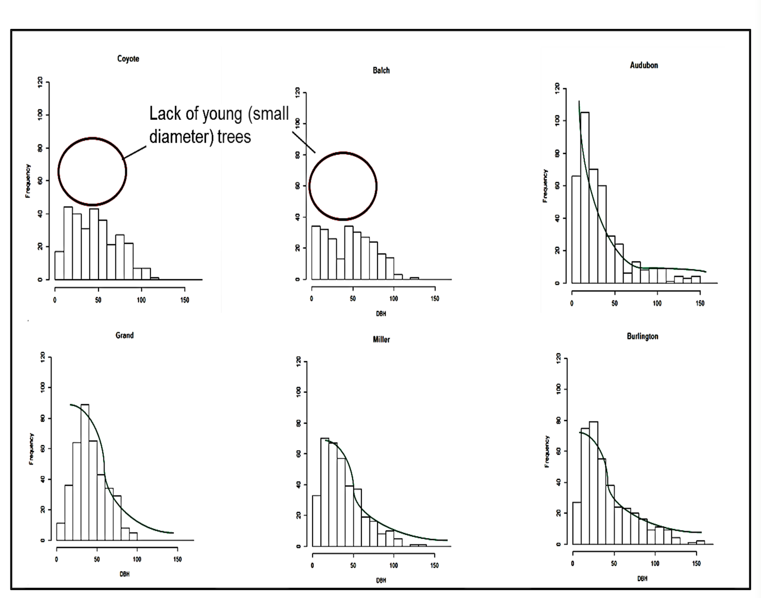
Mature conifer stands close to the urban core are not developing certain late successional features compared to rural stands. Urban stands lack a shade-tolerant conifer understory composed of western hemlock (*Tsuga heterophylla*) and western red-cedar (*Thuja plicata*). They also have fewer legacy features important for biodiversity, such as snags and coarse woody debris.

Common Native Trees of Forest Park









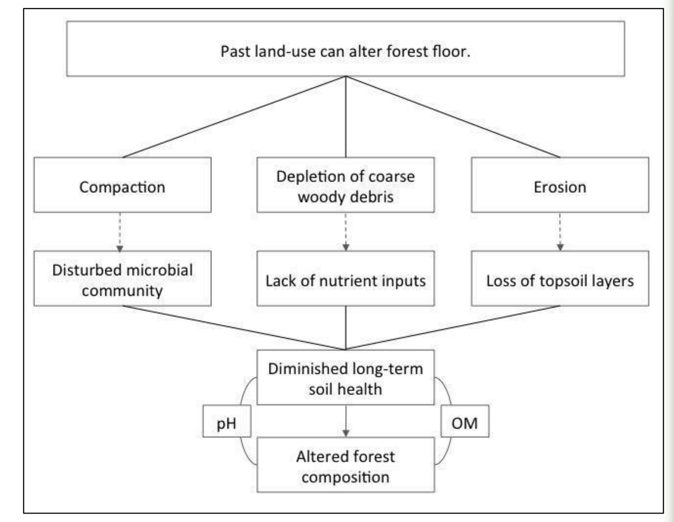
Overarching long term research questions:

- What is driving this lack of recruitment of shade-tolerant tree species?
- Do urban impacts and land-use history prevent development of late-successional features?
- Are we witnessing emergence of novel ecosystem states?

Question 1: Has history of logging impacted soil health?

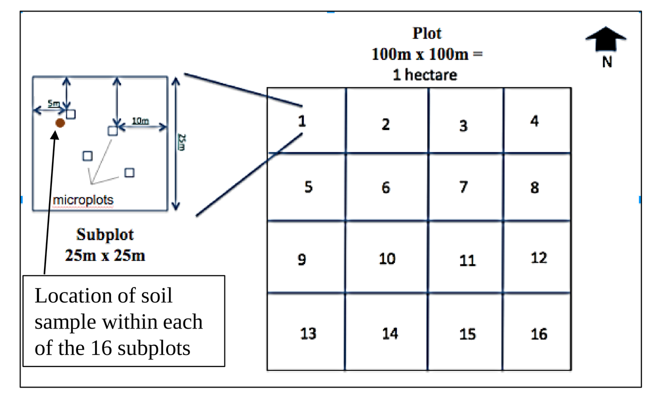
In the century prior to park establishment, most of the park was subjected to repeated clear-cut logging and fire. Urban sections of the park appear to have been logged more intensively, with old skid rows and signs of mass erosion apparent.

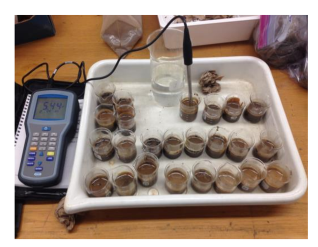
Removal of wood and the standard accompanying practice of burning logging slash can deplete nearly all legacy features of a stand[9]. Soil erosion is elevated for several decades on slopes subject to clear-cut logging, due to the loss of stabilizing belowground roots and surface CWD[10].



Methods:

- In four of the 1-hectare sites, measured soil pH, organic matter, coarse woody debris, and depth of surface mineral soil horizons at 16 locations.

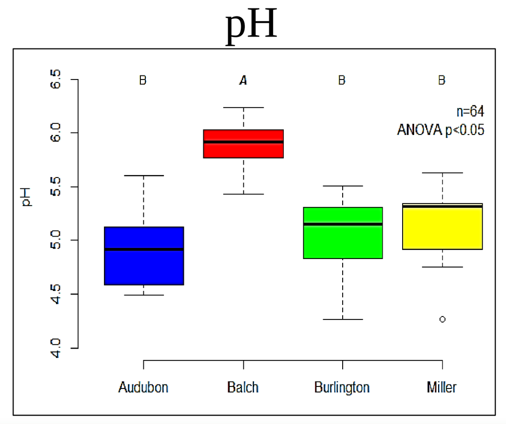


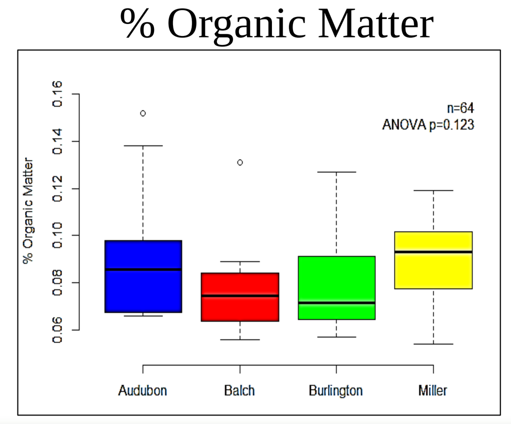


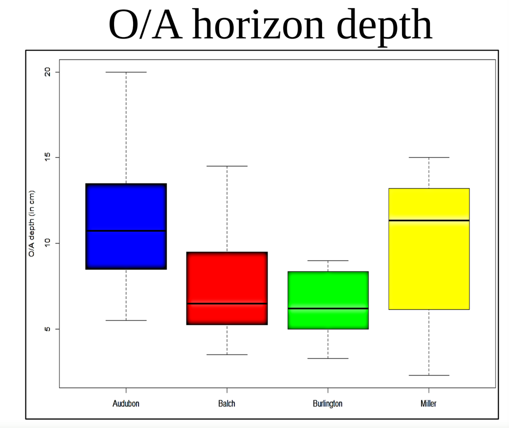
pH

% Organic Matter

O/A horizon depth





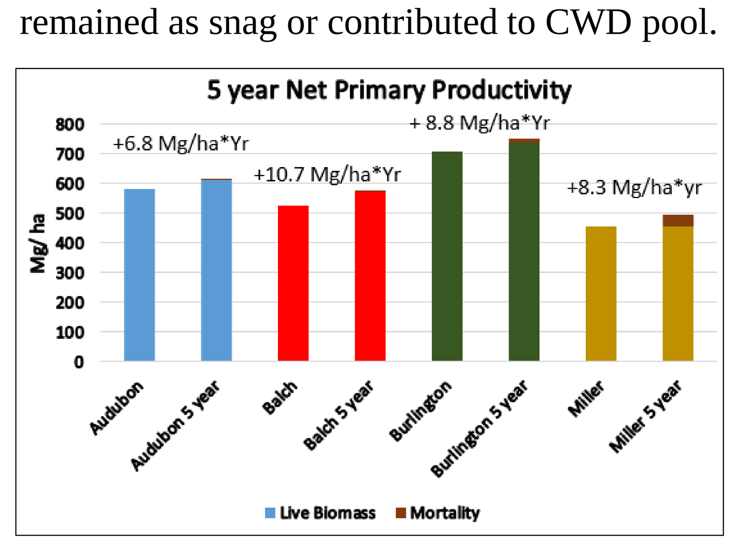


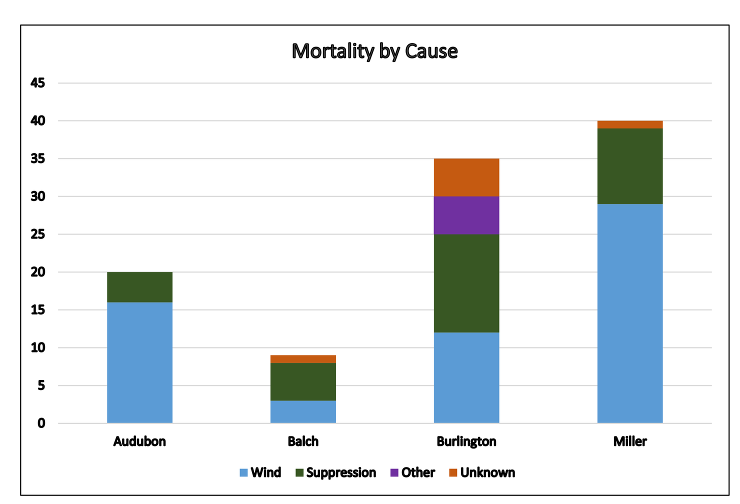
Question 2:Do urban and rural plots differ in productivity and mortality?

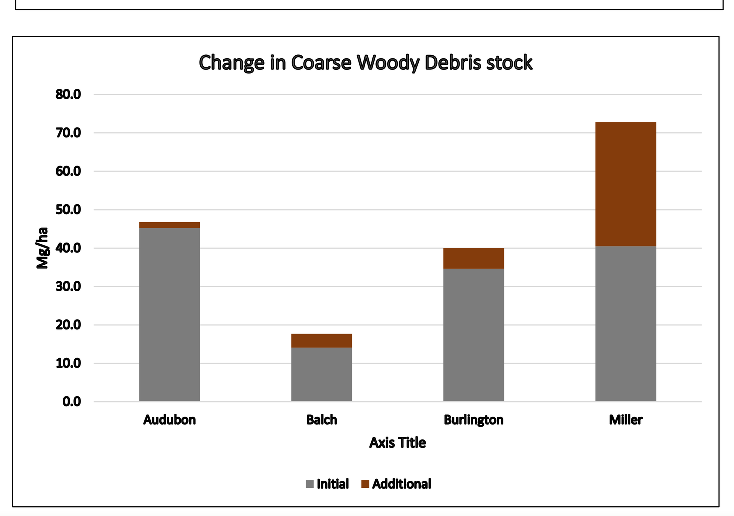
Urban impacts tree growth and mortality in complex ways. Increased CO2 and temperature may enhance tree growth,[5] but ozone and other air pollutants may decrease tree growth and lead to mortality. 5 year remeasurement data provides first napshot into productivity and mortality in Forest Park Plots.Tree boles account for 40-70% of forest carbon in mature Douglas fir stands[12].

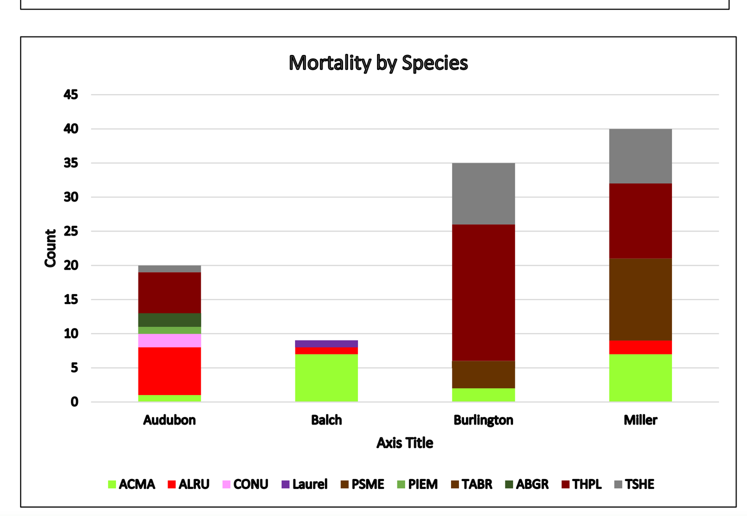
- Net Primary Productivity of Boles (NPPB) = [Δ Biomass (living) + Biomass (dead)]

Methods: Remeasured tree diameter in 4 of 6 LTER plots. Related DBH to biomass and carbon store using standard allometric equations.Noted Tree mortality, and whether cause was density-dependant (i.e., suppression) or density-independent (e.g. windthrow). Also noted if dead bole remained as snag or contributed to CWD pool.



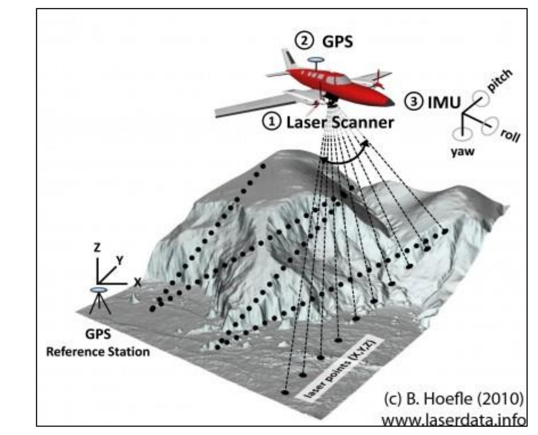






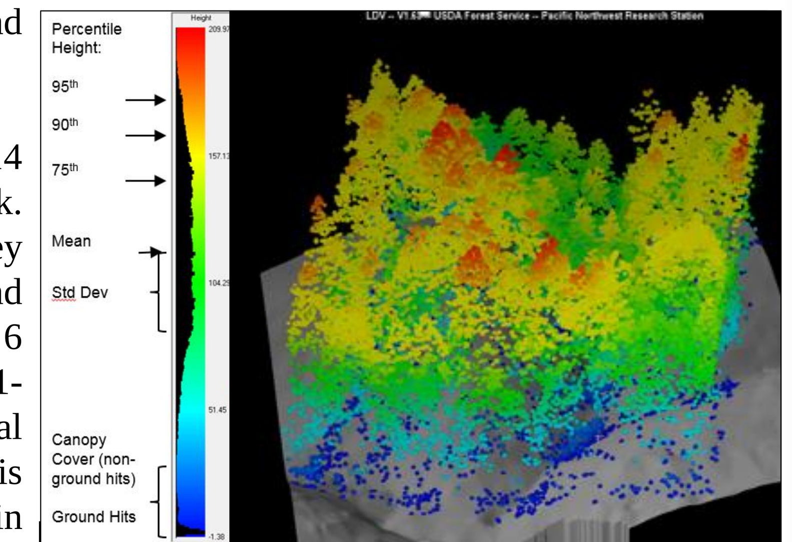
Question 3: Can LIDAR be used as a tool to detect structural differences between plots in the park?

Forest canopy structure- the three dimensional arrangement of trees and their canopy crowns- is an important attribute of developing forests and creates biodiversity[13]. As stands develop toward old-growth, they undergo *vertical* and *horizontal* diversification[8,14].

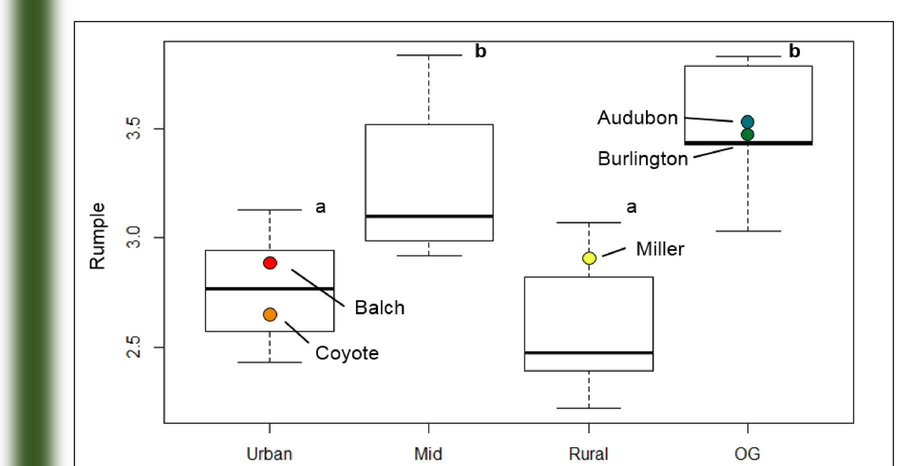


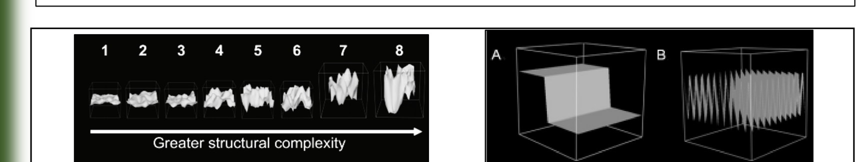
Airborne Laser Scanning LIDAR can provide highly detailed information about elevation of ground features, including forest canopy structure[15,16].

Methods: Analyzed LIDAR data acquired in 2014 by City of Portland, which covers Forest Park. Utilized Fusion software (USFS) to extract 8 key lidar metrics that relate to canopy height and structural variability. Extracted values for 5 of 6 LTER plots, as well as 47 randomly selected 1-hectare mixed conifer plots covering an urban-rural gradient in FP. I ran a Principle Component analysis to determine if there were detectable differences in canopy attributes across the park, and compared canopy rumple across sites.



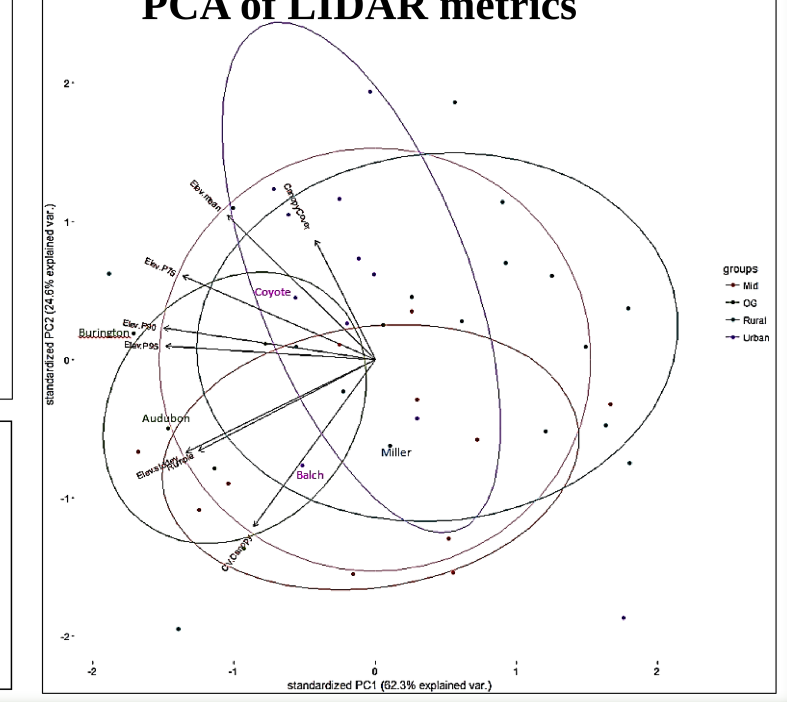
3D LIDAR rendering of Burlington Plot (rural old-growth). Histogram bar indicates metrics used in PCA analysis





Canopy Rumple is a measure of canopy structure. It measures how folded the upper canopy surface is relative to the ground

PCA of LIDAR metrics



Key Results:

- Balch plot has a statistically significant elevation in pH. Measures of organic matter and O/A depth did not vary significantly by plot.
- Biomass and productivity of the plots was within the range of values for similarly aged stands studied in Douglas-fir forests of Western Oregon[12].
- Significant mortality of canopy trees occurred due to density-independent causes (i.e. wind), often crushing underlying saplings. Density dependent mortality (i.e. suppression) played a lesser role. The lack of CWD in Balch plot is not currently being supplanted with new additions.
- PCA analysis showed minor canopy differences between urban, middle, rural and old growth plots. There were, however, significant differences in rumple between plot types, with middle and old-growth sites having more canopy structure compared to urban and rural sites.

Conclusions:

Soil impacts, forest productivity, mortality, and canopy structural patterns showed modest patterns related to urban proximity. Future studies could further explore the role of impacts such as invasive species, lack of CWD microsites for germination, lack of mature seed trees, and possibly altered biogeochemical pathways in these plots, and the effect on late-successional recruitment. These results help inform park managers that regeneration of late successional tree species may require active restoration that focuses on establishing saplings in optimal growing sites.

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