Drivers of carbon stocks across tropical forests: the need to disentangle the response of forest structural components to environment

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Context

The critical role of tropical forests in the global carbon cycle is well known. However, significant uncertainties remain in estimating carbon stocks across tropical forests, which limit our ability to develop effective conservation and restoration strategies for these ecosystems. **This observed-modeled discrepancy underscores persistent gaps in our understanding of how tropical forest carbon stocks respond to environmental changes.**

Hypothesis

Across large-scale gradients, there is a well-established relationship between environmental conditions and aboveground biomass (AGB), shaped by distinct adaptation strategies leading to high AGB levels in tropical forests and low AGB levels in boreal forests. In this study, we argue that within tropical forest ecosystems, **the relationship between environmental variables and AGB cannot be directly predictable due to the interplay of various adaptation strategies, allowing for the maintenance of consistently high levels of AGB despite variations in environmental conditions.**

Method

These adaptation strategies can be characterized by various community-level forest traits (referred to herein as forest structural components), including stem density, community wood density, average diameter, canopy height, and basal area. These traits are key indicators of forest dynamics shaping forest AGB. **Therefore, this study aims to investigate the environmental influence (i.e., climate, soil properties, and topography) on each of these forest traits across tropical forests and to directly compare these relationships with those found for AGB.**

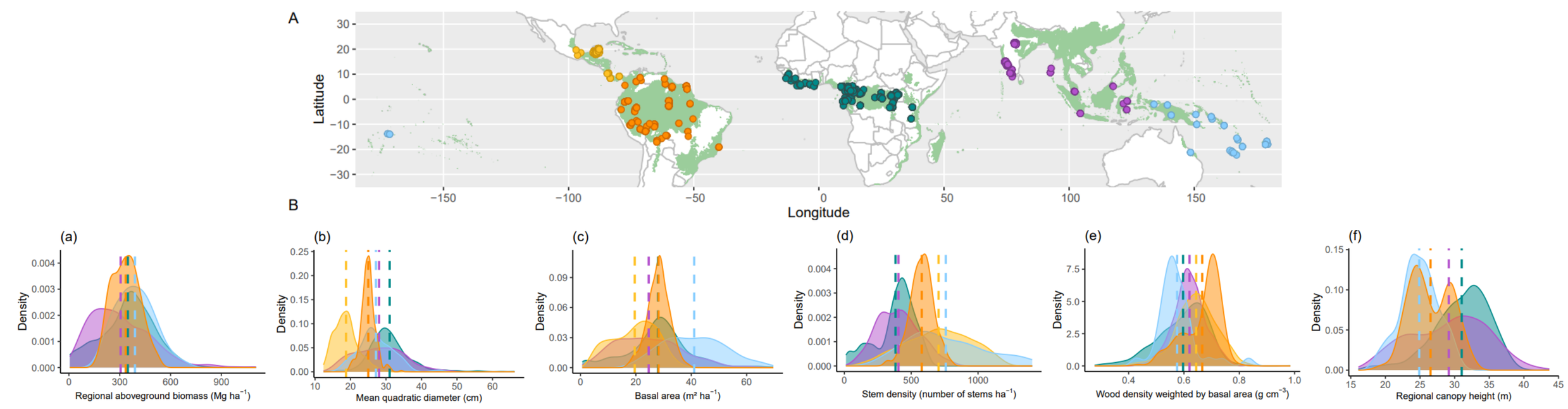

Figure 1. Forest structure and aboveground biomass variations across tropical regions. All these data have been provided to us by the Global Forest Biodiversity Initiative plot network, the FORESTPLOTS network, as well as directly by principal investigators of field plots.

Forest structural components and AGB vary across tropical regions, **revealing sharp discrepancies between continents in forest structure**, while demonstrating small divergence in AGB distribution.

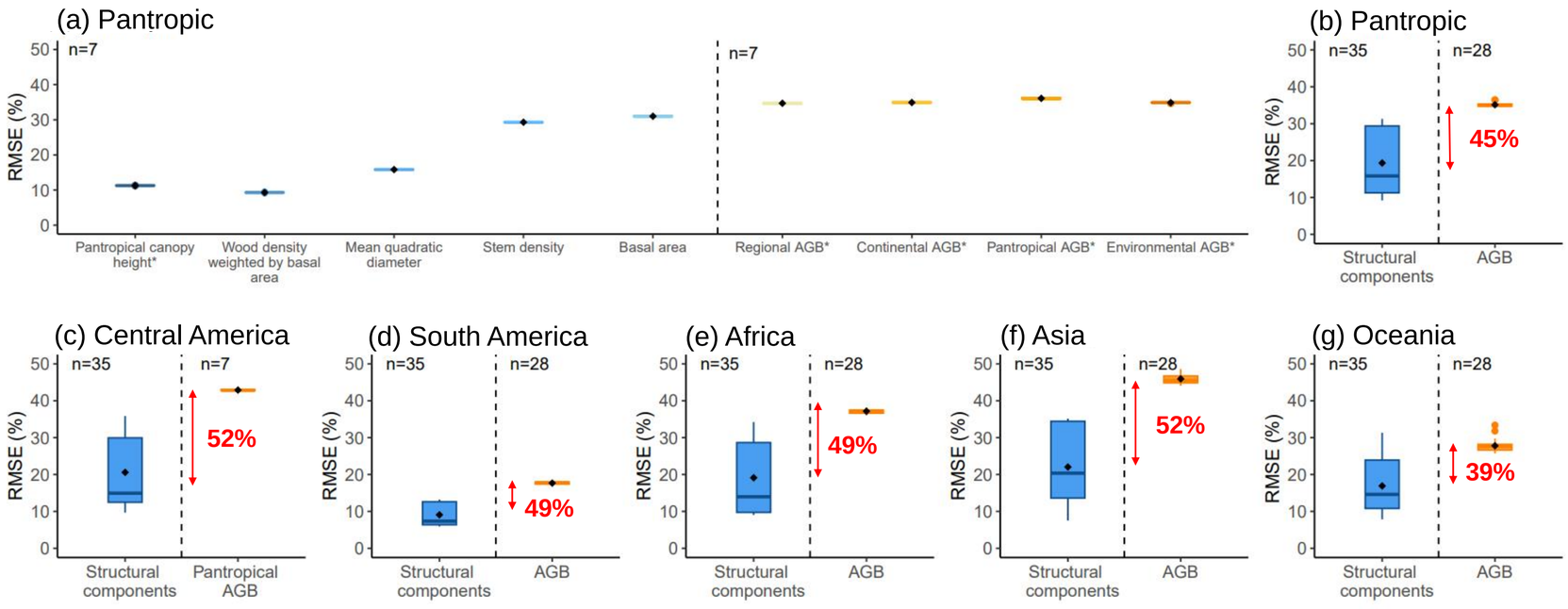

Figure 2. Model error in predicting forest structure vs. aboveground biomass.

Forest structural components reveal stronger relationships with environmental variables compared to AGB, resulting in a reduced model error (i.e., Root Mean Squared Error (RMSE) of Multiple Linear Models) of 45% compared to the error in predicting AGB. Specifically, we observe a reduced model error of approximately 40% in Oceania and 50% in other continents.

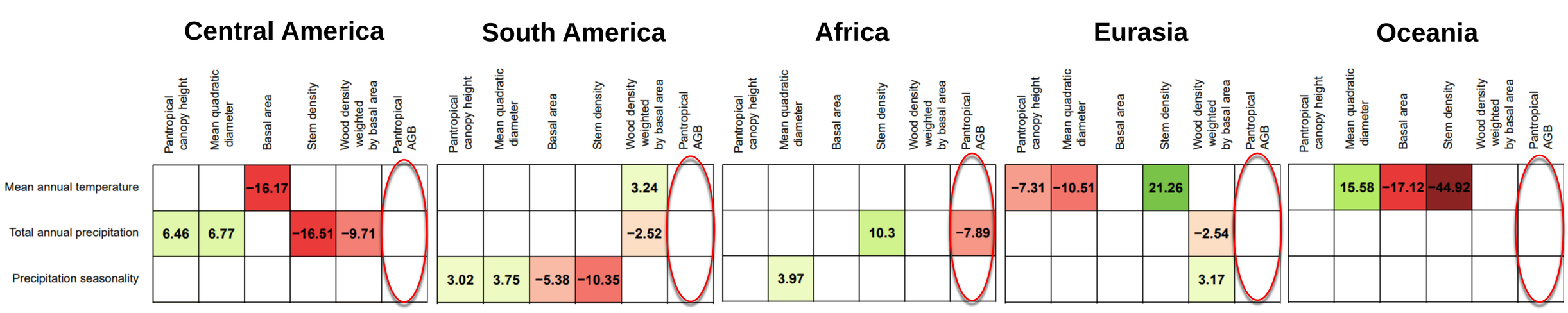

Figure 3. Climatic drivers of forest structural components vs. aboveground biomass : Standardized coefficients of the Multiple Linear Models (expressed as a % compared to the average) predicting each forest structural component and aboveground biomass with three climatic variables and other predictive variables (soil, topographic variables, and Moran's Eigenvectors Maps) are not shown.

In most cases, climate shows no influence on forest AGB. However, deeper investigation reveals a significant impact of all three climatic variables on forest structural components. Specifically, trade-offs between the structural components indicate distinct adaptive strategies along climatic gradients, with continental differences in the climate-component relationships.

Take-home message

Within tropical forests, the focus should shift from studying direct environmental influences on AGB to understanding how forest communities' adaptation strategies along environmental gradients shape the high AGB levels across different continents. This study provides key insights for improving future models predicting tropical forest carbon stocks and guiding effective forest management decisions in the context of climate change.

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