Chapter 21
Meteorological Conditions and Malaria Cases—Study in the Context of Meghalaya

Strong P. Marbaniang and Laishram Ladusingh

> *Malaria defeated the international community many years ago. We cannot allow this to happen again. A single global action plan for malaria control, that enjoys Partnership-wide support, is a strong factor for success.*
>
> Margaret Chan, WHO Director-General

21.1 Introduction

Malaria is caused by parasites belonging to the genus Plasmodium, which is transmitted through the bite of the infected female Anopheles mosquitoes. The parasites multiply in the liver and then start infecting the red blood cells. Symptoms of malaria include fever, headache, and vomiting. If not treated within 24 h, malaria becomes life threatening because it affects the blood supply to the vital organs of the body. In many parts of the world, the parasites have developed resistance to a number of antimalarial medicines. The four types of parasite species that cause malaria in a human being are Plasmodium falciparum (P.f), Plasmodium vivax (P.v), Plasmodium malariae, and Plasmodium ovale (Malaria, n.d.). Malaria transmission depends on climatic conditions, such as rainfall, temperature, and humidity, which may affect the number and survival of mosquitoes. In many places, transmission is seasonal, with the peak happening during and just after the rainy season. Epidemics of malaria can occur when climatic and other environmental conditions suddenly change in places where people have either little immunity or no immunity at all to malaria. People living in stable malaria endemic and high malaria transmission region like the sub-Saharan Africa and the forest area in the Indian states like Jharkhand, Odisha, Chattisgarh, Madhya Pradesh and Northeast India, develop immunity against malaria at the early age, but

S.P. Marbaniang (✉)
International Institute for Population Sciences (IIPS), Mumbai 400088, India
e-mail: marbaniangstrong@gmail.com

L. Ladusingh
Head, Department of Mathematical Demography and Statistics, (IIPS), Mumbai 400088, India

people living in unstable endemic areas tend to have low immunity against malaria (Immunity n.d.). This can also occur when people with low immunity migrate into the region where there is high incidence and continuous transmission of malaria. Exposure over a number of years helps develop partial immunity, which, though does not provide complete protection, does reduce the risk of contracting severe disease (Malaria fever, n.d.). Malaria is a disease that can be prevented and treated if clean and hygienic living environment are maintained by the people. In 2012, approximately 207 million cases of malaria occurred worldwide. In the 11 countries of the South East Asian Region of WHO, 1.2 billion people are exposed to the risk of malaria, most of them live in India (Kondrachine 1992).

The National Vector Borne Disease Control Programme (NVBDCP) is an umbrella program in India for prevention and control of vector-borne diseases (VBDS), including Japanese Encephalitis, Malaria, Kala-Azar, Dengue, Filariasis, and Chikungunya; it is an integral part of the country's National Rural Health Mission (NRHM). The Directorate of the NVBDCP has framed technical guidelines/policies and provides most of the resources for the program. Indicators for the monitoring of the program have been developed at the national level and there is uniformity in collection, compilation, and onward submissions of data. Community Health Centers, Public Health Centers, Malaria Clinics, and other health institutions carry out passive surveillance of malaria. Accredited Social Health Activist (ASHA)—a village volunteer is also involved in the program to provide diagnostic and treatment services such as Rapid Diagnostic Tests and the Artemisinin Combination Therapy (ACT) for the treatment of P. f. malaria cases.

21.2 Background History of Meghalaya

Meghalaya is one of the seven northeastern states—situated in the eastern sub-Himalayas—and also one of the most beautiful states in the country. About 300 km in length and 100 km in breadth, Meghalaya is surrounded in the north by the Goalpara, Kamrup, and Nowgong districts of the state of Assam, in the east by the Karbi Anglong and North Cachar Hills districts also of Assam, and on the south and west by Bangladesh. The state enjoys abundant rainfall, sunshine, unspoiled forests, plateaus, waterfalls, and clear rivers and is home to sturdy, intelligent, and friendly people. Meghalaya became an autonomous state on April 2, 1970 and gained full statehood on January 21, 1972, marking the beginning of an era of mutual under-standing and peace in the region. The total land area of Meghalaya is 22,429 km^2 and 15,675 km^2 are under the forest area (Meghalaya, n.d.). Forest in Meghalaya are not categories as very dense forest, the region of the states mostly covered by forest are Ri Bhoi, southern part of Jaintia Hills, southeastern part of West Garo Hills and southern part of East Garo and South Garo Hills district, geographically Meghalaya varies in altitude from 200 m above sea level (ASL) in the west and northwestern part to 1960 m ASL in the state capital (Dikshit 2014). Shillong, the capital of Meghalaya, is located at an altitude of 1496 meters above sea level. The capital city derives its name

from the manifestation of the creator called Shyllong. The climate of Meghalaya varies with altitude. The climate of the Khasi and Jaintia Hills is uniquely pleasant—neither too warm in summers nor too cold in winters. In the plains of the Garo Hills, the climate is warm and humid, except during the winter. The sky is mostly overcast in Meghalaya, with the average annual rainfall over western Meghalaya being about 2600 mm, over northern Meghalaya between 2500 and 3000 mm, and over south-eastern Meghalaya about 4000 mm. There is a great variation in the rainfall received in central and southern Meghalaya. At Sohra (earlier known as Cherrapunjee), the average annual rainfall is as high as 12,000 mm. By contrast, Shillong, which is no more than 50 kilometers away from Sohra, receives an average of only 2200 mm of rainfall annually (Meghalaya, n.d.).

21.3 Review of Literature

Many studies on malaria cases and its association with meteorological factors have been conducted in the different region of the world. In a study done in Zimbabwe in 1988–1999, inter-annual variations in average temperature, rainfall, and vapor pressure were found to have a strong positive association with the incidence of malaria, while maximum and minimum temperature were found to have no such association (Mabaso et al. 2006). In East African Highland, climate variability was found to be the main causes leading to the increase in the number of malaria outpatients (Zhou et al. 2004). A study in Tanzania found that the incidence of malaria during the month of October to March are due to the increased in rainfall, while during the month of April to September are due to high rainfall together with high maximum temperature (Jones et al. 2007). In a study done in Motuo County found that temperature, rainfall, and relative humidity are the favorable conditions for the transmission of malaria with relative humidity being the main factor that contributes to the survival of mosquito (Huang et al. 2011, Al-Mansoob et al. 2005). A study about the malaria incidence among the forest and non-forest area in Kokrajhar district found that relative humidity is positively correlated with malaria incidence in forest area while the temperature was negatively correlated with malaria incidence in the non-forest area (Nath and Mwchahary 2012).

21.4 Need for the Study

The sixth goal of the United Nations' Millennium Development Goals (MDG) was to halt and begin to reverse the incidence of malaria by 2015, achieving which was a challenge for countries like India with a high prevalence of malaria cases. The NVBDCP is the governing body In India, responsible for policy making, moni-toring, and giving technical help to the states so as to halt and reverse the incidence of malaria. Meghalaya is one of the high malaria endemic states in India among the seven

northeastern states. The main goal of the Global Fund to Fight AIDS, Tuberculosis and Malaria Round 9 was to reduce malaria-related mortality and morbidity in the seven northeastern states by at least 30% by 2015 as compared to 2008. The impact indicators of the program were the Annual Parasite Index and the Number of deaths with Malaria Confirmation. According to the NVBDCP classification based on the Annual Parasite Index (API), malaria is endemic in almost all the districts of Meghalaya. Three districts Eastgaro, Westgaro, and Southgaro have API > 10, Ribhoi has an API ranging between 5 and 10, the West Khasi Hills and Jaintia Hills have an API of 2–5, and the East Khasi Hills have an API of 0.1–1 (NVBDCP, n.d.). A number of studies related to meteorological variables and malaria cases have been done before and the findings are different from one study to another. There have been few studies studying the association between malaria cases and meteorological cases in Meghalaya. This study aims to help understand in what way the meteorological conditions in Meghalaya are related with malaria cases. It has been noted from earlier studies conducted in different geographical regions having different meteorological conditions that there are variations pertaining to the association between malaria cases and temperature and rainfall. This means that one region differs from another in how malaria cases are related to temperature and rainfall, necessitating an in-depth study to get broad insights on the nature of this relationship in the specific context of Meghalaya. This study also aims to gain an understanding of the prevalence of malaria cases in the different districts of the state and an age and sex-wise distribution of malaria and deaths resulting from it so as to help the Malaria State Control Programme in framing a plan and designing activities to tackle malaria and achieve the desired goal.

21.5   Objectives of the Study

The three specific objectives of this study are

1. To study the district-wise prevalence of malaria cases.
2. To assess district-wise age and sex distribution of death cases.
3. To study the relationship between malaria cases and the meteorological conditions in the state of Meghalaya.

21.6   Materials and Methods

The data on malaria for this study were collected from the Department of Health Services (Malaria), Government of Meghalaya. The data on temperature and rainfall were collected from the Directorate of Agriculture, Government of Meghalaya. For this study, we have taken into consideration only 3 years (2011–13) of malaria data and meteorological data on temperature and rainfall, recorded on a

monthly basis for all the seven districts of Meghalaya. Rainfall is measured in millimeter (mm) and temperature in degree Celsius (°C).

For the first objective, we took the sum of the monthly malaria cases for the years 2011, 2012 and 2013, and then the total of all the 3 yearly malaria cases so as to get the district total malaria cases from the year 2011 to 2013. This method was repeated for all the seven districts. To obtain the district total fever cases from 2011 to 2013, a similar method, as in the case of malaria cases, was applied. After obtaining the 3-year total malaria cases and fever cases for each district, we obtained the district-wise prevalence of malaria cases by using the following formula:

District Malaria Prevalence Rate

$$= \frac{\text{District total malaria cases from the year } 2011 \text{ to } 2013}{\text{District total fever cases from the year } 2011 \text{ to } 2013} \times 1000$$

For the second objective, we took the sum of malaria death cases for all the 3 years and the malaria cases for each district for the different age groups and sex. Then we calculated the malaria death cases per 1000 malaria cases for each district for the different age groups and sex.

Malaria Death Rate (Male)

$$= \frac{\text{Total malaria death in male age group } x \text{ to } x+n}{\text{Total malaria Cases in male at the corresponding age group } x \text{ to } x+n} \times 1000$$

Malaria Death Rate (Female)

$$= \frac{\text{Total malaria death in female age group } x \text{ to } x+n}{\text{Total malaria Cases in female at the corresponding age group } x \text{ to } x+n} \times 1000$$

Annual Blood Examination Rate (ABER)

$$= \frac{\text{Total blood smear collected during the year}}{\text{Total population under surveillance}} \times 100$$

Annual Parasitic Indices (API)

$$= \frac{\text{Total number of blood smears positive for malaria during the year}}{\text{Total population}} \times 1000$$

For the third objective, we used multiple linear regressions to test the association between the dependent variables and the independent variables. Here the dependent variable is the monthly Malaria Incidence Rate (MIR), and the independent variables are the monthly average temperature and the monthly rainfall. SPSS 12 was used to calculate the multiple linear regressions.

$$\text{Malaria Incidence Rate (MIR)} = \frac{\text{Total malaria cases during the month}}{\text{Total population during the month}} \times 100,000$$

21.7   Results and Discussion

Figure 21.2 shows the district-wise percentage distribution of malaria cases. West Garo Hills and East Garo Hills were the highest contributors of malaria cases with 33% each in the whole state during 2011–2013. South Garo Hills, with 15%, comes next. The West Khasi Hills (8%), Ri Bhoi (6%), the East Khasi Hills (3%), and the Jaintia Hills (2%) made the lowest contribution of malaria cases. Figure 21.1 shows the district-wise percentage distribution of fever cases. From this figure, we see that the West Garo Hills had the highest percentage of fever cases with 43% of the total cases. The East Garo Hills, with a 13% contribution, come next. This is followed by the Jaintia Hills (11%), Ri Bhoi (10%), the South Garo Hills (8%), and the East Khasi Hills (8%). At 7%, the West Khasi Hills had the lowest percentage of fever cases.

Figure 21.3 shows the district-wise prevalence of malaria cases per 1000 fever cases. We observe that the East Garo Hills had the highest malaria prevalence rate of 164 malaria cases per 1000 fever cases. Next come the South Garo Hills with a malaria prevalence rate of 109 malaria cases per 1000 fever cases. This is followed by the West Khasi Hills with a malaria prevalence rate of 73 malaria cases per 1000 fever cases. The West Garo Hills had a malaria prevalence rate of 47 malaria cases per 1000 fever cases. Ri Bhoi had 36 malaria cases per 1000 fever cases. The East

Fig. 21.1 District-wise prevalence of fever cases

Districtwise Percentage Distribution of Fever Cases (2011-13)
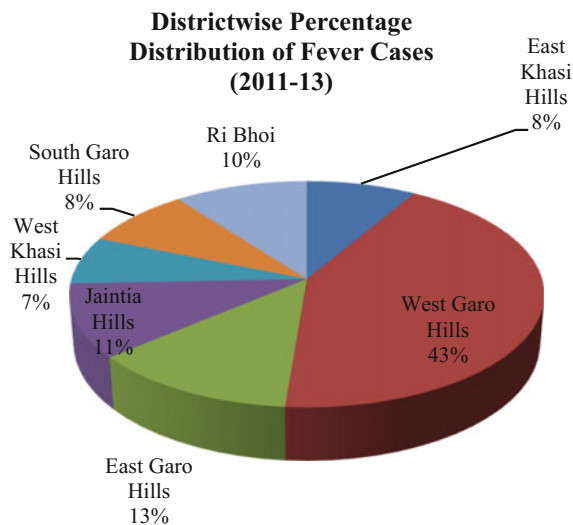
**Districtwise Percentage
Distribution of Malaria Cases
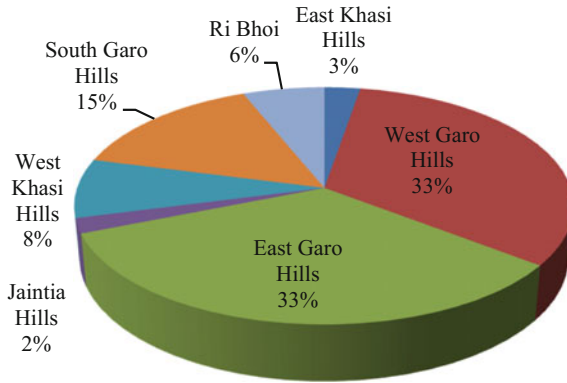(2011-13)**

Fig. 21.2 District-wise prevalence of malaria cases
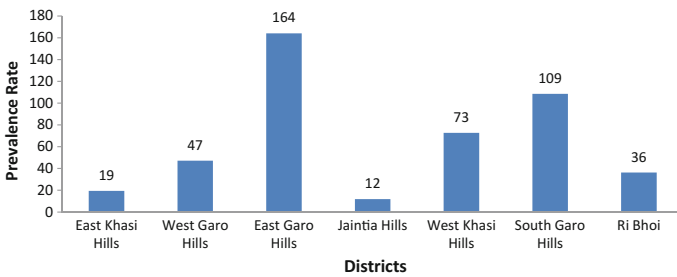

Fig. 21.3 District-wise prevalence of malaria cases per 1000 fever cases

Khasi Hills had a malaria prevalence rate of 19 malaria cases per 1000 fever cases, and the Jaintia Hills showed the lowest malaria prevalence rate of 12 malaria cases per 1000 fever cases.

From Fig. 21.4, we observe that the West Khasi Hills recorded the highest number of deaths per 1000 malaria cases, followed by the Jaintia Hills, East Khasi Hills. The West Garo Hills recorded the lowest deaths per 1000 malaria cases. From Fig. 21.5, we observe that the Jaintia hills recorded the highest death cases per 1000 malaria cases, whereas the East Garo Hills and the West Khasi hills recorded the lowest death cases per 1000 malaria cases. Figure 21.6 shows that the East Khasi Hills had the highest number of deaths per 1000 malaria cases, whereas the other districts were well below it. From Fig. 21.7, we observe that the Jaintia Hills had the highest death cases per 1000 malaria cases, followed by the East Khasi Hills. The East Garo Hills recorded the lowest figure. Figure 21.8 tells us that the East
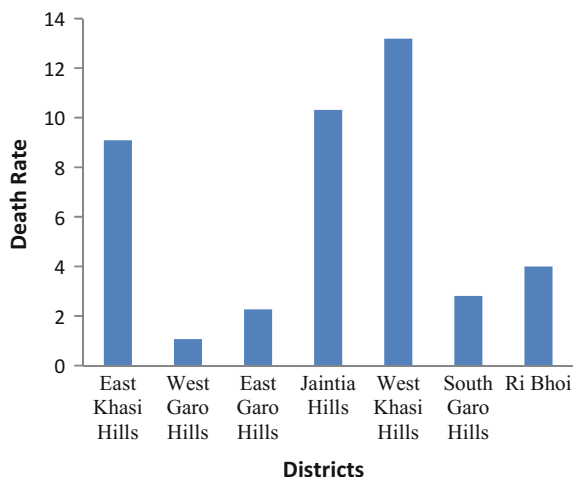
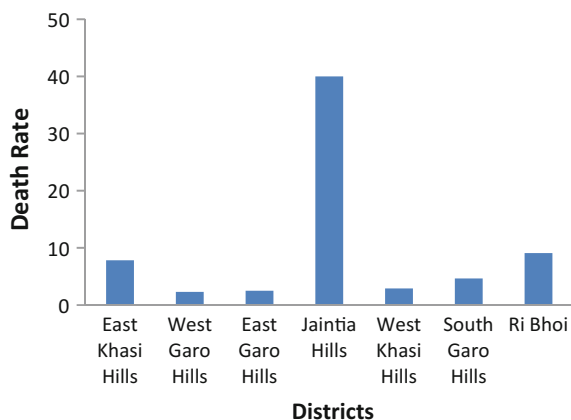**Fig. 21.4** Death cases per 1000 malaria cases in male 0–4 age group

Fig. 21.5 Death cases per 1000 malaria cases in female 0–4 age group

Khasi Hills had the highest death cases, followed by the Jaintia Hills. The lowest deaths were recorded in the West Garo Hills. Figure 21.9 shows that the Jaintia Hills had the highest deaths per 1000 malaria cases, followed by the West Khasi Hills. The East Khasi Hills recorded no death per 1000 malaria cases. Figure 21.10 shows the surveillance of the different district blocks in Meghalaya in terms of ABER (2013). ABER denotes the total number of slides collected per 100 population under surveillance. Most parts of the Garo Hills and Ri Bhoi districts had an ABER of greater than 10, whereas some areas of the West Khasi Hills and the East Khasi Hills, which had a low surveillance, had an ABER of less than 5. On the

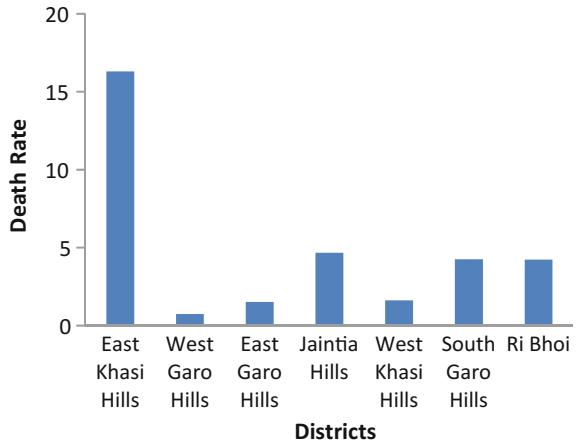**Fig. 21.6** Death cases per 1000 malaria cases in male 5–14 age group

Fig. 21.7 Death cases per 1000 malaria cases in female 5–14 age group
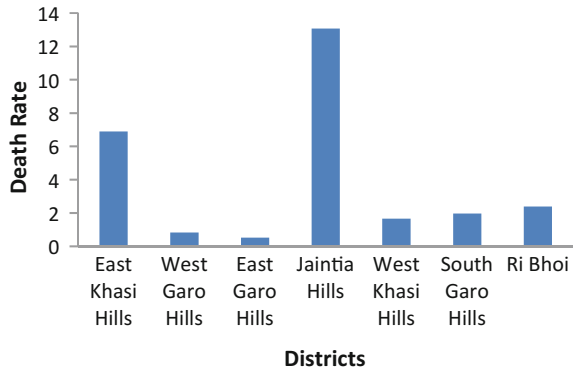

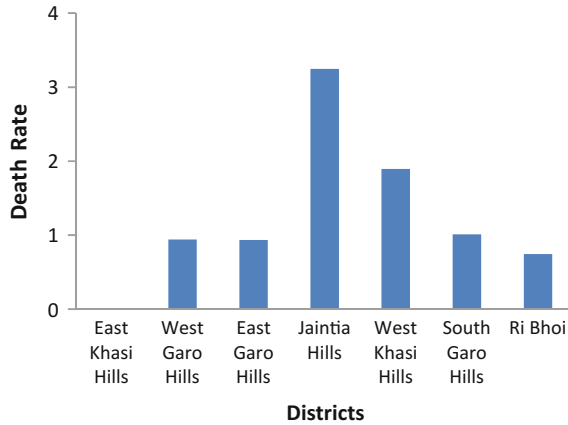**Fig. 21.8** Death cases per 1000 malaria cases in male 15 + age group

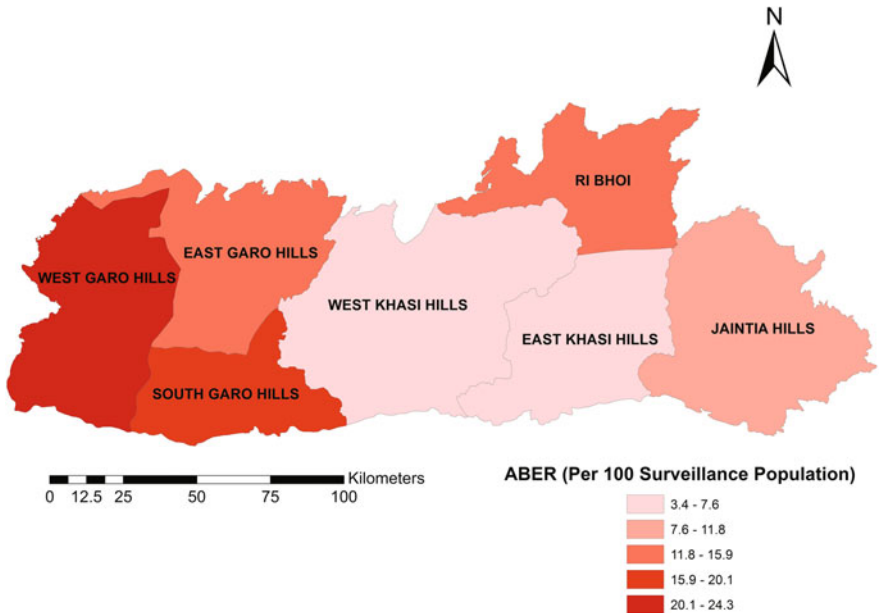**Fig. 21.9** Death cases per 1000 malaria cases in female 15+ age group

Fig. 21.10 District-wise distribution of average annual blood examination rate (ABER), (2011–2013)

other hand, some parts of the Jaintia Hills had an ABER which was a little higher compared to the East Khasi Hills and the West Khasi Hills. In Fig. 21.11 most of the areas in the Garo Hills, where the ABER was high, the API was high too. But in the East Khasi Hills and the West Khasi Hills, where the ABER was low, the API was also low. So Figs. 21.10 and 21.11 give us an idea as to why the East Khasi
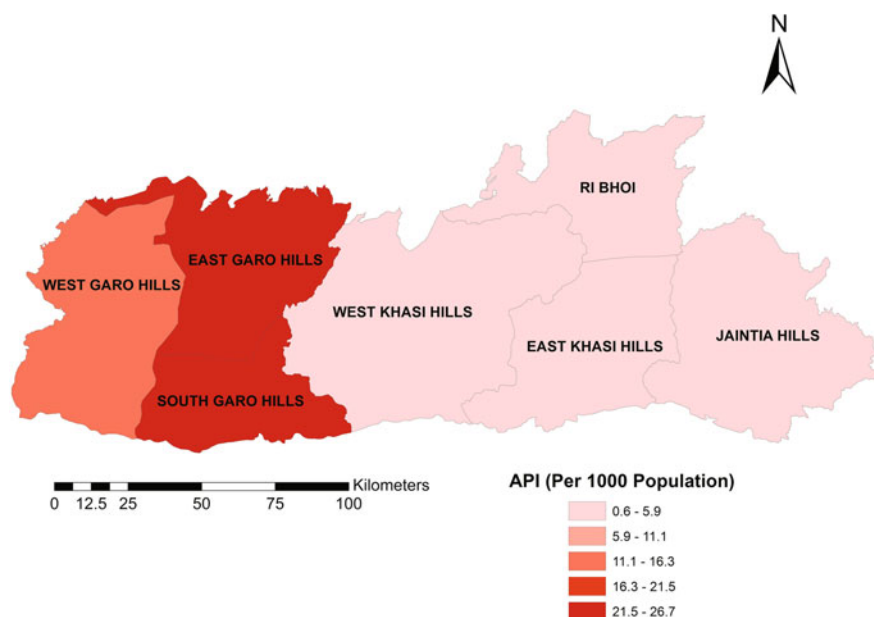
Fig. 21.11 District-wise distribution of average annual parasitic incidences (API), (2011–2013)

Table 21.1 Percentage of malaria cases and fever cases during the year 2011–2013

Districts	Malaria		Fever	
	n	%	*n*	%
East Khasi hills	1863	3	96,101	9
West Garo hills	22,775	33	483,523	43
East Garo hills	23,328	34	142,183	13
Jaintia hills	1415	2	118,994	11
West Khasi hills	5602	8	77,120	7
South Garo hills	10,349	15	95,366	8
Ri Bhoi	4253	6	117,097	10

n: Number of cases

Source Analyzed by authors using data from Department of Health Services (Malaria), Government of Meghalaya

Hills, the Jaintia Hills, and the West Khasi Hills are statistically higher in death cases per 1000 malaria cases as compared to the districts of the Garo Hills and Ri Bhoi. And the reason may be the low surveillance in these areas (Tables 21.1, 21.2 and 21.3).

Table 21.2 District-wise prevalence of malaria per 1000 fever cases

Districts	Prevalence rate	%
East Khasi hills	19	4
West Garo hills	47	10
East Garo hills	164	36
Jaintia hills	12	3
West Khasi hills	73	16
South Garo hills	109	24
Ri Bhoi	36	8

Source Analyzed by authors using data from Department of Health Services (Malaria), Government of Meghalaya

Table 21.3 District-wise death cases per 1000 fever cases (2011–2013)

District	Male			Female		
	0–4 year	5–14 year	15+ year	0–4 year	5–14 year	15+ year
East Khasi hills	9	16	19	8	7	0
West Garo hills	1	1	2	2	1	1
East Garo hills	2	2	4	3	1	1
Jaintia hills	10	5	12	40	13	3
West Khasi hills	13	2	7	3	2	2
South Garo hills	3	4	3	5	2	1
Ri Bhoi	4	4	8	9	2	1

Source Author's calculation using the data from Department of Health Services (Malaria), Government of Meghalaya

Table 21.4 Multiple linear regression analysis

Predictors	Coefficient	95% confidence interval	
Average temperature	0.20983***	0.1955	0.224
Rainfall	−0.0006***	−0.00081	−0.00043
Constant	1.57118***	1.25982	1.88254

Dependent Malaria Incidence Rate, $p < 0.01$:***
Source Author's calculation using the data from Department of Health Services (Malaria) and Directorate of Agriculture, Government of Meghalaya

21.7.1 Relationship Between Malaria Cases and the Meteorological Condition

Table 21.4 depicts the multiple linear regression analysis. The results from the data demonstrate that average temperature has a significant positive association (coeff. 0.2, $p < 0.01$) with the incidence rate of malaria cases in Meghalaya, whereas rainfall indicates a significant negative association. However, there is a

relatively small negative effect that rainfall has on the rise in malaria cases (coeff. −0.0006, $p < 0.01$).

21.7.2 Discussion

The high cases of malaria in East Garo Hills, South Garo Hills, West Khasi Hills and West Garo Hills may be due to the lack of proper healthcare facilities in these districts, the lack of health facilities and private hospital makes the people in these areas to depend only on the government health center, transportation is another problem which affects the supply of medical resources to these areas. The whole part of Garo Hills district lies in low altitude area and mostly covered with forest area as compared with the Khasi and Jaintia Hills. Garo Hills district has tropical climate characterized by high rainfall and humidity generally warm summer and moderately cold winter. Khasi and Jaintia Hills have high rainfall, moderately warm summer and severe winter with periodic depression below freezing point marked by the appearance of ground frost at night and morning over higher elevated areas. This geographical and climatic condition of Garo Hills makes the environment conducive for the breeding and survival of mosquitoes. The prevalence of malaria cases in West Khasi Hills is high in those areas which are bordering with East Garo Hills and South Garo Hills. Another finding in this study is that the district of East Garo Hills, South Garo Hills and West Khasi Hills with high prevalence of malaria cases shows a low prevalence in the death cases, but the district of Jaintia Hills, East Khasi Hills and Ri Bhoi district which have less prevalence of malaria cases shows a high prevalence of death cases. The reason for this may be that people from the districts having a high prevalence of malaria cases developed immunity against severe malarial infections which prevent them from malaria death, whereas those people from districts with a low prevalence of malaria lack in the immunity against severe malarial infections which result in the increase of malaria death. People living in high endemic areas also known as stable malaria zone usually exhibit a high level of immunity. This immunity against malaria is developed by people with repeated episodes of malaria, whereas people living in low endemic areas also known as unstable malaria zone have weak immunity to the disease and they are vulnerable to malaria (Communicable, n.d.). A study done in East Africa highland found that people living in the region, where they are regularly exposed to malarial infection, develop immunity against severe malarial infection, whereas people living in the region not exposed to malarial infection regularly lack immunity against severe malarial infections (Zhou et al. 2004).

Weather conditions like temperature play a major role which leads to the rise in the malaria cases in the state of Meghalaya but the rainfall shows a negative effect on the malaria cases. A study in Madhya Pradesh found no association between the rainfall and malaria incidence (Singh and Sharma 2002). Cases of Malaria usually rise after the rainfall period, but if there is continuous excess heavy rainfall, this may result in flushing away the mosquito larvae from the breeding places (Gonzalez et al. 1997).

The limitations of the study include lack of information on malaria cases in age group classification and also for pregnant women, because it will help in understanding the prevalence of malaria cases among children under 5 and pregnant women. Humidity, which is the important factor that influences the breeding of the malaria parasite, is not considered in the study due lacking information.

21.8   Conclusion

According to this study, weather conditions like temperature play a major role in the rise in the malaria cases in the state of Meghalaya. However, rainfall shows a very small negative effect in increasing the malaria cases. This leads to the idea that with an increase in temperature, which is conducive for the malaria parasites, there is a chance that malaria cases may rise in the region. This finding may help the malaria control program in eradicating the disease. We also observed here that there are districts where the prevalence of malaria cases is low but the death rate in terms of per 1000 malaria cases is high. This regional difference in the prevalence of malaria cases and death cases may help the policy makers of the malaria eradication program make a region-wise plan and policy so that malaria can be eradicated.

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