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Climate-biomes, pedo-biomes and pyro-biomes: which world view explains the tropical forest - savanna boundary in South America?

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Elucidating the drivers of broad vegetation formations improves our understanding of earth system functioning. The biome, defined primarily by the dominance of a particular growth strategy, is commonly employed to group vegetation into similar units. Predicting tropical forest and savanna biome boundaries in South America has proven difficult. Process based DGVMs (Dynamic global vegetation models) are our best tool to simulate vegetation patterns, make predictions for future changes and test theory, however, many DGVMs fail to accurately simulate the spatial distribution or indeed presence of the South American savanna biome which can result in large differences in modelled ecosystem structural properties. Evidence suggests fire plays a significant role in mediating these forest and savanna biome boundaries, however, fire alone does not appear to be sufficient to predict these boundaries in South America using DGVMs hinting at the presence of one or more missing environmental factors.

We hypothesise that soil depth, which affects plant available water by determining maximum storage potential and influences temporal availability, may be one of these missing environmental factors. To test our hypothesis we use a novel vegetation model, the aDGVM2. This model has been specifically designed to allow plant trait strategies, constrained by trade-offs between traits, evolve based on the abiotic and biotic conditions where the resulting community trait suites are emergent properties of model dynamics. Furthermore it considers root biomass in multiple soil layers and therefore allows the consideration of alternative rooting strategies, which in turn allows us to explore in more detail the role of soil hydraulic factors in controlling biome boundary distributions.

We find that changes in soil depth, interacting with fire, affect the relative dominance of tree and grass strategies and thus the presence and spatial distribution of forest and savanna biomes in South America. Using the ISRIC-WISE soil depth dataset we show that applying spatially variable soil depth, in contrast to globally fixed soil depth, improves the accuracy with which we predict the South American savanna biome distribution when compared to multiple contemporary biome maps and that the emergence of the savanna biome results in markedly different ecosystem structural properties such as tree height, tree cover and above ground biomass. Many of these areas are capable of supporting forest and savanna biome states and have been deemed bi-stable areas, we show that, in these bi-stable areas the emergent tree community trait suite differs markedly between forest and savanna biome states.