Plant functional diversity and the biogeography of biomes in North and South America

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Introduction

Understanding functional differences among biomes is critically important to modeling the global carbon cycle and the functioning of the Earth system, including responses to anthropogenic global change. Our goals in this study are (1) to document the extent of the available data that characterize the functional diversity and distinctiveness of biomes, to highlight persistent data shortfalls. (2) Given the available data, we quantify the functional distinctiveness of a biome by identifying the most common functional strategies of the most widespread species within it. (3) we explore whether biomes are in fact characterized by functionally distinct collections of species using measures of functional similarity based on multidimensional hypervolumes in functional trait space.

Methods

We used the BIEN database to extract range maps and trait measurements of plant species distributed in North and South America. The BIEN (Botanical Information and Ecology Network) database integrates standardized plant observations stemming from herbarium specimens and vegetation plot inventories (Enquist, B.J. et al. 2016, Goldsmith et al., 2016).

Figure 1: **7,842 species with complete trait information and range maps**

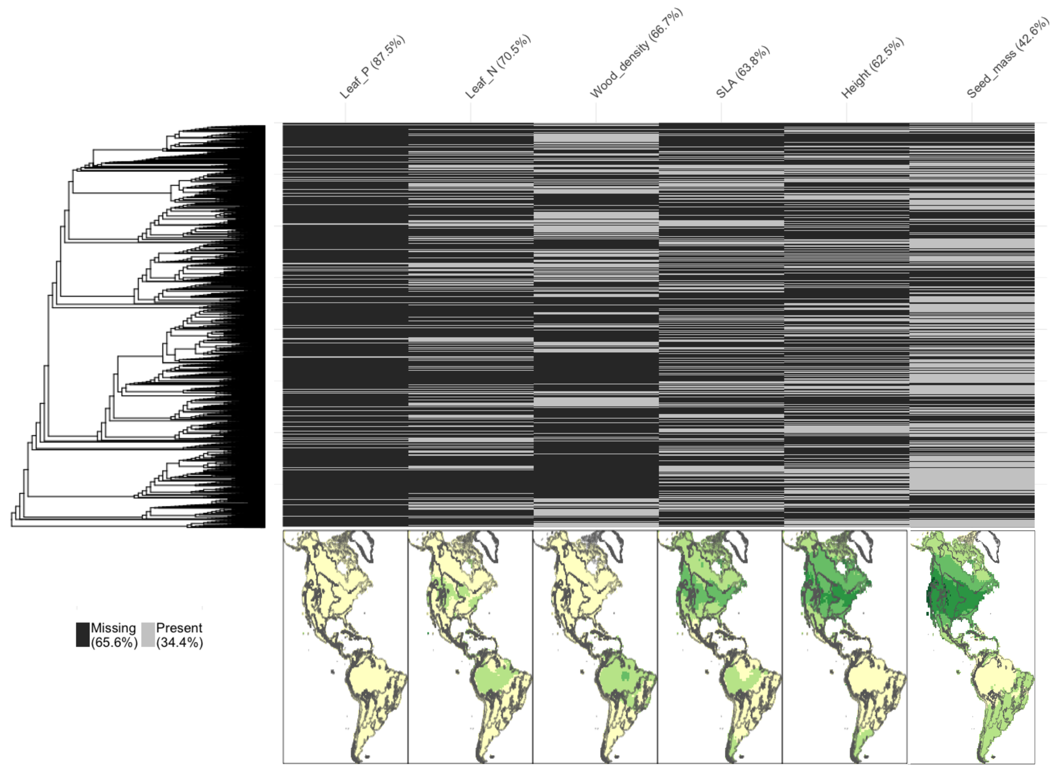

Figure 2: Proportion of species with known (gray) or missing (black) trait values to the total number of species in the BIEN 3.0 database. Phylogeny at the left corresponds to the ALLBM tree from Smith and Brown, 2018, which was used to phylogenetically imputed missing trait data using the R package "Rphylopars" v 0.2.9 (Goolsby et al., 2017)

Trait hypervolumes

- Estimated per grid cell and collections of cells per biome
- R package "hypervolume" (Blonder et al., 2014, 2018)

Functional distinctiveness

- Following the conceptual framework of functional rarity by Violle et al. 2017.
- Functional distinctiveness: average functional distance of a species to the N other species within the biome species pool.
- Geographic widespreadness: measured as the number of sites occupied by the species within a community over the total number of sites.

Acknowledgments

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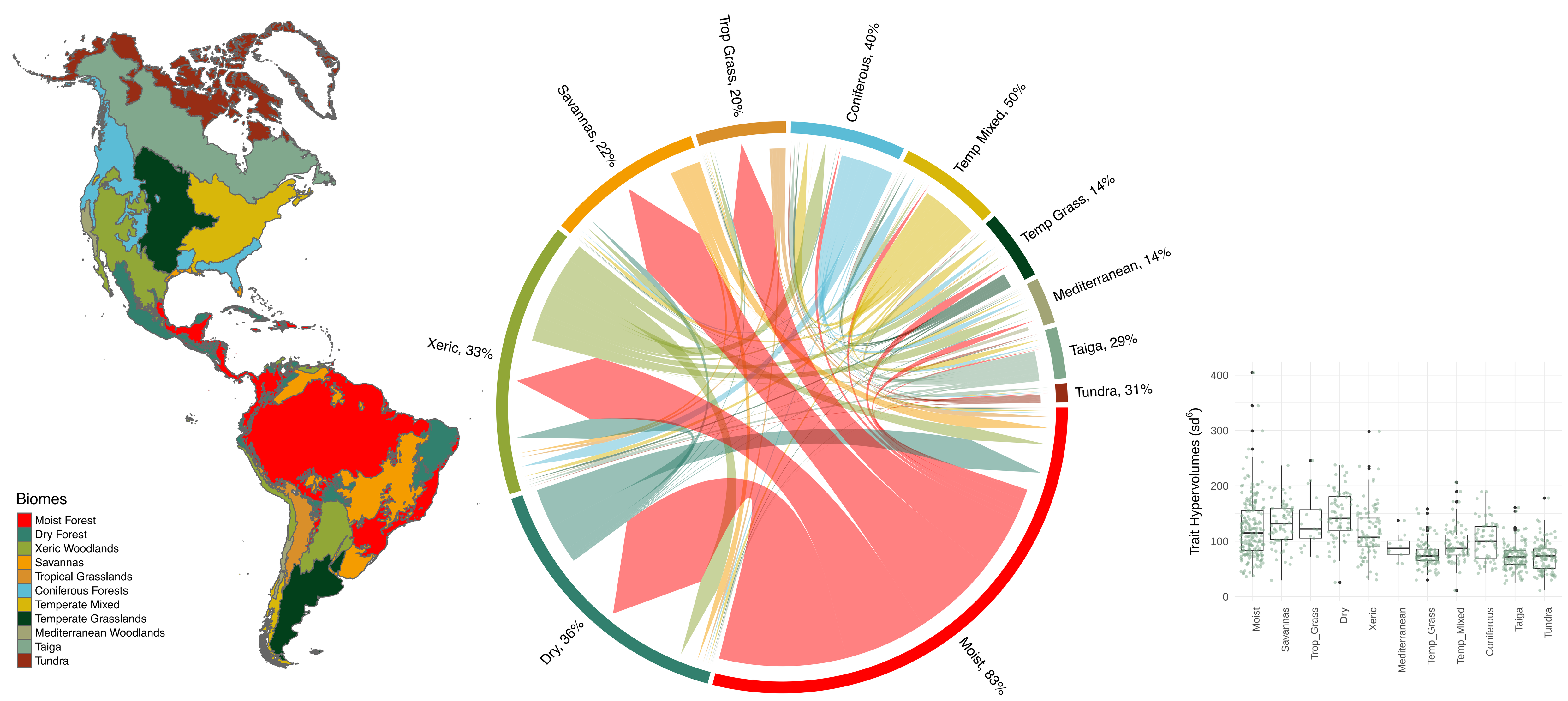

Figure 3: (A) Overlap of plant species among biomes of the New World. Percentage values express the fraction of species that have the greatest proportion of their geographic range in each biome. (B) Distribution of trait hypervolumes of 20% of randomly selected 100X100 km cells in each biome. Hypervolumes are reported in units of standard deviations to the power of the number of traits used. Despite substantial hypervolume overlap among all the biomes, tropical, temperate, and cold biomes all appear to occupy distinguishable regions of functional space.

Results

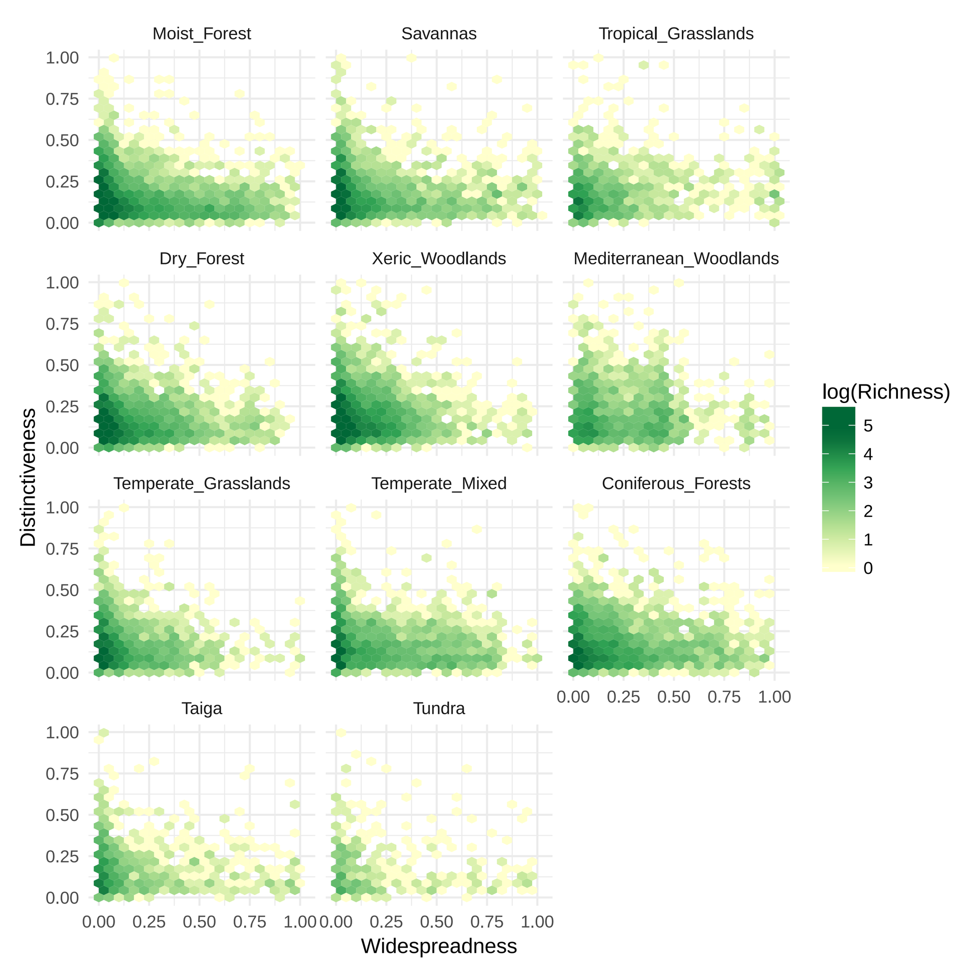

Figure 4: Patterns of functional distinctiveness among biomes. Distinctiveness represents how species are functionally distant from another within a biome (i.e., the mean pairwise phenotypic distance from a focal species to all the others). The larger the value, the more distant a species is to the centroid of the biome's functional space. Widespreadness measures how geographically common a species is. A value of 0 indicates that a species is present in a single biome cell.

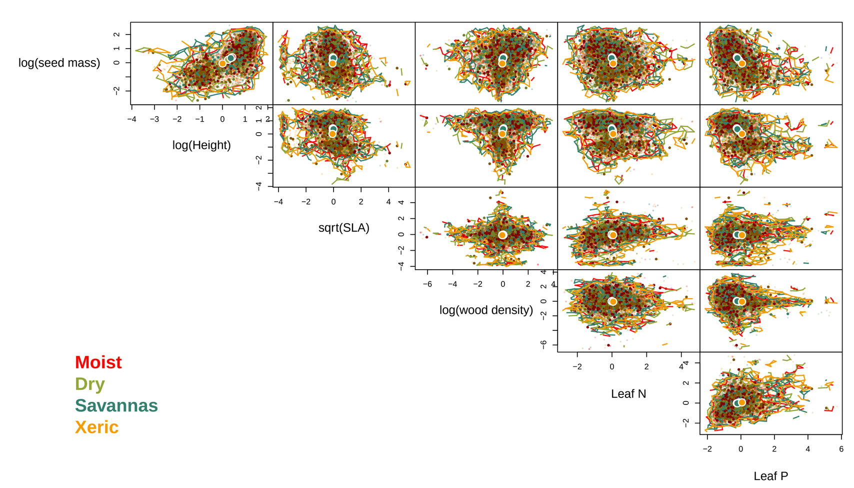

Figure 5: Trait hypervolumes for tropical biomes using the whole pool of species. Hypervolumes are shown in a 2D projection using the combination of all six trait axes implemented in this study.

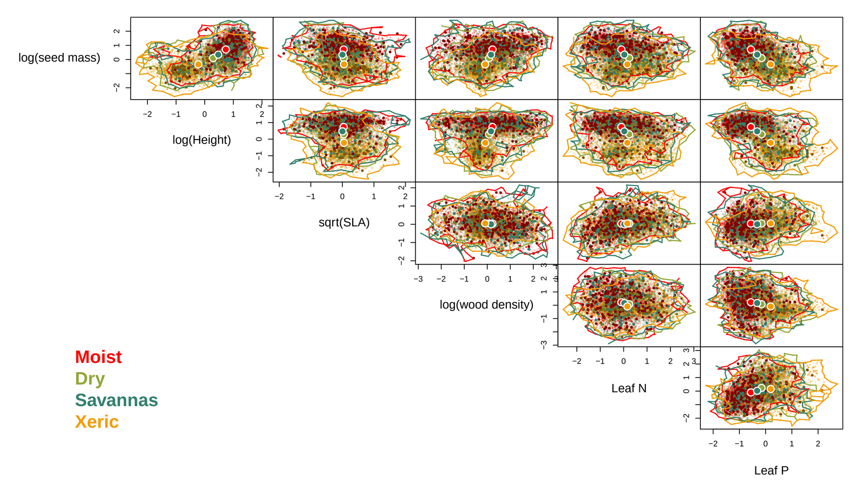

Figure 6: Trait hypervolumes for tropical biomes using species that are functionally redundant and widespread in each biome. The main traits differentiating biomes appear to be traits related to overall plant size, including both mature height and seed mass, rather than by leaf economics trait

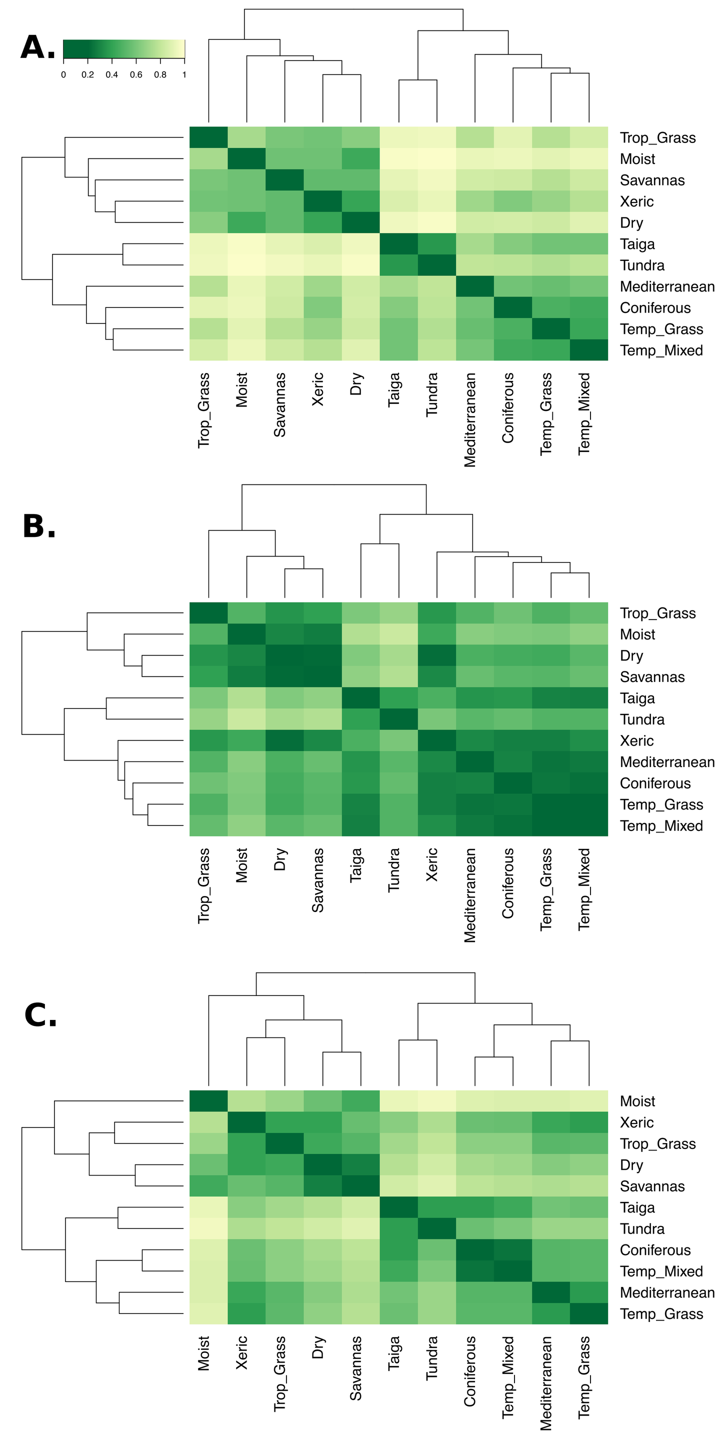

Figure 7: (A) Pairwise dissimilarity in species composition among biomes. (B) Pairwise dissimilarity in trait hypervolumes (1-Sørensen similarity) among biomes using the total number of species. (C) Pairwise dissimilarity in trait hypervolumes (1-Sørensen similarity) among biomes using only those species that are considered as functionally redundant and widespread. The lighter the cell the greater the dissimilarity.

Conclusions

- Despite progress in the compilation and synthesis of primary biodiversity data, significant knowledge shortfalls persist that may limit our ability to quantify the functional biodiversity of biomes on continental to global scales.
- when only the widespread and functionally redundant species are considered, biomes can be more readily distinguished functionally, and patterns of dissimilarity between biomes appear to reflect a correspondence between climate and plant functional niche space.
- Our results suggest that while the study of the functional diversity of biomes is still in its formative stages, further development of the field will yield insights linking evolution, biogeography, community assembly, and ecosystem function.

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