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Spatial and statistical analyses of the relations between vegetation cover and incidence of cutaneous leishmaniasis in an endemic province, northeast of Iran

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PEER REVIEW

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Comments
This is a good study where authors have linked normalized difference vegetation index with cutaneous leishmaniasis cases.This will help in planning to control cutaneous leishmaniasis.
Details on Page 179

ABSTRACT

Objective: To investigate the relations between the vegetation cover and occurrence of cutaneous leishmaniasis (CL) in Golestan province during 2010-2012.
Methods: Data of monthly CL incidence and remote sensing normalized difference vegetation index (NDVI) of moderate resolution imaging spectroradiometer sensor were used in the study. Pearson's correlation analysis was conducted to examine the type and strength of relationships between the spatially averaged NDVI variables (*i.e.* minimum, maximum and mean NDVI values) and CL incidence in township level. Spearman rank correlation was carried out to explain associations between the monthly CL incidence and NDVI variables at 0, 1, 2, 3 and 4 months lagged periods. Locations of CL cases at village level were geocoded and compared with frequency of CL cases in each NDVI-derived vegetation categories.
Results: Pearson's analysis revealed significant associations between the NDVI variables and CL incidence at the township level ($P<0.05$). Results of Spearman analysis indicated that the highest correlations between NDVI variables and monthly CL incidence were established when the NDVI time-series lagged the CL incidence series NDVI variables. Purely spatial analysis demonstrated that despite majority of cases occurred at partially-vegetated areas, the possibility of CL occurrence was higher in bare soil areas by taking into account area of each vegetation zones.
Conclusions: lack or low vegetation cover is a major determinant of CL frequencies in Golestan province. The decrease of the mean vegetation density in townships is accompanied by increase of CL occurrence and vice versa.

KEYWORDS
Cutaneous leishmaniasis, Geographical information system, Normalized difference vegetation index, Correlation analysis

1. Introduction

The World Health Organization considers leishmaniasis as one of the most neglected tropical diseases which has received little attention and resources despite its serious impacts on both the economic developments and quality of life[1]. Cutaneous leishmaniasis (CL) represents the most frequent vector-borne parasitoses in Iran[2,3]. The number of CL cases in this country during the period of 2001 to 2008 dramatically increased from 11 505 to 26 824[4]. Distribution and abundance of vectors and reservoirs of this disease is directly or indirectly affected by different environmental factors. Climatological factors (*e.g.* temperature, rainfall and vegetation cover) and human interventions (*e.g.* deforestation, building of dams and urbanization) are the most known environmental factors on CL occurrence[1,5,6].

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CL is endemic in almost half of 31 provinces of Iran[7]. Golestan province, one of the Iranian provinces with several high endemic districts, still shows meaningful morbidity rates. Previous entomological studies carried out in this province indicate that CL is caused by the *Leishmania major*, the main vectors are *Phlebotomus papatasi, Sergentomyia sintoni* and *Rhombomys opimus* (great gerbil)[8,9]. However, numerous epidemiological aspects of CL have been recently studied in various provinces of Iran including the Mazandaran, Kerman, Kashan, Ilam and Isfahan[10-14]. Nevertheless all the above mentioned epidemiological studies mostly overlooked spatial components of the disease and restricted to investigation of the characteristics of the individual patients and vectors or reservoirs of their study area.

As expressed by Kallury *et al*.[15], incorporating remotely sensed information in epidemiological studies can help public health policy makers to better understand relationships between the disease and environment. Remote sensing provides valuable temporal information about the vegetation cover known as the vegetation indices such as the normalized difference vegetation index (NDVI). This index together with the other remotely sensed data have been widely used to monitor some vector-borne diseases including malaria throughout the world[16]. Despite very limited studies on the relationships between the vegetation cover and other environmental factors influencing the CL incidence, several studies in regard of visceral leishmaniasis (VL), another fatal form of leishmaniasis, have been reported in different parts of the world. In Eastern Sudan, Elnaiem *et al*.[17] calculated the annual mean, minimum, maximum, and medium values of NDVI and pointed out that VL incidence correlated closely with the mean and minimum NDVI and did not appeared to have an association with maximum NDVI. Salahi-Moghaddam *et al*.[18] used NDVI in addition to other environmental factors as data inputs to map high-risk area of VL using geographic information system with satellite imagery in Ardebil, Iran. Using NDVI satellite data from the moderate resolution imaging spectroradiometer (MODIS) sensor, Bhunia *et al*.[19] studied the correlation of vegetation cover with distribution of VL in northern part of India. Their results showed that most of cases occurred in non-vegetative or low-density vegetation zones.

Vegetation cover can be regarded as a surrogate indicator representing the environmental interactions and climatic conditions[20]. Development of low-cost and efficient management models for effective control of the CL is an important objective which requires comprehensive efforts and studies including the ecology of the disease and role of the vegetation cover. For this purpose, this study was designed to investigate correlations and relations between the vegetation cover and occurrence of CL in Golestan province of Iran.

2. Material and methods

2.1. Study area

Golestan province consisting of 14 counties with 60 townships, lying within the 36°30′ to 38°8′ N and 53°57′ to 56°22′ E, is located in north-eastern parts of Iran (Figure 1). This province with more than 1 750 000 populations covers an area of 20 893 km^2. Climate of different parts of the province is notably heterogeneous. Northern regions are located in the arid and semi-arid climate, southern regions represent a mountainous climate, and central and southern west regions are located in a moderate Mediterranean climate[21].

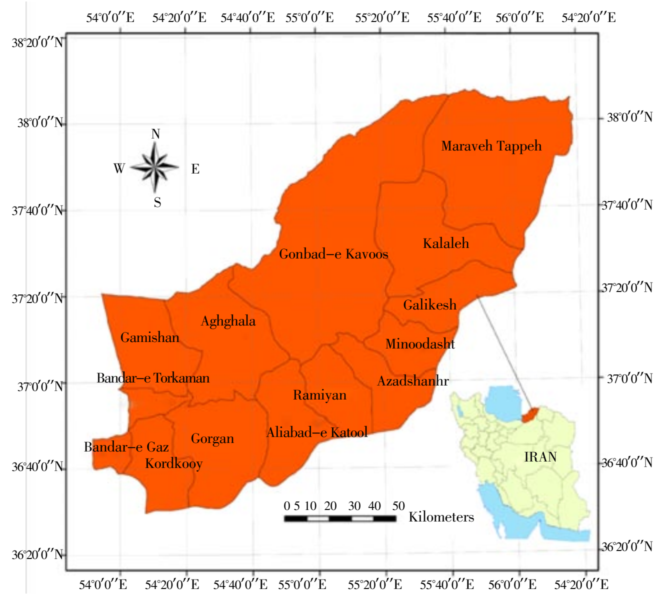

Figure 1. Geographic location of the study area, Golestan province and its counties and townships, in northeast of Iran.

2.2. Data collection and preparation

During the January 2010 to November 2012, a total of 2 983 CL cases, diagnosed by smear examination, were officially reported by Golestan Center for Disease Control and Prevention. CL data were checked meticulously to prevent any possible mistakes. These data were then linked with their respective geographic location at village level. In addition to CL data, the MODIS 16-day composites time-series with 250 meter spatial resolution derived from MODIS website[22] were used to measure the time-lagged vegetation cover for the period of September 2009 to December 2012. According to the paper of Momeni *et al*.[23], vegetation cover of the study area classified into three categories including the bare soil areas (NDVI<0.156), partially vegetated areas (0.156≤NDVI≤0.461) and fully vegetated areas (NDVI>0.461). Vegetation categories were visually compared with Google Earth images and had proper conformity with mentioned NDVI classes.

2.3. Spatial and statistical analysis

The analyses consist of three main parts. Firstly, monthly and annual CL incidences of each township were calculated and mapped. Then, Pearson's correlation analysis was conducted to examine the type and strength of relations between the spatially averaged NDVI variables and annual CL incidence rates in townships. Secondly, Spearman rank correlation was carried out to explain the associations between the monthly CL incidence rates and NDVI variables at 0, 1, 2, 3 and 4 months lagged periods. Finally, locations of CL cases at village level were geocoded and compared with frequency of CL cases in each NDVI-derived vegetation classes with and without regarding the areas of each vegetation zones.

3. Results

Figure 2 shows the annual CL incidence rates at township level. As can be seen in this figure, townships with the highest CL incidence rates mainly located at northern part of the study area. Results of the Pearson's correlation analysis showed that there were statistically significant associations between the spatially averaged NDVI variables and annual CL incidence rates at the township level. This indicated that CL incidences tended to be more prevalent in townships with the lowest average NDVI values as an indicator of drought. Examination of correlations between the CL incidence rates in different townships of Golestan province and NDVI variables including the maximum, minimum and mean NDVI values resulted in observation of the negative correlations. Results indicated that there were highly significant associations between average maximum and mean NDVI with CL incidence rates in different townships of Golestan province ($P<0.01$), also the association between the minimum NDVI and CL incidence rates was significant ($P<0.05$).

Based on the results of the Spearman rank correlation at the province level, monthly CL incidence rates showed an indirect correlation with Max-NDVI. Among the NDVI variables, Max-NDVI showed the highest correlations with the monthly CL incidence rate whereas Min-NDVI showed the least correlations with the monthly CL incidence rates. In addition, direct correlation was observed between the Min-NDVI and CL incidence rate. However, there was no significant association between the Min-NDVI and monthly CL incidence rate throughout the province. Table 1 represents results of the Spearman rank correlation between the monthly CL incidence rates and NDVI variables at 0, 1, 2, 3 and 4 months lagged periods.

Table 1

Spearman rank correlation between the monthly CL incidence rates and NDVI variables at 0, 1, 2, 3 and 4 months lagged periods.

Monthly CL incidence	Min-NVDI	Max-NDVI	Mean-NDVI
0-Month	0.101	-0.182	-0.385*
1-Month	0.290	-0.461**	-0.322
2-Month	0.182	-0.577**	-0.130
3-Month	0.310	-0.525**	0.145
4-Month	0.066	-0.316	0.366*

**: Correlation is significant at the 0.01 level, *: Correlation is significant at the 0.05 level.

Comparison of the CL frequencies at village level with the NDVI-derived vegetation categories for each three year (Table 2) shows that majority of cases occurred at partially vegetated areas. As depicted at Figure 3, it can be seen that almost there is a persistent strong negative relations between the vegetation cover and occurrence of CL in Golestan province. This means the relations remains somewhat similar.

Table 2

CL occurrence in villages of Golestan province in different vegetation categories (2010-2012) [CL possibility occurrence in parentheses (%)].

Year	Bare soil (NDVI<0.156)	Partially vegetated (0.156≤NDVI≤0.461)	Fully vegetated (NDVI>0.461)
2010	13.74% (71.52%)	84.74% (27.06%)	1.52% (1.42%)
2011	13.76% (48.87%)	83.72% (46.62%)	2.52% (4.51%)
2012	12.47% (66.36%)	85.88% (33.42%)	1.65% (0.22%)

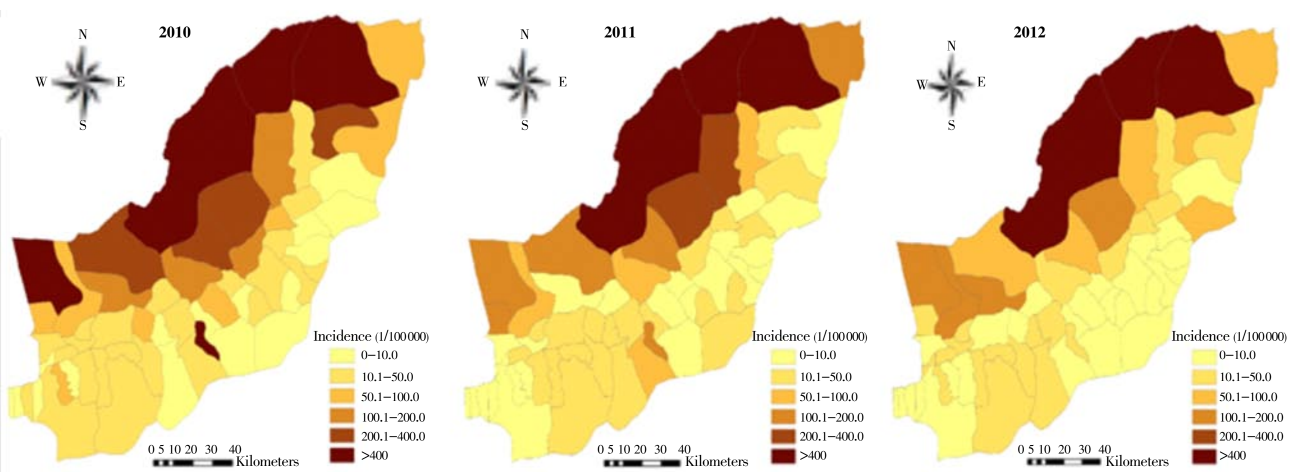

Figure 2. Incidence of CL cases at the township level per 100000 individuals in Golestan of Iran in 2010, 2011 and 2012.

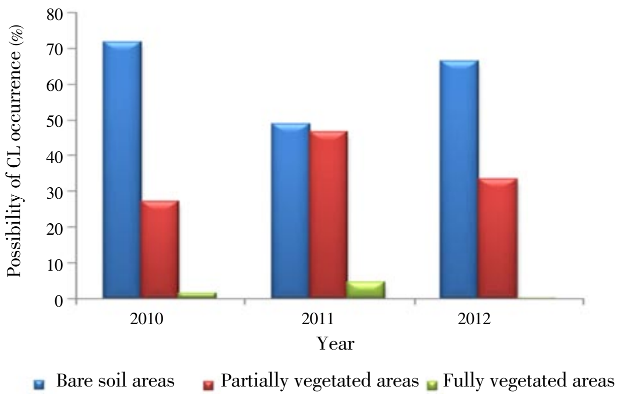

Figure 3. Possibility of CL occurrence in villages of Golestan province in different vegetation densities (2010–2012).

4. Discussion

The present study emphasized on spatial relations of the CL incidence with vegetation cover, as a proxy of environmental changes especially temperature, humidity and rainfall, aimed to improve understanding of the relations in this endemic area. Visual comparison of the spatial distribution of CL incidence with climate conditions of the province showed that lowest incidences has reported from the southern parts of the province with high vegetation indices. While townships with the highest CL incidence rates were located in northern parts of the province, with the arid and semi-arid climate and low vegetation indices, suggests that lack or low vegetation cover provides favourable conditions for CL occurrence in these areas. To assess this hypothesis several spatial and statistical analyses in varying local and global levels were applied. A local correlation at township level between CL incidence rate and NDVI variables was conducted using the Pearson correlation. Excepting the min-NDVI, other variables showed very strong negative correlations with the township's CL incidence at the 99% level of significant. Level of significance in the case of min-NDVI was 95%. In the all tested cases, increase of the vegetation cover at township level resulted in decrease of the CL incidence rate and vice versa. According to results of the Spearman rank correlation, monthly NDVI significantly correlated with monthly CL incidence during three years period of study. However, NDVI variables did not show a strong correlation with CL incidence rates in the same months. The best correlations between the NDVI variables and monthly CL incidence rates were observed when NDVI time-series were lagged the CL incidence series. This indicates that vegetation cover change prior to the disease active period is an important influencing factor and at least one month time is needed for vegetation cover to effect on occurrence of CL in humans. Purely spatial analysis using the classified NDVI confirmed the notable role of vegetation cover on frequency of CL cases. Purely spatial analysis demonstrated that despite majority of cases occurred at partially-vegetated areas, the possibility of CL occurrences consistently were higher in bare soil areas by taking into account area of each vegetation zones for each year, separately.

Observation of the highest infection rates in areas with low and very low NDVI values are in agreement with those of the Bavia *et al.*[24] in Brazil and Bhunia *et al.*[19] in India. The main limitations of this study are attributed to present surveillance system in Iran which misses considerable numbers of cases. In addition, short period of this study (3 years) may not lead to robust and reliable results. Further studies should concentrate on investigation of the other environmental and socioeconomic factors which may influence on the spatial and temporal patterns of the disease. Results can provide critical guidelines for initiating control strategies for policy makers to monitor and predict the disease based on the vegetation cover. Moreover, vegetation cover together with the other influencing factors can be used to develop early warning systems to forecast CL incidence in this endemic area.

Conflict of interest statement

We declare that we have no conflict of interest.

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Comments

Background

Leishmaniasis is one of the most neglected tropical diseases, which is transmitted through the bites of infected sand flies. Cutaneous leishmaniasis (CL) represents the most frequent vector borne parasitoses in Iran.

Research frontiers

In recent years, Geospatial technologies, such as the geographic information system, remote sensing images, and spatial statistics have been utilized to study the relationships between environmental factors and the vectors that transmit cutaneous leishmaniasis.

Related reports

Aparicio and Dantas (2004) had employed NDVI to understand the spatio-temporal pattern of CL transmission in Brazil. Özbel *et al.* (2011) have used NDVI to predict the spatial distribution of phlebotomine sand flies in Western Turkey. Colacicco-Mayhugh *et al.* (2010) have built an ecological niche model for CL-vectors in the Middle East based on NDVI.

Innovations & breakthroughs

The authors explored the dynamic relationship between the NDVI and CL transmission in Golestan province, Iran.

Applications

Results can provide critical guidelines for initiating control strategies for policy makers to monitor and predict the disease based on the vegetation cover. Moreover, vegetation cover together with the other influencing factors can be used to develop early warning systems to forecast CL incidence in this endemic area.

Peer review

This is a good study where authors have linked NDVI with CL cases. This will help in planning to control CL.

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