

Conference Abstract

Future-Proofing Chocolate: The Environmental Resilience of Cacao Wild Relatives

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Abstract

Cacao (*Theobroma cacao* L.) is a globally important crop, forming the basis of the multi-billion-dollar chocolate industry and supporting livelihoods in tropical regions worldwide (Houston and Wyer 2012). Cacao is highly sensitive to drought stress, a significant threat to plant growth and survival, pod yield, and bean quality (Mensah et al. 2023). Periods of water deficit can cause yield losses up to 50%, likely worsening with climate change-induced increases in drought frequency and intensity (Gateau-Rey et al. 2018).

Theobroma cacao is a member of *Theobromateae*, a tribe in the Malvaceae family with 40 species in three genera known collectively as cacao wild relatives (CWRs). It is likely that some CWRs are adapted to drought and may provide valuable genetic material suitable for “future proofing” chocolate production against climate change (Medina and Laliberte 2017). While there have been low success rates for cross-breeding *Theobroma* species, recent advances in plant molecular biology are making the use of CWRs in crop breeding programs much more viable (Bohra et al. 2022).

This project has two aims:

1. Develop a database of occurrence records of all CWRs and use this to produce Species Distribution Models (SDMs). The SDMs will provide data on the climatic

tolerance of each CWR and indicate which of them are likely sources of drought tolerance genes/traits.

2. Assessing the conservation status of CWRs is crucial in order to protect this natural bank of potentially useful genetic resources. We will predict the CWR range changes under various climate and land-use scenarios to determine their conservation status.

Distribution data have been collated from taxonomic treatments (Cuatrecasas 1964, Schultes 1958, Colli-Silva in prep.), large and globally important herbaria (e.g., Herbaria Nacional Colombiano ([COL](#)), The New York Botanical Garden ([NY](#))) and Latin American herbaria (e.g., Instituto Nacional de Pesquisas Amazonia ([INPA](#)), Pontificia Universidad Católica del Ecuador ([QCA](#)), abbreviations follow Thiers (2001)).

Specimens will be taxonomically verified with reference to the taxonomic literature, georeferenced to within 5 km (Hackeloeer et al. 2014) and cleaned through automatic (Zizka et al. 2019) and manual plotting in geographic space to check for outliers. Spatial biases will be minimized using spatial filtering (Kramer-Schadt et al. 2013).

We will use three SDM methodologies, all fit with data from freely available global datasets (Karger et al. 2017):

- [MaxEnt](#), the most commonly used SDM methodology;
- one of the recently developed trait-based SDMs designed to incorporate prior knowledge about trade-offs and plasticity in functional traits, minimising the risk of model over-prediction (Benito Garzón et al. 2019);
- a novel, modified SDM methodology that accounts for CO₂ fertilisation in future predictions (Prentice et al. 2022).

These SDMs will estimate Predicted Niche Occupancy profiles (Heibl and Calenge 2018) that will

- characterise drought resistance of CWRs,
- test for associations with species' genes/traits.

To assess the conservation status of these CWRs, SDMs will be projected into future climate and emission scenarios, represented by the [Intergovernmental Panel on Climate Change's Shared Socioeconomic Pathways](#), mediated by models of future land-use change. Species will be characterised by the overall change in their projected range sizes and the loss of their current range sizes. The results will be used to assess the conservation status of CWRs under International Union for Conservation of Nature criteria (IUCN 2012).

Keywords

species distributions, crop wild relatives, global change, drought tolerance, genetic resources, climate projections

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Conflicts of interest

The authors have declared that no competing interests exist.

References

- Benito Garzón M, Robson TM, Hampe A (2019) Δ TraitSDMs: species distribution models that account for local adaptation and phenotypic plasticity. *New Phytologist* 222 (4): 1757–1765. <https://doi.org/10.1111/nph.15716>
- Bohra A, Kilian B, Sivasankar S, et al. (2022) Reap the crop wild relatives for breeding future crops. *Trends in Biotechnology* 40 (4): 412–431. <https://doi.org/10.1016/j.tibtech.2021.08.009>
- Colli-Silva M, et al. (in prep.) A Taxonomic Revision of *Theobroma*.
- Cuatrecasas J (1964) Cacao and its allies: A taxonomic revision of the genus *Theobroma*. 35. Contributions from the United States National Herbarium, 379–614. pp. URL: <http://hdl.handle.net/10088/27110>
- Gateau-Rey L, Tanner EJ, Rapidel B, et al. (2018) Climate change could threaten cocoa production: Effects of 2015–16 El Niño-related drought on cocoa agroforests in Bahia, Brazil. *PLOS ONE* 13 (7). <https://doi.org/10.1371/journal.pone.0200454>
- Hackeloeer A, Klasing K, Krisp J, et al. (2014) Georeferencing: a review of methods and applications. *Annals of GIS* 20 (1): 61–69. <https://doi.org/10.1080/19475683.2013.868826>
- Heibl C, Calenge C (2018) Package 'phyloclim'. Integrating Phylogenetics and Climatic Niche Modeling. R Version 0.9.5. CRAN. Release date: 2018–5–25. URL: <http://download.nust.na/pub3/cran/web/packages/phyloclim/phyloclim.pdf>
- Houston H, Wyer T (2012) Why sustainable cocoa farming matters for rural development. Center for Strategic & International Studies. URL: <https://www.csis.org/analysis/why-sustainable-cocoa-farming-matters-rural-development>
- IUCN (2012) IUCN Red List Categories and Criteria: Version 3.1. Second edition. Gland, Switzerland and Cambridge, UK: IUCN. iv + 32pp. International Union for Conservation of

Nature URL: <https://portals.iucn.org/library/sites/library/files/documents/RL-2001-001-2nd.pdf> [ISBN 978-2-8317-1435-6]

- Karger DN, Conrad O, Böhner J, et al. (2017) Climatologies at high resolution for the earth's land surface areas. *Scientific Data* 4 (1). <https://doi.org/10.1038/sdata.2017.122>
- Kramer-Schadt S, Niedballa J, Wilting A, et al. (2013) The importance of correcting for sampling bias in MaxEnt species distribution models. *Diversity and Distributions* 19 (11): 1366-1379. <https://doi.org/10.1111/ddi.12096>
- Medina V, Laliberte B (2017) A review of research on the effects of drought and temperature stress and increased CO₂ on *Theobroma cacao* L., and the role of genetic diversity to address climate change. *Bioversity International*.. URL: <https://hdl.handle.net/10568/89084>
- Mensah EO, Ræbild A, Asare R, et al. (2023) Combined effects of shade and drought on physiology, growth, and yield of mature cocoa trees. *Science of The Total Environment* 899 <https://doi.org/10.1016/j.scitotenv.2023.165657>
- Prentice IC, Villegas-Díaz R, Harrison S (2022) Accounting for atmospheric carbon dioxide variations in pollen-based reconstruction of past hydroclimates. *Global and Planetary Change* 211 <https://doi.org/10.1016/j.gloplacha.2022.103790>
- Schultes RE (1958) A synopsis of the genus *Herrania*. 34. *Journal of the Arnold Arboretum*, 217–278. pp. URL: <https://doi.org/10.5962/bhl.part.19112>
- Thiers BM (2001) *Index Herbariorum*. <https://sweetgum.nybg.org/science/ih/>. Accessed on: 2025-10-02.
- Zizka A, Silvestro D, Andermann T, et al. (2019) CoordinateCleaner: Standardized cleaning of occurrence records from biological collection databases. *Methods in Ecology and Evolution* 10 (5): 744-751. <https://doi.org/10.1111/2041-210x.13152>