Ecological niche model and global potential distribution of *Apis mellifera*

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Introduction

Apis mellifera, the European honeybee, plays a crucial role in pollination services, supporting biodiversity and global food security. It is responsible for pollinating crops that feed the world (Roessink et al., 2007). Simultaneously, *A. mellifera* poses ecological risks as an invasive species, potentially outcompeting native pollinators and altering local ecosystems. Besides, threats like climate change, habitat loss, and diseases underscore the urgent need to understand its ecological niche and potential distribution.

Ecological niche modeling provides insights into critical conservation areas and evaluates the species' vulnerability to environmental and anthropogenic factors. This approach also helps predict the impacts of climate change and land-use modifications on *A. mellifera* populations.

Methodology

Data: Occurrence data for *A. mellifera* were sourced from Dorey et al. (2023). The data were cleaned to remove spatial autocorrelation and ensure geographic and environmental consistency. A total of 31 variables were analyzed, with correlation analysis used to eliminate multicollinearity. We followed best practices for modeling niches and species distributions: geographical and environmental records were checked for consistency and filtered to reduce spatial autocorrelation. Ellipsoidal Ecological Niche Models were built using the R package NicheToolbox. Variable selection was based on AUC and omission rates. Suitability was calculated using Mahalanobis distance. Spatial resolution used was 1 km. Continuous and binary global suitability maps were generated using the optimal variables.

Table 1. Best performance model

Fitted_variables for ENM	# of variables	Omission on train	Omission on test	Background prevalence	Binomial significance test	Partial ROC test	pAUC ratio	AUC
Annual Mean Temperature, Climate Moisture Index, Soil cfvo	3	0.06	0.06	0.75	p<0.05	p<0.05	1.28	0.87

Results

Continuous Suitability: Temperate regions showed the highest suitability, particularly in Europe, North America, and parts of Asia (Figure 1).
Binary Suitability: Suitable areas for *A. mellifera* overlap with major agricultural regions and biodiversity bees hotspots (Figure 2).
Key Drivers: Annual mean temperature and precipitation were the most influential variables.

Figure 1. Suitability habitat of *A. mellifera* ranging from 0 to 1, where 1 indicate the hingh suitability.

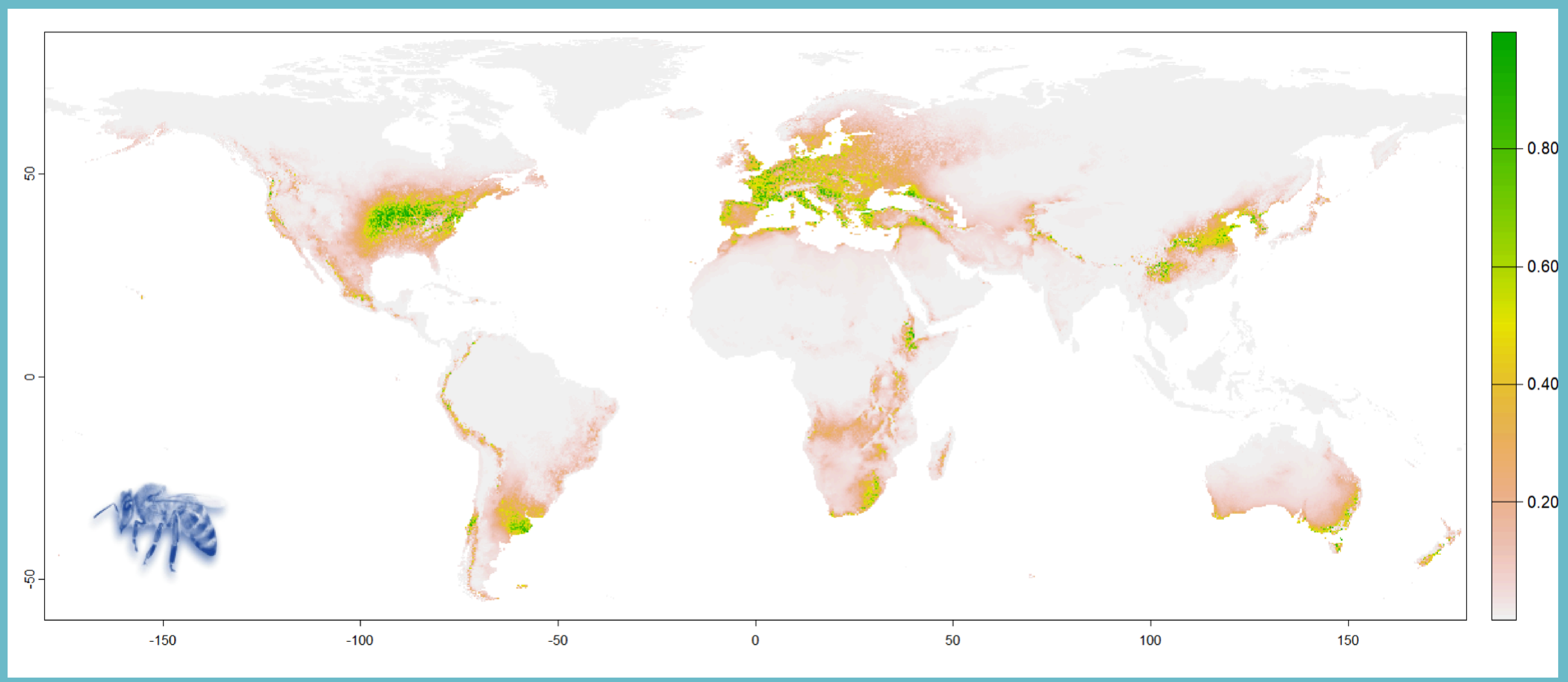
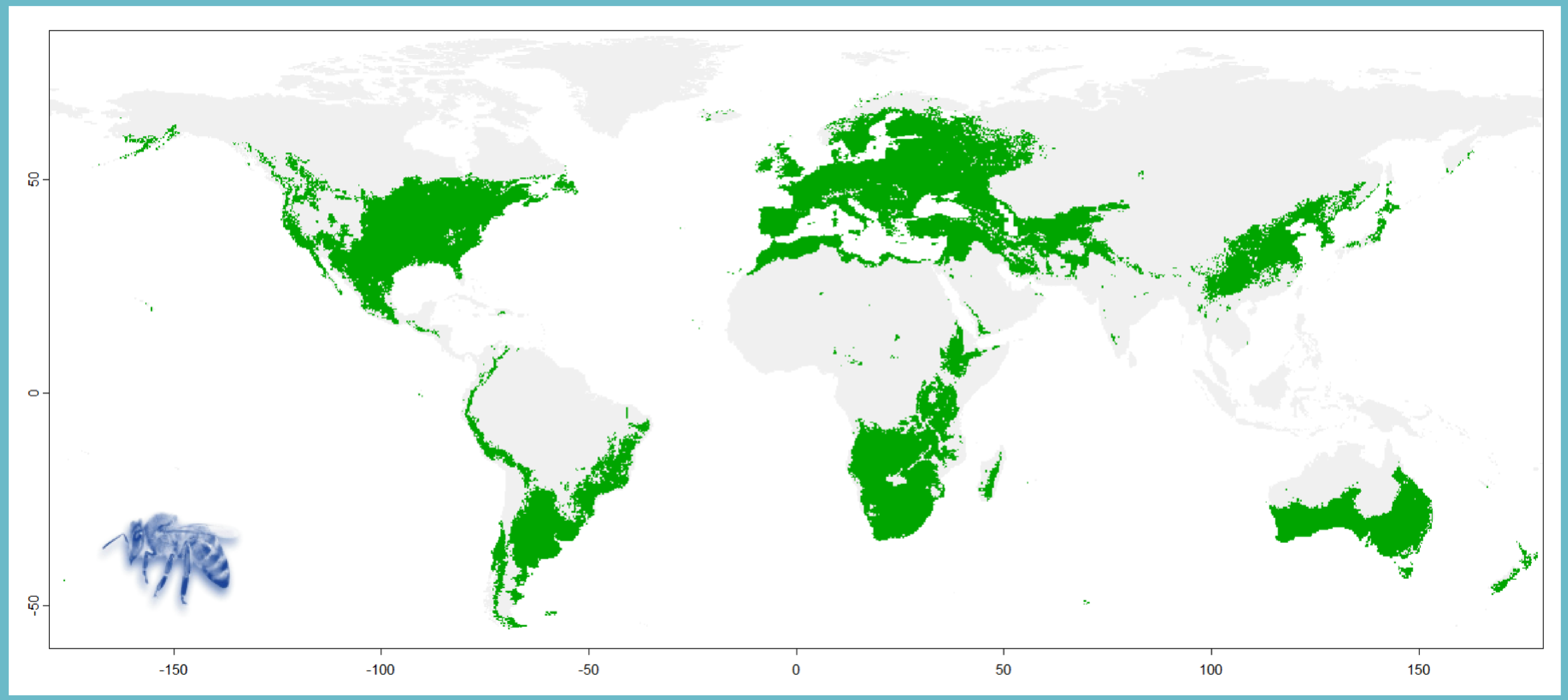


Figure 2. The presence-absence projection of the *A. mellifera* niche model in green indicates the potential distribution sites.



Discussion and conclusions

Ecological niche modeling is a powerful tool for predicting the distribution of *A. mellifera*. This study wants to highlight the importance of integrating ecological models into global conservation strategies. The generated maps provide information about potential distribution of *A. mellifera*, which provides ecosystem services but, as well, acts as an invasive species competing with native pollinators in some ecosystems. Suitable habitats were found to overlap with biodiversity bees hotspots, underscoring its ecological importance but also raising concerns about its invasive potential in these areas. The next steps are to model future climate scenarios and incorporate anthropogenic factors, such as urbanization. For example, global warming could push habitats to higher latitudes, while agricultural intensification may further shrink suitable areas.

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