RESEARCH ARTICLE

The Incidence and Geographical Distribution of Brucellosis in Iran Using Geographic Information System and Prediction of its Incidence in 2021

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Keywords

Incidence rate • Brucellosis • Geographic Information System • Iran

Summary

Background. *Brucellosis is one of the most challenging health issues in many developing countries including Iran. The purpose of this study is to investigate the incidence and geographical distribution of brucellosis using Geographic Information System (GIS) and to predict its incidence in Iran in 2021.*

Method. *This is a descriptive-analytical cross-sectional study, which contains spatial and climatic information along with the prevalence rate of brucellosis in Iran. Disease information was obtained from the National Center for Infectious Diseases Management during 2011-2015. Then, Arc GIS version 9.3 was used to plot the geographical maps for the incidence and frequency of the disease. Using the Raster calculator tool, the disease prediction map for the future was plotted. For proper spatial distribution of hot and cold spots, Getis-Ord-Gi statistic was employed.*

Findings. *The highest incidence of brucellosis during 2009-2015 was observed in the western provinces of Iran (North Khorasan, South Khorasan and Razavi Khorasan provinces). The incidence of brucellosis in Iran decreased from 2009 to 2011 but it exhibited an increasing trend from 2011 to 2014. The provinces of Kurdistan, Lorestan, Ilam, Zanjan and Kermanshah may be among the hot spots in terms of brucellosis incidence in 2021.*

Conclusion. *We predicted significant variations in brucellosis risk distribution in Iran in the coming years. In the western and northwestern provinces, which are among the high risk areas for the incidence of this disease in the future, this disease can pose a serious health threat to the residents of these areas.*

Introduction

Brucellosis is not only the most common zoonotic disease, but as a newly emerging disease, poses serious challenge to health policy makers worldwide [1]. Brucellosis is a major economic and public health issue with diverse geographical distributions worldwide [2].

The incidence of brucellosis is about 200 per 100,000 population in some parts of the world [3]. This disease is still endemic in the Mediterranean, Middle East and Central Asian countries [4]. In some European and North American countries, the disease has been eradicated due to restrictions posed on international trade of animals and animal products [5]. Compared to Europe, North America and other developed areas of the world, the main burden of the disease is felt in the Mediterranean, South and Central America, Africa, Asia, the Indian subcontinent, Eastern Europe and the Middle East, especially Syria, Iraq, Egypt, Turkey and Iran [6, 7]. In addition, brucellosis care data often remains unknown due to diagnostic errors and lack of reporting and diversity of clinical cases [8].

There are significant differences in the incidence of this disease among countries. Iraq and Egypt have witnessed a 4 to 5-fold increase compared to other areas. This difference in incidence rates across regions reflects disparity in geographic, environmental, social, and economic factors and lifestyle [9].

Iran has the second highest prevalence of the disease worldwide [1]. However, the disease rate is not uniformly distributed throughout Iran, and this figure is higher in the western and northwestern provinces, so that this disease is endemic in some parts of Iran [10]. According to the latest statistics, the highest prevalence of the disease in Iran, ranging from 31 to 41 in 100,000 people, belongs to the provinces of Lorestan, Markazi, East Azarbaijan and Kermanshah [11, 12].

Location and time are two important factors in the distribution of brucellosis in Iran. Hence, many studies have used GIS to investigate the distribution of this disease in Iran and elsewhere in the world [13, 14].

The GIS is utilized in two health spheres of epidemiology and health care [15, 16]. Therefore, since public health issues and disease spread are directly related to the geography of a region and always possess a spatial dimension, GIS can play a crucial role in managing and

planning public health issues and studying disease spread [17]. Therefore, as with other epidemics, gaining insights into the geographical pattern of brucellosis incidence is vital to interventions and disease management. The purpose of this study is to evaluate the incidence and geographical distribution of brucellosis using GIS in Iran.

Method

This is a descriptive-analytical cross-sectional study. The study includes spatial and climatic information as well as information on the prevalence rate of brucellosis in Iran. Initially, data on brucellosis from 2009 to 2015 were collected and categorized from the Centers for Disease Control. The tables of brucellosis frequency and incidence were drawn for each year. The incidence rate for 100,000 people in the country was calculated. Then, GIS software was used to plot the map of the incidence and frequency of disease. The 2017 map of political divisions of Iran in vector format, developed by Iranian Mapping Organization, was used to develop a spatial database of the disease (To link descriptive information of the disease to the spatial data, a database is designed in GIS, and then verified by determining its geographical location using Google earth software).

Since data on incidence are obtained based on the findings of routine healthcare system, the difference in incidence that was observed in different provinces can be largely dependent on the sensitivity of the healthcare system to record and report cases in these provinces.

Laboratory diagnostic criteria for this disease are based on:

A) Separation of the agent (Brucella spp.) from clinical specimens in the culture site;
B) Brucella agglutination titers (STAT≥1/80) or seroagglutination test in one or more serum samples prepared after the onset of symptoms, or an at least four-fold increase in Brucella agglutination titers 2 weeks after the initial test;
C) Testing 2-ME ≥ 1/40 (2-mercaptoethanol);
D) Coombs Wright test with 3 dilutions greater than Wright.

In order to make laboratory diagnostics at health centers, public and private laboratories across the country, directly on patient serum samples due to inadequate distribution and inadequate maintenance of Rose Bengal antigen, following clinical suspicion and physician testing. The Wright T test is also called standard agglutination test tube (STAT), and called agglutination test serum (SAT) will be done.

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By preparing the geographic database of the disease, descriptive information such as incidence and frequency of disease was included in the GIS descriptive information table by Microsoft Excel software. Subsequently, spatial analysis was performed to map the distribution of disease incidence and frequency in Iran from 2009 to 2015.

With the information of each province available, the incidence and frequency of disease was developed for the whole country. In order to plot the map of interpolation, the inverse distance interpolation (IDW) method was used [18]. Interpolation map was plotted according to the total frequency and incidence of the disease. In order to plot the disease prediction map, we assumed that in regions with the highest incidence or frequency of the disease and the highest recurrence in a given period, the disease is more likely to spread. The fuzzy map of the disease over a specific period were multiplied by recurrence map of the disease in a given period by the Raster calculator, and finally the projection map of disease in future was plotted. In this map, the most likely areas of disease are shown in red.

Hotspot analysis

The Getis-Ord-Gi* statistic was used for appropriate spatial distribution of hot and cold spots. A disease is recognized as a hot spot when its figures and those of its surrounding conditions are fairly high. When Getis-Ord-Gi* statistic is calculated to be 1, 2, 3, the confidence interval is estimated at 99%, 95%, 90%, respectively. The Getis-Ord-Gi* statistic is computed as follows [19].

Results

The results of the study revealed that brucellosis incidence in males was significantly higher females (59% vs 41%).

About 78% of patients lived in rural areas and 21% in urban areas. The incidence was 21% (1%) in the nomadic population, which may be due to the lack of reporting of the disease in the nomadic population.

A history of contact with livestock was reported in 78.7% of cases. 60% of patients had a history of consuming non-pasteurized dairy products and about 19% reported a history of contact with an infected person in the family as a source of contamination.

According to the results of study, the highest incidence of brucellosis was observed in the age group of 59-30 (42.98%), and of all cases of brucellosis, 5.61% was related to children under 8 years of age and 11.22% to people aged above 60 (Tab. I).

The results of the study exhibited that the highest incidence of brucellosis during 2009-2015 was in Lorestan, Hamedan and Kurdistan, Markazi, Kermanshah, East and West Azerbaijan and North, South and Razavi Khorasan provinces, with 28 to 103 cases per 100,000 people (Tab. II).

The results showed that the trend of brucellosis in Iran from 2009 to 2015 has been decreasing and increasing (Fig. 1).

The GIS maps show the incidence of brucellosis in different provinces during 2009-2015 (Fig. 2).

As displayed in Figure 3, the southern provinces (regions with higher temperatures, rainfall, vegetation and lower

Tab. I. Demographic information of patient with brucellosis in Iran from 2011 to 2015.

Frequency (%)	Variable	
28137 (41)	Female	Gender
40612 (59)	Male	
53371 (78)	Rural	Living environment
14314 (21)	Urban	
459 (1)	Nomadic	
54683 (78.7)	Yes	Domestic animals contact
11648 (16.8)	No	
3163 (4.6)	Indistinctive	
41303 (59.4)	Yes	History of non-pasteurized dairy products
10441 (15)	No	
17750 (25.6)	Indistinctive	
13276 (19.1)	Yes	History of contact with affected person
49732 (71.6)	No	
6486 (9.3)	Indistinctive	
3798 (5.61)	0-8	Age group
9831 (14.53)	9-18	
17330 (25.61)	19-29	
29080 (42.98)	30-59	
7593 (11.22)	60 ≤	
463 (0.7)	Yes	Complications of the disease
20103 (28.9)	No	
48925 (70.4)	Indistinctive	

livestock grazing) had the lowest incidence rates, and the northern, western, and northwestern provinces (regions with lower temperatures but rainfall, vegetation and higher livestock grazing) had the highest incidence of brucellosis during 2009-2015 period.

The incidence rate was projected for 2021 using ARC GIS software version 9.3, as shown in Figure 4. The prediction results for 2021 suggest that these provinces may witness a higher incidence rate in 2021, but this rising trend may be variable between provinces, with Lorestan, Hamedan and Kurdistan provinces facing a more steeped upward trend. Sistan and Baluchestan, Hormozgan and Khuzestan provinces may see slight variations in the incidence rate. In other words, tropical provinces are less likely to demonstrate any increasing or decreasing trends whereas cold and mountainous provinces (Lorestan, Hamedan, Kurdistan, East and West Azerbaijan, etc.) may experience a high incidence of brucellosis in 2021.

Overall, the results regarding brucellosis incidence rate in 2009–2015 and the prediction of its incidence rate in 2021 suggest the absence of comprehensive measures to control the disease. With the current trend, we may observe a substantial increase in the incidence rate in most provinces of Iran.

Tab. II. Brucellosis incidence per 100,000 people in Iran during 2009-2015 period.

2015	2014	2013	2012	2011	2010	2009	Year	ID
							Province	
44.24	44.55	41.35	35.05	21.40	41.39	43.85	East Azerbaijan	1
50.22	50.86	56.49	56.67	34.47	32.07	31.52	West Azerbaijan	2
19.69	19.83	20.13	14.55	14.90	16.41	16.96	Ardabil	3
16.53	16.68	19.21	13.27	10.47	8.17	9.42	Isfahan	4
5.24	5.34	6.47	3.42	3.19	1.45	0.00	Alborz	5
25.99	26.26	23.73	22.38	20.61	16.58	25.14	Ilam	6
4.99	5.09	3.06	2.94	2.71	1.00	2.06	Bushehr	7
2.74	2.77	2.55	2.01	1.52	2.62	1.58	Tehran	8
23.69	23.94	21.99	24.67	28.72	16.14	11.96	Chaharmahal and Bakhtiari	9
53.97	54.61	33.07	23.21	29.26	36.53	21.20	South Khorasan	10
39.48	40.05	42.23	35.24	32.65	30.75	30.09	Razavi Khorasan	11
44.44	44.94	39.08	29.16	23.73	15.54	16.35	North Khorasan	12
6.60	6.69	9.42	7.33	7.35	10.19	15.64	Khuzestan	13
58.32	58.93	43.01	30.99	27.95	22.79	26.36	Zanjan	14
31.05	31.57	33.79	19.50	18.54	15.57	24.27	Semnan	15
3.51	3.60	6.09	4.31	6.08	7.54	4.47	Sistan and Baluchestan	16
24.36	24.60	24.87	28.05	20.54	14.75	18.75	Fars	17
35.84	36.19	29.53	26.52	26.04	16.74	18.45	Qazvin	18
7.45	7.58	11.90	6.31	6.86	6.64	3.61	Qom	19
103.19	103.94	64.46	50.66	35.88	24.78	28.25	Kurdistan	20
16.33	16.57	19.17	15.96	14.32	16.60	19.89	Kerman	21
62.77	62.99	53.92	39.10	39.74	37.44	43.85	Kermanshah	22
27.17	27.60	12.92	10.16	9.26	9.04	17.90	Kohgiluyeh and Boyer-Ahmad	23
27.59	28.06	32.08	19.08	11.14	16.28	16.77	Golestan	24
2.36	2.37	2.63	3.04	2.66	2.84	1.80	Gilan	25
96.86	97.67	71.54	65.48	48.18	37.86	48.02	Lorestan	26
11.19	11.28	16.69	18.23	14.15	14.85	12.68	Mazandaran	27
34.69	35.03	41.33	51.47	42.36	37.64	46.50	Markazi	28
1.05	1.07	1.71	1.37	1.08	2.66	3.32	Hormozgan	29
93.65	94.12	84.30	64.71	47.50	37.55	32.78	Hamedan	30
15.24	15.56	26.86	13.95	15.08	12.30	13.76	Yazd	31
25.6	25.94	24.83	21.11	16.96	16.52	17.61	Total country	---

Fig. 1. Trend of Brucellosis in Iran during 2009-2015.

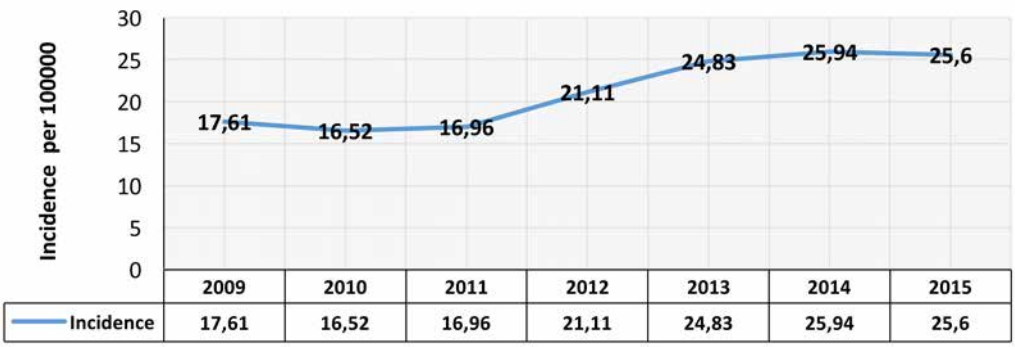


Fig. 2A. The incidence of brucellosis from 2009 to 2015.

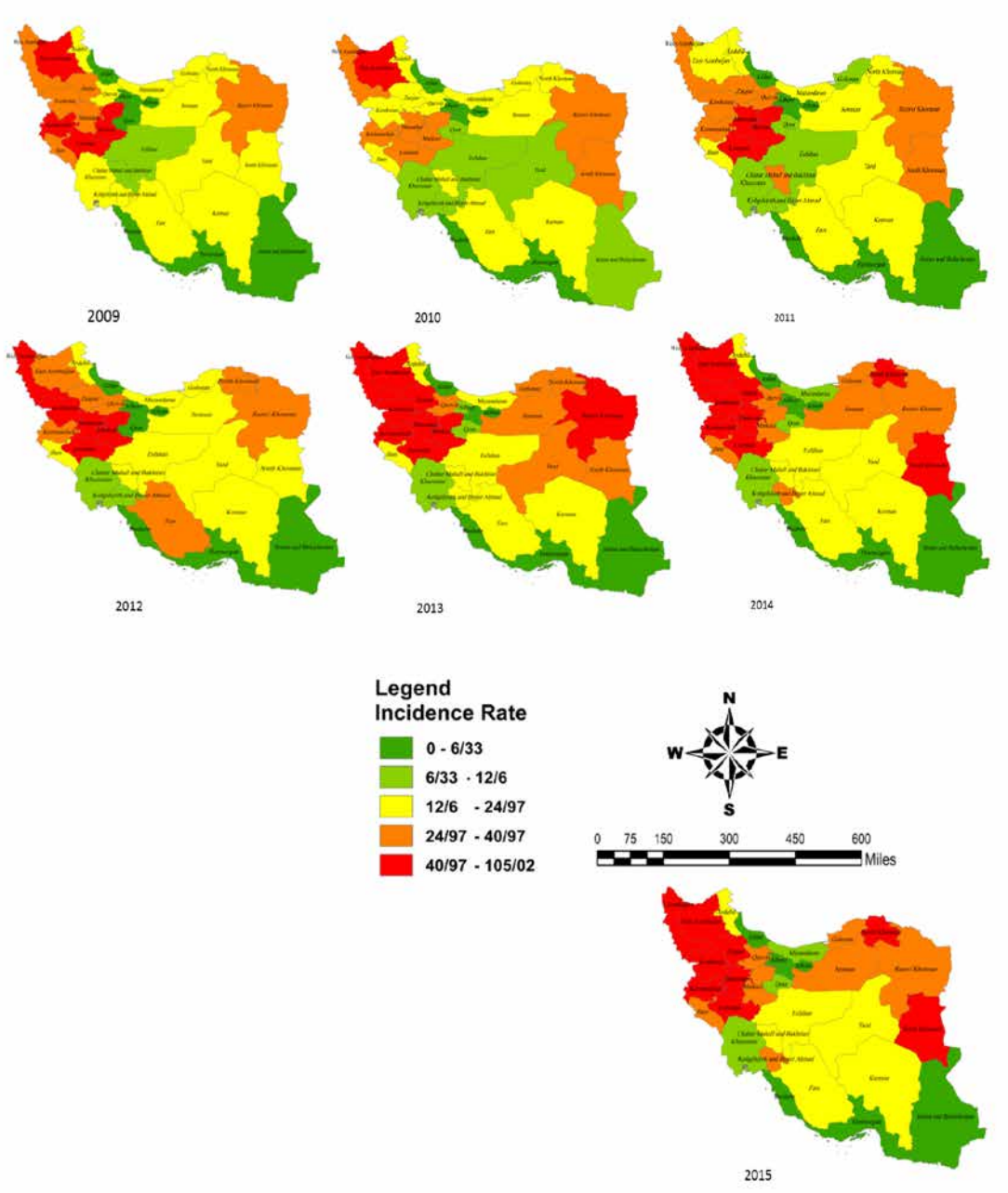


Fig. 2B. The incidence of brucellosis in 100,000 people over 2009-2015 period in each province.

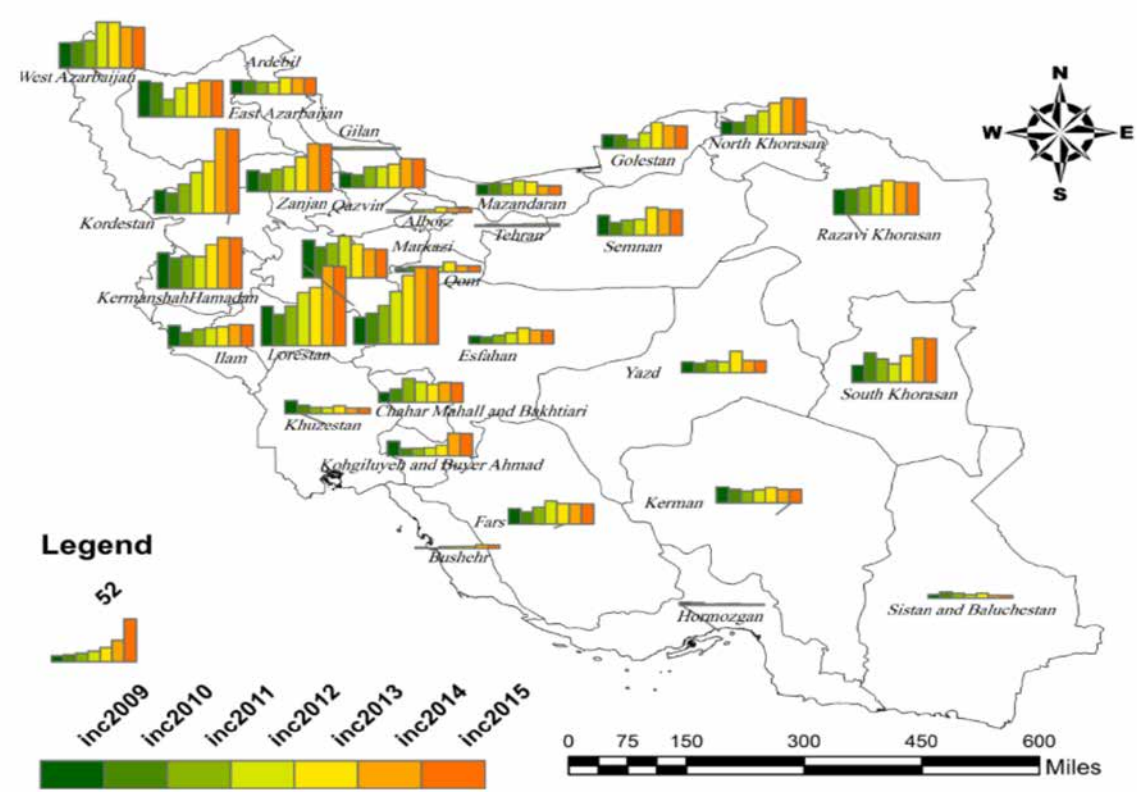


Fig. 3. Average incidence rate of brucellosis in Iran during 2009-2015.

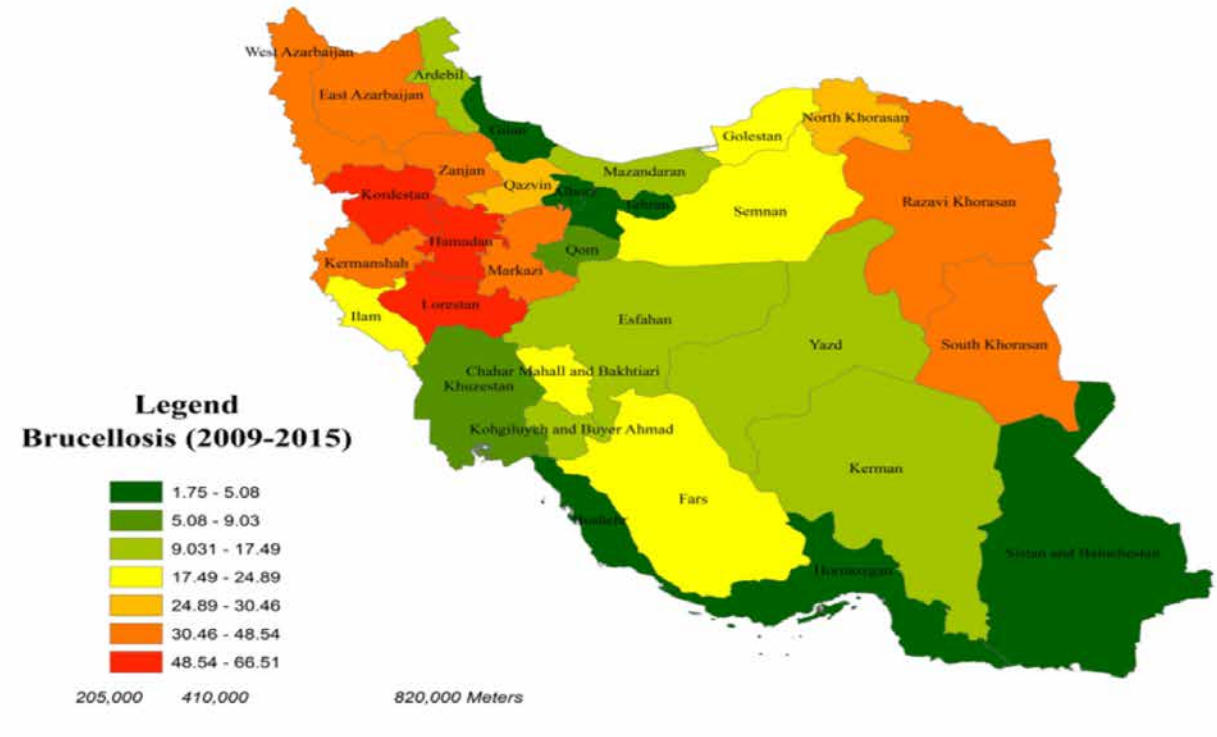


Figure 4. Prediction of brucellosis incidence rate in 100,000 people in Iran in 2021.

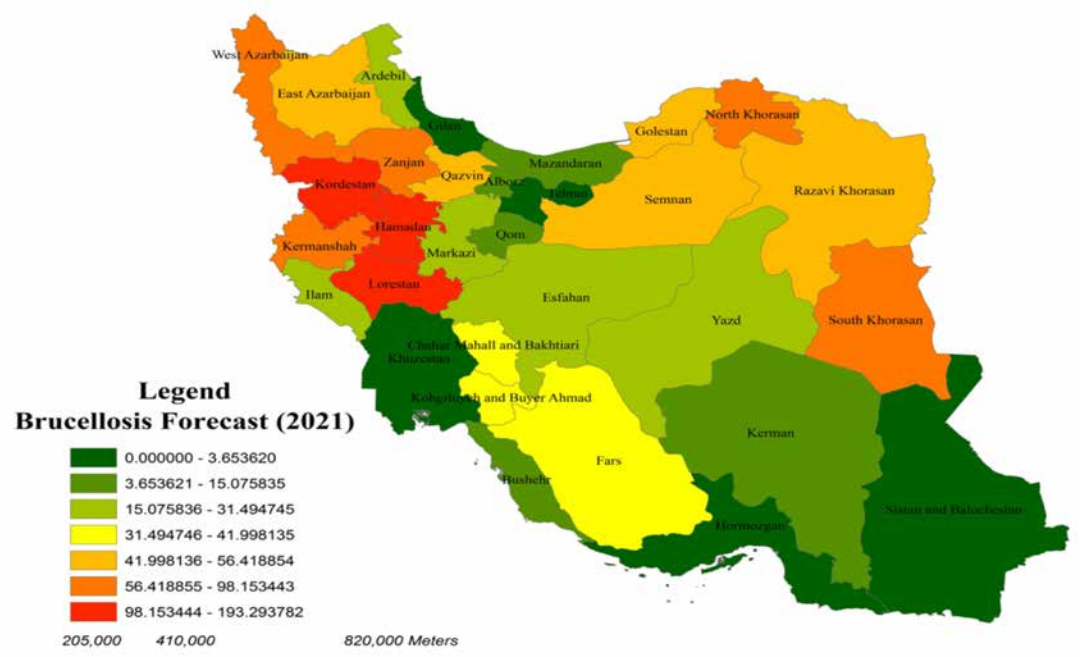
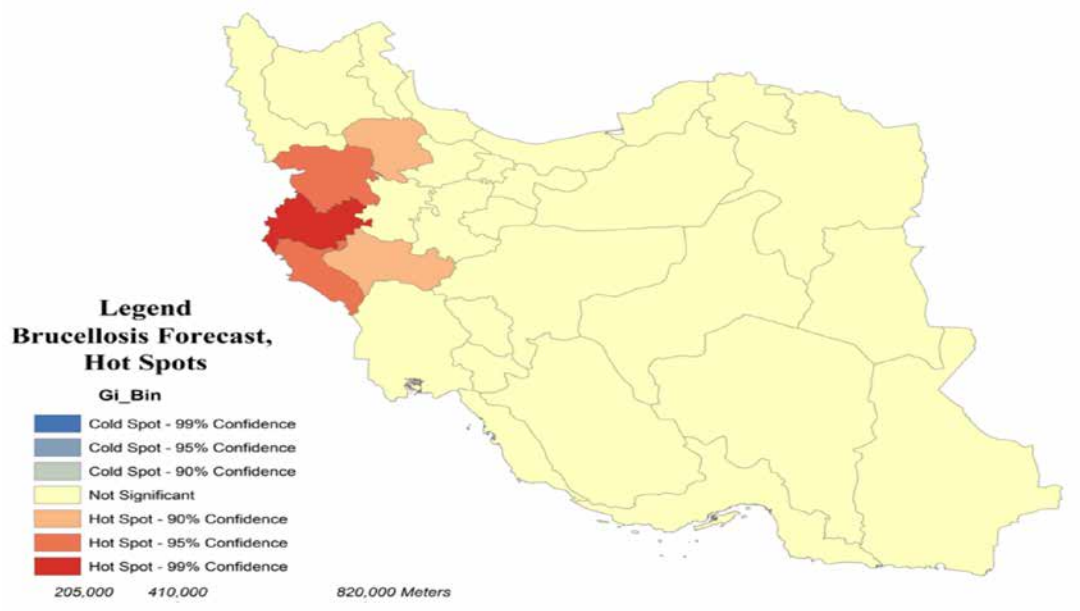


Fig. 5. The predicted hot and cold spots for the incidence rate of brucellosis in Iran in 2021.



According to the results of hot spot analysis in Figure 5, Kurdistan, Lorestan, Ilam, Zanjan and Kermanshah provinces may be among the hot spots in terms of incidence rate in 2021. The incidence rate of this disease in 2009-2015 period as well as the results of the hot spot analysis reveal that Lorestan and Kurdistan provinces face a grim prospect compared to other provinces and the incidence rate is expected to grow exponentially in future with the current increasing trend.

Discussion

The importance of brucellosis is not due to health-related complications of this disease but rather grave economic challenges posed by this disease, especially in developing countries [20, 21]. Iran is an endemic area for brucellosis and the incidence of this disease represents a serious national public health issue [21].

There are substantial variations in the frequency of

brucellosis in different regions of Iran. The incidence varies from 98 to 130 cases per 100,000 people, with the southern regions of Iran reporting the lowest rate of infection [22]. The highest incidence rate in Iran, 130 per 100 000 population, has been reported from Hamedan province in the west of the country [23].

According to the results of our study, the highest incidence of brucellosis during 2009-2015 was in Lorestan, Hamedan and Kurdistan, Markazi, Kermanshah, East and West Azerbaijan and North Khorasan, South Khorasan and Razavi Khorasan provinces. The results illustrate that the incidence of brucellosis in Iran dropped from 2009 to 2011 but it assumed an increasing trend from 2011 to 2014. Based on the results of modeling in Iran, Hamedan, Lorestan, West Kurdistan and East Azerbaijan provinces with 100%, 99.3%, 98.66%, 98.2% and 97.1% of their area, respectively, are at a higher risk of brucellosis breakout in the coming years.

Comparing the incidence of brucellosis in Iran to other countries shows its significantly higher incidence rate in Iran compared to developed countries such as the US and most European countries [24, 25]. The incidence rate in Iran closely resembles to eastern Mediterranean countries such as Saudi Arabia. Saudi Arabia [26], the United Arab Emirates [27], Turkey and Iraq [28].

Given that this disease is endemic in the Middle East region, its uneven distribution in different countries can be attributed to the low socioeconomic status and underdevelopment in the agricultural and livestock industry [7].

The results of this study reflect a rise in the incidence of brucellosis in Iran from 2011 to 2014 and a decline in 2015 compared to 2014. This rising trend may be due to improved statistical system and data recording in Disease Registration System of Iran over the years and its decline in 2015 could be attributed to enhanced livestock health and vaccination [29]. The study of Zhang et al. (2014) in China showed that the total incidence of brucellosis in humans was 0.92 per 100,000 people in 2004, increasing to 2.6 per 100,000 people in 2010 [30]. In Turkey, the incidence rose to more than 25.6 [31].

According to the World Health Organization's report, the prevalence of brucellosis varies widely (from 0.01 to 200 per 100,000 populations), so that it is in the Native American regions, 1 in 100,000, in the UK, 0.3 in 1 million. Germany is 0.03 per 100,000 and in rural Greece 0.3 per 100,000 [32-36].

According to a study (2003), the average incidence of brucellosis in the Iranian population was 21 per 100,000, however the rate varied between 1.5 and 107.5 per 100,000 in different regions of the country [20].

In a systematic meta-analysis and review study conducted by Mirnejad et al. on the incidence of brucellosis over an 18-year period, from 1996 to 2014, across the country, results from 34 articles showed tha the incidence of brucellosis was varied in different provinces, with the lowest reported incidence from Qom at 7 per 100,000 and the highest incidence from Kermanshah province with 276.42 per 100,000 (38).

Thus, the growing incidence of the disease in the community is a wake-up call that this disease is turning into a public health problem in the community, which can inflict economic consequences to the community [37].

According to the results of our study, the highest incidence during 2006-2015 was in Lorestan, Hamedan and Kurdistan, Markazi, Kermanshah, East and West Azerbaijan and North Khorasan, South Khorasan and Razavi Khorasan provinces. The findings of the present study are aligned with those reported by other Iranian researchers [12, 13]. In the western provinces of Iran, due to proximity to the Zagros Mountains and the presence of dense oak forests and fertile soil, the main economic activities of the people are agriculture and animal husbandry. Also, due to the commute of nomadic tribes, these areas have a higher incidence of brucellosis than other parts of Iran [13, 38].

Based on the results of our study, the western provinces of the Iran including Hamedan, Lorestan, Kurdistan and West and East Azerbaijan may be high brucellosis risk areas in the coming years. High incidence rates in these provinces have been reported in other studies as well [12, 39].

Environmental or geographical factors, low and medium altitudes, humidity and vegetation, and climatic conditions in the west and northwest of the country have provided a fertile ground for the survival and spread of the disease. Therefore, the impact of geographical factors on the incidence of zoonotic diseases is undeniable [40]. Underdevelopment or absence of traditional health infrastructure and traditional lifestyle, low education and lower socioeconomic status in the western and northwestern parts of Iran can also be major factors in the transmission of this disease in these areas, which can turn them into high risk areas in the future [11, 37]. Evaluation and controlling the disease by identifying the center of the disease and assessing the incidence and prevalence of the disease at specific times and health-quarantine measures could lead to adopting appropriate plans for disease control and prevention.

Conclusion

In general, the results suggest significant variations in the distribution of brucellosis incidence in Iran in the present and future. In the western and northwestern provinces of Iran, this disease can pose a major health issue, giving rise to a plethora of problems for people living in these areas. This calls for greater attention of health decision makers to the high risk areas of the country in the coming years to control the incidence of diseases in these areas by developing appropriate health plans and interventions. Providing policy and selection of appropriate operational methods using the facilities of the national health networks for the prevention and control of brucellosis based on disease diagnosis, early diagnosis, appropriate treatment, increasing awareness of the ways of transmission and prevention of the disease and coordination between different parts of the relevant organizations in a way that throughout the country is

accessible and is practiced uniformly can be used as a practical target to combat this disease.

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Conflict of interest

This authors have no conflict of interest to declare.

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