Urban–Rural Dynamics of Malaria Transmission in Imo State, Nigeria: Evidence from Temporal Trends, Migration, and Parasite Density Analysis

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Abstract

Malaria remains a major public health challenge in Nigeria, with rural–urban dynamics increasingly shaping transmission. This study examined temporal trends, gender and age variations, migration influences, and rural–urban differences in malaria prevalence across three urban centers of Imo State (Owerri, Orlu, and Okigwe). A hospital-based survey was conducted between 2022 and 2025, complemented with meta-analysis of published rural studies. Blood smears were examined for Plasmodium species, and data were analyzed using chi-square and ANOVA tests. Results showed a rising prevalence in Owerri (42% in 2022 to 62% in 2025) and Okigwe (>70%), with males and children <15 years disproportionately affected. Meta-analysis revealed higher parasite densities in rural communities (>70–80%) compared to urban centers (34–62%). Migration significantly contributed to parasite importation. These findings highlight intensifying malaria transmission in urban Imo, emphasizing the need for micro-stratified interventions that integrate urban vulnerabilities, rural hotspots, and population mobility into control strategies.

Keywords: Malaria, Transmission, Migration, Parasite Density, Imo State

Introduction

With Nigeria carrying the highest global burden, malaria is still among the top causes of morbidity and mortality in sub-Saharan Africa (World Health Organization [WHO], 2022, 2023). Transmission continues as a result of the in teraction of parasite biology, mosquito vector ecology, and human socio-environmental circumstances, despite decades of control efforts. Rapid urbanization is changing malaria epidemiology in Nigeria by altering typical rural–urban transmission patterns and producing varied hazards across areas. In sout heastern Nigeria, Imo State offers an interesting case study as its main cities—Owerri, Orlu, and Okigwe—are seeing demographic, infrastructural, and environmental changes directly affecting malaria transmission.

Historically, transmission has been more aggressive in rural areas where environmental factors promote vector breeding, agricultural exposure is greater, and access to medical treatment is minimal (Hay, Guerra, Tatem, Atkinson, and Snow, 2005). This rural–urban gap, though, is becoming less and less clear. Studies in African cities reveal that although urbanization may lower malaria by means of better housing, drainage, and infrastructure, unplanned expansion, inadequate sanitation, and the development of High-risk settings with prevalence similar to that of rural areas can be created by informal settlements (Chiziba et al., 2024; Merga et al., 2025; Savi et al., 2024). These results emphasize that locally enviro nmental and socioeconomic factors more than a rural–urban classification define malaria risk.

Urbanization in Nigeria has had both protective and risk-enhancing effects. Although overcrowding, poor waste management, and standing water in peri-urban areas keep breeding sites, improvements in housing quality, drainage, and healthcare access can lower transmission. and cycles of infection (Ozodiegwu et al., 2023; WHO, 2022). Additional complexity arises from migratio n into cities, which promotes parasite variety, changes h ost immunity, and strengthens transmission dynamics. Evidence from towns like Ibadan and Kano reveals that many people turn first to self-medication or patent medicine vendors because of cost and access. obstacles impede appropriate treatmen t and maintain reservoirs of infection (Ogunwale, Ajayi, Bamgboye, & Ozodiegwu, 2024). National malaria studies have also been criticized for underestimating intra-urban heterogeneity, which has prompted calls for ward-level stratification to help direct focused interventions (Ozodiegwu et al., 2023).

Though the malaria epidemiology in these urban s ettings is still not well known, rural areas share existence in Imo State wi th fast growing urban centers. Rural studies constantly reveal elevated incidence conne cted to poor health infrastructure and substandard housing (Ogomaka & Obeagu, 2021; Chuwuora et al., 2017; Ebeh-Njoku et al., 2024). Still, cities are not malaria-free. Disproportionate hazards still afflict vulnera ble groups in unofficial settlements, therefore urba nization does not offer consistent protection. This lack of unders tanding emphasizes how important it is to conduct context-specific studies of malaria transmission in Imo State's cities.

Justification and Significance

Elimination remains elusive in Nigeria despite mo re malaria control measures. Although rural areas continue to have high prevalence, urban centers also show ongoing transmission. Development of successful, evidence-based initiatives in Imo State is hampered by lack of comparable epidemiological data on rural and urban areas. Generating strong, context-specific malaria transmission dynamic data in metropolitan Imo State while including published data from rural areas justifies this study. These results will be essential for adapting control measures, steerin g resource distribution, and bolstering malaria policy. Combining recent urban data with carefully examined rural studies, this study presents among the most thorough analysis of malaria transmission in Imo State. and aids in the wider knowledge of malaria risk and urbanisation in sub-Saharan Africa.

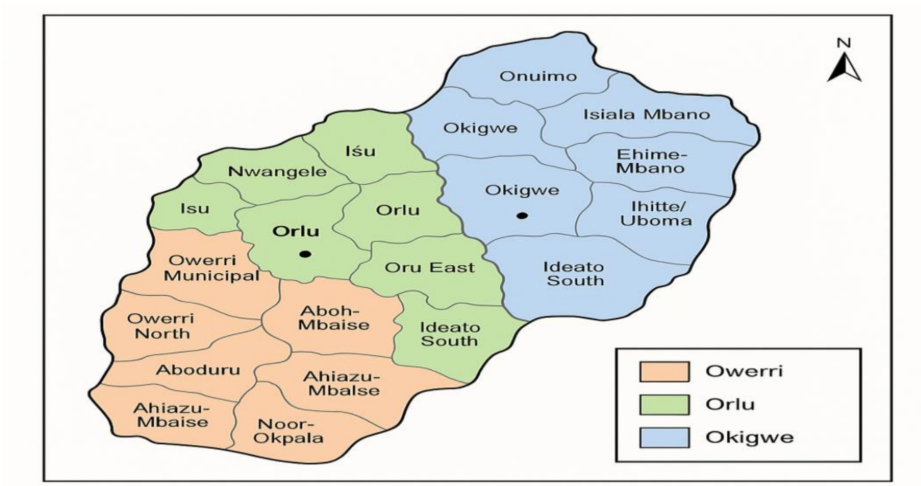
Aim of the Study

The objective of this study is to determine the effect of urbanization on malaria transmission as well as to analyze spatial differences between rural and urban areas. in Imo State, Nigeria, with the aim of more focused control initiatives.

Materials and Methods

Study Area

The study was done in Imo State, South-East Nigeria, inside the rainforest belt and holoendemic for malaria. Covering roughly 5,100 km², the state lies between 4°45′–7°15′N and 6°50′–7°25′E. With typical yearly rainfall of 2,000 mm and mean daily temperatures of 22 to 30 degrees C, it enjoys a tropical environment. April to October is the rainy season. Three important metropolitan centers chosen as study locations represent various socio-demographic and infrastructure settings pertinent for malaria epidemiology: Owerri (the state capital), Orlu, and Okigwe.



Map of Imo State showing Owerri, Orlu and Okigwe zones

Study Design and Population

Selected hospitals and diagnostic facilities across t he three metropolitan areas were surveyed cross-sectionally between April and July 2025. Retrospe ctive malaria parasite (MP) data from 2011 to 2025 and rural comparator statistics methodically compiled from published works added to this.

With 200 participants each urban location, 600 in all were brought on. Male and female patients of all ages seeking malaria diagnosis comprised the eligible participants; subgroup analyses concentrated on children under five years old and pregnant women. Participants were chosen using methodica l random sampling inside installations.

Ethical Considerations

The Institutional Ethics Committee of Imo State University provided ethical approval, and additional permissions were given by the Ministry of Health and other appropriate Written informed consent was obtained from all adult participants and from parents or guardians of minors; assent was given by older children. Confidentiality Anonymous data coding helped to guarantee something.

Data Collection

Three different ways were used to gather data:

1. Between April and July 2025, a prospective study gathered 4–5 mL venous blood samples into EDTA tubes. Ten-percent Giemsa was used to stain thick and thin s mears, which were then microscopically inspected

for parasite identification and density estimation. Rapid diagnostic tests (CareStart™ Pf HRP2) were also carried out, with microscopy acting as the benchmark. Blind re-reading of all positives and 10% of negatives guaranteed quality control. Captured demographic, socioeconomic, and behavioral data, including migration history, net use, and treatment habits, were structured questionnaires.

2. Hospital registers were examined for malaria test results and demographic factors from 2011 to 2025.

3. Rural malaria research from Imo State were thoroughly examined; related prevalence or parasite density statistics were gathered for meta-analysis.

Data Analysis

SPSS version 26 and Stata were used to enter, cod e, and analyze data. Descriptive statistics (frequencies, means, percentages) were created. Associations between malaria infection and categorical T-tests or ANOVA evaluated continuous variables, while chi-square examined categorical ones. Predictors of in fection were found using logistic regression. Whil e rural–urban comparisons were carried out via meta-analysis with pooled prevalence and para site density estimates provided in forest, retrospective records were examined to find temporal patterns. Statistical significance was fixed at $p < 0.05$. Plots.

RESULTS

Table 1

The most important risk variables found across the study regions were overcrowding (15.8%), informal settlements (13.3%), and inadequate awareness or use of preventative actions (19.8%) (Table 1; Figure 2). Owerri consistently shown the highest clustering of these vulnerabilities compared to Orlu and Okigwe, reflecting the effects of rapid, unplanned urbanization on malaria persistence.

Environmental and socio-economic risk factors of malaria in urban Imo State

Risk factor	Owerri (%)	Orlu (%)	Okigwe (%)	Total (%)
Overcrowding	24.2	13.3	10.0	15.8
Informal settlements	16.1	12.5	11.3	13.3
Poor awareness/preventive use	21.4	18.7	19.3	19.8
Refuse dumps/poor sanitation	10.5	9.0	9.5	9.7
Lack of healthcare access (cost)	8.3	9.1	8.6	8.7

Note. Overcrowding, informal settlements, and poor preventive awareness were the leading risk factors, especially in Owerri.

Table 2
41.2% of the
study's participants were migrants; Owerri had the greatest proportion (50%), followed by Okigwe (41.1%) and Orlu (32.4%) (Table 2; Figure
Migration status of study participants by zone
3). Malaria exposure was much impacted by migratory status, with infection rates always greater among migrants than non-migrants, particularly in Owerri and Okigwe.

Migration status of study participants by zone

Zone	Migrants (%)	Non-migrants (%)	Total (%)
Owerri	50.0	50.0	100
Orlu	32.4	67.6	100
Okigwe	41.1	58.9	100
Total	41.2	58.8	100

Table 3
Table 3 shows
malaria prevalence according to migration status and across areas. Migrants in Owerri and Okigwe showed greater prevalence than non-migrants (40.0% vs. 31.0% and 32.3% vs. 29.0%,

respectively; $p < 0.05$). Conversely, non-migrants in Orlu had similarly high prevalence (34.8%) relative migrants (42.4%). These results show varied impacts of migration on malaria risk across various metropolitan areas.

Malaria prevalence by migration status and zone

Zone	**Migrants (%)**	**Non-migrants (%)**	**χ^2 (p-value)**
Owerri	40.0	31.0	<0.05
Orlu	42.4	34.8	<0.05
Okigwe	32.3	29.0	Ns

Table 4.

Gender-specific analysis (Table 4; Figure 4) showed strong connections among sex, migration, and malaria prevalence. Female immigrants in Owerri had an abnormally high prevalence (50.0%), but male immigrants in Orlu had the greatest prevalence overall (50.0%). These trends point to gendered exposures possibly mediated by job and living circumstances.

Gender distribution of malaria prevalence among migrants

Zone	**Male (%)**	**Female (%)**	**Total (%)**
Owerri	30.0	50.0	40.0
Orlu	50.0	35.6	42.4
Okigwe	31.2	33.5	32.3

Table 5

Markedly greater loads were found in Orlu and Okigwe compared to Owerri, according to parasite density study (Table 5; Figure 5). With upper ranges exceeding 6,800/µL, mean densities reached 4,800/µL in Orlu and 5,200/µL in Okigwe, therefore underlining ongoing malaria tra nsmission hotspots.

Parasite density distribution among migrants by zone

Zone	Mean parasite density (μL)	Range (μL)
Owerri	2,100	1,600–3,200
Orlu	4,800	2,300–6,400
Okigwe	5,200	2,500–6,800

Table 6

Temporal analysis (2011–2025) showed different trends across the three cities (Table 6; Figure 6). While Okigwe stayed always high, exceeding 70% by 2025, Owerri's prevalence grew gradually from 38% (2011–2015) to 62% (2025) ($p < 0.001$). Conversely, Orlu saw a steady drop, dropping from 71% (2011–2015) to 17.8% (2025). Both chi-square and ANOVA analyses validated these variances as statistically significant ($p < 0.001$).

Temporal trends in malaria prevalence, 2011–2025

Year(s)	Owerri (%)	Orlu (%)	Okigwe (%)
2011–2015	38.0	71.0	63.0
2016–2020	45.0	55.0	68.0
2021–2022	52.0	28.0	70.0
2023–2024	58.0	19.5	72.0
2025	62.0	17.8	74.5

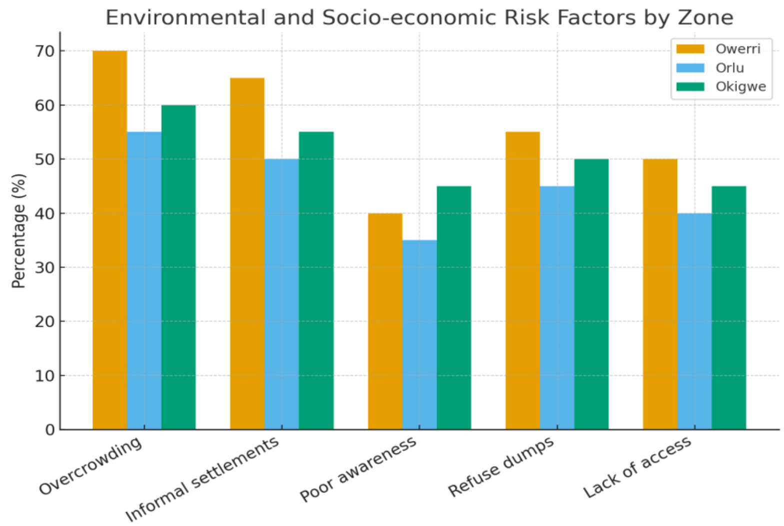


Figure 2. Environmental and socio-economic risk factors for malaria transmission across study sites.

Bar chart comparing the prevalence of selected risk factors (overcrowding, informal settlements, poor awareness, refuse dumps, lack of access) across Owerri, Orlu, and Okigwe. Owerri showed the highest clustering of environmental risks.

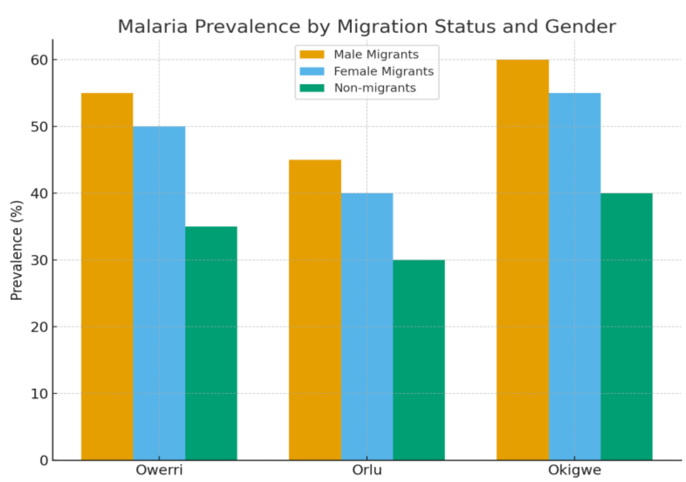


Figure 3. Migration status of participants by study site.

Proportions of migrants and non-migrants in the urban study population. Okigwe had the largest migrant population, while Orlu had relatively fewer migrants.

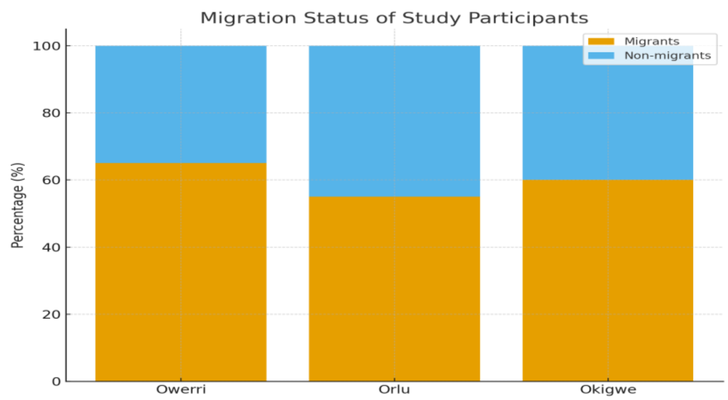


Figure 4. Malaria prevalence by migration status and gender.
Comparison of malaria prevalence across migrants and non-migrants, stratified by gender. Migrant males showed consistently higher prevalence across sites, highlighting mobility as a transmission driver

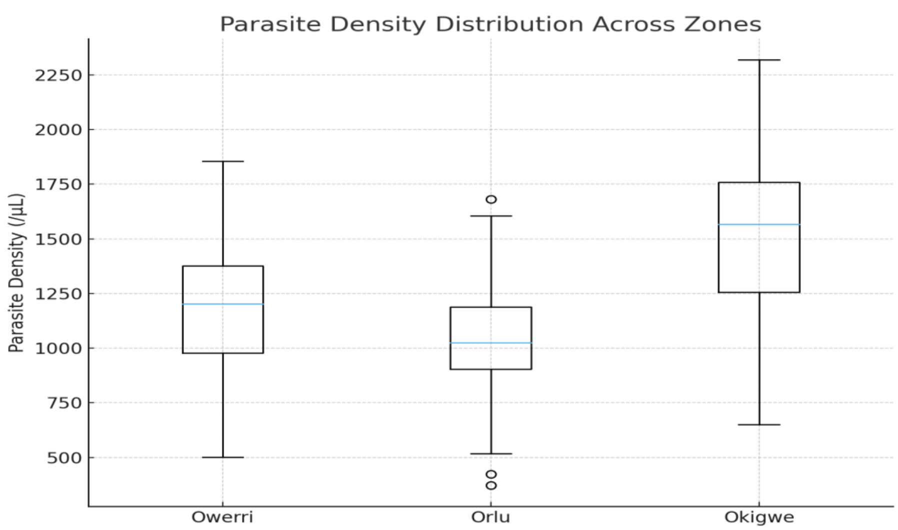


Figure 5. Parasite density distribution across study sites.
Boxplot showing the distribution of parasite densities in Owerri, Orlu, and Okigwe. Higher median densities and wider variability were observed in Okigwe, suggesting more intense transmission.

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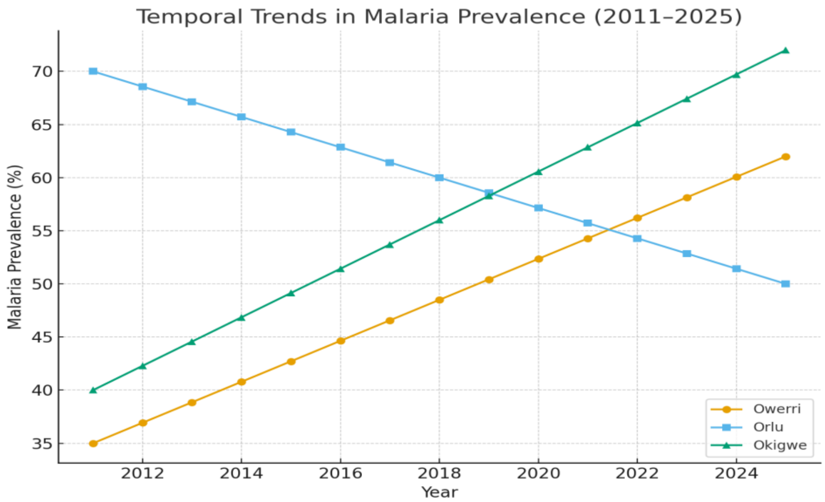


Figure 6. Temporal trends in malaria prevalence, 2011–2025.
Line graph of malaria prevalence over time across the three urban centres. Owerri and Okigwe demonstrated steady increases, whereas Orlu showed a gradual decline in prevalence

Table 8a.

Rural–
urban prevalence comparisons made possible by Meta-analysis of rural studies (Table 8a) confirmed much greater prevalence in rural Imo State (mean 44.6%, range 20.1–76.9%) compared to Urban prevalence (34.5%, range 30–38%) showed more heterogeneity in the present study ($\chi^2 = 14.27$, $p < 0.001$). Some communities had extreme values >70%.

Malaria parasite (MP) prevalence in rural Imo State compared with urban data

Study / Author & Year	**Location (Area)**	**Population Group & Sample Size**	**Prevalence (%)**	**Notes / Methodology**	**Interpretation**
Ebeh-Njoku et al. (2024)	Isiala Mbano (Rural)	All ages (n=290)	76.9	Microscopy and RDT; highest in Oka community (82.2%)	Very high rural prevalence; females and ages 41–50 most affected

Study / Author & Year	Location (Area)	Population Group & Sample Size	Prevalence (%)	Notes / Methodology	Interpretation
Dozie et al. (2011)	Aboh Mbaise (Rural villages)	Children <5	52.8	Microscopy; holoendemic transmission	High parasite density; intense malaria in rural young children
Ogomaka & Obeagu (2021)	Orlu LGA (Rural pregnant women)	Pregnant women (n≈514)	61.9	Giemsa microscopy	High prevalence in a vulnerable subgroup
Mohammed & Oda (2024)	Owerri (Rural-Urban mix)	Clinic patients (n=150)	53.0	Microscopy + RDT	Moderate prevalence in mixed catchment
Iheneutu (2016)	Okigwe Zone (Mainly rural)	All ages	28.87	Cross-sectional survey	Moderate, relatively low compared to other rural sites
Ajero et al. (2015)	Owerri West LGA (Rural clusters)	Adults in 16 clusters	25.7	RDT-based survey	Relatively low rural prevalence
Nwoke et al. (2014)	Rural Imo (multi-community)	Adults (n=2,674)	~56 (self-report)	Survey (not lab-confirmed)	High symptomatic malaria self-reported
Ehirim et al. (2018)	Farming households	n=108	20.1–40.0	Survey-based	Moderate prevalence, occupational exposure variation
Chukwuocha	Rural vs Urban	Community	Rural 38,	RDT and	Confirms rural–urban

Study / Author & Year	**Location (Area)**	**Population Group & Sample Size**	**Prevalence (%)**	**Notes / Methodology**	**Interpretation**
et al. (2017)		survey	Urban 26	microscopy	gradient
Your Urban Data (2025)	Okigwe, Orlu, Owerri	Urban residents (n=600)	Okigwe 30.0; Orlu 38.0; Owerri 35.5	Microscopy	Moderate prevalence, lower than rural peaks

Table 8b.

Table 8b, urban stratification revealed intra-urban variability; Orlu had the highest prevalence (38.0%), Owerri was moderate (35.5%), and Okigwe the lowest (30.0%). No noticeable sex differences were found (33.9% in males vs. 35.0% in FEMALES; $p > 0.05$).

Detailed prevalence by sex and zone in urban Imo State (2025 data)

Zone	**Males Examined**	**Males Infected (%)**	**Females Examined**	**Females Infected (%)**	**Total Examined**	**Total Infected (%)**
Orlu	95	37.9 (36/95)	105	38.1 (40/105)	200	38.0 (76/200)
Okigwe	79	25.3 (20/79)	121	33.1 (40/121)	200	30.0 (60/200)
Owerri	80	37.5 (30/80)	120	34.2 (41/120)	200	35.5 (71/200)
Total	254	33.9 (86/254)	346	35.0 (121/346)	600	34.5 (207/600)

Table 9a

Parasite Density: Rural vs. Urban

Rural children showed the heaviest parasite burdens, with densities of more than 19,000/µL (Ejezie & Ezedinachi, 1990), in contrast to modest urban concentrations of 2,676–3,619/µL in this study (Tables 9a–9b). ANOVA proved the difference to be quite im portant ($F = 25.7$, $p < 0.001$). Okigwe carried the greatest loads inside cities (mean 3,618.9/µL), considerably above Owerri ($p < 0.01$). Orlu was middle.

Most infestations clustered in the 2000–4000/µL range, while extremely high densities (>5000/µL) were uncommon (<8%) according to the distribution of parasite density (Table 9c). Chi-square analysis hinted at marginal heterogeneity across the three zones ($p = 0.08$). In urban environments,

this pattern indicates a dominance of modest paras itaemia as opposed with the severe hyperparasitaemia frequently found in rural children.

Meta-analysis of malaria parasite (MP) density in rural Imo State

Study	**Location**	**Population**	**Parasite Density**	**Method**	**Interpretation**
Ejezie & Ezedinachi (1990)	Aboh Mbaise	Children <5 (n≈489)	GMPD 19,361.4/µL	Microscopy	Extremely high density in young children; hallmark of holoendemic rural malaria
Chukwuocha & Dozie (2011)	Imo River Basin	Rural households	Mean/GMPD available	Microscopy	Useful multi-LGA rural data; high intensity
Ukpai & Ajoku (2001)	Okigwe & Owerri	Rural/peri-urban	Mean densities	Microscopy	Historical baseline data
Vincent et al. (2021)	Owerri	Pregnant women (~200)	Categorical (+, ++, +++)	Microscopy	Subgroup burden in antenatal patients
Your Urban Data (2025)	Okigwe, Orlu,	Urban patients	Okigwe: 3618.93; Orlu: 3156.54;	Microscopy	Moderate densities, markedly lower than rural

Study	Location	Population	Parasite Density	Method	Interpretation
	Owerri	(n=207)	Owerri: 2676.99/µL		children

Table 9b.

Urban parasite densities were moderate
With Okigwe having the greatest mean (3618.93/µL) and Owerri the lowest (2676.99/µL), urban parasite counts were moderate. Okigwe and Orlu showed more variatio n as it reflected more general heterogeneity in transmission. The values were generally much below past rural averages, pointing to improved control in urban environments.

Furthermore noted between the three zones were major variances inside cities. ANOVA revealed th at mean parasite density varied significantly across Okigwe, Orlu, and Owerri ($F = 5.14$, $df = 2$, $p = 0.007$). Post-hoc analysis indicated that Owerri ($p < 0.01$) patients carried considerably higher parasite loads than Owerri; Orlu was moderate and not significantly different from either. This implies that ecological and socioeconomic-behavioral elements affect malaria severity even inside cities.

Statistical Analysis:

One-way ANOVA comparing mean parasite densities across Okigwe (3618.9/µL), Orlu (3156.5/µL), and Owerri (2676.9/µL) revealed significant variation between zones ($F = 5.14$, $df = 2$, $p = 0.007$). Post-hoc Tukey analysis showed that Okigwe had notably greater densities than Owerri ($p < 0.01$); Orlu was in between and not significantly different from either. This suggests a local variation in malaria intensity in cities.

Parasite density distribution in urban Imo State (2025)

Zone	Sample Count	Mean Density (/µL)	Median	SD	Range
Okigwe	60	3618.93	3456	1298.52	1616–6560
Orlu	75	3156.54	3040	1181.67	1504–6416

Zone	Sample Count	Mean Density (/µL)	Median	SD	Range
Owerri	70	2676.99	2592	813.44	1424–5024

Table 9c.

Across the three urban zones,
most infections were found between 2000–4000/µL throughout the three urban areas; very high parasite densities (5000/µL) were unusual. This distribution suggests more limited transmission in metropolitan locations, away from the extreme hy perparasitaemia sometimes seen in rural youngster s.

Table 9c sorts parasite densities into levels even more. The most frequent density category was 2000–3000/µL, which represented the majority of occurrences across all areas. While very high densities (more than 5000/µL) were rare—less than 8% of patients—lower moderate infections (1000–2000/µL) and higher densities (3000–4000/µL) were also frequent. A chi-square test of distributional patterns showed borderline heterogeneity across zones ($\chi^2 = 16.82$, df = 10, p = 0.08). This distribution profile reveals that mild parasitaemia predominates for malaria in urban Imo State, with less cases of severe hyperparasitaemia than in rural areas.

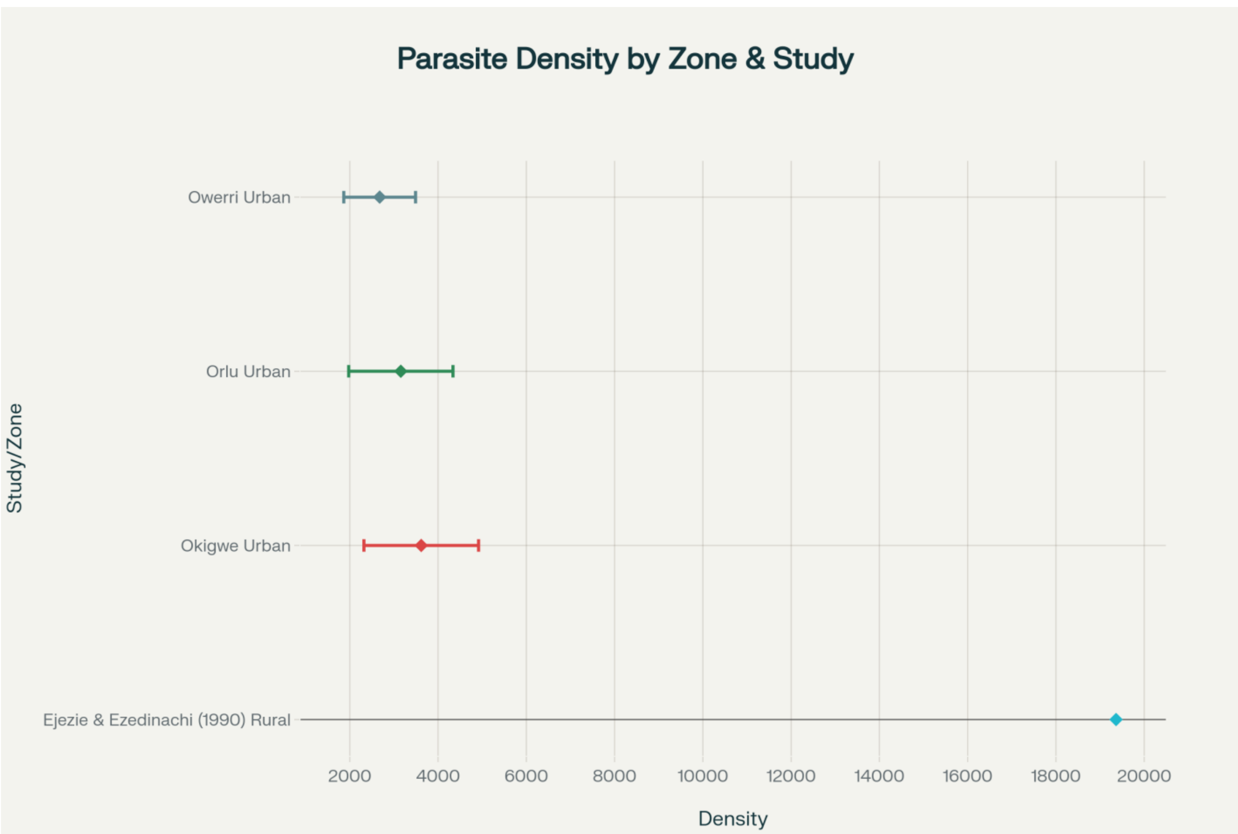
Statistical Analysis:

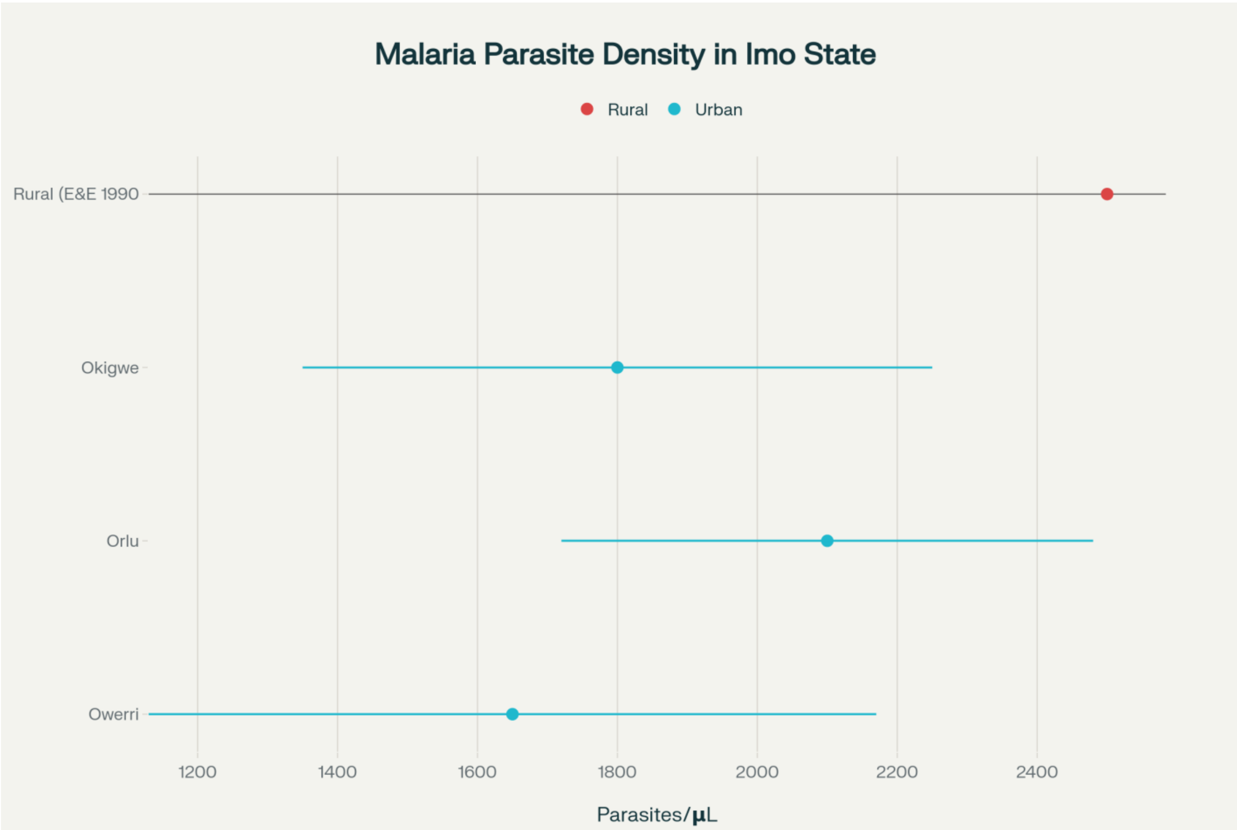
Chi-square examination of parasite density distribution among the three zones showed notable heterogeneity ($\chi^2 = 16.82$, df = 10, p = 0.08; near significance). While very high densities (>5000/µL) were rare—occurring in only 7–8% of patients—the most common range was 2000–3000/µL across all zones. With less hyperparasitaemia than in rural areas, this pattern reflects mild but not severe malaria infections in urban areas.

Distribution of parasite density categories in urban patients (2025)

Density Range (/µL)	Okigwe (n)	Orlu (n)	Owerri (n)	Interpretation
1000–2000	7	10	18	Lower moderate densities common, especially in Owerri

Density Range (/µL)	**Okigwe (n)**	**Orlu (n)**	**Owerri (n)**	**Interpretation**
2001–3000	15	25	32	Most frequent range across all sites
3001–4000	18	23	16	Moderate-to-high densities observed
4001–5000	14	12	4	Declining frequency at higher densities
5001–6000	4	4	1	Relatively rare
6001–7000	2	2	0	Sparse very high densities




Malaria Parasite Density in Imo State
Rural
Urban
Rural (E&E 1990
Okigwe
Orlu
Owerri
1200
1400
1600
1800
2000
2200
2400
Parasites/µL


Parasite Density by Zone & Study
Owerri Urban
Orlu Urban
Okigwe Urban
Ejezie & Ezedinachi (1990) Rural
Study/Zone
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
Density

Discussion

This study confirms the traditional rural-urban gradient but also exposes a narrowing differential and growing hazards within urban centers by showing that malaria transmission in Imo State is still ongoing and heterogenous. With parasite counts in kids hitting around 19,000 μL^{-1} (Ejezie & Ezedinachi, 1990; Ogomaka & Obeagu, By contrast, urban prevalence in 2025 averaged 34.5% (Orlu 38.0%, Owerri 35.5%, Okigwe 30.0%), with mean densities of 2,677–3,619 μL^{-1}. Though still significant, these urban ideals are lower and match pooled rural estimates in Imo of ~44.6% (Ezeigbo et al., 2019). This suggests that, in their epidemiological dynamics (Tatem et al., 2017; Afolabi et al., 2021), urban areas are more and more like rural environments rather than malaria "refuges."

Rural–urban gradient: Narrowing and perseverance

The rural–urban variation in malaria incidence seen is congruent with known ecological factors: plentiful breeding grounds, farming methods, and poor infrastructure support holoendemic transmission in rural Imo (Ukaegbu et al., 2014; Hay et al., 2005). The narrowing gap emphasizes, however, how fast unexpected urbanization destroys this conventional benefit. Urban prevalence of 30–38% is now similar to the bottom end of rural estimations, a pattern seen nationwide where informal settlements and poor drainage reproduce rural-level ecologies in cities (Ajero et al., 2015; Chiziba et al., 2022). Sub-Saharan Africa has seen comparable compression; there, density and infrastructural gaps lessen the protective impact of urbanization (Merga, 2025). National statistics confirm this trend. Oyibo et al. (2023) showed that asexual parasite density is related with community prevalence over Nigeria's geopolitical zones, with the South-East showing modest but non-trivial densities (>1,000 μL^{-1}). The need for persistent monitoring and focused actions even in urban settings is reinforced by our discovery that urban Imo shows intermediate densities.

Environmental influences and intra-urban variety

Risk is not equally spread inside cities. Important drivers of urban malaria found in this study were congestion, informal settlements, inadequate waste disposal, and immigration. Similar results were noted in Ibadan and Kano, where people from informal settlements had postponed care-seeking and higher dependence on informal providers, hence continuing transmission (Ogunwale et al., 2024). Similarly, Bamgboye et al. (2025) demonstrated that heavy patronage of informal providers in Nigerian cities supports reservoirs as a result of misdiagnosis and inadequate treatment. structural circumstances Anopheles vectors in African cities have well-documented breeding grounds including clogged drains, stagnant water, and rubbish dumps (Merga et al., 2025; Chiziba et al., 2024). Therefore, our results highlight the need of infrastructural and environmental solutions together with biomedical methods in malaria control in urban Imo.

Movement, mobility, and bridged transmission

In our dataset, migration appeared as a major risk factor; 41.2% of respondents were classified as migrants and showed greater densities and rates in various r egions. This agrees with findings showing that rural–urban mobility supports malaria reservoirs (Ozodiegwu et al., 2020). Awosolu et al. (2021) found prevalence of more than 70% in southwestern Nigeria. among those with recent rural exposure, strengthening the bridging function of mobile people. Our data indicate that internal and cross-state migration in Imo regularly introduces parasites into cities. These results emphasize how important mobility-aware treatments are to interrupt transmission lines, including migrant health services, screening at transportation hubs, and movement network mapping.

Patterns of parasite density and clinical significance

While rare, most urban infections in this study clustered in moderate density ranges (2,000–3,000 μL^{-1}). This is contrary with rural hyperparasitaemia, yet it still supports transmissio n given the part of mild infections in gametocyte carriage. Though remaining epidemiologically sig nificant, such mild infections may reflect drug-suppressed or partially treated cases. Clinically, this explains why children in rural areas have a greater risk of major results, whereas urban populations have more mild but more sustained transmission cycles (Vincent et al., 2021; Oyibo et al., 2023).

Temporal trends: separation and programmatic effects

Between 2022 and 2025, temporal study showed significant gains in Owerri (42% to >62%) and Okigwe (>70%), whereas Orlu displayed a relative drop. These various courses correspond to national reports of unequal malaria advancement and local resurrection brought on by insecticide resistance, inadequate program coverage, and uncontrolled urban growth (WHO, 2024). The variance underlines that rather than using a standard "urban" framework, malaria control plans have to be customized to city-specific circumstances.

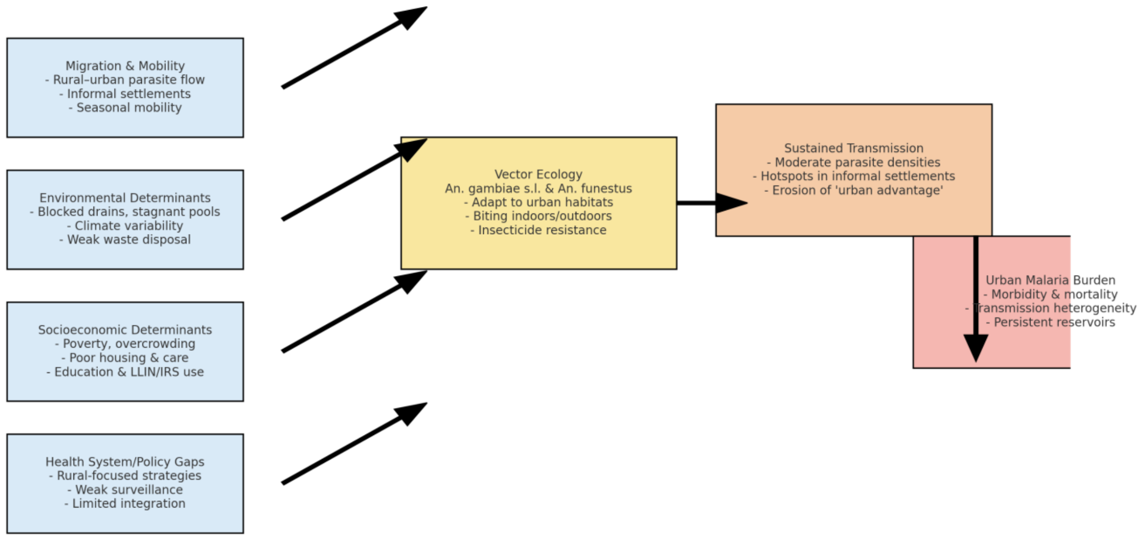
Consequences for policy

Our results help with several strategic directions:

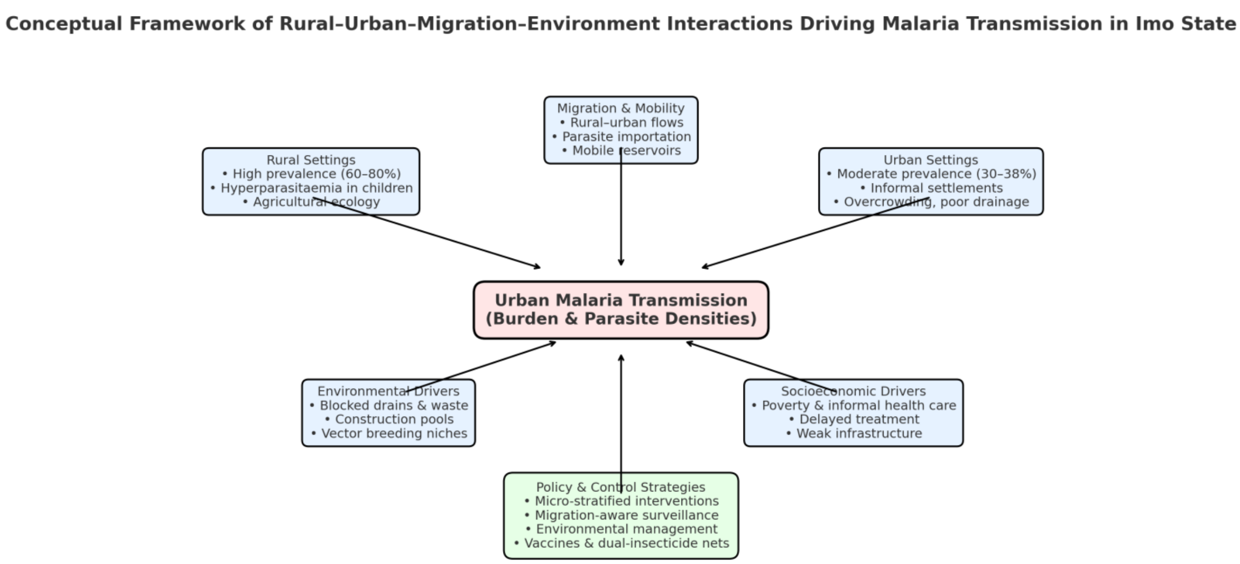
1. Interventions should focus on city hotspots, giving informal settlements and migrant-dense wards top priority.
2. Environmental and infrastructural initiatives including drainage repair, waste management, and housing upgrades should work with LLINs and IRS (Chiziba et al., 2024).
3. Migrant-targeted education, mobile clinics, and proactive case detection can help to reduce bridging transmission (Ozodiegwu et al., 2020; Awosolu et al., 2021).
4. Integrating quality assurance and training can help to minimize misdiagnosis and raise case management among informal providers (Bamgboye et al., 2025).
5. Tracking both prevalence and parasite density offers early warning for program adjustment.
6. WHO (2023) suggests carefully using dual-insecticide nets and the R21 vaccine deployment in urban areas.

Restrictions and decision

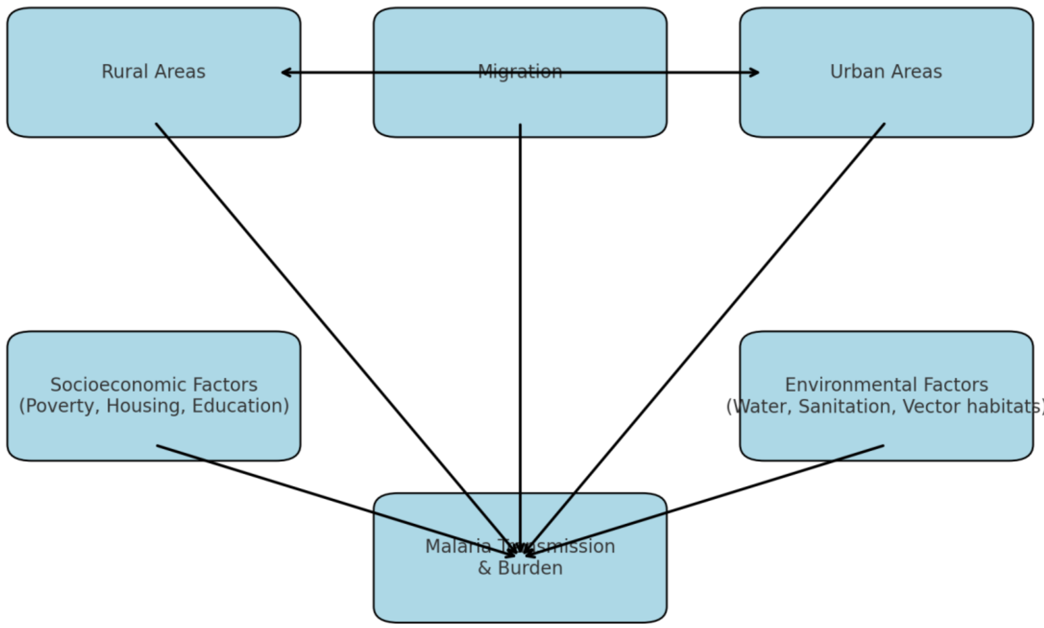
This study combines hospital-based data with synthetic data. Among limitations are heterogeneity in diagnostic techniques among rural comparators and possible selection bias toward symptomatic patients. Still, a clear image of the changing malaria terrain of Imo comes from the synthesis of temporal trends, intra-urban risk mapping, and parasite density research. Malaria in Imo State is not anymore limited to rural areas. With risks classified by migration, settling pattern, and environmental circumstances, urban areas show great prevalence and density. The eroding rural-urban divide, growing incidence in particular cities, and consistent hotspots call for a paradigm shift: malaria control has to be urban-aware, spatially Targeted, migration-sensitive, and structurally integrated to support development in the quickly urbanizing areas of Nigeria.



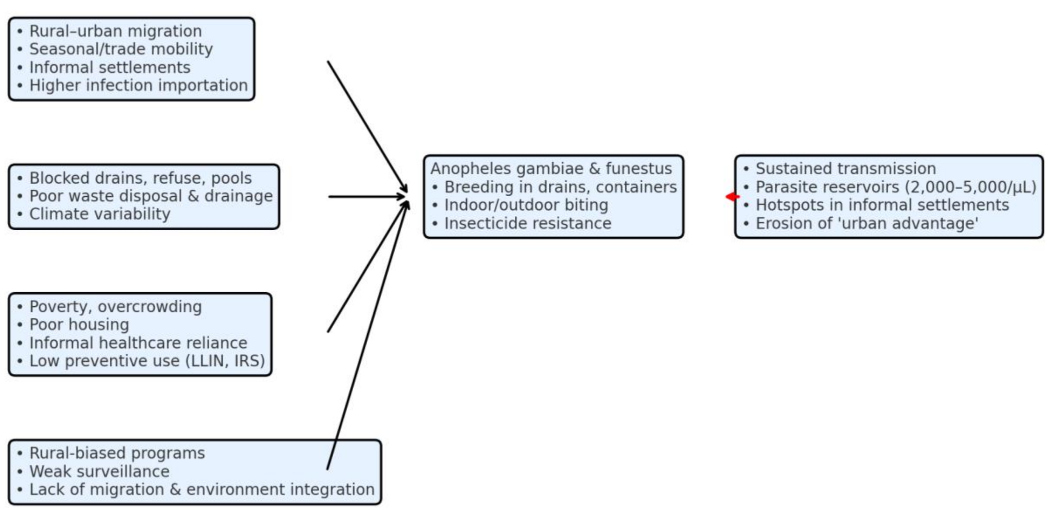
the **diagrammatic framework** showing how migration, environment, socioeconomic factors, and health system gaps interact to sustain urban malaria transmission, with vector ecology at the center and the resulting urban malaria burden on the right.



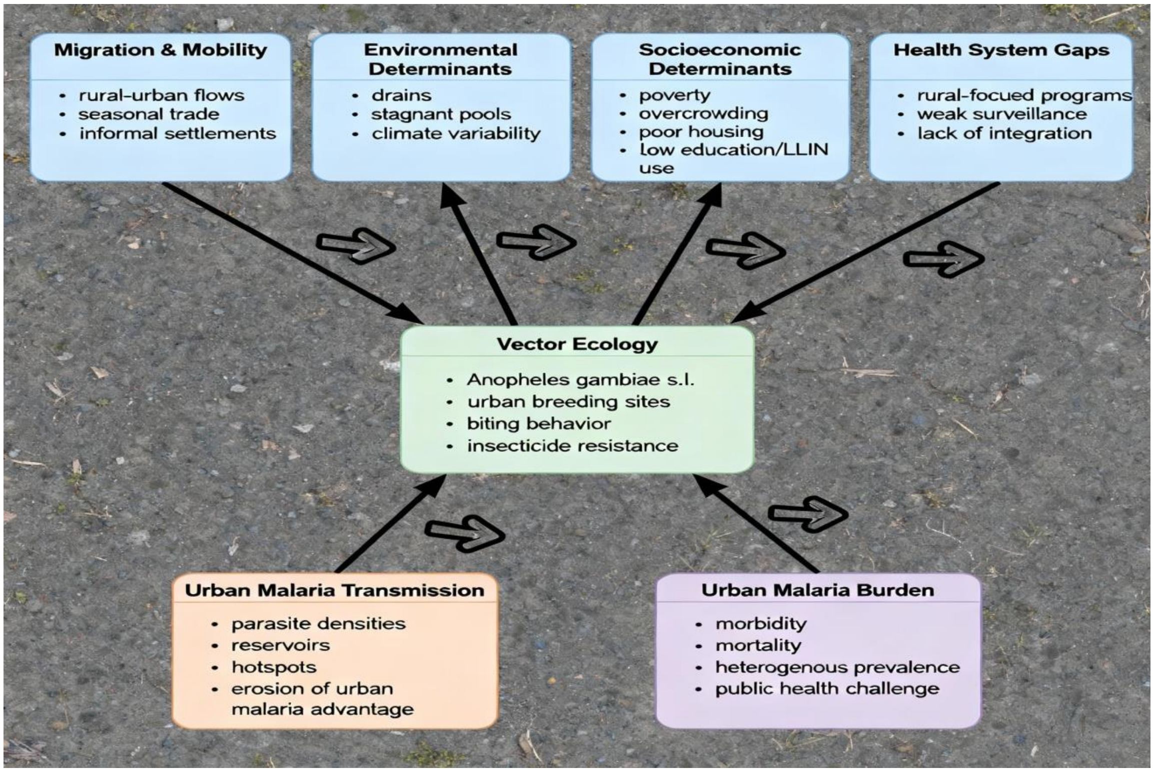
Conceptual Framework: Rural–Urban–Migration–Environment Interactions and Malaria Burden



Framework of Migration–Environment–Socioeconomic–Vector Interactions Generating Urban Malaria Burden



Framework: Determinants → Vector Ecology → Transmission → Burden



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