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COMPUTATIONAL MODELING AND ANALYSIS OF MALARIA TRANSMISSION DYNAMICS IN FEDERAL POLYTECHNIC, MUBI, ADAMAWA STATE, NIGERIA

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Abstract
Malaria remains a major public health challenge in sub-Saharan Africa, particularly within dense institutional communities such as tertiary institutions. In this conference paper, we present a computational model (SEIR-SI) to analyze the transmission dynamics of malaria among students of Federal Polytechnic, Mubi, Adamawa State Nigeria. The model incorporates human and mosquito populations, factoring in the unique demographic mixing, student hostel conditions, and localized environmental factors of the Mubi region with seasonal rainfall. We derive the basic reproduction number (R_0) using the next-generation matrix method and evaluate the stability of both the disease-free equilibrium (DFE) and endemic equilibrium (EE). Numerical simulations in HTML 5 are performed using data obtained from the institution's clinic. The results indicate that the current institutional reproduction number stands at $R_0 \approx 1.84$, indicating sustained endemicity. Sensitivity analysis reveals that the mosquito biting rate and the usage rate of insecticide-treated nets (ITNs) are the most critical parameters influencing transmission. Discussion focuses on targeted institutional interventions, including rapid test screening for students resuming school every session, mandatory hostel fumigation, usage of treated net, and improved drainage infrastructure to mitigate malaria burden in Federal Polytechnic Mubi Adamawa State Nigeria.

Keywords*: Modeling, Malaria, Analysis, Dynamics, simulation*

1.0 Introduction
Malaria is a life-threatening disease caused and spread by an infected vector (infected female Anopheles mosquito) or through transfusion of plasmodium-infected blood to susceptible individuals. The disease burden has resulted in high global mortality, particularly among young adult. Many intervention responses have been implemented to control malaria disease transmission, including blood screening, Long-Lasting Insecticide Bed Nets (LLIN), treatment with an anti-malaria drug, spraying chemicals/pesticides on mosquito breeding sites, and indoor residual spray, among others (Adeniyi *et al*., 2023).

Olaniyi *et al.* (2023) studied a time-dependent deterministic mathematical model whose focus was on the role of prevention and control in the transmission dynamics of recurrent malaria. They asserted that by four optimal control functions; personal preventive effort against mosquito bites, anti-relapse measure, anti-malaria treatment and insecticide spraying.

Recurrence of malaria symptoms after treatment constitutes one of the major factors affecting malaria control in the population. The transmission of malaria may persist in the given population, if effective and considerable control measures are not put in place (Olaniyi et al., 2023).

Despite decades of global control efforts, sub-Saharan Africa continues to bear a disproportionately high share of the global malaria burden. Within Nigeria, transmission is perennial but exhibits strong seasonal peaks driven by ecological and climatic variations.

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Tertiary institutions represent micro-ecosystems characterized by high population densities, communal living arrangements, and unique behavioral patterns among young adults (Abdulkadir, & Mutah, 2018).

The Federal Polytechnic, Mubi, located in Adamawa State, Nigeria, serves a large population of students and staff. The campus environment, coupled with the climatic conditions of Mubi characterized by distinct wet and dry seasons creates favorable breeding sites for vectors, thereby magnifying the risk of infection.

1.1 Statement of the Problem

High incidence rates of malaria among students of higher institution can lead to increased absenteeism from lectures, poor academic performance, economic tension due to medical expenditures, and general reduction in institutional productivity. Despite routine treatments at the institutional clinic, malaria outbreaks persist, particularly at the onset and peak of the rainy season. Understanding the underlying transmission system within this specific campus community requires a quantitative framework that goes beyond simple statistical compilation (Jacob, *et al.*, 2026).

1.2 Aim and Objectives of the Study

The aim of the study is to develop a computational Modeling and Analysis of Malaria Transmission Dynamics in Federal Polytechnic, Mubi, Adamawa State, Nigeria.

The specific objectives are:

i. To develop a compartmental mathematical model that captures the dynamics of malaria transmission specifically tailored to the institutional structure of Federal Polytechnic, Mubi.
ii. To compute the basic reproduction number (R_0) for the campus ecosystem.
iii. To perform numerical simulations in other to evaluate the long-term behavior of the disease under varying seasonal rainfall.
iv. To offer suitable recommendations for institutional health policies.

2.0 Methodology and Model Formulation

2.1 Model Assumptions

The model partitions the total population into human hosts (N_h) and mosquito vectors (N_v). The following assumptions govern the system:

i. The human population is closed, except for natural birth/recruitment (new students) and natural mortality.
ii. The host population is homogeneous, meaning all individuals in a compartment share the same risks and rates.
iii. Recovered individuals gain temporary immunity, which decreases over time, returning them to the susceptible compartment.
iv. Mosquitoes do not recover from infection; they remain infectious until death.
v. Vertical transmission in both humans and vectors is negligible.

2.2 Compartmental Structure

The human population $N_h(t)$ is subdivided into four distinct classes:

i. Susceptible (S_h) : Individuals who are healthy but can contract the parasite.
ii. Exposed(E_h): Individuals who have been bitten by an infectious vector and are in the latent period.
iii. Infectious (I_h) : Individuals showing symptoms and capable of transmitting the parasite back to vectors.
iv. Recovered(R_h): Individuals who have cleared the infection and possess temporary immunity.

$$N_h(t) = N = S_h(t) + E_h(t) + I_h(t) + R_h(t) \qquad (1)$$

The mosquito vector population N_v (t) is subdivided into two classes:

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i. Susceptible (S_v) **:** Uninfected mosquitoes.
ii. Infectious (I_v): Mosquitoes carrying sporozoites in their salivary glands.

$$N_v(t)= S_v(t) + I_v(t) \quad (2)$$

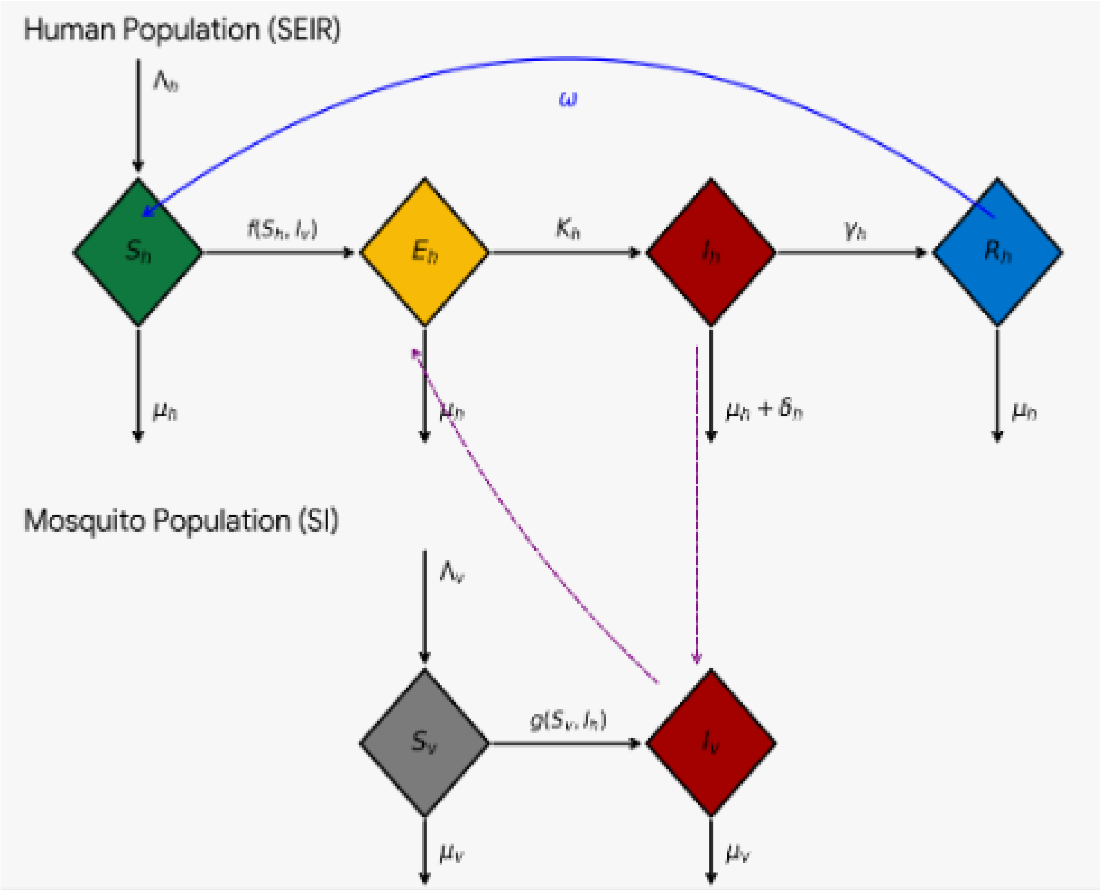

Figure.1 Model Diagram of the compartments

2.3 Mathematical Model Equations

Based on the transmission pathways, the dynamics are governed by the following system of non-linear ordinary differential equations (ODEs):

$$\frac{dS_h}{dt} = \Lambda_h + \omega R_h - \frac{abI_v}{N_h} S_h - \mu_h S_h \quad (3)$$

$$\frac{dE_h}{dt} = \frac{abI_v}{N_h} S_h - (K_h + \mu_h)E_h \quad (4)$$

$$\frac{dI_h}{dt} = K_h E_h - (\gamma_h + \mu_h + \delta_h)I_h \quad (5)$$

$$\frac{dR_h}{dt} = \gamma_h I_h + (\omega - \mu_h)R_h \quad (6)$$

$$\frac{dS_v}{dt} = \Lambda_v - \frac{acI_h}{N_h} S_v - \mu_v S_v \quad (7)$$

$$\frac{dI_v}{dt} = \frac{acI_h}{N_h} S_v - \mu_v I_v \quad (8)$$

Where the parameters are defined as follows:

Λ_h: *Recruitmnet rate of humans into the campus communit.*
Λ_v: *Birth rate of female anopheles mosquitoes.*
a: *Average biting rate per mosquito.*

b: $Transmission\ probability\ from\ an\ infectious\ mosquito\ to\ a\ susceptible\ human.$
c: $Transmission\ probability\ from\ an\ infectious\ human\ to\ a\ susceptible\ mosquito.$
μ_h: $Natural\ mortality\ rate\ of\ human$
μ_v: $Natural\ mortality\ rate\ of\ mosquitoes.$
δ_h: $Disease - induced\ mortality\ rate\ in\ humans.$
K_h: $Rate\ at\ which\ exposed\ human\ become\ infectious\ (inverse\ of\ incubation\ period0.$
γ_h: $Recovery\ rate\ of\ infectious\ humans.$
ω: $Rate\ of\ loss\ of\ immunity\ in\ humans.$

3. Mathematical Analysis

3.1 Invariant Region

It is assume that the model is naturally important; we establish that all state variables remain non-negative for all time $t \geq 0$.
Summing the human equations (SEIR), we have :

$$\frac{dN_h}{dt} = \Lambda_h - \mu_h N_h - \delta_h I_h \leq \Lambda_h - \mu_h N_h \quad (9)$$

By Birkhoff and Rota's theorem, it follows through integration that:

$$N_h(t) \leq \frac{\Lambda_h}{\mu_h} + (N_h(0) - \frac{\Lambda_h}{\mu_h})e^{-\mu_h t} \quad (10)$$

$As\ t \to \infty, N_h(t) \to \frac{\Lambda_h}{\mu_h}$ Thus, the feasible region for the human population is:

$$\Omega_h = \left\{(S_h, E_h, I_h, R_h) \in \mathbb{R}_+^4 : S_h + E_h + I_h + R_h \leq \frac{\Lambda_h}{\mu_h}\right\} \quad (11)$$

Similarly, for the mosquito population (SI):

$$\frac{dN_v}{dt} = \Lambda_v - \mu_v N_v \Rightarrow N_v(t) \to \frac{\Lambda_v}{\mu_v} \quad (12)$$

$$\Omega_v = \left\{(S_v, I_v) \in \mathbb{R}_+^2 : S_v + I_v \leq \frac{\Lambda_v}{\mu_v}\right\} \quad (13)$$

The total biologically feasible region for the system is $\Omega = \Omega_h \ x\ \Omega_v$ which is positively invariant.

3.2 Disease-Free Equilibrium (DFE)

$$F = \begin{bmatrix} 0 & 0 & \frac{abS_h^0}{N_h^0} \\ 0 & 0 & 0 \\ 0 & \frac{acS_v^0}{N_h^0} & 0 \end{bmatrix} \quad (14)$$

$$V = \begin{bmatrix} K_h + \mu_h & 0 & 0 \\ -K_h & \gamma_h + \mu_h + \delta_h & 0 \\ 0 & 0 & \mu_v \end{bmatrix} \quad (15)$$

Evaluate at E_0 where $S_h^0 = N_h^0\ and\ S_v^0 = \frac{\Lambda_v}{\mu_v}$, the spectral radius $\rho(FV^{-1})$ yeilds the basic reproductive number:

$$R_0 = \sqrt{\frac{a^2 * b * c * k_h * \Lambda_v}{\mu_v^2 * \Lambda_h * (k_h + \mu_h)(\gamma_h + \mu_h + \delta_h}} \quad (16)$$

This non-dimensional quantity determines whether the disease will die out ($R_0 < 1$) or persist ($R_0 > 1$) within the Polytechnic community.

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4.0 Parameter Estimation and Data Source

4.1 Data Collection Site

Data was collected from the Federal Polytechnic, Mubi, Clinic for the 2025/2026 academic sessions. In additional regional ecological metrics (temperature, rainfall trends affecting mosquito lifecycle values) were obtained from neighbouring institution (Adamawa state University Mubi meteorological reports.

4.2 Parameter Table

The baseline parameters assumed for the model environment are summarized below:

Parameter	Disruption	Baseline Value	Source
Λ_h	Human Recruitment Rate	10 day^{-1}	The Institutional Clinic
Λ_v	Vector Recruitment Rate	500 day^{-1}	Assumed based on Environment
a	Average biting rate	0.25 day^{-1}	Literature
b	Transmissions prob, (Human-vector)	0.35	Clinical estimates
c	Transmission prob, (Human-vector)	0.40	Clinical estimates
μ_h	Human natural mortality Rate	$(70*365)^{-1}$ day^{-1}	National Demographic data
μ_v	Vector natural mortality Rate	0.04 day^{-1}	Field Entomology data
k_h	Progression rate to Infectious state	0.10 day^{-1}	Incubation period tracking
γ_h	Human recovery rate	0.14 day^{-1}	Clinic charts
δ_h	Disease-induced mortality rate	0.0005 day^{-1}	Clinic archives
ω	Immunity waning rate	0.005 day^{-1}	Epidemiological literatures

5. 0 RESULTS

Using the baseline parameter values from Section 4, the computed basic reproduction number for the Federal Polytechnic, Mubi environment is: R_0= 1.841. Since $R_0 > 1$, the disease-free equilibrium is unstable, and the disease establishes endemic status within the population.

5.1 Sensitivity Analysis

To identify the parameters that exert the greatest influence on transmission dynamics, we

$$\gamma_{\rho}^{R_0} = \frac{\partial R_0}{\partial p} x \frac{p}{R_0} \tag{17}$$

The evaluated indices are detailed below:

-Mosquito biting rate (a): +1.00
-Vector recruitment rate (Λ_v): +0.50
-Transmission efficiency (b,c): +0.50
-Vector mortality rate (μ_v): -1.00
-Human recovery rate (γ_h): -0.48

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An index of +1.00 implies that a 10% increase in the mosquito biting rate will result in a 10% increase in R_0. On the other hand, a negative index indicates an inverse relationship.

5.2 Numerical Simulations

The system of ODEs was simulated over a 300-day timeline to project the path of infection inside the institution.

5.2.1 Case profile Evaluation Over Time

Initial conditions were set based on a single academic session onset with a baseline index case load:

$$S_h(0) = 12000, E_h(0) = 45, I_h(0) = 15, R_h(0) = 120, S_v(0) = 40000, and\ I_v(0) = 250. \quad (18)$$

a. Days 0-45: Active growth phase. Rapid conversion of exposed individuals (E_h) to active symptomatic infectious unit (I_h) occurs as rainy deposits enhance local vectors.
b. Days 45-90: Peak infection phase. Active infected human counts stabilize around an equilibrium highland of approximately 480 concurrent active infections within the campus perimeter.
c. Days 90-300: Steady-state phase. The system approaches the Endemic Equilibrium, demonstrating that without structural external intervention, malaria remains fully persistent.

5.2.2 Impact of Vector Control Interventions

Simulations were re-run to model the effect of localized vector management (for instance, intensive larvicide application and indoor residual spraying) which systematically reduces the mosquito lifespan, effectively increasing vector mortality μ_v

-At baseline $\mu_v = 0.04$, R_0 = 1.84(Endemic).

-Increasing μ_v to 0.06 drops to R_0 to 1.122, reducing the active clinical cases at equilibrium by over 55%

-Increasing μ_v to 0.085 effectively drops to R_0 to 0.86. Under this scenario, the infection level slowly drops, and the system asymptomatically converges toward the Disaese Free Equilibrium (E_0) within 180 days.

5.2.3 Impact of personal protection (ITNs)

Simulations modifying parameter a (biting frequency reduction via scaling insecticide treated net usage among hostel residents) yielded distinct transmission drops:

a. 20% usage expansion: Suppresses peak clinical cases during mid-semester by 32%
b. 60% comprehensive institutional usage: Safely stabilizes transmission vectors below high-risk thresholds, showing a flat path.

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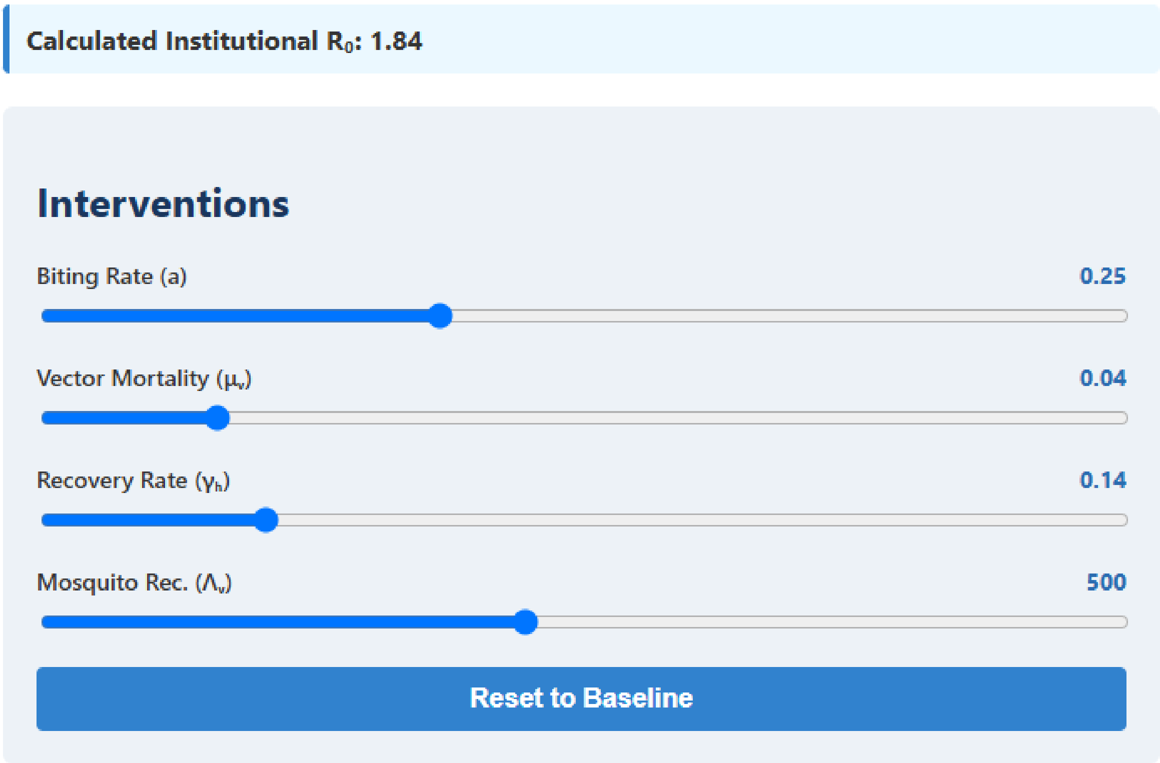

Figure 2. Impact of Vector Control Interventions In real time

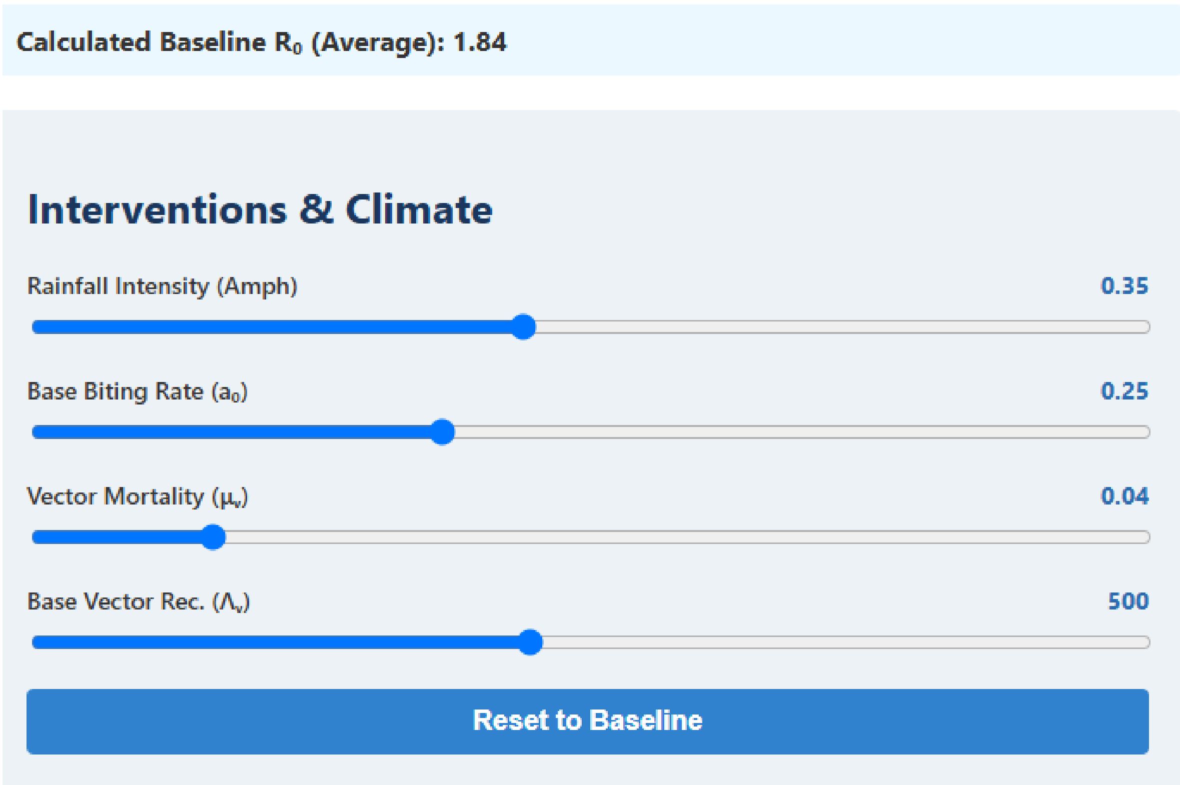

Figure 3 Vector parameters based on seasonal rainfall

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6. 0 Discussion

The computational models present evidence regarding the persistence of malaria within the Federal Polytechnic, Mubi community. The calculated value of $R_0 = 1.841$ shows that transmission is self-sustaining inside the student hostel and instructional zones. This high endemic potential is driven by environmental conditions and behavioural factors within institutional limits. These factors agreed with (Adepoju & Olaniyi, 2021) which shown that incorporating optimal control helps in preventing vertical transmission of infection, and in turn diminishes the spread of the disease in any population.

Mubi in particular features a specific geographical conditions that promote micro-breeding grounds for vectors. The simulation results showing high sensitivity to mosquito recruitment (Λ_v) point directly to open structural drainage channels, stagnant rain pools near student hostel, and clearing oversights along perimeter walls. When the rain season begins, these pools remain viable for long periods, lowering the vector mortality rate (μ_v) and increasing vector counts relative to the human host base.

The behavioural and housing dynamics shows the high sensitivity of the system to the mosquito biting rate (a) underscores the impact of high-density housing setups. Student hostels feature multi-bunk arrangements with high room occupancy. This layout maximizes vector efficiency, as a single infectious vector can easily feed on multiple susceptible hosts within a single night. This dense interaction shortens the transmission interval, causing the rapid rise in clinical infections observed between Day 20 and day 60 in the simulation timeline.

The sensitivity indices indicate that interventions focusing on vector mortality u_v and human exposure rates (a) yield the most substantial reductions in malaria incidence. Standard clinical case management (treating symptomatic patients at the medical center) is valuable for patient care but has a lower sensitivity index (-0.48) on overall transmission dynamics compared to vector control measures. Therefore, relying only on anti-malarial medication cannot break the institutional transmission cycle. Preventive environmental measures must be prioritized alongside clinical care.

6.0 Conclusion and Recommendations

6.1 Conclusion

Conclusively, we developed a computational model to track malaria transmission dynamics within the Federal Polytechnic, Mubi, Adamawa State Nigeria. The analytical framework established a baseline reproduction number of $R_0 = 1.841$, showing that malaria is firmly endemic within the campus. Sensitivity and simulation analyses demonstrated that structural vector suppression and mechanisms such as altering vector survival and human biting exposure rates provide a more reliable path to disease suppression than therapeutic interventions alone.

6.2 Recommendations

To achieve a disease-free state ($R_0 < 1$) within the institution, the following measures are recommended:

i. Enhanced or Upgrade the institutional clinic to include rapid diagnostic tests (RDTs) during registration screening cycles. This method will help identify and manage asymptomatic parasite pools within the incoming student population.
ii. The Institution should liaise with Non-Governmental organization (NGOs) to get and distribute long-lasting insecticide-treated nets (LLINs) to all campus residents, coverage of 95% at the start of each academic session.
iii. There is need to implement a campus-wide drainage restoration program to eliminate stagnant water pockets around student hostels and staff quarters.

iv. Federal Polytechnic Mubi should enforce and mandate, scheduled indoor residual spraying (IRS) and larvicidal treatments across all the campus facilities prior to the onset of the seasonal rains which normally start from mid Aprils.
v. Finally equipped the institutional clinic with simple anti-malaria drugs.

References

Abdulkadir, S. S., & Mutah, Y. (2018). Forecasting the Effects of Roll Back Malaria Intervention in Mubi North Local Government Area, Nigeria: A PAR (p) Model Approach.

Adeniyi, M.O., Aderele, O.R., Oludoun, O.Y., Ekum, M.I., Matadi, M.B., Oke, S.I., Ntiamoah, D. (2023). A mathematical and exploratory data analysis of a malaria disease transmission through blood transfusion. Front. Appl. Math. Stat. (**9)**, 1105543 (2023). https://doi.org/10.3389/fams.2023.1105543

Adepoju, O.A., Olaniyi, S.(2021). Stability and optimal control of a disease model with vertical transmission and saturated incidence. Sci. Afr. (**12)** e00800 (2021). https://doi.org/10.1016/j.sciaf.2021.e00800

Federal Ministry of Health, Nigeria. (2023). *National Malaria Slide Positivity Trends and Regional Survey Reports*. Strategic Health Publication, Abuja.

Jacob, T. G., Sambo, E. O., Alexander, W. J., & Wazakari, R. R. (2026). Prevalence And Perception on The Prevention and Control Strategies of Malaria Among Patients Attending PHC Centre Lokuwa, Mubi, Adamawa State. *ADSU International Journal of Social Sciences (ADSUIJOSS)*, *2*(1).

Mubi Weather and Ecology Monograph. (2024). *Climatic indicators and vector population shifts in Adamawa Northern*. State Meteorological Review.

Okoye, C. I., & Ibrahim, U. K. (2022). Vector dynamics in Sahelian microclimates: Analysis of institutional endemicity. *African Journal of Infectious Diseases*, 16(3), 204–219.

Olaniyi, S., Ajala, O.A., Abimbade, S.F.(2023). Optimal control analysis of a mathematical model for recurrent malaria dynamics. Oper. Res. Forum **4** (14). https://doi.org/10.1007/s43069-023-00197-5

Suleiman AG, Kareem L, Obi C.(2025). Modelling the Effect of Indoor Residual Spraying on Malaria Transmission in Nassarawa State, North-central Nigeria. Niger Med Journal; 66(2):528-539. doi: 10.71480/nmj.v66i2.672. PMID: 40703883; PMCID: PMC12280297.