An Epidemiological Assessment of Malaria Cases in Udalguri District of Assam with Special Emphasis on Intensified Malaria Control Project (2008 to 2017)

Rahim Ali Ahmed (rahim.ahmed48@gmail.com)
National Vector Borne Disease Control Programme https://orcid.org/0000-0002-3689-7206

Avdhesh Kumar
National Vector Borne Disease Control Programme

Ananta Swargiary
Bodoland University

Keshab Barman
National Vector Borne Disease Control Programme

Afluza Begum
Bodoland University

Research Article

Keywords: Malaria, Plasmodium falciparum, P. vivax, Annual Parasite Index, Udalguri, Assam

Posted Date: September 29th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-83707/v1

Abstract

Udalguri district of Assam, North East India is endemic to malaria. There is a high prevalence of vector-borne diseases in this part of Assam, including malaria. In the present study, an epidemiological assessment was carried out for the period of 2008 to 2017 to understand the prevalence of malaria in the district in accordance with Intensified Malaria Control Project, Government of India. The databases for the study were collected from district NVBDCP unit under the establishment of Joint Director of Health Services, Udalguri. All the data were analyzed using Microsoft excel in statistical method ($P \leq 0.05$). The study found that the annual parasite index (API) drastically declined from 14.54 to 1.24 cases per 1000 population during 2008 to 2017. Among all the positive cases, two plasmodium species, *Plasmodium falciparum* and *Plasmodium vivax* were found to be the major species followed by some mixed infection. The malaria cases caused by *P. vivax* were more (68.5%) than *P. falciparum* (31.5%). The disease prevalence by *P. vivax* cases are significantly decreased from 12.06 cases per 1000 population in 2008 to 0.28 cases per 1000 population in 2017. Similarly the *P. falciparum* cases also declined from 3.94 cases per 1000 population in 2008 to 0.96 cases per 1000 population in 2017. The decrease of disease prevalence of malaria cases may be because of effective implementation of vector and disease control strategies. The transmission starts from April onwards and reach peak during the month of June & July. LLINs were found to be effective strategies to control & prevent the disease transmission.

Introduction

Malaria is a major global health problem and one of the most important infectious diseases in tropical and sub-tropical countries. According to the World Malaria Report (WHO, 2019), about 228 million malaria cases were reported throughout the globe in 2018 out of which more than 405 thousand people succumbed to death (WHO, 2019). It is estimated that 1.6 billion people are at risk of malaria (Sharma et al., 2019). Although there is a steady decline of malaria cases throughout the world since 2010, there is still a high prevalence of malaria cases in the African and South-East Asian countries. Out of 228 million cases, almost 93% were reported from WHO African countries including Nigeria, The Democratic Republic of Congo, and Uganda. The South-East Asia region is the region with the second highest estimated malaria burden globally (WHO 2019). As per the recent WHO report, there were 750000 malaria cases in 2018 in SEAR and 165 deaths cases due to malaria. In India, malaria is a major public health problem for centuries. At the time of independence in 1947, out of 330 million total population, about 75 million were estimated to be infected with malaria and 0.8 million death (Lal et al., 2000; Kumar et al., 2007). To combat this menace, the Government of India launched the National Malaria Eradication Programme (NMEP) in April 1953. The programme proved highly successful and the number of malaria cases declined significantly to about 2 millions by 1958 (NVBDCP, India). However, the eradication programme faced major challenges due to several reasons including technical, operational, and administrative reasons and the cases started rising again. As a result in 1976, about 6.5 million cases were recorded by the NMEP, highest since 1958 (NVBDCP, India). Malaria, at one time was a rural health problem in India

which diversified and emerged into several ecotypes such as forest malaria, urban malaria, rural malaria, industrial malaria, border malaria, and migration malaria (Sharma, 1996). The biggest burden of malaria is seen in the most backward, poor and remote rural areas with more than 90% cases while merely 5 - 10% cases are reported from urban areas (Dev et al., 2003; Gupta and Chowdhury, 2014). In India, malaria is highly endemic in rural and tribal areas of Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Gujarat, Jharkhand, Chhattisgarh, Andhra Pradesh, West Bengal, and Karnataka (Shukla et al., 1995; Nema et al., 2020). The proportion of *P. vivax* and *P. falciparum* varies in different parts of India. *P. falciparum* accounts for 30–90% of the malaria cases in the forest areas and <10% of malaria cases in mostly Indo-Gangetic plains and northern hilly states, northwestern India, and southern Tamil Nadu (Singh et al., 2006).

The North-Eastern (NE) states account for 15% of total malaria cases in India (Sarma et al., 2019). The hilly and forested areas of NE India are mostly inhabited by the tribal population and they are at the highest risk of malaria. *P. falciparum* is predominant species in Assam, Mizoram, Tripura and Meghalaya, while *P. vivax* is dominant in Nagaland, Arunachal, and Manipur. Apart from Pf and Pv, other species, *P. ovale* and *P. malariae* have also been reported from Assam and Arunachal Pradesh (Gogoi et al., 1995; Mutheneni et al., 2014). From 2008 to 2012, Assam reported the maximum number of malaria cases followed by Meghalaya. In 2009, Assam reported 91413 number of malaria cases where 66557 were due to *P. falciparum*. There was a steep decline in the Pv cases in Assam from 2008 (25815 cases) to only 957 cases in 2018. As of 2018, Pf and Pv contribute 74.9 and 25.1% of the cases in Assam (Mohapatra et al., 1998). Udalguri is a small district of Assam endemic to many vector-borne diseases including malaria. Majority of the population of the district live in rural areas and are vulnerable to malaria due to lack of proper health standard and malaria related knowledge. Although the district is endemic to mosquito borne diseases, very few work have been carried out to study prevalence of such disease. The present study, therefore, investigates the epidemiological dynamics of malaria in Udalguri district of Assam for the period of 2005-2017.

Materials And Methods

Study Area

Udalguri District of Assam, NE India is high endemic on Malaria and contributes highest number of Malaria cases in the state. Geographically, Udalguri district is located at 26°46'N 92°08'E / 26.77°N 92.13°E at an altitude of about 345' above the mean sea level (MSL). Total geographical area of the district is about 1,985.68 sq. km. Males constitute 52% of the population and females 48% of 9.1 lakh population of the district. The district has an average literacy rate of 74%, higher than the national average of 59.5%: male literacy is 80%, and female literacy is 67%. In Udalguri, 12% of the population is under 6 years of age (5).

The southern parts of the district are situated on the plains of the Brahmaputra Valley Zone. Major tributaries of the river Brahmaputra viz. Pachnoi, Dhansiri, Jiya Dhansiri, Mora Dhansiri, Noa, Kulsi, Dipila and Bornoi, which originate from the foothills of the Himalayan Range flow through the district and they mainly contribute towards the sustenance of the agrarian economy of the district. In northern part of the district share its border with Bhutan & Arunachal Pradesh.

Collection of Data

The information regarding district profile, malaria epidemiological data, vector control, and seasonal prevalence etc were collected from the district NVBDCP Unit under the establishment of Joint Director of Health Services, Udalguri district and Intensified Malaria Control Project – Phase I & II (2008 to 2017) of Government of India. The epidemiological data were collected from 2005 to 2017 and the data related to Sessional variation of malaria cases were collected from 2011 to 2017.

Statistical Analysis

All the statistical analysis and preparation of graphs were carried out in Microsoft excel and OriginPro softwares. Statistical significant test was carried out at $P \leq 0.05$ level.

Results

Demographic profile of District

Table 1 showed the demography and capacity building for malaria control programme of Udalguri district of Assam. With 955 villages, 171462 households, the district has a population of 910261 as per the population census 2018 (Source NVBDCP Udalguri). The tribal population of the district constitutes about 44% of the total population. The population density of the district currently stands at 497 per sq km. The district has also a satisfactory sex ratio. The health-care system of Udalguri District comprises of 3 Block Primary Health Centers (Orang, Khairabari, and Udalguri, 1 District Hospital, 10 Primary Health Centers, 4 Community Health Centers, 9 Dispensaries, and 153 Sub Centers that have facility for diagnosis and treatment of Malaria.

Table 1. Demography and capacity building of Udalguri district of Assam, India

Udalguri District Profile		Capacity Building	
Population	909442	District Malaria Officer	1
Tribal Population	401802	District VBD Consultant (GFATM)	1
Population Density	497 per sq km	Asst. Malaria Officer	1
Sex Ration (Male : Female)	1000:996	SA Cum DEO (GFATM)	1
Literacy Rate	80%	Malaria Technical Supervisor (GFATM)	3
District Hospital	1	Malaria Inspector	3
Block PHC	3	MPW (M)	46
CHC	4	SW/BHW/SI/BHI	72
PHC	10	Lab Technician	25
Dispensary	9	ASHA	1052
Sub-Centers	153		
Tea Estates	23		
No. of villages	955		

The public health delivery system was also observed in the district. One District Malaria Officer, One District Vector Borne Disease Consultant, One Assistant Malaria Officer and one Secretarial Assistant cum Data Entry operator to monitor and supervise the programme activity in the district. The district has three block PHCs (2 to 5 lakh population) and each block PHC have one Malaria Inspector, one Malaria Technical Supervisor and one Laboratory Technician. There are 10 Primary Health Centers and 9 State Dispensaries (0.5 to 1.5 lakh population) and each have one Health Inspector and one Laboratory Technician in each lab of the PHC. Under this PHCs/SDs there are 153 Sub Centers and each SC having a population of 5 to 10 thousand populations and one Health Worker (M) designated as SW/BHW/MPW (M) and two health worker (Female) designated as ANM are appointed for active surveillance. And each Sub center have 3 to 5 village in average, each village have one or more than one Accredited Social Health Activist (ASHA) covering about 1000 population in average for passive surveillance. The ASHA workers were provided with RDKs, Slides and anti-malarial tablets like CQ & ACT for diagnosis and treatment of the Malaria patient at village level through passive surveillance. It was also observed that in 2018, under Intensify Malaria Control Project, phase I, the post of Malaria Technical Supervisor was created under the GFATM budget suppot and during 2012, Intensified Malaria Control Project, the post of District VBD Consultant was created as a technical support to the Programme along with a SA cum DEO for data management in district level under the GFATM budget head. There are 25 laboratories in the district and one Sentinel site Laboratory at District Hospital. It was observed that the reports are generate

from the villages and first compilation was done at Sub Center level for both active and passive blood slide collection and forwarded to higher authority. It was observed that during 2017, a total no of 83414 numbers of blood slides were collected and 1102 of collected slides were found to be positive for malaria.

Malaria Prevalence in Udalguri District

Udalguri district is highly endemic in malaria, and several cases reported throughout the year. It was noticed that two major Plasmodium species (*P. falciparum* and *P. vivax*) are reported from the district. Figure 2 showed the population sizes of Udalguri district, blood sample examined as well as the positive cases of malaria reported during the year 2005 to 2017 in Udalguri district of Assam. It has been observed that there was a big increase in the population size of the district during the year 2005-2006. However, since 2006 onwards till 2017 there was a very little increase in the total population of the district. The blood smear collected and examined was about 6.22% of the total population in 2005 which increased up to 21.40% in 2012. The study also observed that there is no positive correlation ($P \leq 0.05$ level) to the number of BSC /BSE and ABER with the population size. The rate of annual blood examination rate decreased from 21.40% in 2012 to 9.21% in 2017. During the period since 2005 to 2017, the average value of ABER is 12.91%. We also observed that there is lesser blood examination since 2015 to 2017 averaging 9.44% per year. The study also observed that there is a significant decline in the trend of positive cases of malaria from 2005 to 2017. The percentage of positive cases out of blood smear collected and examined were found to be about 24% in 2005 and the rate decreased up to 1.35% in 2017.

Table 3: Comparative Epidemiological Reports 2005 to 2017- Udalguri District.

Year	Population	BSC /BSE	ABER (%)	Total Positive	Pf	API	SPR	SFR	Death
2005	524400	32633	6.22	7832	1025	14.94	24.00	3.14	4
2006	813423	86328	10.61	16780	3909	20.63	19.44	4.53	4
2007	816208	66488	8.15	12075	2999	14.79	18.16	4.51	1
2008	929213	113039	12.17	13510	3219	14.54	11.95	2.85	5
2009	872888	126660	14.51	14376	4140	16.47	11.35	3.27	0
2010	867842	163446	18.83	13767	3188	15.86	8.42	1.95	2
2011	873262	156108	17.88	9584	3189	10.97	6.14	2.04	0
2012	876862	187688	21.4	8050	2163	9.18	4.29	1.15	0
2013	895171	145632	16.27	3874	1231	4.33	2.66	0.85	0
2014	875725	118114	13.49	2887	1739	3.3	2.44	1.47	0
2015	901396	92735	10.29	2386	1598	2.65	2.57	1.72	0
2016	901511	79724	8.84	1770	1139	1.96	2.22	1.43	0
2017	905688	83414	9.21	1129	874	1.22	1.35	1.05	0

BSC/BSE- Blood Smear Collected/ Examined; ABER- Annual Blood Examination Rate; P*f- Plasmodium falciparum,* API – Annual Parasite Index, SPR – Slide Positivity Rate, SFR – Slide Falciparum Rate

Figure 3 showed the prevalence of *P. falciparum* burden among the population of Udalguri district of Assam. It is observed that among the positive cases only two plasmodium species i.e., *P. falciparum* and *P. vivax* were reported to be most active in the district followed by some mixed infections. Although there is sharp decline in the number of positive cases but the percentage of *P. falciparum* infection increased significantly over the period of 2005 to 2017. The burden of *P. falciparum* in 2005 was only 13.09% out of 7832 positive cases. In 2017, the total numbers of positive cases were 1129 with Pf value of 874 which represents about 77.41% of the total positive cases. On the contrary, the infection due to *P. vivax* was gradually declining.

The Annual Parasitic index (API) is an important parameter of malaria surveillance which provides important information about the malaria morbidity in a given year per 1000 population. Figure 3 showed the API and slide positivity rate of malaria cases per year in Udalguri district of Assam during the period since 2005 to 2017. The API was found to be 14.94 in 2005 and then declined to 1.12 by 2017. Similarly, the slide positivity rate per 100 individual screened for malaria burden was at very high 24% in 2005 and the SPR declined to 1.35% by 2017 indicating the significant decrease in the malaria cases in Udalguri

district. However, while analysis the annual slide positivity rate (SPR), it was observed that highest no of cases reported (19%) in 2006, which decreased to 1.32% in 2017. Similarly the population of the District increased from 8.1 lakh in 2006 to 9.1 lakh in 2017. Similarly, the API decreased significantly from 20.63 per 1000 population in 2006 to 1.22 per 1000 population in 2017.

The disease prevalence by *P. falciparum* cases significantly decreased from 3.94 in 2008 to 0.96 cases per 1000 population in 2017. SFR was calculated to know the disease burden due to *P. falciparum*. It was noticed that the SFR is higher in comparison to Slide positivity rate (SPR). The SRF and SPR was found to be 2.85 and 11.35 in the year 2008 and 1.05 and 1.05 in the year 2017, respectively. It indicates that, the API and SPR were gradually declining but the PF% was increasing. In 2008, the Pf% was estimated as 23.82% and in 2017, it increased to 77.41%. Similarly, the prevalence of *P. vivax* cases was significantly decreasing from 12.06 cases per 1000 population in 2008 to 0.28 cases per 1000 population in 2017. The Pv% was 76% in 2008, and decreased by 22% in 2017.

Seasonal Prevalence of Malaria in Udalguri District (2011 – 2017)

Figure 4 showed the seasonal occurrence of malaria cases in Udalguri district during the period 2011 to 2017. It is observed from the study that there is a significant month-wise variation of malaria cases. The peaks of the cases were observed between the months of May to September every year. Highest spike of more than 1800 cases were observed in the year 2011 during the month of July. It is apparent from our study that the number of positive case declined significantly every year till 2017. The total and annual average positive cases in the year 2011 was found to be 9661 and 805.08, respectively. While in the same year the cases almost double 1375.75 during the months of April to August. We have found a steady decline in the malaria cases over the study period. In 2017, the number of positive cases stood at 1262 with an annual average 105.17. Similarly, the number of cases in the peak months (April to August) also declined significant to 154.5 cases.

Spatial Distribution of Malaria Endemicity

Spatial distribution of API of malaria has been done from 2010 to 2017. Because the malaria prevalence varied largely between different health centers of the district (ranging from 0 to 10 and above), stratification of API were also calculated (Fig. 6a,b). During 2010 out of 147 health centers, 95 health centers reported >1 API which covered 71% of total district population. But in 2017, it is observed that there was significant decline of malaria cases and only 8 Health centers out of 153 had 1 or more than 1 API covering only 8% of total district population (Fig. 5).

A spatial map of malaria endemicity was prepared to classify the endemic areas of the district and compared with different colors in Figure 6. Red marked indicates the highest endemicity, API above 10 and the dark green indicates API less than 1. Dark yellow indicates API ranges from 5-10, while light yellow indicated 2 to 5 API. It is observed that during 2013 there were so many health centers which API more than 10. But in 2017, only one health centers that reported API >10.

Discussion

Malaria cases reported in Udalguri district of Assam were mainly caused by infection with *Plasmodium vivax* and *Plasmodium falciparum*. Persistence of malaria in the region may be caused by lack of awareness and low socio-economic conditions of the people, difficult terrain to reach and ideal climatic condition for mosquito breeding (Dev, 1997). Because of these prevailing factors it is difficult to monitor malaria dynamics in the district. To understand the pattern of disease transmission a detailed epidemiological study was conducted in Udalguri district 2008 to 2017 and achievement during Intensified Malaria Control Project (IMCP) Phase I (2008-2012) and Phase II (2012-2017) supported by Global Fund to Fight AIDS, TB and Malaria (GFATM). Compared to 2008, there was a huge decline in malaria cases in 2017 (>90%) in the district which might be because of effective implementation of Malaria and vector control programs such as the Modified Action Plan for Malaria Control (1995), EMCP (1997), The National Anti-Malaria Programme (1999), IMCP (2005) and the introduction of Long Lasting Insecticide Nets by Government of India. In North Eastern states of India, the IMCP started from 2008 to 2012 (Phase-I) and 2012-2017 (Phase II), supported by the Global Fund to Fight AIDS, TB, and Malaria (GFATM) as externally aided component in the project. The National Strategic Plan for Malaria control in India 2012-2017 by National Vector Borne Disease Control Programme (NVBDCP) introduced Bivalent RDT to ensure early diagnosis and complete treatment at the doorstep. In 2013, the National Drug Policy was revised and introduced ACT AL for North Eastern States of India for the treatment of *P. falciparum*.

Udalguri district have 3 block PHCs and it was noticed that Orang Block PHC which covers 26% of the district population reported more than 85% of the total malaria cases of the district in 2017. The Malaria cases caused by *P. vivax* were more (68.5%) than *P. falciparum* (31.5%). However, it is observed that malaria with *P. vivax* cases significantly decreased from 12.06 cases per 1000 population in 2008 to 0.28 cases per 1000 population in 2017. Similarly, *P. falciparum* cases were also significantly decreased from 3.94 cases per 1000 population in 2008 to 0.96 cases per 1000 population in 2017. It was observed that during 2013 there were 63 health centers (covers about 48% of district population) which reported >1 cases per 1000 population and. Similarly, the situation improved by 2017, where only 8 health centers reported >1 case/1000 population. It was also observed that there was a decline Blood slide collection/Blood Slide Examination towards 2017, it was because of successful implementation of Vector control strategy and creating awareness among the community reduced the fever cases. Udalguri district created in the year 2003, hence there was a huge difference in population during 2005 -2006, and it was also observed that there was a fluctuation of population in the 2008 and 2013; it was because of migration due to communal riots in the district.

Udalguri district has a sub-tropical humid climate with semi dry condition. During summer (May to early September), heavy rainfall occurs due to south – west monsoon. It is observed that average annual rainfall of about 2000 mm and the temperature varies between max- 34.5°C and min - 13.5°C. Relative humidity ranges between 82% and 88% (Dash et al., 2008). Malaria is widespread in tropical and subtropical conditions and mortality is associated mainly with *P. falciparum* infection. The Government of India primarily targeting the control of infections, because this parasite is reported to develop resistance capacity to the common malarial drugs (Dev et al., 2010; Alout et al., 2017). Earlier Artemisinin based Combination Therapy – Sulfadoxine Pyrimethamine (ACT-SP) was used to treat the *P. falciparum* cases; later on ACT AL was introduced in North-Eastern states as per Revised National drug policy 2013 due to drug resistance (NVBDCP, 2013). Season play a major role in the transmission of malaria. In our study it is observed that the transmission starts from April onwards and reach peak during the month of June, July, and August. The rise of malaria cases in these months may be because of high vector density and increase in the biting rates of malaria vectors. The seasonal abundance pattern of these vectors in different habitats was significantly higher in monsoon season than that of pre- and post-monsoon season (Mohapatra et al., 2003; Sanei-Dehkordi et al., 2019). Higher number of malaria cases in this region may be because of the presence of many breeding habitats throughout the year with favorable temperature that led to constant risk of malaria transmission (Shil and Balasubramanian, 2020).

Government of India has implemented various vector control strategies to minimize the risk of malaria transmission. During the study period, it was observed that indoor residual spray (DDT 50%) was implemented to reduce the transmission and report shows that average 75-80% populations were covered in malaria endemic areas of the district based on API. It was also observed that DDT spray was not much more effective in rural areas due to poor housing conditions and most of the part of the district is covered by Tea plantation. It was also found that the tea tribes of the district are more vulnerable to malaria than other community of the district. DDT 50% spraying was not allowed in Tea Gardens as it was completely banned in agriculture area. But, during 2015-16, in GFATM project implementing States, a large number of LLINs were distributed in malaria endemic areas to control the malaria transmission. In Udalguri, a total no of 273840 numbers of LLINs were distributed and protect more than 6 lakh population of the district under LLINs. As a result, there was 47% decline of malaria cases in the year 2017.

Conclusion

Malaria is an important health issue in Assam, especially in Udalguri district of Assam. The study revealed that there was a steady decline of malaria cases in Udalguri district during the period 2004 to 2017. Meanwhile, the study also revealed that although the overall numbers of malaria cases were decreasing during the period of study, the Pf cases were increasing. There was a shrinking map of malaria cases in Udalguri district improving the condition of vector-borne diseases. However, given the endemicity of malaria in Assam and North east India, a thorough investigation need to be carried out to study the emergence of any insecticide resistant mosquito vectors in the area so that an effective control strategy can be made to eliminate malaria and other vector-borne diseases.

Declarations

Acknowledgement

Authors acknowledge the financial support in the form of Intensified Malaria Control Project (2008 to 2017), Government of India and GFATM for carrying out this work. Authors are also thankful to District NVBDCP unit, Udalguri district for their active collaboration during the study. Specially thanks Dr Tayebur Rahman, Jt. Director of Health Services, Udalguri and Sri Jatin Chandra Rabha, Asst Malaria Officer, Udalguri for their active support during the study. The corresponding also likes to thank the State NVBDCP unit, Assam for their guidance during the study. The Directorate of NVBDCP, New Delhi and GFATM are also acknowledged for giving me the opportunity to conduct the study.

Conflict of Interest

Authors declare no conflict of Interest

References

1. Alout H, Roche B, Dabiré RK, Cohuet A. (2017) Consequences of insecticide resistance on malaria transmission. PLoS Pathog, 13(9): e1006499.
2. Kumar K, Valecha N, Jain T, Dash AP. (2007) Burden of Malaria in India: Retrospective and Prospective View. Am J Trop Med Hyg, 77(6): 69-78.
3. Dash AP, Valecha N, Anvikar AR, Kumar A. (2008) Malaria in India: challenges and opportunities. J Biosci, 33: 583-592.
4. Dev V, Bhattacharyya PC, Talukdar R. (2003) Transmission of malaria and its control in the north eastern region of India. J Assoc Physicians India, 51: 1073–1076.
5. Dev V, Sangma BM, Dash AP. (2010) Persistent transmission of malaria in Garo hills of Meghalaya bordering Bangladesh, north-east India. Malar J, 9: 263.
6. Dev V. (1996) *Anopheles minimus*: its bionomics and role in transmission of malaria in Assam, India. Bull World Health Organ, 74: 61–66.
7. Gogoi SC, Dev V, Choudhury B, Phookan S. (1995) Susceptibility of *Plasmodium falciparum* to chloroquine of Tea Garden tribes of Assam, India. Southeast Asian J Trop Med Public Health, 26: 228–230.
8. Gupta I, Chowdhury S. (2014) Economic burden of malaria in India: the need for effective spending. WHO South-East Asia J Public Health, 3: 95–102.
9. Mohapatra PK, Namchoom NS, Prakash A, Bhattacharya DR, Goswami BK, Mahanta J. (2003) Therapeutic efficacy of anti-malarials in *Plasmodium falciparum* malaria in an Indo-Myanmar border area of Arunachal Pradesh. Indian J Med Res, 18: 71–76.
10. Mohapatra PK, Prakash A, Bhattacharyya DR, Mahanta J. (1998) Malaria situation in north-eastern region of India. Icmr Bull, 28: 21–30.

11. Mutheneni SR, Upadhyayula SM, Kadiri MR, Nishing K. (2014) Malaria prevalence in Arunachal Pradesh–a northeastern state of India. Am J Trop Med Hyg, 91(6): 1088-1093.
12. National Vector Borne Disease Control Programme (2013) National Drug Policy On Malaria. Retrieved on 20-09-2020. https://nvbdcp.gov.in/Doc/National-Drug-Policy-2013.pdf
13. National Vector Borne Disease Control Programme. Retrieved on 15-09-2020. https://nvbdcp.gov.in/
14. Nema S, Ghanghoria P and Bharti PK. (2020) Malaria Elimination in India: Bridging the Gap Between Control and Elimination. Indian Pediatrics, 57: 613-17.
15. Sarma DK, Mohapatra PK, Bhattacharya DR, Chellapan S, Karuppusamy B, Barman K, Kumar NS, Dash AP, Prakash A, Nina PB. (2019) Malaria in North East India: Importance and Implications in the era of Elimination, Microorganisms, 7 Special issue. 673.10.3390/microorganism7120673
16. Sharma VP. (1996) Re-emergence of malaria in India. Indian J Med Res, 103: 26–45.
17. Sharma VP. (2000) Status of drug resistance in malaria in India. In: Mahajan RC, Therwath A, editors. Multi Drug Resistance in Emerging and Re-Emerging Diseases. Delhi, India: Narosa Publications; 2000. pp. 191–202.
18. Sanei-Dehkordi, A., Soleimani-Ahmadi, M., Jaberhashemi, S.A. et al. (2019) Species composition, seasonal abundance and distribution of potential anopheline vectors in a malaria endemic area of Iran: field assessment for malaria elimination. Malar J, 18: 157.
19. Shil P, Balasubramanian R. (2020) Meteorological Parameters and Mosquito Species Diversity and Abundance along the Arabian Sea Coastline of Alappuzha District, India: A Year-round Study (2017-18). Journal of Mosquito Research, 10(2).
20. Shiv Lal, Sonal GS, Phukan PK. (2000) Status of Malaria in India. Journal of Indian Academy of Clinical Medicine, 5(1): 19-23.
21. Shukla RP, Pandey AC, Mathur A. (1995) Investigation of malaria outbreak in Rajasthan, Indian journal of Malariology 32: 119-128
22. Singh N, Chand SK, Mishra AK. (2006) Epidemiology of malaria in an area of low transmission in central india. Am J Trop Med Hyg, 812-816
23. World Health Organization (2019) World Malaria Report, 2018. Geneva: WHO; 2019

Figures

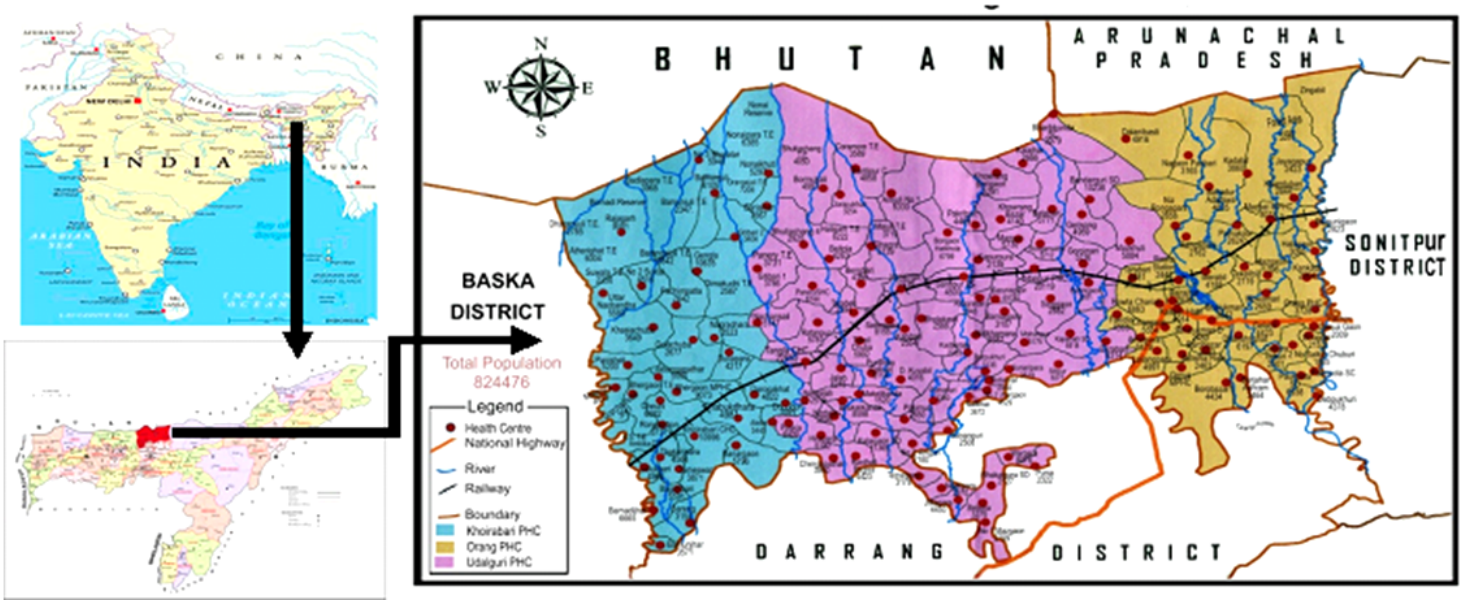

Figure 1

Map of Udalguri District showing health centers. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

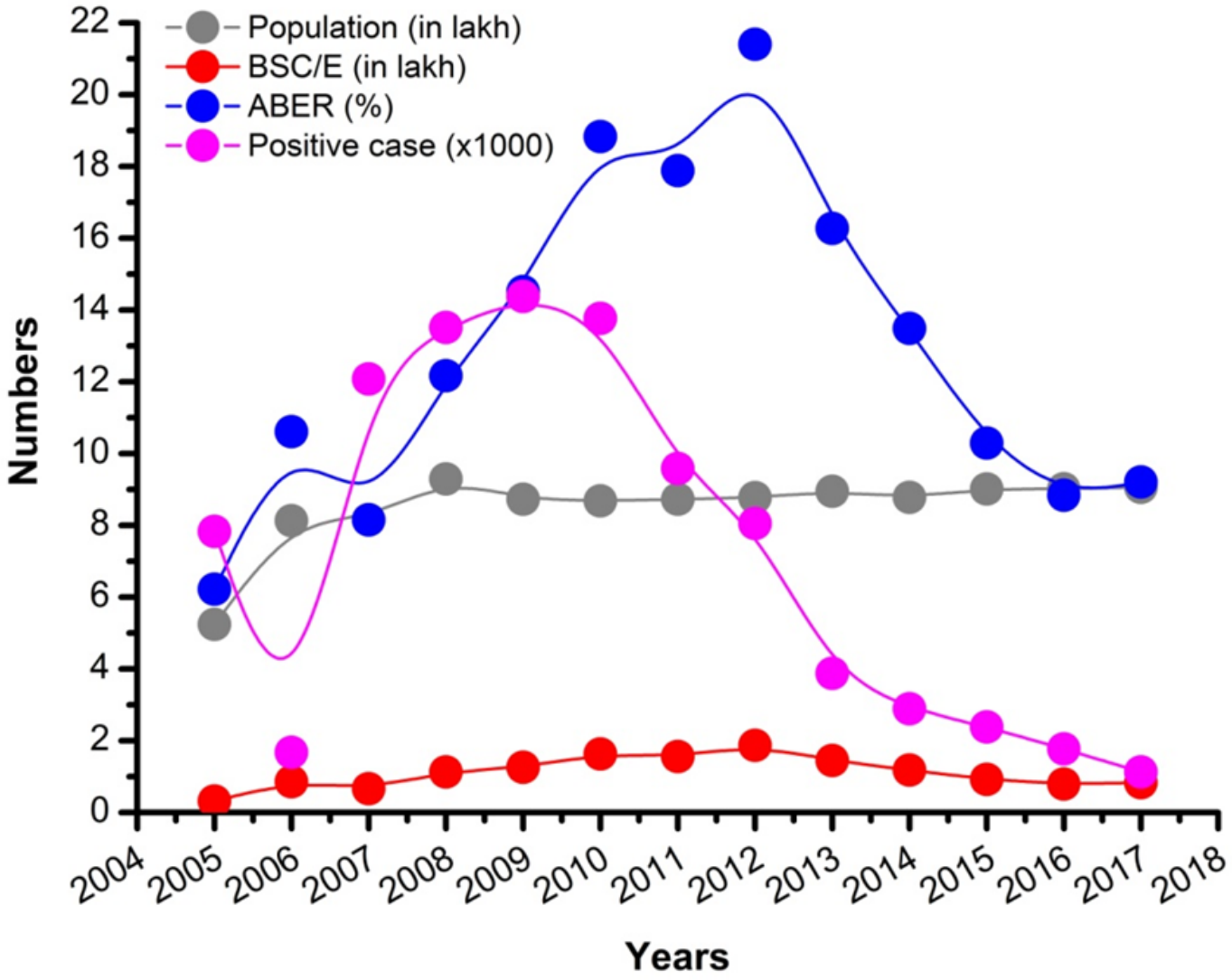

Figure 2

Population, blood samples collected and examined (BSC/E), Annual Blood Examination Rate (ABER), and positive malarial cases reported during the year 2005 to 2017

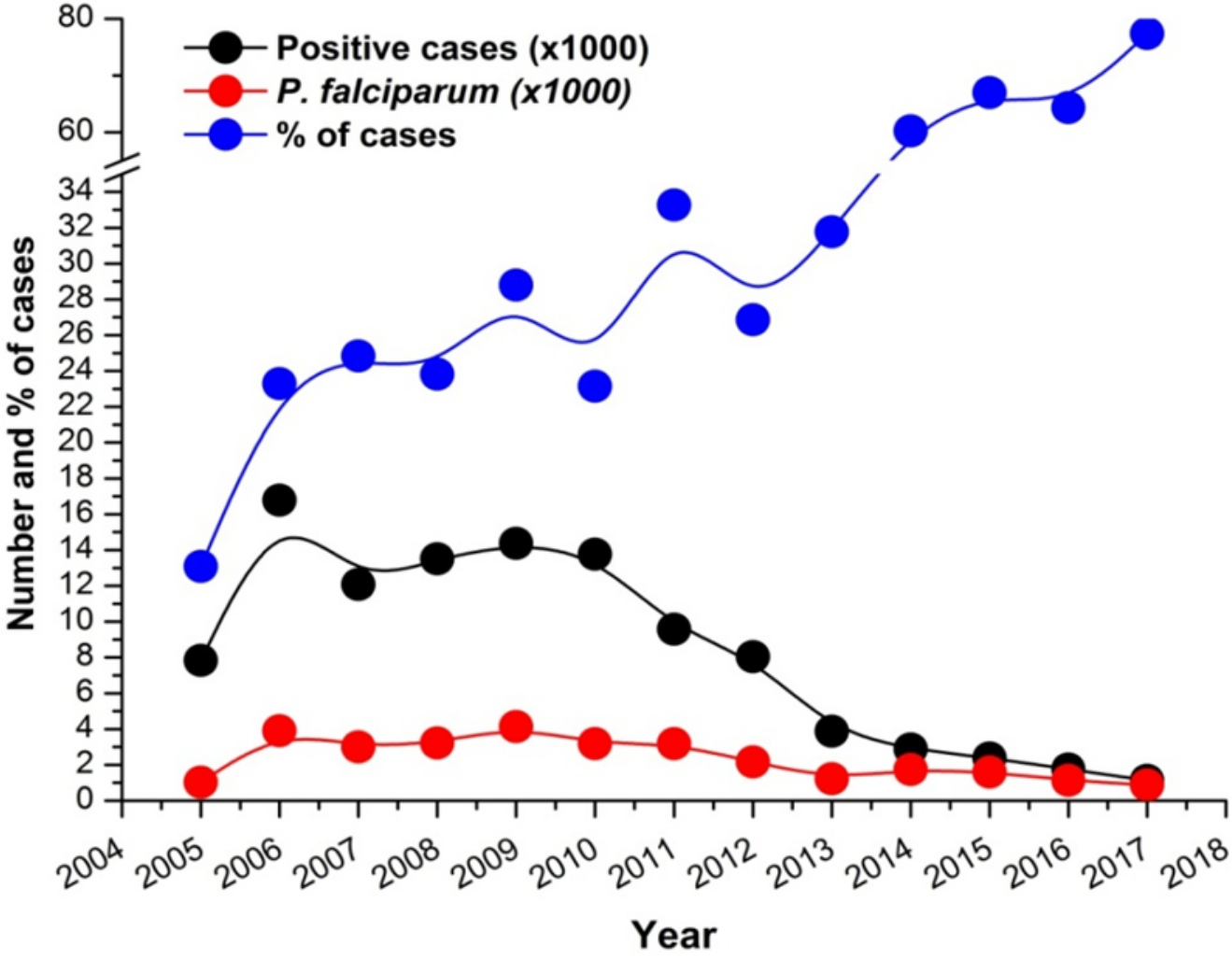

Figure 3

Year wise Malaria cases and Pf cases, 2005 - 2017

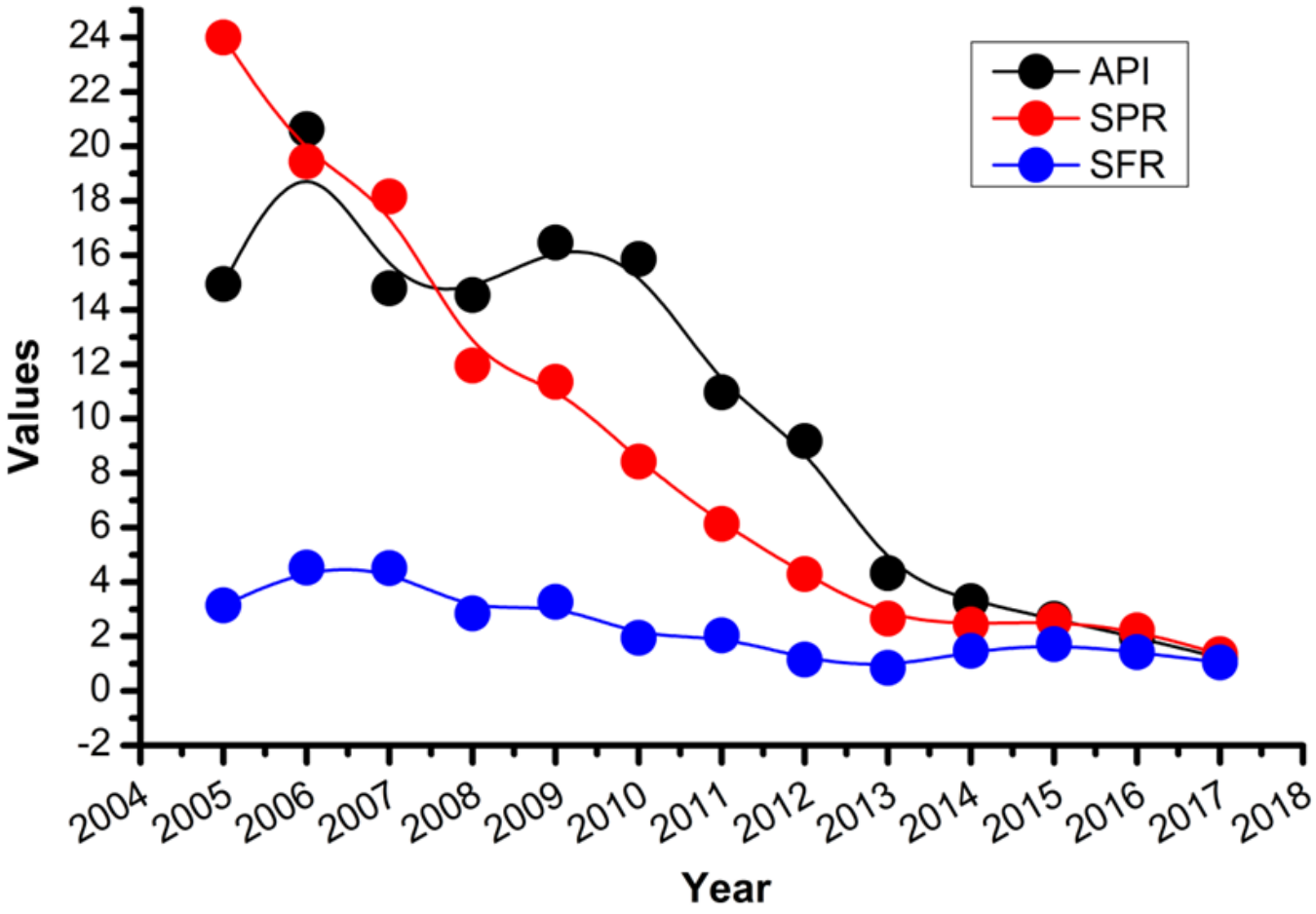

Figure 4

The Annual Parasite Index, Slide Positivity rate, and SFR of malaria cases in Udalguri district during 2005 – 2017.

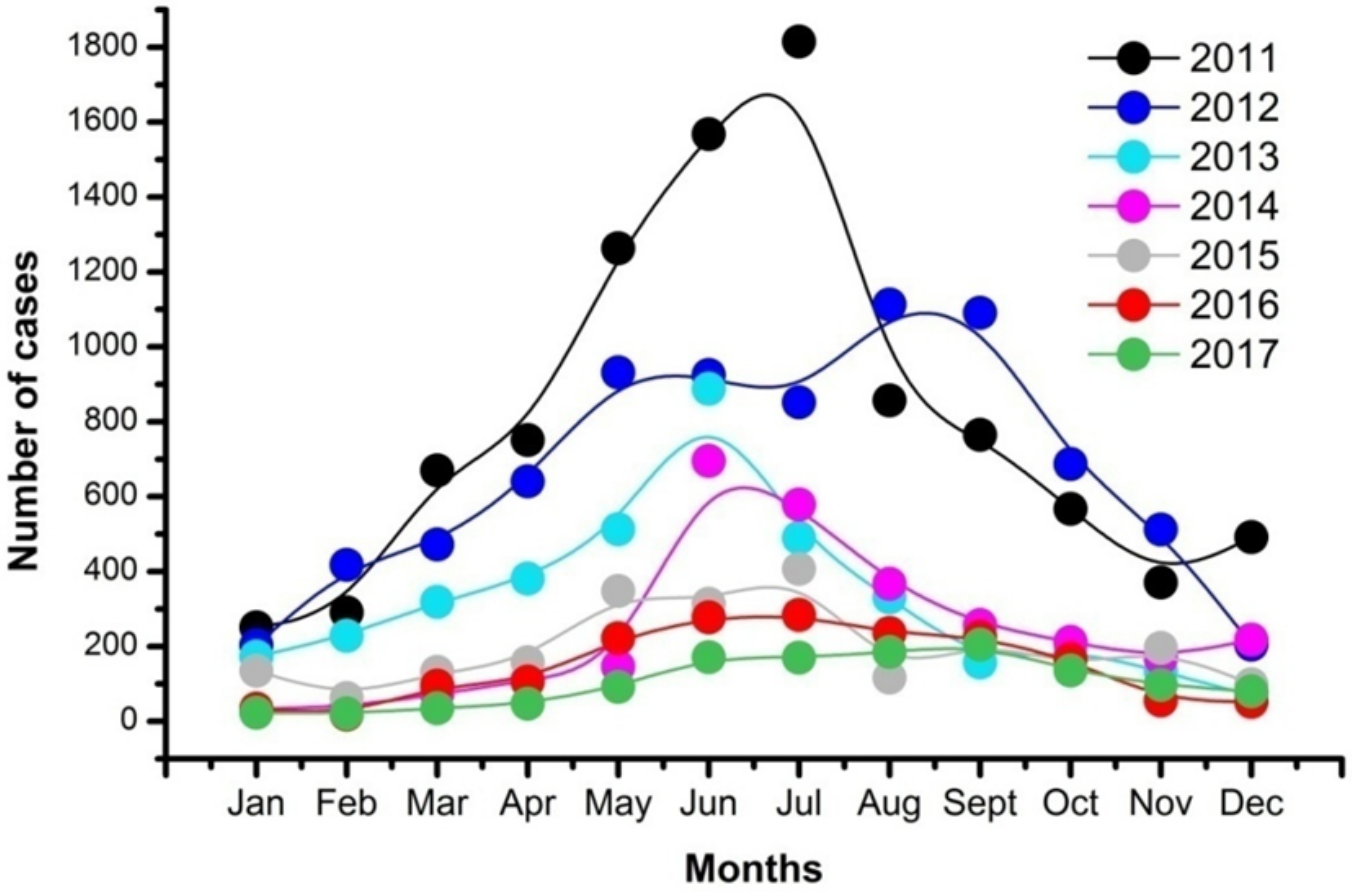

Figure 5

Month-wise distribution of Malaria cases of Udalguri District from 2011 to 2017

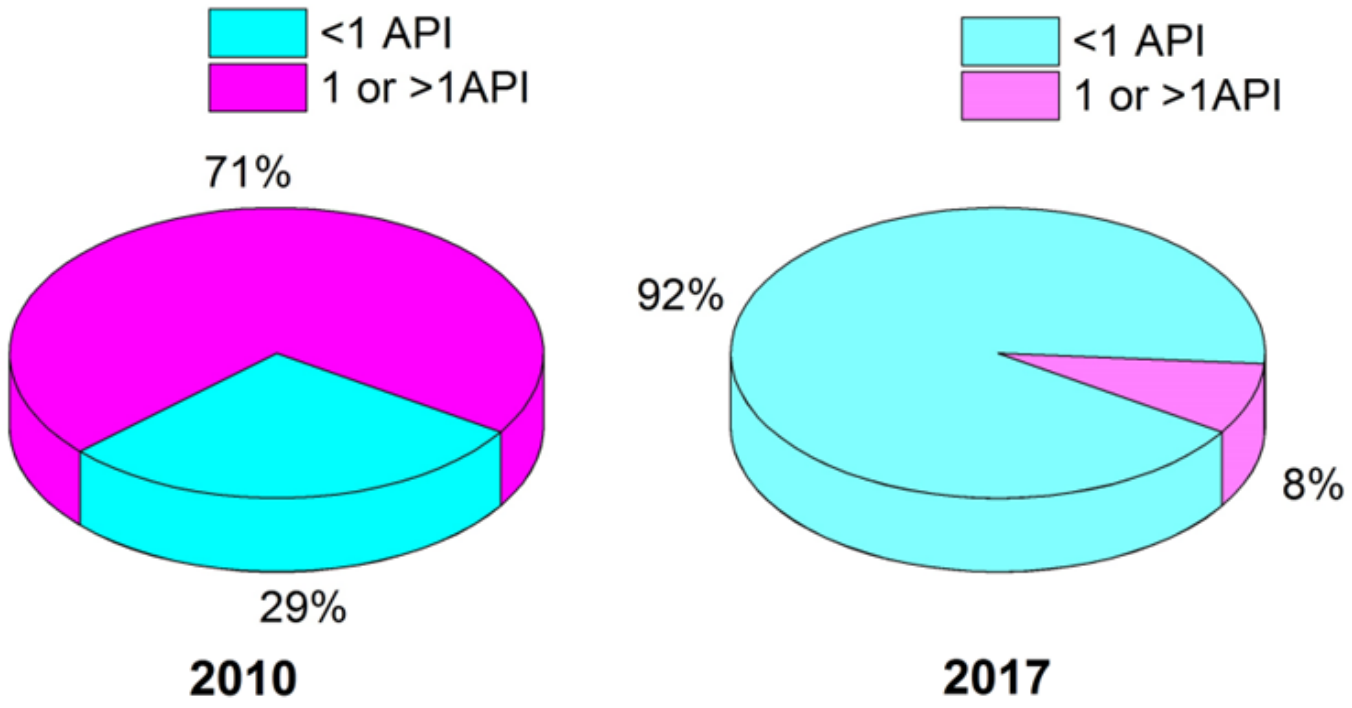

Figure 6

Percentage of population under malaria threat

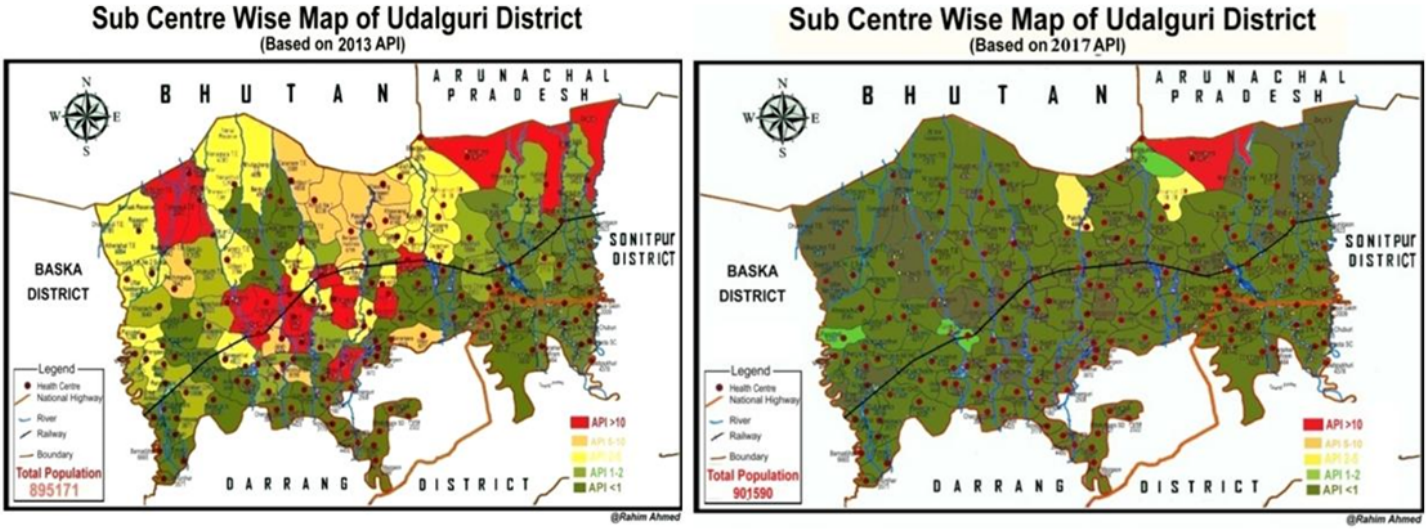

Figure 7

Map showing the comparative API of malaria cases for the year 2013 (left) and 2017 (right).Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.