Original Article

# Interactive Effects of Climatic Changes and Environmental Factors on Distribution of Cutaneous Leishmaniasis in Kashan City, Central Iran, from 2007 to 2019

**Mousa Dehghani, Hossein Moradi, Alireza Soffianian**

Department of Natural Resources, Isfahan University of Technology, Isfahan 84156-83111, Iran

**ORCID:**

Mousa Dehghani: https://orcid.org/0000-0002-7501-7291

Hossein Moradi: https://orcid.org/0000-0001-9916-8492

## Abstract

**Aims:** Climate change and environmental factors are two factors affecting the ecosystem and life cycle of vector insects. In this study, the effects of climatic elements and environmental factors on cutaneous leishmaniasis in Kashan were studied. **Materials and Methods:** This study has adopted an analytical-descriptive method. Climatic data were compared with 3949 cases of cutaneous leishmaniasis from 2007 to 2019 using SPSS 22 software and Pearson correlation. Furthermore, the prevalence of cutaneous leishmaniasis cases in Kashan city was displayed on the land use maps, land cover map, rainfall map, thermal classification map, and digital elevation model and then was investigated. **Results:** Pearson correlation analysis showed a negative correlation between cutaneous leishmaniasis cases and spring temperature while a positive correlation with total rainfall and winter rainfall was observed. Investigating the spatial distribution of cases of cutaneous leishmaniasis in Kashan city was observed that the frequency of this disease was higher near Kashan desert belt from Abuzeidabad to Abshirin, the landfill areas, around the agricultural fields, the main roads, and the outskirts of the city. **Conclusion:** The frequency of cutaneous leishmaniasis has a significant negative correlation with reduction of temperature in spring to the desired level for the activity of sandflies. Rainfall has also caused a significant increase of this disease. Autumn has the most cases and spring the least ones. In the spatial distribution of the disease, a clear relationship with the desert areas, where the disease reservoir mice were living, and the agricultural fields, where sandflies reproduced and had activity, was observed.

**Keywords:** Climate changes, cutaneous leishmaniasis, environmental factors, Kashan

## Introduction

Consumption of fossil fuels and the release of large amounts of CO2 gas increase the earth's temperature. The average global temperature is expected to increase by 2°C–5°C in the coming decades. As a result of these changes, the earth will experience changes such as rising temperatures, rainfall, and drought, as well as frequent and severe storms. Climate change also affects disease cycles, arthropods, pathogenic parasites, disease vectors, and their hosts.[1-3]

Climate change and global warming will have catastrophic effects on human, animal, and environmental ecosystems.[4,5]

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Studies have shown that climate-sensitive diseases, that is, diseases transmitted through vectors, are dependent on diversity and climate change.[6] Temperature changes can directly affect the growth rate, behavior, and overall dynamics of pest and parasite populations and complete their life cycle much faster.[7] Water quality parameters such as dissolved oxygen (DO), water temperature (Tw), and dissolved organic carbon have significant effects on aquatic ecosystem species. Any

**Address for correspondence:** Dr. Hossein Moradi, Department of Natural Resources, Isfahan University of Technology, Isfahan, Iran.
E-mail: hossein.moradi@iut.ac.ir



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disturbance in water quality such as rising Tw and low DO concentrations can threaten the survival of aquatic ecosystems and their species.[8] Heavy rains lead to changes in the prevalence and occurrence of diseases. Exposure to dust storms and air pollution also exacerbates respiratory diseases.[9] Global climate change affects the consumption of resources such as water and agricultural products and increases the danger of malaria around the world.[10] Every year thousands of people are displaced in the coastal areas of Bangladesh due to natural disasters related to climate change.[11] Research shows that the two phenomena of temperature and relative humidity affect the number of international tourists in Indonesia. Every 1% increase in temperature and relative humidity is associated with a decrease in the number of international tourists in Indonesia by 1.37% and 0.59%, respectively.[12] The interaction of human activities and climate change has played an important role in vegetation.[13] The rapid global spread and health effects of COVID-19 on human society have shown humanity's vulnerability to pandemics and common diseases of humans and animals. Land-use change is known as a very important factor in the process of transmission and spread of diseases; therefore, it is necessary to know its consequences.[14] Evidence suggests that emerging infectious diseases, such as COVID-19, originate in wildlife species and that land-use change is an important route for the transmission of pathogens to humans.[15] The transformation of an ecosystem into agricultural field, and the resulting changes in soil properties and hydrological equilibrium change ecosystem services, and these changes affect the human health.[16,17] Flood risks may increase rapidly due to a combination of land-use change and climate change.[18] Children living in areas covered with coniferous forests are significantly more likely to suffer from wheezing, asthma, and allergies.[19] Urbanization, pollution, and change of natural landscapes are the characteristics of the modern society, and change in the type of human relationship with the environment and the impacts on biodiversity are environmental determinants that affect the health of society.[20] Climate change disorders, such as severe droughts and fires, affect the albedo coefficient in the Middle East's forest region of the Zagros Mountains.[21] The risk of endemic viral diseases in Iran is very high due to its geographical location and proximity to major disease centers.[22] Leishmaniasis is a common zoonosis disease transmitted by sandflies that affects millions of people worldwide. Clinical signs range from self-healing skin lesions to potentially fatal visceral leishmaniasis, all of which are associated with different species of *Leishmania*. The transmission of these parasites is complex due to the different ecological relationships between hosts, humans and animals, parasites, and sandflies. In addition, vector-borne diseases such as leishmaniasis are complexly associated with environmental changes and socioeconomic risk factors.[23] Increased population movement from rural to urban areas could lead to the possible movement of *Leishmania* to urban areas.[24] Climate change may alter the distribution of sandflies at certain altitudes and latitudes.[25] Research has shown that the presence of visceral leishmaniasis significantly affects the distribution of grasslands and shrubs.[26] Rodent populations are related to the density and distribution of vegetation, and the movement and scattering of these rodents hosting the *Leishmania* parasite from one place to another depends entirely on food and food sources.[27] The distribution of *Leishmania* vector species is related to climatic anomalies and the occurrence of El Nino and La Nina; therefore, these changes affect the frequency and distribution of *Leishmania* vectors.[28] Inadequate sewage system and unsanitary water sources, unsanitary landfilling of garbage, and dumping of garbage on the outskirts of cities and villages expand the habitat of sandflies.[29,30] Three forms of leishmaniasis, including *Leishmania tropica*, the causative agent of urban cutaneous leishmaniasis, *Leishmania major*, the causative agent of rural cutaneous leishmaniasis, and *Leishmania infantum*, the causative agent of visceral leishmaniasis, have been reported in Iran.

Since climatic elements are factors affecting the ecosystem and biological cycle of living organisms, especially pathogens, this study is an investigation on the effects of climatic elements and environmental factors on cutaneous leishmaniasis in Kashan city.

## Materials and Methods

Kashan's climate has two mountainous and desert parts. The desert areas are located in the north and east and mountainous areas in the south and west of Kashan.

This study is conducted by an analytical-descriptive method. The data related to cutaneous leishmaniasis during the statistical period of 2007–2019 were obtained from 32 health centers in Kashan which include 3949 cases of cutaneous leishmaniasis, and also the meteorological data related to temperature and precipitation variables were collected from the General Meteorological Department of Isfahan Province. All statistical calculations of this study were performed using IBM SPSS Products. U.S.A (SPSS 22) software including Pearson correlation and ANOVA to show the relationship between research variables, and ArcGIS 10.5 software was used to show the areas infected with cutaneous leishmaniasis.

First, the meteorological data were summarized to match the up-to-date disease information and extracted on a monthly, annual, and seasonal basis in each of the elements. After that, the statistical indices of each element in the mentioned period were examined.

To investigate the relationship between climatic elements and up-to-date cutaneous leishmaniasis, the cases were classified into five categories, including annual cutaneous leishmaniasis and cutaneous leishmaniasis in spring, summer, autumn, and winter. Then, the climatic variables including total precipitation, total maximum temperature, total minimum temperature, precipitation, maximum temperature, and minimum temperature were classified into four seasons. Thus, each category of cutaneous leishmaniasis with 15 different variables was examined and the relationship and correlation between climatic elements were analyzed through Pearson correlation in SPSS 22 software. Due to the incubation period after sandfly bites until the onset of symptoms, a delay of 3–6 months between the variables and disease was considered. The spring disease data were also evaluated with the climatic elements of the previous year. Then, to investigate the spatial relationship of the disease and its spatial distribution in Kashan city and county, shapefiles of land use information layers, road maps, digital elevation model (DEM), thermal classification, rainfall map, and land cover were prepared with the help of ArcGIS 10.5 software.

## Results

From 2007 to 2019, a total of 3949 cases of cutaneous leishmaniasis were reported from health centers in Kashan. The highest number of cases was reported in autumn with 1470 cases, while spring with 474 cases had the lowest number of cases. As it can be seen in Figure 1, the highest number of cases was in November with 538 cases, while June with 127 cases was the lowest month of the year [Figure 1]. Pearson correlation analysis is shown between the frequency of cutaneous leishmaniasis and climatic variables including the means of total minimum temperature, total maximum temperature, total precipitation, minimum and maximum temperatures of the four seasons, and precipitation of the four seasons of the year [Table 1].

Out of the 32 health centers that have reported cases of cutaneous leishmaniasis, 8 centers with more than 70% of all cases in the city have been the main centers of the

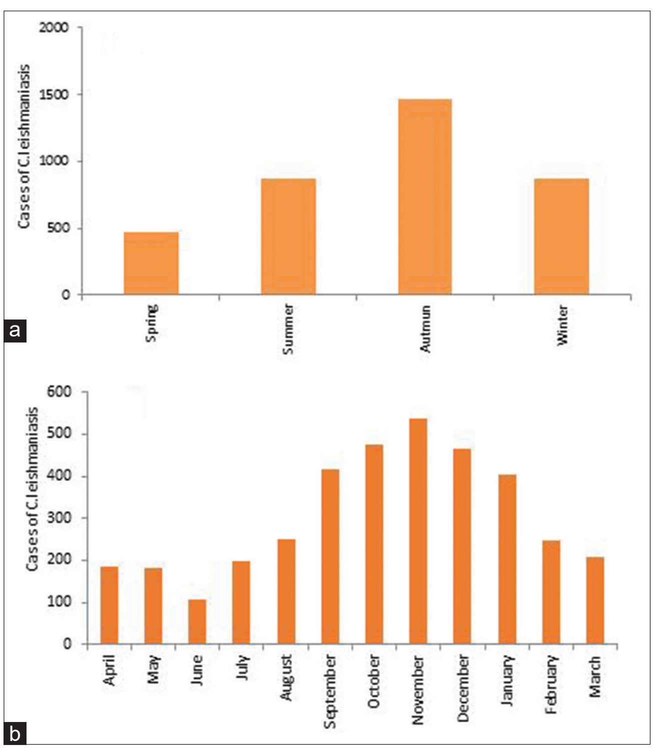


**Figure 1:** (a) Seasonal frequency distribution of cutaneous leishmaniasis from 2007 to 2017. (b) Monthly frequency distribution of cutaneous leishmaniasis from 2007 to 2019

**Table 1: Pearson correlation between climate data and cutaneous leishmaniasis**

| Number of cases of cutaneous leishmaniasis | Annual maximum temperature | Annual minimum temperature | Annual precipitation | Spring maximum temperature | Spring minimum temperature | Spring precipitation | Summer maximum temperature | Summer minimum temperature |
|---|---|---|---|---|---|---|---|---|
| Annual | −0.11 | −0.18 | 0.42 | −0.67* | −0.68* | 0.25 | 0.16 | −0.14 |
| Spring | −0.16 | −0.37 | 0.65* | 0.05 | −0.22 | −0.08 | 0.21 | −0.19 |
| Summer | 0.19 | 0.06 | 0.17 | 0.07 | −0.05 | −0.08 | −0.03 | −0.26 |
| Autumn | −0.39 | −0.51 | 0.26 | −0.35 | −0.59* | −0.05 | −0.23 | −0.49 |
| Winter | 0.14 | 0.22 | 0.70* | −0.25 | −0.08 | 0.52 | 0.53 | 0.22 |

| Number of cases of cutaneous leishmaniasis | Summer precipitation | Autumn maximum temperature | Autumn minimum temperature | Autumn precipitation | Winter maximum temperature | Winter minimum temperature | Winter precipitation |
|---|---|---|---|---|---|---|---|
| Annual | 0.18 | 0.16 | 0.02 | 0.14 | 0.05 | −0.02 | 0.40 |
| Spring | 0.12 | −0.07 | −0.06 | 0.05 | −0.23 | −0.39 | 0.59* |
| Summer | −0.14 | 0.30 | 0.26 | −0.08 | 0.06 | 0.04 | 0.32 |
| Autumn | 0.31 | 0.10 | −0.06 | 0.02 | −0.25 | −0.35 | 0.40 |
| Winter | −0.01 | −0.16 | 0.35 | 0.33 | 0.21 | 0.11 | 0.3 |

*Correlation is significant at the 0.05 level (two-tailed)

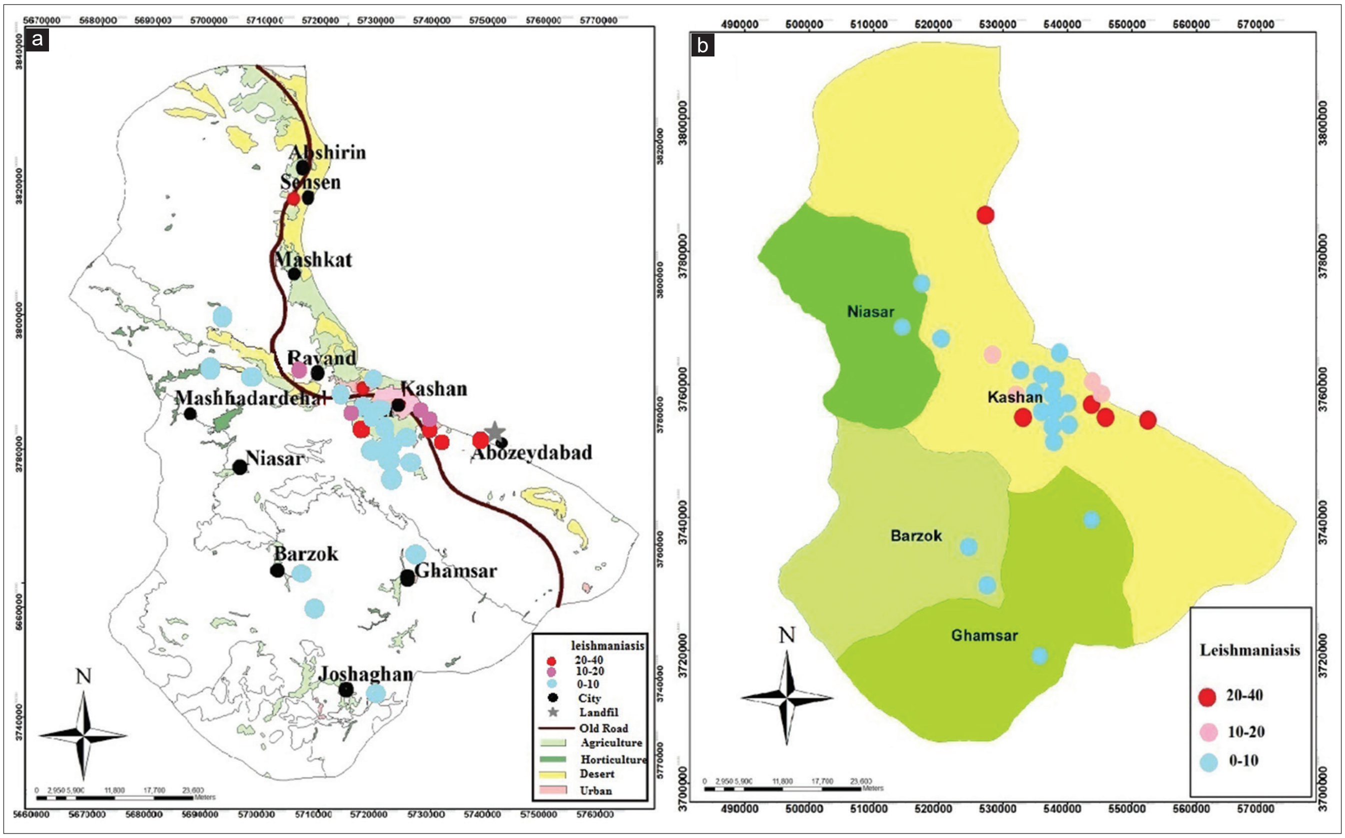


**Figure 2:** (a) Distribution of the centers of cutaneous leishmaniasis in the land use map of Kashan. (b) Distribution of the centers of cutaneous leishmaniasis in cities of Kashan county in terms of number per year

disease [Figure 2b]. The results showed that the prevalence of the disease has been observed in agricultural lands on the outskirts of the urban areas as well as in the desert areas. The prevalence of the disease was higher near Kashan desert belt from Abuzeidabad to Abshirin and around the agricultural fields, landfills, main roads, and the outskirts of the city [Figure 2a].

Figure 3b shows the distribution of the main health centers of cutaneous leishmaniasis in the DEM of Kashan city in five classifications: 800–1200 m, 1200–1600 m, 1600–2000 m, 2000–2500 m, and 2500–3500 m. Figure 3a also shows these centers in the land cover map. Figure 4a and b shows the distribution of the main centers of cutaneous leishmaniasis in the rainfall map and Kashan thermal classification map, respectively.

## Discussion

According to the research findings, out of 3949 cases of cutaneous leishmaniasis from 2007 to 2019, the highest number of cases was reported in autumn with 1470 cases, in November with 538 cases, and the lowest number was reported in spring with 474 cases, in June with 127 cases, which are consistent with previous studies.[31] The results showed that there is a relationship between the frequency of cutaneous leishmaniasis and temperature in the region. The incidence of cutaneous leishmaniasis with a delay of 3–6 months is positively correlated with the amount of rainfall, and negatively correlated with the mean temperature of spring. The annual correlations between cutaneous leishmaniasis and minimum and maximum spring temperatures were −0.67 and −0.68, respectively, with a reliability coefficient of 0.95. Furthermore, for cutaneous leishmaniasis in autumn with the minimum spring temperature, a negative correlation of −0.59, with a reliability coefficient of 0.95, was observed. The correlations between spring cutaneous leishmaniasis and total rainfall and winter rainfall were +0.59 and +0.65, respectively.[32]

Although the activity of sandflies starts with the commencement of spring and heat, considering that the most suitable temperature for the activity of sandflies is 18°C–28°C[33] and that the average minimum and maximum temperatures of spring in Kashan are about 17°C and 31°C, respectively, the results obtained about the negative correlation of spring temperature with the frequency of cutaneous leishmaniasis in Kashan can be justified and confirmed that matches the results of other studies.[32-35] In fact, a set of climatic, environmental, natural disasters and seasonal parameters affect the vector of cutaneous leishmaniasis.[36] The study of the spatial distribution of the disease shows that the main foci of cases of cutaneous leishmaniasis are located in the east of Kashan city [Figure 2a]. Furthermore, the predominant type of cutaneous leishmaniasis in this

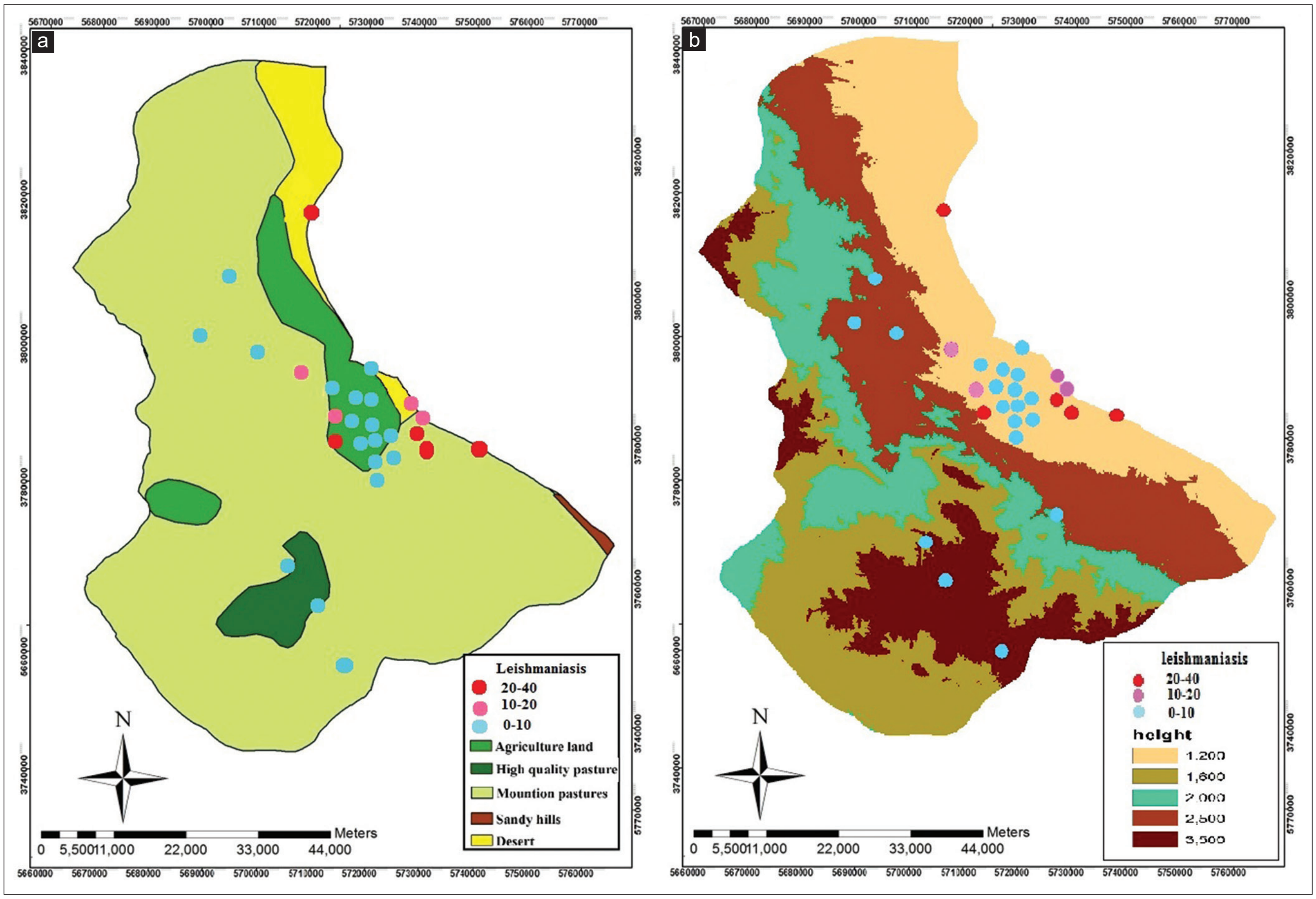


**Figure 3:** (a) Distribution of the centers of cutaneous leishmaniasis in the land cover of Kashan. (b) Distribution of the centers of cutaneous leishmaniasis in the digit elevation model (DEM) of Kashan

region is rural cutaneous leishmaniasis, and the main hosts of this cutaneous leishmaniasis, i.e., rodents, live in the desert and *Haloxylon* areas.[37] The study shows that there is a relationship between the spread of the disease and agricultural fields [Figure 3a]. In fact, farms and places for keeping domestic animals, livestock, and poultry are suitable for the activity and reproduction of sandflies.[38,39] Furthermore, the location of the landfill in Abuzeidabad region has provided the resources for reproduction and activity of vectors and hosts of cutaneous leishmaniasis that has caused an increase of the disease.[40] In fact, the location of agricultural fields in the desert belt of Kashan and landfills in the same area can be mentioned as aggravating factors of cutaneous leishmaniasis in this area. Due to the low flying power and distribution of sandflies, leishmaniasis occurs near these areas. All active foci of the disease are located at an altitude of 800–1200 m, i.e., in the lowest altitude of the city, which indicates the inverse relationship between the spread and frequency of cutaneous leishmaniasis with altitude [22; Figure 3b]. Furthermore, the main centers of this disease in the thermal map of Kashan are located in the classification of 16°C–18°C and in the rainfall map of the region in the classification of 50–200 mm [Figure 4]. The main focus of cutaneous leishmaniasis is where agricultural fields are located next to the desert areas. All the main centers of the disease are located near the main intercity roads and the city border, most of which are located on the side of the old Kashan road and an active center near the new Amirkabir highway. These areas appear to be at the center of the disease due to the connection of the host, vectors, and human cycles to each other.

## Conclusion

The results showed that a combination of climatic and environmental factors affects cutaneous leishmaniasis. Climate changes and environmental factors mutually affect each other. Due to the correlation of climatic factors with cutaneous leishmaniasis, the necessary measures can be taken to get prepared for and deal with the spread of this disease by using climate forecasting models, but in the case of environmental factors, human's role in controlling and reducing cutaneous leishmaniasis is more evident. The most logical way to prevent this is either breaking the cycle of the disease or eliminating it. Collecting construction garbage, monitoring and improving landfills, controlling and eliminating the pollution along the main roads near cities to a suitable distance, and controlling the main reservoirs by using methods compatible with nature

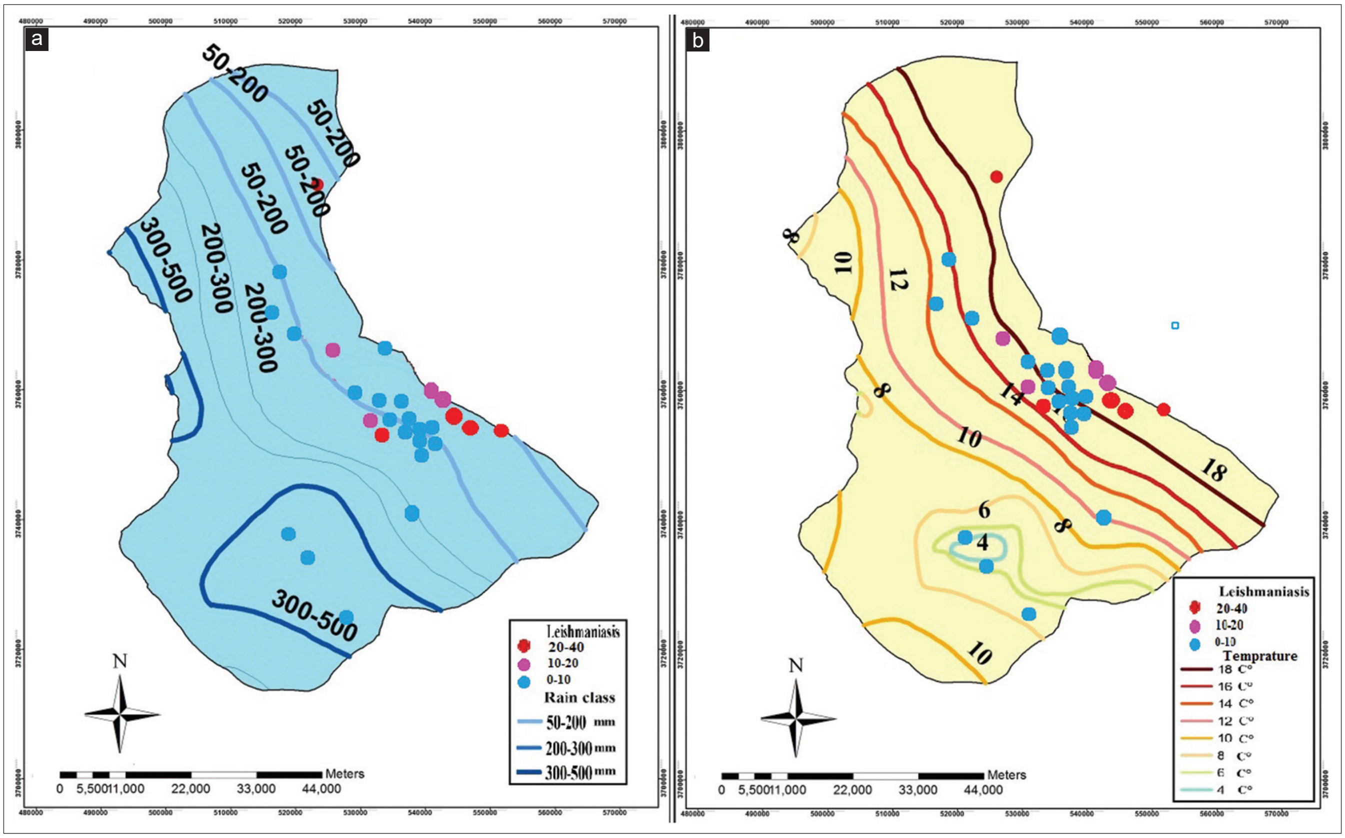


**Figure 4:** (a) Distribution of the centers of cutaneous leishmaniasis in the rainfall map of Kashan. (b) Distribution of the centers of cutaneous leishmaniasis in the thermal classification map of Kashan

and keeping them away from food resources and agricultural fields can be effective in reducing and controlling this disease. The results of this study have been obtained according to the climatic and environmental conditions of Kashan and may not be generalizable to areas with different conditions.

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## Conflicts of interest

There are no conflicts of interest.

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