



Prevalence of Malaria and Climate Change in District Sohbatpur, Balochistan

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Abstract: - This study identifies the malaria prevalence and estimate its association with climatic situations, including temperature, rainfall, and humidity, in the three-year post-flood period (2023-2025) in District Sohbatpur. The study was done using a retrospective observational cohort study based on secondary data (DHIS-2 system of District Headquarter Hospital Sohbatpur) and primary data (structured questionnaire). Meteorological information was available in online climatic databases. To assess patterns and correlations between the malaria incidence and climatic variables, descriptive statistics and regression analysis were used. A total of 242,799 people were tested with 66,893 confirmed cases. Test Positivity Rate (TPR) fell in 2023 to 40.55% in 2025 which shows a decrease in the total malaria burden. Nevertheless, the rate of Plasmodium falciparum rose to 63.9% as compared to 47.2% with a decline in Plasmodium vivax and mixed infections. The male percentage was 50.40% indicating occupational exposure. There was a high seasonality in malaria incidence, which was highest during the times of increased temperature and rainfall. The highest increase in transmission occurred at temperatures above 20-25°C with moderate humidity contributing to the survival of the vectors. Regression analysis showed that the temperature, rainfall, and malaria incidence were meaningfully associated. The prevalence of malaria decreased overall, but the proportion of the more serious P. falciparum is increasing, reflecting a changing epidemiological trend. Climatic conditions, and especially temperature and rainfall are very critical in transmission. The concept of climate-informed surveillance and intervention strategies is key to effective malaria control in susceptible post-disaster environments such as Sohbatpur.

Keywords: Malaria, incidence, rainfall, humidity, temperature.



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1.0 INTRODUCTION

Climate modification has ceased to be a concern in the future to be greatly affected by the presence of a pressing issue in the public health status quo that has impacted greatly on the distribution of the vector-borne diseases across the globe¹. Malaria is one of these and has been among the most climate sensitive diseases, where the transmission dynamics of Malaria is very much associated with climatic conditions like temperature, rainfall and humidity². Malaria is still a significant public health matter in Pakistan, with millions of cases suspected and confirmed every year.^[3] The province of Balochistan is one of the few provinces, which continuously records one of the highest malaria burdens in the country and high Annual Parasite Incidence (API) in comparison to other provinces^{3,4}. Malaria morbidity trends have been alarming in the world with the world reporting 282 million cases and an approximate number of 610,000 deaths in 2024⁵. The youngest under five years are the most vulnerable group, with a large percentage of death due to malaria⁶. Climatic variability is an important factor in the transmission of malaria. High temperatures increase the life cycle of both the Anopheles mosquitoes and Plasmodium parasites, reducing the extrinsic incubation period and enhancing the potential of transmission^{2,7}. Rainfall aids in the breeding environment formation and humidity increases the survival of the mosquitoes and its life span⁸. The seasonal and climatic factors contribute significantly to malaria transmission in Pakistan, especially in the flood-prone areas⁴. The 2022 floods were one of the most devastating climatic events in the history of the country that caused the general disruption of the environment, stagnant water levels, and breeding of the vectors⁹. This led to a high malaria incidence within the post-flood period [4]. The District Sohbatpur is a very vulnerable area in Balochistan in the southeastern region as it is low-lying area, with a large irrigation system, and constant susceptibility to floods⁹. There has been significant flooding in the district in 2010, 2012, and most recently in 2022 with the amount of rainfall being up to six to seven times higher than the historical average⁹. The changes in the environment have provided favorable conditions of enduring malaria. Plasmodium parasites that are passed on by the bite of an ill female Anopheles mosquito cause malaria in humans¹⁰. Among the five species infecting humans, Plasmodium falciparum and Plasmodium vivax are the greatest widespread in Pakistan, with P. falciparum associated with more severe disease and higher mortality¹¹. The recent evidence indicates that there has been a changing trend in the epidemiology with P. falciparum gaining predominance in some of the endemic areas creating a concern of resistance to drugs and diminished efficacy of the current control measures¹². Although malaria has a high burden in Balochistan, there is a significant deficit in district-level epidemiological

literature, especially in Sohbatpur. The majority of the available studies have revolved around other provinces like Punjab and Sindh, which have left significant gaps in the realization of localized dynamics of diseases in climate prone areas. Thus, the proposed study will (i) identify the prevalence of malaria in District Sohbatpur, (ii) examine climatic variations such as temperature, rainfall, and humidity in a three-year post-flood (2023-2025) period, and (iii) test the correlation between climatic variability and malaria incidence. The study offers a vital baseline data to underpin climate-sensitive malaria control interventions in an area that was not adequately represented before.

2.0 MATERIALS AND METHODS

2.1 Study Type and Duration

This retrospective cohort study was carried out to analyze the changes in the occurrence of malaria and the association between malaria and climatic conditions (temperature, rainfall, and humidity) in District Sohbatpur during three years (2023-2025). The research employed both epidemiological and meteorological data to evaluate the time relationship between the environmental factors and malaria transmission^{2,7}.

2.2 Malaria Data Collection

The data on cases of malaria were obtained through a two-price method. The DHIS-2 database of the District Headquarter Hospital Sohbatpur was used to extract secondary data and the structured questionnaires were used to collect primary data by giving the questionnaires to the patients. Informed consent was given by all the participants before the data collection. Malaria was diagnosed by Rapid Diagnostic Tests (RDT), which are popular in endemic areas because of their reliability and feasibility of operation¹¹. Verification of data was done at the district and provincial level in order to have accuracy and consistency. Only the laboratory-confirmed cases of residents of Sohbatpur were entered into the final analysis.

2.3 Meteorological Data Collection

Monthly meteorological data, including temperature (°C), rainfall (mm), and humidity (muggy days), were obtained from online climate databases. These climatic variables are well-established determinants of malaria transmission, influencing mosquito breeding, survival, and parasite development^{2,8}.

2.4 Study Area

District Sohbatpur is located in the southeastern region of Balochistan and is characterized by low-lying terrain, extensive irrigation systems, and high vulnerability to flooding events⁹. The region experiences extreme temperatures and seasonal monsoon rainfall, both of which

contribute to favorable conditions for malaria transmission². Health facility wise map has been shown in Figure 1.

2.5 Statistical Analysis

Statistical examination was done using SPSS version 22. Time-series analysis and Poisson regression models were applied to assess trends and associations between

malaria incidence and climatic variables. The autoregressive distributed lag (ARDL) model was used to evaluate lag effects between environmental factors and disease occurrence, as commonly applied in climate–health studies^[8] A p-value of <0.05 was considered statistically significant

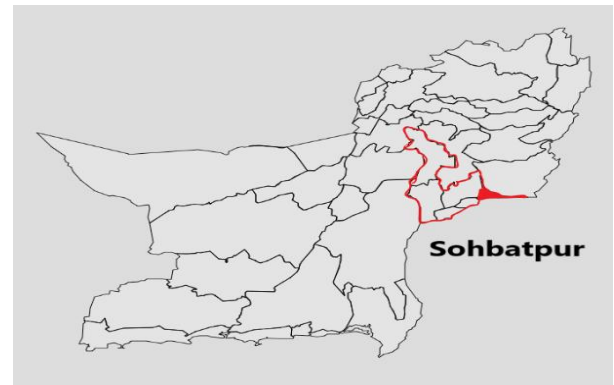


Figure 1. Basic Health Facility-wise map of district Sohbatpur

3.0 RESULTS AND DISCUSSION

3.1 Descriptive statistics of malaria

A total of 242,799 individuals were tested during the study period, of whom 66,893 were confirmed malaria cases. The Test Positivity Rate (TPR) declined substantially from 40.55% in 2023 to 15.13% in 2025, indicating a reduction in overall malaria burden. Similar declining trends have been reported following strengthened surveillance and control interventions in endemic regions. Despite this decline, the proportion of *Plasmodium falciparum* increased from 47.2% to 63.9%, while *Plasmodium vivax* and mixed infections decreased. This change has indicated a changing

epidemiological trend and potential adaptation of *P. falciparum* to environmental and intervention stressors as shown in Table 1.

3.2 Time series plot of malaria

The time sequence plot of malaria cases demonstrates a visible downward trend over three years, from 2023 to 2025. Here, observations taken over three years showed that the number of malaria cases steadily dropped. There was also a similar pattern of monthly malaria cases in each year, which showed that the relative amplitude of seasonal changes stayed the same over time, as shown in Figure 2.

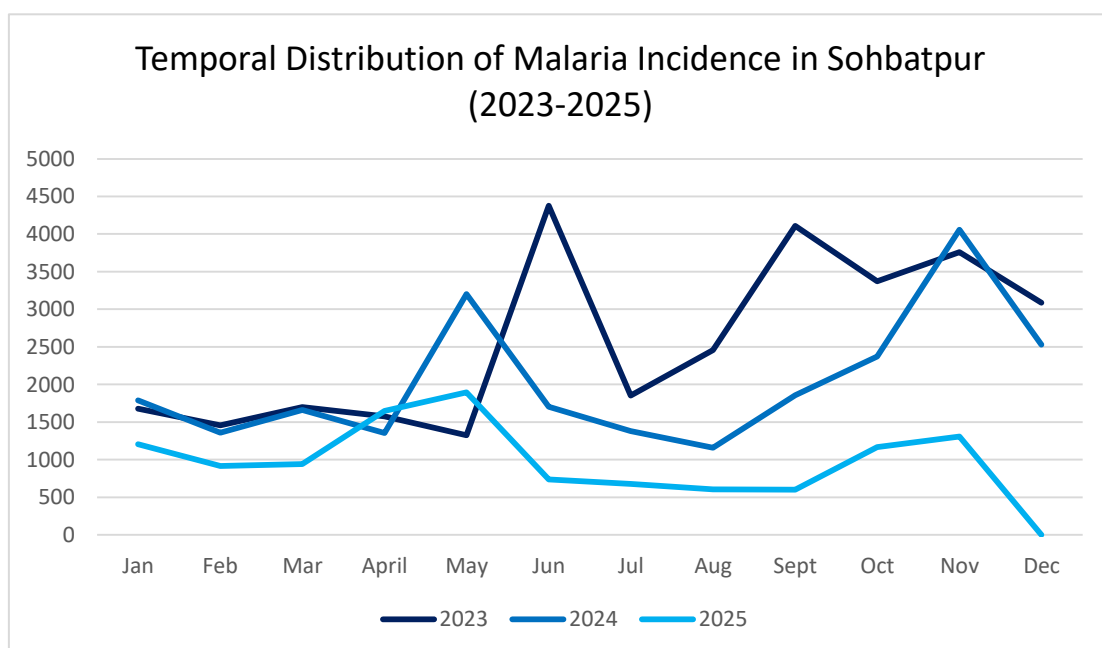


Figure 2. Time series plots of monthly malaria cases and meteorological variables in Sohbat pur district in Balochistan.

3.3. Malaria Trends (Descriptive statistics of malaria)

Statistics that describe weather variables The average monthly temperature and rainfall during the study period are shown in Table 1. The mean monthly rainfall ranged from 0

mm to 238 mm. The average monthly temperature's lowest and highest values were 17.8 °C and 27.2 °C, respectively, as shown in Table 1.

Table 1. Cases by Type

Year	Tested	Confirmed Cases	Positivity rate	Proportion of P. Falciparum	Proportion of Vivax	Proportion of Mixed Type
2023	75838	30749	40.55	47.20	45.69	7.19
2024	89563	24431	27.28	55.60	41.29	3.11
2025	77398	11713	15.13	63.91	34.17	1.92
To tal	242799	66893	27.55	53.19	42.07	4.78

Formula

$$\text{Test Positivity Rate (TPR)} = \frac{\text{Confirmed cases}}{\text{Tested}} \times 100$$

3.4 Gender Distribution

The proportion of males was 50.40% above that of females. This gender gap is not new and is common with past literature and is usually explained by the fact that occupational exposures are more prevalent especially in an outdoor setting where contact with mosquitoes is more common as shown in Table 2.

Table 2. Cases by Gender

Year	Cases	Male%	Female%	Pregnant%
2023	30749	48.15	45.87	2.08
2024	24431	52.50	47.50	0.97
2025	11713	51.95	48.06	0.57
Total	66893	50.40	46.85	1.40

3.5 Descriptive statistics of meteorological variables

Table 3 shows descriptive statistics of monthly recorded rainfall, temperature and humidity during the study

period where a mean monthly rainfall was 22.63 mm, temperature 27.06 °C and Humidity 4.64 respectively.

Table 3. Descriptive statistics of variables

Variable	Mean	Median	Standard Deviation
Confirmed cases	22,297.67	24,431.00	9,695.53
Temperature(°C)	27.06	28.50	8.10
Rainfall(mm)	22.63	7.50	54.11
Humidity(muggy days)	4.63	0.15	7.52

4.0 Malaria and Climatic Factors

4.1 Temperature

At temperatures over 20-25 °C malaria was found to be more prevalent. This is in line with already established fact that the temperature increases the growth rate of mosquitoes and the multiplication rate of the parasite, increasing the chances of transmission as shown in Figure 3.

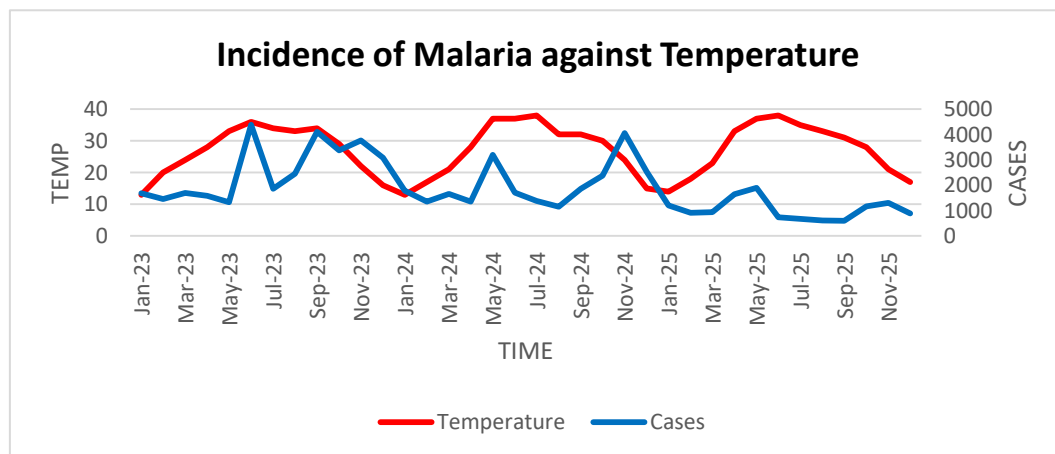


Figure 2. Malaria incidence vs temperature. Cases of malaria and rainfall during the 3 years have been demonstrated.

4.2 Rainfall

During the season of higher rainfall, there was a rise in the number of cases of malaria. Rainfall also forms breeding

grounds to the mosquitoes, which add to the density and risk of transmission as indicated in Figure 4.

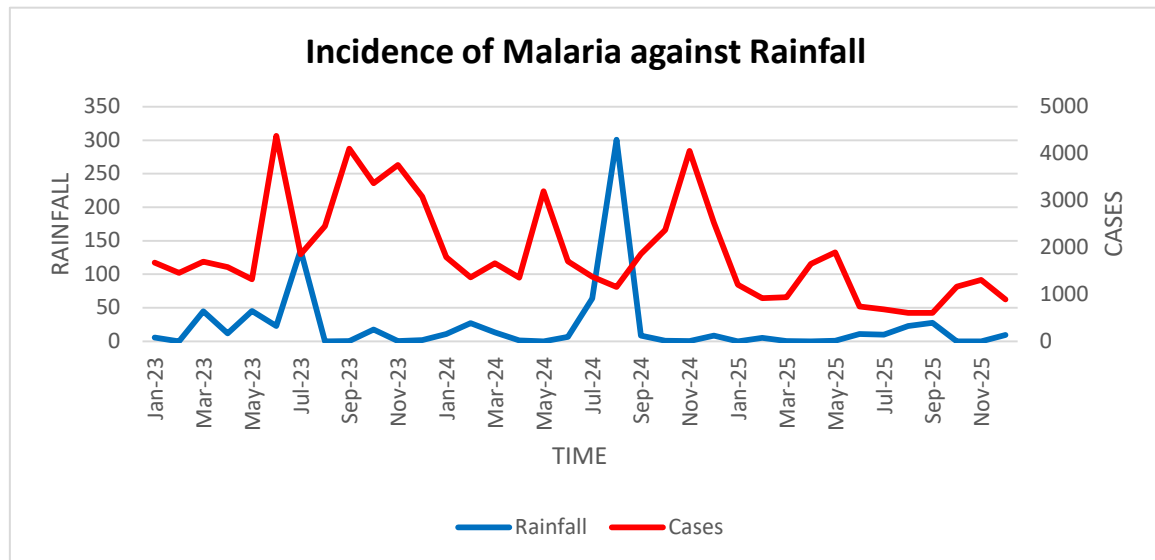


Figure 4. Incidence of malaria against rainfall. Malaria cases and temperature over the 3 years have been indicated

4.3 Humidity

Malaria incidence showed a positive association with moderate humidity levels, which enhance mosquito survival.

However, extremely high humidity did not correspond to proportional increases in cases, suggesting a non-linear relationship as shown in Figure 5.

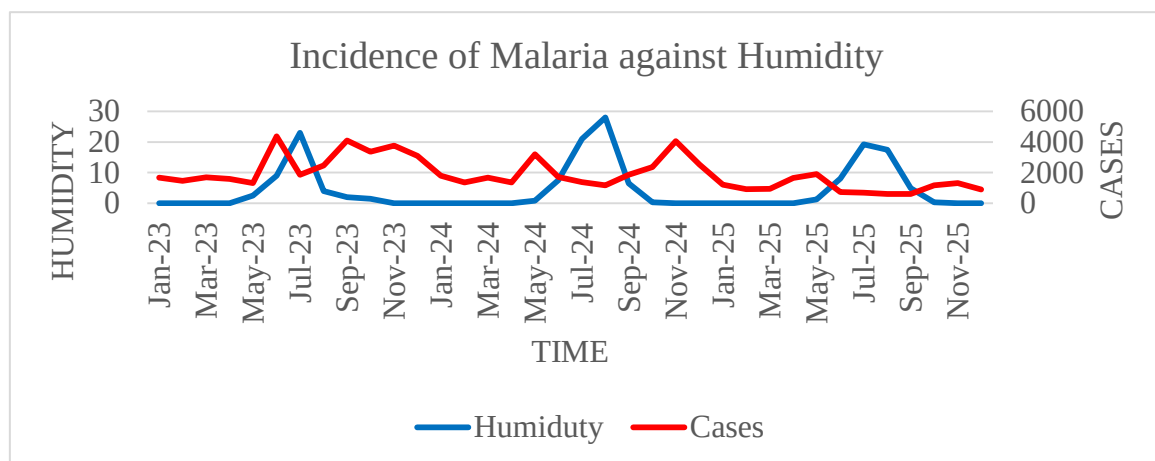


Figure 5. Incidence of malaria against humidity. Malaria cases and humidity over the 3 years have been indicated

5.0 Regression Analysis

Poisson regression analysis demonstrated significant relations between malaria incidence and climatic variables. Temperature and humidity showed positive associations, while rainfall exhibited a complex relationship with transmission dynamics. These findings are consistent with previous climate–malaria modeling studies⁸.

Results of Poisson regression model

The coefficients add up on the log(y) scale, and the IRR/odd ratio multiplies on the y scale. The Poisson regression model that fits is Temp = Temperature. Rain = how much it rains. Hum stands for humidity. Table 4 shows that the odds ratio for the percent change in the odds ratio of incidence goes up when the temperature and humidity go up. Table 5 shows that the rise in rainfall, temperature, and humidity had a big effect on the number of malaria cases (p

<0.05). This shows that rain increases the thickness of parasites shortly after the start of the period. The occurrence of malaria is closely associated with temperature and humidity. Table 5 shows the statistical results of

autoregressive distributed lag (ARDL) models., which demonstrates the substantial outcomes of various variables. The results include an estimate of the test that shows there is autocorrelation among the residuals.

Table 4. Poisson regression results of covariates

Parameter Estimates										
Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test			Exp(B)	95% Wald Confidence Interval for Exp(B)	
			Lower	Upper	Wald Chi-Square	Df	Sig.		Lower	Upper
(Intercept)	7.29	.0269	7.176	7.282	72066.661	1	.000	1379.000	1308.104	1453.738
Temp	1.24	.0541	1.178	1.390	563.955	1	.000	3.613	3.249	4.017
Temp	-.269	.0534	-.374	-.165	25.480	1	.000	.764	.688	.848
Rainfall	.618	.0341	.551	.685	328.736	1	.000	1.855	1.735	1.983
Humidity	-.400	.0318	-.462	-.337	157.679	1	.000	.670	.630	.714
Dependent Variable: Positive										
Model: (Intercept), Temp ©, Rainfall (mm), Humidity (muggy days)										

Table 5. Autoregressive distributed lag (ARDL) model Results

Coefficients ^a											
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
	(Constant)	481.767	819.955		.588	.561					
	Temp ©	51.439	31.937	.339	1.611	.117	.187	.274	.272	.645	1.551
	Rainfall (mm)	.693	5.946	.030	.117	.908	-.116	.021	.020	.417	2.398
	Humidity (muggy days)	-47.910	48.740	-.297	-.983	.333	-.094	-.171	-.166	.312	3.204
a. Dependent Variable: Positive											

6.0 DISCUSSION

The research indicates dramatic shifts in the epidemiology of malaria in District Sohbatpur in the post-flood period (2023-2025), both in terms of overall cases burden and the new problems of the species distribution and climate sensitivity.

The high reduction in TPR indicates that there are better surveillance, diagnostic coverage, and control of vectors measures. Similar decreases have been noted in areas where there has been an fortification of integrated

malaria control programs^{2,5}. The growing preponderance of *Plasmodium falciparum* is, nonetheless, a serious issue as it is linked to severe pathology and increased mortality¹¹.

Recent reports have shown the development of partial resistance of Artemisinin-based Common Therapies (ACTs) especially in endemic areas in Africa and Asia.^[12] The increase in *P. falciparum* witnessed in this research could be due to the same mechanisms, such as drug pressure, incomplete adherence to treatment, and adaptation of the vectors.

The decrease in *P. vivax* and mixed infections indicates that the existing interventions, including indoor residual spraying and effective treatment regimens, can be more effective against these species. This trend has been in line with the other available studies in South Asia where *P. vivax* has been observed to be more responsive to control interventions¹¹.

Malaria transmission dynamics were mainly influenced by climatic factors. The analysis showed good seasonality with a high rate of incidence in high temperature and rainy seasons. These results are consistent with available evidence that malaria transmission is optimal in given temperature regimes which favor the growth of the vector and the parasite^{2,7}.

One of the determinants of transmission was found to be rainfall which formed breeding sites, especially in areas where there is a flood. The 2022 floods transformed the ecological situation in Sohbatpur greatly, contributing to a greater stagnant water mass and longer transmissions^{2,9}. Other climate-vulnerable areas have recorded similar post-disaster surges of malaria⁴.

The presence of humidity also contributed to the occurrence of malaria but this was not a strictly linear relationship. Intermediate humidity increased the survival of the mosquito, whereas extreme conditions did not seem to be as conducive. This is found to be true by modeling studies that show there are optimal levels of humidity at which vectors can survive⁸.

The results of the study highlight the need to incorporate the use of climate in malaria surveillance. Early warning systems are climate-informed, which can enhance preparedness and allow targeted interventions in high-risk times².

Although it is strong, the study has weaknesses. The three years are not enough to develop long-term climate change trends and there is a possibility of reporting biases where secondary data is relied on. However, the research also contributes to the understanding of the post-disaster malaria dynamics in an area that has not been well studied before.

7.0 CONCLUSIONS

This study intended to identify the correlations and predictive relationships between the climate variables and malaria incidence in Sohbatpur. It did so by employing national malaria case data of the country from 2023 to 2025. The aim here was to develop a predictive model as a proof-of-concept based on the major climate variables i.e., maximum, minimum and median temperatures; diurnal temperature variation; median temperature at 18:00-21:00; precipitation-total and anomaly; and relative humidity. The mentioned variables were pooled to national monthly values

and their effectiveness in a predictive malaria model was compared. This research warried on with in the climate vulnerability of Asian countries of infections by disease. The literature in this area has already linking climate and malaria and coming up with EWSs (early warning systems) based on this, but there is still a scarce amount of research conducted on sohbatpur context, where extreme weather and other climatic events often occur as well as malaria being endemic. The research contributes towards a system integrated with the corresponding infrastructure and health decision-making in EWS, which will provide one or two months' lead-time for the systems to get prepared in advance for the high-risk periods of malaria. Changing climate and diseases are interacting problems that mainly target the already vulnerable regions and thus necessitate the preparedness measures to be increasingly specific and flexible as per the situation.

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Conflict of interest:

We have no conflict of interest

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