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"Towards multi-functional agro-ecosystems
promoting climate resilient futures"

# Predicting climate-resilient habitats for *Vicia faba* L.: A data-driven approach to enhance multifunctional agroecosystems

Samaneh Samaei-Daryan[1,2], Martin Wiehle[2], Behnam Kamkar[1]

[1] *Ferdowsi University of Mashhad, Dept. of Agrotechnology, Iran*

[2] *University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics (OPATS), Germany*

**Abstract**

Faba bean (*Vicia faba* L., Fabaceae) plays a multifunctional role in sustainable agroecosystems, providing high-quality dietary protein while enhancing soil fertility through symbiotic nitrogen fixation with *Rhizobium* spp. *Vicia faba*, domesticated around 10,000 years ago, has a distribution driven by climate and human activities. Under climate change, its capacity to improve soil health, reduce dependence on synthetic fertilisers, and support crop diversification makes it a key component of climate-resilient agriculture.

Species distribution models (SDMs) offer a robust framework for assessing habitat suitability and predicting future spatial distribution patterns. Although traditionally applied to wild species, SDMs are increasingly recognised as a data-driven approach for sustainable crop production and conservation planning. However, applying SDMs to cultivated crops introduces specific challenges, including managing heterogeneous occurrence data, adapting niche assumptions to human-mediated distributions, and accounting for non-climatic drivers such as agricultural management. Despite growing availability of modelling tools, integrated methodological guidance remains limited. This study examines these challenges using *Vicia faba* as a case study, delineating its current and projected suitable habitats under climate change scenarios and identifying the key environmental drivers governing its global distribution.

Occurrence records (n = 105,390) were downloaded from GBIF (www.gbif.org) following taxonomic backbone verification via *rgbif* (name_backbone; taxonKey 2974832). Records were screened for taxonomic errors and filtered to retain only records relevant to the study objectives. A systematic coordinate quality pipeline using *CoordinateCleaner* addressed missing coordinates, spatial biases, coordinate errors, geographic outliers (quantile method), and sampling biases. Coordinate uncertainty and temporal ( 1970) filters retained 36,939 high-quality records (35 %). Nineteen WorldClim 2.1 bioclimatic variables (30 arcseconds; ~1 km) were stacked using terra, with CRS compatibility verified before environmental extraction. Collinearity was reduced (Pearson r $>$ 0.8; *caret*) and environmental outliers identified via Mahalanobis distance (97.5$^{\text{th}}$ percentile) and *flexsdm*. Subsequent steps include model tuning using machine learning algorithms (e.g., Maxent), future projections, and transferability assessment, are currently in progress.

The reproducible framework addresses key methodological challenges of applying SDMs to cultivated crops, offering a transferable foundation for land suitability assessment. Suitability maps and variable importance analyses will inform agricultural planning and *in-* and *ex situ* conservation strategies for *Vicia faba*.

**Contact Address:** Samaneh Samaei-Daryan, Ferdowsi University of Mashhad, Dept. of Agrotechnology current address: University of Kassel, 37213 Witzenhausen, Germany, e-mail: uk112631@guest.uni-kassel.de

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