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| Application of 3D-lacunarity derived from terrestrial LiDAR for quantification of forest structure |
| **Introduction/Aim:** Lacunarity describes the space-filling properties or “gappiness” of fractal patterns. In forest ecology, 2-dimensional lacunarity has been used as a tool to search for structural and dynamic forest properties within and among different landscapes, and lacunarity analyses can offer insights into the spatial distribution of structural properties of forest canopies. However, while the applicability of lacunarity to voxel data, including the analysis of LiDAR point clouds, has been supported by tests with simulated data, the method has received little attention with empirical data. Here, we present a new R package ‘lacunr’, which computes 3D lacunarity for voxelized LiDAR data. We then use this package to examine changes in forest structure pre- and post-disturbance in northern California forests.  **Methods:** We quantified change following disturbance by hand-measuring stand density and composition in plots (400 m2) at two sites in northern California forests before and after timber harvest (n=22) and natural wildfire (n=22). Collected metrics included basal area (BA), quadratic mean diameter (QMD), trees per plot, species per plot, and lowest live crown (LLC). We then used voxelized TLS data also collected from these plots to estimate lacunarity before and after disturbances using ‘lacunr’.  To better relate lacunarity directly to forest structure, and to use it as a proxy for forest structural heterogeneity, we conducted principal component analysis on lacunarity. The first principal component represented fine to medium scale spatial heterogeneity, and the second principal component represented large scale heterogeneity. We regressed the lacunarity-based principal components against the hand-measured stand metrics to explore how traditional forest measurement metrics are sensitive to the spatial scale of structural changes.  **Results:**  Significant post-disturbance changes in forest stand characteristics were observed at both sites (particularly in basal area and trees per plot). The first two principal components at the logging site accounted for ~91% of the total variance, while they accounted for ~93% of the variance at the wildfire site. Lacunarity changes were demonstrated most clearly in the first dimension of principal component analysis; both sites changed most dramatically in the fine to medium scale range (0.25m to 10m). Interestingly, this change was dependent on site, with the natural wildfire leading to increased lacunarity (i.e. greater heterogeneity) in smaller scales, and logging leading to less. Finally, the lacunarity principal components related significantly to traditional metrics, but only at the logging site. BA, LLC, and trees per plot were found to be sensitive to fine scale changes in forest structure, and QMD and LLC were found to be sensitive to large scale changes in forest structure.  **Conclusion:**  Understanding forest structure is integral to management strategies related to forest health and resilience, including fuel reduction, timber productivity, biodiversity and wildlife habitat. Our new approach can quantify the spatial arrangement of vegetation across scales (spatial heterogeneity) utilizing voxelized TLS data and relates to other forest structure metrics. In the future, our computationally efficient approach can be applied across larger spatial scales to further evaluate the applicability of lacunarity to assess forest structure. |

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