Distribution and diversity of leaf-cutting ants in northeastern Argentina: species most associated with forest plantations

Andrés F. Sánchez-Restrepo1,2,3; Nadia L. Jiménez1,3; Viviana A. Conflonieri2,3 & Luis A. Calcaterra1,3

1 Fundación para el Estudio de Especies Invasivas (FuEDEI), Bolívar 1559, Hurlingham, Buenos Aires, Argentina. email: andres.sanchez@javeriana.edu.co
2 Grupo de Investigación en Filogenias Moleculares y Filogeografía (GIFF), Dpto. de Ecología, Genética y Evolución, FCEyN, Universidad de Buenos Aires, Buenos Aires, Argentina.
3 Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), CABA, Argentina.

SUPPLEMENTARY MATERIAL

Occurrence data
In order to make the ENM, we reduce the dataset using a geographic distance criterion employing the “spThin” R package (Aiello-Lammens et al. 2015), setting a thinning parameter distance of 25, 50 or 100 km (according to species extent) and 100 replicates. All process of filtering, for each species, is summarized in table 1 and thinning plots in figure 1. Some records found in the published databases presented inconsistencies with the known distribution of the species. In particular, Acromyrmex lundii has been reported in Colombia from Valle del Cauca and Nariño (Bustos 1994; Aldana et al. 1999). These records are far away from the current known distribution of this species and in an unusual habitat for this species. Acromyrmex hystrix have been recently mentioned by Mason et al. (2017) in the province of Buenos Aires based from records published in biodiversity databases and literature. Acromyrmex hystrix is known to be mainly distributed in the north of South America and it had never been mentioned for Argentina. In both cases, we believe that these are cases of erroneous identification in the case of A. lundii, or confusion due to the similarity of the names with other similar species, possibly A. hystrix could be referring to A. heyeri. For these reasons, we excluded those records from the ENM analyzes as since they could not be adequately verified.
Table 1. Total known occurrence records for the seven leaf-cutting ant species, distance parameter used to thinning the records and total records finally used to make the models.

| Genus            | Species         | Distance parameter (km) | Number of records before thinning | Number of records after thinning |
|------------------|-----------------|-------------------------|-----------------------------------|----------------------------------|
| Acromyrmex      | ambiguus        | 50                      | 98                                | 48                               |
|                  | crassispinus    | 50                      | 97                                | 60                               |
|                  | heyeri          | 50                      | 148                               | 42                               |
|                  | lobicornis      | 50                      | 254                               | 108                              |
|                  | lundii          | 50                      | 210                               | 117                              |
| Atta             | sexdens         | 100                     | 230                               | 79                               |
|                  | vollweideri     | 25                      | 36                                | 28                               |

Figure 1. Differences of the spatial distribution patterns in each species. Occurrence records before (raw data as red points) and after the cleaning and filtering (as blue points) by geographic distance criteria.
Environmental variables

To make the ENM we use 20 variables (19 bioclimatic, plus elevation). Bioclimatic were obtained from Worldclim version 1.4 (Hijmans et al. 2005; http://www.worldclim.org/). Of these, only the least correlated variables were used. To identified the most correlated, we used a test for multicollinearity between each pair of variables (Pearson’s correlation coefficient) and all variables strangely correlated ($r > 0.8$) were excluded (Figure 2). Second, the variance inflation factors (VIF) was calculated for each variable using the R base and “usdm” package (Naimi et al. 2014). The VIF represents the proportion of variance in one predictor explained by all the other predictors in the model. As explained by Zuur, Ieno & Elphick (2016), VIFs can be used to identify and discard the collinear predictors by sequentially drop the covariate with the highest VIF, recalculate the VIFs and repeat this process until all VIFs are smaller than a preselected threshold. In this case any variable with VIF > 10 was excluded (Table 2). In both cases, the selected set variables were very similar and the final set was defined according with the biological importance of the variables.

**Figure 2.** Correlogram of the 19 bioclimatic variables, plus elevation. Numbers and colors refer to the Pearson’s correlation coefficient for each pair of variables.
Table 2. Selected environmental variables (Worldclim version 1.4) and their corresponding VIF values.

| Code   | Variables                                                                 | VIF   |
|--------|---------------------------------------------------------------------------|-------|
| Bio02  | Mean Diurnal Range (Mean of monthly (max temp - min temp))                | 2.389 |
| Bio04  | Temperature Seasonality (standard deviation *100)                         | 5.125 |
| Bio08  | Mean Temperature of Wettest Quarter                                       | 4.010 |
| Bio09  | Mean Temperature of Driest Quarter                                        | 7.830 |
| Bio13  | Precipitation of Wettest Month                                           | 5.546 |
| Bio14  | Precipitation of Driest Month                                            | 3.993 |
| Bio15  | Precipitation Seasonality (Coefficient of Variation)                     | 2.696 |
| Bio18  | Precipitation of Warmest Quarter                                         | 3.350 |
| Bio19  | Precipitation of Coldest Quarter                                         | 3.895 |
| BioAlt | Elevation                                                                | 5.766 |

Ecological niche models

Figure 3. Complete ecological niche models for seven species of leaf-cutting ants generated with MaxEnt. Values of the color scale represent the probability of occurrence of the species: none (<0.2) low (0.2-0.4), medium (0.4-0.6), high (>0.6).
Ac. ambiguus

Ac. crassispinus

Ac. heyeri

Ac. lobicornis

Ac. lundii
**Figure 4.** Receiver operating characteristic curve (ROC), averaged over the replicate runs, in red the average test AUC and in blue the standard deviation, and the Jackknife test of variable importance, both for each species.

**References**

Aiello-Lammens ME, Boria RA, Radosavljevic A, Vilela B, Anderson RP. 2015. spThin: An R package for spatial thinning of species occurrence records for use in ecological niche models. Ecography (Cop.). 38:541–545. doi:10.1111/ecog.01132.

Aldana RC, Chacón de Ulloa P, De HF, Cecilia R. 1999. Megadiversidad de hormigas (Hymenoptera: Formicidae) de la cuenca media del río Calima (Valle, Colombia). Rev. Colomb. Entomol. 25:37–47.

Bustos J. 1994. Contribución al conocimiento de la fauna de hormigas (Hymenoptera: Formicidae) del Occidente del Departamento de Nariño. Boletín del Mus. Entomol. la Univ. del Val. 2:19–30.

Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A. 2005. Very high resolution interpolated climate surfaces for global land areas. Int. J. Climatol. 25:1965–1978. doi:10.1002/joc.1276.

Mason SC, Sgarbi C, Covachina JC, Martin J, Berensztein ND, Margaria C, Ricci M. 2017. *Acromyrmex* Mayr (Hymenoptera: Formicidae: Myrmicinae): patrones de distribución de las especies en la provincia de Buenos Aires, Argentina. Rev. del Mus. Argentino Ciencias Nat. 19:185–199.

Naimi B, Hamm NAS, Groen TA, Skidmore AK, Toxopeus AG. 2014. Where is positional uncertainty a problem for species distribution modelling? Ecography (Cop.). 37:191–203. doi:10.1111/j.1600-0587.2013.00205.x.

Zuur AF, Ieno EN, Elphick CS. 2016. A protocol for conducting and presenting results of regression-type analyses. Methods Ecol. Evol. 7:636–645. doi:10.1111/1464-2805.01592.