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Spatial outline of malaria transmission in Iran

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ABSTRACT

Objective: To conduct for modeling spatial distribution of malaria transmission in Iran. **Methods:** Records of all malaria cases from the period 2008-2010 in Iran were retrieved for malaria control department, MOH&ME. Metrological data including annual rainfall, maximum and minimum temperature, relative humidity, altitude, demographic, districts border shapefiles, and NDVI images received from Iranian Climatologic Research Center. Data arranged in ArcGIS. Results: **Results:** 99.65% of malaria transmission cases were focused in southeast part of Iran. These transmissions had statistically correlation with altitude (650 m), maximum (30 ℃), minimum (20 ℃) and average temperature (25.3 ℃). Statistical correlation and overall relationship between NDVI (118.81), relative humidity (⩾45%) and rainfall in southeast area was defined and explained in this study. **Conclusions:** According to ecological condition and mentioned cut-off points, predictive map was generated using cokriging method.

1. Introduction

According to the World Health Organization, malaria is the most important parasitic disease in the world[1]. About 3.3 billion people equal to around half population of the world are living in malaria-endangered area with one million death cases from this disease[2]. After the centuries of investigations and notable investment and considerable progress in elimination of malaria,1.7 billion dollars was spend in around 108 countries which was faced with malaria in 2009[3] and 610 000 to 1.2 million mostly children and pregnant women die due to malaria[4].

According to report of John Gilmour in 1924, Malaria was one of the most important diseases in Iran, which controlled Iran population. This report explained niche of disease in urban and rural area and indicates that ecology of Iran may consider in different zones. One of these zones is south coastal zone that is located between southern shore and southern mountains of Iran. In this area climate is hot and humid with low precipitation and low altitude. Another zone is main land and considered its climate as "healthy area". Dr. Gilmour explained existence of some disease like plague, malaria, cholera and abundance of rodents in southern zone and their relationship with northern mainland in past centuries[5]. Later investigators reported some other tropical diseases like ankylostomiasis[6], schistozomiasis[7], darcuntiasis[8] and high population of scorpions[9] report from Iranian southern zone. Metrological diversity in Iran vary in 15 climatologic area[10]. From geopathological point of view, Iran is divided to northern zone as palearctic and southern coastal band, called afrotropical and indomalaeian[11]. While malaria eliminates in northern zone of Iran, transmission of disease is still reporting from tropical zone. According to classic definition, malaria-

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endemic area is where malaria transmission occurred in three continuous years[12]. In past 3 years, from 2008-2010, 11 282 autochthonous cases reported to Iranian disease control center.

Although autochthonous malaria cases and transmitted from imported cases are drop down from 6 824 cases in 2008 to 1 262 cases in 2010, it shows importance of malaria in Iran.

Today, modeling malaria and generating malaria early warning system (MEWS) is economic and useful technology for facilitating malaria control and vector control[13] using Geo-Spatial Information System (GIS). The GIS is able to storage, analysis, planning, synthesis and mapping of spatial data[14] and its related software are useful in control programs of disease[15]. Gathering terrestrial data and mapping disease is first and essential part of above mentioned procedure[16]. To attain this warning system, it is necessary to have distributional and seasonal outline of malaria, this is possible by using computer and mass data recording and perhaps satellite technology.

Considering importance of malaria in Iran and necessity to clarify of ecological pattern of disease in Iran, this study conducted in 2011 using geospatial information system (GIS).

2. Material and method

2.1.Study site

Iran is located in the Middle East longitudes 44° to 63.5° East and latitudes 25′ to 39° North, with 1 648 195 km^2 area and about 75 million populations. Average altitude of synoptic stations in Iran is 1 113 m. Iran have different climatic zone, including Caspian littoral plane with moderate Mediterranean area in the north, mountainous cold and dry climate in west and north-west, hot and humid area in the south, arid and semi arid region with two disserts in the east and central Iran. According to Iranian calendar, each year start in 21 March so each Gregorian year consist of 9 compatible month and 3 month of past Iranian year. For convenience in this study, 3 month is considered in next related year. As this study persist on climatologic potentiality of area for transmitting malaria, both "Autochthonous" and "transmitted from imported cases" are considered together as "transmitted cases" and indicates the location instead of human cases.

This investigation conducted in the 2011 and national records in 3 years period from 2008-2010 were included in this study (21 march 2008 to 21 march 2011).

Iran was endemic area of malaria and transmission of disease may occur in approximately all around country. Now, transmissions in each district varies from 1-3 085 times, third quartile of these transmission is 14.5 times. Considering this high potentiality in Iran, districts were arbitrarily considered "High transmission potentiality" climate if more than 15 transmissions were reported. District with 14 or less transmission reports considered as "Low transmission potentiality" climate. Classical description for Endemic area is recurrence of transmission for tree consequent years[17].

2.2.Data collection

Records of all malaria cases from the period 2008-2010 in Iran retrieved for Malaria control department, Center for Diseases Management and Control (CDMC). These reports are accurate and reliable, based on active screenings of people by health centers. Diagnosis based on blood smears performed by well-trained technician attained special certification for malaria diagnosis and supervised by Provincial reference labs of local medical universities. Malaria patients and malaria treatment is strongly supervised by governmental universities[18] and self-treatment or on-desk selling anti-malaria drugstore unavailable in Iran. Therefore, all cases of malaria, active and or passive, will register in Iranian CDMC anyway[19].

Meteorological data in past three years (1 095 d), including temperature, annual rainfall, elevation, relative humidity registered in 258 synoptic stations all around country retrieved from the Iranian Metrological Center.

Normalized Deviation Vegetation Index (NDVI) data of LandSat satellite already downloaded from NOAA website (http://www.noaa.gov) and images generated by ERDAS software.

ArcGIS, version 9.3 (http://www.esri.com/arcgis) was used for the spatial analysis. The metrological information added to the terrestrial data previously collected and saved in the form of shape-files. Demographic information and data on elevations and other facts such as the location of villages and borders was use as shape-file base-layers. Geo-database exported to a .DBF file for more professional statistical analysis, using SPSS ver. 16.

2.3.Mapping malaria in Iran

Imported cases was scattered in 112 districts all around Iran in 2010, as imported cases have not ecological pattern and may act as confounding factor, these cases removed from the database. The "Autochthonous" and "transmitted from imported cases" incurred.

Meteorological, epidemiological, terrestrial and satellite data joined and compared by Geospatial Information System. Prediction map generated using cokriging method with related variables with their cut off points.

3.Results

3.1.General

In past three years 11 358 "Autochthonous" and 309 "Transmitted from imported" cases, totally 11 667 malaria cases was reported and were analyzed.

Mapping malaria in Iran shows that 99.99% of malaria transmission cases in past 3 years, focused in southeast part of Iran. This area is within the three provinces of "Sistan-Baluchestan", "Kerman" and "Hormozgan" (Figure 1-4). Parasitic agent was *P. vivax* or *P. falciparum* and mix of them, in which about 85.38% of reported cases were due to *P. vivax*, 11.96% due to *P. falciparum* and 2.65% were mixed infection in 2010. These three provinces considered as stratum I and all other provinces of Iran are consider as stratum II in this study (Figure 5). Comparing these groups may useful because of different climatic area in Iran. Analysis data in the stratum I may have important results because of short distance and same socio-economic condition.

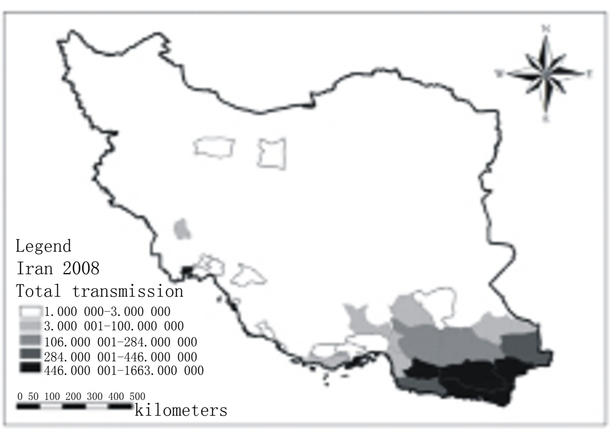

Figure 1. Malaria transmission cases in Iran 2008.

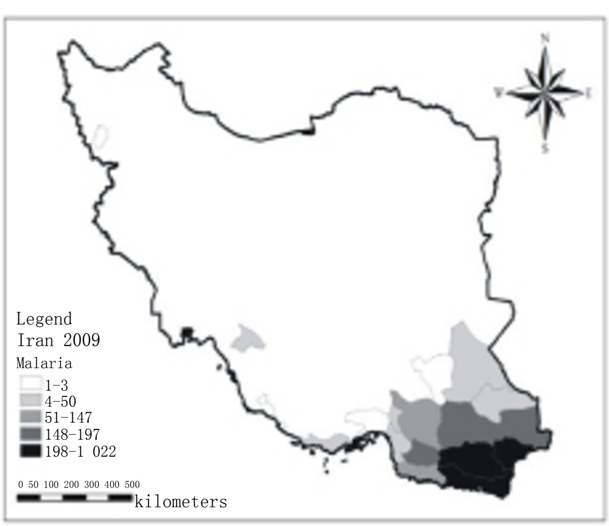

Figure 2. Malaria transmission cases in Iran 2009.

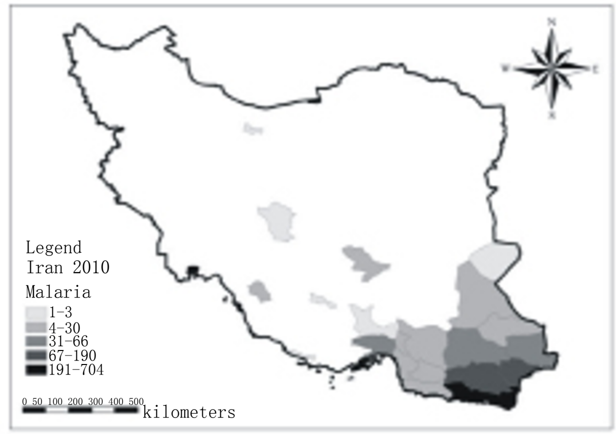

Figure 3. Malaria transmission cases in Iran 2010.

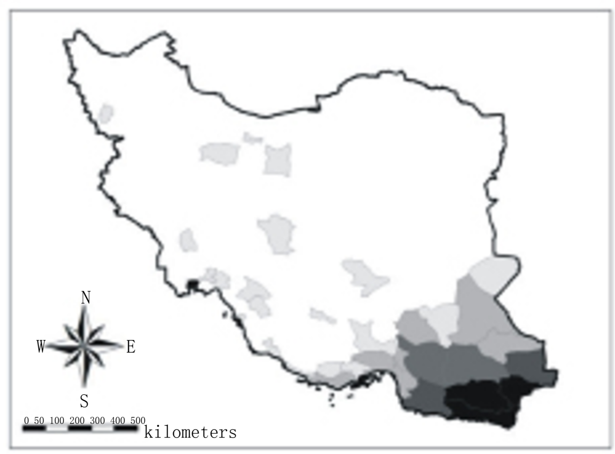

Figure 4. Malaria transmission cases in Iran 2008-2010.

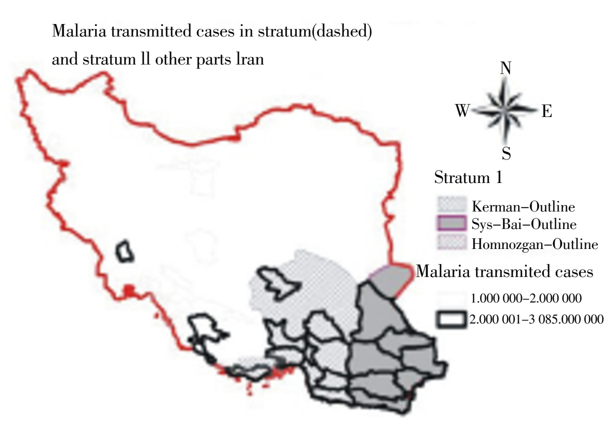

Figure 5. Malaria transmission cases in different parts of Iran 2008-2010.

Another stratification of malaria transmission in Iran performed based on high potentiality for malaria transmission, more than 15 transmission, and equal to third quartile of transmission median. Figure 7 shows these high potential malaria transmission areas in Iran.

Regression analysis shows statistically correlation between altitude and malaria transmitted cases (P=0.029).

Regression analysis shows that elevation of stratum I and II have significant difference (P=0.019). While 91.1% of malaria transmission cases happened in less than 650 meters, about8.8% of cases were reported from higher elevation. Malaria transmitted cases in the two groups of high and lower than 15 cases has statistically difference in area with more and less than 650 m based on χ^2 analysis and (P=0.00).Although it is assumed that Iran is a low altitude country, average altitude of metrological synoptic stations is about 1 100 m and more than this critical elevation.

Temperature is another criteria of malarious area (P=0.038). Regression analysis for temperature show statistical correlation between malaria transmission and minimum and maximum temperature in Iran (P=0.00 and P=0.002 respectively). It means that just three transmission cases were happened in area with less than 20 degrees of Celsius (℃) minimum temperature and "more than 30 ℃ area. Figure 8 and 9 show these findings. Independent sample T-test show meaning correlation between temperature more and less than 25.3 ℃ with malaria transmission (P=0.045). According to χ^2 analysis, statistical correlation between high transmission (more than 15 cases in past three years) and high temperature (more than 25.3) is assumed (P=0.00).

Although it is believed that three southeast provinces of Iran have low rainfall, comparing stratums II and I with annual rainfall, rejected statistical difference between raining in different zones.

3.2. Focus on southeast Iran: Endemic area and intra stratum I analysis

Results show Districts of Iranshahr, Saravan, Nikshahr, Chabahar, Fanuj, Konarak, Zaboli, Delgan, Khash, Jask, Rudan, Minab, Jiroft, Kahnuj, Manujan, Rudbar-Jonub and Ghal`e-Ganj are classical endemic area of Iran in past three years (2008-2010) this area is 164 257.2 km^2 and 9% of Iran region (Figure 6). Population in endemic area is about 1 400 000 people (1.5% of total population).

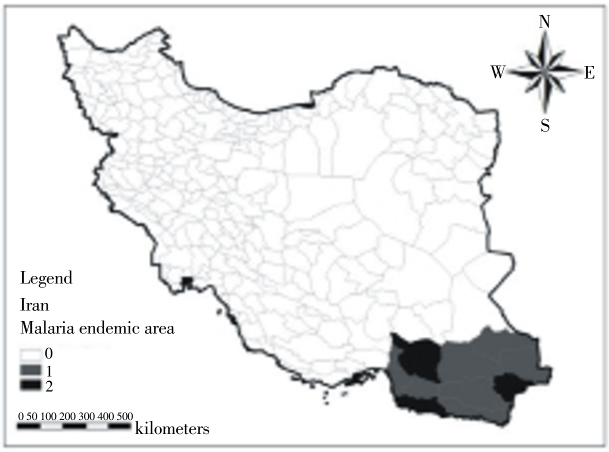

Figure 6. Endemic area of Iran.

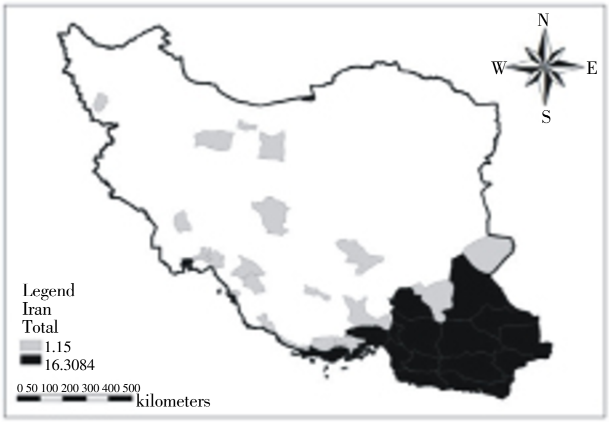

Figure 7. High transmission area in Iran 2008-2010.

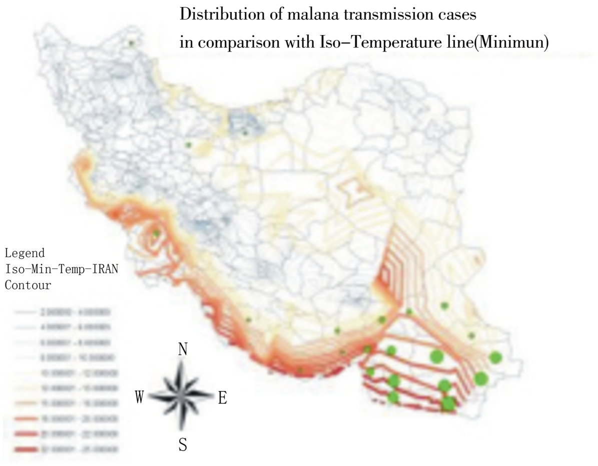

Figure 8. Distribution of malaria in different minimum temperature area.

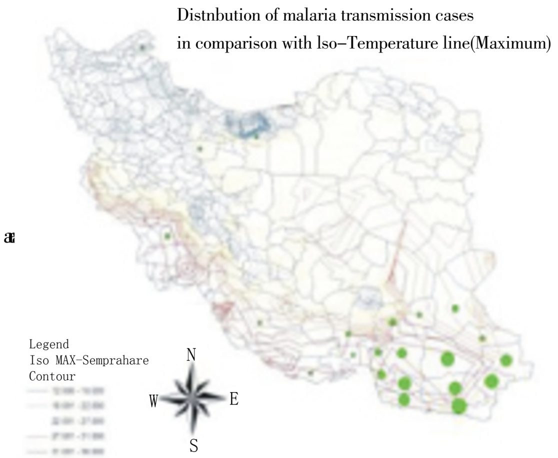

Figure 9. Distribution of malaria in different maximum temperature area.

All above-mentioned findings about ecology of malaria transmission, with small changes, were seen again in study of endemic or malarious area with clean area within southeast Iran. The most differences were the P–values and small changes in cut–off numbers.

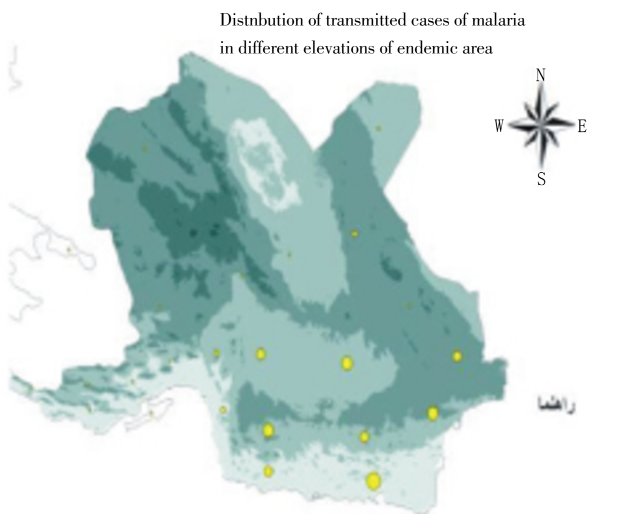

Figure 10. Distribution of transmitted cases of malaria in different elevations.

NDVI (Scale 0–256) in stratum–I varies from 1–141. Regression analysis shows statistically correlation between NDVI and heavy malaria transmission (more than 15 transmission in past three years) in stratum–I (P=0.028), it means that most heavy malaria transmissions were occurred in area with NDVI > 111.81(P=0.024). Figure 11 show the correspond map.

In all part of study, there was no significant correlation between relative humidity and malaria transmission cases. Sophisticated study on transmission shows that in Iranshahr, Nikshahr and Saravan district 3 597 malaria transmission cases was reported and mean relative humidity was low (about 25%–26%). These exceptions diminish the pattern of transmission. With considering this exception, relative humidity and malaria transmission have statistically correlation in this area (P=0.019). According to χ^2 analysis, more than 15 transmission have statistically correlation with relative humidity 45% (P=0.029) and may consider as cut–off point.

3.3. Stratum II

In stratum II, most Autochthonous cases was restrict to 1 or 2 (transmission from Imported) cases in three past years. The notable exceptions in stratum II are "Farrashband" in Fars province and "Behbahan" in Khuzestan province with 14 and 7 Autochthonous respectively.

From 11 282 studied Autochthonous cases, about 82% was happened in Afrotropical, 17.7% in indo–malayan and 0.1% cases was reported from pale–arctic area.

According to above mentioned information and cut–off points, malaria potentially transmission map was generated using cokriging method (Figure 12).

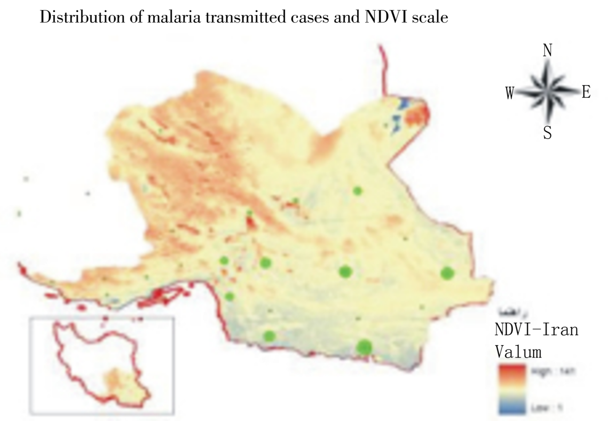

Figure 11. Distribution of malaria transmitted cases and NDVI values.

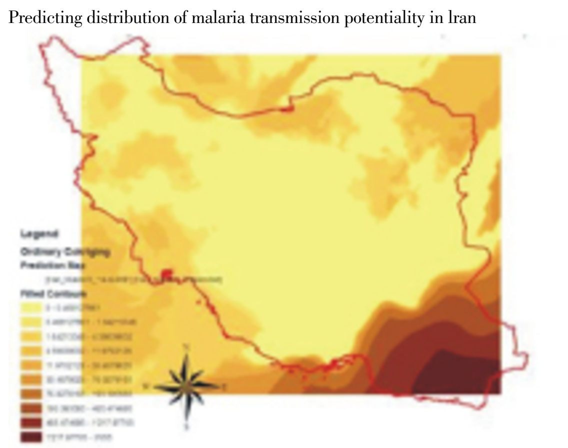

Figure 12. Predictive map of malaria distribution in absence of control programs.

Figure 13. Distribution of malaria in 1949, before malaria eradication program.

4. Discussion

The term Malaria is referring to climate. The distribution of malaria in Iran is restricted to southeastern provinces, including tropical region of Kerman, Hormozgan and Sistsn-baluchestan and this is well known distribution of disease in Iran since past decades and is compatible with all other studies[20-23].

Immigrants from Afghanistan and Pakistan are the source of some imported disease including malaria[24] and cholera. While imported cases of cholera from east northern borders distributes in northern part and imported cases from east southern border distribute in south of Iran[25], all cases of Autochthonous Malaria are restricted to southeast part of Iran.

As the climate may significantly affect the temporal and spatial incidences and distribution of pathogens and vectors, mapping of their distribution in spatial and chronicle dimension determine epidemiological assessment[14]. By means of GIS model revealed that malaria distributed from east Mediterranean region to Southeast Anatolia regions in Turkey from 1975-2008[26]. In our 3 years study, malaria cases was moved around restricted area in southeast Iran and patchy outbreak in the mainland was not stable. A long term look at distributions shows that malaria transmitted cases are limited from scattered pattern around the country in past 5 decades to southeast part of Iran and remains there since 1998[21].

Biological GIS-Based approach to malaria vector distribution and its ecology is highly demanded in Iran Provides essential knowledge for malaria control programs

Our findings about distribution of disease and environmental factor such as climatic characteristics including rainfall and temperatures, corresponds with classical malariological facts and other GIS based studies[15,27] and we could define these findings and their correlation by numbers and it may use for the probable malaria early warning system (MEWS).

Map of malaria transmission distribution have similarities to the mapping 5 important malaria vectors, including, *A. dthali, An. fluviatilis, An. stephensi, An. culicifacies, An. pulcherrimus*[28].

Relation between malaria transmission and relative humidity has known since Hippocrates and is documented in 1969 by Pampana. In this study, although most malaria transmitted cases reported in humid area, but we did not find strong logical correlation (P=0.094). This bias happened in Iranshahr district. This dry area is a well-known malarious district of Iran, where mosquitoes have rest in humid microclimates, such as wells and pit shelters or even small water holes. It seems that *An. culicifacies, An. pulcherrimus* are dominant vectors in this zone[28]. The same condition is seen in neighborhood district, the "Saravan", but logical correlation between relative humidity and malaria transmission is seen in the mentioned area.

Although there was overall relation between rainfall and malaria incidence in the other studies, but statistical correlation was not assumed. The same pattern was mentioned in studies with entomological and epidemiological approach in endemic zone, Bashagard district in Hormozgan province[29]. Another study in Sistan-Baluchestan province shows inverse correlation between rainfall and malaria risk[30].

Corresponding author believe that malaria condition in Iran is affected from global warming and periodic drought and probably may reduce more than the past. Since many parts of Iran have a history of malaria transmission. Report and maps remains from past century may use as guide for correction of predicting systems. The generated predicting map has a good compatibility with malaria transmission map in past years, before malaria eradication campaign in Iran (Figure 13).

Conflict of interest statement

This project was financially supported by School of Public Health deputy for education, Tehran University of Medical Sciences (TUMS), as PhD student project 2010-2012. This manuscript was prepared with the kind cooperation of Dr. Gouya; Director General CDMC, we do appreciate all his cooperation. The authors declare that there is no conflict of interests.

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