ECOLOPES

# A novel framework to generate plant functional groups for ecological modelling

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Technical Summary #1

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## Short Summary

An effective way to reduce complexity to model plant communities is by grouping species that share similar characteristics into plant functional groups (PFGs). We proposed a new framework that generate PFGs by including the most important ecological dimensions, is applicable globally, and emerges from patterns of functional redundancy across species. We demonstrated and validated the framework by applying it to a global dataset of plant characteristics including a functional traits dataset and a plant-soil co-occurrence dataset for 19,102 species worldwide. Our framework generated 465 global, robust data driven PFGs with non-overlapping combinations of plant characteristics divided by growth form.

## Introduction

Generating reliable predictions of ecological community dynamics under varying biotic and abiotic constraints and environmental changes is a central research topic in predictive ecology (Mouquet et al., 2015). In plant ecology, this has been carried out with predictive vegetation models (e.g., hybrid-DVMs; Sitch et al., 2008). The basic unit at which behaviour is modelled is the modelling entity (Grimm et al., 2010). Modelled entities are usually groups of individuals with similar characteristics such as plant functional groups (PFGs). PFGs are created by grouping species by attributes or functional traits, and thus underlying convergent ecological strategies (Lavorel et al., 2007, Figure 1).

Several PFGs classifications already exist but are in their majority tailored to a specific study region, or conversely, they are unable to capture fine scale processes and it has been difficult to apply them across varying spatial scales and ecosystems. One major reason is overall trait data availability and species coverage, which has so far acted as a key limiting factor on the level of detail and number of groups to be developed. Here, we generalize the methodological approach by Boulangeat et al. (2012) by implementing a broader set of traits and species. This provides a data driven generic framework that can classify worldwide trait data to derive PFGs that are suitable for modelling plant biodiversity, vegetation dynamics and ecosystem functioning potentially anywhere on Earth.

## Materials and Methods

The proposed generic framework is designed to develop objective PFGs classifications based on the ecological dimensions and the geographical context of interest. The steps for building the classification scheme, together with the methods and data used are presented in Fig. 2.

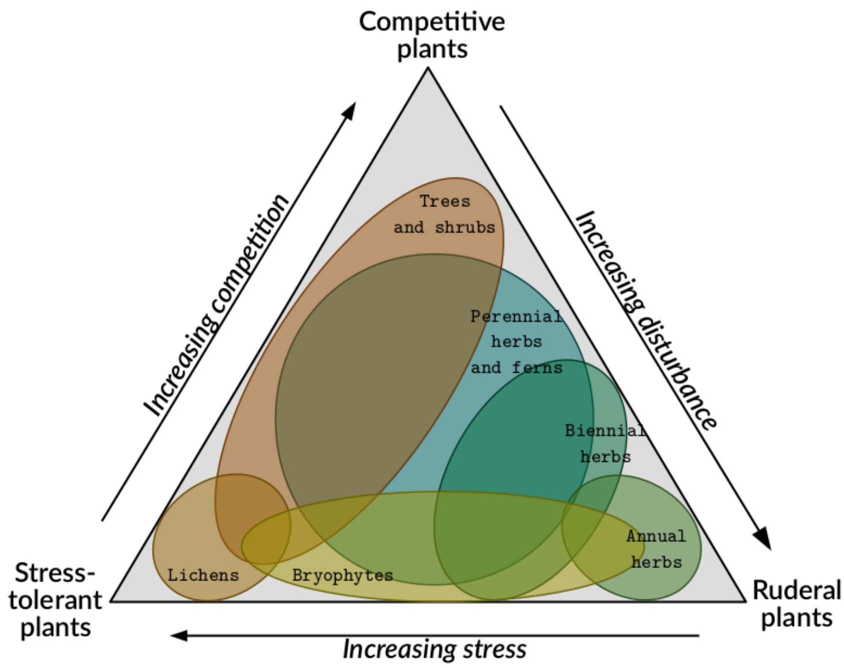


*Figure 1. Plant and Lichens Functional Groups triangle, https://leca-dev.github.io/RFate/articles/fate_tutorial_1_PFG.html*

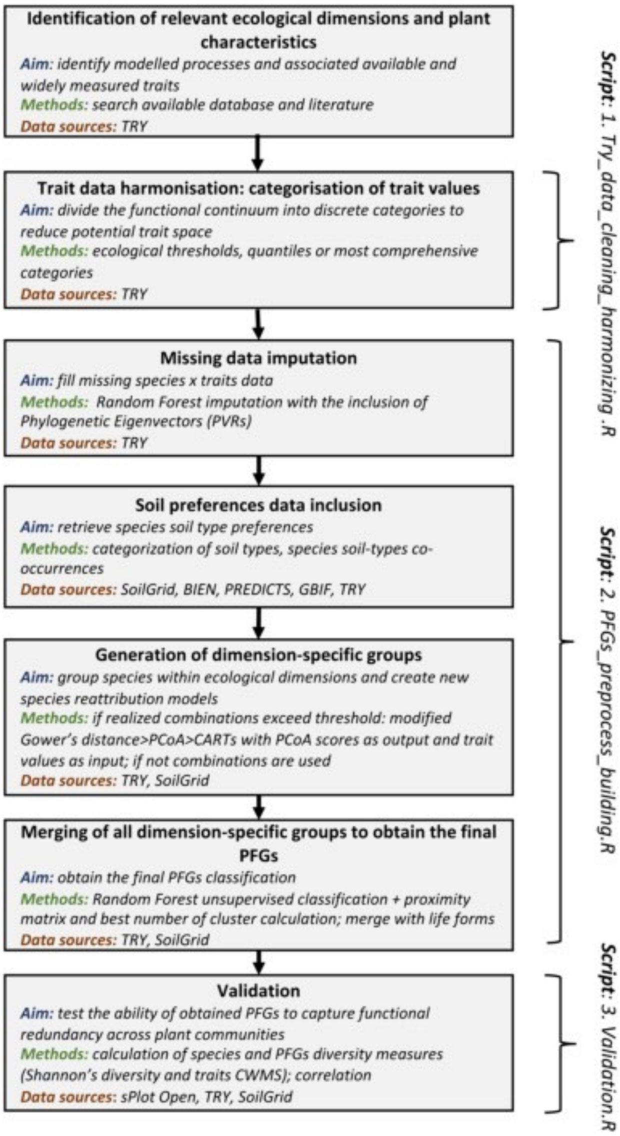


*Figure 2: Calbi et al. (2024): 1. Fig. 1. PFGs building applied workflow with main aims, methods and data sources for each step. Corresponding supplementary R script are indicated. TRY=Plant Trait Database; SoilGrid = global gridded soil information; BIEN=Botanical Information and Ecology Network; PREDICTS: Projecting Responses of Ecological Diversity In Changing Terrestrial Systems; GBIF=and Global Biodiversity Information Facility: sPlotOpen = an environmentally balanced, open-access, global dataset of vegetation plots:; PCoA=principal coordinate analysis; CARTs = classification and regression trees; CWMs = community weighted means.*

## Results

The successful development and application of the framework retrieved an optimal number of 465 PFGs, based on 19 functional traits and soil preferences (Fig. 3). 27 PFGs were composed by aquatic species, 72 climbers_lianas, 26 epiphytes, 150 herbs, 8 parasitic, 125 shrubs_trees, and 57 were composed by small_shrubs species. The employed pool of 19,102 species represented about 5.45 % of the 350,699 accepted species names in the TPL database (https://www.theplantlist.org), an unprecedented coverage across PFGs classifications both regarding the number of species and the number of used features. The ten most species rich PFGs (Table 3) comprised mostly herbs, shrubs trees and only one climber and lianas group. Most species rich PFGs of these growth forms shared very similar combinations of traits. The most important ecological dimensions were dispersal, habitat, disturbance, and competition response. The least important were demography, competition effect, and soil. The most influential traits underline the two main uncorrelated gradients in PFGs distribution in the traits space (Fig. 3).

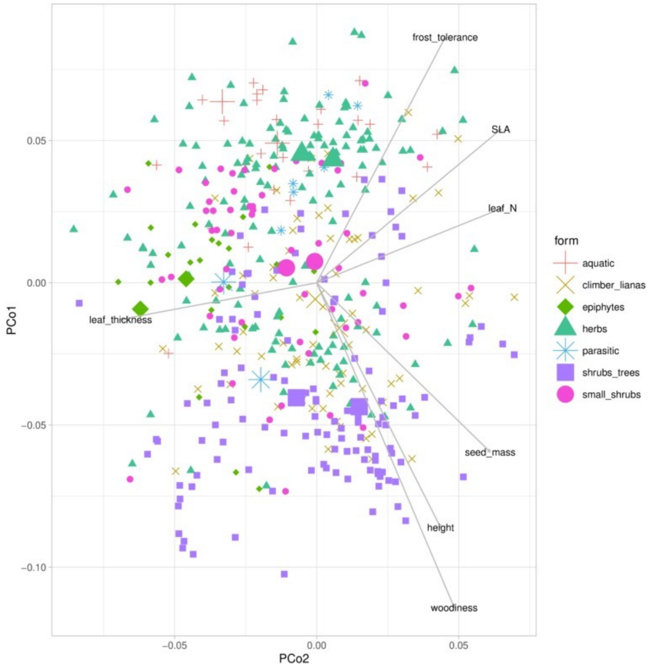


*Figure 3: Calbi et al. (2024): Principal Coordinates Analysis (PCoA) of plant functional groups (PFGs) in the plant characteristics space (including functional traits and soil preferences), symbols are PFGs centroids. Arrows show the gradient of the seven fitted variables (traits) most correlated (r2 > |0.2|) with the first two ordination axes: woodiness, frost tolerance, height, seed_mass, SLA, leaf_N, and leaf_thickness. Bigger symbols represent the two most species rich PFGs for each growth form. SLA=specific leaf area; leaf_N=leaf Nitrogen content.*

## Conclusions

The proposed robust and globally applicable PFGs can be implemented to model plant responses and community dynamics in different ecosystems and even at a global scale. In principle, our classification framework allows to retrieve functional groups that maintain a high level of detail and characterization of response to abiotic conditions, species interactions, and spatial and temporal dynamics, something that no other approach allows in the present time. Furthermore, the ability of the proposed PFGs classification framework to provide effective functional groups for different ecological modelling efforts can be tested with different selections of species, ecological dimensions and species traits and features.

### Authors / Contributions

M. Calbi: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. G. Boenisch: Writing – review & editing, Methodology, Data curation. I. Boulangeat: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Conceptualization. D. Bunker: Writing – review & editing, Data curation. J.A. Catford: Writing – review & editing, Data curation. A. Changenet: Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization. V. Culshaw: Writing – review & editing, Methodology, Conceptualization. A.S. Dias: Writing – review & editing, Data curation. T. Hauck: Writing – review & editing, Investigation, Conceptualization. J. Joschinski: Writing – review & editing, Methodology, Formal analysis, Conceptualization. J. Kattge: Writing – review & editing, Supervision, Methodology, Data curation. A. Mimet: Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization. M. Pianta: Writing – review & editing, Methodology, Data curation. P. Poschlod: Writing – review & editing, Data curation. W.W. Weisser: Writing – review & editing, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization. E. Roccotiello: Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

### References

Mouquet, N., Lagadeuc, Y., Devictor, V., Doyen, L., Duputié, A., Eveillard, D., ... & Loreau, M. (2015). Predictive ecology in a changing world. Journal of applied ecology, 52(5), 1293-1310.

Sitch, S., Smith, B., Prentice, I. C., Arneth, A., Bondeau, A., Cramer, W., ... & Venevsky, S. (2003). Evaluation of ecosystem dynamics, plant geography and terrestrial carbon cycling in the LPJ dynamic global vegetation model. Global change biology, 9(2), 161-185.

Grimm, V., Berger, U., DeAngelis, D. L., Polhill, J. G., Giske, J., & Railsback, S. F. (2010). The ODD protocol: a review and first update. Ecological modelling, 221(23), 2760-2768.

Lavorel, S., Díaz, S., Cornelissen, J. H. C., Garnier, E., Harrison, S. P., McIntyre, S., ... & Urcelay, C. (2007). Plant functional types: are we getting any closer to the Holy Grail?. Terrestrial ecosystems in a changing world, 149-164.

Boulangeat, I., Philippe, P., Abdulhak, S., Douzet, R., Garraud, L., Lavergne, S., ... & Thuiller, W. (2012). Improving plant functional groups for dynamic models of biodiversity: at the crossroads between functional and community ecology. Global change biology, 18(11), 3464-3475.

Calbi, M., Boenisch, G., Boulangeat, I., Bunker, D., Catford, J. A., Changenet, A., ... & Roccotiello, E. (2024). A novel framework to generate plant functional groups for ecological modelling. Ecological Indicators, 112370.