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# The Effect of Climatic Change on the Current and Future Niche of Zoonotic Cutaneous Leishmaniasis Vector and Reservoir Species in Yazd Province

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**ABSTRACT**

**Introduction:** *Leishmania tropica* and *Leishmania major* are the causative agents of Anthroponotic Cutaneous Leishmaniasis (ACL) and Zoonotic Cutaneous Leishmaniasis (ZCL) in various areas of Iran, respectively. Yazd province is one of the endemic centers of ZCL. Therefore, this study aimed to investigate and predict the effects of the climate change on the potential scattering of the vector and reservoir species of ZCL disease in Yazd province, as one of the endemic centers of ZCL in Iran in the present (1950-2000) and prospective time (2030).

**Methods:** According to the findings of prior studies conducted in Yazd province, the data related to the vectors and reservoir of the ZCL were collected and recorded in the databank. ArcGIS 10.3 and MaxEnt software were used to estimate the suitable ecological niches using 19 variables. In this study, Beijing Climate Center Climate System Model and scenario of Representative Concentration Pathway 4.5 were applied with respect to 2030 horizon.

**Results:** According to results of Jackknife test, the climate variables of Bio8 & Bio6 for the current period, and climate variables of Bio8 & Bio7 for the future (2030) produced the most effects on the distribution of vector and reservoir species in Yazd province. These results indicated that temperature had the greatest impact on the vector's distribution in the present and future. Currently, eastern and central areas of the province are more likely to receive most of the vector and reservoir species. It is anticipated that in the future, we will observe an increase in the presence of vector in the western districts and reservoirs in the northern and central regions of the province.

**Conclusion:** Climate conditions provide suitable habitats for easy transfer of ZCL disease in Yazd province. This research confirmed that suitable climatic conditions for the vector and reservoir will be expanded in coming years in comparison with the current period.

**Keywords:** Climate Change; Leishmaniasis, Cutaneous; Zoonoses; Yazd province

## Introduction

Leishmaniasis is an important zoonosis transmitted through infected sand-fly (phlebotomus) bites (1, 2). The agent of cutaneous type is a

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protozoan of flagellates, Trypanosomatidae family and Leshmania genus, which is transferred from the animal and human resources to healthy individuals (mainly desert rodents and sometimes dogs) (3, 4). Symptoms of the disease are ulcers that can remain on the body, face, hand, legs as, well as other parts of the body for one year (5, 6). *Leishmania tropica* and *Leishmania major* are the causative agents of ACL and ZCL in various areas of Iran with high endemicity intensity, respectively (3).

Some evidences suggest that climate changes can increase the number of disease cases and extend the range of ZCL (7, 8). Climate variables play a significant role in the increase of ZCL, because they can result in favorable conditions for diseases such as exacerbating the parasite activity or increase the population of the reservoir and the vector of the disease (9). For example, a rise in precipitation might raise the density of vegetation as well as the quality and total of rodent breeding places (10). Earlier studies in Iran showed the importance of climate change as a risk factor for the prevalence of ZCL (11, 12). Therefore, this research was conducted to model the scattering of ZCL vector and reservoir in Yazd province and to investigate the effect of climate changes on the vectors and reservoir spreading pattern in the 2030 horizon.Yazd province is divided into ten counties: Abarkuh, Ardakan, Bafq, Behabad, Khatam, Mehriz, Meybod, Ashkezar, Taft, and Yazd.

## Materials and Methods

*2.1. Vector and reservoir data*

Existing records were collected from earlier researches conducted on *P. papatasi*, as the vector of ZCL in Yazd province. The data were recorded in a databank. Prior studies in the Yazd conveyed *R. opimus*, as the main reservoir of ZCL. Geographic coordinates of collection sites for this rodent were also noted in the databank.

*2.2. GCM models*

In the current study, one scenario was used for modeling: RCP4.5. In the RCP4.5 scenario, $CO_2$ concentration was assessed as 650 PPM, with a radiative forcing level of 4.5 watts per square meter (13,14, 15). This scenario was estimated as a stabilization scenario, without an overshoot, in which the total radiative forcing was stabilized shortly later years 2100 (16, 17, 18). The bioclimatic data based on RCP 4.5 scenario for the year 2030 were downloaded from www.ccafs. cgiar. org (http://ccafs-climate.org/ data).

*2.3. Bioclimatic and environmental variables*

Bioclimatic variables were achieved from the *www.ccafs.cgiar.org* at the spatial resolution of 30s. These variables represent seasonality, annual trends, and extremity or limitation of environmental factors (Table 1). Then, layers were changed to ASCII format (American Standard Code for Information Interchange) using the ArcMap 10.3 software. MaxEnt model was used for forecast using all variables.

## Results

**Investigating the bioclimatic status of *P. papatasi* vector in the current conditions in Yazd province**

The classification of the results achieved from the MaxEnt model demonstrated that the vector is more likely to exist in the eastern and central regions of the province (more than 60%) compared to the northern and western regions (less than 60%). In general, it can be stated that the vector is mostly present in Taft, Abarkouh and Yazd; while its least possibility was in Bafq, Ardakan, and Khatam. Jackknife analysis demonstrated the effect size of each variable used in the modeling. In expression 1, this analysis measures the impact of each factor individually (the dark blue column), the other expression assesses the impact of the rest of the factors without interference of one factor (light blue line), and third expression it calculates the effect of all factors together (red line). As it can be observed in Figure 1, Bio8 (Mean Temperature of Wettest Quarter) can be regarded as the most influential factor in the model (Dark blue column is higher than all other similar columns). In addition, when the software measures the effect of factors without interference of one factor, Bio2 factor (annual temperature range) had the greatest effect on the model (the length of the light blue column is shorter than the rest of light blue

columns). Thus, if this factor is omitted from the model, it will have the most negative effect on its prediction.

**Figure 1** indicates the sensitivity of the MaxEnt model. After implementation of the model, a curve shows us that the surface under the numerical curve is between zero and one. The line drawn in the middle of the curve in a skew form represents number 0.5. In fact, half of the curve is below this line.

**Table 1** shows the relative contribution of environmental variables in MaxEnt model for the ZCL vector and reservoir at the present time.

**Investigation the bioclimatic status of *R. opium's* (reservoir) in the current conditions**

The classification of the results from the MaxEnt model shows that the regions susceptible to the presence of *R. opium's* have a high probability in the south and central regions of Yazd province. Jackknife analysis also showed that the Bio6factor caused the most effect on the model. Moreover, when the software measures the effect of factors without interference of an individual factor, this factor produces the most effect on the model. Curve No. 2 expresses the sensitivity of the MaxEnt model. The model's sensitivity is 0.840 for the data with which the model was implemented. In fact, it indicates a good prediction of the model concerning the ecological niches of the target species. In this sample, the sensitivity of the test points was 0.613 according to which the model's acceptability was confirmed. **Table 1** represents the relative contribution of the bioclimatic variables for the related scenario. After reviewing status of the ZCL vector and reservoir in the current situation, we further evaluated their likelihood of occurrence in the 2030 prospect.

**Table1**. Variables used to forecast the potential dissemination of *Ph. papatasi* and *Rh. Opium's*, as the vector and the main reservoir of Cutaneous Leishmaniasis in Yazd Province, Central Iran

| Variable | Description | Contribution (%) | |
|---|---|---|---|
| | | ***P. papatasi*** | ***R. opimus*** |
| BIO1 | Annual Mean Temperature ($^{o}$C) | 0.3 | 0 |
| BIO2 | Mean Diurnal Range (Mean of monthly (max temp - min temp)) ($^{o}$C) | 4.7 | 38.3 |
| BIO3 | Isothermality (BIO2/BIO7) (×100) | 5.5 | 0 |
| BIO4 | Temperature Seasonality (standard deviation ×100) | 2.3 | 0 |
| BIO5 | Max Temperature of Warmest Month ($^{o}$C) | 0 | 0 |
| BIO6 | Min Temperature of Coldest Month ($^{o}$C) | 0 | 20.5 |
| BIO7 | Temperature Annual Range (BIO5-BIO6) ($^{o}$C) | 0.4 | 39.7 |
| BIO8 | Mean Temperature of Wettest Quarter ($^{o}$C) | 19.5 | 0.2 |
| BIO9 | Mean Temperature of Driest Quarter ($^{o}$C) | 3.3 | 0 |
| BIO10 | Mean Temperature of Warmest Quarter ($^{o}$C) | 0 | 0 |
| BIO11 | Mean Temperature of Coldest Quarter ($^{o}$C) | 15.9 | 0 |
| BIO12 | Annual Precipitation (mm) | 0.7 | 0 |
| BIO13 | Precipitation of Wettest Month (mm) | 0 | 0 |
| BIO14 | Precipitation of Driest Month (mm) | 1.4 | 0 |
| BIO15 | Precipitation Seasonality (Coefficient of Variation) | 15.6 | 0 |
| BIO16 | Precipitation of Wettest Quarter (mm) | 2.7 | 0 |
| BIO17 | Precipitation of Driest Quarter (mm) | 1.8 | 1.3 |
| BIO18 | Precipitation of Warmest Quarter (mm) | 17.4 | 0 |
| BIO19 | Precipitation of Coldest Quarter (mm) | 8.6 | 0 |

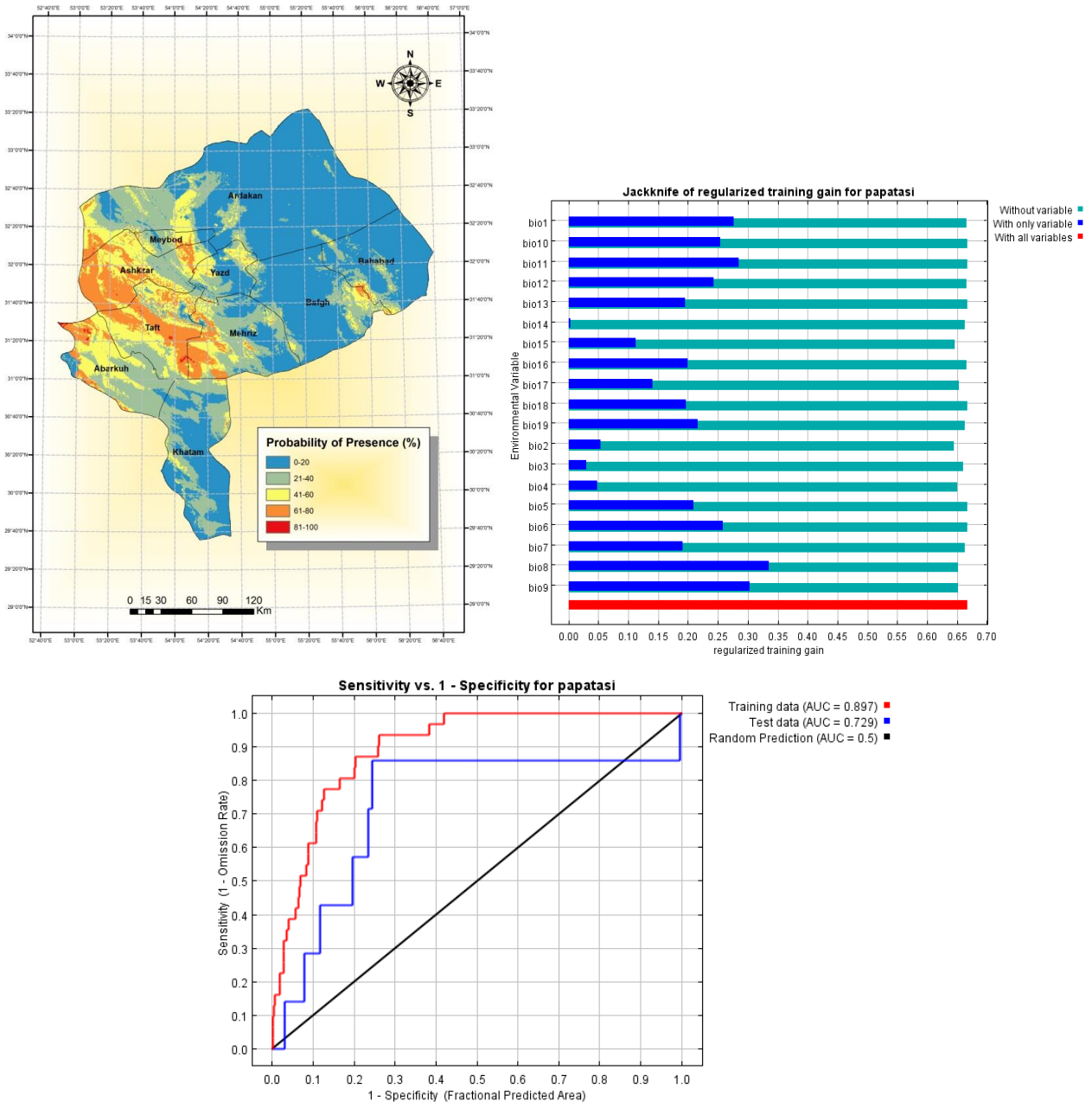



**Figure 1.** Output of MaxEnt model and jackknife analysis for *Ph. papatasi* in Yazd province, Central Iran

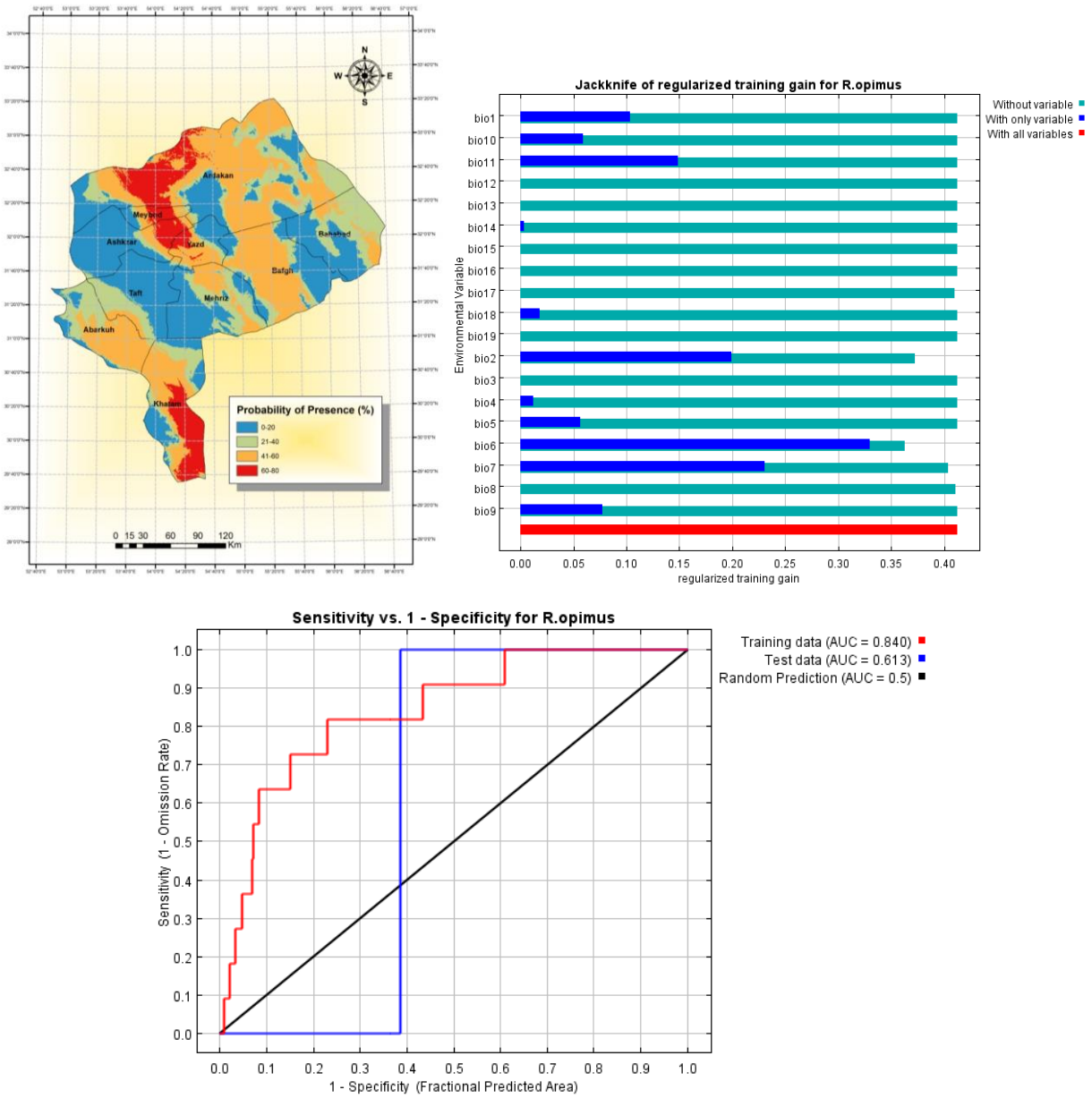



**Figure 2.** Output of MaxEnt model and jackknife analysis for *R. opimus* in Yazd province, Central Iran

**Investigating the status of ZCL vector and reservoir species in 2030 horizon, BCC-CSM1-1(m) model**

In this model and scenario, western (including Mehriz, Taft) and central (Yazd city) regions of the province had the highest probability with respect to *P. papatasi* presence. Moreover, the western regions of the province with susceptibility of the vector presence included the cities of Ashkezar, Taft, and Abarkuh. The least likelihood for occurrence of the vector was reported the northern (Ardakan), eastern (Bafq and Bahabad), and also southern parts of the province (Khatam). In this sample, the sensitivity of our test points (blue line) was obtained as 0.781, which is greater than 0.75 and is acceptable. In this sample, the factor with the greatest effect on the model was the mean temperature of three wet months of the year (Bio8) **(Figure 3)**.

In this model and scenario, the most probable presence of the reservoir was related to the southern (Khatam) and the central (Meybod, Ardakan, Yazd, Bafq, Abarkuh and Mehriz) regions of the province; whereas, the least probable

presence was related to the eastern regions (Bahabad and Bafq) **(Figure 4)**. In the corresponding diagram, Jackknife analysis showed the annual temperature (Bio7) as an individual factor with the greatest effect on the model. In this sample, the model sensitivity of the data with the model was implemented was 0.851, which indicates a good prediction of the model for the ecological niches of *R. opium's*.

Furthermore, the sensitivity of the test points (blue line) was 0.726, which represents the acceptable results for the model **(Figure 4)**. **Table 2** represents the relative contribution of bioclimatic variables for the reservoir**.**

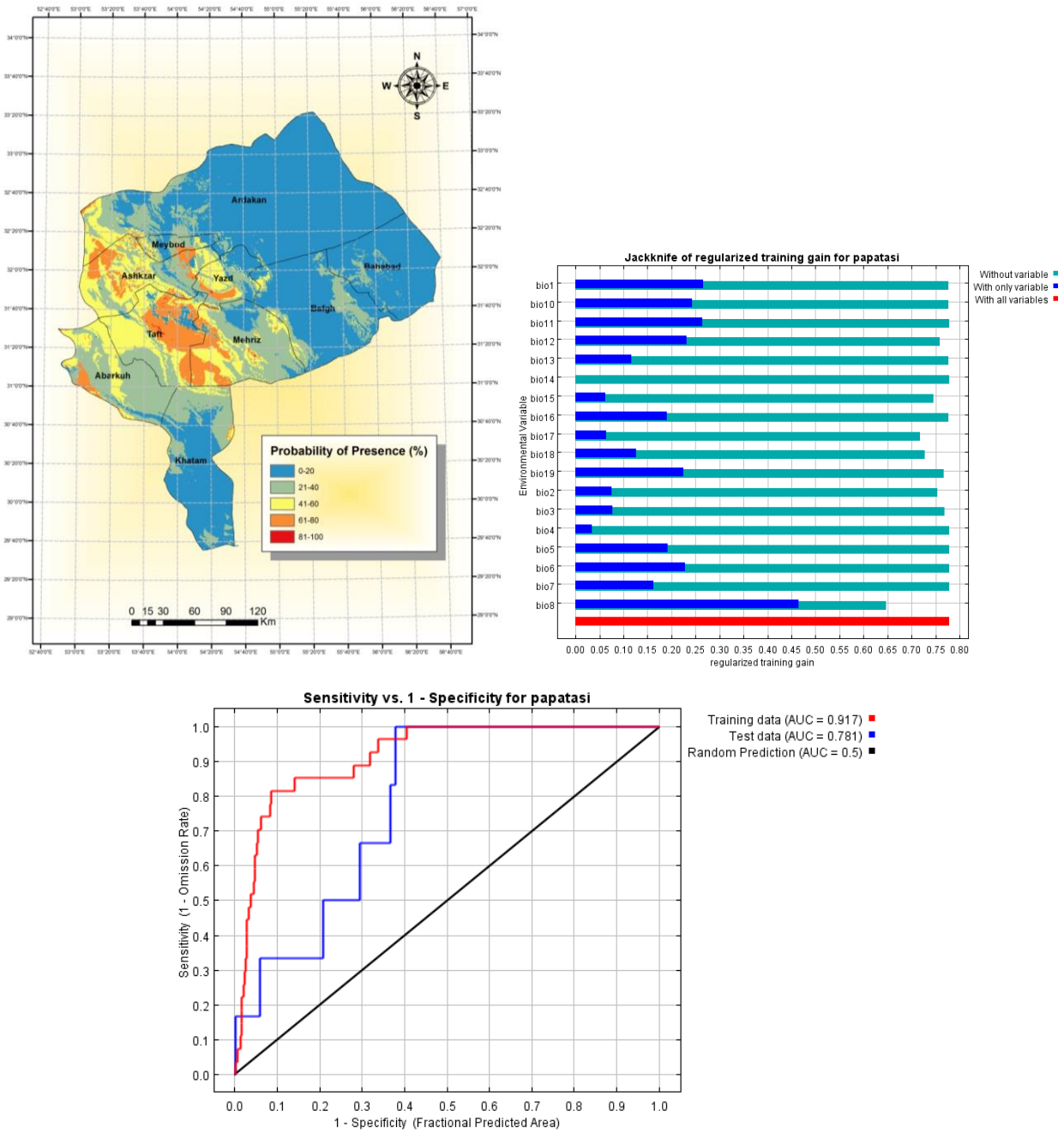
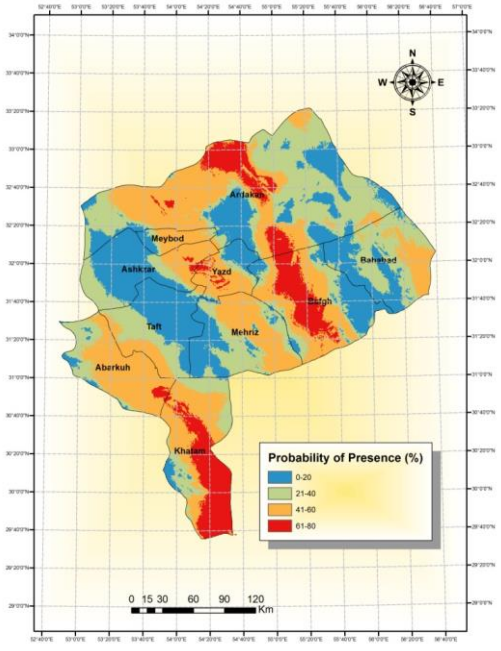



**Figure 3.** Output of MaxEnt model and jackknife analysis for P. papatasi in Yazd province, Central Iran, Horizon 2030: RCP 4.5 scenario, BCC-CSM1-1(m) model

**Table 2.** Variables used to forecast the potential dissemination of *P. papatasi* and *R. opimus* in Yazd Province, horizon 2030: RCP 4.5 scenario, BCC-CSM1-1(m) model

| Variable | Contribution (%) | |
|---|---|---|
| | ***P. papatasi*** **RCP4.5** | ***R. opimus*** **RCP4.5** |
| BIO1 | 0 | 0 |
| BIO2 | 4.6 | 41 |
| BIO3 | 2.3 | 0 |
| BIO4 | 0 | 0 |
| BIO5 | 0 | 0 |
| BIO6 | 0.8 | 0 |
| BIO7 | 0 | 50.4 |
| BIO8 | 73.5 | 0 |
| BIO9 | 1.7 | 0 |
| BIO10 | 0 | 0 |
| BIO11 | 0.2 | 0 |
| BIO12 | 6.5 | 0 |
| BIO13 | 0 | 0 |
| BIO14 | 0.5 | 0 |
| BIO15 | 4.7 | 8.5 |
| BIO16 | 0 | 0 |
| BIO17 | 2.8 | 0 |
| BIO18 | 0.8 | 0 |
| BIO19 | 1.5 | 0 |



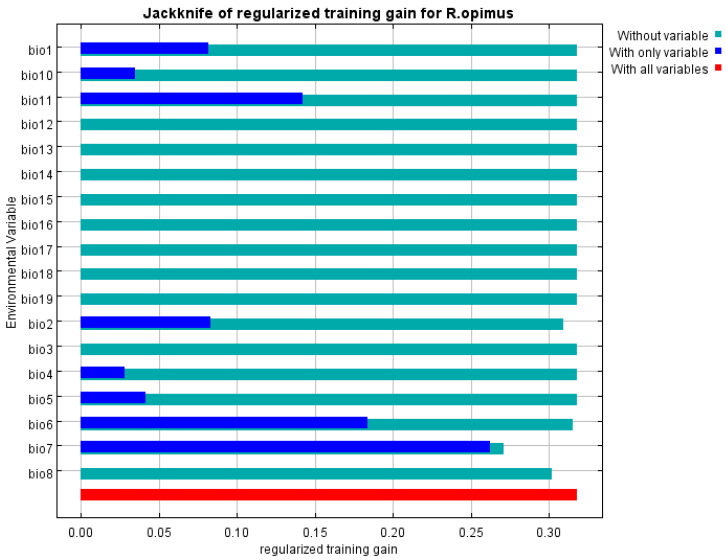




**Figure 4.** Output of MaxEnt model and jackknife analysis for *R. opimus* in Yazd province, Central Iran, Horizon 2030

## Discussion

This study showed that appropriate bioclimatic conditions for the vector and reservoir will be expanded in the coming years in comparison with the current, At present, the central and eastern parts of the Yazd county are more likely to receive the vector and reservoir species. It is anticipated that in the future, will be observed an increase in the presence of the vector in the western regions. Reservoir dispersion is also expected to spread in the northern and central portions of the province. The finding of another study conducted in Yazd province, under RCP 8.5 and 4.5 Scenario, the calculated AUC values for *R. opimus* were 0.96 and 0.91, respectively (7). Consequently, these findings support the current study. The AUC values for *P. papatasi* were 0.897 and 0.917 in current and future period, respectively. These values also confirm the excellent prediction of the model. The values of AUC obtained from different studies on this species throughout the world were in the range of 0.90 - 0.99 (19, 20), while another research conducted in Yazd province reported that the AUC was 0.91 (7). By comparing the AUC values gained from our model and comparing them with those of other studies conducted in the world and Iran, we can conclude that the forecast made for the distribution of both species (for the current period and 2030) in our study was acceptable and verifiable. A study conducted in Yazd province (7) showed that the probability of *P. papatasi* in the western part of this province was higher than the other parts. Similar to this result, future projections from our models indicate that the climatically suitable region for *P. papatasi* would expand mainly towards the west regions of Yazd province in the 2030s. Therefore, measures should be taken to prevent and control vector and reservoir in susceptible areas.

## Conclusion

In recent decades, factors such as drought, planting certain plants such as Haloxylon and Atriplex around cities and villages to stabilize sandy soils, and unauthorized use of groundwater for the development of agriculture around villages and cities have played an important role in the growth and convergence of rodent colonies in areas of human settlement. Possibility of rodent increases near the human settlements to find food and shelter. This also increases the exposure of the rodents to *P. papatasi*, which feeds on the reservoir rodents and contaminate humans through biting. Climate factors have a major influence on the spatial distribution of ZCL in Yazd Province. These findings can provide essential basis for public health policy makers to monitor and predict the disease dynamics based on the climate projections for future controlling strategies. In other words, appropriate personnel, budget, and resources should be allocated more efficiently by

concentrating on the major determinants of ZCL epidemiology in Yazd Province.

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## Conflict of interest

The authors of this study have no conflict of interest.

## Authors' contribution

All authors contributed in this project equally. All authors read and approved the final manuscript

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