Climate and Malaria in Indonesia

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Abstract

Introduction: Some regions in Indonesia still have a problem with malaria, particularly in eastern Indonesia. Notwithstanding, Java island has some regencies that have not reached a target of elimination like in a Menoreh Hill. A factor of climate influences the transmission of malaria vector. A suitable climate eases the vector to breed and is the potential for transmitting disease. Information on climate and malaria endemicity is very beneficial to arrange a policy of malaria control to reach the target of malaria elimination in 2030 in Indonesia.

Objective: This study aimed to describing climate and malaria endemicity on Menoreh Hill from 2005 to 2015.

Method: This was a descriptive spatial analysis. The unit of analysis was all 43 endemic villages located on Menoreh Hill. Monthly malaria data were collected for 11 years and obtained from health centers. Data on population number per village per year were obtained from the Central Bureau of Statistics. Meanwhile, data of climate were collected from four stations available at the research site. Furthermore, descriptive and spatial analyses were performed using the software of Arc Gis. Data on climate were analysed using an interpolation method of IDW and then were overlaid with malaria cases.

Results: The results of this research showed that API on Menoreh Hill tended to increase until the year of 2015. In addition, number of villages with categories of MCI and HCI also rose significantly, especially in Purworejo Regency. The results of interpolation for temperature and rainfall data demonstrated that an area with temperature ranging from 25.0^{o}C to 26.5^{o}C and rainfall ranging from 5.6 mm/month to 6.5 mm/month was the most malaria cases.

Keywords: *climate, endemicity, malaria*

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INTRODUCTION

In 2012, the number of malaria cases in the globe was about 207 million. The majority of the cases occurred in Africa (80%), Southeast Asia (13%), and Eastern Mediterranean (6%). The number of malaria cases was estimated to increase from 226 million in 2000 to 244 million in 2005, and then decrease to be 207 million in 2012. It was estimated about 627,000 deaths due to malaria around the world in 2012 that consisted of 90% of deaths in Africa, 7% of deaths in Southeast Asia, and 3% of deaths in the Eastern Mediterranean. There were about 482,000 deaths due to malaria occurred among children under five years old or 77% of total death (1). Malaria is one of the infectious diseases that is being a target of Indonesia's government to eliminate it gradually until 2030. According to a report of Basic Health Research in 2013, the incidence rate of malaria in 2013 was 1.9% lower than that of in 2007 (2.9%). Notwithstanding, some provinces had high *Annual Parasite Incidence* (API) and potentially occurred a transmission and an outbreak. Data demonstrated that 17 of 33 provinces had API < 1 per 1,000 citizens, the other 10 provinces had API ranging from 1-5 per 1,000 citizens, and 6 provinces had API > 5 per 1,000 citizens. Moreover, there was any province that had API > 50 per 1,000 citizens(2). There was about 70.3% of the area in Indonesia as *unstable transmission* and most people lived in this area (3). Topographic diversity and climatic factors influence Anopheles species diversity and malaria cases in Indonesia (4).

A climate has an important role in transmitting malaria especially in highlands of a tropical area. Some previous studies in China, West Africa, Burundi, and Bhutan demonstrated that a climate significantly influenced malaria (5)(6)(7)(8). A study in Purworejo Regency, Indonesia showed that humidity and rainfall significantly influenced malaria (9). Rainfall is influenced by the lifecycle of mosquitoes by providing media for a lifecycle in water. In Indonesia, a study of endemicity and a climate in a malaria transmission is still limited.

Menoreh hill is a region administratively located in Magelang and Purworejo Regencies in Central Java and Kulonprogo Regency in Yogyakarta. Menoreh Hill contributed the highest malaria cases in Java Island (10). There were 3812 malaria cases reported on Menoreh Hill for 11 years (11). Purworejo Regency contributed the highest malaria cases in 2015 as many as 1,411 cases(12). Malaria cases mostly occurred on Menoreh Hill with a height between 300-750 meters, a border area, around mosquito breeding (river, water springs, ditch, and the puddle of water) with a low-density category(13). This study aimed to describing climate and malaria endemicity on Menoreh Hill from 2005 to 2015.

METHODS

This was a descriptive study using spatial analysis. The population was all endemic areas on Menoreh Hill, cross border Central Java and Yogyakarta Province, Indonesia. Samples consisted of 3 sub-districts (43 villages) namely Bagelensub-district (17 villages), Kaligesingsub-district (21 villages), and Kokapsub-district (5 villages). Bagelenand Kaligesing sub-districts were located in Purworejo Regency whereas Kokapsub-district was located in Kulonprogo Regency. Monthly reports of malaria for each village were collected from 1 January to 31 December 2015. Meanwhile, data of citizen numbers per village per year were obtained from the Central Bureau of Statistics. The calculation of API was performed by dividing the number of positive malaria cases per 1,000 citizens on a related year. Each year, API was grouped to be LCI, MCI, and HCI. A village with LCI category if API < 1 per 1,000 citizens, MCI if API ranging from 1.0 to 4.9 per 1,000 citizens, and HCI if API ≥ 5 per 1,000 citizens.Furthermore, data would be presented descriptively and spatially from 2005 to 2015.Data on climate encompassed monthly average temperature and rainfall obtained from four climate stations at the research site namely a station of Kradenanin Purworejo Regency, a station of Sempu Secangin Magelang Regency, stations of KalibawangandWates in Kulonprogo Regency. These data were interpolated to result in spatial maps. An interpolation method used *Inverse Distance Weighted* (IDW). The IDW method was grouped into deterministic estimation namely interpolation that was performed based on mathematic calculations. Then, resulted maps were overlaid with malaria cases.

RESULTS

Malaria Endemicity at Menoreh

Malaria cases and API at Menoreh ecosystem fluctuated during periods of 11 years. API tended to decrease in 2009 but it dramatically increased in 2015. The increase in API was very significant during the last five years. The highest number of cases and API occurred in 2015 (Figure 1). A trend of malaria cases increased during the last 11 years at Menoreh. The highest average malaria cases were in 2015 namely 80 cases/month and the lowest average malaria cases occurred in 2009 namely 4 cases/month.

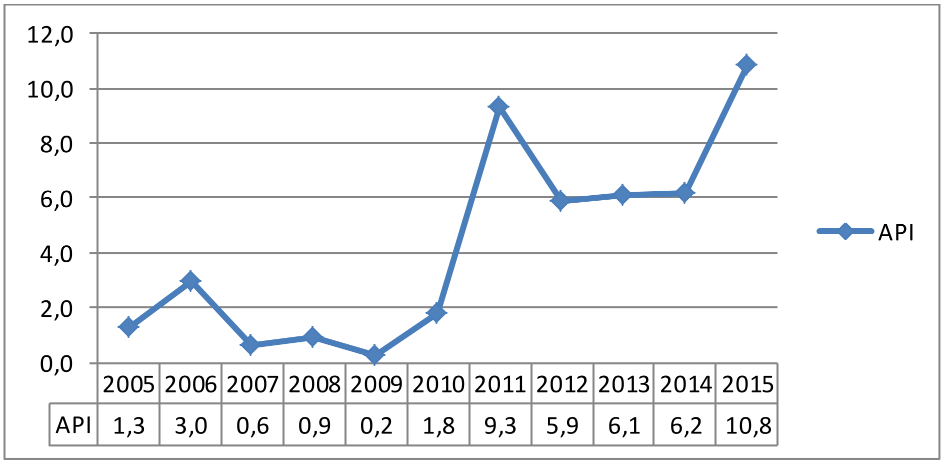

Figure 1.API of malaria at Menorehhill in 2005-2015

Villages had various API for 11 years. In the last five years, the number of endemic villages, Low Case Incidence (LCI), Moderate Case Incidence (MCI),and High Case Incidence(HCI) gradually rose. Moreover, in 2015, villages at Menoreh were dominated by HCI villages.There were 17 (39.5%) as HCI villages in 2015 higher than that of in 2014 namely 11 (25.6%). Each sub-district at Menoreh ecosystem had HCI villages in 2015, namely Kalirejo (Kokap sub-district), Jatirejo, Somongari, Hulosobo, Kaliharjo, Kaligono, Purbowono, Ngaran, Hardimulyo, and Sudorogo (Kaligesing sub-district), and Soko, Sokoagung, Somorejo, Hargorejo, Durensari, Semono, Semagung (Bagelen sub-district). There were only 11 villages (25.5%) that did not have malaria cases in the Menoreh ecosystem in 2015. HCI villages during 11 years mostly occurred in Purworejo Regency rather than in Kulonprogo Regency. Table 1 shows a distribution of malaria endemicity based on API per village during 11 years at the Menoreh ecosystem.

Table1.API of malaria per village at Menorehhill year 2005-2015

No	Name of Health Centre/Village	API										
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
I	KOKAP I HEALTH CENTRE											
	Hargomulyo	0.21	2.42	0.00	0.00	0.00	0.00	0.23	0.12	0.37	3.05	0.00
	Hargorejo	0.55	1.10	0.83	0.38	0.76	0.09	0.19	0.84	0.21	0.11	0.64
	Kalirejo	1.59	3.35	0.35	0.36	0.36	0.00	4.27	9.38	2.56	1.57	6.96
II	KOKAP II HEALTH CENTRE											
	Hargotirto	11.35	3.84	1.48	0.25	0.97	1.09	9.43	10.45	2.52	1.90	3.37
	Hargowilis	3.29	1.29	1.00	0.14	2.39	1.55	1.58	1.01	0.31	0.33	2.14
III	KALIGESING HEALTH CENTRE											
	Jatirejo	1.24	9,11	0,00	0,00	0,00	5,80	56,34	14,50	34,80	51,37	21,96
	Somongari	0.00	9,98	0,00	0,27	0,00	0,81	50,71	2,43	16,99	7,01	24,82
	Donorejo	4.04	3,23	0,00	0,00	0,00	0,00	7,00	10,77	8,34	2,15	4,04

	Hulosobo	0.96	0,00	2,88	0,00	0,00	0,00	4,79	2,88	4,79	3,84	6,71
	Kaliharjo	2.29	1,72	0,00	0,00	0,00	0,00	11,47	16,63	8,03	23,51	31,54
	Kaligono	1.30	0,87	0,87	0,43	0,00	0,43	6,50	3,47	5,42	5,42	23,40
	Tlogoguwo	1.26	0,76	0,00	0,50	0,00	0,00	1,26	1,77	3,78	6,56	4,03
	Pandanrejo	0.00	0,00	0,00	0,00	0,00	0,00	0,76	4,58	0,00	0,00	0,00
	Tawangsari	0.00	0,00	0,00	0,00	0,00	0,00	0,87	0,00	0,00	0,00	1,74
	Tlogobulu	1.13	2,26	0,00	0,00	0,00	2,26	0,00	0,00	0,00	0,00	0,00
	Purbowono	0.00	1,02	1,02	7,15	0,00	0,00	7,15	0,00	0,00	0,00	24,51
	Ngaran	0.74	7,42	1,48	5,94	0,00	0,00	2,23	2,23	0,00	1,48	23,01
	Kedunggubah	3.67	3,67	0,00	0,00	0,00	0,00	2,75	47,75	10,10	0,00	0,00
	Jelok	4.57	3,66	0,00	0,00	0,00	0,00	4,57	19,21	4,57	0,91	0,91
	Tlogorejo	0.96	0,96	0,00	0,00	0,00	6,70	0,96	0,96	0,96	0,00	1,91
	Gunungwangi	0.00	0,00	3,66	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Hardimulyo	0.79	15,89	5,56	2,38	2,38	9,53	0,00	0,79	1,59	0,00	30,18
	Sudorogo	5.41	18,63	1,20	17,43	0,60	24,04	2,40	5,41	3,61	28,85	9,01
	Somowono	1.59	4,77	0,00	1,59	0,79	0,79	0,79	1,59	1,59	0,00	1,59
	Ngadirejo	0.00	0,00	4,74	1,19	1,19	2,37	2,37	1,19	5,93	0,00	0,00
	Pucungroto	0.00	0,00	0,00	0,00	0,00	0,00	0,00	3,51	0,00	1,76	0,00
IV	BAGELEN HEALTH CENTRE											
	Soko Agung	0.94	0,47	0,00	0,00	0,00	0,00	11,83	2,89	17,31	35,87	13,24
	Bagelen	0.00	0.00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Kalirejo	0.00	0.00	0,00	0,00	0,00	0,00	0,00	2,19	1,64	1,82	0,00
	Krendetan	0.00	0.00	0,00	0,00	0,00	0,00	0,00	0,95	0,32	0,00	0,00
	Bugel	0.00	0.00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	Clapar	0.00	0.00	0,00	0,00	0,00	0,00	0,00	0,00	2,57	0,99	0,97
	Soko	0.00	0.53	0,00	0,00	0,00	0,00	1,36	0,00	3,99	1,69	25,29
	Piji	0.00	0.00	0,00	0,00	0,52	0,00	0,00	0,00	0,00	0,00	1,08
	Kemanukan	0.00	0.46	0,00	0,00	0,00	0,41	0,82	0,00	0,00	0,48	0,47
V	DADIREJO BAGELEN HEALTH CENTRE											
	Dadirejo	0.00	17.15	0,00	0,90	0,00	0,32	0,00	0,00	0,32	0,00	0,29
	Tlogokotes	0.00	1.99	0,00	0,00	0,00	0,00	1,98	0,00	6,92	0,98	3,91
	Bapangsari	0.00	0.00	0,00	0,00	0,00	0,00	0,37	0,00	1,11	0,00	1,13
	Somorejo	0.38	6.08	0,00	0,00	0,00	0,00	8,72	4,92	16,24	1,51	5,21
	Hargorojo	5.52	3.68	1,22	0,00	0,00	0,61	56,43	25,45	47,16	7,86	24,05
	Durensari	0.50	0.50	0,00	0,00	0,00	0,00	32,59	8,38	9,85	22,16	73,11
	Semono	2.28	0.00	0,00	0,00	0,00	15,43	70,03	37,76	23,04	38,41	70,11
	Semagung	0.00	1.26	0,00	0,63	0,00	6,29	37,08	10,03	14,38	13,76	24,18
	Rata-rata di Menoreh	1.32	2.98	0,61	0,92	0,23	1,83	9,30	5,91	6,08	6,17	10,83

The results of the spatial analysis demonstrated that a trend of malaria endemicity at each village fluctuated. Since 2010, the number of villages with an API category has increased. The number of villages with categories of MCI andHCI gradually rose. HCI villages were more dominated by Purworejo Regency in the last six years (Figure 2).

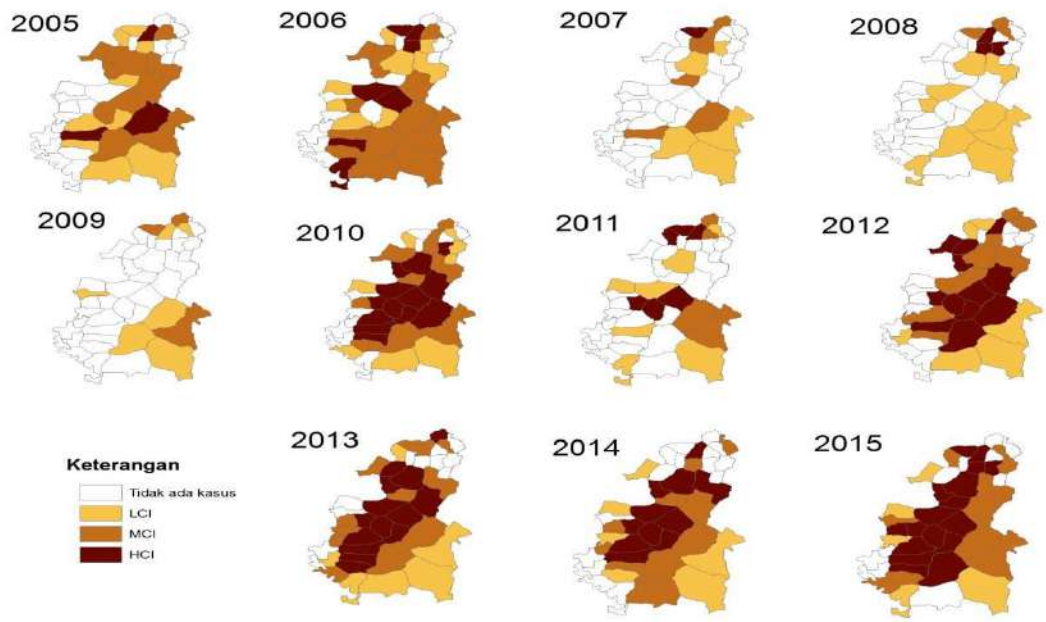

Figure2.Villages of malaria endemicity at Menorehhill in 2005-2015

The climate at Menoreh

The annual average temperature on Menoreh Hill in 2005-2015 ranged from 23.4^{o}C to 25.0^{o}C with the lowest temperature was 20.3^{o}C and the highest temperature was 26.8^{o}C. In the meantime, monthly average rainfall during the same period ranged from 130.8 to 276.2 with the highest rainfall occurred in 2010.

This study performed interpolation for data of temperature and rainfall obtained from four stations. Then, these data were overlaid with malaria cases.Four stations used for measuring weather namely a station of KradenaninPurworejo Regency, a station of SempuSecanginMagelang Regency, and stations of KalibawangandWatesin Kulonprogo Regency. Annual data of average temperature and rainfall were also overlaid with annual malaria cases. Data on malaria during 11 years showed that the highest number of malaria cases occurred in October 2011 (259 cases), August 2015 (162 cases), and September 2015 (155 cases). Generally, malaria cases mostly occurred during a rainy season (August-February).

The interpolation of temperature data that was overlaid with malaria cases in 2012-2014 demonstrated that most malaria cases occurred consecutively in temperatures of 25.0-26.5^{o}C, 25.0-26.0^{o}C, and 25.0-26.5^{o}C. In addition, in 2010-2011, malaria cases mostly occurred in temperatures of 25.5-26.5^{o}C and 24.01-25.5^{o}C. In 2008-2009, malaria cases mostly occurred in temperatures of25.0-25.5^{o}C and 26.0-27.0^{o}C. Similarly, in 2010-2011, in 2005-2007, malaria cases mostly occurred consecutively in temperatures of 26.0-26.5^{o}C, 25.0-26.5^{o}C,and 26.0-27.5^{o}C even though in the other temperature ranges, there was found some malaria cases. Figure 3 presents interpolation between temperature and malaria cases at Menoreh ecosystem in 2005-2014.

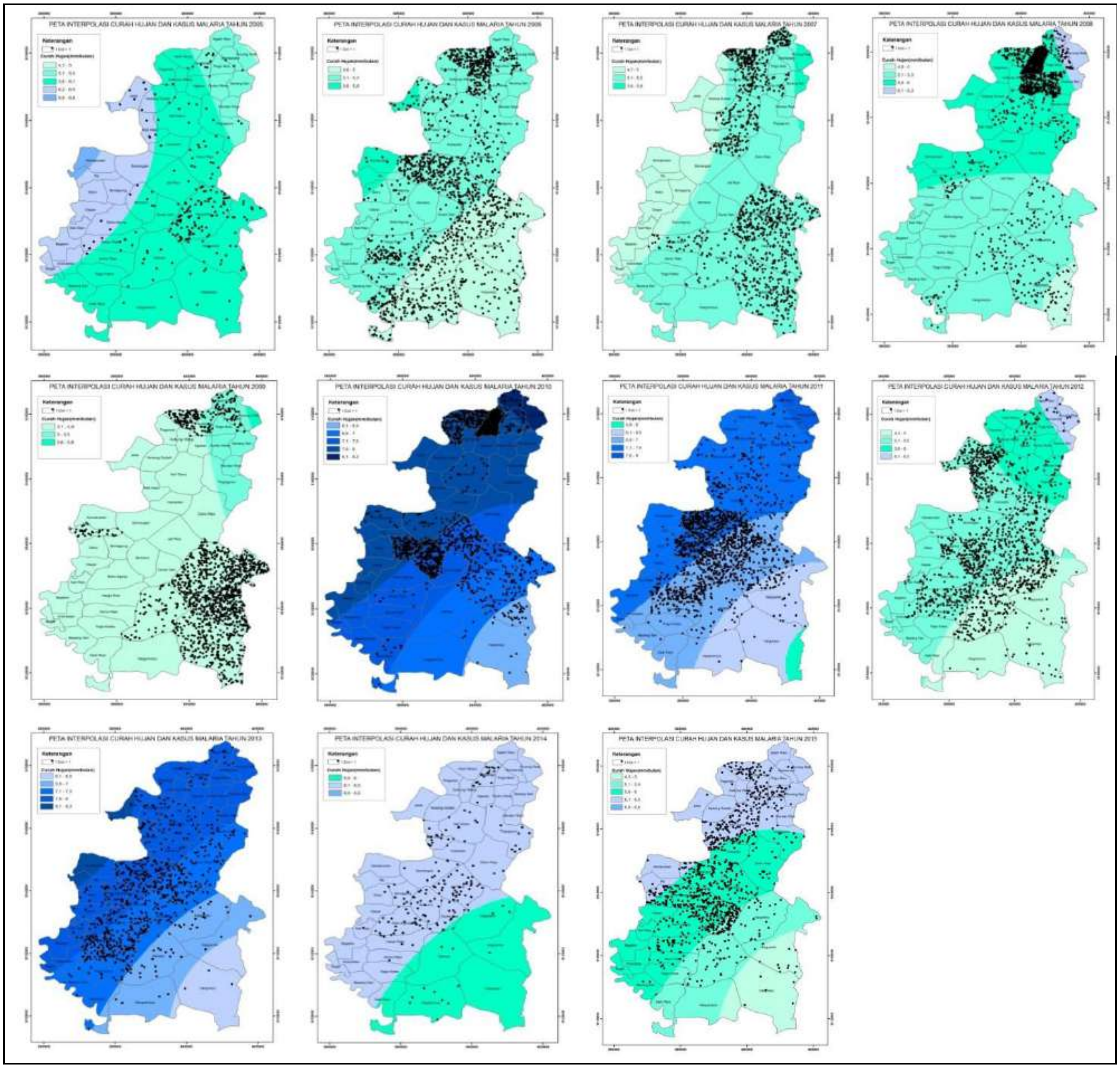

Figure 3.Interpolation between a temperature and malaria cases at Menoreh hill in 2005-2014

The interpolation of a temperature overlaid with malaria cases in 2015 was almost similar to the results of interpolation in 2014 that showed mostly malaria cases occurred in temperatures ranging from 25 to 26.5^{o}C. These temperature ranges were suitable for the developments of parasite and a malaria vector. Data during 11 years (2005-2015) demonstrated mostly malaria cases occurred in temperatures ranging from 25.0-26.5^{o}C.

Furthermore, the results of the interpolation of rainfall overlaid with malaria cases during 11 years (2005-2011) demonstrated malaria cases mostly occurred in rainfall ranging from 5.0-6.5 mm/month. In 2005, malaria cases mostly occurred in rainfall ranging from 5.6-6.1 mm/month. In 2006, malaria cases mostly occurred in rainfall ranging from 4.6-6.1 mm/month. In 2007-2008, malaria cases mostly occurred in rainfall ranging from 5.1-5.5 mm/month and 5.6-6.0 mm/month even though generally malaria cases were distributed in almost all intervals of interpolation.In 2009-2014, malaria cases mostly occurred in rainfall consecutively ranging from5.1-5.5 mm/month, 7.1-8.0 mm/month, 6.6-7.5 mm/month, 4.3-5.5 mm/month, 7.1-8.0 mm/month, and 6.1-6.5 mm/month.

Meanwhile, most malaria cases occurred in 2015 whereas rainfall ranged from 5.6-6.5 mm/month. Rarely rain areas had severalmalaria cases lower than that of in rainy areas.Figure 4 presents the results of the interpolation of rainfall and malaria cases in 2015.

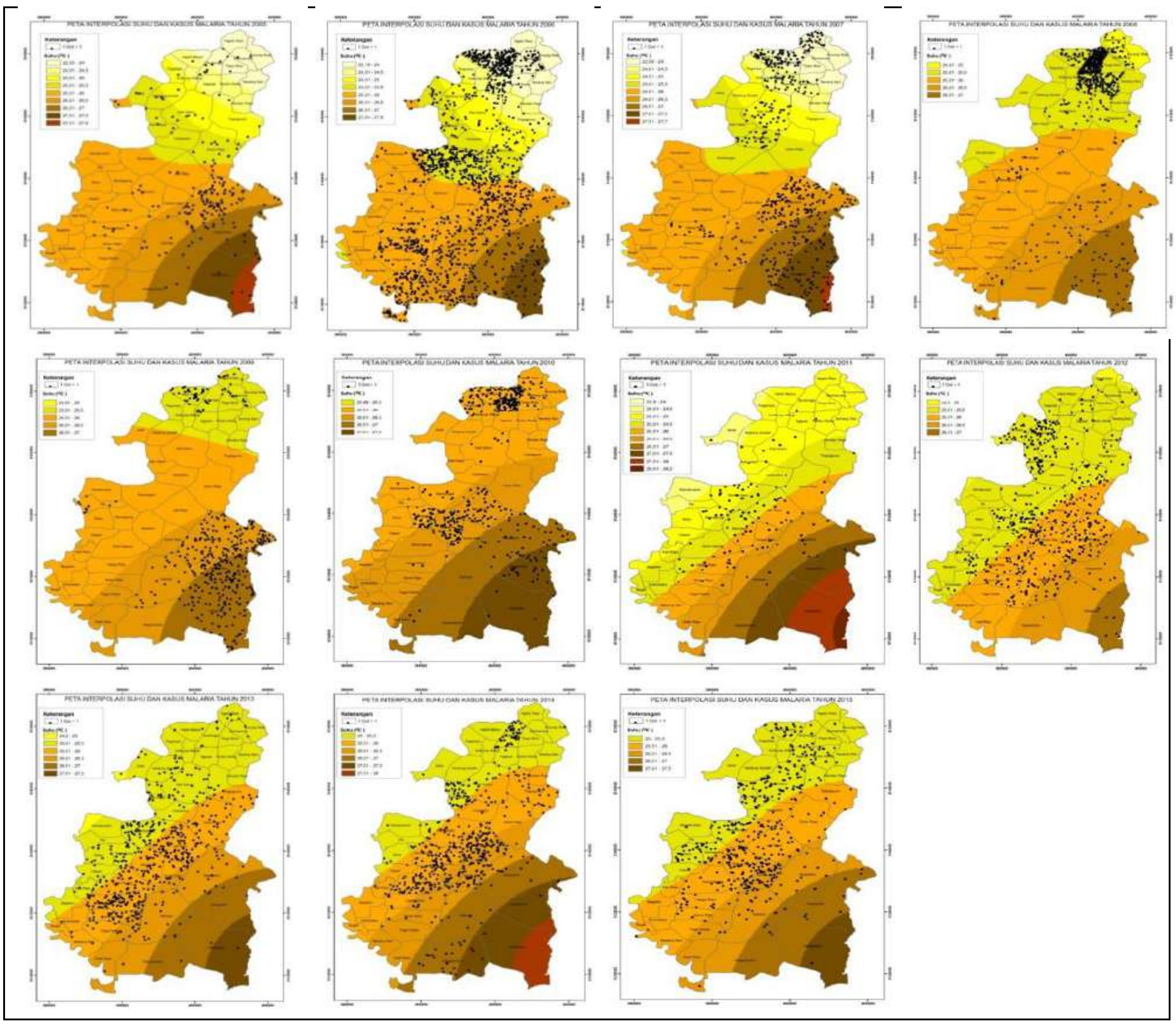

Figure 4.Interpolation of rainfall on Menoreh Hill in 2005-2015 overlaid with malaria cases

The relationship between average temperature and malaria cases

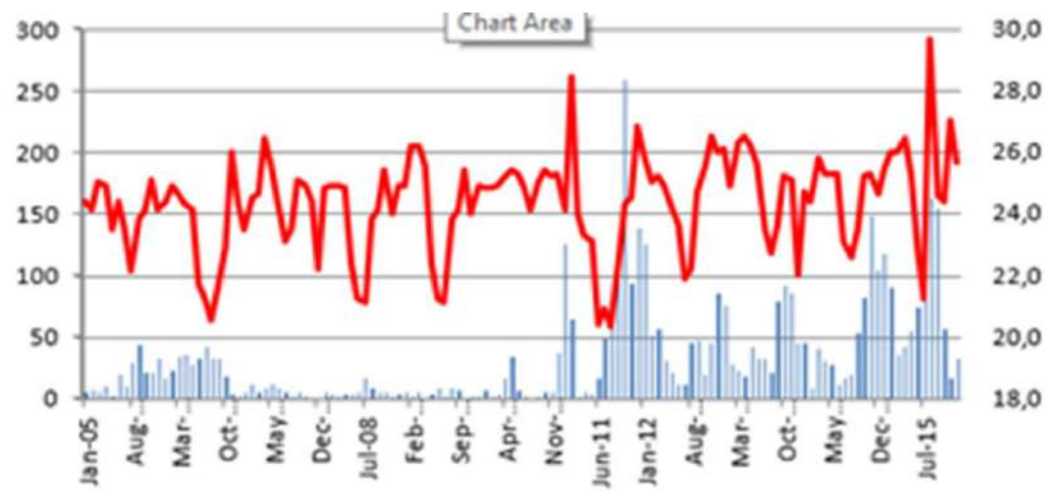

Figure5.The relationship between average temperature and malaria casesat Menoreh hill in 2005-2015

Monthly malaria cases tended to increase at the beginning and the end of the years during the last five years. In July, the average temperature tended to decrease.In addition, the monthly average temperature during 11 years was 24.3ºC.

The relationship between average rainfall and malaria cases.

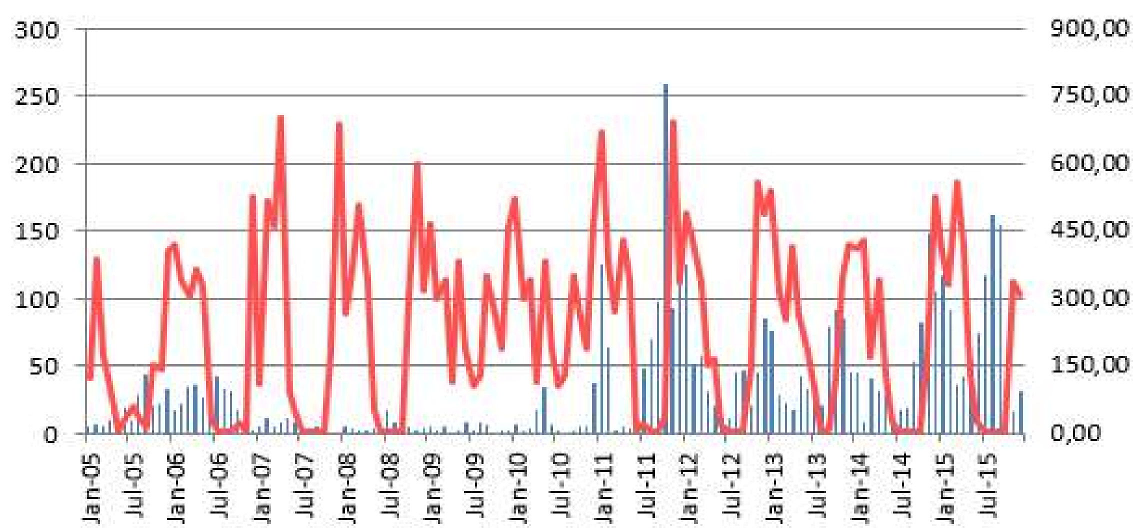

Figure6.The relationship between average rainfall and malaria casesat Menoreh hill in 2005-2015

Generally, in 2011-2015, rainfall and malaria cases had similar patterns, namely in every January, rainfall, and malaria cases tended to increase and every July, they tended to decrease.

DISCUSSION

Malaria has been an endemic disease for decades ago. An activity of intervention like Mass Blood Survey or Mass Fever Survey influence in finding malaria cases on Menoreh Hill (14).The highest rainfall at the Menoreh ecosystem occurred in 2010 with average rainfall was 276.2 mm/month and the highest rainfall was inJanuary and December. Nowadays, the change of seasons is difficult to predict. A dry season that usually occurs in April-September, it changed in 2010 to be in May-September. This climate change is caused by global warming and leads to the spread of diseases in a community. Some biological agents like bacteria, viruses, and protozoa will spread in a new environment to keep the temperature of their bodies.This condition accounts for transmitting infectious diseases like dengue hemorrhagic fever, malaria, cholera, typhoid, and hepatitis. Data during the last 20 years demonstrated that malaria had a five-year cycle.In 1999-2004, malaria cases tended to be high. In contrast, in 2005-2010, the number of malaria cases tended to decrease.Then, in 2011-2015, malaria cases rose again. In 2016, malaria cases gradually went down.Besidesthe high intensity of rainfall, there was a high temperature in 2010 compared to preceding and following years. Warm temperature will shorten a cycle of sporogony by which a mosquito can be more infectious and spread wider. The changes in rainfall and temperature contribute to the increase of spreading vector-borne diseases like malaria.

The result of interpolation, temperatures, and malaria cases during 11 years (2005-2015) demonstrated that the majority of malaria cases on Menoreh Hill occurred in temperatures ranging from 25-26.5^{o}C. The temperature at the research sites was suitable for the breeding of malaria mosquitos. Optimal temperature for the breeding of mosquitos ranged from 25-27^{o}C. Mosquitos could survive at a low temperature but their metabolisms slowed down or were inhibited. Physiological prose was also slowed down by higher temperatures ranging from 32-35 ^{o}C (15). Temperature was an important factor to prolong or shorten a parasite lifecycle inside a mosquito's body. Temperature and rainfall were the most important factors in the transmission cycle of malaria. A warm temperature could shorten the duration of an extrinsic cycle (a sporogony cycle) by which a mosquito would quickly infective and spread widely (8)(16). A temperature lower than 16^{o}C would stop the development of parasite inside a mosquito's body(17).

The result of interpolation of rainfall overlaid with malaria cases during 11 years, in 2005-2011, showed that a majority of malaria cases occurred in rainfall ranging from5.0-6.5 mm/month.Rainfall influencesthe lifecycle of mosquitos in water. Rainfall provides benefits as a breeding place for them. Notwithstanding, it has adverse effects on larvae if there is too much water. Rainfall can also increase relative humidity that contributes to prolonging the life of mosquitos. The temperature has a role as a regulator. The increase of temperature will quicken the digestive process of mosquitos by which they will look for food again. The relationships between temperature, rainfall, and humidity are very complex and the process is influenced by an atmosphere condition(18).

Climate change has a direct impact on the transmission of vector-borne diseases through shifting geographic distance of vectors, increasing reproduction and a biting rate, and shortening the incubation period of pathogens.A temperature, rainfall, and humidity influence the Anopheles population and malaria incidence (19). A warm temperature or hotter will shorten the duration of an extrinsic cycle (a sporogony cycle) by which mosquitos will be more infectious and wider spread (20)(8). A temperature, rainfall, and humidity relate to the dynamic population of malaria vectors and the spreading of malaria disease. A suitable temperature for the life of mosquitos ranging from 16^{o}C – 36^{o}C with life sustainability is 90%. The highest proportion in sustaining an incubation period of mosquitos is a temperature ranging from 28^{o}C – 32^{o}C (21).

Even though rainfall does not have a direct effect on parasite, rainfall has a role in transmitting malaria. Rainfall results in puddle as a breeding place of *Anopheles*. High rainfall can increase humidity and prolong imago's age. I.e. at Sub Sahara, the transmission of malaria mostly occurred in a rainy season(21). A study in India revealed the higher rainfall, the larger number of malaria cases (22). A study in Tibet demonstrated that rainfall and temperature were two factors that play an important role in transmitting malaria but there was no linear influence (23). The role of rainfall in the transmission of malaria was influenced by a geographical position and local behaviour of mosquitos. Rainfall provides benefits for mosquitos to breed if the amount of water is sufficient. However, rainfall can damage and exclude larvae if there is too much water(24). A study in Jimma Ethiopia, Shucher China, and Ghana showed rainfall significantly related to malaria incidence(21)(25)(26). High and low rainfalls will influence the existence of the breeding habitat of malaria vectors. Rainfall does not influence adult vectors in the same month but it will affect in the following months followinga lifecycle of mosquitos in nature. Studies conducted in Sukabumiand Lampung demonstrated that rainfall index significantly related to *Man Bitting Rate* (MBR) for *An.aconitus*, *An.maculatus* and *An.sundaicus*(27). Rainfall will increase number and type of puddle that might not exist during a dry season. The number of ponds, puddles, swamps rises as breeding places for mosquitos. A rainy season interrupted with hot weather can increase number of Anopheles (27). A study in Banyumasshowed that rainfall did not relate to API (*Annual Parasite Incidence*) of malaria (28). The relationship between global warming and the increase of malaria incidence in around the world is still debatable. This attracts researchers to investigate (29)(5). Limitation this study, it does not investigateclimate factor and*Anopheles sp*.

CONCLUSION

Menoreh Hill in 2005 – 2015 had an average temperature ranging from 23.4^{o}Cto 25.0^{o}Cwith thelowest temperature was20.3^{o}Candthe highest temperature was 26.8^{o}C. Meanwhile, during the same period, Menoreh Hill had annual average rainfall ranging from 130.8 to 276.2 mm and the highest rainfall occurred in 2010.Generally, the number of malaria cases mostly occurred during a rainy season namely between Augustand February.A majority of malaria cases occurred at a temperature ranging from 25.0^{o}C – 26.5^{o}C.

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