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Original Article

Using GIS in Explaining Spatial Distribution of Brucellosis in an Endemic District in Iran

AA Haghdoost [1], L Kawaguchi [2],*A Mirzazadeh [1], H Rashidi [3], A Sarafinejad [1], AR Baniasadi [4], C Davies [2]

[1]*Physiology Research Center, Kerman University of Medical Sciences, Iran*
[2]*Disease Control and Vector Biology Unit, Dept. of Infectious and Tropical Diseases, London School of Hygiene and Tropical Medicine (LSHTM), England*
[3]*Kerman Veterinary Organization (Provincial Office), Kerman, Iran*
[4]*Dept. of GIS, Management and Planning Organization, Kerman, Iran*

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Abstract

Background: To check the feasibility of using geographical information system (GIS) methods, we linked the brucellosis data of human and animals. **Methods**: In a village-based ecological study in Bardsir- a district in Kerman Province located nearly to the central part of Iran- data of human brucellosis, socio-economic level, and livestock characteristics (2001-3) were linked by using GIS methods. **Results**: Annual incidence of human brucellosis was 141.6 cases per 100,000 inhabitants. Most of the high risk villages were seen in the north and south of Bardsir (3.6% of villages). A positive association was observed between the frequency of brucellosis and density of cattle (OR=1.81, *P*= 0.007). In addition, the size of human population was an independent determinant factor (OR= 1.94, *P*< 0.001). No association was found between frequency of the disease and socio-economic indicators and also the density of sheep. **Conclusion**: Our study showed that we could generate informative risk maps of brucellosis using health and veterinary data which might improve the quality of control programme in Iran.

Keywords: *Risk map, GIS, Human brucellosis, livestock, Iran*

Introduction

There is a well established primary health care (PHC) delivery system in Iran, particularly in rural area. More than 16000 health houses in main villages around the country cover close to 95% of the rural population (1, 2). Health workers not only deliver primary health cares, but also keep health records of people in their catchments areas and play an important role in surveillance system.

In spite of well-established PHC, brucellosis still is an endemic disease in Iran, particularly in rural areas. Unfortunately, Iran is one of the top five countries with high incidence of brucellosis (3). Although the current surveillance system in Iran misses a considerable proportion of cases, more than 17,000 cases were reported in 2003, second only to Syria (4).

Despite of the bilateral effects of human and animal diseases, unfortunately it is not easy to link these datasets in Iran. Well known diseases such as TB, brucellosis, rabies, hydatic cysts, and even new treats such as bird flu are examples of common diseases between human and animals. The human and animal datasets are compiling under supervision of different ministries, and there is no direct link between these datasets. However, we believe that health system can response much faster and on time to outbreaks if these data can be shared effectively. The spatial modeling using the capacity of geographical information system (GIS) is directly

***Corresponding author:** Tel/ Fax: +98 341 2114559, E-mail: amirzazadeh@kmu.ac.ir

applicable to understand the spatial variation of disease such as brucellosis, and its relationship to environmental factors (livestock's parameters). Although, GIS is a well known tool in health system in developed countries (5), its application is very limited in developing courtiers such as Iran.

In this study, we linked the brucellosis surveillance data of human and animals in an endemic district in central part of Iran, Bardsir (Kerman), using GIS methods. We aimed to find determinates of human brucellosis and check the feasibility of such a model in generation, by linking between human and animal data.

Materials and Methods

Study area Bardsir is located in Kerman Province, south-eastern Iran, with 10,000 square kilometres area. Its population is about 50,000 and around half of them live in rural areas. It consists of steppes and semiarid plateaus, covered by brown soil that supports grassy vegetation. The height ranges from 1900 to 2900 m. Main industries in Bardsir rural areas are agriculture and husbandry. Wheat, corn, sunflowers, pistachios and fruits are cultivated (6). According to the veterinary census data, about 25,000 cattle and 500,000 sheep/ goats are raised in the study area. Bardsir district is an endemic region in Iran for brucellosis based on the results of surveillance system (3).

Health facilities in Bardsir are mostly provided by governmental system. Health workers in rural health houses survey people actively and record diseases such as brucellosis and report suspected/diagnosed human cases monthly to the centre of province. All of these suspected cases were visited by physicians and their final diagnosed were based on serological tests.

In parallel, district veterinary office surveys livestock's populations and their related conditions such as diseases and pastures. The number of livestock is reported for each ‘epidemiological unit’, which is defined as an interacting herd of livestock. However, the numbers of inoculated vaccines has not being recorded classified accurately to epidemiological units. The veterinary data is being reported annually.

Datasets and electronic maps Brucellosis cases in 2002-4 have been collected from district health offices, classified by village. Human demographic information of villages included number of households, population in each village, number of literate people, and data on employment were estimated from 1996-1997 census data (6). Availability of Health House, midwives, nurses, pharmacy and trained veterinary staff were also counted as health facilities.

The annual census data of sheep, goats, cattle and other livestock is collected from district veterinary office. The number of livestock has been reported to each ‘epidemiological unit’.

Electronic map of the district was received form the National Statistics Office in Tehran in UTM format in scale of 1:50,000. Provincial veterinary office also provided coordinates of epidemiological units.

Calculating and Statistical methods Using add event function in ArcView software, a new layer was added to the electronic maps to illustrate the location of epidemiological units. There were substantial mismatches in the spatial distribution of epidemiological units and villages, since animals were mostly kept outside the villages. Therefore, we used kernel smoothing (an interpolation technique) to find the best estimate of animal density in each village using all available information of animals around villages. Using sensitivity analysis, a bandwidth of 3,000 meters was adopted as the most appropriate bandwidth in the kernel smoothing.

The villages were classified as high risk one if at least one case of human brucellosis was reported between 2002 and 2004.

A village with easy access to health facilities was defined as a village with at least one of these facilities: Health House, midwives, nurses, pharmacy and trained veterinary staff.

The crude and adjusted odds ratios were calculated to estimate the determinant factors of high risk villages. The final model was selected by

backward stepwise method using logistic regression, by excluding least significant determinant factors one by one. We used the natural logarithm of human and livestock population, entered in the models as explanatory variables because of their positive skewness; we add one to the populations of livestock to deal with zeros.
All geographical analyses were done by the ArcView GIS software ver3.3 and its extension package ArcView Spatial Analyst (Environmental System Research Institute, Inc.). The statistical analysis was done in Stata version 8.

Results

During 2002 and 2004, 97 patients were reported in 34 villages; that meant 10.9% of villages were high risk for brucellosis (34 out of 311 villages) (Table 1). The annual incidence of human brucellosis was 141.6 per 100,000 inhabitants (95% CI: 134.4-149.2).
The clusters of high risk villages and high density spots for cattle, not for sheep were spatial matched. Most of high risk villages were located in the north and south of the district. In addition, three main clusters with the highest cattle density were in north and one in south. There were much more clusters with high density of sheep, mostly located in north and south; however, they were distributed within wider the district than the cluster of cattle (Fig. 1).
Human and cattle populations were significant determinant factors for being high risk villages. The proportion increased with density of cattle, and reached up to 29% in villages where the density was higher than 20 cattle per square kilometres. Even after adjustment for other potential risk factors (Socio-economic indicators, Education and Geographic factors), human and cattle population were positive determinant factors for being high risk villages (human population: OR= 1.94, cattle population: OR= 1.81) (Table 2).
On the other hand, the density of sheep did not show a linear relationship with occurrence of human disease in a village (Table 1). Having adjusted, a negative association was observed between population of sheep and risk of being a high risk area and it has borderline significance. (OR= 0.75, 95% CI: 0.56-1.01) (Table 2).
Villages supplied with clean water and electricity had a twofold increase in the probability, compared to villages without supplies. Moreover, villages with health facilities had four times greater risk (31.8% compared to 7.5% in village without health facilities). Villages with higher literacy (50% and above) and villages located at flatlands had higher risks (16.4% compared to 7.8% in villages with lower literacy), but the statistical tests revealed that the differences were not significant (Table 2).

Discussion

Our study showed that we could generate informative risk maps of brucellosis using health and veterinary data which may improve the quality of control programme in Iran. Our findings imply that human brucellosis is highly associated with population size and distribution of cattle in rural areas of Bardsir district, while we could not find any associations between socio-economic status of villages and risk of brucellosis. Most of the high risk villages were seen in the north and south areas of Bardsir which had more density of cattle (No. per square kilometres).
GIS is not a new system in medical research nonetheless a few papers have been published on the application of GIS in brucellosis control programme. Having searched Pub Med, up to 2006, we could find only one relevant article; the GIS was performed for determined the contact rates and exposure to inter-species disease transmission in mountain ungulates in France (7).
Using GIS, it seems that we may generate better conclusion on human health in Iran if we link the human and veterinary data. It is clear that we can implement more effective control programme if we use the data of both human and animals. Both systems are collecting data and generating comprehensive datasets; therefore, we just need to create a link to combine whole information. Overall it seems that, it does

not add much more cost to the ongoing systems, but it could generate much more efficient results. According to our findings in this study, it is not difficult to explain the associations between the human and livestock populations and risk of brucellosis. Since cows and sheep are the main sources of the disease transmission to human, the number of effective contacts would be a result of livestock and human population sizes which was also observed in other studies (4, 8).

In Zinstagg et al. survey on livestock-to-human brucellosis transmission in Mongolia in a period of 10 yr (1990-99), it was shown that trends of brucellosis in both human and animals were identical (9). They mentioned more domestic infected animals, increased the risk of human brucellosis, which is similar to our finding. Although they mentioned that more than 90% of human brucellosis in Mongolia was small-ruminant (sheep) derived, but it seems that brucellosis in Bardsir is mostly cattle derived which is not compatible with the fact that most common species is *Brucella melitensis* in Iran (10).

Furthermore, despite performing control programme and livestock's vaccination more than one decade, annual incidence of human brucellosis in rural areas of Bardsir remains considerable. It seems that such a control programme in rural areas could not be as effective as urban. Perhaps, this is partly due to difficulties in conducting thorough and sustainable disease control programme, and partly due to the wide and scattered distribution of livestock in rural areas which cause more effective contact with infected animals and their diary products. In this study, we did not focus on determining each risk factor of brucellosis, but some local customs, environmental variation, difference in species of pathogens and their distribution are likely to be factors that would affect the local incidence differences. It's believed that fresh cheese and milk are the major source of human brucellosis in Iran, and the disease is more common in rural areas, where cheese is usually produced by local small factories or in households (8). However, it is difficult to estimate to what extent each of the two transmission routes (occupational or food-born) takes part in the human disease incidence in rural area, as both could be deeply related to the size of local animal population.

In contrast with our expectation, access to satiated water, electricity and health facility and even asphalt road increased the risk of brucellosis in our univariate models. This could be either because of a more accurate diagnose and reporting system in those villages with access to these facilities or because of great human and livestock population in these villages.

However, we should acknowledge to the limitations of such a model. We used surveillance data which are not perfect from the research point of view. Nevertheless, in Iran such as other endemic areas, the numbers of reported brucellosis are always underestimated. The low incidence reported in known brucellosis-endemic areas may reflect the absence or the low levels of surveillance and reporting (11). We have to mention that we produced a model based on ongoing data to check its effectiveness in real system. Furthermore, we did not have accurate village based information on the animal vaccination. These types of information can be collected in veterinary system if their staffs know the importance of such type of data.

For better conclusion, further investigation on other possible risk factors, e.g. disease prevalence of animal population, livestock vaccination coverage and local customs would give some new evidence of local animal population association with epidemiology of human disease. Moreover we suggest that more study should be carried out to explore the feasibility of GIS systems on the other types of common diseases between human and animals in larger scales.

As conclusion, this study not only showed the implication of GIS to link human and animal data, but also exposed the limitations and weak points in ongoing systems. Therefore, we suggest that the impact of control programmes can be improved by using GIS methods and linking human and animal data.

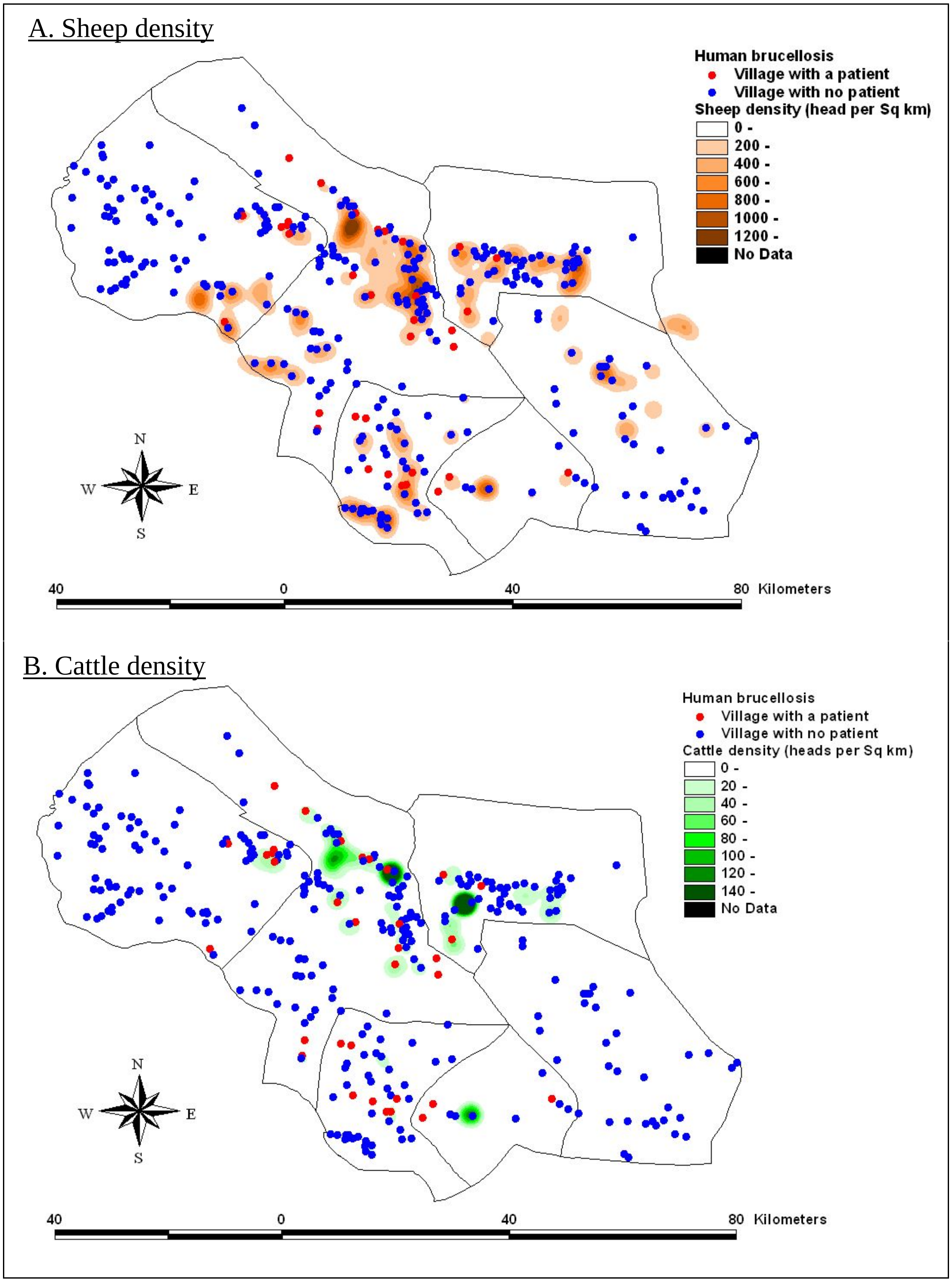

Fig. 1: Animal population density map in Bardsir A: sheep, B: cattle. Both maps were created by setting bandwidth of 3,000 metres. Location of village with brucellosis (red) and without disease (blue) is overlaid on the maps.

Table 1: Frequencies of villages with at least one positive case, classified by potential risk factors, in Bardsir district

Variable		Number of villages	Villages with at least on case (%)			
			n (%)	95% Confidence interval (%)		
Number of inhabited villages		311	34 (10.9)	7.4	-	14.4
Human population (person)						
	1-10	100	5 (5)	0.7	-	9.3
	11-50	118	6 (5.1)	1.1	-	9.1
	51-100	39	4 (10.3)	0.3	-	20.2
	>100	54	19 (35.2)	22.0	-	48.3
Animal population						
Sheep/goat	0-9.9	67	4 (6.0)	0.1	-	11.8
(heads per Sq. km)	10-99.9	58	3 (5.2)	0.0	-	11.0
	100-499.9	115	19 (16.5)	9.6	-	23.4
	>=500	71	8 (11.3)	3.7	-	18.8
Cattle	0-0.9	141	6 (4.3)	0.9	-	7.6
(heads per Sq. km)	1-9.9	56	5 (8.9)	1.2	-	16.6
	10-19.9	52	5 (9.6)	11.2	-	26.8
	>=20	62	18 (29.0)	1.5	-	55.6
Socio-economic factors						
Access to piped water	no	183	12 (6.6)	3.0	-	10.1
	yes	128	22 (17.2)	10.7	-	23.7
Access to electricity	no	131	8 (6.1)	2.0	-	10.2
	yes	180	26 (14.4)	9.3	-	19.6
Access to health facility	no	267	20 (7.5)	4.3	-	10.6
	yes	44	14 (31.8)	18.1	-	45.6
Asphalted road	no	262	19 (7.3)	4.1	-	10.4
	yes	49	15 (30.6)	17.7	-	43.5
Education						
Literacy (%)	<49	64	5 (7.8)	1.2	-	14.4
	>=50	146	24 (16.4)	10.4	-	22.5
Geographic factors						
Location of	mountain	165	13 (7.9)	3.8	-	12.0
village	flatlands	146	21 (14.4)	8.7	-	20.1

* chi-square test for trend

Table 2: Crude and adjusted odds ratios of potential risk factors for high risk villages, only human and animal populations were entered in multivariate analysis

	Crude		adjusted	
Variable Population* **	**OR**	**95% CI**	**OR**	**95% CI**
Log(population)	2.27	1.68-3.06	1.94	1.41-2.67
Log(cattle density+1)	1.74	1.35-2.26	.81	1.18-2.78
Log(sheep density+1)	1.16	0.97-1.39	0.75	0.56-1.01
Socio-economic indicators				
Access to water	2.96	1.39-6.30	-	-
Access to electricity	2.60	1.13-5.99	-	-
Access to health facility	5.76	2.56-12.99	-	-
Asphalted road	5.64	2.54-12.53	-	-
Education				
High literacy (>50%)	2.32	0.84-6.45	-	-
Geographic factor				
Located in flatlands	1.96	0.94-4.10	-	-

* Observed variable converted into its natural logarithm.
** Univariate logistic regression was used to estimate odds ratios for these continuous variables (odds ratios for 1 unit increase in the explanatory variable)

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