Mixed-effects modeling with the `lme4` package: a modern tool for the analysis of plant morphological data in R

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Mixed-effects modeling is a relatively recently developed technique to describe relationships between a response variable and some covariates in data that are grouped according to one or more classification factors (Pinheiro & Bates, 2000). In traditional statistical analyses, the inside-group variability is removed by averaging measurements over the group levels, or by treating the sampling units of the same groups as independent measurements. Mixed-effects models account for the inside-group dependency by adding random effects to the model structure, and are thus lowering the risk of capitalization on chance (Type I error) (Quené & van den Bergh, 2008). Further, mixed-effects models are useful for the estimation of inside-group variation, which can be interesting in itself. The function `lmer` in the `lme4` package (Bates & Sarkar, 2007), an extended version of the earlier `nlme` package, is widely known as a powerful and flexible tool for the fitting of linear and generalized mixed-effects models in R. The `lme4` package offers fast and reliable algorithms for parameter estimation, as well as tools for evaluating the model (using Markov chain Monte Carlo sampling).

Mixed-effects modeling has strong roots in biomedical and educational research, where researchers need to acknowledge multiple random effects affecting their data: *e.g.* students' school performances are affected by the individual students, their school class, their school, etc. (Quené & van den Bergh, 2008). As such, this technique is frequently used in the aforementioned research domains. In ecological studies, the use of mixed-effects models for data analysis is, up till now, surprisingly scarce. Nevertheless, similar data structures as in social sciences are frequently encountered in ecology, especially in morphological studies: leaf characteristics are for example affected by the tree where they belong to, but also by the trees' provenance or by the trees' surrounding environment.

This poster presents a practical example of the use of mixed-effects modeling in ecological research. In this study, we use the `lme4` package for the fitting of linear as well as generalized linear mixed-effects models to baobab (*Adansonia digitata* L.) leaf morphological data. The leaf morphological parameters are clustered in trees, which are, on their turn, clustered in provenances. The aim of the study is to evaluate the effects of pruning (on tree level), as well as climate (on provenance level), on the aforementioned data. Further, an analysis of the different variance components is made. It is shown that mixed-effects modeling is an appropriate technique for data-analysis in ecological research domains, especially for research on plant or animal morphology.

References

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