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Climate Change Will Cause a Pollination Crisis in the Mediterranean Basin

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Abstract: In the study, habitat suitability simulations of *Apis mellifera* species, which have great service in pollinating many natural and cultural plants, were made according to climate change scenarios that may occur in the Mediterranean Basin. The most striking result among the results obtained is that, for the pessimistic scenario, it shows that the Mediterranean Basin will face drought at the end of the century and *A.mellifera*, a pollinator insect species, will move away from the seacoast and seek suitable climatic conditions inland due to this drought. If this scenario is realized, it is predicted that coastal areas will be affected by the pollination crisis in Mediterranean countries.

Keywords: Pollination crisis, Climate change, Apis, Mediterranean Basin.

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1. INTRODUCTION

Today, more than 400,000 natural and agricultural plant species are known to be pollinated by pollinator insect species. Honey-bee colonies may include up to 80,000 individuals, making them one of the largest and most essential pollinator populations (Grünewald, 2010). It has been revealed as a result of experimental research that *Apis mellifera* is the most effective type of pollinator species (Abdulnabi, 2019). In addition, it has been determined that *Apis mellifera* plays an active role in the pollination of more than 300 plant species from 71 different families (Sıralı and Deveci, 2002).

It is possible that bee populations will decline as a result of global warming. Given the close evolutionary ties between insect-pollinated flowers and their pollinators, it stands to reason that a drop in local bee species could disrupt plant-pollinator networks, potentially setting off extinction cascades (Grünewald, 2010). For example, it is known that the Paspalum genus, which is the most important forage plant of the Mediterranean Basin, that is, the Mediterranean climate zone, is pollinated by *Apis mellifera*. The deterioration of this mutual relationship between the two due to climate change will cause a decrease in the grass plant, which is important for the pasture plant, or, in other words, a decrease in the quality of forage pastures (Cho and Lee, 2015).

The aim of this study is to first determine the climatic conditions that *Apis mellifera* has adapted to from the recent past to the present in the Mediterranean Basin, and then to determine where the climatic conditions adapted in the climate change scenarios will survive on the map.

Finally, we will discuss how climate change can affect bee populations in the Mediterranean Basin and change the natural synchronization between pollinator and plant life cycles.

2. MATERIAL AND METHOD

2.1. Species Data

In order to obtain the species data of our target species, *A.mellifera*, the Wallace platform was opened by installing the relevant packages in Rstudio (Kass et al., 2018; 2022). On the Wallace platform, 581 records of *A.mellifera* species were obtained to cover the Mediterranean Basin.

2.2. Bioclimate Data

Historical climate data (1970–2100) and SSPs climate change scenarios data were downloaded from the www.worldclim.org data facility. The downloaded data is at 10 arc minutes of resolution. The 2081-2100 period of the SSPs 126, SSPs 245, SSPs 370, and SSPs 585 climate scenarios was downloaded from the CanESM5 climate model and made ready for analysis.

2.3. Pre-Statistics and Modeling

To get over the issue of multicollinearity amongst bioclimatic data, Principal Component Analysis has been used. Thus, 5 out of 19 bioclimatic data participated in the modeling phase (Table 1 and 2). These are Bio9 (Mean Temperature of Driest Quarter), Bio10 (Mean Temperature of Warmest Quarter), Bio11 (Mean Temperature of Coldest Quarter), Bio14 (Precipitation of Driest Month) and Bio19 (Precipitation of Coldest Quarter).

Table 1. Total Variance Explained

Component	Initial Eigenvalues			Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6,513	34,279	34,279	6,513	34,279	34,279
2	4,735	24,922	59,201	4,735	24,922	59,201
3	3,431	18,060	77,261	3,431	18,060	77,261
4	1,473	7,751	85,012	1,473	7,751	85,012
5	1,231	6,481	91,493	1,231	6,481	91,493
6	0,910	4,789	96,282			
7	0,304	1,599	97,881			
8	0,145	0,761	98,642			
9	0,098	0,518	99,160			
10	0,066	0,347	99,507			
11	0,048	0,254	99,761			
12	0,014	0,076	99,837			
13	0,014	0,073	99,909			
14	0,007	0,037	99,946			
15	0,005	0,028	99,974			
16	0,004	0,019	99,994			
17	0,001	0,006	99,999			
18	0,000	0,001	100,000			
19	2,529E-11	1,331E-10	100,000			

Extraction Method: Principal Component Analysis.

Table 2. Component Matrix

	Component				
	1	2	3	4	5
Bio1	0,756	0,543	0,288	0,171	-0,104
Bio10	0,380	0,583	0,680	0,192	0,016
Bio11	0,869	0,409	-0,124	0,159	-0,166
Bio12	0,744	-0,564	0,218	-0,087	0,210
Bio13	0,833	-0,219	0,070	-0,332	0,360
Bio14	0,208	-0,771	0,438	0,231	-0,144
Bio15	0,187	0,679	-0,426	-0,294	0,363
Bio16	0,827	-0,241	0,054	-0,329	0,366
Bio17	0,244	-0,770	0,441	0,237	-0,127
Bio18	0,716	-0,319	0,351	-0,417	-0,043
Bio19	0,123	-0,494	-0,131	0,485	0,613
Bio2	-0,314	0,632	0,125	-0,268	0,108
Bio3	0,466	0,198	-0,636	-0,107	-0,167
Bio4	-0,611	0,079	0,074	-0,004	0,200
Bio5	0,161	0,716	0,643	0,130	0,103
Bio6	0,885	0,238	-0,194	0,281	-0,145
Bio7	-0,626	0,331	0,640	-0,141	0,199
Bio8	0,642	0,218	0,505	-0,222	-0,346
Bio9	0,377	0,586	-0,145	0,550	0,263

Extraction Method: Principal Component Analysis.
a. 5 components extracted.

The climatic envelope model was developed using MaxEnt 3.4.1 (Phillips et al., 2017). MaxEnt software predicts, based on the presence data of organisms, which environmental conditions affect the distribution of organisms. Based on the model's AUC, it is rated as ">0.90: excellent, 0.90-0.80: good, 0.80-0.70: suitable, 0.70-0.60: poor, not informative." (Baldwin, 2009; Phillips vd., 2006). During the modeling process, 581 *A.mellifera* data were sliced as 75% training data and 25% test data. Each model was performed with 10 replications.

3. RESULTS

As a model output, receiver operating characteristic (ROC) curves showing the AUC value of the model, a Jackknife analysis graph showing the contribution of bioclimatic data to the model, and maps were obtained.

The training data AUC value of the obtained model is 0.938, and the test data AUC value is 0.937 (Figure 1).

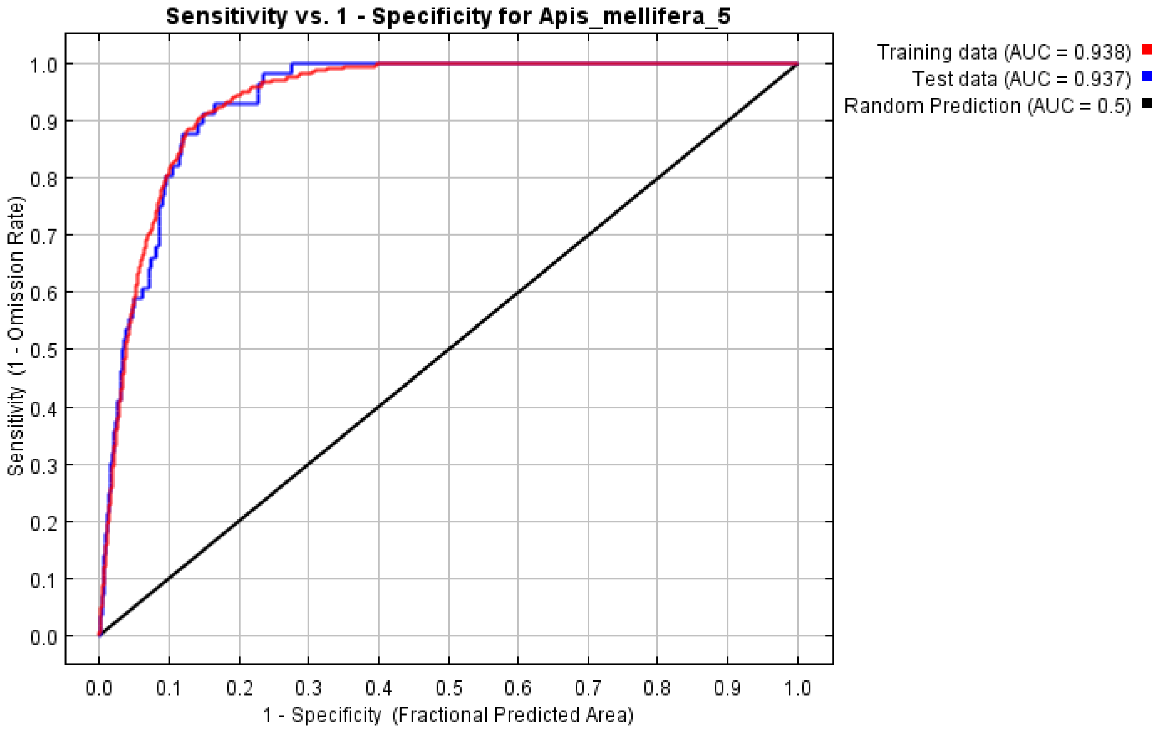

Figure 1. The receiver operating characteristic (ROC) curves for *Apis mellifera*

Inspecting the Jackknife analysis graph, we notice that Bio11 and Bio19 play a significant role in the dissemination of *A.mellifera* (Figure 2).

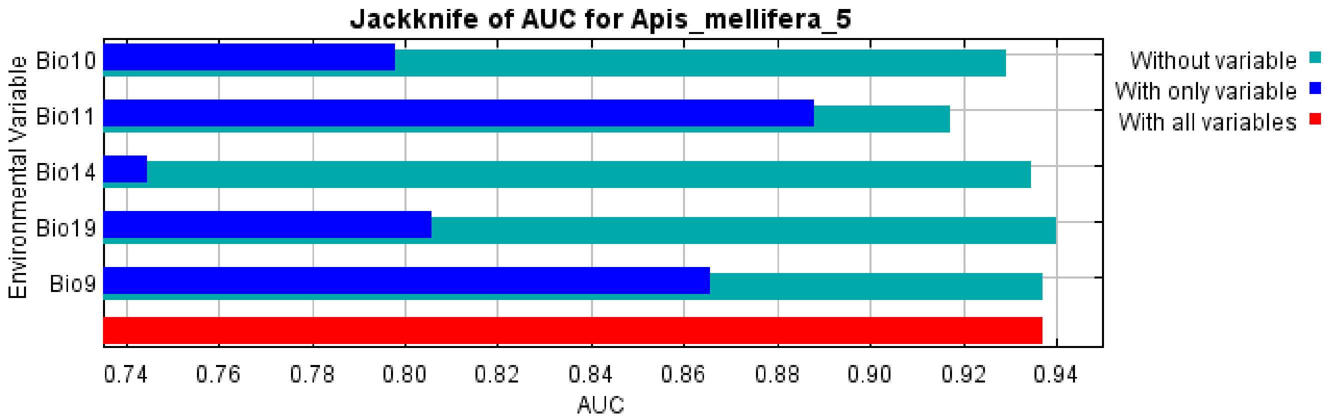

Figure 2. Results of the Jackknife test for evaluating the relative importance of environmental variables for *Apis mellifera*

When the maps from the model outputs are examined, the areas with suitable climatic conditions for *A. mellifera* in the coastal areas along the Mediterranean basin are shown in red (Figure 3.A). At the end of the century, it is seen that suitable climatic conditions have shifted from the optimistic scenario to the pessimistic scenario towards the interior (Fig. 3. B-E).

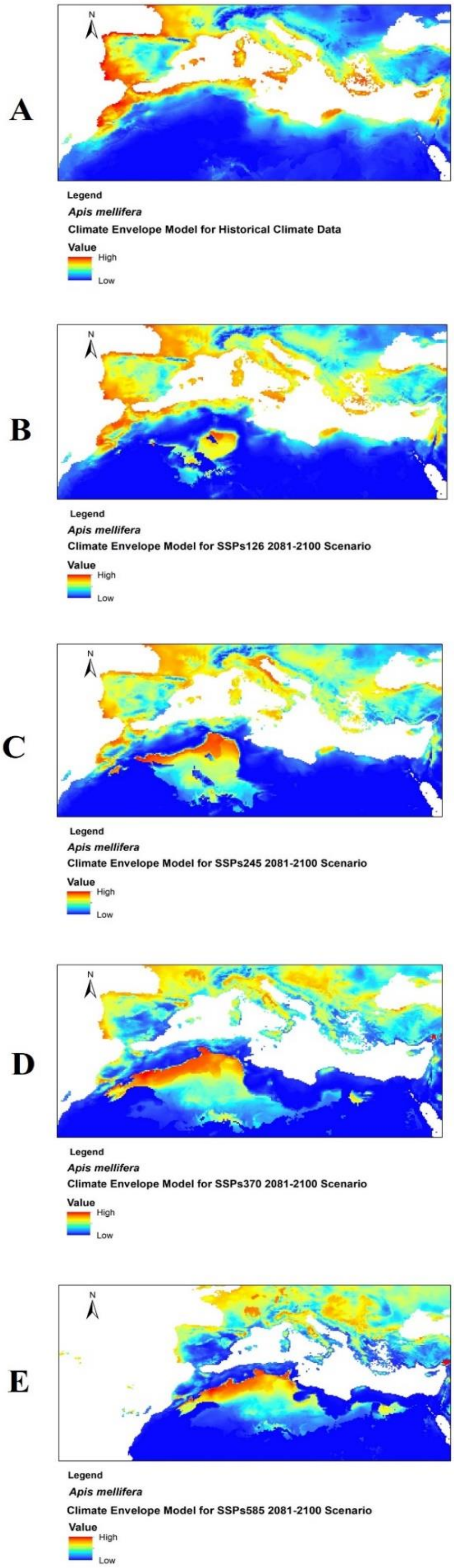

Figure 3. A: Climate envelope model for historical climate data. B. SSPs 126 2081-2100 scenario. C: SSPs 245 2081-2100 scenario. D: SSPs 370 2081-2100 scenario. E: SSPs 585 2081-2100 scenario

4. DISCUSSION AND CONCLUSIONS

A. meliifera is a species complex distributed all over the world. Most populations are adapted to many different habitats and climates. Therefore, climate change probably will not cause the extinction of honeybees. The life cycle of *A.mellifera* might be disrupted as a result of climate change. Because of the changing seasons, bee colonies in temperate areas of the world are unable to forage for food during extended periods of cold weather. In these places, the breeding season occurs only during the spring and summer months. If climate change causes winters to be warmer and springtime to arrive sooner, then there is a possibility that nutrition during the critical period of brood initiation will not be at its ideal level. However, honey bees, which are ectothermic creatures, may need special climatic conditions to keep their body temperatures within a certain range, and therefore changes such as extreme heat, drought, and decreased precipitation can be very harmful to *A. mellifera* species that experience habitat loss. Therefore, as a result of climate change, bees will most likely quit locations that have become too dry and will move towards regions that have a higher relative humidity. It is possible for them to colonize chilly locations that have seen warming and become more suitable for bees. There is a good chance that the distribution of different flower species will shift as a result of climate change (Grünewald, 2010; Kluser et al., 2010; Le Conte and Navajas, 2008). Migration towards suitable climatic conditions, displacing inland, seems to be the most logical option, as is the case highlighted in our results.

In a study conducted with Paspalum plants, known as watergrass, it was reported that these plants, which are distributed in the coastal areas of the Mediterranean Basin, will shift their distribution towards the interior in the future in the face of climate change (Cho and Lee, 2015). These results coincide with our study, considering the fact that *A.mellifera* plays a role in the pollination of Paspalum plants.

The literature and results show that, on the basis of species ecology, climate change seems to overcome the threat of extinction by changing species' distributions to more favorable conditions. However, drought along the Mediterranean coast, which we will call the old habitat before climate change, will bring a pollination crisis with it. The pollination crisis will lead to a decrease in rangelands, agriculture, and natural plant species, and thus a decrease in biodiversity. So, at least the steps that need to be taken to make the most optimistic climate change scenario happen will make sure that biological diversity will still be around at the end of the century.

Ethics Committee Approval
N/A

Peer-review
Externally peer-reviewed.

Author Contributions
Conceptualization: A.K., S.B.; Investigation: A.K., S.B.; Material and Methodology: A.K.; Supervision: A.K., S.B.; Visualization: A.K; Writing-Original Draft: A.K., S.B.; Writing-review & Editing: A.K., S.B.; Other: All authors have read and agreed to the published version of manuscript.

Conflict of Interest
The authors have no conflicts of interest to declare.

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