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Original Research Article

Spatiotemporal distribution of malaria prevalence in the district Anuppur, central India

Manish Kumar Dwivedi[1], Sanjeev Bakshi[2], Shruti Sonter[1], Shringika Mishra[1], Prashant Kumar Singh[1]*

[1]Department of Biotechnology, [2]Department of Statistics, Indira Gandhi National Tribal University, Amarkantak, Madhya Pradesh, India

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***Correspondence:**
Dr. Prashant Kumar Singh,
E-mail: Prashant.singh@igntu.in.ac

ABSTRACT

Background: In the current study, 2013±16 medical data were examined to evaluate intervention effects on malaria prevalence in central India. Spatiotemporal variation in the distribution of malaria types (PV, PF, and PV-PF) was also investigated and geographical distribution of malaria prevalence in central India first time.
Methods: The data was collected from the primary health centers, sub health centers, community health centers, and district hospital. The data was used for the calculation of annual blood examination rate, annual parasite incidence, blood slide positive rate, blood slide *falciparum* rate, % PF, % PV, and % PV-PF types of malaria. The rate of malaria was transformed ($\text{Sin}^{-1}\sqrt{\text{r}}$) for carrying out statistical analyses. ANOVA models were considered for analysis of the data. The minimum deviation informatics statistic has been used to compare the spatiotemporal distribution of malaria types. The spatiotemporal distribution maps of malaria prevalence and mosquito breeding sites were generated using the geographic component software ArcGIS 10.3.
Results: The results display that space was an important significant factor for malaria prevalence. Kotma, one of the blocks of the study region displayed varying geographic patterns of dominance. The analysis for the presence of malaria types indicated that space was an important source of variation for the rate of malaria due to *Plasmodium falciparum*. The distributional patterns of the malaria types, as observed in the empirical data were tested using the MDIS statistic and findings indicate that the distributions of malaria types for the spatial points, namely Pushparajgarh, Kotma, and Anuppur were not the same over the selected time points. The geographical maps mainly displayed the active mosquito breeding sites in river areas and handpump areas namely Karpa, Laidara, Khamraudh, Rajendragram, Sivarichndas, Basaniha, Soniyamar, Kiragi. The maps also displayed 46% high risk, 34% moderate risk, and 20% low-risk area.
Conclusions: The prevalence of malaria in this tribal-dominated area shows that was governed by mosquitogenic factors and their transmission.

Keywords: ANOVA, Malaria incidence, Malaria prevalence, Minimum deviation informatics statistic, Spatiotemporal

INTRODUCTION

Malaria is one of the severe life-threateningvectors borne infectious diseases. It spreads from one person to another through bites of female adults of mosquitoes belonging to the insect genus Anopheles.[1,2] World Health Organization (WHO) propelled the Global Malaria Eradication Program in 1950 in India which was a great success as the incidence of malaria came down from 75 million cases, and 8,00,000 deaths in 1947 to 49,151 cases and no deaths in 1961.[3] However, in 1971 malaria cases rose to

13,22,398 (11.2% of PF cases) and in 1976, 64,67,215 cases of malaria were recorded.[3] The reasons for such failure were attributed to the complacency, operational and technical problems such as resistance in vectors for DDT and in parasite to chloroquine. Learning from this failure, the Indian government implemented the modified plan of operation in 1977. As a result, malaria cases dropped and stabilized to 2-3 million cases per annum in the subsequent years.[4] As consequence malaria attributed deaths dropped and were 1,37,846 deaths in 1985 and 72,285 deaths in 1987. According to the 1991 annual report of the National Malaria Eradication Programme-India, WHO estimated 19,500 to 20,000 deaths per annum in India.[5] However, in 1996, 30,35,588 cases and 2,803 deaths were reported due to outbreaks and epidemics. In 2006, the number of reported cases stood at 16,69,333. Hence the numbers reported by the National Vector Borne Disease Control Programme (NVBDCP) reflect the best trend and it isnoteworthythat there has been a gradual increase in the number of deaths.[6]

Based on the world malaria report (2020), there were an estimated 229 million malaria cases in 2019 in 87 malaria-endemic countries. There were 409000 malaria deaths in 2019 globally. Children below 5 years are the maximum susceptible affected group through malaria accounting for 67% (274000) of total malaria deaths in 2019.[7] 29 countries reported 95% of global malaria cases, amongst them Nigeria, the Democratic Republic of the Congo, Uganda, Mozambique, and Niger being the major ones. In 2019, there were 215 million cases, the majority of them (94%) were from the World Health Organization (WHO) African Region while the WHO South-East Asia Region reported around 3% of the total global malaria burden.[7] There has been a decline in malaria cases that was evidenced by the 73% reduction (6.3 million) in 2019 as compared to 2000 (23 million). Malaria case incidence has been reduced to about 18 cases per 1000 population at risk in 2000 to about four cases in 2019. India has been successful in reducing the cases from about 20 million cases in 2000 to about 5.6 million in 2019. Sri Lanka, Timor-Leste, China, and El Salvador are some countries that have eradicated malaria or have requested certification of malaria eradication.[8]

The state of Madhya Pradesh (MP) has a large proportion of the population residing in the forest or near forest areas.[9] The primary health centers, sub-health centers, and community health centers are remotely placed, with minimal or no transportation facilities. Malaria is prevalent in MP due to vast forest tracts.[10] Malaria control in this region requires specific approaches and control programmes.[11] This region covered more than 25% tribal population and reported a high malaria burden API>2%.[12,13] The NVBDCP is a project targeting eight districts benefiting the tribal populations and has the flexibility to divert resources to any needy areas in case of an outbreak of malaria.[14] This project was completed in December 2005 and since then the project continued under the substance phase (NVBDCP). The number of malaria cases across in 2017 amounted to approximately 46,176, down from about 69,106 malaria cases in 2016.[15]

Access to health care services is difficult in tribal-dominated areas due to technical and geographical difficulties. Public or private transport is not easily available. Despite the efforts of the government for the upliftment of the public health infrastructure, the availability of trained medical staff is a major concern.[16] People find it more convenient to consult the traditional healers and local practitioners for the treatment of malaria and other diseases as they are available in the vicinity and can understand the language and social beliefs of the tribal communities.[17] There are an adequate number of health workers like accredited social health activists (ASHAs), auxiliary nurse midwives (ANMs), multipurpose workers (MPWs) posted at sub-center and primary health centre (PHC) levels in tribal areas but they also have associated problems.[16-18] The health-seeking behavior of the tribal population in the context of malaria requires in-depth investigation as it will provide the assessment of major issues that need to be addressed for providing health care facilities.

Geographical information system (GIS) has emerged as a powerful technique for monitoring public health in various geographical locations.[19] Database in the field of health science includes data that vary in diversity, size, and complexity and can be analyzed in an efficient manner using GIS tools.[20] Till now, GIS has been primarily utilized to describe malaria risk, often limited to hospital-based morbidity and mortality. However, for practical purposes use more detailed maps containing comprehensive information are required.[19] With regard to the spatial epidemiology of malaria, recent studies have been benefited from major advances in the development of GIS-based technology. Control and eradication of the disease require targeting vector control in high-risk areas, focusing on asymptomatic and symptomatic infections, and management of import risk factors. Currently, due to reasons attributed to cultural beliefs, inaccessibility of geographical terrains, and basic infrastructure, the region remains a malaria hot-spot in India. Given this background, the present study investigates the incidence of malaria in a spatiotemporal context in Anuppur district (MP) India. Further, the distribution of malaria types namely PV, PF, and PV-PF were also studied in a spatiotemporal context and relevant policy suggestions are made.

METHODS

Study area

Anuppur, a tribal populated district is situated in the northeastern corner of MP, India. Anuppur spans across an area of 3724 sq.km, lies between 22º7’ and 23º25’N latitude and 81º10’ and 82º10’ E longitudes and the total area is 3724 sq.km. It has been divided into four administrative blocks Pushparajgarh, Kotma, Jaithari, and

Anuppur having 585 villages.[21] The total population of the district is 7,49,522 (379,114 males and 370,123 females). The literacy rate of Anuppur is 67.88%, with male literacy around 78.26%, while the female literacy rate is 57.30%.[21] Nearly 47.9% of the total population of Anuppur district is comprised of scheduled tribes, who prefer to live in and around the forested area. The primary health infrastructure of the district includes 01 district hospital, 16 primary health centers, 127 sub-health centers, and 07 community health centers.[22]

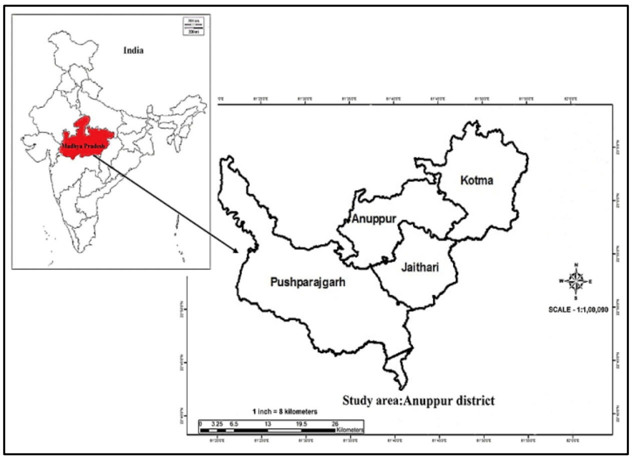

Figure 1: Representative map of study area showing position of Madhya Pradesh, Anuppur district, in India.

Primary blood smear data

The primary data of blood smear was collected from the district hospital, primary health centers, sub-health centers, and community health centers where the slides were screened for the presence of malaria parasite and recorded as being negative and positive for PF, PV, and PF-PV (mixed types) of malaria. The obtained primary data was utilized for the calculation of annual blood examination rate (ABER), annual parasite incidence (API), blood slide positive rate (SPR), blood slide *falciparum* rate (SFR), percent of positive slides that are positive for PF (% PF), percent of positive slides that are positive for PV (% PV) and same for the mixed types of malaria (Table 1).

Developing GIS-based maps

We created GIS maps that depict the associated factors that are responsible for malaria prevalence. GIS maps of malaria distribution were prepared to highlight their geographical distribution in the study regions. The maps were created based on the overlay operation method which can provide new information. Malaria breeding sites, malaria prevalence, and slope maps were prepared that could play a major role while policy framing. The GIS maps were prepared with the help of village location, and satellite imageries. Collected information was visualized, analyzed, and managed with geographic component software ArcGIS 10.3. The slope is another topographic parameter that may be associated with the formation of mosquito larval habitat, a measure of the rate change of land per unit distance that can affect the stability of aquatic habitat.[23] In the study, areas from 0 to 5 degrees were classified as high-risk, areas with 5 to 15 degrees were classified as moderate risk, and areas greater than 15 degrees were classified as lowest risk.

Statistical analysis

In the current study all the descriptive and statistical data analysis was done with the help of IBM SPSS Advanced Statistics 20 software. The current study analyzed the data for the years 2013-2016 obtained from different health centers across the Anuppur district. The rates of incidence were obtained for each space-time pair. The rates so obtained and classified according to four spatial points and four temporal points that make up a 2-way classification of rates of prevalence. This two-way classified data was analyses utilizing two-way and one-way ANOVA techniques. The application of this technique requires the rates of incidence of malaria "r", to be normally distributed. The rates are hence transformed using the transformation ($\mathrm{Sin}^{-1}\sqrt{\mathrm{r}}$) so as to normalize the data. These transformed rates, in a two-way classified format, are analyzed using the ANOVA technique. Each space-time combination has data on the number of people infected with the three categories of malaria types, namely, the PV, the PF, and the PV-PF. It was assumed that this three-category data arises out of an underlying multinomial distribution with the respective probabilities as parameters and there is no difference between the observations from each space or between the spaces themselves. It was also assumed that there were no significant outliers. The change in this distribution over space and over time has been investigated by utilizing the minimum deviation informatics statistic (MDIS).[24] The null hypothesis assumed that for each of the reference periods under consideration this distribution remains unchanged over the four spatial points. Wherever the difference was found to be significant a pairwise comparison for spatial points was performed.

Looking from temporal points of view, for each of the spatial points, the distribution of malaria types is expected to remain unchanged over different reference periods. This hypothesis is tested for Pushparajgarh, Kotma, Anuppur, and Jaithari using MDIS statistics. Where the difference is found to significant pair-wise comparisons of reference periods is performed. The calculations were carried out on MS-Excel and SPSS.

RESULTS

Examined blood smear data

The ABER for Pushparajgarh, Kotma, Anuppur, and Jaithari blocks was calculated and has been presented in Table 1. It was observed that ABER increased in each block in 2015-2016 respectively. The SPR was calculated for all the four blocks for the study period (Table 1) and it was observed that SPR rates were higher for Pushparajgarh and Anuppur blocks as compared to the other blocks. The SVR and SFR were calculated and have been tabulated in Table 1. SVR indicates the annual screened slide *vivax* percentage in this area while the SFR indicates the annual screened slide *falciparum* percentage in this area. The percentage of PF cases as compared to PV or PF-PV mixed infections were higher in Pushparajgarh, Anuppur, and Jaithari while PV was more prevalent in Kotmablock in all the study years (Table 1). The composite types of malaria (PF-PV) infections were found to be highest in Kotma block during the study years (Table 1).

The values of API rate in Pushparajgarh were highest followed by Anuppur, Jaithari, and Kotma. The current data reported three deaths in Pushparajgarh division due to malaria during 2013, 2014, and 2015. In Anuppur division, there were two deaths reported in 2014 and one death each in 2015 and 2016 from Jaithariblock (Table 1).

Table 1: Blood slide examination data of Anuppur district (Pushparajgarh, Kotma, Anuppur and Jaithari). *Plasmodium falciparum, P. vivax* and mixed infection (PV-PF) cases from 2013-2016.

Block/Division	Year	*Total Population	**Total blood slide examination	Total malaria positive case	Total PF case	Total PV case	Total PF+PV case	ABER	API	SPR	SFR	SVR	#PF%	PV%	PF+PV%	Death case
Pushparajgarh	2013	223931	20188	237	165	54	18	9.02	1.06	1.17	0.82	0.27	69.62	22.78	7.60	1
	2014	246082	20849	788	592	84	112	8.47	3.20	3.78	2.84	0.40	75.13	10.66	14.21	1
	2015	246082	25204	939	734	125	80	10.24	3.82	3.73	2.91	0.49	78.17	13.31	8.52	1
	2016	246082	27520	756	412	183	161	11.18	3.07	2.74	1.52	0.66	54.49	24.20	21.31	0
Kotma	2013	275957	22955	156	39	54	63	8.32	0.57	0.68	0.17	0.23	25.01	34.61	40.38	0
	2014	285730	26029	304	68	153	83	9.11	1.06	1.17	0.26	0.58	22.37	50.32	27.31	0
	2015	285730	18268	79	26	34	19	6.39	0.28	0.43	0.14	0.18	32.91	43.04	24.05	0
	2016	285730	22756	134	70	40	24	7.96	0.47	0.52	0.31	0.17	52.24	29.85	17.91	0
Anuppur	2013	160193	25777	362	191	110	61	16.09	2.26	1.40	0.74	0.43	52.76	30.39	16.85	0
	2014	173315	26680	402	304	35	63	15.39	2.32	1.51	1.14	0.13	75.62	8.71	15.67	2
	2015	173315	20953	901	465	316	120	12.09	5.20	4.30	2.22	1.50	51.61	35.07	13.32	0
	2016	173315	21984	540	270	130	140	12.68	3.11	2.45	1.22	0.60	50	24.07	25.93	0
Jaithari	2013	98645	10510	101	58	32	11	10.65	1.02	0.96	0.55	0.3	57.43	31.68	10.89	0
	2014	106179	12289	126	71	38	17	11.57	1.19	1.03	0.58	0.31	56.35	30.15	13.50	0
	2015	106179	15344	88	55	21	12	14.45	0.83	0.57	0.36	0.13	62.50	23.86	13.64	1
	2016	106179	16236	98	54	26	18	16.31	0.92	0.56	0.31	0.15	55.10	26.53	18.37	1

ABER (Annual Blood Examination Rate): Number of blood smears examined in a year x100 / Total population. API (Annual Parasite Incidence): Total no. of positive slides for malaria parasite in a year x 1000 / Total population. SPR (Slide Positive Rate): (Total positive slides/ Total slides examined) x100
SFR (Slide Falciparum Rate): (Total positive PF/ Slides examined) x100. SVR (Slide Vivax Rate): (Total positive PV/ Slides examined) x 100
#PF%: The percentage of PF positives was calculated using the formula PF%= (no. of PF positive/total number of malaria positives) *100; the same formula was used to calculate the percentage of PV and PV-PF mixed infections. *Total population, Anuppur district as per Census 2011, **Total blood slides examined referred as sample size.

Analysis of variance

The one-way and two-way ANOVA were applied to verify the unequal prevalence rate of malaria among the blocks. Before applying ANOVA, we needed to test the assumptions underlying the one-way and two-way ANOVA. There are two assumptions independent variables that include spatial points (Anuppur, Jaithari, Kotma, and Pushparajgarh) and temporal points (2013-14, 2014-15, 2015-16) for two-way ANOVA and only spatial points (Anuppur, Jaithari, Kotma, and Pushparajgarh) for one-way ANOVA. The results of two-way ANOVA show that there was significant variation in spatial points between the prevalence rate of malaria (all) ($F=7.43$ and $p<0.001$) and significant variation in spatial points between the prevalence rate of malaria PF ($F=13.68$ and $p<0.001$) (Table 2). The results clearly displayed that there was no significant variation in temporal points for overall malaria occurrence ($F=0.95$ and $p=0.45$) and types of malaria (PF, PV, and PV-PF). The results of one-way ANOVA also show that there was significant variation in spatial points Jaithari and Kotma for overall malaria prevalence ($F=-0.08$ and $p<0.001$, and $F=-0.08$ and $p<0.001$) and malaria PF ($F=-0.07$ and $p<0.001$, and $F=-0.09$ and $p<0.001$) respectively. Taking the account of the above-listed findings, a reduced model with spatial effect as an independent variable was considered for all malaria types and malaria PF transformed rates. The results for this model are presented in Table 2 with Pushparajgarh as a reference spatial point. Further, the pair-wise comparisons were tested in pair-wise spatial points and types of malaria. Significant variation was observed in Jaithari-Pushparajgarh and Kotma-Pushparajgarh. For all malaria transformed rates, Anuppur and Pushparajgarh did not differ significantly, whereas Jaithari and Kotma had transformed rates less than that of Pushparajgarh ($F=-0.08$ and $p<0.02$, and $F=0.08$ and $p<0.01$) respectively (Table 2).

Table 2: P values for F-statistic for Model-1 (two-way ANOVA) and Model-2 (one-way ANOVA) for transformed rates of Malaria and its types, PV, PF and PV-PF and Pair-wise comparison of spatial points for transformed rates of malaria (all) and Malaria PF.

Two-way ANOVA				
Independent variables	F-statistics (p values) for			
	Malaria (all)	Malaria PV	Malaria PF	Malaria PV-PF
Spatial points	7.43* (<0.001)	1.20 (0.36)	13.68*(<0.001)	3.21* (0.07)
Temporal points	0.95 (0.45)	0.23 (0.87)	1.60 (0.25)	0.72 (0.56)
One way ANOVA				
One way ANOVA	Spatial points	Malaria (all)	Malaria PF	
	Anuppur	-0.01 (0.53)	-0.03 (0.17)	
	Jaithari	-0.08*(<0.001)	-0.07*(<0.001)	
	Kotma	-0.08*(<0.001)	-0.09*(<0.001)	
	Pushparajgarh®	0	0	
	F (p value)	7.51*(<0.001)	11.89*(<0.001)	
	Model R^2	0.65	0.75	
Pair of special points	Pair of spatial points	Difference of rates (p value)		
		Malaria (all)	Malaria PF	
	Anuppur-Jaithari	0.63 (0.06)	0.17 (0.08)	
	Anuppur- Kotma	0.68* (0.04)	0.67* (0.01)	
	Anuppur-Pushparajgarh	-0.01 (0.92)	-0.25 (0.49)	
	Jaithari- Kotma	0.00 (0.99)	0.02 (0.64)	
	Jaithari- Pushparajgarh	-0.08* (0.02)	-0.71* (0.01)	

*Indicates that the difference is significant at level 5 percent or less. ®denoted the reference category

Table 3: MDIS statistic and p-vale for equivalence of distribution of malaria types over space for a given time and times over given spatial points, malaria types for consecutive years, and the difference between the distributions of malaria types for different pairs of spatial points for 2013-2016.

Time points	MDIS statistic (p value)	Spatial points	MDIS statistic (p value)	
2013	74.79*(<0.001)	Pushparajgarh	136.99*(<0.001)	
2014	69.74*(<0.001)	Kotma	166.04*(<0.001)	
2015	76.50*(<0.001)	Anuppur	93.49*(<0.001)	
2016	1.90 (0.93)	Jaithari	4014 (0.66)	
Spatial points	**2013-2014 MDIS statistic (p value)**	**2014-2015 MDIS statistic (p value)**	**2015-2016 MDIS statistic (p value)**	
Pushparajgarh	12.71*(<0.001)	7.74*(<0.001)	55.33*(<0.001)	
Kotma	5.79 (0.06)	1.80 (0.41)	3.82 (0.15)	
Anuppur	32.35*(<0.001)	57.38*(<0.001)	21.24*(<0.001)	
Jaithari	0.18 (0.91)	0.54 (0.76)	0.61 (0.74)	
Pair of spatial points	**2013 MDIS statistic (p value)**	**2014 MDIS statistic (p value)**	**2015 MDIS statistic (p value)**	**2016 MDIS statistic (p value)**
Pushparajgarh-Kotma	46.70 *(<0.001)	139.54*(<0.001)	33.50*(<0.001)	1.06 (0.59)
Pushparajgarh-Anuppur	9.43* (0.01)	0.71 (0.70)	76.80*(<0.001)	2.04 (0.36)
Pushparajgarh-Jaithari	2.30 (0.32)	14.90*(<0.001)	5.06 (0.08)	0.28 (0.87)
Kotma-Anuppur	2.39*(<0.001)	115.4 3*(<0.001)	5.94 (0.05)	2.26 (0.32)
Kotma-Jaithari	18.97 *(<0.001)	22.80*(<0.001)	7.41* (0.02)	0.15 (0.92)
Anuppur-Jaithari	1.19* (0.56)	16.20*(<0.001)	2.49 (0.29)	1.34 (0.51)

*Indicates that the difference is significant at level 5 percent or less.

Distribution of malaria and malaria types

The distributional patterns, of the malaria types, as observed in the empirical data were tested using the MDIS statistic. The findings indicate that the distributions of malaria types for the spatial points, namely Pushparajgarh, Kotma, and Anuppur were not the same over the selected time points while Jaithari had consistent distributional patterns over time. In Pushparajgarh, Anuppur, and Jaithari the malaria PF is the major infectious parasite followed by PV type infections. Irrespective of this order of dominance, the change in the proportion of malaria types, over the years, makes the distribution differ significantly. Table 3 displays a comparison of distributions of malaria types for consecutive years for the selected spatial points. Distribution for Anuppur and Pushparajgarh varies from time to time in three pairs. It shows the dynamically changing pattern of malaria types in these two blocks. However, in Kotma and Jaithari, the consecutive years did not differ significantly vis-à-vis the distribution of malaria types. While analyzing time points, analysis of distribution was done on spatial points. The types of malaria type for the selected spatial points were not the same for the years 2013, 2014, and 2015. However, for 2016, there was not much difference in the distribution for Pushparajgarh, Kotma, Anuppur, and Jaithari. A pair-wise comparison of the spatial point for the years 2013-2015 has been presented in the following paragraph. Kotma shows a significantly different distribution when compared to Pushparajgarh, Anuppur, and Jaithari for it was 2013, 2014, and 2015 (Table 3).

Pushparajgarh and Jaithari show the same distributional patterns in 2013, 2015, and 2016 except in 2014, when the distributions were found to be significantly different. Anuppur and Jaithari, except for the years 2014, do have not have a significantly different distribution of the malaria types. This may be due to contiguity among Anuppur and Jaithari. Pushparajgarh and Anuppur had not had significantly differing distribution during 2014 and 2016. However, the distribution differed in the years 2013 and 2015 for the two spatial points (Table 3).

Table 4: The empirical distribution of malaria type for the four spatial points for 2013-2016.

Place	2013	2014	2015	2016
Pushparajgarh				
Malaria PF	0.70	0.75	0.78	0.54
Malaria PV	0.23	0.11	0.13	0.24
Malaria PVPF	0.08	0.14	0.09	0.21
Kotma				
Malaria PF	0.25	0.22	0.33	0.52
Malaria PV	0.35	0.50	0.43	0.30
Malaria PVPF	0.40	0.27	0.24	0.18
Anuppur				
Malaria PF	0.53	0.76	0.52	0.50
Malaria PV	0.30	0.09	0.35	0.24
Malaria PVPF	0.17	0.16	0.13	0.26
Jaithari				
Malaria PF	0.57	0.56	0.63	0.55
Malaria PV	0.32	0.30	0.24	0.27
Malaria PVPF	0.11	0.13	0.14	0.18

The empirical distributions of the malaria types, for spatial as well as temporal points, are shown in Table 4. A bird's eye approach to the proportion of each year indicates that the maximum proportion of infected people is malaria PF type in Pushparajgarh, Anuppur and Jaithari. The dominance of malaria PF in Pushparajgarh, Anuppur and Jaithari remain consistent over the time points under consideration. However, Kotma which is geographically at the extreme shows varying patterns of the dominance of the malaria types. In 2013, malaria PV-PF was found to be effective because 40% of these are infected. For, the next two consecutive years, i.e., 2014 and 2015, malaria PV dominated with respectively 50% and 43% of the infected ones falling under this category. Besides, in 2016, malaria PF was a prevalent type of malaria in Kotma, and reporting it in 52% of cases.

Geographical distribution incidence maps

Figure 2 presents the maps of the distribution of mosquito breeding sites in different areas of study. Based on the map Pushparajgarh presented the mosquito breeding sites mainly showed in river area and handpump area. The map shows that the central regions of India namely Karpa, Laidara, Khamraudh, Rajendragram, Sivarichndas, Basaniha, Soniyamar, Kiragi while the other some mosquito breeding sites show in a pond, well, and drainage areas such as Amagma, Lapti, Doniya, Jaraha, Charkumar, Bhejari, Khati, and Lilatola.

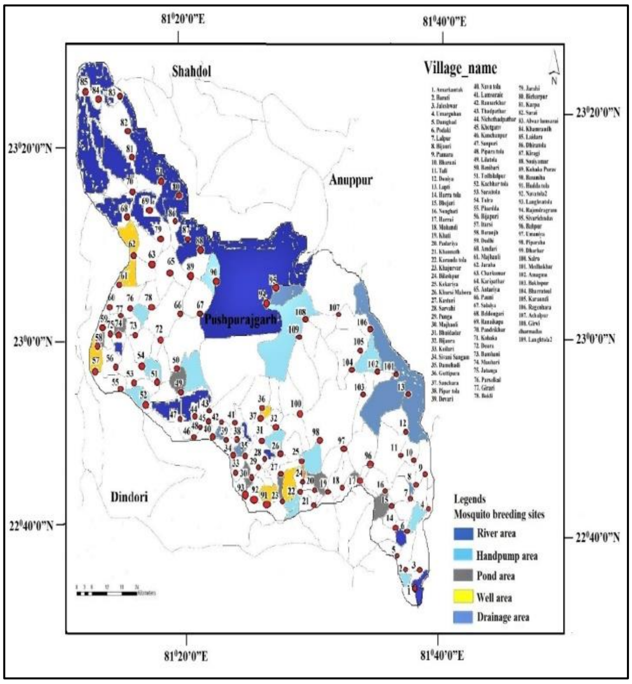

Figure 2: Representative map of study area showing mosquito breeding sites in different villages.

Figure 3 present the maps of the distribution of malaria prevalence in different areas of study. The maps showed 46% high risk, 34% moderate risk, and 20% low-risk areas. The maps displayed high-riskareas namely Karpa, Laidara, Khamraudh; moderate risk areas namely Basaniha, Rajendragram, Sivarichndas; low-risk areas namely Girivi, Langhatola.[2]

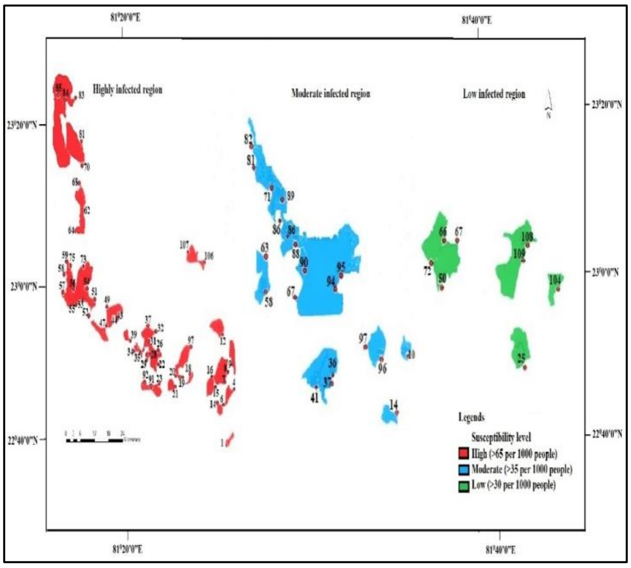

Figure 3: Representative map of study area showing malaria prevalence define high, moderate and low risk.

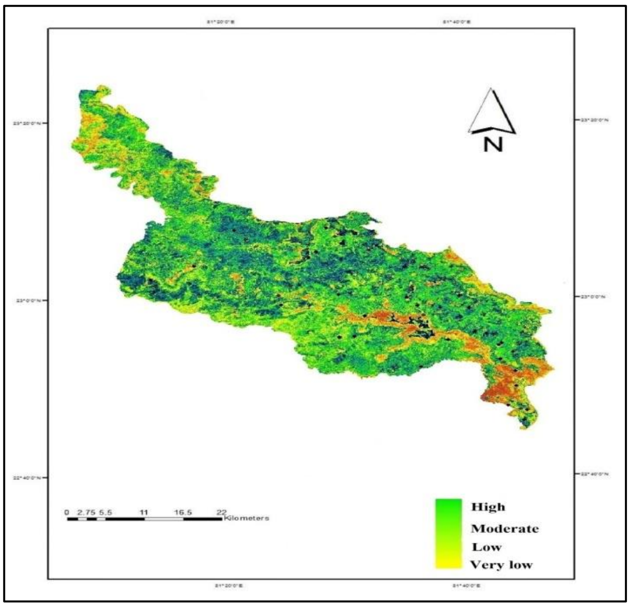

Figure 4: Representative map of study area showing slop map of malaria risk.

DISCUSSION

Public health is a constantly evolving domain as the capacity for the public health system is tremendous in improving health and saving lives. At the same time, public health reform needs to be undertaken for improving the health and wellbeing of individuals and populations.[25] Public health issues are complex and need to be addressed on a wide scale, and require long-term solutions.[26] Due to the large diversity in the population of India, dealing and combating the burden of infectious disease is a challenge. There have been several epidemics of emerging and re-emerging infectious diseases in the past. However, these have been controlled due to timely support and action taken by the Government of India including the Health Department.[27]

The measurement of malaria incidence requires every suspected malaria case to be diagnosed through a comprehensive surveillance system including passive case detection and supplemented by active case detection. In the present study, the incidence levels of malaria were measured in terms of ABER, API, SPR, SER, and SVR along with calculation of prevalence rates of PF, PV and PF-PV mixed infections. The ABER indicator provides information on overall diagnostic monitoring activity and may be useful in interpreting trends in cases of malaria. The indicator guideline suggested, that the ABER should be in the region of 10% in order to provide reliable trends and recommended for an active surveillance system. Initially, the ABER rates were below 10% in Pushparajgarh and Kotma but they increased in 2015 and 2016. The ABER rates in Anuppur and Jaithari were well above 10%, however, the rates continuously decreased from 2013-2016 as observed for Anuppur and Kotma. In Jaithari, ABER rates continuously increased from 2013-2016 that might be due to the active involvement of the ASHAs workers and their regular contact with local people. The situation was different in other blocks, although the government policies and necessary infrastructure exist the awareness level among the general public needs to be lifted.The ABER in the forest-clad regions was lower than the respective ABER of non-forest areas, although, the forest area has been reported with high ABER as compared to non-forest regions, and variation in ABER rates from different regions in Kokrajhar District of Assam, India has been reported[28]. There are several reasons for varying ABER in the region the major one is the low percentage of febrile patients visiting health facilities and thereby undergoing a laboratory test.[29] API gives approximate disease burden per thousand populations and is measured from data of those patients who visit PHCs or health centers for the treatment. The national API rates as per the NVBDCP incidence records were <2 and around 2-5 in scattered regions. It is used by NVBDCP to identify areas for vector control measures, these areas fall under the radar as they are caught in a cycle of limited access to malaria service, under investigation, under-reporting, underserved and hence continued malaria transmission. The API rates in the study region varied and no specific pattern was observed, the API rates in Pushparajgarh were highest indicating the high malaria prevalence in forest-cladregions. Similar higher API rates from the forest region of Kokrajhar, Assam has been earlier reported.[28] It is also to be noted that block Pushparajgarh has the highest tribal population which is less likely to utilize the formal health care facilities as compared to other social groups. There are several other factors associated with tribal communities like low education levels, delayed treatment-seeking behavior, self-medication, belief in traditional healers, poverty that contributes to the high disease burden in the community.[29]. Besides all these factors the convenience in reaching the health care center is a big issue that needs to be addressed. There is a lack of public transport in the region that makes travel tough and expensive. SPR has been used as a substitute to measure the incidence of malaria and found to be positive for *Plasmodium* among all blood smears data studied. SPR correlates to the malaria endemicity levels and helps in the identification of high-risk areas. SPR under 2.9% is considered as the absence of indigenous transmission. SPR rates were less than 5% in all blocks of Anuppur district except in 2015 when the SPR rate was above 5%. Less than 5% of SPR is considered as the transition from the control phase to the pre-elimination phase.[30] The use of SPR values has provided us with an alternative method for estimating changes in the incidence of malaria. *P. falciparum* was dominantly prevalent in Pushparajgarh, Anuppur, and Jaithari blocks while in Kotma block *P. vivax* is the major prevalent species. Specific studies for understanding the *P. vivax* high prevalence rates are required as it is responsible for severe and incapacitating clinical symptoms with significant effects on human health.[31] The spatiotemporal analysis of malaria incidence and ANOVA for the two-way classified transformed malaria rates indicated that space was a significant factor in explaining the variation in rates for all malaria and malaria PF (Table 2). However, PF prevalence was not found to be time associated and the incident rates varied yearly. On the other side none of the factors namely space or the time were not found to be significant for PV and PV-PF infections.

The results display that malaria demographics for Kotma displayed deviation in malaria distributional patterns from the other three blocks and displayed more cases of mixed infections. The reasons for such deviation may be geographical location of Kotma or the requirement of a more stringent surveillance system as the ABER and API values of Kotma were low as compared to the other blocks. The results show that the surveillance system improved effectively after 2014. The results also show that from mid-2014 to 2016 health system was working well due to awareness training, supportive supervision, and ensuring adequate stocks of diagnostic kits and drugs at the village level. The Government initiatives to improve health care access by engaging ASHAworkers in hard-to-reach villages, which had limited access to malaria services under the routine system have led to a significant increase in people being tested and malaria cases being detected, in general, and at the village level, in particular. All these activities have led to a greater increase in passive malaria testing (ABER and SPR) and API helping in the establishment e of better intervention strategies in malaria-endemic regions. This rise in three important indicators in the intervention area over the control may be causally ascribed to these activities. Lessons can be learned from the studies where the malaria burden was reduced remarkably by 89% in the remote Baigachuk villages that are inhabited by the Baiga's, the particularly vulnerable tribal groups by employing the intervention methods like indoor residual spray, long-lastinginsecticide-treated bed nets, prompt diagnosis and treatment along with intensive Information, Education and Communication involving school children.[28]

Application of GIS in epidemiological studies helps to visualize, and analyze the geographic distribution of diseases, revealing spatiotemporal trends and patterns that would be more difficult or obscure to find in any other applications, it performs a spatial statistical function, disease outbreaks, and environmental factors. There has been unprecedented growth in the GIS-based approach for mapping of vector-borne diseases and it has become a principal tool in malaria mapping. GIS maps visually indicated the distribution of mosquito breeding sites and malaria prevalence in the different villages in the study area. Themaps highlighted the regions where malaria cases occurred along with a depiction of mosquito breeding sites. The mosquito breeding sites were mostly present in Rajendragram, Sivarichndas, Basaniha, Soniyamar, and Kiragivillages of block Pushparajgarh that correlated well with high, moderate, and low-risk areas. Spatial and temporal resolution maps of malaria risk can help and visualization of all these risk areas in an efficient way.[32] Risk maps can be used for accurate public health, but available maps for malaria were produced at continental magnitudes, regional or national, such as MARA and have a limited operational use to support local programme activities.[33] The slope map also displayed malaria risk in the Pushparajgarh region (Figure 4). The technology helps us in quick retrieval of information, hot spot identification based on malaria prevalence or on vector breeding sites. Several other factors like socio-economic conditions, population, literacy rates, geographical features can be amalgamated with the malaria indices while preparing the GIS-based maps.[34] In this context, we have also prepared the GIS-based maps of the antimalarial plants used in traditional medicine by the tribal communities of the Amarkantak region.[35]

CONCLUSION

The major factor that keeps the tribal communities away from accessing the modern healthcare system is the rising cost of medical care and the remote habitat locations of the tribal communities. Primary care remains important and effective for promoting good health and reducing illness and attendant costs. The current scenario of high costs is making hospital care unsustainable and, in this situation, comprehensive primary care is required to prevent, avert and manage the disease at the early stages. In India, the prevention, promotion and prompt diagnosis are a cost-effective option as early diagnosis leads to cost-effective treatment which is the main pillar of malaria elimination. It should be emphasized that every new case must be documented and reported to the local health authorities for proper follow-up activities.

Smart and effective surveillance systems at the grass-root level are required, use of mobile phones and GIS-based mapping in disease surveillance, case management, treatment, and follow-up should be introduced, and paramedical and health workers like ASHA should be trained in their use. The workers can be trained for vector surveillance systems including the listing of vector breeding sites, studying the prevalence and demographics of different vector species in the region. The results of these studies can help in designing alternative vector control strategies and understanding malaria epidemiology in tribal areas. Considerable implementation of health programs at remotely located PHC, SHC,and CHC is required. Proper training for the front-line workers should be provided from time to time. Extensive awareness campaigns with the use of proper Information, Education and Communication tools are required in low literacy regions. A proper supply of insecticides such as indoor residual spraying (IRS) and insecticide-treated nets (ITNs) and long-lasting insecticidal nets (LLINs) should be ensured to the remote locations. Intensive epidemiological studies like ours are required to analyze the spread patterns of various infectious and non-infectious diseases. Overall, these findings will be useful in understanding the malaria demographics in particular areas that can be utilized to formulate area-specific intervention guidelines for tribal communities residing in remote forest regions.

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