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Epidemiological Assessment of Climate Change and Malaria Trend

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Being a vector-borne disease, malaria transmission is determined by vectors, hosts and pathogens. Also these determinants are thought to be affected by changes in climate conditions of the environment. This study aimed to detect the trend of malaria and climatic factors change with malaria transmission. Community-based, cross-sectional descriptive study was done in Pyin Oo Lwin Township, Mandalay Region from January to December, 2014. Data of the climatic factors were collected from Meteorological Department of the studied township. Monthly data of malaria morbidity and mortality from 2004 to 2014 were collected from Vector-borne Disease Control Unit of the township. Geographical information for malaria detections was collected at endemic areas during this period. Percentage of malaria patients among the patients attending at both primary health centers and hospitals were significantly reduced (p=0.001) but, climate variables such as temperature, rainfall and humidity did not changed significantly from 2004 to 2014. In correlation analysis, percentage of malaria patients among the patients attending at both hospitals and primary health centers were significantly increased with increasing humidity (p=0.008 & 0.018). However, percentage of malaria patients among hospital admitted patients was significantly reduced with increasing monthly mean temperature. In conclusion, monthly humidity showed significant correlation with malaria prevalence in Pyin Oo Lwin. An outlook on environmental conditions favorable for the occurrence and spread of malaria could be a part of reporting and monitoring to aid future predictions on malaria occurrence.

Key words: Climate, Malaria trend, Epidemiology

INTRODUCTION

Malaria can become a re-emerging public health problem due to climatic and ecological changes, population migration, development of multi-drug resistant *Plasmodium falciparum* parasite, development of insecticide resistant vectors and changes in behavior of malaria vectors.[1]

According to the World Malaria Report, 2011,[2] malaria disease was found in about 216 million cases and 655,000 malaria deaths were estimated as malaria deaths in 2010 in 106 malaria endemic countries. It is a leading cause of death in many developing countries, where young children and pregnant women are mostly affected.

In Myanmar, according to Health in Myanmar 2014, malaria morbidities were 11.11, 9.32, 10.75, 11.68, 8.09 and 6.44 (per 1,000 populations) in 2004, 2005, 2008, 2011, 2012 and 2013, respectively. Mortalities were 3.65, 2.91, 1.84, 1.33 and 0.48 (per 100,000 populations) in 2004, 2006, 2008, 2010 and 2013, respectively. In accordance with ecological changes and malaria morbidity reduction, the micro-stratification showing high risk areas for the malaria was about 38.9% in the 1990 and it was reduced to 17.0% in 2013.

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In 2010, percentage of populations living under malaria high risk, moderate risk, low risk and no risk areas were 22%, 25%, 16% and 37%, respectively.[1, 3] Being vector-borne disease, malaria transmission is determined by vectors, hosts and pathogens. These determinants are also thought to be affected by changes in climate conditions of the environment such as temperature, humidity and rainfall.[4] During the past 100 years, the global temperature has been increasing significantly with an enhanced warming trend since the mid-1950s.[5] Global warming will enhance transmission rates of the mosquito-borne diseases including malaria, causing wider spread on its geographical distribution,[6] in particular, being identified as a potential impact of climate change.[7]

Some studies relating climate variability and malaria epidemics in East Africa in 2004, 2005 done by Zhou G, *et al*. and 2006 by Pascual M, *et al*. reported an increase in the spread of the disease in the current malaria endemic areas,[8-10] or some studies done in 1998 and 2001 in East Africa revealing reemergence of the disease in areas which have controlled transmission or eliminated the disease in the past,[11, 12] others conducted in 2012 reported no association between malaria and climate change.[13]

Climate change will increase the chances for malaria transmission in habitually malarious areas, in areas the disease has been controlled, as well as in new areas which have been previously non-malarious. A study done in 1996 showed an increase in temperature, rainfall and humidity may cause a proliferation of the malaria-carrying mosquitoes at higher altitudes, resulting in an increase in malaria transmission in areas in which it was not reported earlier.[14] At lower altitudes of some countries where malaria have been already a problem, the studies in 1996 and 1998 showed that warmer temperatures will alter the growth cycle of the parasite in the mosquito enabling it to develop faster, increasing transmission and thus having implications on the burden of disease in Southern Africa.[15, 16] Temperature plays an important role in the life cycle of malaria parasites in the mosquito. As the temperature is lower, the duration necessary to complete the cycle becomes longer for a given *Plasmodium* species. Survival of the mosquito larva and adult also depends on temperature. Increasing environmental temperature during both larval and adult stages decreases the survival of larva and adult mosquitos. Increases of 4ºC (from 23ºC to 27ºC, 27ºC to 31ºC, 31ºC to 35ºC) caused larval and adult mosquito mortality.[17] As water collections after the rains favor vector breeding, malaria transmission is highest following the rainy season. Relative humidity affects malaria transmission through its effect on the activity and survival of mosquitoes.[17]

Pyin Oo Lwin Township, located in Mandalay Region, 3538 feet above sea level, is mountainous and has malarious areas. It has become an endemic area for many years. It has many mosquito breeding sources such as forested areas, stream, swamps, wells and rivers. Malaria prevalence studies are not carried out for Pyin Oo Lwin Township in last decade.

This study aimed to detect the trend of malaria and climatic factors association with malaria transmission. Retrospective analysis of the prevalence of malaria in this township from the year 2004 to 2014 was conducted to study in relation to environmental factors like climatic conditions; rainfall, temperature and humidity.

MATERIALS AND METHODS

Descriptive study with retrospective analysis was conducted in Pyin Oo Lwin Township, Mandalay Region from January to December, 2014. Data of environmental factors (rainfall, temperature, humidity) were collected from Meteorological Department of Pyin Oo Lwin Township. Rainfall was measured with standard rain gauge and measurements were expressed in inches. Surface air temperature was measured with air thermometer and read as Celsius.

Relative humidity was measured with hygrometer and expressed by a percentage. Data of GIS (map, tract and location) were collected using Global positioning system (GPS) and ArcGIS mapper. Garman GPS apparatus was used for collection of data of map, location and tract.

Monthly malaria morbidity and mortality of Pyin Oo Lwin from 2004 to 2014 were collected from Vector-borne Disease Control Unit of the studied township and from the rural health centers (main source). Malaria morbidity was expressed as both absolute number and relative number. Malaria out-patients and in-patients attending the hospitals and primary health care centers were measured as absolute number. Percentage of malaria cases among total out-patients and percentage of malaria cases among total in-patients were measured as relative number, i.e. percentage. The study obtained the information concerning environmental factors such as rainfall, temperature and humidity in the studied area during past 10 years.

Moreover, the information concerning monthly malaria morbidity and mortality of the studied area over 10 years were also recorded. The recorded data were compiled, coded, entered into SPSS 20.0 software and analyzed. Descriptive statistics was done for environmental factors (climatic change), malaria morbidity, mortality and demographic characteristics. Data of GIS were explained in ArcGIS mapping. Association between malaria prevalence and climatic change was analyzed using analysis of variances (ANOVA).

RESULTS

The number of malaria patients including both out-patients and in-patients attending at both the hospitals and the primary health care centers were gradually decreased from 2004 to 2014. The number of malaria cases yearly attended the Out-patients Department of hospitals and health centers were increased in 2004 and 2005 with 174 and 278 cases, respectively. Then, malaria prevalence was gradually reduced in later 9 years with 141, 79, 58, 67, 53, 80, 31, 27 and 14 cases per year.

The mean percentage of malaria cases among those attending yearly at Out-patient Departments of hospital and health centers were increased in early years, i.e. 2004 to 2006, with 6.1%, 11.0% and 6.8%, respectively. In later 8 years, i.e. from 2007 to 2014, mean percentages were gradually reduced with 4.0%, 2.3%, 2.1%, 2.0%, 3.1%, 1.2%, 0.6% and 0.2%, respectively.

According to analysis by ANOVA, percentage of malaria patients among the patients attending both Out-patient and In-patient departments were significantly reduced from the year 2004 to 2014 (p=0.001).

Table 1. Yearly rainfall in inch

Year	Month	Mean±SD	Range*	95%CI	
				Lower	Upper
2004	11	5.3±4.7	0.04-14.37	2.18	8.45
2005	10	4.9±2.3	1.54-8.79	3.21	6.48
2006	9	7.5±5.2	0.20-17.49	3.52	11.48
2007	9	6.64.4±	0.55-12.17	3.18	9.94
2008	11	4.7±4.5	0.08-14.29	1.69	7.75
2009	9	7.0±5.9	0.75-16.65	2.45	11.49
2010	9	7.4±6.6	0.16-18.84	2.30	12.48
2011	11	6.7±5.7	0.33-18.35	2.81	10.48
2012	11	4.9±3.9	0.16-12.32	2.25	7.58
2013	10	5.6±5.8	0.12-17.87	1.45	9.82
2014	10	8.0±7.2	1.10-23.47	1.40	14.65

*=Minimum-Maximum

One of the climate variables, yearly rainfall was revealed in Table 1. Yearly rain fall distribution showed that rainfalls were reduced in 2005, 2008 and 2012 with 4.9, 4.7 and 4.9 inches, respectively.

Table 2. Yearly maximum temperature in Celsius

Year	Month	Mean±SD	Range*	95%CI Lower	95%CI Upper
2004	12	26.0±2.13	22.3-30.3	24.6	27.3
2005	12	26.9±2.84	21.8-31.3	25.1	28.7
2006	12	27.1±2.36	23.4-30.8	25.6	28.6
2007	12	26.3±2.47	23.3-31.1	24.7	27.8
2008	12	26.5±2.27	22.9-31.3	25.1	28.0
2009	12	27.0±2.09	23.5-30.9	25.6	28.3
2010	12	27.4±2.93	22.7-33.0	25.5	29.3
2011	12	26.0±1.86	22.2-28.7	24.7	27.1
2012	12	26.6±2.32	23.2-30.5	25.1	28.1
2013	12	27.0±2.81	21.9-32.0	25.1	28.6
2014	12	27.6±2.44	23.5-31.2	25.7	29.4

*Minimum-Maximum

Table 2 shows yearly maximum temperature in Pyin Oo Lwin Township. Yearly maximum temperature had no significant changes over study period from 2004 to 2014.

Table 3. Yearly humidity in percentage

Year	Month	Mean±SD	Range*	95%CI Lower	95%CI Upper
2004	12	75.7±14.3	36-86	66.6	84.8
2005	12	80.7±9.2	59-89	74.9	86.6
2006	12	77.2±6.3	63-85	73.1	81.3
2007	12	79.2±5.1	68-85	75.9	82.5
2008	12	81.9±2.9	78-87	80.0	83.8
2009	12	76.3±10.9	56-89	69.3	83.3
2010	12	77.4±12.2	54-92	69.6	85.1
2011	12	78.6±9.4	61-92	72.6	84.6
2012	12	76.8±13.1	51-91	68.4	85.1
2013	12	78.0±12.1	56-91	70.3	85.7
2014	12	77.6±9.1	62-87	70.6	84.6

*=Minimum-Maximum

Yearly humidity over study period was expressed in Table 3. Mean humidity was reduced in the years 2004, 2009 and 2012 with 75.7%, 76.3% and 76.8%, respectively. The monthly mean rainfall was also found that rainfalls were increased from the month of May to October every year, during study period.

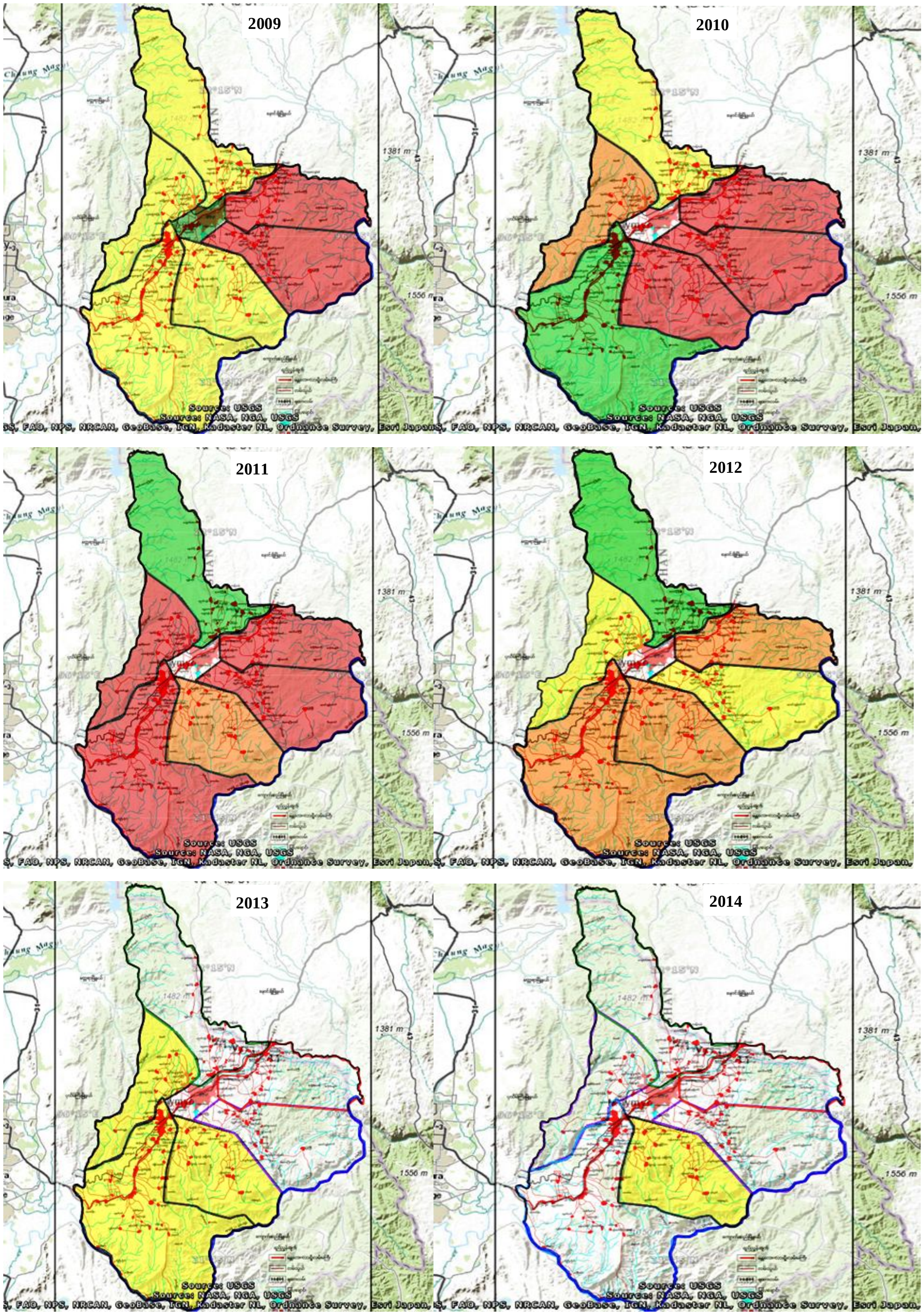
Data of GIS (altitude, tract and location) were collected using Garman GPS apparatus and data were viewed in ArcGIS mapper. Figure 1 shows GIS mapping displaying yearly percentage of malaria among total out-patients in each health center area in studied township from 2009 to 2014. According to the prevalence of malaria in decreasing order, malaria prevalence with >4% of total out-patients were mapped with red color which present in most of health center areas in 2009 to 2011. Before 2009, malaria prevalence was >4% in every area of study sites.

Therefore, those areas had to be colored the whole in red in those years. However, in the years of 2012 to 2014, such higher prevalence was not mapped in any health center areas as the prevalence was reduced. In 2013 and 2014, malaria prevalence with ≤0.5% of total out-patients was mapped with no color in most of health center areas. Only 3 areas in 2013 and one area in 2014 were mapped with yellow color i.e. >1 to 2% of total out-patients. Therefore, malaria morbidity was reduced in studied areas in recent years. Correlation analysis between climate factors and malaria prevalence is described in Table 4.

Table 4. Correlation between climate factors and malaria prevalence

Variables	Mean % of malaria among in-patients	Mean % of malaria among out-patients
Rainfall in inch		
Pearson correlation	0.41	-0.003
P value	0.678	0.972
Maximum temperature		
Pearson correlation	-0.195	-0.152
P value	0.027	0.085
Humidity		
Pearson correlation	0.232	0.208
P value	0.008	0.018

It is found that humidity is positively correlated with mean percentage of malaria among in-patients (p=0.008) and also with mean percentage of malaria among out-patients (p=0.018). The percentage of malaria patients among the patients attending both hospital and primary health centers were significantly increased with humidity increasing. However, percentage of malaria among hospital admitted patients was negatively correlated with increasing mean temperature (p=0.027).



% of malaria among total Out-patient

>4% >2 to 4% >1 to 2% >0.5 to 1% =<0.5%

Fig. 1. GIS mapping showing malaria prevalence in health centre areas

DISCUSSION

Since late 2002, Pyin Oo Lwin Township was provided with treatment strategy through basic health staff with rapid diagnostic testing and Artemisinin Combinational Therapy (ACT). Insecticide Treated Net (ITN) for malaria endemic areas by national malaria program through the collaboration with NGOs has been started in Pyin Oo Lwin Township since 2002 also. Thus, malaria prevalence was thought to be reduced by these control activities like other regions in Myanmar. Similar explanation was also justified in Copenhagen Consensus that it may be affected by many factors such as rapid diagnostic testing and ACT provisions by local health workers, ITN supply, population and demographic dynamics, drug resistance, insecticide resistance, human activities such as deforestation, irrigation, swamp drainage, etc.[19]

This study found that humidity is positively correlated with mean percentage of malaria among in-patients and also with among out-patients significantly. Similarly, a study in India showed that high correlation was found between humidity and malaria transmission during monsoon period.[20] The different studies found that malaria incidence was positively correlated with increasing of maximum temperature.[21-23] In this study, changes in mean temperature was negatively correlated with percentage of malaria among in-patients. This is due to some limitations relating measurement of climatic variables of the study. Daily temperature may be responsible for the survival of vector and incubation period of parasites. However, temperature was collected as mean of monthly data in the study. Another limitation is that the temperature was only measured at high altitude areas where meteorological stations were based.

Rainfall was not correlated with malaria transmission in this study. The analysis could not be done between one month lag of rainfall and malaria incidence. Malaria incidence could not be assessed in this study. This study could assess the malaria prevalence. However, malaria cases were high in the rainy season from June to November. Monthly rainfall and one month lag of monthly mean temperature show significant correlation with malaria prevalence in Chennai, however the socio-economic factors and lack of awareness on sanitation and hygiene is a more contributing factor for malaria prevalence at that area.[24] Western and north-western India recorded more malaria cases with higher rainfall during La Niña in 1996 and less rain and fewer malaria cases in the same area during El Niño in 1998.[25]

Conclusions and recommendations

According to this study, malaria prevalence was gradually decreased over 10-year period from 2004 to 2014. This may be mainly due to malaria control activity with widely covered rapid diagnostic testing and ACT provision through basic health staff. Humidity was significantly correlated with mean percentage of malaria from both hospital in-patients and out-patients. However, increasing rainfall and temperature were negatively correlated with malaria transmission in this study. Therefore, it may not be possible to conclude as strong relation between climate factors and malaria prevalence. Therefore, this study recommend that an outlook on environmental conditions favorable for the occurrence and spread of malaria could be a part of reporting and monitoring to aid future predictions on malaria occurrence. To identify the malaria endemicity, malaria mapping might be crucial for health centers. Future research focused on vector ecology, population and demographic dynamic, and populations' behavior will be necessary.

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