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Menba Kastamonu Üniversitesi Su Ürünleri Fakültesi Dergisi 2024; 10 (2): 93-104 Araştırma Makalesi/Research Article

İklim Değişikliği Ev Serçesinin (*Passer domesticus*) Potansiyel Dağılımını Değiştirmekte midir?

Özkan EVCİN[1*]

[1] Kastamonu University, Faculty of Forestry, Forest Engineering Department, Kastamonu/Türkiye

[*]**E-mail:** oevcin@kastamonu.edu.tr

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- Maxent
- Ekolojik modelleme
- Ornitoloji

Öz

İklimsel etkilerin ve parçalanmanın habitatlar üzerindeki etkilerini belirlemek önem arz etmektedir. Küresel iklim değişikliği, habitatlarda ve türlerin dağılımında değişikliklere yol açabilen ve yaban hayatı türleri için tehdit oluşturan bir unsurdur. Türlerin ve yaşadıkları habitatların doğru dağılımını tahmin etmek, türlerin iklim değişikliği altında sürdürülebilirliği ve yönetimi için esastır. Ev serçesi (*Passer domesticus*), Passeridae familyasına ait yaygın bir kuş türüdür. Bu tür, Dünya çapında geniş bir alana yayılmış olup varlığının çoğu dönemi boyunca insanlarla yakın ilişki içinde olmuştur. Bu çalışmada, Türkiye için gelecekteki iklim senaryoları (2021-2040, 2041-2060 ve 2061-2080) altında Ev Serçesi türünün (*Passer domesticus*) için potansiyel uygun habitatları tahmin etmek için Maksimum Entropi (Maxent) modeli kullanılmıştır.

Does Climate Change Affect the Potential Distribution of House Sparrows (*Passer domesticus*)?

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Abstract

Determining the results of climatic effects and fragmentation on habitats is very important. Global climate change is a threat to wildlife species, which can lead to changes in habitats and the distribution of species. Estimating the correct distribution of species and their habitats is essential for the sustainability and management of species under climate change. House Sparrow (*Passer domesticus*) is a common bird species in the Passeridae family. This species has a wide range around the World and has been closely associated with humans for most of its existence. In this study, we used the Maximum entropy (Maxent) model to predict the potential suitable habitats for House Sparrow (*Passer domesticus*) under future climatic scenarios (2021-2040, 2041-2060 and 2061-2080) for Türkiye.

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INTRODUCTION

The increasing global population and the concentration of production and consumption in cities have led to significant anthropogenic changes and climate change, impacting ecosystems and biodiversity. It highlighted the impact of anthropogenic climate change on terrestrial organisms, emphasizing the potential increase in impact with latitude (Deutsch et al., 2008). Furthermore, it pointed out the substantial suffering of coastal ecosystems due to worldwide population growth and increasing land demands (Steibl, 2020).

The vulnerability of almost 50% of the world's biodiversity to extinction due to these impacts is also supported by various references and discussed the high extinction risk in large mammal species, attributing it to impacts of internal and environmental factors (Cardillo et al., 2005). Additionally, it demonstrated the correlation between surface indicators and soil multifunctionality in global drylands, indicating the sensitivity of ecosystems to environmental changes (Eldridge et al., 2020). Moreover, it highlighted the concentration of recent bird and mammal extinctions in certain genera and families, emphasizing the selective nature of extinction vulnerability (McKinney, 1997).

In light of the predicted effects of climate change, the need to monitor ecological changes gains importance. Various wildlife species have long been used as indicators to assess and monitor ecological changes. The most commonly used indicators for ecological monitoring are birds, sensitive to even minor environmental changes and are therefore useful models for studying various ecological issues (Gregory et al., 2003).

Numerous wildlife species live in various cities across the world due to their access to an abundance of resources for basic needs, including food, water, shelter, and nesting (Baldock et al., 2015; Goertzen and Suhling, 2015; Kowarik and von der Lippe, 2018; Asik & Kara, 2021). Birds are significant among these animal species since they are widespread and simple to see. Cities are considered ecosystems that can support various bird groups (Shochat et al., 2010;). 20% of bird species on earth reside in urban areas (Aronson et al., 2014). The sparrow is one of the bird species that has adapted to city life worldwide.

The Passeridae family, a unique group of Old-World sparrows, is a distinct passerine family with a widespread distribution across the Afrotropics, Palearctic, and certain areas of the Oriental Region. Notably, the Australian Region and Madagascar are the only regions where members of the Passeridae family are not naturally found, except for the house sparrow introduced by humans. Currently, 43 officially recognized species within the Passeridae family are classified into eight genera (Gill et al., 2020; Schrey et al., 2021).

Passer stands out as the most diverse genus, comprising 28 recognized species (del Hoyo & Collar, 2016; Gill et al., 2020). Among these species, the House sparrow (*Passer domesticus*) is notably one of the most extensively studied (Anderson, 2006; Liebl et al., 2015). This heightened attention is largely attributed to its widespread presence across its range as a commensal of human civilization (Saetre et al., 2012).

The House sparrow (*Passer domesticus*) is widely recognized as one of the most closely associated bird species with humans across various regions of the world (Schrey et al., 2011; Albayrak & Pekgöz, 2021). This species exhibits a strong affinity for human environments, being commonly found in densely populated urban areas as well as in small, isolated agricultural settings while being notably absent in uninhabited regions (Schrey et al., 2011). The house sparrow has demonstrated remarkable success in adapting to urban landscapes, rendering it one of the most prevalent avian species globally (Anderson, 2006; Cramps and Perrins, 1994; Schrey et al., 2011; Swaileh and Sansur, 2006). Its distribution spans nearly all continents, either as a native species or through introduction (Schrey et al., 2011). Due to its extensive global presence, the house sparrow is considered an ideal bioindicator species (Albayrak and Mor, 2011; Bichet et al., 2013; Gushit et al., 2016).

Furthermore, the morphometric characteristics of body mass, tarsus length, and wing length serve as key indicators for understanding the health status of house sparrows (Dauwe et al., 2006; Albayrak & Pekgöz, 2021). These measurements provide valuable insights into the physiological condition and overall well-being of the species, contributing to a comprehensive understanding of their ecological dynamics and interactions within human-influenced environments.

The impact of climate change on birds, including those within the Passeridae family, is of significant concern due to their potential impact on species distributions, phenology, and population dynamics. Climate change has been associated with changes in the timing of migration and nesting, as well as alterations in species richness and composition within bird communities. These changes may lead to shifts in the ranges of bird species, affecting their habitat suitability and availability of resources. Furthermore, climate change can influence the interactions between birds and their environment, potentially leading to changes in species interactions and ecosystem functioning. The Passeridae family, being a distinct passerine family with a widespread distribution, may experience alterations in their geographic ranges and population dynamics as a result of climate change. Additionally, the sensitivity of birds to even minor environmental changes makes them valuable models for studying the ecological impacts of climate change. Therefore, understanding the effects of climate change on birds, including those within the Passeridae family, is crucial for predicting and mitigating potential ecological disruptions.

The impacts of climate change on avian populations have been extensively researched, with numerous studies highlighting the effects of climate change on bird communities and ecosystems. Climate change has been shown to influence vital rates and population abundance of birds, affecting their life history traits and overall population size and composition Jenouvrier (2013). Additionally, climate impacts on plant-animal interactions have been found to have far-reaching effects on plants, birds, and ecological interactions, emphasizing the interconnectedness of species within ecosystems (Martin & Maron, 2012). Studies have also utilized various approaches to assess the potential effects of climate change on bird populations, highlighting the need to understand the ecological and evolutionary changes in response to climate change (Rodenhouse et al., 2007; Lemoine et al., 2006). Furthermore, the impact of climate change on bird migration patterns, community dynamics, and ecosystem functions has been a focus of research, shedding light on the complex and multifaceted effects of climate change on avian populations (Iknayan & Beissinger, 2020; Segan et al., 2015; Pautasso, 2012). The influence of climate change on bird species distributions, habitat availability, and community responses has been a key area of investigation, emphasizing the need to understand the consequences of climate change on bird populations and their ecological interactions (Jarzyna et al., 2015; Roberts et al., 2019; Arab et al., 2016). Moreover, the effects of climate change on bird phenology, migratory patterns, and species interactions have been studied, providing insights into the ecological and evolutionary responses of birds to changing climatic conditions (Li et al., 2022; Patterson & Guerin, 2013; Wu & Zhang, 2015). Overall, these studies underscore the importance of understanding the multifaceted impacts of climate change on avian populations and their ecological significance within changing environments.

Identifying the climatic impacts on Habitats of the species and their fragmentation is very essential, as habitat loss is the most important factor threating the survival of species. For effective conservative action and sustainability of species under climate changes, prediction of accurate distribution of species is very important. In this study, the distribution changes of the House sparrow under climate change will be discussed. The sparrow species are vulnerable to climate change due to its short movement range, wide distribution, and physiology. The potential effects of climate changes on the house sparrow species in Türkiye were evaluated using ecology modelling. In this study, the potential distribution patterns of species belonging to the Passer genus throughout Türkiye due to the changing climate were revealed for the first time. The results are expected to be used in local-scale conservation activities.

MATERIAL AND METHOD

The study area encompasses the entirety of Türkiye, located at the crossroads of Europe and Asia, covering approximately 783,356 square kilometers. This region features a wide range of climatic zones and habitats, from coastal areas to high mountains, providing a diverse environment for the study of house sparrow.

A flowchart was given that encapsulates the entire methodological process, from data acquisition and preparation to modeling and result interpretation, ensuring a systematic approach to studying the distribution of *Passer domesticus* in Türkiye (Figure 1).

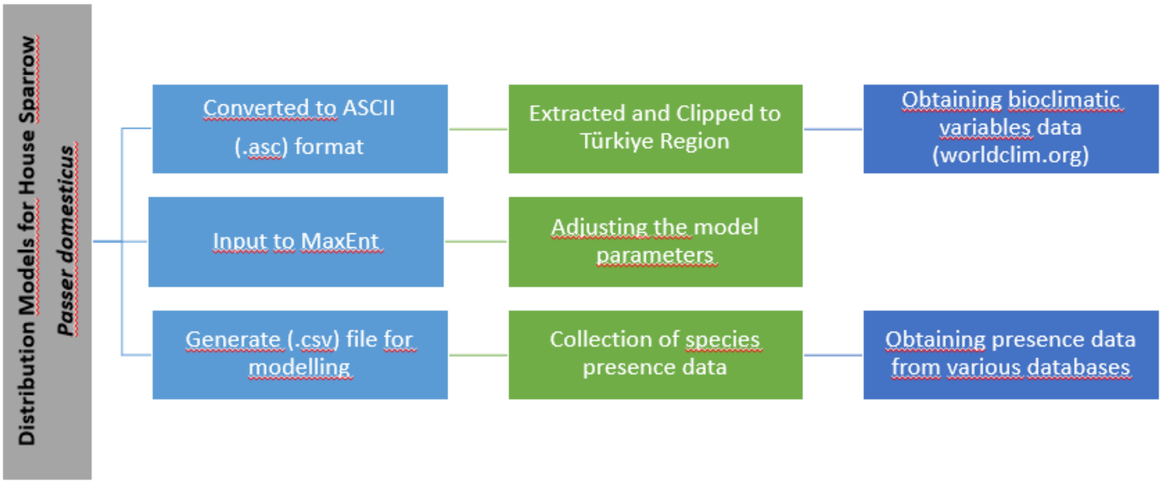


Figure 1: Flowchart of the study

Occurrence data for house sparrows were obtained from the Global Biodiversity Information Facility (GBIF,2024). The dataset includes all available records up to the year 2024. The GBIF occurrence data were filtered to include only georeferenced records with precise locality information within the boundaries of Türkiye. Duplicate records and those with coordinate uncertainties greater than 3 km were excluded to ensure data quality. Thinning were done by R Package spThin to overcome with overfitting problem for model. A total number of 47,206 data were obtained for Türkiye (Figure 2).

Figure 2: Presence data for house sparrow distributed in Türkiye (GBIF, 2024)

Nineteen bioclimatic variables were obtained from the WorldClim database at a 30 arc-second resolution (Fick & Hijmans ,2017). The filtered occurrence data and selected environmental variables were then input into Maxent software for modeling (Table 1). The distribution range of the species projected future climate variables for 2050 (averaged for 2041–2060) and 2070 (averaged for 2061–2080) with semi-optimistic (RCP4.5) and pessimistic (RCP8.5) greenhouse gas emission scenarios were modeled based on the climate change scenario of the Hadley Global Environment Model 2 - Earth System (HadGEM2-ES) (Deng, 2024).

Table 1: Bioclimatic variables used for the modelling

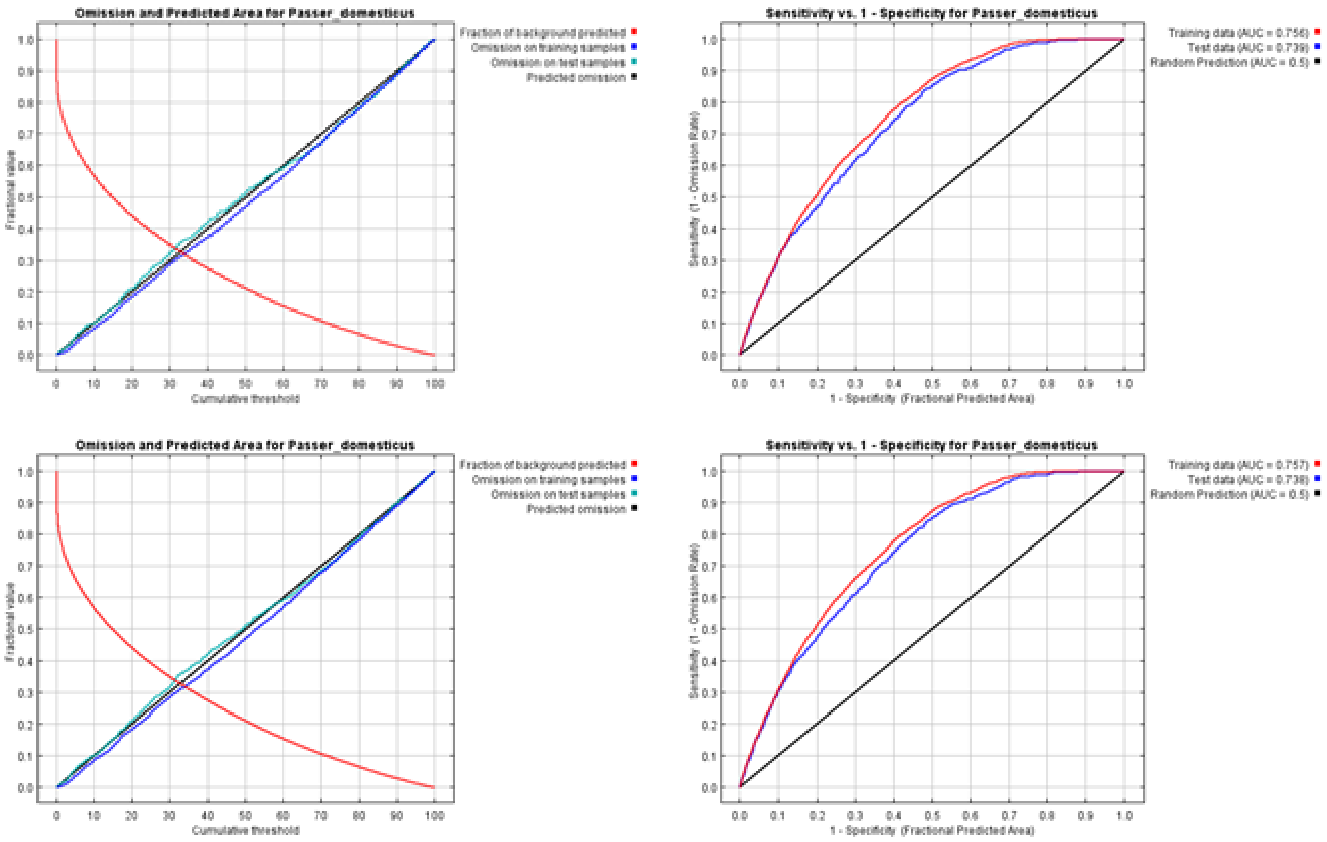
BIO1 = Annual Mean Temperature
BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))
BIO3 = Isothermality (BIO2/BIO7) (×100)
BIO4 = Temperature Seasonality (standard deviation ×100)
BIO5 = Max Temperature of Warmest Month
BIO6 = Min Temperature of Coldest Month
BIO7 = Temperature Annual Range (BIO5-BIO6)
BIO8 = Mean Temperature of Wettest Quarter
BIO9 = Mean Temperature of Driest Quarter
BIO10 = Mean Temperature of Warmest Quarter
BIO11 = Mean Temperature of Coldest Quarter
BIO12 = Annual Precipitation
BIO13 = Precipitation of Wettest Month
BIO14 = Precipitation of Driest Month
BIO15 = Precipitation Seasonality (Coefficient of Variation)
BIO16 = Precipitation of Wettest Quarter
BIO17 = Precipitation of Driest Quarter
BIO18 = Precipitation of Warmest Quarter
BIO19 = Precipitation of Coldest Quarter

MaxEnt is a widely used technique in ecology and conservation biology for species distribution modeling. It leverages presence-only data to predict suitable habitats for species by maximizing entropy while considering constraints from environmental variables. This method has gained popularity due to its ability to handle incomplete data and provide reliable predictions of species distributions across various landscapes. MaxEnt is particularly effective in modeling the potential distribution of species under current and future climatic conditions, making it a valuable tool for assessing the impacts of climate change on biodiversity. Researchers have successfully applied MaxEnt in wildlife studies to explore habitat preferences and distribution patterns of various species, from insects to mammals, aiding in conservation planning by identifying critical habitats and guiding management strategies (Papeş & Gaubert, 2007; Duengen et al., 2022; Smith et al., 2020). MaxEnt estimates species' habitat suitability using presence-only data and environmental variables. Maximizing entropy finds the distribution closest to being geographically uniform while adhering to constraints derived from ecological conditions at known occurrence locations. These constraints are defined based on environmental features like temperature, ensuring that the mean of each feature matches the sample mean. This approach is akin to maximizing the likelihood of a parametric exponential distribution (Papeş & Gaubert, 2007). Recent studies highlight the importance of incorporating spatially independent model evaluation and correcting for sampling bias to enhance the robustness of presence-only Species Distribution Models (SDMs) for effective conservation planning. MaxEnt is known for its predictive accuracy compared to other modeling methods, especially with opportunistic, presence-only data (Duengen et al., 2022; Smith et al., 2020). Furthermore, MaxEnt has been recognized for its ability to predict species distributions accurately even with limited sample sizes, making it a valuable tool in conservation biology and ecology. The model's capability to handle incomplete data and provide reliable predictions has made it a go-to method for researchers studying species distributions and assessing the impacts of environmental changes on biodiversity (Terribile et al., 2010; Magalhães-Júnior et al., 2017).

The Maxent settings were configured to use auto features, a regularization multiplier of 1, and to perform cross-validation (Özdemir et al, 2020a, Özdemir et al, 2020b). This configuration allowed the Maxent model to generate suitability habitat suitability predictions for *Passer domesticus*. Model performance was assessed using the Area Under the Curve (AUC) of the Receiver Operating Characteristic (ROC) curve, which was calculated to evaluate accuracy further (Evcin, 2023). Finally, the habitat suitability maps were visualized using Global Mapper (v21) software, and spatial analyses were conducted to identify key areas of high suitability and potential distribution patterns of *Passer domesticus* in Türkiye.

RESULTS AND DISCUSSION

Passer domesticus was modeled for the years 2021-2040, 2041-2060, and 2061-2080 (HadGEM3 RCP 2.6 and RCP 8.5), and six models were created. When the results were evaluated, habitat suitability model performance was generally reliable (Philips et al. 2006) (Figure 3).



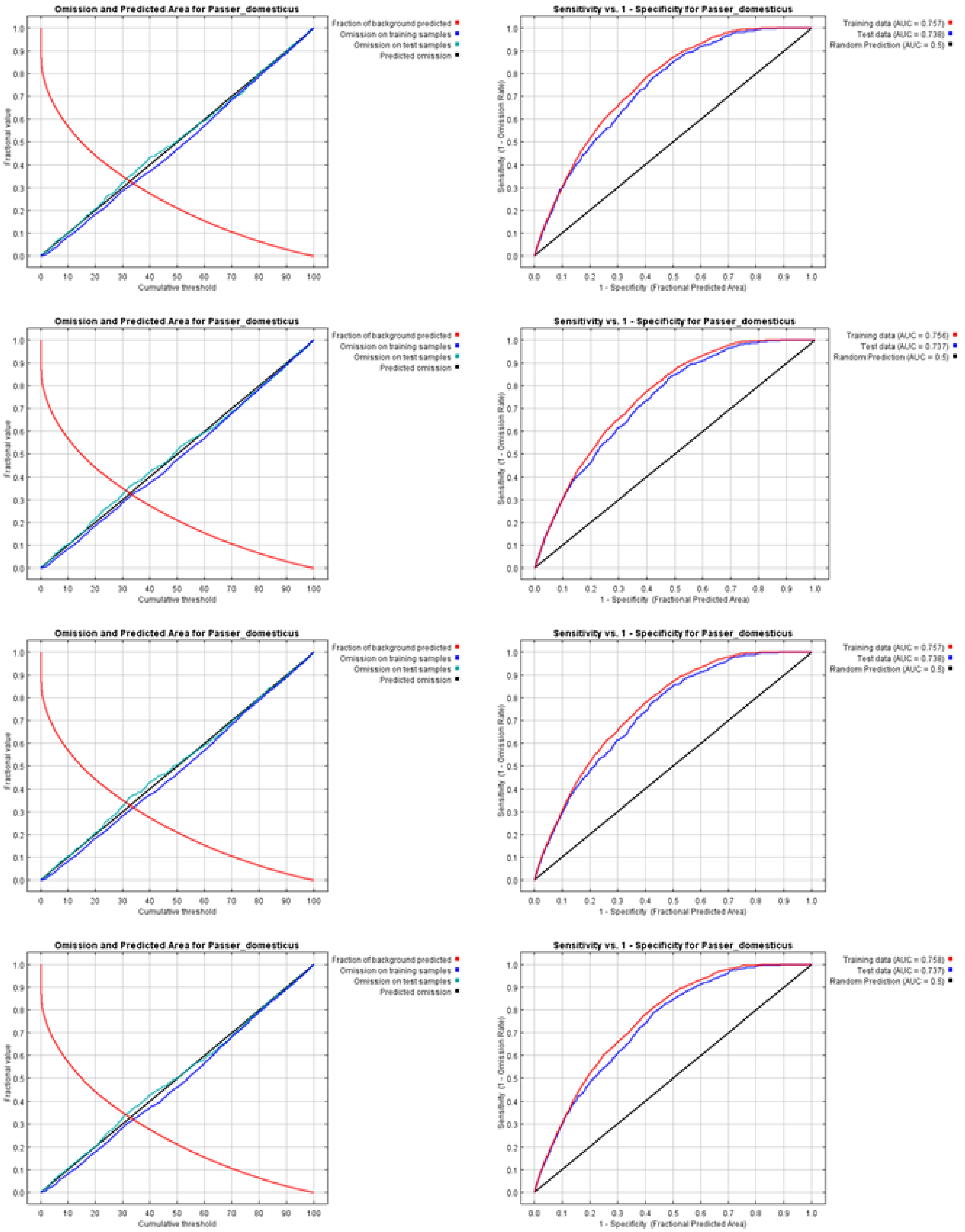


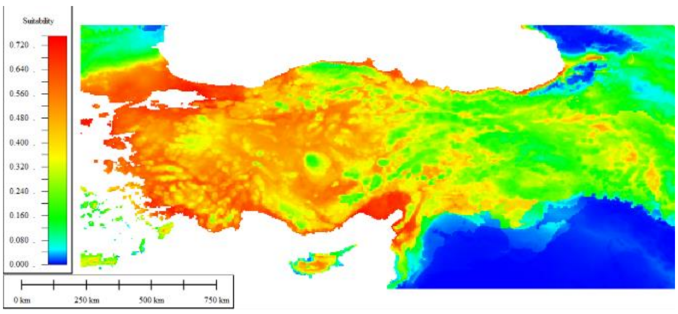
Figure 3: Graphs showing the AUC values and Omission & Predicted Areas

Variable contributions and permutation importance of the model were obtained as a result of the model. Mean variable contributions and the importance of the permutation of the models were calculated (Table 2). The Maxent model for predicting the distribution of *Passer domesticus* in Türkiye identified five bioclimatic variables as the most influential: bio14 (precipitation of the driest month), bio6 (minimum temperature of the coldest month), bio9 (mean temperature of the driest quarter), bio15 (precipitation seasonality), and bio17 (precipitation of the driest quarter). Bio14 had the highest contribution to the model, indicating that water availability during the driest month is critical for the survival and distribution of house sparrows. Bio6 was the second most important variable, suggesting that the minimum temperature during the coldest month is a key factor in determining the suitability of habitats. The distribution of house sparrows is positively associated with regions where the minimum temperature does not fall below a critical threshold, highlighting their sensitivity to extreme cold. Bio9 also played a significant role, indicating that the mean temperature during the driest quarter affects the distribution of house sparrows. The species prefers habitats where the mean temperature during the driest quarter is within a specific range, avoiding excessively hot and cold areas. Bio15's contribution reflects the importance of consistent precipitation patterns for house sparrows. The model suggests that regions with high precipitation seasonality are less suitable for *Passer domesticus*, which prefers more stable and predictable precipitation patterns. Bio17, while less influential than the other variables, still significantly impacts the distribution of house sparrows. Like bio14, the species favors regions with moderate precipitation during the driest quarter, avoiding extremes.

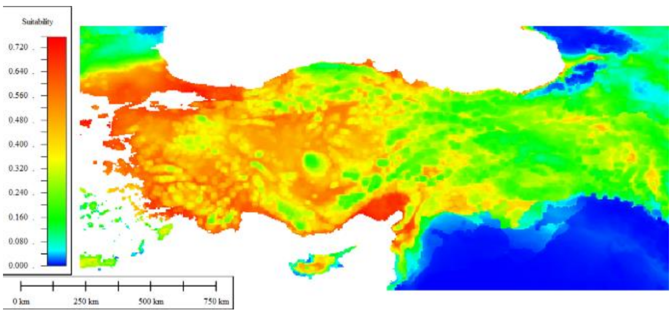
Table 2: Mean variable contributions and permutation importance of models

SSP 2-4.5			**SSP 5-8.5**		
Variable	**Percent contribution**	**Permutation importance**	**Variable**	**Percent contribution**	**Permutation importance**
bio 14	37,4	16,3	bio 14	37,5	15,6
bio 6	11,8	10,06	bio 6	13,4	6,5
bio 9	11,8	7,96	bio 9	10,7	6,87
bio 15	10,8	10,9	bio 15	9,7	7,46
bio 4	9,4	1,7	bio 17	8,3	26,83

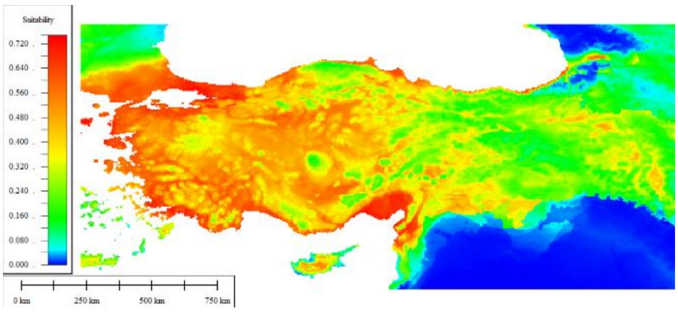
The habitat suitability map for the House Sparrow (Passer domesticus) is given in Figure 4. Habitat suitability is represented from lowest suitability (in green) to highest suitability (in red). The first image on the left represents the distribution of *Passer domesticus* under the SSP 245 scenario for the first 20-year period. The model predicts moderate suitability in western and southern regions of Türkiye, with lower suitability in central and eastern areas. In 2040 – 2060, there is a slight expansion in the areas of high suitability, particularly in the western regions, indicating a potential shift or expansion of the species' range. On 2060 – 2080 the areas of high suitability continue to expand, particularly towards the central regions, suggesting a trend of increasing habitat suitability under the SSP 245 scenario.



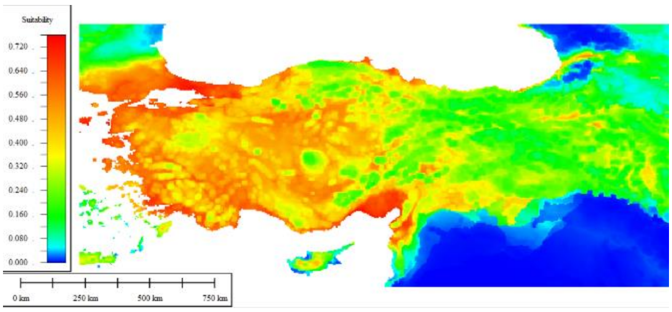
RCP 2.6 2021-2040



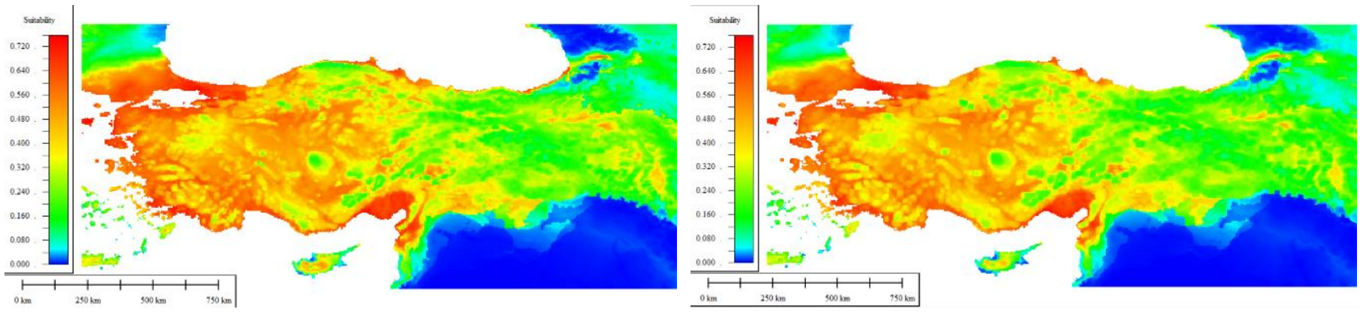
RCP 8.5 2021-2040



RCP 2.6 2041-2060



RCP 8.5 2041-2060



RCP 2.6 2061-2080 **RCP 8.5 2061-2080**

Figure 4: Potential distribution map of the House Sparrow, Passer domesticus, in Türkiye with Maximum Entropy Approach (MaxEnt)

The first image on the right shows the distribution under the SSP 585 scenario for the first 20-year period. The suitability is higher in the western regions, with noticeable areas of high suitability, but central and eastern regions remain less suitable. On 2040 – 2060, there is an evident increase in suitable habitats in the western and southern regions, with some expansion towards the central areas. On 2060 – 2080, high suitability areas expand significantly, especially in western Türkiye, indicating that the SSP 585 scenario might lead to a more pronounced shift in the distribution of *Passer domesticus*.

CONCLUSION

This study utilizes climate modeling to understand how House sparrow populations will be affected by future climate change scenarios in Türkiye. The findings indicate that sparrows' habitat distribution will be significantly impacted by climate change. Particularly in regions where sparrow populations are currently dense, such as the Mediterranean and Central Europe, an increase in temperature and drought is expected to shrink their habitats. Conversely, in northern regions (e.g., Scandinavia and Baltic countries), sparrows might find new habitats and their populations could increase.

Climate change will have significant impacts on *Passer domesticus* (House sparrow) for Türkiye populations. The findings show that sparrows' current habitats will be affected by climate change, and their geographic distribution will change considerably. Especially in southern habitats, a contraction is expected, while an expansion is likely in northern areas.

The prominence of bio14 and bio17 highlights the critical role of water availability during dry periods. *Passer domesticus* appears to thrive in regions where water resources are not overly scarce, emphasizing the necessity of consistent hydration for survival and reproduction. The significant contribution of bio6 underscores the species' sensitivity to low temperatures. *Passer domesticus* is likely to avoid regions with harsh winters, which could impact their food availability and increase energy expenditure for thermoregulation. The sensitivity to precipitation seasonality (bio15) suggests that regions with increasingly erratic rainfall patterns may become less hospitable, impacting the species' ability to find consistent food and water sources.

Under the SSP 245 scenario, the distribution of *Passer domesticus* shows a gradual increase in suitability, with a moderate expansion of suitable habitats over time. In contrast, the SSP 585 scenario depicts a more rapid and extensive increase in suitable habitats, particularly in the western regions of Türkiye. This suggests that *Passer domesticus* may find more favorable conditions under the higher emission scenario, potentially due to increased temperatures and changes in precipitation patterns. The differing rates of habitat suitability expansion under the two scenarios highlight the potential impact of climate change on the distribution of *Passer domesticus*. Under the SSP 585 scenario, the more substantial changes in climate may facilitate a quicker adaptation and expansion of the species, but this could also bring challenges related to resource availability and competition with other species. The moderate changes under the SSP 245 scenario suggest a slower adaptation, which may be beneficial in maintaining ecological balance but could also limit the species' ability to respond to rapid environmental changes.

Climate change poses potential risks to the distribution of *Passer domesticus* in Türkiye. Changes in precipitation patterns and temperature extremes could alter the suitability of current habitats. An increase in the frequency or intensity of dry periods and cold spells could restrict the range of house sparrows, pushing them to seek new areas with favorable conditions.

Understanding the key bioclimatic variables influencing *Passer domesticus* distribution aids in developing targeted conservation strategies. Efforts to preserve and manage habitats should focus on maintaining stable water sources and mitigating the impacts of extreme weather events. Monitoring changes in these critical bioclimatic factors can provide early warnings of potential range shifts, enabling proactive measures to support the species' adaptation to changing environmental conditions.

COMPLIANCE WITH ETHICAL STANDARDS

a) Author Contributions

Ö.E.: Conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing—original draft preparation, writing—review and editing, visualisation.

b) Conflict of Interest

No conflict of interest.

c) Statement on the Welfare of Animals

This study does not involve animals.

d) Declaration of Human Rights

This study does not involve humans.

e) Acknowledgements

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