Analysis of forecasting malaria case with climatic factors as predictor in Mandailing Natal Regency: a time series study

D Aulia¹, S F Ayu², and A Matondang³

¹,²Faculty of Public Health, University of Sumatera Utara
³Faculty of Agribusiness, University of Sumatera Utara

Email: ¹aulia_destanul@yahoo.com, ²srifajar.ayu@gmail.com,
       ³apriyantinamatondang9@gmail.com

Abstract. Malaria is the most contagious global concern. As a public health problem with outbreaks, affect the quality of life and economy, also could lead to death. Therefore, this research is to forecast malaria cases with climatic factors as predictors in Mandailing Natal Regency. The total number of positive malaria cases on January 2008 to December 2016 were taken from health department of Mandailing Natal Regency. Climates data such as rainfall, humidity, and temperature were taken from Center of Statistic Department of Mandailing Natal Regency. E-views ver. 9 is used to analyze this study. Autoregressive integrated average, ARIMA (0,1,1) (1,0,0)¹² is the best model to explain the 67.2% variability data in time series study. Rainfall (P value = 0.0005), temperature (P value = 0.0029) and humidity (P value = 0.0001) are significant predictors for malaria transmission. Seasonal adjusted factor (SAF) in November and March shows peak for malaria cases.

1. Introduction

Malaria cases have decreased to 18% in 2015, from 262 million cases in 2000 to 214 million cases in 2015. Most cases in 2015 occurred in Africa (88%), Southeast Asia (10%), and the Eastern Mediterranean (2%). It was estimated that there has decreased to 37% cases in 2000-2015. Malaria transmission decreased from 106 countries in 2000 to 57 countries in 2015, resulting in transmission of malaria more than 75%. Furthermore, 18 countries ere able to reduce the case of malaria to 50-75% [1].

North Sumatra Province was not categorized as the highest and lowest of Annual Paracitic Incidence (API). The province was decreased in API and has reached the target of health ministry plan’s for malaria morbidity (API) less than 1 per 1,000 risk population in 2015. Nevertheless, there are 3 regencies / cities in North Sumatera Province that have not reached national targets and have high API number. The highest prevalence of malaria with API are Mandailing Natal with 6.88%, GunungSitoli is 3.38%, and Batu Bara Regency is 1.40% [2].

The case of malaria in Mandailing Natal has decreased from 4029 in 2008 to 3465 patients in 2011. While in 2012 there was an increased of 7544 cases, then decreased significantly from 754
to 905 patients in 2016. This is due to the fluctuation of malaria cases every month as malaria is still problem.

Studies of malaria epidemics shows the relationship among climatic conditions: rainfall, temperature, and humidity. The transmission is seasonal, with the peak happens in raining season when the temperature is between 20\(^\circ\)C and 30\(^\circ\)C and the mean relative humidity is at least to 60% because of the increasing breeding sites [4].

2. Methods

The study was conducted in Health Departement of Mandailing Natal. This regency occupied in 662,070 km\(^2\) area, which is divided into 23 districts and 407 villages (definitive sub-district). According to Departement of Centre Statistic Mandailing Natal Regency, the total population of Mandailing Natal was 211,506 in 2015. The altitude area 2.145 metres and influenced by monsoon, dry and rainy season temperature, and precipitation [5]. Rainy season in Mandailing Natal starts in December to March, but dry season starts in June to September. This situation changed each year after the transition period in April to May and in October to November [6].

Data of positives malaria cases occur in January 2008 to December 2016 takes from Health Departement of Mandailing Natal. It represented the malaria cases in this research. The data for rainfall, humidity, and temperature data were taken from Departement of Centre Statistic of Mandailing Natal. E-views ver. 9 software was used for analysed this data. Stationarity data was used with auto correlation function (ACF) and partial autocorrelation function (PACF). Seasonal adjusted factor (SAF) was determined the peak of seasonal variation. The Ljung-Box was used to determining if the model was good to acted the confounding factors, forecasting of the incidence malaria cases

3. Result and discussion

3.1 Result

The total number of laboratory confirmed about malaria case in 2008 to 2016 is showed in (Table 1). It was increased in 2012 and 2013 as shown in Table 1. The exploration of malaria infections : rainfall, temperature, and humidity in 2008 to 2016 shown that no trend and suggestion in seasonal dependency. The autocorrelation function (ACF) was significant in peak with a lag of 12 months (autocorrelation=0.137; Box-Ljung statistics \(P = 0.027\)), partial autocorrelation function (PACF) was significant in peak with a lag of 12.

| Month   | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---------|------|------|------|------|------|------|------|------|------|
| January | 429  | 237  | 238  | 260  | 660  | 809  | 500  | 441  | 174  |
| February| 251  | 216  | 375  | 223  | 711  | 638  | 494  | 360  | 180  |
| March   | 512  | 298  | 293  | 387  | 698  | 764  | 356  | 346  | 187  |
| April   | 262  | 329  | 315  | 329  | 699  | 778  | 469  | 304  | 105  |
| May     | 103  | 278  | 227  | 250  | 640  | 904  | 413  | 217  | 87   |
| June    | 278  | 218  | 241  | 201  | 553  | 627  | 389  | 283  | 27   |
| July    | 312  | 109  | 214  | 97   | 566  | 500  | 260  | 213  | 29   |
| August  | 465  | 389  | 108  | 210  | 327  | 365  | 439  | 321  | 32   |
| September| 273  | 317  | 396  | 256  | 546  | 683  | 637  | 329  | 23   |
| October | 258  | 349  | 366  | 305  | 643  | 602  | 536  | 259  | 22   |
| November| 498  | 371  | 356  | 598  | 857  | 401  | 455  | 183  | 20   |
| December| 388  | 286  | 354  | 349  | 796  | 473  | 350  | 165  | 19   |
| Total   | 4029 | 3397 | 3483 | 3465 | 7696 | 7544 | 5298 | 3421 | 905  |
(a)

(b)

(c)
Figure 1. Rainfall, relative humidity, and mean maximum temperature of malaria cases with in January 2008 to December 2016 (a-d)

Observations have component with not seasonal variation. Table 2 shown that in November and March, the seasonal adjustment factor (SAF) was greater than other month. This period coincides with the rainy season in Mandailing Natal Regency. In November had the highest with 10,72 SAF, followed in March which is 10,12 SAF. So that the peak of malaria transmission which risk is 10,72 times and 10,12 more than typical month.

Table 2. Seasonal Adjustment Factor (SAF) for Malaria Cases

| Month    | Observed Cases | SAF  |
|----------|----------------|------|
| January  | 3748           | 9,22 |
| February | 3448           | 8,45 |
| March    | 3841           | 10,12|
| April    | 3590           | 9,51 |
| May      | 3119           | 8,58 |
| June     | 2817           | 7,65 |
| July     | 2300           | 6,32 |
| August   | 2656           | 8,46 |
| September| 3460           | 9,8  |
| October  | 3340           | 9,68 |
| November | 3739           | 10,72|
| December | 3180           | 9,23 |

Eviews ver. 9 was the best model for forecasted malaria cases with rainfall, temperature, and humidity as predictor. ARIMA (0,1,1) (1,0,0) model was the best statistical for this time series study. There were three climatic factors, mean rainfall ($P$ value = 0.005), temperature ($P$ value = 0.0029) and relative humidity ($P$ value = 0.001), the lagged was significant.

The Ljung-Box (modified Box-Pierce) statistics shows in (Table 2). ARIMA(0,1,1) (1,0,0) model was the best statistical for this time series study. There was a difference of statistics with stationary $R$-squared used can estimate estimate of the variation and proportion. $R$-squared was better with trend or seasonal pattern. The stationary squared (up to a maximum value of 1) indicated was good, and 0,672 of $A$ value have shown in Table 3.
Figure 2. The actual and predicted of malaria

(ARIMA) model was using in this research for identified, estimate, and forecasted. ARIMA model for seasonal was 
\((p, d, q)(P,D,Q)^s\), where \(p\) and \(P\) are the autoregressive and seasonal autoregressive, respectively, \(d\) and \(D\) are the nonseasonal differences and seasonal differencing, respectively, \(q\) and \(Q\) are the moving average parameters and seasonal moving average parameters, respectively, and \(s\) represents the length of the seasonal period.

ARIMA \((0,1,1)\) \((1,0,0)^{12}\) model used for forecasting the monthly malaria for next period which in January 2017 to December 2018 that have significant predictors in rainfall, temperature, and humidity which were lagged for one month. Model of forecasted shows 701 cases in 2017 and 1890 cases in 2018 with significant peaks during rainy season (Figure 3).

Figure 3. Fluctuation of malaria cases in Mandailing Natal Regency

Table 3. Stationary of malaria case monthly

| Model of malaria parameter | Stationary \(R^2\) | \(P\) value | Model type |
|----------------------------|-------------------|-------------|------------|
| Malaria infections         | 0.672             | 0.000000    | ARIMA \((0,1,1)\) \((1,0,0)^{12}\) |
3.2 Discussion

ARIMA model was the best of a time series in epidemiological surveillance for this research. ARIMA (0,1,1) (1,0,0)\(^{12}\) was a useful software for estimated the total malaria case for monthly in future with using the climatic factors like rainfall, temperatur, and relative humidity as predictors. These climatic was contributed because anopheles vector took two weeks to completing their life cycle and two more weeks for the generation of parasites to be a new host. Wangdi et al. Research shown that ARIMA (2,1,1) (0,1,1)\(^{12}\) was the best model for predicted malaria in Bhutan [9]. ARIMA model was also used for forecasting malaria cases in Sri Lanka [10] and Ethiopia [11]. Kumar et al research also taken ARIMA (0,1,1) (0,1,0) for predicted malaria in New Delhi [7].

Malaria transmission was found between in November and March. Rainy season in Mandailing Natal in December to last March. From this we can take that there is a strong correlation malaria with rainfall in Mandailing Natal with peak was occurring in March.

It was related with Widiastuti research, that rainfall have be increasing the malaria incidence in near beach of Kalianda with 48 cases every month, with highest proportion is 89% after rainfall in 7 months regularly. In Kotabumi, the malaria incidence 45 cases with rainfall 1 per month and highest proportion of 93 % after rainfall 3 months regularly. The two district with limit rainfall was 25 mm, it was explain the malaria incidence [12].

Temperature also acts significant role in malaria transmission. Temperature is expected to increase transmission and prevalence of malaria with shortening the incubation period of the parasite in the mosquitoes. Sporogonic cycles take about in 9 to 10 days at temperatures of 28 °C but higher than 30 °C and below 16 °C have negative impact on parasite development [13]. Malaria transmission also depends on relative humidity since mosquitoes have a limited range of tolerable relative humidity. The high surface area to ratio volume of mosquitoes makes them especially sensitive to desiccation in low humidity levels [14].

Transmission of malaria will happen in the relative humidity is at least 60% as one of predictor. The research of Mofu showed that there was relationship between Anopheles density and humidity, where the correlation results \( p = 0.002 \) with average humidity at the time of the study was 82.6%. The highest density of Anopheles (4.1 head / person / hour) in humidity was 85.3% and the lowest was 1.0 / person / hr at 78.5% and 76.0% air moisture with average humidity when the study was 82.6% [15].

There were many factors such as the type of parasite, movement, immunity for malaria, resistance of insecticide that can contributed for malaria case.

4. Conclusion and recommendation

4.1 Conclusion

Based on the research, rainfall, temperature and relative humidity are predictors and have strong correlations with malaria cases in Mandailing Natal. ARIMA in time series study is the best model for this research to predict malaria case monthly, annually and will happen in next year.

4.2 Recommendation

This data can be used to make a plan and policy about malaria prevention and inform the best time for people to travel into this area.
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