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Spatial and Temporal Modeling of Cutaneous Leishmaniasis in Yazd Province, Iran: Based on the Geographic Information System (GIS)

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ABSTRACT

Background: Cutaneous Leishmaniasis (CL) remains a significant health concern in Iran, particularly in specific areas of Yazd province in central Iran. This investigation was conducted with the aim of presenting the spatial and temporal modeling of CL in Yazd province.

Methods: This was an ecological study, using data from the health department of Yazd province. The data for the cases of CL during 2004-2013 were extracted and merged into Arc Geographic Information System (GIS) 9.3 software. Cochran-Armitage test, Choropleth Map, Hot-Spot Analysis, and High/Low Clustering analysis were used to determine time trend, distribution of disease, hot-spots, and possible abnormal clustering, respectively.

Results: The results indicated a decreasing trend of incidence of CL from 199 to 29.2 cases (per 100,000 populations) during 2004-2013. The findings of the choropleth map showed that cities of Khatam and Abarkuh had a high incidence of CL. The results of the analysis of hot spots showed that during 2004-2008, cities of Yazd and Saduq were classified as cold spots of disease and the difference with neighboring cities was statistically significant ($p = 0.031$). No hot spots were obtained. In the cluster analysis, no results were obtained to separate high or low level.

Conclusion: Maps of spatial distribution of CL were generated to facilitate the decision-making capacity at provincial health department. These results showed that in regions of Yazd province neighboring Fars, Isfahan and Kerman provinces, there was a high risk of disease. Hence, in these areas, preventive strategies can be focused and pursued more purposefully.

Keywords: Leishmaniasis, spatio-temporal analysis, geographic information systems, disease hotspot

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Introduction

Cutaneous leishmaniasis (CL) is a vector borne disease worldwide. There are reservoir host and vector in its transmission cycle. The disease is transmitted by the bite of the female sand fly, phlebotomus sp. and numerous environmental factors affect the distribution and dispersion of this disease (1, 2).

Knowledge of geographical distribution and high risk areas of diseases is among the basic prerequisites in management, decision-making, and planning for health systems of the country. Currently, Geographic Information System (GIS) is a valuable instrument in the realm of health-related programs, as it enables the cost-effective formulation of disease plans and the examination of factors that affect disease patterns. This system additionally provides data pertaining to meteorological and ecological prerequisites required for specific varieties of pathogens and their vectors. Therefore, application of GIS can be a useful tool to predict the seasonal variations in diseases based on weather patterns and environmental conditions of specific regions (3-5).

CL has been seen both in the Old World and in the New World, but the kind of parasite varies in different regions. CL is endemic in 87 countries. The disease exists in 20 countries in the New World (South and Central America) and 67 countries in the Old World (Europe, Africa, the Mediterranean, Central Asia, and the Indian subcontinent); that each region has its own parasites and vector (6). A total of more than 70% of the cases (7) occur in 10 countries, including Afghanistan, Algeria, Brazil, Columbia, Costa Rica, Ethiopia, Iran, Peru, Sudan and Syria. In addition, CL is increasing in some countries such as Afghanistan, Venezuela, Pakistan, and Turkey (8, 9).

Studies have shown that the distribution of CL in Iran is non-uniform and has different focus areas in the country, including Fars, Kerman, Yazd, Isfahan, Semnan, and Ilam provinces (10). CL is mostly seen in the central regions, afar from Zagros and Alborz mountains. The distribution of the disease in the country is in accordance with dry-desert climate and is less seen in cold regions (11). Although leishmaniasis is more associated with dry weather conditions, sandflies need high humidity, cool temperatures and rich soil (12). In addition, since sand fly has short flight range, it needs to be close to humans for transmitting the disease.

According to the studies, it seems that geographic factors affect the occurrence of the disease (7, 12). Perhaps, it can be said that spatial dimension is one of the most important epidemiological factors affecting the incidence and prevalence of CL disease both in humans and in animals. This effect can be evaluated using tools such as GIS (13). Accordingly, there have been different studies in Iran evaluating the prevalence and incidence of leishmaniasis (14-19). Mapping and distribution of its vector and host reservoirs have been also prepared (20, 21). Thus, due to the role of animal hosts and vectors in CL transmission, it is difficult to control the disease (22), but through active case detection, identification of high risk areas, early treatment, and factors determining transmission, the disease is effectively controlled and more effective care programs are established (23).

CL is considered as a health problem in Yazd province and since there are various focus areas for this disease and its geographical distribution in this province is different (24), identifying and examining high-risk areas and their temporal trends can be effective for the distribution of health services and improvement of high quality service. It seems necessary to conduct case studies in this area to mark the areas that have the potential outbreak of disease, and to plan for preventing health, ecological and environmental problems. Therefore, this study aimed to determine the temporal and spatial process of CL in Yazd province.

Methods

The study area

As one of the focal points of occurrence of this disease, Yazd province in Iran was studied in this research. This province is in central Iran

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and located between latitudes 29 ° and 48 'to 33° and 30 minutes North and longitudes 52° and 45 minutes to 56° and 30 minutes east of the prime meridian. It is limited to Isfahan province from North and West, to Khorasan from the northeast, to Fars from the southwest and to Kerman from southeast (Figure 1). This province has an area of 76,469 km^2, and covers 5.4 percent of country which is located in the center of Iran.

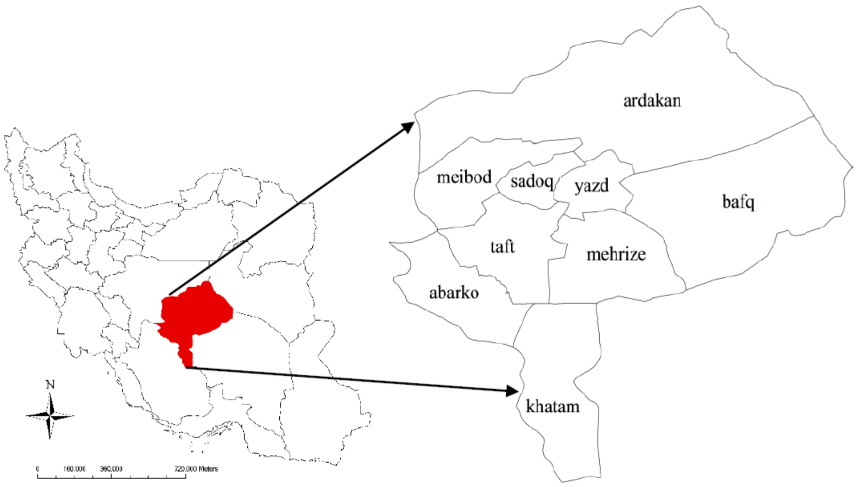

Figure 1. Map showing the location of Yazd province.

Collecting and managing data

The data related to those who had been treated and followed up in health centers in Yazd province with a diagnosis of CL during 2004-2013 was obtained from University of Medical Sciences in this province. In order to obtain the high-risk population, demographic information was obtained from statistics center of the province and was divided on the basis of cities and was recorded into Excel software. Latest updated electronic map of the province was prepared at the city level and revised according to the level of disease reporting. To ensure seamless connection of data tables from Excel the attribute table of the map, an ID was added in Excel tables of CL incidence. This code was then used to merge two databases. Arc GIS software version 9.3 was used for spatial and temporal analysis.

Measuring disease incidence

After entering the data of cities, calculations of incidence per hundred thousand people in the city were performed using the following formula.

$$incidence = \frac{Number\ of\ reported\ cases\ of\ cutaneous\ leishmaniasis}{Total\ number\ of\ people\ at\ risk} \times 100{,}000$$

For calculating ten-year cumulative incidence of CL in each city, total number of CL cases reported during the decade was placed in the numerator and the average population at risk during that period was used in the denominator.

Time trend analysis

Cochran-Armitage test for linear trend was used to analyze the possible trends of disease incidence over the study period. This test assessed either decrease or increase in the rate of disease over different period and also was used to determine significant changes in the process of disease (25).

Choropleth maps

A choropleth map is a mapping tool that uses a color range to represent changes in variables across the polygons generated at the district level. Choropleth maps were used to demonstrate spatial distribution and temporal changes of disease incidence. These were thematic maps depicting changes within each polygon over the period of five and ten years.

Hot Spot Analysis

The general test of hot spots analysis was used for the entire province to identify hot spots of the disease incidence. Hot spots analysis computes

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Getis-OrdGi* statistics for each polygon in the data. The calculated G score indicates where the data values are greatly or slightly clustered. This tool, in fact, considers every polygon in the framework of polygons in its neighbors. If a complication has high value, it is interesting and holds importance, but a hot spot alone may not be statistically significant. To consider a statistically significant hot-spot, a polygon itself and polygons that are in its neighbors must have high values. Total local polygon and its neighbors are relatively compared with total polygons. When the total local is relatively different such that the difference cannot be considered by random, statistically significant G scores are achieved (26). The greater the Z score, the higher values are clustered and hot spot is formed. For statistically significant negative G score, smaller G score means severe clustering of smaller values and thus reflecting cold spots. Given that one of the objectives of the study was to determine the shifts in focus areas and this may happen over a period of more than one year, to achieve this objective, a map of hot spots was drawn for five- and ten-year periods.

Clustering of disease distribution analysis (High/low clustering)

The analysis of high/low clustering was used to determine the clustering pattern of CL disease. To attain this objective, the study utilized General statistics (G statistics), a technique created by Getis and Ord with the capacity to gauge the distribution of high or low incidence regions. The presence of a positive or negative z-score for G statistics signifies the spatial concentration of high or low incidence, respectively (11). The clustering analysis was performed in one, five, and ten years.

Results

Overall result and time trend

The total number of cases reported were 6810. An average incidence of 75.89 per 100000 was estimated in Yazd province. Fig 2 depicts the incidence time trend of CL. As shown in this figure, the time trend in Yazd province represents degrees of fluctuations. The highest and lowest levels of incidence were reported in 2004 (199.1 per 100,000 people) and 2013 (29.2 per 100,000 people), respectively. In addition, Cochran-Armitage analysis revealed the departure of the incidence from linear trend ($p < 0.001$).

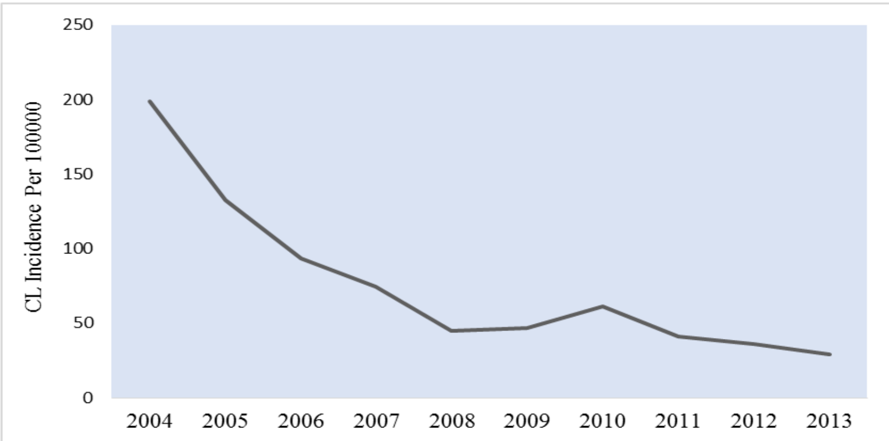

Figure 2. Time trend of CL incidence in Yazd province during 2004–2013.

Investigation of disease incidence within each city also showed that cities of Khatam, Abarkuh, Bafq, and Ardakan, had the highest disease incidence, so Khatam city was ranked first for most of years (Fig 3).

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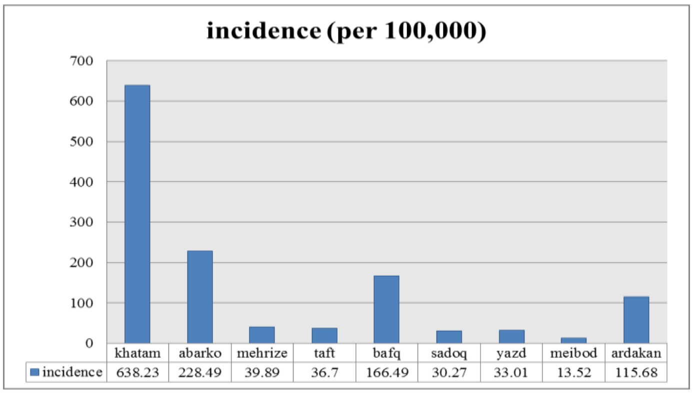

Figure 3. The overall mean of CL incidence in cities of Yazd province from 2004 to 2013.

Choropleth Map

Choropleth mapping showed that during entire study period, Khatam and Abarkuh cities had the highest incidence of disease, followed by Bafq (during 2004 – 2008) and Ardakan (during 2009 – 2013) (Fig 4).

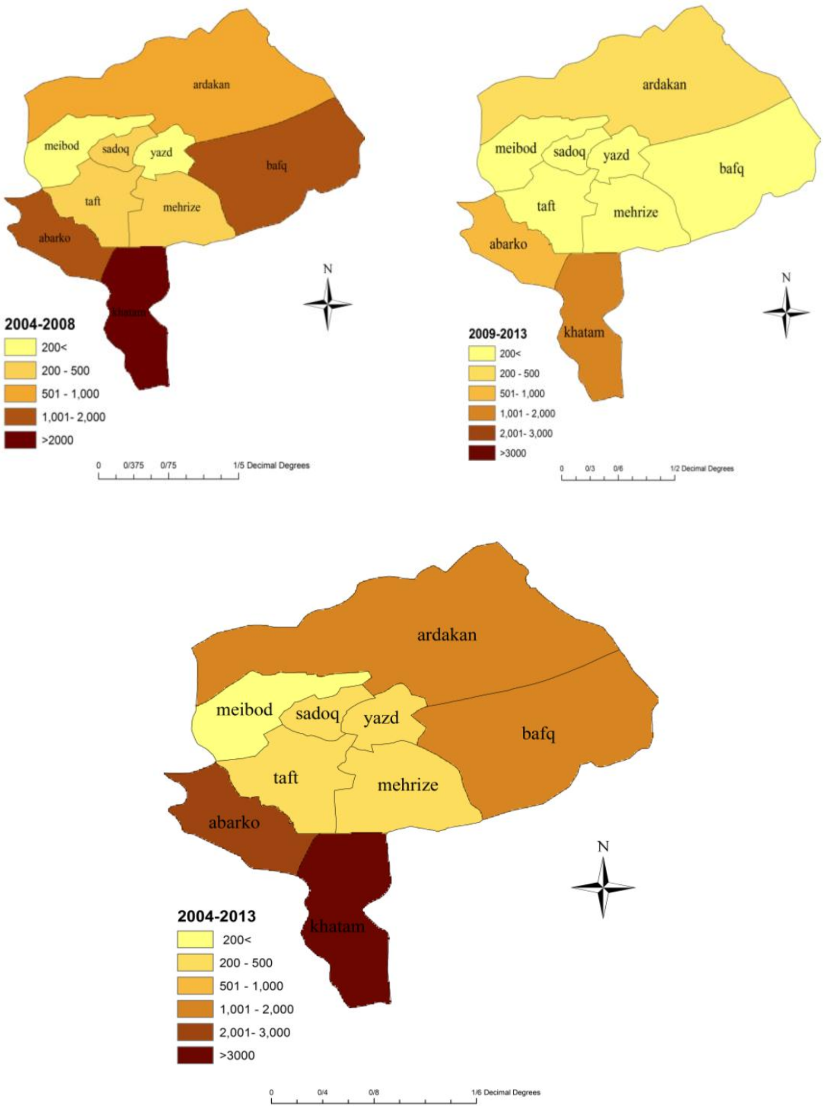

Figure 4. Choropleth map of CL incidence in Yazd province from 2004 to 2013.

Analysis of hot spots

The results from the hot-spot analysis showed that during 2004-2008 years, cities of Yazd and Saduq were classified as cold spots of disease and the difference with neighboring cities was statistically significant ($p = 0.031$). Although the average incidence rates of the disease in Saduq ($p = 0.088$) and Yazd ($p = 0.069$) were lower than the average for the province during 2009-2013, this difference was not significant. During the ten-year period, cities of Saduq ($p = 0.041$) and Yazd ($p = 0.036$) were recognized as cold spots; this difference was significant (Fig 5).

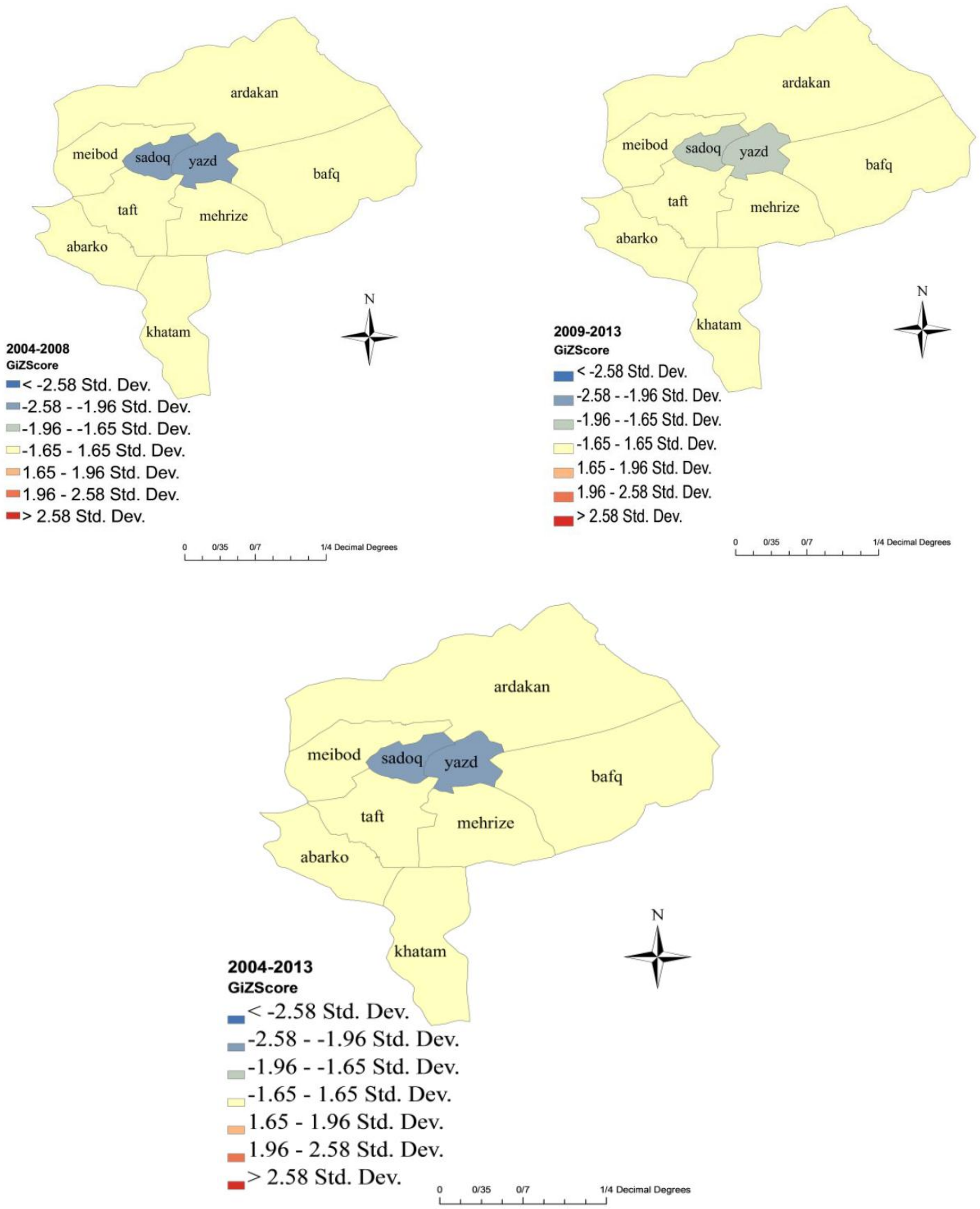

Figure 5. Hot-Spot map of CL in Yazd province from 2004 to 2013.

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Hot spots analysis showed that the disease incidence in the central part of the province was less; therefore, this central region is considered as a low risk area.

Cluster analysis

Based on the clustering analysis characterized by high and low values, as explored in this study through the dissection of one-, five-, and ten-year periods, no significant high or low clusters were observed.

Discussion

CL is a parasitic disease that is common in most parts of the world, especially in the tropical and subtropical areas (27). The disease has spread across the world, including Iran and its cases have been increasing in recent years due to the gradual migration towards urban areas, population displacement, encounter of susceptible people, environmental and ecological degradation, climate changes, malnutrition, and HIV (1).

CL has been endemic in Yazd province for many years; therefore, its prevention and control is one of the most important health priorities in the area (24, 28). In this study, efforts have been carried out to identify the spatial and temporal variations of its distribution during the last ten years using GIS. Existing literature regarding leishmaniasis, its vectors and important reservoirs in Iran, highlights that CL is mostly seen in grasslands, deserts and semi-deserted areas and are away from areas of higher altitudes i.e. Zagros Mountains (16). Due to this geographical position, Yazd province has been affected by this disease.

In the present study, the total number of cases reported in the province during the study (2004-2013) was 6810. Studies have estimated the ratio of undiagnosed cases to diagnosed ones as 3 to 5 times (29). Therefore, in this study the true extent of the disease in this period can be estimated around 18-30 thousand people.

Generally, the disease incidence over a ten-year period has declined. Similarly, many epidemiological studies on CL around the world have also indicated that the incidence of this disease in different regions has been altered in a way that most regions show a downward trend (9, 30-32). A study conducted in Iran suggests that the disease incidence increased in 2004 and then had a decreasing trend that results of this study are consistent with the present study (11, 33). These results indicate that the disease was epidemic in 2004 in some of provinces of Iran. Some studies have attributed decreasing rainfall as the major reason for increase in the cases of CL. Reduced rainfall and drought lead to the reduction in farming activities, resulting in migration of rodents to dwelling places (33).

For the entire period of the study, Khatam city had the highest incidence of the disease. Due to the geographical location of the city, which is bordered by provinces of Fars and Kerman, plausibly it is affected by these provinces and also in Bafq city which is adjacent to Kerman and Abarkuh city bordering with Fars city, high incidence of the disease was reported and the same trend was observed in Ardakan city bordered by Isfahan province.

One study conducted an analysis of hot spots in Iran and revealed that the prevalence of CL disease is concentrated primarily in the central region. Distribution of disease is in accordance with dry and desert climates and it is less common in colder regions. Thus, Yazd, Kohgiluyeh and Boyer-Ahmad were identified as hot spots of disease (11).

Studies have indicate that the prevalence of CL exhibits spatial variations. An investigation has identified the northeastern and southwestern regions of Qom province as areas of heightened risk for the disease (34). Another study that was conducted in Bihar, India, showed that the disease is more common in the South, East, and Northwest areas and is less common in central areas (35).

Based on the results of high\low clustering analysis, which examines the pattern of disease distribution in the population, no high or low frequencies foci were reported; as a result of which clustering of disease in space and time was not statistically significant. Therefore, it can be concluded that no specific pattern of disease

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clustering was observed in this province.

Consistent to the current study result, the study by Holakouee et al., (11) showed that the reason for lack of clustering is likely to be related to the level of study analysis; if the study was conducted at lower levels such as district and villages, more accurate results would have been gained from the cumulative pattern. Therefore, in the present study with a higher level of analysis, we failed to find significant clustering due to smaller number of polygons under study.

However, several studies have shown that CL disease has spatio-temporal clustering patterns. In a study conducted in Turkey, distribution of the disease was non-random and significant clustering was observed in the southeast of the country (36). Likewise, a similar study in Afghanistan showed that most cases of the disease in the Northeast and Southeast regions of the country has a clustering pattern (37).

Another study by Rodríguez EM et al. in rural areas of Venezuela indicated that the clustering of disease in space and time dimension was statistically significant. The disease had clustering distribution in Northeast areas (38).

Given that leishmaniasis manifests in both rural and urban settings, the epidemiology of these two types of the disease differs. However, the majority of available data fails to account for this distinction, rendering it impractical to differentiate between the data types. The primary limitations of this study stem from deficiencies in Iran's current monitoring system, resulting in under-reporting of diagnosed cases and/or inadequate and delayed diagnoses. Consequently, the actual number of disease cases is likely underestimated.

In addition, it should be noted that this study only examined the spatial and temporal distribution of this disease; while in infectious diseases especially leishmaniasis, other factors including social, economic and environmental factors affecting the incidence of the disease such as individual and collective safety and factors affecting the hosts and carriers must also be considered. It is, therefore, expected that in future more studies should be performed examining various socio-demographic factors related to the disease and its distribution.

Conclusion

The spatial distribution of CL and geographic maps derived from it can serve as a valuable tool for health policymakers. Such an analytical approach can facilitate the identification of regions that require urgent attention in terms of budget allocation, human resources, and equipment. The findings of this investigation indicated that the prevalence of the disease was substantially lower in the central areas of Yazd province, whereas the adjoining cities of Fars, Isfahan, and Kerman provinces exhibited a higher incidence of CL. Consequently, the higher prevalence of the disease in the neighboring provinces had a significant impact on the cities adjacent to Yazd province border.

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Conflict of interest

The authors declare that there is no conflict of interest.

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None.

Ethical considerations

This research was conducted in strict compliance with the ethical principles outlined in the Declaration of Helsinki (2013 revision) and adhered to all applicable institutional ethical guidelines and regulations. Prior to commencing any research-related procedures, the study protocol underwent formal review and received approval from the Ethics Committee of Shahid Sadoughi University of Medical Sciences.

Code of ethics

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Authors' contributions

H. B, M. HL, conceived and designed the analysis; R. P, F. M, M. B, Data collection; H. B, M. B, Data analysis; E. F, Drafting of the manuscript. All authors contributed to and reviewed the final version of the manuscript. All the authors met the criteria of authorship based on the recommendations of the international committee of medical journal editors.

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