Original Article

Zoning the Prevalence of Leishmaniosis and the Effect of Climatic Parameters on Its Occurrence in Isfahan

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Abstract

A geographic Information System (GIS) is an important tool for monitoring phenomena in space. In addition to studying diseases over time, this system helps us to study geographic distributions of diseases. The known global center with leishmaniosis disease is almost entirely between 28- 42 degrees north latitudes. In research on this disease, a clearer picture of the process of changes and spatial distribution of disease can be provided by identifying risky cores and important transmission factors. The risky time and place can also be predicted by using climatological data. In this applied study, ArcGIS prepared the disease zoning plan in Isfahan province. Then, the relationship between climatic parameters and disease cases was investigated using SPSS. The results showed that the temperature parameter has a reverse relation with the number of diseases and directly with the moisture and precipitation. In overlapping the map of disease centers with an interpolation map of temperature, humidity, precipitation, topography and vegetation in Isfahan province, it was observed that in places with a temperature range of 14-17˚C and relative humidity of 36-39% and are among the low precipitation, the prevalence of leishmaniosis disease is more.

Keywords: Zoning, Leishmaniosis, Climatic parameters, Isfahan province

INTRODUCTION

Geographic information systems (GIS) were first introduced in Canada in the early 1960s and became popular globally in the 1980s. Currently, most developed countries have already formed national and all-inclusive geographic information systems to provide valuable, timely information and data to public and private institutions, thus preventing duplicated efforts at data collection and digitization of maps in the process [1]. This system generates new pages that address a specific problem by placing different layers on top of each other, each of which is related to particular factors such as climatic information (temperature, humidity, and rainfall), ecology (vegetation, altitude, etc.) and other information related to that phenomenon. Variability in data acquisition has expanded its applications to other fields such as agriculture, veterinary, and medicine [2].

GIS is an important instrument for tracking phenomena in their spatial dimension in all fields, especially for diseases' biological and epidemiological aspects. This system allows us to study the trend of phenomena, including diseases, and evaluate their geographical distribution, hence taking more effective steps for monitoring or altering them by drawing thematic maps and risk maps related to that particular phenomenon. Various studies have been performed on controlling leishmaniasis using GIS. These studies have employed spatial information, mosquito movements, animal reservoirs, and patients to analyze the disease. The disease has been effectively controlled by identifying high-risk focal points and important transmission factors. More efficient care programs have been established. By employing geographic information systems and providing risk maps of diseases, a clearer picture of the disease's alteration trend and spatial expansion can be provided for health policymakers as components of an urban health system [3].

Geographical information systems can be considered an important way to understand how humans interact with their environment and promote or hinder the overall health of their immediate environment. The capacity of spatial modeling in GIS is directly applied to understand the spatial distribution

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of diseases and their relationship to environmental factors and the health care system [4].

By inputting information into geographical information systems, their various applications can be used properly, especially in studying infectious diseases. One of the particular applications of such geographic information systems in studying infectious diseases is the analysis of high-risk areas, where the rate of infection outbreak and transmission is abnormally high. It is noteworthy that data on infectious diseases can be collected either point-by-point or regionally [5].

Today, experts in the field highly consider studying the geographical distribution of disease carriers and subsequent mapping of climatic phenomena and illnesses. The data obtained from databases of the Geographic information systems can also be used to predict potential hazards. This method has been used to evaluate other environmental hazards, including disease reservoirs. Studies have indicated that the even relationship between geographical elements such as altitude, biological hazards, and living organisms can be illustrated using mapping. Moreover, climatic data can also be employed to predict high-risk temporal and spatial parameters [6].

Disease Zoning Maps and Determination of High-Risk Areas

Geographic information systems and sciences have a plethora of applications in healthcare and medicine, addressing the spatial and ecological aspects of disease and approaches to providing health services in the dimension of space. Before the development of modern science and technology, medical geographers also collected data required for performing spatial analyzes using field methods (e.g., information on the habitats of malaria-carrying insects) and prepared the necessary maps by only relying on manual techniques; Yet, with the advent of remote sensing technology, GPS devices, GIS, and computers with high data processing power, as well as highly efficient and advanced software programs for spatial analysis, these fields have enjoyed dramatic upturn interest. Consequently, providing a variety of thematic maps related to diseases and other health-related phenomena in a short period became a reality [7].

Maps are greatly proficient in providing health information. They can depict changes in local health and highlight specific disease clusters or the frequency (concentration) of people at risk. Hence, GIS can be heavily involved in managing and planning public health issues and studying diseases. On the other hand, the high capacity of GIS modeling permits health policymakers to analyze the spatial roots of disease [8].

The Situation of Leishmaniasis in Iran and the Study Area

Iran is one of the world's significant outbreak hubs of leishmaniasis, especially the zoonotic cutaneous leishmaniasis [9]. This disease causes many health problems for the residents of infected areas. The prevalence of cutaneous leishmaniasis in Iran has been ever-increasing in recent years. New outbreak foci have been identified in the country [10]. Despite extensive efforts and national and international investments, leishmaniasis has always been highly regarded in the country's planning [11].

The figures representing zoonotic cutaneous leishmaniasis in Isfahan province are significant. Its parasite, Leishmania major, is caused by a kind of rodent with long sweeping tails. In Isfahan, only two species of mosquitoes (*Phlebotomus papatasi* and *P. sergenti*) carry the disease. Areas infected with zoonotic cutaneous leishmaniasis in Isfahan province are the north, east and northeast parts of Isfahan city (including the Eighth Base of Air Force), Borkhar plain from Borkhar city, Shahin Shahr and Maymeh, Zavareh and Mahabad areas of Ardestan, Badrud and Agha Ali Abbas area of Natanz and Abuzid Abad region of Aran and Bidgol [12]. Isfahan province's climatic conditions and vegetation cover are very suitable for the growth of rodents and the multiplication of mosquitoes that can transmit this disease [13].

Location of the Study Area

With an area of about 107045 km^2, which equals 6.3% of the total area of Iran, Isfahan province is located between 30º43'–34º27'N 49º38'-55º32'E of the Greenwich meridian. Its capital, Isfahan city, is at 1550 meters.

Isfahan province is one of the arid and semi-arid regions of Iran. The presence of Zagros mountain range in the west of the province has hindered the arrival precipitation systems to the central and eastern regions of the province. On the other hand, the existence of low and desert areas in the eastern part of the province has affected a large part. Precipitation and rainfall in the province are a function of the topographic situation of the region, which means that in the western and southern regions of the province, which are covered by high mountains, the average annual temperature is as low as about 4 degrees Celsius. In contrast, in the plains of the eastern part of the province, the average temperature reaches about 22 degrees. Therefore, the average temperature in Isfahan province increases the gradient from west to east. The average annual rainfall is about 120 mm. The average rainfall in the western highlands of the province reaches 1300 mm, while it is as low as 60 mm in the eastern lowlands [14].

Materials and Methods

This study is descriptive-analytical research in which data regarding the frequency of people suffering from disease and its foci were gathered from the Isfahan Health Center, and data on climatic parameters (temperature, precipitation, humidity) were obtained from meteorological stations in the province. Their spatial distribution map was drawn using GIS version 9.3 (ESRI, Redlands, USA). Then, graphs of climatic parameters in different months of the year with the frequency of patients were plotted.

Results and Discussion

The maps of the location of meteorological stations, precipitation **(Figure 1)**, humidity **(Figure 2)**, and temperature **(Figure 3)** of the province and the spatial distribution of leishmaniasis in Isfahan province were plotted using GIS software.

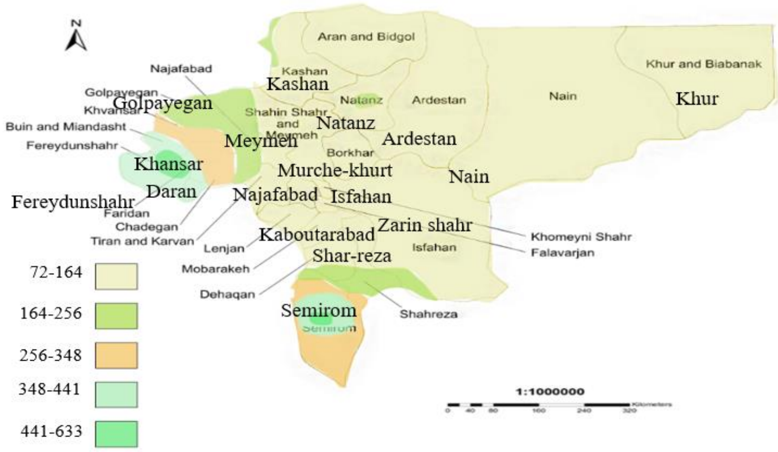

Figure 1. Map of precipitation of Isfahan

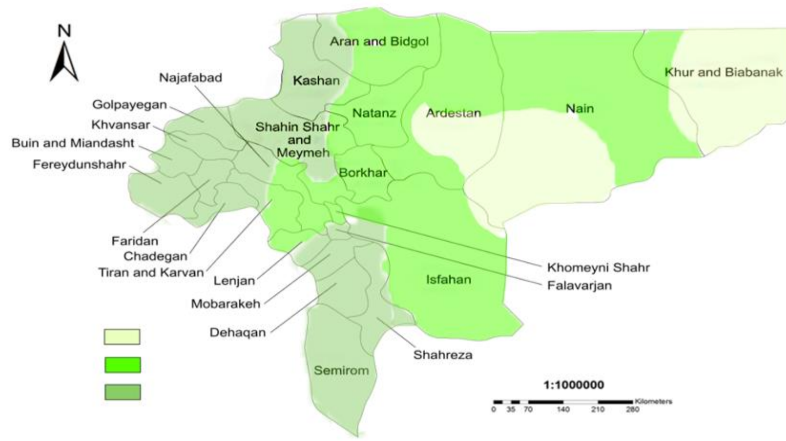

Figure 2. Map of the relative humidity of Isfahan

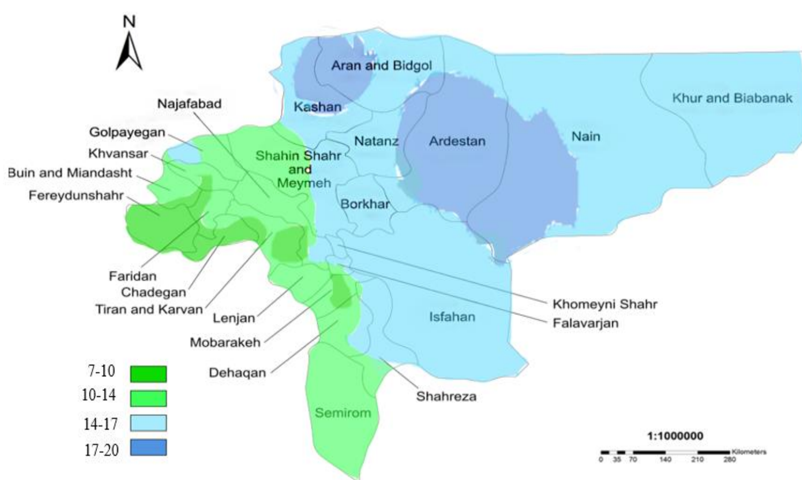

Figure 3. Temperature map of Isfahan province

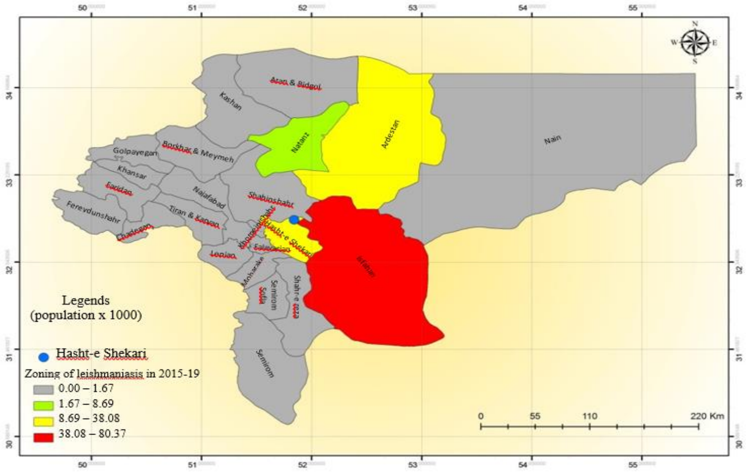

Figure 4. Spatial distribution map of leishmaniasis in Isfahan province in 2015-2019

The analysis of this map indicates that the cities of Isfahan, Hasht-e Shekari, Ardestan, and Natanz are the areas of the leishmaniasis outbreak in Isfahan province **(Figure 4)**.

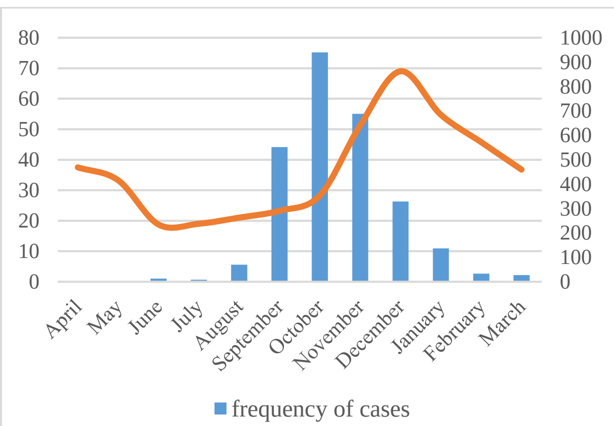

Figure 5. Graph representing the frequency of cases and monthly relative humidity in Isfahan

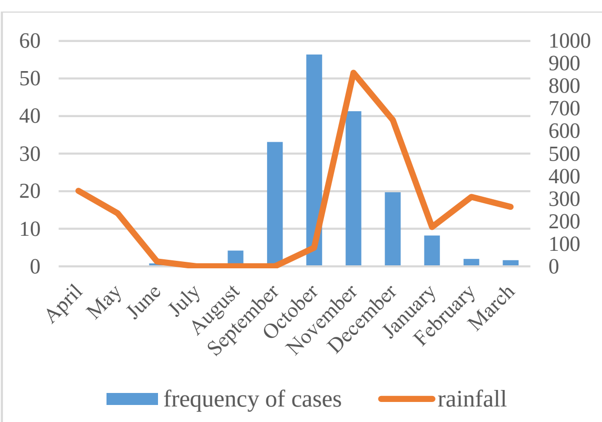

Figure 6. Graph representing the frequency of cases and mean monthly precipitation in Isfahan

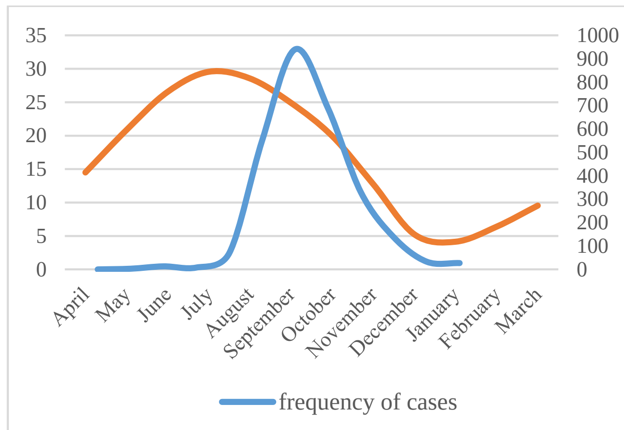

Figure 7. Graph representing the frequency of cases and mean monthly temperature in Isfahan

Investigating the Effect of Climatic Parameters on the Prevalence of Leishmaniasis in the Study Area

One of the causes of incidence and prevalence of leishmaniasis is the impact of climatic factors as well as environmental changes. Examining these factors and their relationship with the periods of occurrence and outbreak of this disease assists the authorities in predicting the intervals of an outbreak and thus adopting control measures for prevention and timely treatment of infected people, ultimately cutting the chain of transmission of leishmaniasis and preventing its spread. Similar studies conducted in Iran and around the world suggest that climatic factors are involved in the prevalence of leishmaniasis, some of which are mentioned below.

In a paper entitled “Mapping areas at high-risk of kala-azar (visceral leishmaniasis) in parts of the states of Bihar, India,” Subhakar *et al*. (2006) employed methods of RS and GIS in the study of land use information and vegetation cover and concluded that ponds, streams, irrigation canals, and rivers are very effective in maintaining the moisture of soil and subsoil surfaces with an average of 65 to 80%, which itself is suitable for feeding and spreading of immature and adult sandflies, and the two are directly correlated [15]. Morronea *et al*. (2011) studied the geographical and epidemiological aspects of leishmaniasis in Tigray. They concluded that climate and environmental changes in the region and land degradation are effective factors in leishmaniasis distribution [16]. Singh (1999) studied the role of climatic factors in the distribution of phlebotomine sandflies in arid regions of Rajasthan, India [17]. This article has studied the temperature and relative humidity during the year and the frequency of 8 different species of sandflies. In the study area, sandflies were observed only in the relative humidity range of 31 to 85%, and no sandflies were observed in relative humidity below 30%. Also, their persistence was maintained in the temperature range of 17 to 36 °C, varying for different sandfly species. The highest number of species was reported from May to October, when the relative humidity and temperature range were 40-58.1% and 28.7-34.7%, respectively. There was a significant correlation between temperature and the prevalence of phlebotomine at the alpha level of 0.05 and a weak negative correlation with relative humidity.

In a study entitled "Studying the development of high-risk foci of cutaneous leishmaniasis in the city of Kerman, and the examining environmental factors affecting them using GIS, 2002-2005," Mirzazadeh *et al*. (2008) concluded that the main foci of leishmaniasis in the eastern and central parts of the city, including Sar-Asiab, Imam and Sarbaz, are still active, while new hubs are being formed in other areas. Environmental risk factors are associated with barren lands, dirt roads, and old urban textures [3]. In a study entitled "Study of visceral leishmaniasis using GIS and remote sensing (RS) in Iran," Fakhar *et al*. (2011) described visceral leishmaniasis in an endemic center located in the northwest of Fars province to identify and prepare a map of high-risk areas. According to the results of this study, indices of vegetation cover, rainfall, altitude, and temperature are the most important risk factors in the study area and employ GIS. Remote sensing (RS) has facilitated identifying the risk factors for the disease [18].

In Isfahan province, climatic parameters (temperature, relative humidity, precipitation) were evaluated on the prevalence of leishmaniasis in prevalent areas. Based on the results of, the average peak temperature in Isfahan **(Figure 7)** city starts in June, and in July, it reaches its peak of 29.55 degrees Celsius, yet the frequency of cases is minimal. In the city of Isfahan, the incidence of the disease is very low in the spring to mid-summer, while from late summer, the frequency of cases increases and reaches its peak in October and November. The disease rate again decreases from the middle of autumn, mostly due to relative humidity and rainfall **(Figures 5 and 6)**.

Based on the results obtained from the graphs representing the relationship between climatic parameters and the rate of disease, it can be argued that the peak of leishmaniasis in foci located in the northern parts of the province, such as Ardestan, Aran and Bidgol, Kashan and Natanz cities is witnessed in September, while for the foci located in the central and southern parts of the province, the peak occurs in October. In effect, the disease started one month earlier in the northern centers of the province. This is because the climatic conditions suitable for the emergence of sandflies in the northern foci of the province are achieved one month earlier than the southern ones. However, in general, the peak months of the disease for all foci are considered to be September and October. Among all cities, when the temperatures were high, the disease rate was low, while with the increase in relative humidity and precipitation, the rate of the disease also increased. Therefore, it can be said that the rate of disease in all cities follows a seasonal and climatic trend, and considering that leishmaniasis has an incubation period of 2 weeks to a maximum of 3 months, it can be argued that the period with the most sandflies bites should be associated to two to three months before the peak of the disease, i.e., in months when the temperature is high, and the humidity and precipitation are low. This coincides with an interval when the air temperature reaches 27-30 degrees Celsius, the relative humidity is at 18-25%, and the rainfall reaches its lowest annual level.

The Effect of Vegetation and Topography on the Prevalence of Leishmaniasis

According to the findings overlapping maps of leishmaniasis outbreak foci with topographic and vegetation maps in Isfahan province, the vegetation cover of areas where leishmaniasis is more prevalent is steppe, particularly arid steppes, and then desert lowlands, which has been mostly used in agricultural applications. Hence, this type of vegetation has provided the ground for the life of the disease reservoir (parasites within rodents). With the persistence of such evidence, the research hypothesis can be confirmed in that the aforementioned geographical components are involved in the incidence of leishmaniasis.

Conclusion

Leishmaniasis is highly prevalent in semi-arid and hot regions of Isfahan province. According to studies performed in this research, in areas of the province where the growth of adult phlebotomies is seasonal, the pattern of cutaneous leishmaniasis infection in humans also follows a seasonal trend. Thus, in areas of the province that have a semi-warm and dry climate, such as Ardestan, Natanz, Aran and Bidgol, Kashan, Borkhar, Shahin Shahr and Isfahan, mature sand flies evolved in spring and summer, and new cases of leishmaniasis usually emerge in late summer and autumn. Therefore, the present study's highest disease incidence was witnessed in September and October. In Isfahan province, the main hubs of the outbreak were witnessed in hot and semi-arid regions.

Meanwhile, considering the population density, the highest rate of prevalence among all cities in the province occurred in Ardestan, to the extent that it is known as one of the prevalent areas of the disease in the province, after which the cities of Natanz, Kashan, Borkhar, Aran and Bidgol, and Shahin-Shahr are the next in terms of prevalence. The present study showed a direct relationship between climatic factors such as temperature, precipitation, humidity, and cutaneous leishmaniasis in Isfahan province. The findings suggest that in cities where the disease emerges locally by disease-carrying sandflies, the growth of adult sandflies has a seasonal trend, causing the pattern of cutaneous leishmaniasis infection in humans to follow a seasonal trend as well. In Ardestan, Natanz, Aran, Bidgol, Kashan, Borkhar, Shahin-Shahr, and Isfahan, sandflies mature in spring and early summer. In the summer, they begin dispersing and biting; hence, new leishmaniasis cases usually occur in late summer and early autumn. On the other hand, personal-social factors such as age, gender, occupation, travel, and the characteristics of a residential home are heavily featured in the prevalence of leishmaniasis.

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