



Spatial analysis and mapping of malaria risk in an endemic area, south of Iran: A GIS based decision making for planning of control

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ABSTRACT

Bashagard district is one of the important malaria endemic areas in southern Iran. From this region a total of 16,199 indigenous cases have been reported in recent years. The aim of this study was to determine the situation of the disease and provide the risk map for the area. ArcGIS9.2 was used for mapping spatial distribution of malaria incidence. Hot spots were obtained using evidence-based weighting method for transmission risk. Environmental factors including temperature, relative humidity, altitude, slope and distance to rivers were combined by weighted multi criteria evaluation for mapping malaria hazard area at the district level. Similarly, risk map was developed by overlaying weighted hazard, land use/land cover, population density, malaria incidence, development factors and intervention methods. Our results reveal that the disease mainly occurs in north and east of the study area. Consequently the district is divided into three strata. Appropriate interventions are recommended for each stratum based on national malaria policy. Malaria hazard and risk map, stratification based on relevant information and data analyzing provide a useful method preparedness and early warning system for malaria control, although regular updating is required timely.

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1. Introduction

Malaria is an environmental related disease affected by a variety of factors. It is one of the important communicable diseases in southeastern part of Iran. Its local transmission foci are distributed in 3 provinces of Sistan & Baluchistan, Hormozgan and Kerman. This area is bordered with Afghanistan and Pakistan countries, where malaria cases due to *Plasmodium vivax* and *P. falciparum* are prevalent. Different activities and programs promoted since 1950s. All activities lead to decline annual cases from more than 5 out of 16 million population of the country to about 3000 cases in a population of 74 millions in the year 2010 (Raeisi et al., 2009; MOH, 2010). Therefore, Iran is considered as pre-elimination phase by World Health Organization (WHO, 2010). There are eight vectors of malaria in the country: *Anopheles culicifacies* s.l., *An. dthali*,

An. fluviatilis s.l., *An. maculipennis* s.l., *An. sacharovi*, *An. stephensi* and *An. superpictus* are proven vectors, while *An. pulcherrimus* is reported as suspected one (Zaim et al., 1993; Naddaf et al., 2003; Sedaghat et al., 2003a, 2003b; Sedaghat and Harbach, 2005; Azari-Hamidian, 2007; Oshaghi et al., 2007; Hanafi-Bojd et al., 2011a; Mehravaran et al., 2011).

Mapping malaria cases can help health authorities to understand more about spatial distribution of the disease in their area as well as its temporal occurrence. The provided information will provide a guideline for control programs and preparing health facilities based on the requirement of each area. GIS have been continuously used for the analysis of spatial health related data. It can be a useful tool for analyzing the spread of diseases in both developed and developing countries. This tool is useful for management strategy to allocate resources for preparing the needs for control of disease in high risk areas of disease. GIS also enable us to generate revised maps as soon as new data are available (Srivastava et al., 2009).

Hormozgan province, southern Iran, has different endemic malarious areas. All the malaria vectors of the country except *An. maculipennis* s.l. and *An. Sacharovi* are found in this region. There

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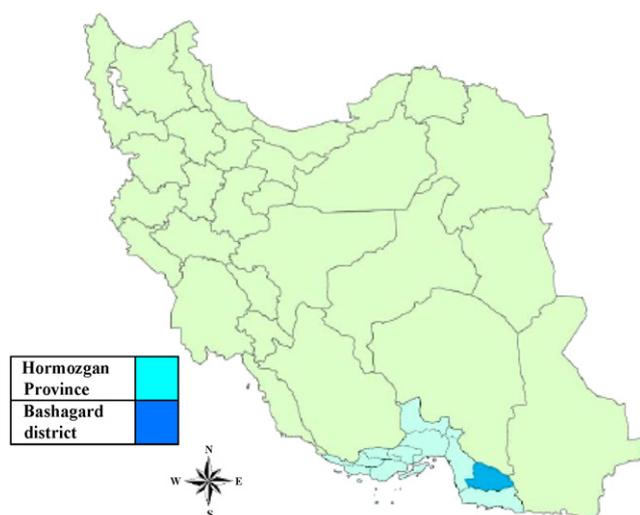


Fig. 1. Study area in Hormozgan province, Southern Iran.

are reports of studies on different aspects of malaria and Anopheles line vectors in this province including larval habitats (Vatandoost et al., 2004), insecticides/larvicides resistance and repellent studies (Vatandoost and Hanafi-Bojd, 2005, 2008; Hanafi-Bojd et al., 2006; Davari et al., 2007; Shahi et al., 2010), vectors bionomics, systematic and ecology (Oshaghi et al., 2006; Vatandoost et al., 2006, 2007; Azari-Hamidian et al., 2010; Hanafi-Bojd et al., 2012), and malaria situation analysis and planning (Hanafi-Bojd et al., 2010; Vatandoost et al., 2011). Bashagard is one of the important malaria endemic areas in southern Iran. Malaria cases, mostly indigenous, are reported from different parts of this district (Hanafi-Bojd et al., 2012). Five malaria vectors including: *An. culicifacies* s.l., *An. dthali*, *An. stephensi*, *An. superpictus* and *An. fluviatilis* s.l. have been reported from the area and *An. culicifacies* s.l. is the main species (Hanafi-Bojd et al., 2012). Vector control strategies include Indoor Residual Spraying (IRS), distributing Long Lasting Insecticide Treated Nets (LLINs) as well as larviciding using granule of *Bacillus thuringiensis* accompanied with environmental management.

The aim of current study was to produce a GIS-based databank for malaria cases, health facilities, development factors and intervention methods at the village level. The objective was to develop malaria risk map and identify hot spots for planning and management of the malaria control program judiciously. The developed maps from this survey will help the authorities to understand the current malaria risk of the area and hot spots to make an appropriate plan for control program.

2. Methods

2.1. Study area

Bashagard district with a total population of 31,292 in 2009 is an underdeveloped area in Hormozgan province, southern Iran. It is located in latitude and longitude of 26°21'N, 57°54'E (Fig. 1). The area has low precipitation with hot and dry climate. The monthly averages of relative humidity and temperature range from 30 to 65% and 7 to 45 °C, respectively. Average of annual rainfall is 265 mm. The district is mostly mountainous and hilly, with scattered population inhabited mainly close to main and seasonal rivers, in sheds and houses as well. The agriculture in the area is limited to growing palm trees on riversides or near springs. The soil texture is mainly sandy and is not able to preserve the precipitation as surface water.

2.2. Malaria data

Monthly cases of malaria incidence at village level based on parasite type (*P. vivax* or *P. falciparum*) were obtained from health center of Bashagard district during 1999–2009. The accuracy of malaria data was checked by comparing the provided records with original records in 6 rural units for malaria reporting and treatment in the district. A dataset including location of morbidity (village name), type of parasite and time of infection (month and year) was created in excel software. A spatial databank was created in ArcGIS using geo-referenced data of villages in the area, obtained from topography map of Iran. Our findings as new fields were linked to this databank. Inverse distance weighting (IDW) spatial analysis of ArcGIS was conducted on annual and monthly mean of 11 years incidence of malaria to determine the actual clusters of case distribution in the area.

2.3. Climatic, environmental and population data

Information of climate variables was obtained from Hormozgan province meteorology Center. These data were collected from 8 stations in Bashagard district. Shape files of temperature, relative humidity, digital elevation model (DEM) as well as Indian Remote sensing Satellite (IRS) image of the area (date: 2009) were obtained from National authorities. Demographic data about population, roads, electricity and other relevant information were received from the Statistical Center of Iran (<http://www.amar.org.ir>) and added as new fields to the spatial databank of the area in ArcGIS.

2.4. Data preparing for use and processing

ArcGIS9.2 software was employed for mapping spatial distribution of malaria incidence at the village level. The study area was determined using political border of Bashagard district. Factors influence on malaria hazard including temperature, relative humidity, distance to rivers, slope and altitude were considered (Table 1). The last three shape files were prepared using DEM.

ER-Mapper 7.1 was used for analyzing the IRS image and preparing land use/land cover layer of the area. The image was classified using an unsupervised classification method and GPS points collected from the field used as ground accuracy in the classification process. Topography map of the study area were used as collateral information. A total of six classes were identified by this classification, i.e., standing water as ponds, human settlements (villages), farming area, bare land, scattered trees and rivers. This layer was reclassified in to five classes based on the order of vulnerability for mosquito breeding site, source of blood and resting places for the vector (s). Thus, the new values were assigned to each class based on this classification as 5, 4, 3, 2 and 1 (Table 2).

Hazard map, i.e. a map that highlights areas which are vulnerable for breeding and maintenance of malaria vectors and parasites, was prepared by weighting and overlaying environmental factors (see Jeefoo et al., 2008). For selecting and weighting of different factors for hazard and risk maps, a questionnaire was sent to experts in the field of malaria, who were familiar with situation of the study area. Each expert suggested some factors and their vulnerability in malaria transmission cycle. After collecting and evaluation of their comments, suggested ratings and classes for each factor were ranked as low (rank = 1), moderate (rank = 2), high (rank = 3) and very high (rank = 4). The figure for hazard was considered as very low (rank = 1), low (rank = 2), moderate (rank = 3), high (rank = 4) and very high (rank = 5) as shown in Tables 1 and 2. Every layer was then re-classified based on these ranks. Rating was standardized followed by using analyst of Arc GIS 9.2 software. Re-classified layers were multiplied by their standard weight and then added to others for providing the hazard/risk layer/maps. Factors that

Table 1
Factors affecting malaria hazard in Bashagard district, Southern Iran.

Factor	Rating	Standard weight	Class	Ranks	Degree of Vulnerability
Temperature	35	0.35	24–30 °C	4	Very high
			18–24 °C	3	High
			16–18 °C	2	Moderate
			<16 °C	1	Low
Relative humidity	15	0.15	>60%	4	Very high
			50–60%	3	High
			40–50%	2	Moderate
			<40%	1	Low
Main rivers	30	0.3	0–1000 m	4	Very high
			1000–1500 m	3	High
			1500–2500 m	2	Moderate
			>2500 m	1	Low
Seasonal rivers	10	0.1	0–500 m	4	Very high
			500–1000 m	3	High
			1000–1500 m	2	Moderate
			>1500 m	1	Low
Altitude	5	0.05	0–800 m	4	Very high
			800–1200 m	3	High
			1200–2000 m	2	Moderate
			>2000 m	1	Low
Slope	5	0.05	<8%	4	Very high
			8–15%	3	High
			>15%	1	Low

influence on malaria hazard are temperature, relative humidity, and distance to rivers, slope and altitude.

Similarly risk map, i.e. a map that shows risk of malaria transmission in the area (hot spots) was prepared by hazard, population density, mean of malaria incidence during the 11 years of the study period, development factors (electricity, appropriate road, health house) and intervention activities (larviciding, Indoor Residual Spraying, Long Lasting Impregnated Nets). The accuracy of hot spots in risk map was assessed by comparing with the spatial

distribution of malaria incidence map in the study area. The obtained risk map was then divided into high, moderate and low risk areas as three strata for planning control interventions.

3. Results

During the study period a total of 16,199 malaria cases were recorded and treated with antimalarial drugs according to the national policy of drug treatment. *P. vivax* (98.38%) was the main

Table 2
Factors affecting malaria risk in Bashagard district, Southern Iran.

Factor	Rating	Standard Weight	Class	Ranks	Degree of Vulnerability
Hazard	40	0.4	4<	5	Very high
			3.01–4	4	High
			1.91–3	3	Moderate
			1.01–1.9	2	Low
			<1	1	Very Low
Population density	20	0.2	901<	5	Very high
			301–900	4	High
			101–300	3	Moderate
			31–100	2	Low
			30	1	Very Low
Mean of incidence	10	0.1	22.41<	5	Very high
			13.2–22.4	4	High
			7.21–13.1	3	Moderate
			3.21–7.2	2	Low
			0–3.2	1	Very Low
Land use/land cover	10	0.1	Rivers and pounds	5	Very high
			Garden	4	High
			Farm land	3	Moderate
			Oasis	2	Low
			Bare land	1	Very Low
Development factors	10	0.1	Non	5	Very high
			1 factor	3	Moderate
			2 factors	2	Low
			3 factors	1	Very low
Control activities	10	0.1	Non	5	Very high
			1 method	3	Moderate
			2 methods	2	Low
			3 methods	1	Very low

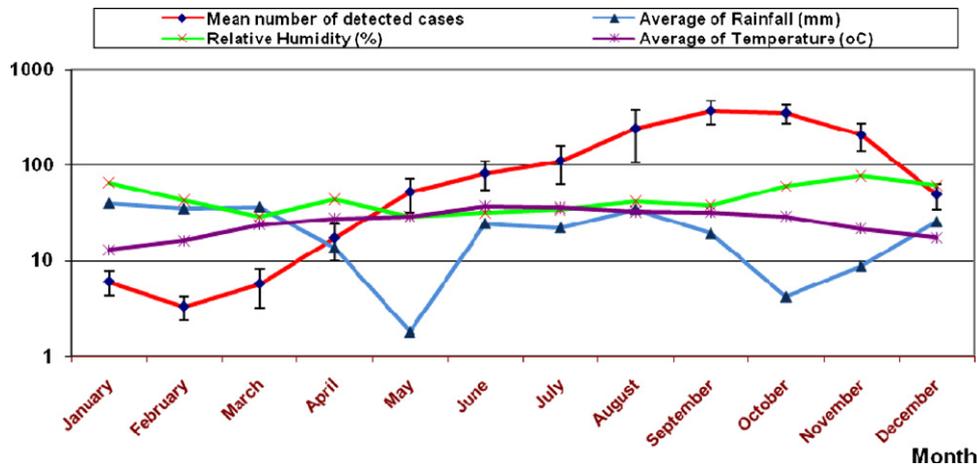


Fig. 2. Mean of malaria cases in relation to climatologically parameters, Bashagard districts, Southern Iran (1999–2009).

causative agent of the disease, although *P. falciparum* (1.61%) and mix infection (0.01%) were reported. The monthly mean of positive cases in relation to the meteorological parameters is shown in Fig. 2. Positive cases are reported during the whole year with the highest and lowest rates in September and February, respectively.

To visualize the intensity of positive cases in the area, cumulative distribution map of malaria reported cases is provided (Fig. 3). Most of cases have been reported from north and east of the district. Fig. 4 shows the actual clusters of malaria cases distribution, obtained from IDW spatial analysis based on the mean of 11 years incidence of malaria.

Six layers of environmental factors were rated, weighted and ranked based on their influence and importance in malaria transmission potential (Table 1). Combination of these layers by computing their weights yielded the malaria hazard map for the area (Fig. 5). The same method was used to produce the malaria risk map in five classes by natural breaks using ArcGIS software. These classes are as follows: very low risk (14.4%), low risk (26.4%), moderate risk (29.6%), high risk (13%) and very high risk (16.6%) (Table 2, Fig. 6).

The stratification of malaria risk was conducted by considering very high risk area as hot spots (stratum I), high and moderate risk areas as stratum II, and the low and very low risk areas as stratum III. The areas for each stratum (calculated by ArcGIS) as well as its population were: 808 km², 8000; 4668 km², 19,000; and 3555 km², 5000 respectively.

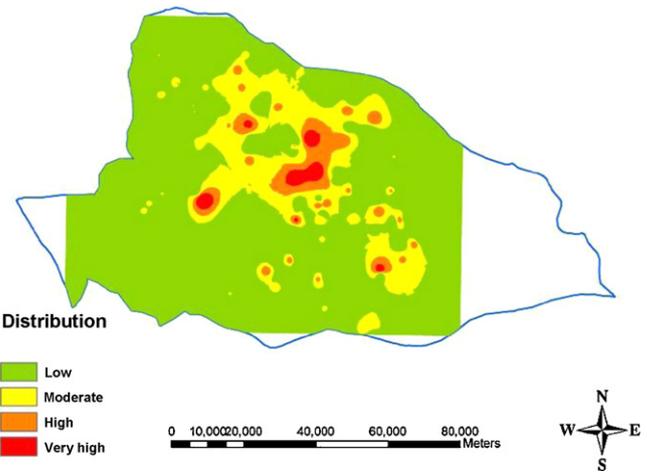


Fig. 4. Spatial distribution of malaria incidence (mean) during 1999–2009, Bashagard district, Southern Iran.

4. Discussion

GIS in public health, especially vector borne disease, is a young research field in Iran. Malaria is one of the most important parasitic diseases in southern and southeastern of the country, although

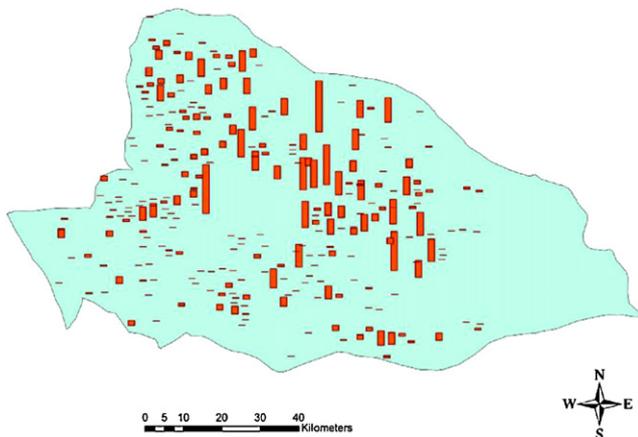


Fig. 3. Cumulative malaria cases in Bashagard district, Southern Iran, 1999–2009.

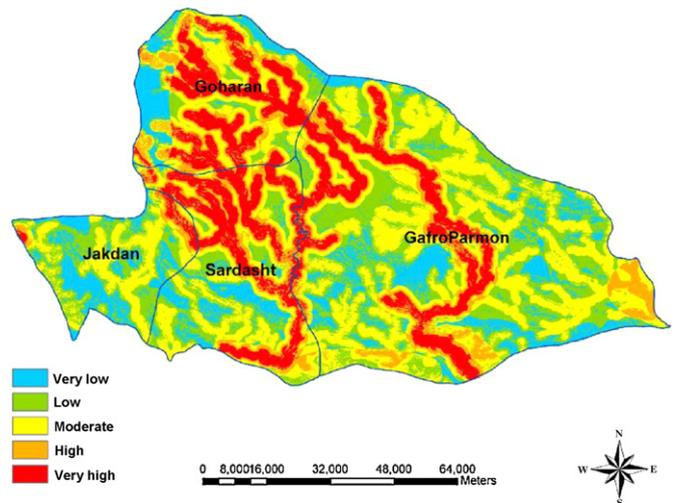


Fig. 5. Malaria hazard map, Bashagard district, Southern Iran, 2010.

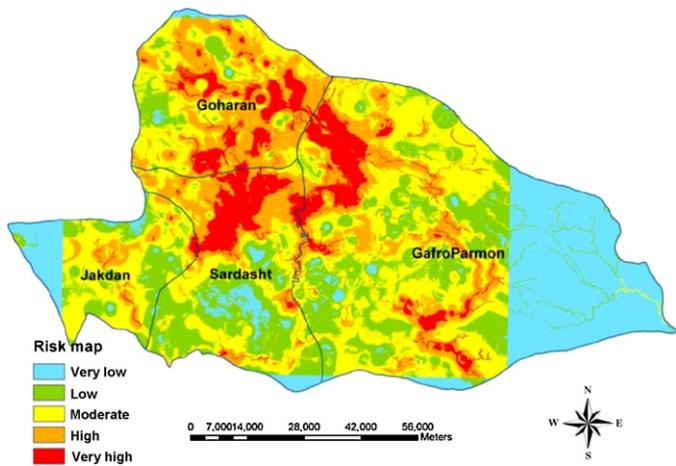


Fig. 6. Malaria risk map, Bashagard district, Southern Iran, 2010.

the country encounters with occasionally outbreaks in borderline with neighboring countries. The goal of national malaria control program is to eliminate the disease by 2025. Malaria distribution and risk maps will help health policy makers to target control interventions at high risk areas and enhance the cost-efficiency of program. It is suggested to prepare database for malaria, demographic data, socio-economic level and access to health facilities of the endemic areas for malaria in the country. This database will help to monitor any changes significantly and manage the elimination program appropriately. Adding temperature, rainfall, relative humidity, altitude, vector distribution, vegetation, surface waters, and other relevant layers to malaria database of each area in GIS will provide clear hot spots. This is important for stratification of the disease and planning control program. The mapping type and the conditions for hot spots selection can be changed depending upon the requirement and malaria situation (Srivastava et al., 2009). Statistical modeling techniques are frequently included into a GIS framework to recognize the spatio-temporal patterns of vectors and vector borne disease (Eisen and Eisen, 2010).

This study clearly provides malaria risk mapping and stratification in an endemic area in Iran. More than 16,000 positive cases were recorded during 11 years period of study with a peak occurs in September. Spatial analyzing of mean incidence shows the clusters of the disease are located in north and northeast of the study area, where the development level and socio-economic status of people is very low. The produced maps provide a visual tool for decision making about where the control programs must be initiated and focused. In this study we used evidence-based weighting method, which specifies the relationship among selection factors through weighting. This allows project managers to compare different selection factors more efficiently, even when a large number of factors are involved (Jeefoo et al., 2008).

Hanafi-Bojd et al. (2012) reported five malaria vectors with different behaviors from Bashagard district. Hazard mapping show the potential breeding places for these mosquitoes based on environmental factors. We used environmental and climatic data, to map the malaria hazard. Different mosquito species have special ecological niches. Temperature, relative humidity and slope play important roles for distribution of malaria vectors (Drakeley et al., 2005). A research in Kenya showed independent association of altitude and wetness indices with malaria incidence (Cohen et al., 2008). A study in Papua New Guinea showed increasing distance from the village center and decreasing elevation were positively associated with the malaria risk (Myers et al., 2009).

We noted rivers as the main breeding places of Anopheline mosquitoes in Bashagard district. Previous studies of geographic

associations with malaria prevalence have found a positive association with proximity to rivers and increased mosquito density and malaria (Van der et al., 2003; Oesterholt et al., 2006; Zhou et al., 2007). Although rainfall can potentially provide the conditions for breeding of Anopheline mosquitoes and increase the malaria hazard, but in Bashagard district it is usually showery; the soil texture of the area is sandy and porous, and is not able to preserve the rain water on the surface. Therefore, the riverside and riverbank of main and seasonal rivers are the potential breeding places for mosquitoes. The showery rainfall washes the breeding places and will result to decreasing in Anopheline vectors population. We postulated the negative effect of raining; therefore precipitation layer in calculation for mapping malaria hazard was not included. In parallel to our finding, Haghdoost et al. (2008) and Salehi et al. (2008) have found the negative effect of rainfall on malaria incidence in southern Iran, while they reported positive correlation of temperature and relative humidity. The hazard map will help us to identify potential breeding places for malaria vectors.

High spatial resolution satellite images can detect small and temporary water bodies and vegetation as suitable places for mosquito rearing and resting. Although spatial resolution of IRS image (each pixel = 24 m²) cannot cover the small bodies of surface water (as the potential breeding places), because the sandy soil texture of the area and high radiation, almost all breeding places are located in riverbeds and riverbanks. We covered the potential breeding places by considering the main and seasonal rivers in hazard calculation.

For managing an accurate malaria control program, it is necessary to identify population at risk, their economic level and access to health facilities. Because malaria is an environmental dependent disease, by integration of these data with socio-economic and health levels of the community it is possible to establish an early warning system for epidemics. We have collected data of 11 years distribution of malaria, made a databank including monthly and annual variations in distribution of malaria at the village level based on parasite species. Analyzing spatial and temporal trends of the disease enable us to monitor its actual sources across the district in time and space. The risk maps can be produced based on the latest data for strengthening and improving the intervention measures.

Another human factor affecting malaria risk is the knowledge, attitude and practice of people about malaria. Previous study in the area showed the knowledge of people in Bashagard district about malaria transmission and its symptoms is rather good, but their practice about self protection needs to be improved by educational programs (Hanafi-Bojd et al., 2011b). More knowledge will results in better attitude and practices, and will reduce the malaria risk hazard.

In conclusion we can stratify the district into three strata for planning malaria control. The first stratum is high risk area with five Anopheline vectors including *An. culicifacies*, *An. dthali*, *An. stephensi*, *An. superpictus* and *An. fluviatilis* (Hanafi-Bojd et al., 2012). Due to both exophilic and endophilic behaviors of these vectors, we recommend targeting indoor residual spraying (IRS) during epidemics, vast distribution of long lasting impregnated nets (LLINs) and larviciding as intervention methods. Also active cases detection and treatment, monitoring population movements and regular training programs for health personnel are essential. The second stratum, including high and moderate risk areas in Fig. 6, has moderate risk for malaria transmission. Therefore distribution of LLINs, larviciding, passive case detection and treatment, monitoring population movements is recommended. For the third stratum or low and very low risk areas as indicated in Fig. 6, we only recommend larviciding as well as passive case detection and treatment. Insecticide resistance status of vectors, drug resistance and routine entomological checks are advised for all strata.

This is the first study about malaria hazard and risk in the area. These basic infrastructures that is now available for Bashagard can use as a base for future studies, with regular updating. It can also be attributed to the surveillance system for other mosquito-borne diseases.

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