Micro-density variation in alpine forests of central México mirrors the normalized difference vegetation index (NDVI)

A. Correa-Díaz[1, 2], A. Gómez-Guerrero [1,*], J. Vargas- Hernández[1], Philippe Rozenberg[3] and W. R. Horwath[4]

[1] Posgrado en Ciencias Forestales, Colegio de Postgraduados, Km 36.5 Carr. México-Texcoco, Montecillo, Estado de México, CP 56230, México; correa.arian@gmail.com (A.C.-D.); agomezg@colpos.mx (A. G.-G.); vargashj@colpos.mx (J. V.-H.)

[2] Centro Nacional de Investigación Disciplinaria en Conservación y Mejoramiento de Ecosistemas Forestales CENID-COMEF, INIFAP. Av. Progreso No. 5, Barrio de Santa Catarina, Coyoacán, Ciudad de México, CP 04010, México.

[3] INRA, UMR 0588 BIOFORA, 2163 Avenue de la Pomme de Pin, CS 40001 ARDON, 45075 Orléans Cedex 2, France; philippe.rozenberg@inra.fr (P. R.)

[4] Biogeochemistry and Nutrient Cycling Lab. Department of Land Air and Water Resources. University of California, Davis. One Shields Avenue. Davis CA, 95616, USA; wrhorwath@ucdavis.edu (W. R. H.)

Abstract: Ongoing climate variability strongly affects high-elevation forests, influencing the wood formation process. Furthermore, spatio-temporal studies to establish links of wood properties and tree performance are needed. Using linear mixed-effects models, empirical cumulative distribution functions, and spatial analysis, we explore time trends and space connections of wood density of *Pinus hartwegii* Lindl. to remotely sensed variables (Moderate Resolution Imaging Spectro-radiometer MODIS-derived) in two high-elevation forests in México, Tláloc (TLA) and Jocotitlán (JOC) Mountains. Results indicated that elevation and cambial age effects are important factors explaining wood density variation. Minimum earlywood—MID, average—AVE, and maximum latewood density—MXD were statistically similar between mountains ($p > 0.05$), but TLA showed a significant increase in MID over time with higher values after 1950. Wood density values and spatial correlations were site-dependent with TLA exhibiting the highest correlations between MXD and the Normalized Difference Vegetation Index (NDVI) of the spring season ($r = 0.59$, $p < 0.05$). Overall, correlations to remotely sensed information were positive with MXD, negative for MID and divergent for AVE. Historical temperature defines MID along the elevation gradient, while MXD was related to soil moisture only at low-elevation sites where soils are deeper. We found that two high-elevation forests, 115 km away from each other, with similar climate, soil, and vegetation, behaved differently regarding their wood formation process, indicating the potential of using the link between wood micro-density and remotely sensed information to understand forest response to climate change effects.