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Modeling spatial risk of zoonotic cutaneous leishmaniasis in Central Iran

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ABSTRACT

Zoonotic Cutaneous Leishmaniasis (ZCL) is one of the endemic diseases in central part of Iran. The aim of this cross-sectional study was to find the areas with a higher risk of infection considering the distribution of vector, reservoir hosts and human infection. Passive data recorded the positive cases of cutaneous leishmaniasis in Yazd province health center were collected for 10 years, from 2007 to 2016 at the County level. Considering all earlier studies conducted in Yazd province, records of *Phlebotomus papatasi*, the main vector of ZCL, and *Rhombomys opimus*, the main reservoir of ZCL, were collected and entered in a database. ArcGIS and MaxEnt model were used to map and predict the best ecological niches for both vector and reservoir. The most cumulative incidence of the disease was found to be in Khatam County, south of Yazd province. The area under curve (AUC) for *R. opimus* and *P. papatasi* was 0.955 and 0.914, respectively. We found higher presence probability of both vector and reservoir in central and eastern parts of the province. The jackknife test indicated that temperature and normalized difference vegetation index (NDVI) had the most effect on the model for the vector and reservoir, respectively. The areas with higher presence probability for the reservoirs and vectors were considered having the higher potential for ZCL transmission. These findings can be used to prevent and control the disease.

1. Introduction

Cutaneous Leishmaniasis (CL) is one of the most important vector-borne diseases in some parts of the world, including Iran. The endemic foci of these diseases are in 18 out of 31 provinces of Iran and about 80% are due to Zoonotic Cutaneous Leishmaniasis (ZCL). Anthroponotic Cutaneous Leishmaniasis (ACL) is responsible for the remaining percentage (Yaghoobi-Ershadi, 2012).

Cutaneous leishmaniasis in both forms, thus Anthroponotic (ACL) and Zoonotic (ZCL) exists in endemic foci of Yazd province (Yaghoobi-Ershadi et al., 2001, 2004). Although ACL is limited to some quarters of Yazd city, ZCL is endemic in some counties of the province with many registered cases annually (Yaghoobi-Ershadi et al., 2001; Jafari et al., 2007). According to the CL incidence records, this province was reported to be among the 10 provinces with the highest incidence during 1983–2013 (Holakouie-Naieni et al., 2017). Phlebotomine sand flies (Diptera: Psychodidae) are the well-known vectors of Leishmaniasis. Previous studies have reported 50 species of sand flies from different parts of Iran (Karimi et al., 2014). *Phlebotomus papatasi* Scopoli and *Phlebotomus salehi* Mesghali are the main and suspected/secondary vectors of ZCL in Iran respectively (Kasiri and Javadian, 2000; Davami et al., 2011; Azizi et al., 2012). Previous studies in the endemic foci of ZCL in Yazd province showed that *P. papatasi* is distributed in the province (Jafari et al., 2007). Earlier surveys have reported gerbils (Rodentia: Gerbillidae) as main reservoir hosts of ZCL in Iran. *Leishmania major* Yakimoff & Schokhor, 1914 has been detected in four species of gerbils in many occasions in different foci of ZCL. *Rhombomys opimus* Lichtenstein, 1823, *Meriones libycus* Lichtenstein, 1823, *Meriones hurrianae* Jordon, 1867 and *Tatera indica* Hardwicke, 1807 have been introduced as main reservoirs of this disease in their distribution range (Gholamrezaei et al., 2016). Among the above-mentioned gerbils, *R. opimus* and *M. libycus* were infected with *L. major* and therefore reported as the main reservoirs of ZCL in Yazd province (Yaghoobi-Ershadi et al., 2001; Jafari et al., 2008).

Vector-borne diseases (VBDs) are highly affected by environmental conditions. Because vector population and its' life cycle depends on climatic and geographical variables, any change in these variables will directly affect the situation of the vector-borne diseases transmitted by

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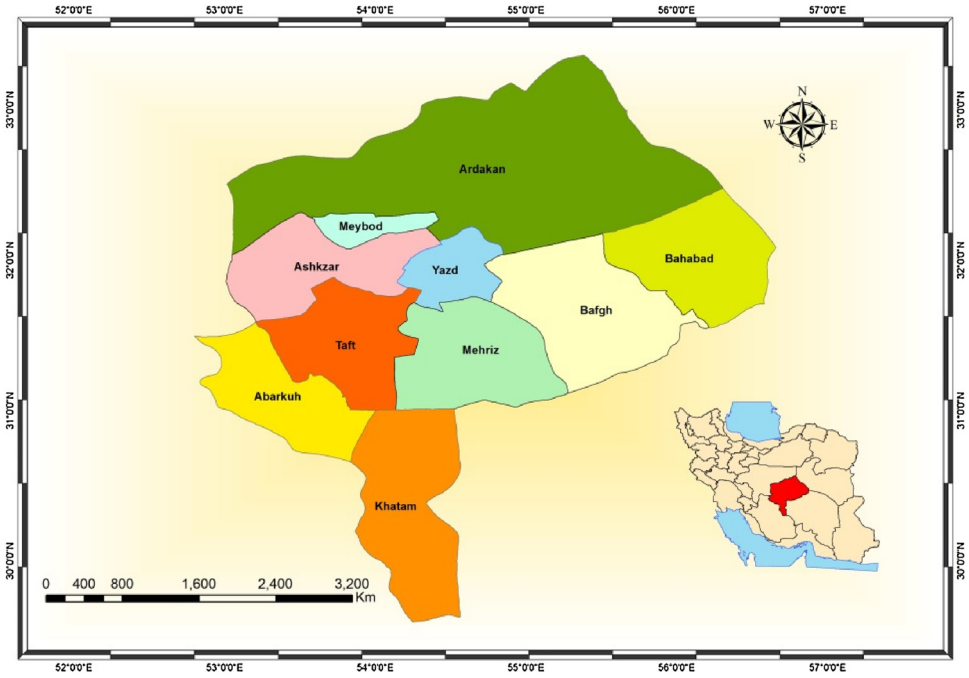

Fig. 1. Yazd province in central Iran.

Table 1
Variables used to predict the potential distribution of *Phlebotomus papatasi* and *Rhombomys opimus* as vector and main reservoir of Cutaneous Leishmaniasis in Yazd Province, Central Iran.

Variable	Description	Contribution (%)	
		P. papatasi	*R. opimus*
Altitude	Elevation above the sea level (m)	0	0
Aspect	Direction of Slope (Degree)	1.6	0
BIO1	Annual Mean Temperature (°C)	0	0
BIO2	Mean Diurnal Range (Mean of monthly (max temp - min temp)) (°C)	3.4	7.3
BIO3	Isothermality (BIO2/BIO7) (×100)	0.3	0
BIO4	Temperature Seasonality (standard deviation ×100)	1.9	0
BIO5	Max Temperature of Warmest Month (°C)	0	0
BIO6	Min Temperature of Coldest Month (°C)	0	27.4
BIO7	Temperature Annual Range (BIO5-BIO6) (°C)	0	11.4
BIO8	Mean Temperature of Wettest Quarter (°C)	10.6	0
BIO9	Mean Temperature of Driest Quarter (°C)	4.6	0
BIO10	Mean Temperature of Warmest Quarter (°C)	0	0
BIO11	Mean Temperature of Coldest Quarter (°C)	19.7	2.9
BIO12	Annual Precipitation (mm)	0.7	0
BIO13	Precipitation of Wettest Month (mm)	0	0
BIO14	Precipitation of Driest Month (mm)	0.7	0
BIO15	Precipitation Seasonality (Coefficient of Variation)	13.2	0
BIO16	Precipitation of Wettest Quarter (mm)	0	0
BIO17	Precipitation of Driest Quarter (mm)	0.5	0.2
BIO18	Precipitation of Warmest Quarter (mm)	11.2	0
BIO19	Precipitation of Coldest Quarter (mm)	0.8	0
NDVI	Normalized Difference Vegetation Index	15.3	49.8
Slope	Slope obtained from altitude (%)	15.5	0.9

that vector. Different models were developed to predict the distribution of vectors, reservoirs, or disease agents. These models help us to predict the hot spots for VBDs and to plan to prevent infection in human communities. The most commonly modeled VBDs are malaria and dengue (Reiner et al., 2013), but many others such as leishmaniasis cause a notable burden of disease in humans. Ecological niche modeling, or species distribution modeling, refers to the process of using computer algorithms to predict the distribution of target species in a geographic space based on its' known distribution in the area. These models allow for interpolating between few species occurrence and they are used in several research areas. MaxEnt is one of the most used models in this context. In recent years, geographical information system (GIS) and ecological niche modeling have been used for mapping, spatial analysis and modeling risk factors of cutaneous leishmaniasis in different countries that have problem with CL transmission (Hanafi-Bojd et al., 2015; Abedi-Astaneh et al., 2016; Melchior et al., 2017; Talmoudi et al., 2017; Sofizadeh et al., 2017; Holakouie-Naieni et al., 2017).

The aim of this cross-sectional study was to find the areas with higher risk of infection considering the distribution of vector, reservoir hosts and human infections.

2. Materials and methods

2.1. Study area

Yazd province, with a land area of 129,285 km^2, is located in central part of Iran (Coordinates: 54.3570 °E, 31.8948 °N). According to the administrative division, Yazd province is divided into 10 counties, in which each county has at least one town and several urban and rural districts, and villages (Fig. 1). Most of the province's area is arid and desert. According to the last national population and housing census 2016, the province has a total population of 1,138,533 with population density of 8.8/km^2 (National census, 2016). Yazd province is one of the driest provinces in Iran. The mean annual precipitation across the province is about 100 mm, while the average in the city of Yazd is about 60 mm, and most of which falls in the winter months. Around July, the temperatures in Yazd city frequently rise above 40 °C, and the average temperatures range between 39 °C and 23 °C for high and low, respectively. This give the distinct almost 20 °C cooling in the late evening and night. Social activities in Yazd province during summer often take place in the evenings. January is the coldest month in the city with an average high and low temperature of 12 °C and −1 °C, respectively. Due to this climatic variations and geographic morphology, the province is prone to transmission of cutaneous leishmaniasis and thus is one of the main endemic areas for zoonotic cutaneous leishmaniasis in Iran.