Research Journal of Medical Sciences 9 (2): 18-27, 2015
ISSN: 1815-9346

Climate Variability and a Disease Forecasting Model for Dengue Hemorrhagic Fever in North Sumatera Province, Indonesia

[1]Fazidah A. Siregar, [2]Mohamed Rusli Abdullah, [2]Julia Omar,
[1]Sori Muda Sarumpaet, [3]Teguh Supriyadi, [4]Tri Makmur and [5]Nurul Huda
[1]Faculty of Public Health, University of Sumatera Utara, 20155 Medan, North Sumatera, Indonesia
[2]School of Medical Science, University Sains Malaysia, 16150 Kubang Kerian, Malaysia
[3]North Sumatera Health Department, Medan, 20155 North Sumatera, Indonesia
[4]Faculty of Medicine, Islamic University of Sumatera Utara, Medan, North Sumatera, Indonesia
[5]Food Technology Program, University Sains Malaysia, 11800 Penang, Malaysia

Abstract: Transmission of dengue virus depends on the presence, density and distribution of Aedes mosquitoes and the development of these mosquitoes is known to be influenced by climate. This study was performed to determine the influence of climatic factors on Dengue Hemorrhagic Fever (DHF) and to help predict the occurrence of DHF in North Sumatera Province, Indonesia. Monthly reported dengue cases and climate data for the years 2003-2011 were obtained from the district health offices and the Climatological Division of the Meteorological Department of North Sumatera Province, respectively. The climatic data comprised the monthly total rainfall, monthly rainy days, the monthly average, minimum and maximum temperatures and average relative humidity. A time series analysis was conducted by using a cross-correlation function and Seasonal Autoregressive Integrated Moving Average (SARIMA) modeling to predict the occurrence of DHF and the influence of climate on dengue was examined by a time series regression approach. The results demonstrated that the reported DHF cases showed a cyclical pattern with seasonal variation. Temperature, rainfall, rainy days and humidity all play roles in sustaining and increasing the dengue incidence in North Sumatera Province. The SARIMA (0,1,1)(0,1,1) Model had the lowest mean square error and was the best model. The SARIMA Model could be applied to predict the occurrence of DHF in North Sumatera Utara Province and could assist with public health decisions needed to prevent and control the disease.

Key words: Dengue, climate variability, disease forecasting model, seasonal autoregressive integrated moving average, time series

INTRODUCTION

Dengue Hemorrhagic Fever (DHF) is one of the most important public health problems worldwide. Currently, >100 countries are endemic for dengue virus infection (Guzman and Isturiz, 2010; Guzman *et al*., 2010). DHF has become a leading cause of morbidity with 3.6 billion people living in areas at high risk for dengue infection. Recent studies suggest that there are approximately 230 million infections of dengue fever worldwide each year (Wilder-Smith *et al*., 2012). Approximately, 50-100 million cases of dengue fever occur annually and 250,000-500,000 cases are DHF (Guzman *et al*., 2010). DHF is a leading cause of hospitalization among children in several countries in Southeast Asia including Indonesia (MHI, 2010).

The first reported cases of DHF in Indonesia occurred in Jakarta and Surabaya in 1968. Since then, the incidence of DHF as well as the number of districts affected, has increased. In 2011, the Ministry of Health of Indonesia reported that North Sumatera Province ranked the third highest for DHF cases (MHI, 2011). Out of 25 districts in North Sumatera Province, 16 were dengue endemic districts.

DHF is caused by the dengue virus which is transmitted by the bite of a female mosquito. The disease is found in tropical and subtropical regions, especially during the rainy season when areas of stagnant water that serve as breeding sites for mosquitoes are created (MHI, 2005). The factors that are responsible for the incidence of DHF are complex and include the following key determinants: population density, urbanization,

Corresponding Author: Fazidah A. Siregar, Faculty of Public Health, University of Sumatera Utara, 20155 Medan, North Sumatera, Indonesia

inadequate water supply, waste management, ineffective vector control programs, climate and socioeconomic factors (Guzman and Kouri, 2002; Torres and Castro, 2007). Climate variability is an important parameter in the epidemiology of vector-borne diseases. The ecology, development, behavior and survival of the mosquito and the transmission of disease are influenced by climate (Thammapalo *et al*., 2005; Zhang *et al*., 2008; Johansson *et al*., 2009). Rainfall plays a role in the survival and behavior of the mosquito vector and in the life cycle of the virus whereas temperature affects the vector reproduction rate, the susceptibility of the mosquito and the extrinsic incubation period (Gubler *et al*., 2001; Promprou *et al*., 2005; Chowell and Sanchez, 2006; Pham *et al*., 2011). The optimum temperature for mosquito development is 25-27°C (Kalluri *et al*., 2007). Humidity affects the life cycle of the mosquito by influencing its feeding patterns and can also increase vector survival rate (Wu *et al*., 2007).

Time series methodology has been increasingly used in epidemiological research of infectious disease, particularly in the assessment of health services. Climatic variables as potential predictors of dengue incidence have been examined in time series studies (Wongkoon *et al*., 2011). Some studies have established correlations between climatic factors and dengue transmission. Chowell and Sanchez (2006) found that maximum temperature was correlated with time series dengue cases with a lag of 1 month while evaporation correlated with dengue with a lag of 3 months (Chowell and Sanchez, 2006). Similarly, a study by Johansson *et al*. (2009) in Puerto Rico and a study by Colon-Gonzalez *et al*. (2011) in Mexico found that dengue incidence was associated with temperature (Johansson *et al*., 2009; Colon-Gonzales *et al*., 2011). Meanwhile, Wu *et al*. (2007) in Taiwan found that temperature and humidity were negatively associated with the incidence of dengue fever with a lag of 2 months (Wu *et al*., 2007). Other studies have found that rainfall was associated with dengue incidence (Wongkoon *et al*., 2011; Wiwanitkit, 2006). Pham *et al*. (2011), Vietnam and Karim *et al*. (2012) in Dhaka also found that rainfall was correlated with dengue cases (Pham *et al*., 2011; Karim *et al*., 2012). A study by Martinez *et al*. (2011) concluded that when the Seasonal Autoregressive Integrated Moving Average (SARIMA) Model is used as a tool to monitor the incidence of dengue fever, it is capable of predicting the number of cases that will occur in the next year (Martinez *et al*., 2011).

Presently, no vaccine or specific treatments are available for DHF. The only way to prevent the disease is with vector control. Prevention and control measures for DHF are based on national policies and require improvements of the surveillance system, disease management and community participation (Kusriastuti and Sutomo, 2005). To implement effective control measures for DHF, the factors associated with DHF incidence must be considered. Climate change has an impact on the transmission and incidence of DHF (Banu *et al*., 2011). Previous research has revealed that climate has an effect on dengue transmission. Therefore, a better understanding of the disease patterns and the factors associated with DHF, especially in regard to climatic variables is needed. With such an understanding, disease epidemics could be modeled which would assist with the prevention and control of the disease.

MATERIALS AND METHODS

Study area: This study was conducted in North Sumatera Province, an endemic area for DHF in Indonesia. It is situated between 1 and 4°N and between 98 and 100°E. North Sumatera Province has an area of 72,981,23 km^2 with a human population of 12,982,204 inhabitants. The Province of Nanggroe Aceh Darussalam lies to the North, Malaysia lies to the East, the province of Riau lies to the South and the Province of Samudera Hindia lies to the West. North Sumatera Province has two seasons. The rainy season is from November to March. The dry season follows in June to September. The average annual rainfall is 2,205 mm per year. The average maximum and minimum temperatures are 32.7 and 23.6°C, respectively. The average humidity is 83%.

North Sumatera Province comprises 25 districts. Of the 25 districts, 6 districts were selected for this study, 3 high incidence and 3 low incidence districts based on the DHF incidence data in 2007 and considering feasibility and logistics. Medan, Pematang Siantar and Tebing Tinggi were selected to represent high incidence districts whereas Langkat asahan and Deli Serdang represent low incidence districts (Fig. 1). All districts are endemic for dengue.

Data collection: Monthly reports of dengue hemorrhagic cases for 2003-2011 were obtained from district health offices. Reported cases were diagnosed by physicians using WHO criteria and reported following national surveillance system guidelines. Monthly climatic data were obtained from the Climatological Division of the Meteorological Department. The climate data comprised

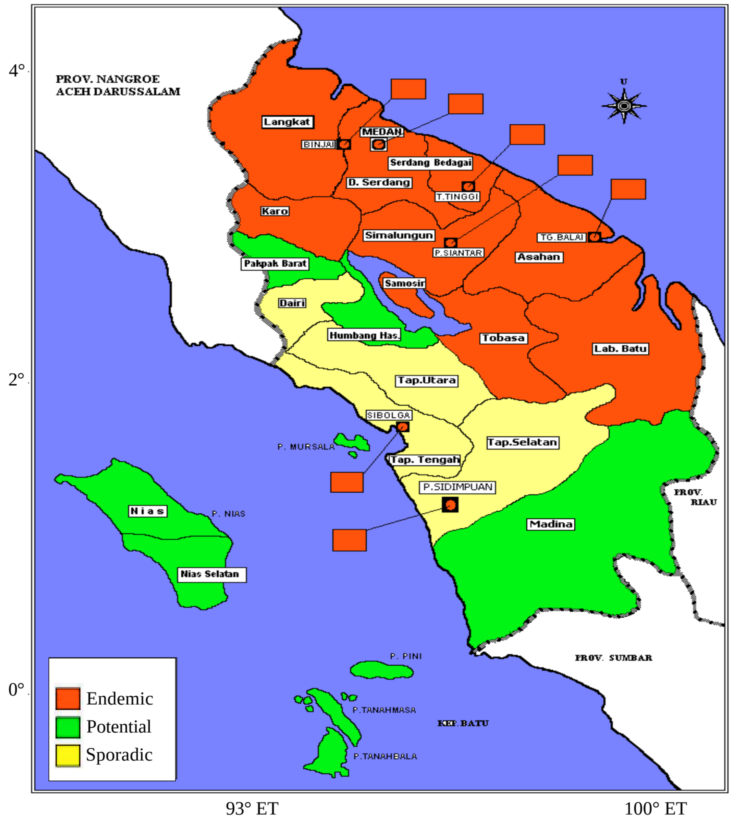

Fig. 1: North Sumatera Province

the monthly total rainfall, monthly rainy days, the monthly average, minimum and maximum temperatures and the average relative humidity.

Statistical analysis: Minitab Version 16.0 was used for the statistical analysis. Pearson's correlation analysis was used to examine the relationship between monthly climatic variables and the incidence of DHF. A cross-correlation was used to assess the degree of correlation between climatic data and dengue cases over a range that showed a time lag effect from 0-3 months of lagged effect. The Seasonal Autoregressive Integrated Moving Average (SARIMA) Model was used to estimate the contribution of each climatic variable and to predict the occurrence of DHF. Three steps were undertaken in modeling the relationship between climatic variation and dengue transmission. First, the SARIMA Model was developed using the monthly incidence of dengue. Second, the goodness of fit of the model was checked for adequacy. Finally, data collected between January 2003 and December 2011 were used to construct a SARIMA Model and the forecasting accuracy of this model was verified using data collected between January and December 2012. The effect of climate variability on the DHF incidence in North Sumatera Province was then examined using a time series regression approach.

Table 1: The number of DHF cases in North Sumatera Province

Districts	Lowest	Highest	Mean (SD)
Medan	9	456	138 (94.4)
Pematang Siantar	0	134	33.1 (29.8)
Tebing Tinggi	0	88	17.3 (16.1)
Langkat	0	139	14.7 (24.0)
Asahan	0	55	8.4 (10.4)
Deli Serdang	0	157	40.8 (3.5)

RESULTS

The overall and mean numbers of DHF cases in all districts in North Sumatera Province for the period 2003-2011 are listed in Table 1. The monthly numbers of DHF cases showed a seasonal pattern for each district and tended to increase significantly during the study period (Fig. 2). DHF cases were identified each year with varying intensities from month to month. The number of DHF cases initially increased in June, peaked between July and December and then gradually decreased. From the high-incidence districts, the highest DHF cases in the study period (2003-2011) occurred in Medan in November 2010 with 456 DHF cases when the average temperature was 27°C, the rainfall was 246 mm and the average humidity was 82%. In Pematang Siantar, the highest number of cases occurred in August 2010 when the average temperature was 25.6°C, the rainfall was 408 mm and the average humidity was 84%. In Tebing Tinggi, the highest number of cases occurred in November 2007 when the average temperature was 26.3°C, the rainfall was 428 mm and the average humidity was 87%. From the low-incidence districts, the highest number of DHF cases in the study period (2003-2011) occurred in Langkat in August 2010 with 456 DHF cases when the average temperature was 27.4°C, the rainfall was 153 mm and the average humidity was 84%. In Asahan, the highest number of cases occurred in August 2010 when the average temperature was 27.8°C, the rainfall was 156 mm and the average humidity was 81%. In Deli Serdang, the highest number of cases occurred in July 2010 when the average temperature was 26.2°C, the rainfall was 136 mm and the average humidity was 88% (Fig. 3).

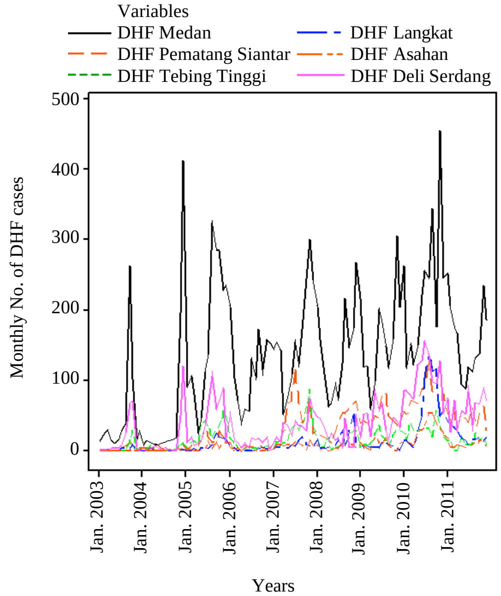

Fig. 2: Monthly number of DHF cases in six districts in North Sumatera Province

Monthly maximum, minimum and average temperatures were positively associated with the monthly incidence of DHF reported in the Medan District over the study period with a lag of 3 months. Rainfall was also positively associated with the monthly incidence of DHF with a lag of 1-3 months. The number of monthly rainy days was positively associated with the monthly incidence of DHF with a lag of 0-3 months. The monthly maximum temperature was negatively associated with the incidence of DHF with a lag of 0 month. The monthly humidity was also negatively associated with a lag

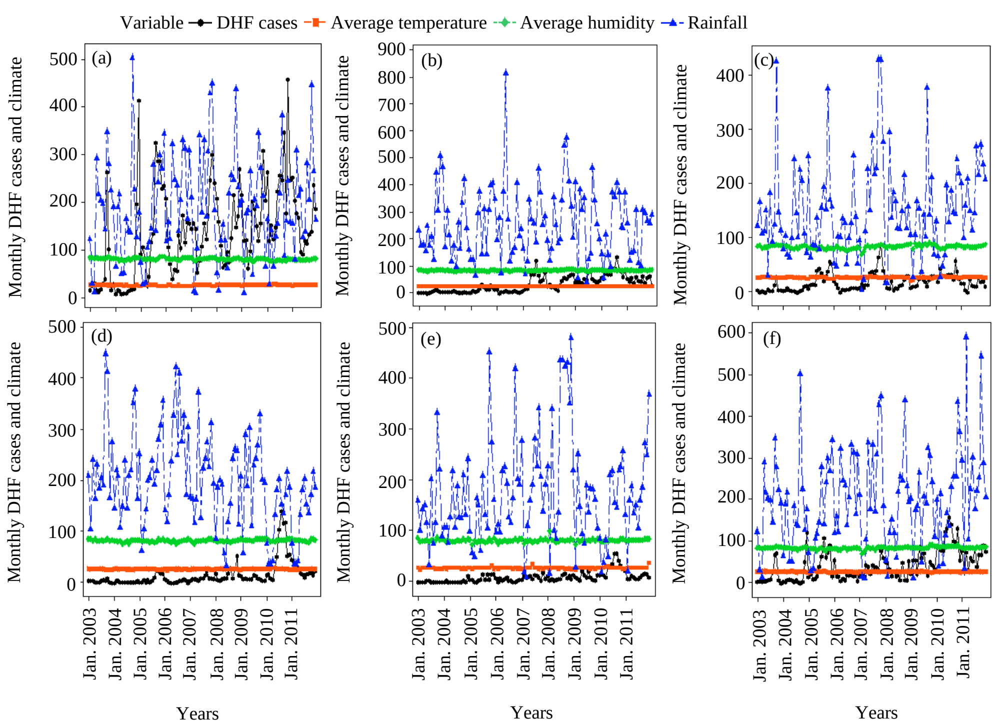

Fig. 3: Monthly DHF cases and climatic factors in six districts in North Sumatera Province from 2003-2011. Monthly DHF cases and climatic factors: a) in medan from 2003-2011; b) in Pematang Siantar from 2003-2011; c) in Tebing Tinggi from 2003-2011; d) in Langkat from 2003-2011; e) in Asahan from 2003-2011 and f) in Deli Serdang from from 2003-2011

of 3 months. For Pematang Siantar District, the monthly minimum and average temperatures were positively associated with the monthly incidence of DHF 0-3 months. Monthly rainy days were positively associated with the monthly incidence of DHF with a lag of 0 month. For Tebing Tinggi, the monthly average and maximum temperatures were positively associated with the monthly incidence of DHF with a lag of 3 months. Monthly rainfall and rainy days were positively associated with the monthly incidence of DHF with a lag of 0-2 months. For Langkat district, monthly rainfall, rainy days and maximum temperature were positively associated with the monthly incidence of DHF with a lag of 3 months. The mean monthly temperature was positively associated with the monthly incidence of DHF with a lag of 2-3 months. The minimum temperature was also positively associated with the incidence of DHF with a lag of 0-3 months. Humidity was positively associated with the incidence of DHF with a lag of 0-1 month. For Asahan, the monthly rainy days were positively associated with the monthly incidence of DHF with a lag of 0-2 months. The monthly mean temperature was positively associated with the monthly incidence of DHF with a lag of 1-3 months. The minimum temperature was also positively associated with the incidence of DHF with a lag of 2-3 months. For Deli Serdang, the monthly minimum temperature was positively associated with the monthly incidence of DHF with a lag of 0-3 months. The monthly maximum temperature was positively associated with the monthly incidence of DHF with a lag of 3 months. The average humidity was positively associated with the incidence of DHF with a lag of 0-3 months (Table 2).

After the cross-correlation analysis, adjusted for seasonality was performed, the incidence of DHF in Medan was positively associated with the monthly rainfall with a lag of 1-3 months; number of rainy days with a lag of 0-3 months; minimum temperature with a lag of 3 months and average temperature with a lag of 3 months. Meanwhile, the incidence of DHF was negatively associated with the maximum temperature with a lag of 0-2 months. In Pematang Siantar, the incidence of DHF was positively associated with average temperature with a lag of 0-1 months and was negatively associated with the monthly minimum temperature with a lag of 2-3 months and the average of humidity with a lag of 2 months. In Tebing Tinggi, the incidence of DHF was positively associated with the average temperature with a lag of 0-3 months; monthly maximum temperature with a lag of 0-2 months; average humidity with a lag of 3 months; rainfall with a lag of 0-3 months and the number of rainy days with a lag of 3 months. In Langkat, the incidence of DHF was positively associated with the maximum temperature with a lag of 2-3 months and average temperature with a lag of 3 months.

Meanwhile, it was negatively associated with the monthly minimum temperature with a lag of 1-3 months and monthly rainfall and monthly rainy days with a lag of 3 months. In Asahan, the incidence of DHF was positively associated with the number of rainy days with a lag of 3 months and average temperature with a lag of 2 months. In Deli Serdang, DHF was positively associated with the maximum temperature with a lag of 3 months and humidity with a lag of 0-3 months. Meanwhile, it was negatively associated with the minimum temperature with a lag of 0-3 months (Table 3).

Table 2: Pearson's correlation between climatic factors and the incidence of DHF in North Sumatera with a lag of 0-3 months

Districts	Lag	Rainfall	Rainy days	Maximum temperature	Minimum temperature	Average temperature	Humidity
Medan	0	-	0.304	-0.295	-0.189	-	-
	1	0.260	0.305	-	-	-	-
	2	0.322	0.398	-	-	-	-
	3	0.335	0.265	0.203	0.255	0.227	-0.194
Pematang Siantar	0	-	0.203	-	0.268	0.316	-
	1	-	-	-	0.308	0.437	-
	2	-	-	-	0.351	0.470	-
	3	-	-	-	0.328	0.445	-
Tebing Tinggi	0	0.360	0.302	-	-	-	-
	1	0.377	0.328	-	-	-	-
	2	0.228	0.235	-	-	-	-
	3	-	-	0.288	-	0.256	-
Langkat	0	-	-	-	0.266	-	0.238
	1	-	-	-	0.327	-	0.192
	2	-	-	-	0.454	0.269	-
	3	-0.262	-0.257	0.250	0.575	0.411	-
Asahan	0	-	0.348	-	-	-	-
	1	-	0.344	-	-	0.239	-
	2	-	0.269	-	0.254	0.267	-
	3	-	-	-	0.273	0.218	-
Deli Serdang	0	-	-	-	-0.473	-	0.418
	1	-	-	-	-0.441	-	0.414
	2	-	-	-	-0.400	-	0.366
	3	-	-	0.236	-0.437	-	0.304

The SARIMA Model was constructed with data collected between January 2003 and December 2011 and was verified using data collected from January to December 2012. Figure 4 shows the actual (observed) and predicted monthly incidence in the six districts. The actual value and the predicted value matched reasonably well. The best fitting model was obtained after performing estimations, diagnostics, checks and selection of the model. The results of the SARIMA Model for the six districts in North Sumatera Province are shown in Table 4. Most of the selected Box-Jenkins Models are SARIMA $(0,1,1)(0,1,1)^{12}$ except for in Langkat for which the model is $(1,0,0)(1,1,0)^{12}$. The most commonly identified model, SARIMA $(0,1,1)(0, 1, 1)^{12}$, indicated that the current incidence can be estimated with the incidence and random shock (error) from the previous month and from the seasonal trend for the previous year.

The results of the SARIMA Model show that the incidence of DHF in Medan was significantly associated with rainfall with a lag of 3 months and with rainy days with a lag of 0-2 months. For Pematang Siantar, the incidence of DHF was significantly associated with the monthly minimum temperature with a lag of 3 months; average temperature with a lag of 1 month and humidity with a lag of 2 months. For Tebing Tinggi, the incidence of DHF was significantly associated with rainfall with a lag of 0-1 month. In Langkat, the incidence of DHF was significantly associated with the minimum temperature with a lag of 3 months. For Asahan, the incidence of DHF was significantly associated with the average temperature with a lag of 2 months. For Deli Serdang, the incidence of DHF was significantly associated with the maximum temperature with a lag of 3 months; minimum temperature with a lag of 3 months and humidity with a lag of 0 month (Table 5).

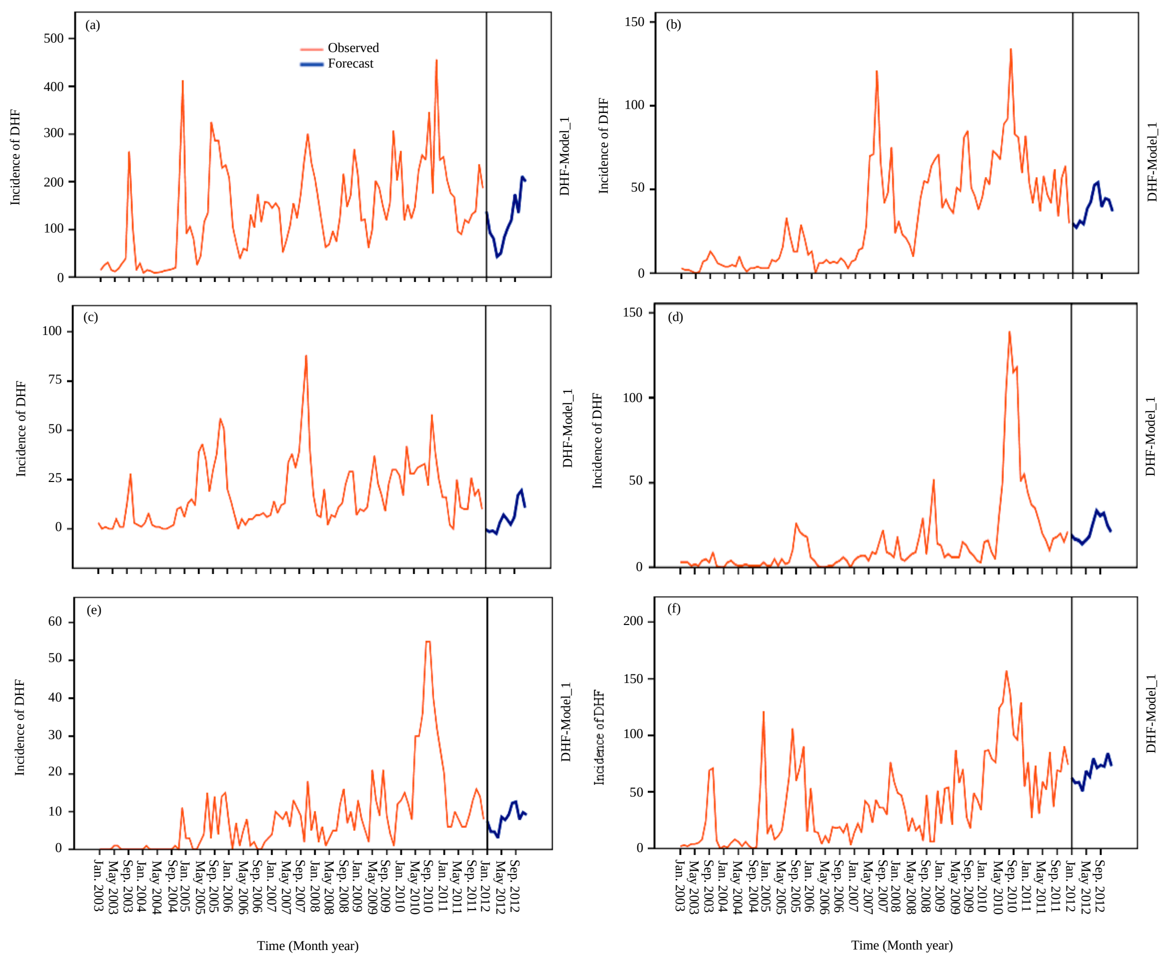

Fig. 4: The actual monthly dengue incidence from 2003-2011 and the monthly dengue incidence predicted for 2012 by the SARIMA Model in North Sumatera Province: a) Medan; b) Pematang Siantar; c) Tebing Tinggi; d) Langkat; e) Asahan and f) Deli Serdang

Table 3: Cross-correlation analysis of climatic factors and the incidence of DHF in North Sumatera with a lag of 0-3 months

Districts	Lag	Rainfall	Rainy days	Maximum temperature	Minimum temperature	Average temperature	Humidity
Medan	0	0.180	0.303	-0.295	-0.189	-0.122	0.076
	1	0.258	0.301	-0.294	-0.205	-0.222	0.030
	2	0.316	0.386	-0.223	-0.208	-0.125	-0.017
	3	0.317	0.250	-0.047	0.255	0.222	-0.141
Pematang Siantar	0	-	-	-	0.028	0.255	-0.490
	1	-	-	-	-0.185	0.245	-0.136
	2	-	-	-	-0.218	0.200	-0.226
	3	-	-	-	-0.262	0.046	-0.103
Tebing Tinggi	0	0.308	0.159	0.213	-	0.310	0.075
	1	0.312	0.218	0.269	-	0.323	0.129
	2	0.248	0.164	0.228	-	0.340	0.130
	3	0.278	0.214	0.110	-	0.226	0.294
Langkat	0	-0.171	-0.199	0.168	-0.042	0.017	-
	1	-0.159	-0.176	0.081	-0.460	0.050	-
	2	-0.069	-0.064	0.294	-0.221	0.161	-
	3	-0.272	-0.296	0.398	-0.282	0.323	-
Asahan	0	-	0.126	-	0.025	0.141	-
	1	-	0.180	-	0.044	0.114	-
	2	-	0.172	-	-0.070	0.217	-
	3	-	0.287	-	0.011	0.176	-
Deli Serdang	0	-	-	0.036	-0.473	-	0.418
	1	-	-	0.105	-0.521	-	0.353
	2	-	-	0.171	-0.480	-	0.332
	3	-	-	0.230	-0.494	-	0.312

Table 4: Characteristics of the SARIMA models for DHF in North Sumatera Province

Districts	SARIMA Model	AR1	MA1	SAR	SMA	MS	p-value (Ljung)
Medan	$(0,1,1)(0,1,1)^{12}$	-	0.6320	-	0.8399	4292.0	0.080
Pematang Siantar	$(0,1,1)(0,1,1)^{12}$	-	0.3413	-	0.8276	267.5	0.364
Tebing Tinggi	$(0,1,1)(0,1,1)^{12}$	-	0.2647	-	0.8593	137.7	0.410
Langkat	$(1,0,0)(1,1,0)^{12}$	0.8028	-	-0.8090	-	183.9	0.284
Asahan	$(0,1,1)(0,1,1)^{12}$	-	0.2497	-	0.7941	44.2	0.146
Deli Serdang	$(0,1,1)(0,1,1)^{12}$	-	0.4414	-	0.8405	735.8	0.202

Table 5: Climatic variables associated with the monthly incidence of dengue hemorrhagic fever in North Sumatera Province

Districts	Variables	B	SE	t-statistic	p-values	MS
Medan	Intercept	-69.60	34.14	-2.04	0.044	6356
	Rainfall, with a lag of 3 months	0.25772	0.08007	3.22	0.002	
	Rainy days, with a lag of 0 month	5.070	1.430	3.55	0.001	
	Rainy days, with a lag of 2 months	4.431	1.520	2.91	0.004	
Pematang Siantar	Intercept	-1212.6	193	-6.28	0.000	611
	Minimum temperature, with a lag of 3 months	8.582	2.771	3.10	0.003	
	Average temperature, with a lag of 1 month	29.525	5.299	5.57	0.000	
	Humidity, with a lag of 2 months	3.912	1.213	3.22	0.003	
Tebing Tinggi	Intercept	-38.93	46.52	-0.84	0.405	209.9
	Rainfall, with a lag of 0 month	0.04408	0.017495	2.52	0.013	
	Rainfall, with a lag of 1 month	0.04355	0.02125	2.05	0.043	
Langkat	Intercept	-666.56	95.67	-6.97	0.000	397
	Minimum temperature, with a lag of 3 months	28.664	4.023	7.13	0.000	
Asahan	Intercept	-44.66	21.10	-2.12	0.037	104.2
	Average temperature, with a lag of 2 months	1.9465	0.7721	2.52	0.013	
Deli Serdang	Intercept	-52.6	157	-0.34	0.738	872
	Maximum temperature, with a lag of 3 months	10.659	3.195	3.34	0.001	
	Minimum temperature, with a lag of 3 months	-20.705	0.368	-4.74	0.000	
	Humidity, with a lag of 0 month	2.9112	0.9858	2.95	0.004	

MS: Mean Square, B: coefficient, SE: Standard Error; *Significant at the 0.01 level (two-tailed)

DISCUSSION

The results of this study revealed that climate variability is associated with the incidence of DHF. Temperature, rainfall, rainy days and humidity all play roles in sustaining and increasing the incidence of DHF in North Sumatera Province. Rainfall is one of the factors significantly associated with an increased incidence of DHF. Rainfall could increase breeding sites, eventually increasing the number of Aedes mosquitoes which may increase the transmission of dengue (Gubler *et al*., 2001). The timing, amount and pattern of rainfall are important. Many studies have shown that rainfall plays an important role in dengue occurrence (Thammapalo *et al*., 2005;

Promprou *et al*., 2005; Chowell and Sanchez, 2006; Pham *et al*., 2011; Wongkoon *et al*., 2011; Karim *et al*., 2012; Su, 2008). Our results indicate that rainfall is one predictor of dengue transmission. This study shows that the incidence of DHF was associated with rainfall with a lag of 3 months for Medan and with a lag of 0-1 months for Tebing Tinggi. Rainfall not only provides the medium for the stages of the mosquito life cycle but it also increases the relative humidity which affects the longevity of adult mosquitoes. A study by Wongkoon *et al*. (2013) in Sisaket, Thailand, Gama and Nakagoshi (2013) in Nganjuk, East Java investigated the effect of climate on the abundance of *Aedes aegypti* and found more *A. aegypti* present during the rainy season (Wongkoon *et al*., 2013 ; Gama and Nakagoshi, 2013). On the other hand, rainfall can also eliminate breeding and excessive rainfall can interrupt the development of mosquito eggs (Thammapalo *et al*., 2005; Gubler *et al*., 2001; Promprou *et al*., 2005).

The number of rainy days was a significant factor in the incidence of DHF. This study shows that the incidence of DHF was associated with rainy days with a lag of 0 and 2 months for Medan. The number of rainy days may influence the life cycle of the mosquito or viral replication. This finding was consistent with a study by Promprou *et al*. (2005) in Southern Thailand who found that the number of rainy days was associated with the incidence of DHF in the Gulf of Thailand (Promprou *et al*., 2005).

Temperature is also an important environmental factor that can enhance vector development, shorten the pathogen incubation period, increase the adult longevity and alter the gonotrophic cycle length, biting rate and the number of blood meals (Scott *et al*., 2000; Thu *et al*., 1998; Watts *et al*., 1986). Temperature indirectly influences the biting frequency of Aedes mosquitoes by reducing the duration of the gonotrophic cycle, increasing the number of blood meals and increasing the survival rate of the vectors (Scott *et al*., 2000). In addition, higher temperatures accelerate viral dissemination by reducing the extrinsic incubation period of the vector. More effective incubation, consequently, promotes accelerated and more frequent transmission (Focks and Barrera, 2006; Rohani *et al*., 2009). This study shows that the incidence of DHF was associated with the minimum temperature with a lag of 3 months; average temperature with a lag of 1-2 months and maximum temperature with a lag of 3 months. This result is consistent with the findings of other studies (Colon-Gonzalez *et al*., 2011; Depradine and Lovell, 2004; Brunkard *et al*., 2007; Gharbi *et al*., 2011; Luz *et al*., 2008; Lu *et al*., 2009). Depradine and Lovell (2004) found that the minimum temperature showed a positive correlation with dengue incidence with a lag of 12 weeks and the maximum temperature also showed a positive correlation with a lag of 16 weeks in their study on a small Caribbean Island in Barbados. In Metamoros, Brunkard *et al*. (2007) found that the maximum temperature had a greater effect compared to the minimum temperature for dengue transmission and that a temperature increase of 1°C was associated with a 19% increase in dengue incidence. Another study by Gharbi *et al*. (2011) found that temperature significantly affected the forecasting of dengue incidence.

Relative humidity influences the feeding patterns of mosquitoes and rising humidity increases vector survival rate. This study shows that the incidence of DHF was associated with humidity with a lag of 0 and 2 months. This finding is consistent with a study by Wu *et al*. (2007) in Taiwan that found that humidity was the major determinant in the fluctuation of dengue incidence (Wu *et al*., 2007). Likewise, Pham *et al*. (2011) found that high humidity was correlated with a high incidence of DHF in a study in Vietnam (Pham *et al*., 2011).

Studies have shown that the SARIMA Model can produce a reliable model for forecasting the incidence of DHF (Martinez *et al*., 2011; Gharbi *et al*., 2011; Luz *et al*., 2008). In this study, the best SARIMA Models for each endemic district in North Sumatera Province are parsimonious and most of them are SARIMA $(0,1,1)(0,1,1)^{12}$ Models, except for Langkat which is a $(1,0,0)(1,1,0)^{12}$ Model. The SARIMA Models indicate that the current incidence can be estimated using the incidence from the previous month and the seasonal trend from the previous year. The model is useful for understanding trends and forecasting the incidence of DHF in dengue endemic area and could be used to strengthen the dengue surveillance system in North Sumatera Province.

However, the limitations of this study should be considered. For example asymptomatic and unreported cases may lead to under-reported DHF cases. Moreover, most of reported DHF cases in North Sumatera Province are diagnosed using WHO criteria by physicians at different health centers and hospitals which may lead to the misinterpretation of DHF diagnoses in some cases. To understand all aspects of disease transmission, both DHF and DF cases should be considered and laboratory confirmation and serotype identification should be required and included in the surveillance system.

CONCLUSION

Climatic factors such as rainfall, number of rainy days, temperature and humidity have been proven to significantly influence dengue transmission in North Sumatera Province. Integrating climatic factors into the national dengue prevention program is necessary to strengthen the dengue control program. The SARIMA Model provides the predicted incidence of DHF in North Sumatera Province and could be used to predict the occurrence of DHF in North Sumatera Utara Province. Application of this model could assist with the design of public health measures to prevent and control the disease.

ACKNOWLEDGEMENTS

We thank the North Sumatera Provincial Health Surveillance Department of Disease Control for Dengue incidence data and the Meteorological Department of North Sumatera Province for Climatic Data. We also thank everyone who was involved in this study.

REFERENCES

Banu, S., W. Hu, C. Hurst and S. Tong, 2011. Dengue transmission in the Asia-pacific region: Impact of climate change and socio-environmental factors. Trop. Med. Int. Health, 16: 598-607.

Brunkard, J.M., J.L.R. Lopez, J. Ramirez, E. Cifuentes and S.J. Rothenberg *et al*., 2007. Dengue fever seroprevalence and risk factors, Texas-Mexico border, 2004. Emerging Infect. Dis., 13: 1477-1483.

Chowell, G. and F. Sanchez, 2006. Climate-based descriptive models of dengue fever: The 2002 epidemic in Colima, Mexico. J. Environ. Health, 68: 40-44.

Colon-Gonzalez, F.J., I.R. Lake and G. Bentham, 2011. Climate variability and dengue fever in warm and humid Mexico. Am. J. Trop. Med. Hyg., 84: 757-763.

Depradine, C. and E. Lovell, 2004. Climatological variables and the incidence of dengue fever in Barbados. Int. J. Environ. Health Res., 14: 429-441.

Focks, D.A. and R. Barrera, 2006. Dengue transmission dynamics: Assessment and implications for control. Report of The Scientific Working Group on Dengue, World Health Organization, Geneva, Switzerland, pp: 92-109.

Gama, Z.P. and N. Nakagoshi, 2013. Climatic variability and dengue haemaorrhagic fever incidence in Nganjuk district, east java, Indonesia. Acta Biologica Malaysiana, 2: 31-39.

Gharbi, M., P. Quenel, J. Gustave, S. Cassadou, G.L. Ruche, L. Girdary and L. Marrama, 2011. Time series analysis of dengue incidence in Guadeloupe, French West Indies: Forecasting models using climate variables as predictors. BMC Infect. Dis., Vol. 11. 10.1186/1471-2334-11-166.

Gubler, D.J., P. Reiter, K.L. Ebi, W. Yap, R. Nasci and J.A. Patz, 2001. Climate variability and change in the United States: Potential impacts on vecto and rodent-borne diseases. Environ. Health Perspect., 109: 223-233.

Guzman, A. and R.E. Isturiz, 2010. Update on the global spread of dengue. Int. J. Antimicrob. Agents, 36: S40-S42.

Guzman, M.G. and G. Kouri, 2002. Dengue: An update. Lancet Infect. Dis., 2: 33-42.

Guzman, M.G., S.B. Halstead, H. Artsob, P. Buchy and J. Farrar *et al*., 2010. Dengue: A continuing global threat. Nat. Rev. Microbiol., 8: 7-16.

Johansson, M.A., F. Dominici and G.E. Glass, 2009. Local and global effects of climate on dengue transmission in Puerto Rico. PLoS Negl. Trop. Dis., Vol. 3. 10.1371/journal.pntd.0000382.

Kalluri, S., P. Gilruth, D. Rogers and M. Szczur, 2007. Surveillance of arthropod vector-borne infectious diseases using remote sensing techniques: A review. PLoS Pathog., Vol. 3. 10.1371/journal.ppat.0030116.

Karim, N.M., S.U. Munshi, N. Anwar and M.S. Alam, 2012. Climatic factors influencing dengue cases in Dhaka city: A model for dengue prediction. Indian J. Med. Res., 136: 32-39.

Kusriastuti, R. and S. Sutomo, 2005. Evolution of dengue prevention and control programme in Indonesia. Dengue Bull., 29: 1-7.

Lu, L., H. Lin, L. Tian, W. Yang, J. Sun and Q. Liu, 2009. Time series analysis of dengue fever and weather in Guangzhou, China. BMC Public Health, Vol. 9. 10.1186/1471-2458-9-395.

Luz, P.M., B.V. Mendes, C.T. Codeco, C.J. Struchiner and A.P. Galvani, 2008. Time series analysis of dengue incidence in Rio de Janeiro, Brazil. Am. J. Trop. Med. Hyg., 79: 933-939.

MHI., 2005. Report of dengue hemorrhagic cases in Indonesia. Ministry of Health of Indonesia (MHI), Jakarta.

MHI., 2010. Report of dengue hemorrhagic cases in Indonesia. Ministry of Health of Indonesia (MHI), Indonesia, Jakarta.

MHI., 2011. Report of dengue hemorragic cases in Indonesia. Ministry of Health of Indonesia (MHI), Jakarta.

Martinez, E.Z., E.A.S. da Silva and A.L. dal Fabbro, 2011. A SARIMA forecasting model to predict the number of cases of dengue in Campinas, State of Sao Paulo, Brazil. Revista Sociedade Brasileira Medicina Tropical, 44: 436-440.

Pham, H.V., H.T. Doan, T.T. Phan and N.N.T. Minh, 2011. Ecological factors associated with dengue fever in a central highlands province, Vietnam. BMC Infect. Dis., Vol. 11. 10.1186/1471-2334-11-172.

Promprou, S., M. Jaroensutasinee and K. Jaroensutasinee, 2005. Climatic factors affecting dengue haemorrhagic fever incidence in Southern Thailand. Dengue Bull., 29: 41-48.

Rohani, A., Y.C. Wong, I. Zamre, H.L. Lee and M.N. Zurainee, 2009. The effect of extrinsic incubation temperature on development of dengue serotype 2 and 4 viruses in *Aedes aegypti* (L.). Southern Asian J. Trop. Med. Public Health, 40: 942-950.

Scott, T.W., P.H. Amerasinghe, A.C. Morrison, L.H. Lorenz and G.G. Clark *et al*., 2000. Longitudinal studies of *Aedes aegypti* (Diptera: Culicidae) in Thailand and Puerto Rico: Blood feeding frequency. J. Med. Entomol., 37: 89-101.

Su, G.L.S., 2008. Correlation of climatic factors and dengue incidence in Metro Manila, Philippines. AMBIO: J. Hum. Environ., 37: 292-294.

Thammapalo, S., V. Chongsuwiwatwong, D. McNeil and A. Geater, 2005. The climatic factors influencing the occurrence of dengue hemorrhagic fever in Thailand. Southeast Asian J. Trop. Med. Public Health, 36: 191-196.

Thu, H.M., K.M. Aye and S. Thein, 1998. The effect of temperature and humidity on dengue virus propagation in *Aedes aegypti* mosquitos. Southeast Asian J. Trop. Med. Public Health, 29: 280-284.

Torres, J.R. and J. Castro, 2007. The health and economic impact of dengue in Latin America. Cad Saude Publica, 23: S23-S31.

Watts, D.M., D.S. Burke, B.A. Harrison, R.E. Whitmire and A. Nisalak, 1986. Effect of temperature on the vector efficiency of *Aedes aegypti* for dengue 2 virus. Army Medical Research Inst of Infectious Diseases Fort Detrick.

Wilder-Smith, A., K.E. Renhorn, H. Tissera, S. Abu Bakar and L. Alphey *et al*., 2012. DengueTools: Innovative tools and strategies for the surveillance and control of dengue. Glob Health Action, Vol. 5. 10.3402/gha.v5i0.17273.

Wiwanitkit, V., 2006. An observation on correlation between rainfall and the prevalence of clinical cases of dengue in Thailand. J. Vector Borne Dis., 43: 73-76.

Wongkoon, S., M. Jaroensutasinee and K. Jaroensutasinee, 2011. Climatic variability and dengue virus transmission in chiang Rai, Thailand. Biomedica, 27: 5-13.

Wongkoon, S., M. Jaroensutasinee and K. Jaroentutasinee, 2013. Distribution, seasonal variation and dengue transmission prediction in Sisaket, Thailand. Indian J. Med. Res., 138: 347-353.

Wu, P.C., H.R. Guo, S.C. Lung, C.Y. Lin and H.J. Su, 2007. Weather as an effective predictor for occurrence of dengue fever in Taiwan. Acta Trop., 103: 50-57.

Zhang, Y., P. Bi and J.E. Hiller, 2008. Climate change and the transmission of vector-borne diseases: A review. Asia-Pac. J. Public Health, 20: 64-76.