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Analysis of the Situation and Factors Associated with Dengue Incidence at the Provincial Level during 2019–2023, Lao PDR

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Abstract

We described the incidence of dengue infection in the Lao People's Democratic Republic (Lao PDR) from 2019 to 2023, presenting seasonal trends, geographic distribution, and socio-environmental factors. We used data from the National Surveillance Database to fit the time-series and random-effects Poisson regression model. In five years, over 111,000 cases were reported, with an annual incidence exceeding 450 cases per 100,000 in 2019 before declining during the COVID-19 pandemic in 2020 and 2021. Most cases were aged less than 30 years. The monthly incidences peaked during the rainy season (July-September). Rainfall, lagged rainfall, house index, and lagged house index were significant positive factors. A higher density of health facilities was also associated with a higher incidence. These findings underscore the importance of targeted public health interventions during peak transmission periods and suggest that additional factors, such as urbanization and economic status, should be addressed to enhance dengue control efforts in Lao PDR.

Keywords: dengue, Poisson regression, seasons, Lao PDR

Introduction

Dengue infection, transmitted by mosquitoes, usually causes mild symptoms such as fever and other influenza-like illnesses. However, severe infections can lead to bleeding, shock, and death. The disease has spread rapidly due to population growth, urbanization, and increased availability and access to air travel, affecting billions of people in endemic areas.[1]

Dengue is endemic in 48 countries in the Western Pacific and Southeast Asia regions. Each year, over 14 million cases and 10,000 deaths are reported globally.[2] Dengue virus (DENV) has four serotypes (DENV-1, DENV-2, DENV-3, and DENV-4), causing a wide range of illnesses from mild symptoms to severe shock. Children aged under 15 years are most affected by dengue hemorrhagic fever (DHF) and dengue shock syndrome (DSS).[3]

Dengue infection remains a significant public health concern in the Lao People's Democratic Republic (Lao PDR). Over 30,000 cases were reported in 2023, and the incidence rate was 480 cases per 100,000 population with 12 out of 18 provinces experiencing outbreaks.[4] The most prevalent serotypes in 2023 were DENV-1 and DENV-2.

While temperature and humidity are key factors in dengue transmission, these factors may not be relevant to Lao PDR due to its unique geographic and climatic conditions, economic factors, cultural practices, healthcare systems, and the prevalence of specific dengue serotypes.[5,6] Studies on factors related to dengue incidence in Lao PDR are scarce, especially after the COVID-19 era. These distinctions emphasize the need for localized studies to better understand the socio-environmental determinants of dengue.

Therefore, the objectives of this study were to (1) describe the magnitude, severity, and characteristics of dengue cases in Lao PDR, (2) determine the trends, seasonality, and geographical patterns of dengue incidence, and (3) identify socio-environmental factors of dengue at the provincial level.

Methods

Study Design

A retrospective analysis was conducted using monthly data at the provincial level and cross-sectional data on individual dengue cases from 2019 to 2023. A descriptive study was conducted to address objective 1 while analytic studies were conducted to address objectives 2 and 3.

Data Source

We obtained data from the National Surveillance Database, National Centre of Laboratory and Epidemiology, Ministry of Health (MOH), Lao PDR, which collected data from public health facilities. We included all 18 provinces: Attapeu, Bokeo, Bolikhamxay, Champassak, Houaphanh, Khammouane, Luang Namtha, Luang Prabang, Oudomxay, Phongsaly, Salavan, Savannakhet, Sekong, Vientiane Capital, Vientiane Province, Xayaburi, Xaysomboun, and Xiangkhouang, which are endemic for dengue.

Operational Definition and Variables of Interest

Table 1 presents the operational definitions of the variables of interest together with the research team's working hypothesis for the outcome.[7]

Table 1. Operational definitions

Variable	Definition	Working hypothesis
Dengue incidence	Number of dengue cases (either dengue fever or dengue hemorrhagic fever or dengue shock syndrome) per 100,000 population	-
Temperature	Mean temperature in Celsius in a province in that month	Higher temperatures, higher incidence
Lagged temperature	Mean temperature in Celsius in a province in prior month	Higher lagged temperatures, higher incidence
Rainfall	Mean rainfall in mm. in a province in that month	Higher rainfall, higher incidence
Lagged rainfall	Mean rainfall in mm. in a province in prior month	Higher lagged rainfall, higher incidence
House index (HI)	Mean HI in a province in that month, from the field survey	Higher index, higher incidence
Lagged house index	Mean HI in a province in prior month from the field survey	Higher lagged index, higher incidence
Provincial population	Population volume in each province	Higher population density, higher incidence
Health facility density	Number of health facilities per 100,000 population	Higher health facilities density, higher incidence

Source: National Surveillance Database, National Centre of Laboratory and Epidemiology, Ministry of Health, Lao PDR.
We imputed missing values with the mean monthly temperature (and its lag), monthly rainfall (and its lag), and monthly house index for each province. Mean temperature was calculated by averaging daily temperatures across all days in a month. Mean monthly rainfall was calculated by summing the daily rainfall and dividing by the number of days in the month. Mean house index was measured by summing the index in all surveyed areas in the province and dividing by all surveyed areas (on average, 68 areas per province).

Data Analysis

For objective 1, we present descriptive statistics including percentage and frequency of dengue cases at the individual level stratified by age and gender. Population morbidity rates and case fatality rates were calculated. Choropleth maps were constructed to visualize and compare the geographical distribution of dengue incidence at the provincial level each year.

For objective 2, we employed time-series regression (Prais-Winsten regression) to decompose trends and seasonal patterns of monthly dengue incidence over time. The unit of analysis was the monthly number of cases. Independent variables were the number of months since 1 Jan 2019 (month index) and the month of the year.

For objective 3, we utilized univariable and multivariable random-effects Poisson regression model where province was considered a higher-level variable. The monthly dengue incidence was the dependent variable. The natural logarithm of the provincial population was used as an offset. Independent variables were monthly temperature and its lag, monthly house index (the number of houses where mosquito larvae presented divided by the total number of houses inspected and expressed in percentage) and its lag, monthly rainfall and its lag, health facility density, the reporting year, month index, and month of the year. The lag period was set at one month. We included lagged variables because previous literature suggested that dengue cases and climatic factors such as the El Nino effect were positively correlated with a lag of 3 to 6 months.[8] Note that the specific duration of monthly lags varies across studies.[9]

We imputed missing data for monthly rainfall, house index, and temperature (about 14% of records) by mean substitution using data in each province in a year. Results were presented in the form of an incidence rate ratio (IRR) and 95% confidence interval (CI). We also assessed the robustness of the final model by excluding variables that exhibited multicollinearity based on the variance inflation factor (VIF). Variables with a VIF value of 10 or higher were excluded and the model was re-analyzed accordingly. We then assessed if and to what extent the findings from the final model would change if variables with potential multicollinearity were dropped from the analysis. Stata version 16 (serial number: 301506215585) and Microsoft Excel were used for the analysis.

Results

There were 111,826 dengue cases reported in Lao PDR from 2019 to 2023. The annual dengue incidence is presented in Table 2. The yearly incidence (cases per 100,000 population) varied from 21.6 in 2021 to 495.6 in 2019. The case fatality rate ranged from 0.04 to 0.14%. The male-to-female ratio remained constant at about 1:1 across all years.

Most cases were identified in younger populations, with more than 70% of the cases involving individuals aged under 30 years. Only 3% of the cases were reported in people aged over 60 years. In 2023, the incidence was highest among people aged 20–29 years (764.48) and lowest among those aged 50–59 years (290.71). Students constituted approximately 30% of the total cases while farmers approximately to about one-fifth of the cases.

Table 2. Key dengue indicators in Lao PDR, 2019–2023

Dengue indicators	Year				
	2019	2020	2021	2022	2023
New cases (n)	**32,334**	**8,215**	**1,585**	**33,163**	**36,529**
By occupations—n (%)					
Students	10,696 (33)	2,086 (25)	315 (20)	8,032 (24)	9,214 (25)
Farmers	4,419 (14)	2,340 (29)	247 (16)	6,457 (20)	9,229 (25)
Government staff	427 (1)	290 (4)	101 (6)	1,821 (5)	2,105 (6)
Others	16,792 (52)	3,499 (42)	922 (58)	16,853 (51)	15,981 (44)
New cases (per 100,000 population)					
Overall	495.93	113.61	21.60	445.58	48.11
By age group (years)					
0–9	1,105.41	129.96	23.22	456.78	512.00
10–19	659.94	172.33	31.12	640.99	699.60
20–29	637.51	212.67	43.32	860.58	764.48
30–39	376.92	140.36	27.19	585.68	656.53
40–49	234.81	92.86	15.15	330.03	397.63
50–59	157.66	74.66	13.82	237.41	290.71
60+	107.87	54.20	10.45	222.68	255.17
Case fatality rate (%)	0.14	0.04	0.06	0.07	0.05
Male to female ratio	1: 1.06	1: 0.99	1: 0.97	1: 1.01	1: 1.03

Dengue fever (DF) constituted approximately 80% of all dengue cases. The incidence in 2022–2023 exceeded the five-year median. As shown in Figure 1, the incidence was highest between May and September, with July and August being the most prominent months.

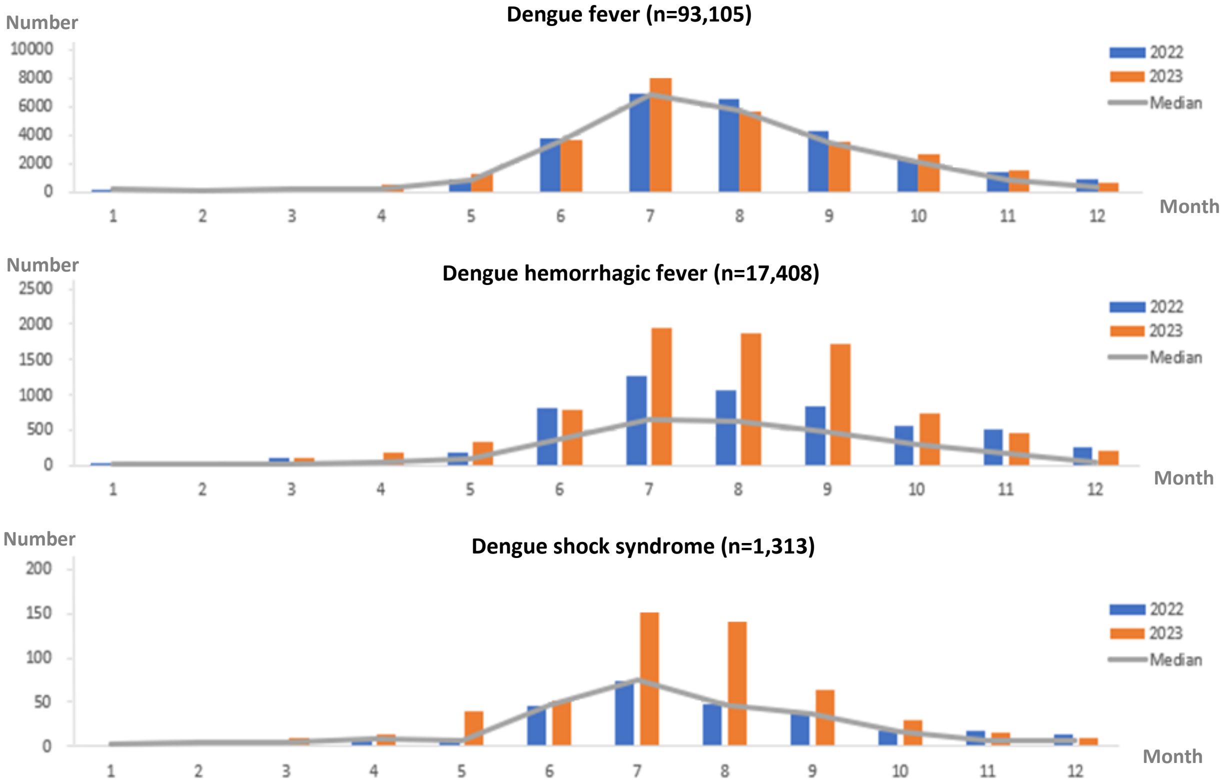

Figure 1. Number of dengue cases by months and disease classifications in Lao PDR, 2022–2023, with the five-year median

As shown in Figure 2, dengue cases were concentrated in the southern and northwestern parts of the country, notably in Khammouane and Luang Namtha, and especially in years 2019, 2022, and 2023.

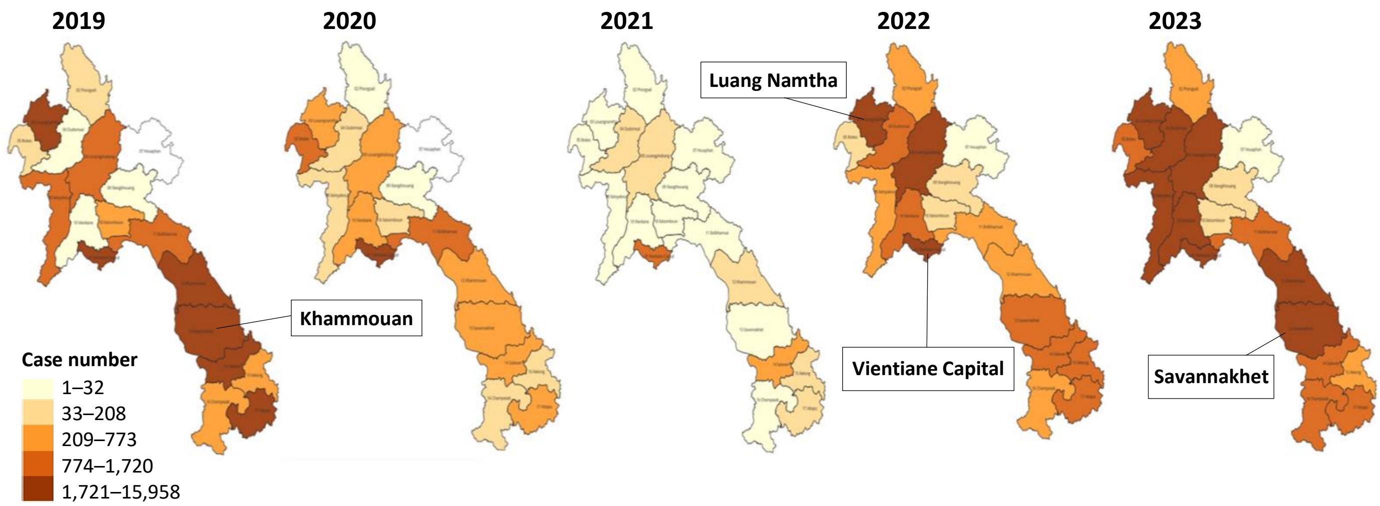

Figure 2. Geographical distribution of dengue cases in Lao PDR, 2019–2023

Table 3 shows the results of the trend and seasonal analysis using the Prais-Winsten regression model. The month index had a coefficient of 7.31, indicating a slight increase in dengue incidence over time, though without statistical significance. However, the seasonal effect was highly significant. Compared to January, the incidence rates during June–October were significantly higher, with a peak observed in July (coefficient 4,775.2, 95% CI 3,399.6–6,150.8). Table 4 displays the results from univariable and multivariable random-effects Poisson regression models. Entomological and environmental factors, such as house index and its lag, rainfall, and lagged rainfall, had significant positive associations with dengue incidence in both univariable and multivariable analyses, although their effect sizes were small. An increase in one unit of health facility density per 100,000 population was associated with an increase in dengue incidence by approximately 69% in the multivariable model, though exhibiting negative association in univariable model. The opposite was found in lagged temperature, where an increase in one degree Celsius was linked to a 2.2%-decline of dengue incidence in multivariable analysis despite presenting a positive association in univariable analysis.

The rainy season (July–September) was associated with an increase in dengue incidence of approximately 10–20 cases relative to January. The incidence in 2023 was roughly 1.66 times larger than the incidence in 2019. A marked decline in the incidence was observed in 2020–2021 (IRR for 2020=0.307, 95% CI 0.298–0.316).

Temperature, lagged temperature, and health facility density, were found to be linearly dependent in VIF analysis. After excluding those variables, the IRR estimates of most of the other variables in the model remained robust (for instance, IRR for house index decreased from 1.029 to 1.025 while remaining statistically significant).

Table 3. Trend and seasonality from time-series regression (Prais-Winsten) of dengue incidence in Lao PDR, 2019–2023

Factors	Coefficient	*P*-value	95% CI	
			Lower limit	Upper limit
Month index*	**7.31**	**0.84**	**-65.80**	**80.43**
Month of the year (ref=January)				
February	-66.18	0.86	-839.25	706.90
March	-16.27	0.98	-1,049.70	1,017.17
April	142.16	0.81	-1,051.28	1,335.60
May	678.34	0.30	-616.43	1,973.12
June	2,335.94	<0.01	982.74	3,689.14
July	4,775.22	<0.01	3,399.63	6,150.81
August	3,964.88	<0.01	2,600.77	5,328.98
September	2,541.41	<0.01	1,224.21	3,858.62
October	1,427.56	0.02	198.56	2,656.57
November	704.67	0.20	-381.37	1,790.72
December	179.33	0.68	-675.82	1,034.48

**Number of months since 1 Jan 2019. CI: confidence interval.*

Table 4. Factors associated with dengue incidence in Lao PDR, 2019–2023, by random-effects Poisson regression model*

Factors	Univariable analysis				Multivariable analysis			
	IRR	*P*-value	95% CI		IRR	*P*-value	95% CI	
			Lower limit	Upper limit			Lower limit	Upper limit
Month (ref=January)								
February	0.721	<0.001	0.657	0.791	0.943	0.286	0.846	1.051
March	0.982	0.680	0.902	1.070	1.320	<0.001	1.187	1.467
April	1.748	<0.001	1.621	1.885	2.489	<0.001	2.245	2.758
May	4.279	<0.001	4.003	4.574	5.491	<0.001	4.974	6.062
June	12.056	<0.001	11.327	12.833	12.935	<0.001	11.743	14.247
July	23.489	<0.001	22.094	24.972	21.757	<0.001	19.762	23.955
August	19.703	<0.001	18.528	20.952	15.653	<0.001	14.196	17.260
September	13.042	<0.001	12.255	13.880	11.513	<0.001	10.457	12.675
October	7.825	<0.001	7.342	8.339	9.196	<0.001	8.386	10.085
November	4.432	<0.001	4.147	4.736	5.988	<0.001	5.473	6.551
December	1.956	<0.001	1.817	2.106	2.696	<0.001	2.450	2.967
Year (ref=2019)								
2020	0.222	<0.001	0.216	0.228	0.307	<0.001	0.298	0.316
2021	0.044	<0.001	0.041	0.046	0.072	<0.001	0.068	0.076
2022	0.893	<0.001	0.878	0.907	1.558	<0.001	1.500	1.618
2023	0.868	<0.001	0.855	0.882	1.660	<0.001	1.585	1.739
House index	1.104	<0.001	1.103	1.105	1.029	<0.001	1.028	1.031
Lagged house index	1.090	<0.001	1.089	1.091	1.006	<0.001	1.004	1.007
Rainfall	1.003†	<0.001	1.003†	1.003†	1.001‡	<0.001	1.001‡	1.001‡
Lagged rainfall	1.003§	<0.001	1.003 §	1.003§	1.000e	<0.001	1.000¶	1.000¶
Temperature	1.173	<0.001	1.170	1.176	1.004	0.426	0.995	1.012
Lagged temperature	1.298	<0.001	1.294	1.302	0.978	<0.001	0.970	0.986
Health facility density	0.851	<0.001	0.837	0.865	1.693	<0.001	1.627	1.761

**n=660 (12 months × 5 years × 11 provinces). However, in multivariable analysis, as lag variables were used, the number of remaining records was 649 (dropping records in year 2019). †Full expression of the rainfall variable in univariable analysis is 1.00342 (95% CI 1.00337–1.00343). ‡Full expression of the rainfall variable in multivariable analysis is 1.00069 (95% CI 1.00064–1.00074). §Full expression of the lagged rainfall variable in univariable analysis is 1.00250 (95% CI 1.00246–1.00252). ¶Full expression of the lagged rainfall variable in multivariable analysis is 1.00023 (95% CI 1.00017–1.00028). IRR: incidence rate ratio. CI: confidence interval.*

Discussion

Our findings confirm that Lao PDR has faced a significant burden from dengue infections between 2019 and 2023. A total of 111,826 dengue cases were reported, with incidence rates varying across the years. The highest incidence occurred in 2019 with over 450 cases per 100,000 population, while 2021 had the lowest incidence. This fluctuation suggests that variations in dengue outbreaks are influenced by multiple factors such as seasonal climatic patterns, public health interventions, and environmental conditions.

The case fatality rate remained low at below 0.1% in most years, consistent with global trends of dengue, but the disease can have a high morbidity rate in some periods.[10,11]

The male-to-female ratio remained constant over the years, with a near-equal distribution between genders. We found that younger populations (age below 30 years) accounted for about three-quarters of dengue cases, while older populations (above 60 years) were less affected (3% of cases), a result consistent with other studies.[12]

Seasonal trends were evident, with peak infections typically occurring between July and September—a rainy season in the region. Findings from multivariable analysis confirmed this result. Studies in neighboring countries found relatively similar results.[13,14] Mean temperature, rainfall, and relative humidity were positively linked with DHF incidence near the Andaman Sea. Minimum temperature, rainy days and relative humidity were also associated with DHF incidence in areas near the Gulf of Thailand.[13] Choi et al reported that 2-to-3 monthly lagged rainfall affects dengue incidence in Cambodia.[14]

We found that house index and its one-month lag had a positive and significant association with dengue incidence, although the effect size was small. Similar findings were reported by Udanyanga et al, highlighting the association between house index, Breteau index, and the lagged values at one and two months, and dengue epidemics.[15]

The large decrease in incidence during 2020–2021 is likely due to the COVID-19 pandemic. In Thailand, the incidence of dengue cases decreased by over 6-fold in 2021 compared to 2019.[16] The reduction in dengue cases amid the COVID-19 era is likely due to an underreporting or the introduction of social distancing measures. Sharma et al suggested that the antigenic cross-reactivity between dengue and COVID-19 might result in false positives for COVID-19 among dengue patients.[17]

Health facility density was strongly associated with dengue incidence in both univariable and multivariable analyses. On the one hand, this may be attributed to the nature of our analysis, which relied solely on data from health facilities. On the other hand, it is possible that mild dengue cases—such as those who sought care at private facilities or those who were self-managed and did not visit any health facilities—were excluded from the analysis. Moreover, a high density of health facilities may partly reflect greater urbanization, where higher population density could contribute to increased dengue incidence.

Limitations

This study contains both strengths and limitations. A major strength lies in the inclusion of lagged variables to capture potential climatic effects on dengue incidence—a technique that, while used in some studies, has rarely been applied in other studies in Southeast Asia.[18,19] The use of data from all provinces in Lao PDR enhances the generalizability of the study. The assessment of multicollinearity adds robustness to the analysis and, although multicollinearity is not a strict violation of regression assumptions, addressing it strengthens the study's validity and academic value.[20] However, some limitations remain. First, the study relied on reported cases from health facilities, which may not fully represent the true disease burden in the population due to potential non-reporting from private facilities or misdiagnoses. Second, although environmental factors such as temperature and rainfall were considered, this study did not fully examine the potential contributions of other environmental influences, such as urbanization and land use changes. The absence of these unmeasured confounders in the model may partly explain the unexpected results that contradict established understanding in the field of dengue studies, such as the observed negative association between lagged temperature and dengue incidence. Moreover, potential measurement errors may have contributed to these findings. Third, since we collected data at the provincial level for objective 3, an ecological fallacy should be heeded. Finally, while the study covered a five-year period (2019–2023), we may not have sufficiently captured the long-term trends of dengue incidence. Thus, re-assessment of the dengue situation over a longer period is warranted

Recommendations

We recommend enhancing dengue surveillance in Lao PDR, particularly during peak transmission months (June–October). Public awareness campaigns should be intensified during periods of increased rainfall and higher temperatures. Regular monitoring of larval indices can provide early warnings of potential outbreaks and aid in disease control efforts. Further studies incorporating other critical factors influencing dengue, such as health system capacity, urbanization levels, and provincial economic status, would greatly benefit public health initiatives against dengue in Lao PDR.

Conclusion

Lao PDR experienced a remarkable public health burden due to dengue infections between 2019 and 2023. Over 110 thousand cases were reported. Fluctuations in the incidence were observed, ranging from 20 to 500 cases per 100,000 population. A decrease in incidence was observed in the years 2020 and 2021. The case fatality rate remained below 0.1% after 2020. The incidence increased substantially during the rainy season. Rainfall, house index, and health facility density were positively correlated with dengue incidence. Further studies that incorporate key potential factors that contribute to dengue incidence, such as health system capacity and provincial economic level, are recommended.

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Author Contributions

Nouannipha Simmalavong: Conceptualization, data collection, formal analysis, methodology, project administration, validation, writing—original draft. **Rapeepong Suphanchaimat:** Conceptualization, formal analysis, methodology, project administration, supervision, validation, writing—original draft, writing—review & editing. **Waraluk Tangkanakul:** Conceptualization, project administration, supervision, writing—review & editing. All authors have read and agreed to the published version of the manuscript.

Ethical Approval

As this study was part of the routine monitoring by MOH, Lao PDR, ethics approval was not required. However, all results are presented anonymously. No individual information has been disclosed.

Informed Consent

Not applicable

Data Availability

The datasets analyzed in the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

None declared.

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Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this work, the authors used ChatGPT to enhance clarity in some parts of the text. The content produced by this tool was reviewed and re-edited by the authors, who accept full responsibility for the final text.

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