EGU26-15464, updated on 11 Nov 2026
https://doi.org/10.5194/egusphere-egu26-15464
EGU General Assembly 2026
© Author(s) 2026. This work is distributed under
the Creative Commons Attribution 4.0 License.

Too much topography! Effects of topography on the estimation of plant functional traits using hyperspectral data

Javier Lopatin
Facultad de Ingeniería y Ciencias, Universidad Adolfo Ibáñez, Santiago, Chile (javier.lopatin@uai.cl)

Mountain ecosystems play a critical role in global biodiversity conservation, water regulation, and climate change adaptation. However, their pronounced topographic complexity poses major challenges for the large-scale estimation of plant functional traits using remote sensing, limiting our ability to characterize ecosystem functioning and vegetation responses to global warming. Variations in slope, aspect, and elevation strongly affect illumination conditions, viewing geometry, and canopy structure, introducing biases that are often overlooked in trait–reflectance relationships. Vegetation indices and empirical models are widely used to estimate plant traits from optical remote sensing data, yet their performance degrades in complex terrain due to topographic artifacts and limited field calibration data. Alternatively, radiative transfer models (RTMs) provide a physics-based framework for linking spectral reflectance to vegetation biophysical and biochemical properties. Despite their theoretical advantages, most commonly used RTMs assume flat or gently sloping terrain and are therefore poorly suited for mountainous landscapes, potentially compromising trait retrievals in these environments.

In this study, we quantify the influence of terrain complexity on the performance of both empirical and physically based models applied to hyperspectral data for estimating functional leaf traits in Andean forest ecosystems. Field data were collected in more than 120 plots distributed according to a fractal sampling design across strong gradients in elevation, slope, and aspect in the Mapocho River basin (central Chile). For each plot, we measured species abundance, leaf-level functional traits, and topographic variables, and linked these data with airborne hyperspectral reflectance. Our results show that model performance is highly sensitive to terrain conditions. Across traits and modelling approaches, explained variance ranged from near zero to approximately 50%, substantially lower than values typically reported in studies conducted in low-relief landscapes. Trait-specific responses were evident: some functional traits were better explained by spectral reflectance, while others were more strongly associated with topographic variables alone. Residual analyses further revealed systematic terrain-driven biases, indicating that both empirical models and RTMs struggle to disentangle spectral signals related to plant traits from those induced by complex topography.

These findings highlight a strong methodological and geographical bias in current remote sensing approaches for trait estimation, driven by the predominance of studies conducted in flat or gently undulating terrain. Because mountainous regions are essential for biodiversity, ecosystem

services, and climate sensitivity, excluding or oversimplifying topographic effects limits the transferability and scalability of trait-based remote sensing models. Our study underscores the urgent need to develop terrain-aware modelling frameworks that explicitly integrate topography into hyperspectral trait estimation to improve ecological inference and support monitoring efforts in complex mountain systems.