CALIFORNIA FIRE SCIENCE CONSORTIUM

Research Brief for Resource Managers

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Using historical forest density estimates to inform management of contemporary Sierra Nevada forests

Levine, C.R., C.V. Cogbill, B.M. Collins, A.J. Larson, J.A. Lutz, M.P. North, C.M. Restaino, H.D. Safford, S.L. Stephens, and J.J. Battles. 2017. Evaluating a new method for reconstructing forest conditions from General Land Office survey records. Ecological Applications 27(5):1498–1513. DOI: 10.1002/eap.1543.

Management Implications

- Density estimates from distance-based estimators support the historical density estimates derived from timber inventories and reconstructions.
- The distance-based Morisita estimator is the most accurate estimator of historical densities from the GLO data sets.
- Density estimates from area-based estimators were consistently 200%-500% higher than true density estimates.
- The results of this study suggest caution in using density estimates derived from area-based estimators to inform forest management and restoration decisions.

Managers use historical forest conditions to inform contemporary management and restoration goals because historical forests are considered to be resilient to ecological disturbances such as fire, pests, and drought. But accurately estimating historical forest conditions, such as tree density, is challenging due to scant, geographically-limited data sets. In an attempt to characterize historical forest conditions at a regional scale, researchers have looked to data from the public land survey system conducted by the General Land Office (GLO). GLO is a systematic, historical sample of the location, species, and size of witness trees recorded in reference to survey points throughout the western US (Schulte and Mladenoff 2001). A key challenge in using the GLO dataset is accurately estimating tree density from the witness trees.

Distance-based density estimation approaches have been used to estimate tree density from witness trees in GLO data. A novel area-based method (the mean harmonic Voronoi density (MHVD)), was developed and purported to overcome some limitations of distance-based approached (Williams and Baker 2011). This new approach was then applied in California forests (Baker 2014). Results from this new area-based method suggested that historical forests were much more dense than previous estimates had shown, exceeding estimates based on historic forest inventories by 200–500% (Stephens et al. 2015). The findings based on this new approach raised questions regarding strategies for restoring and managing contemporary forests; however, this approach was never independently validated.

Levine et al. examined the approach by Williams and Baker by comparing the accuracy and precision of different area-based and distance-

based density estimation methods in six contemporary mixed-conifer forest stands. These stands are aligned across a latitudinal gradient in the Sierra Nevada and Sierra de San Pedro Mártir mountains. The true tree densities (ranging from 159-784 trees/ha) in each stand were measured and mapped. This study compared the accuracy and precision of density estimates derived from three distance-based plotless density estimators (Cottam, Pollard, and Morisita) as well as two Voronoi area (VA) estimators, the Delincé and MHVD, to the true densities in each stand.

The authors found that the least biased estimate of tree density in every stand was obtained with the Morisita estimator and the most biased was obtained with the MHVD estimator. The MHVD consistently overestimated tree density. Estimates were 1–4 times larger than the true densities and performed best in most dense stands, which had been subject to fire exclusion for ~100 years. The overestimation was attributed to two causes: (1) the use of a crown scaling factor that does not correct for the number of trees sampled and (2) the persistent underestimate of the true VA due to a weak relationship between tree size and VA.

The results of this study suggest caution in using the results based on MHVD density estimates to inform forest management and policy. MHVD-derived density estimates have been used to suggest that historical forests were characterized by high densities and extensive stand-replacing fires. However, the results of this study indicate that the MHVD approach overestimates density in the same range (200%-500%) as has been suggested by previous studies (Stephens et al. 2015). The Morisita estimator was found to be the most accurate density estimator and is recommended for use with the GLO data sets.

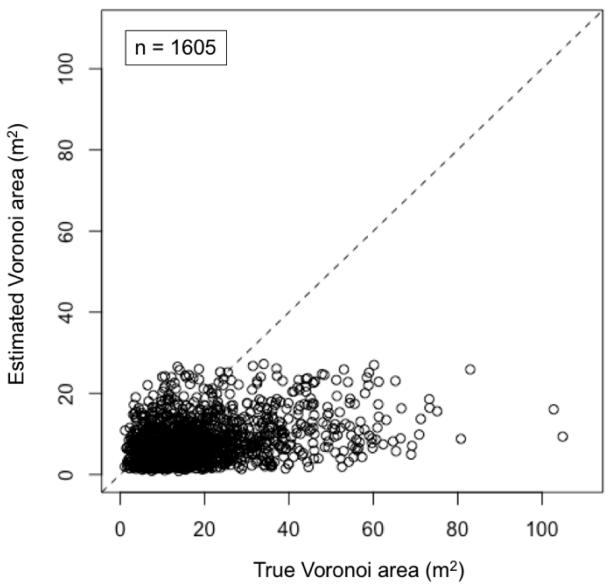

Figure 1. The relationship between the true Voronoi area (VA) and the estimated VA of individual trees in the Yosemite stand included in the Levine et al. study. The Baker method of VA estimation consistently under-predicted VA relative to a tree's true VA, leading to inflated estimates of stand density.

Further reading:

Baker, W. L. 2014. Historical forest structure and fire in Sierran mixed-conifer forests reconstructed from General Land Office survey data. Ecosphere 5:79.

Schulte, L. A., and D. J. Mladenoff. 2001. The original US public land survey records: their use and limitations in reconstructing presettlement vegetation. Journal of Forestry 99:5–10.

Stephens, S. L., J. M. Lydersen, B. M. Collins, D. L. Fry, and M. D. Meyer. 2015. Historical and current landscape-scale ponderosa pine and mixed conifer forest structure in the Southern Sierra Nevada. Ecosphere 6: Article 79.

Williams, M. A., and W. L. Baker. 2012. Spatially extensive reconstructions show variable-severity fire and heterogeneous structure in historical western United States dry forests. Global Ecology and Biogeography 21:1042–1052.