

Climate factors and dengue fever in Burkina Faso from 2017 to 2019

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Abstract

Dengue is now a major health concern in sub-Saharan Africa. Understanding the influence of local meteorological factors on the incidence of dengue is an important element for better prediction and control of this disease. This study aims to assess the impact of meteorological factors on dengue transmission in the central region of Burkina Faso. We analyzed the lagged effects of meteorological factors on the weekly incidence of dengue from 2017 to 2019 in the central region of Burkina Faso using a General Additive Model. The results show that maximum and minimum temperature, relative humidity, and wind speed have a significant non-linear effect on dengue cases in the region with 83% of case variance explained. The optimal temperature that increases dengue cases was 27°C to 32°C for the maximum temperature and 18°C to 20°C for the minimum temperature with a decrease beyond that. The maximum temperature shifted by six weeks had the best correlation with dengue incidence. The estimated number of dengue cases increases as the maximum relative humidity increases from 15 to 45% and then from 60 to 70%. In general, an increase in daily wind speed is estimated to decrease the number of daily dengue cases. The relationship between rainfall and dengue cases was not significant. This study provides local information about the effect of meteorological factors on dengue that should help improve predictive models of dengue cases in Burkina Faso and contribute to the control of this disease.

Introduction

Dengue is a mosquito-borne viral disease that is endemic in tropical and subtropical regions and is increasingly becoming a major health problem in sub-Saharan African countries with epidemic outbreaks.¹

The transmission of dengue is multifactorial with factors related to the vectors such as climate, vegetation cover (bushy, shady areas) which serve as resting places for the vectors, close to dwellings, anarchic urbanization (degraded housing, overcrowding) and lack of sanitation (residual water sources, defective water conveyance systems) which create artificial water collectors that become breeding grounds, and human-related factors such as population density, mobility and immunity.²

Aedes Aegypti is the main vector of dengue in Africa and its life cycle and distribution are influenced directly and indirectly by meteorological factors such as temperature, relative humidity, rainfall and wind. The effect of temperature on the incidence of dengue is consistently reported in several studies and may result from faster viral replication in the vector, a shorter extrinsic incubation period and increased feeding frequency of *Ae. aegypti*.³⁻⁵

Humidity also increases viral spread and the percentage of *Ae. aegypti* egg hatch.⁶ Rainfall can have a variety of effects, in large quantities it can result in the short-term elimination of eggs and larvae from potential containers, but residual water can create longer-term breeding habitats.^{7,8}

An understanding of how meteorological factors influence the transmission cycle of dengue at a small scale is important for the prediction and control of this disease. We did not find any studies that explored this in sub-Saharan Africa. The objective of the present study is to assess the effect of meteorological factors on the incidence of dengue in the central region of Burkina Faso between 2017 and 2019.

Materials and methods

Ethical considerations

In this study, we used data aggregated to a region that does not present any ethical problems. All procedures were performed in accordance with relevant guidelines.

Study area

The central region of Burkina Faso has a surface area of 2869 sq km and includes the capital Ouagadougou (urban area) along with 6 semi-urban provincial departments. In 2017, the population of the region was 2 744 666, representing 14% of the national population. The region is divided in 5 health districts.^{9,10} It is the most populated and urbanized region of the country and the main risk cluster for dengue in Burkina Faso.

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Data source

Dengue cases data included in this study were collected using continuous health center-based passive case detection from 1st January 2017 to 31st December 2019. In the national epidemiological surveillance system of Burkina Faso, health centers are required to provide weekly reports on 11 diseases (including dengue) to their respective health districts; reported cases are then gathered and controlled by the health districts before being sent to the Ministry of Health. Dengue cases were diagnosed based on a rapid diagnostic test (Immunoglobulin M and/or Immunoglobulin G and/or NS1 dengue antigen positive), confirmed or not by Polymerase Chain Reaction analysis.

The meteorological data used in this study were drawn from National Aeronautics and Space Administration's Earth Observing System data and Information System website from 2017 to 2019 which provides estimates of several atmospheric and land parameters at different spatial resolution. These data were aggregated into weekly counts. The meteor-

ological variables included in the analysis were: Weekly rainfall (mm),¹¹ weekly mean of daily minimum temperature (°C), weekly mean of daily maximum temperature (°C), weekly mean of daily minimum relative humidity (%) and weekly mean of daily maximum relative humidity (%),¹² and weekly mean of daily average wind speed (m/s) (Table 1).¹³

Statistical methods

All the six weather variables were initially included in the analysis. Correlation analysis was performed between weather variables and dengue cases. The minimum relative humidity was noted to have a high positive correlation with maximum relative humidity and was thus excluded from further analysis (Table 2).

The effect of weather on dengue cases was evaluated by using the generalized additive model (GAM) with a negative binomial distribution and a smoothing spline function in the “mgcv” R package, version 4.0.4.¹⁴ Firstly, we modelled the time series of total dengue cases as a function of each weather variables for time lags ranging from 1 to 6 weeks (thus generating seven models per weather variable) based on the total duration of the dengue infection of 7 weeks.¹⁵

We compared the 7 models generated for each weather variable using the unbiased risk estimator (UBRE). For each weather variable, the time lag associated with the best model (with the lowest UBRE) was selected for the multivariate analysis in a GAM.¹⁶

Results

Descriptive analysis

A total of 14028 dengue cases were reported in the central region during the study period with a concentration of cases from September to December, most marked in 2017, when an epidemic was declared in the country (Figure 1).

Meteorological variables lags

The time lag that generated the model with the lowest UBRE was 6 weeks for maximum temperature and rainfall, 0 week for the others meteorological variables (Table 3).

In the multivariate model, only lagged

rainfall was not significantly associated with the number of dengue cases ($p=0.26$). The multivariate model that includes maximum and minimum temperature, maximum humidity and wind speed explained 83% (Adjusted R Square) of the variation of dengue incidences in the Central region of Burkina Faso.

Effect of maximum temperature on Dengue cases

The estimated effect of maximum temperature on dengue cases is nonlinear with a higher number of dengue cases occurring between 27°C and 32°C (Figure 2a). The number of dengue cases is expected to reduce when the daily maximum temperature rises above 32°C.

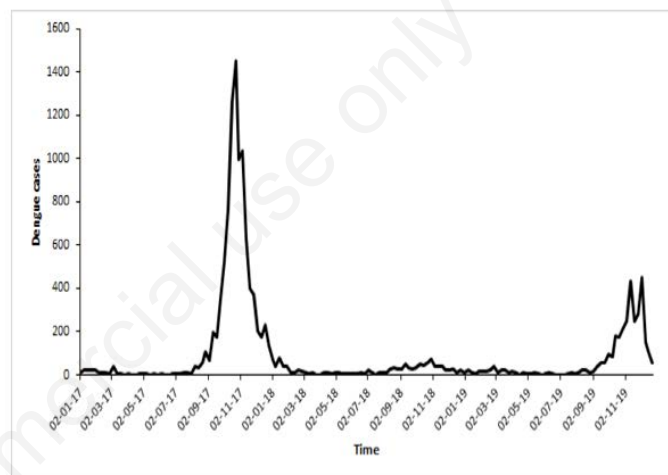


Figure 1. Evolution of dengue cases in the central region of Burkina Faso.

Table 1. List of meteorological variables and descriptive statistics.

Variables	Mean	St. dev	Min	Pctl (25)	Median	Pctl (75)	Max
Weekly mean of daily maximum temperature (°C)	42.3	7.8	27.3	34.9	43.9	48	56.9
Weekly mean of daily minimum temperature (°C)	23.3	3.3	16	20.4	24.1	25.7	29.9
Weekly mean of daily maximum relative humidity (%)	54.6	25.7	14.6	27	58.2	78.5	91.4
Weekly mean of daily minimum relative humidity (%)	34.6	20.1	7.4	14.3	35	54.5	70.5
Weekly rainfall (mm)	2	3.3	0	0	0.2	4	15
Weekly mean of daily average wind speed (m/s)	4.8	11.8	2.8	3.9	4.7	5.6	8.3

St. Dev: standard deviation, Min: minimum, Pctl (25): first quartile, Pctl (75): third quartile, Max: maximum.

Table 2. Correlation between meteorological variables.

	Maximum temperature	Minimum temperature	Minimum humidity	Maximum humidity	Rainfall	Wind speed
Maximum temperature	1	-0.05	-0.82	-0.78	-0.67	0.54
Minimum temperature	-0.05	1	0.55	0.59	0.35	-0.52
Minimum humidity	-0.82	0.55	1	0.97	0.75	-0.74
Maximum humidity	-0.78	0.59	0.97	1	0.7	-0.74
Rainfall	-0.67	0.35	0.75	0.7	1	-0.44
Wind speed	0.54	-0.52	-0.74	-0.74	-0.44	1

Effect of minimum temperature on Dengue cases

The estimated effect of minimum temperature on dengue cases is nonlinear with a higher number of dengue cases occurring between 18°C and 20°C (Figure 2b). The number of dengue cases is expected to reduce when the daily minimum temperature rises above 20°C.

Effect of relative humidity on Dengue cases

The estimated effect of maximum relative humidity on dengue cases is nonlinear with a higher number of dengue cases occurring around 45% and 70% (Figure 2c). The estimated number of dengue cases rises as the maximum relative humidity rises from 15 to 45% then from 60 to 70%. The number of dengue cases is expected to reduce when the daily relative humidity is out these ranges.

Effect of wind speed on Dengue cases

In general, a rise in daily wind speed is estimated to decrease the number of daily dengue cases (Figure 2d).

Discussion

Our analysis reveals that maximum temperature, minimum temperature, relative humidity, and respectively wind speed has a significant nonlinear respectively linear effect on dengue cases in the Central Region of Burkina Faso.

The optimal temperature that rises dengue cases was from 27°C to 32°C for the maximum temperature and from 18°C to 20°C for the minimum temperature with a decrease beyond that.

Other authors have also reported optimal temperature ranges that favor dengue transmission, and temperatures outside this range may reduce dengue transmission.

For example, Gui *et al.* reported in Singapore that the risk of dengue increases steeply up to 29°C and decreases when the temperature is higher than 29°C.¹⁷ Cheong *et al.* reported that the highest risk of dengue

cases occurred within a small temperature range, from 25.4 to 26.5°C.¹⁸ Fairós *et al.* reported that minimum temperature (21-26°C) was associated with an increase in dengue cases.¹⁹

At optimal average temperatures (< 18°C), increasing temperatures could increase the incidence of dengue by shortening the development period of *Aedes aegypti* larvae, improving their blood supply and oviposition and reducing the incubation time of the dengue virus. At the same time, extreme temperatures can reduce the mosquito's ability to survive, thereby reducing the potential for dengue transmission. We also found that there was a significant correlation between dengue cases and the lagged effect of temperature up to six weeks. This is also reported in other studies, although the lag is variable between studies.¹⁷⁻²⁵

Relative humidity was found to positively influence dengue cases around 45% and 70%. In Andi Susilawaty's study in Makassar, humidity had the strongest and

most stable correlation with dengue cases.²⁶

Indeed, relative humidity may be a factor that decisively affects the egg development and adult population number of *Aedes aegypti*.²⁷

Wind speed was only negatively correlated with dengue cases in our study and the time lag did not improve this correlation. Positive correlations between wind speed and dengue cases are described by some authors. This difference could be explained by the relatively high wind speed (4 m/s) in our study.¹⁷

Rainfall although not significantly associated with dengue incidence in our study may create breeding habitats for dengue vectors increasing the risk of transmission, or conversely, in large amounts may destroy or wash away mosquito eggs, thus reducing transmission potential.²⁸

As Gui H reported that slight rainfall increases of up to 7 mm per week gave rise to higher dengue risk. On the contrary, heavier rainfall was protective against dengue in Singapore.²⁷

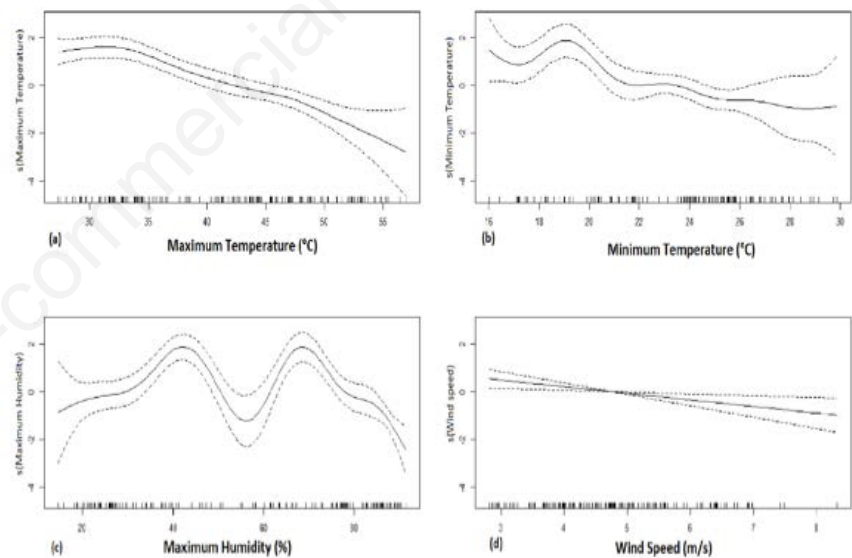


Figure 2. Effect of different weather variables on dengue cases in Burkina Faso. a: maximum temperature; b: minimum temperature; c: maximum relative humidity; d: wind speed.

Table 3. UBRE of univariate lagged additive generalize model of dengue incidence with meteorological variables.

Variables	Lag in week						
	0	1	2	3	4	5	6
Maximum temperature	187	196.5	200.3	195.8	194.2	185.4	171.5
Minimum temperature	184	196.7	211.2	216.4	217	210.4	202.9
Maximum humidity	176.4	200	211.3	211.4	217.3	206.7	190.5
Rainfall	215	225.8	238.5	247.2	251.8	249.9	243.5
Wind speed	240	233.2	221.4	201.4	179	158.4	149.9

Conclusions

This study identified a significant non-linear effect of maximum temperature, minimum temperature, relative humidity, and wind speed on dengue incidences in the Central Region of Burkina Faso. Although the general pattern of this relationship between dengue cases and meteorological factors is consistent with what has been described elsewhere, it offers additional local detail that should help improve predictive models of dengue cases in Burkina Faso and contribute to the control of this disease.

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