Accuracy constraints of gedi-based biomass models in heterogeneous coffee agroforestry

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Abstract

Greater pressure on African forests has meant that they are now a source, rather than a carbon sink, driving an urgent need for land-use systems that restore biomass. While coffee agroforestry is one means to promote carbon sequestration, its quantification in smallholder systems remains highly uncertain. A systematic literature review conducted for this study indicated that global remote sensing models applied to heterogeneous landscapes frequently suffer from range compression, characterised by signal saturation and scale mismatches.

We evaluated the suitability of a remote sensing-derived aboveground biomass (AGB) product for monitoring, reporting, and verification (MRV) in coffee-based agroforestry on Mount Gorongosa, central Mozambique. Field data were collected from 36 circular 400 m^2 plots in smallholder Arabica coffee agroforests established since 2014, spanning a range of stand ages and shade-tree compositions. Field AGB was estimated from woody stem measurements using species-specific, regional and pantropical allometric equations, then scaled to Mg ha ^{1} at the plot level. Remote-sensing AGB was derived from a model trained on GEDI LiDAR AGB footprints and multisource inputs (Sentinel^{-2}, ALOS^{-2} PALSAR, Digital Elevation Model, land cover map) from outside of the study area.

The empirical results confirmed the structural biases identified in the literature. The model showed strong structural bias and poor agreement with field AGB: mean bias was 16.96 Mg ha ^{1}, RMSE 52.86 Mg ha ^{1} and relative RMSE 91.22 %. The regression slope (0.253) and high intercept (60.23 Mg ha ^{1}) revealed systematic overestimation at low biomass and underestimation at high biomass.

These findings illustrate a critical calibration gap where current GEDI-based products fail to capture the structural complexity of smallholder systems. Locally grounded calibration data remain essential for credible AGB accounting in these heterogeneous landscapes.

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