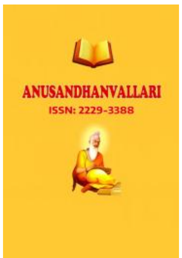

Anusandhanvallari
Vol 2025, No.1
ISSN 2229-3388

Climatic and Socio-Ecological Drivers of Malaria and Dengue Dynamics in Jaipur, India

Anita Choudhary[1], Dr. Sanjay Goyal[2]
[1]Research Scholar, Apex University Jaipur
[2]Assistant Professor, Apex University, Jaipur

Abstract: This study examines the climatic and socio-ecological factors driving malaria and dengue transmission in Jaipur, India, from July 2023 to June 2024. Conducted across urban (Vidhyadhar Nagar, Muralipura) and rural (Chomu, Amer) zones, the research integrates primary entomological data, secondary disease case data, and climatic variables (temperature, humidity, rainfall). Results show strong positive correlations between humidity ($r=0.73, p=0.0076$ for cases; $r=0.76, p=0.0039$ for HI) and rainfall with dengue incidence, with urban *Aedes* House Index (HI) peaking at 80.0 in August 2023, corresponding to 29 dengue cases. Malaria exhibits weaker climatic correlations (e.g., humidity: $r=0.47, p=0.1227$ for cases), driven by rural socio-ecological factors like agricultural water bodies, with *Anopheles* HI peaking at 80.0 in August 2023, tied to 10 malaria cases. Findings highlight the need for targeted vector control, including urban source reduction for dengue and rural water management for malaria, aligned with WHO and NVBDCP guidelines.

Keywords: Malaria, Dengue, Vector-Borne Diseases, *Aedes*, *Anopheles*, House Index, Climatic Factors, Socio-Ecological Drivers, Urbanization, Water Management, Jaipur, Monsoon, Vector Control.

Introduction

Jaipur, the capital of Rajasthan, India (26.9124◦ N, 75.7873◦ E, 431 m elevation), faces significant public health challenges from vector-borne diseases (VBDs), particularly malaria and dengue. VBDs are a major public health concern across India, contributing significantly to morbidity and mortality, and imposing a substantial economic burden due to healthcare costs and lost productivity. Jaipur, with its unique geographical and climatic characteristics, presents a compelling case study for understanding VBD dynamics. Its semi-arid climate, characterized by distinct monsoon (July–September), post-monsoon (October–December), and dry (January–June) seasons, creates cyclical favorable conditions for mosquito breeding and pathogen transmission. The rapid and often unplanned urbanization in areas like Vidhyadhar Nagar and Muralipura leads to the proliferation of artificial breeding sites such as discarded tires, flowerpots, and water storage containers, which are ideal for *Aedes* mosquitoes, the primary vectors of dengue. Conversely, the surrounding rural zones, including Chomu and Amer, are dominated by agricultural landscapes with extensive natural and man-made water bodies like ponds, canals, and irrigation channels. These environments provide optimal breeding grounds for *Anopheles* mosquitoes, the vectors responsible for malaria transmission. This study aims to systematically investigate how a combination of climatic factors (temperature, humidity, and rainfall) and localized socio-ecological conditions influence the spatiotemporal dynamics of malaria and dengue across both urban and rural settings in Jaipur, utilizing detailed data collected over a one-year period from July 2023 to June 2024. Understanding these drivers is crucial for developing evidence-based, localized intervention strategies to mitigate the public health impact of these diseases.

Materials and Methods

Study Area

The study was conducted within the Jaipur district, strategically stratified into four distinct zones to capture diverse environmental and socio-economic contexts: two urban zones (Vidhyadhar Nagar and Muralipura) and two rural zones (Chomu and Amer). The chosen urban areas are representative of high-density residential and commercial sectors, characterized by extensive concrete infrastructure, often with inadequate waste management and drainage systems, leading to numerous artificial water-holding containers conducive to *Aedes* breeding. The rural areas, in contrast, are predominantly agricultural, featuring lower population densities and a greater prevalence of natural landscapes, including rain-fed ponds, rivers, and a network of irrigation channels, which are ideal breeding habitats for *Anopheles* mosquitoes. The city's climate is a critical determinant of mosquito ecology: the heavy monsoon rainfall (July–September) significantly increases water availability for breeding; moderate temperatures during the post-monsoon period (October–December) can sustain vector populations; and the dry seasons (January–June) typically reduce mosquito activity but can create concentrated breeding in persistent water sources.

Data Collection

Primary entomological data were systematically collected through monthly surveys employing the standard white bed sheet method for adult mosquito collection within 400 randomly selected houses (100 houses per zone). Surveys were conducted during morning hours (7:00 AM to 10:00 AM) to maximize the collection of resting mosquitoes. The target mosquito species included key vectors for malaria (*Anopheles culicifacies*, *Anopheles stephensi*) and dengue (*Aedes aegypti*, *Aedes albopictus*). Collected mosquitoes were morphologically identified and counted. The House Index (HI), a standard entomological indicator, was calculated for each mosquito genus in each zone as:

HI=Total Houses CheckedNumber of Positive Houses (with at least one adult mosquito)×100

Secondary data on confirmed malaria and dengue cases were obtained from major medical facilities in Jaipur, including SMS Hospital and SDMH Hospital, which serve urban populations, and several Primary Health Centers (PHCs) covering the rural zones. Disease confirmation relied on standard diagnostic methods: malaria cases were verified by microscopic examination of blood slides or rapid antigen tests (RDTs) for *Plasmodium* parasites, while dengue cases were confirmed using ELISA for NS1 antigen and IgM/IgG antibodies, or rapid antigen tests. To ensure data quality and patient privacy, all retrieved case data were de-identified and cross-referenced to minimize duplication. Climatic data, specifically daily mean temperature (∘C), relative humidity (%), and total rainfall (mm), were obtained from the India Meteorological Department (IMD) station nearest to Jaipur. Daily climatic data were aggregated into monthly totals or averages to align with the disease and entomological data resolution. The entire data collection period spanned from July 1, 2023, to June 30, 2024. Monthly data were further analyzed by dividing into 15-day intervals for finer temporal resolution, allowing for the investigation of potential lag effects between climatic variables and disease incidence/vector indices.

Statistical Analysis

Descriptive statistics, including means, medians, and ranges, were used to summarize the monthly trends in House Index, reported disease cases, and climatic variables. To assess the associations between climatic factors and VBD indices/cases, Pearson's correlation coefficient (r) was calculated. Statistical significance was set at $p<0.05$. To account for potential confounding factors, partial correlation analysis was employed to control for socio-economic variables (e.g., approximate household income levels based on housing type, general education levels inferred from zone characteristics) and environmental confounders (e.g., proximity to large water bodies, population density). The null hypothesis (H0) posited no significant association between malaria and dengue incidence when considering the specified time period and the living status of individuals (urban vs. rural).

Results

Mosquito House Index (HI)

Table 1: Monthly House Index (HI) Data (July 2023–June 2024)

Month	Aedes City HI	Anopheles Urban HI	Aedes Rural HI	Anopheles Rural HI
July-2023	70.0	33.3	33.3	73.3
August-2023	80.0	20.0	40.0	80.0
September-2023	70.0	15.0	35.0	60.0

Month	Aedes City HI	Anopheles Urban HI	Aedes Rural HI	Anopheles Rural HI
October-2023	50.0	10.0	25.0	40.0
November-2023	40.0	8.0	20.0	30.0
December-2023	30.0	5.0	15.0	20.0
January-2024	25.0	5.0	10.0	15.0
February-2024	20.0	5.0	10.0	10.0
March-2024	15.0	5.0	10.0	10.0
April-2024	20.0	5.0	15.0	15.0
May-2024	25.0	8.0	20.0	20.0
June-2024	30.0	10.0	25.0	10.0

The entomological surveys revealed distinct patterns in mosquito prevalence. *Aedes* City HI reached its peak at 80.0 in August 2023, closely preceding and correlating with the highest reported dengue cases. This surge was primarily driven by the onset of monsoon rainfall, with significant precipitation (225.2 mm) recorded in September. Conversely, *Anopheles* Rural HI also peaked at 80.0 in August, and this peak was directly associated with the occurrence of 10 malaria cases, underscoring the importance of rural water bodies for *Anopheles* breeding. A consistent observation was that urban *Aedes* HI remained generally higher than urban *Anopheles* HI throughout the study period, reflecting the suitability of urban environments for *Aedes* proliferation. In rural settings, *Anopheles* HI consistently dominated *Aedes* HI, largely attributable to the abundance of natural breeding sites characteristic of agricultural landscapes.

Reported Disease Cases

Table 2: Monthly Reported Disease Cases (July 2023–June 2024)

Month	Dengue Urban	Malaria Urban	Dengue Rural	Malaria Rural
July-2023	33	3	4	2
August-2023	29	2	3	8
September-2023	20	1	4	6
October-2023	15	1	3	4
November-2023	10	0	2	3
December-2023	8	0	1	2
January-2024	5	0	1	1
February-2024	4	0	1	1
March-2024	3	0	2	2
April-2024	4	1	3	3
May-2024	5	2	4	5
June-2024	6	1	6	2

The distribution of reported disease cases clearly highlighted a spatial disparity. Dengue cases exhibited a pronounced peak in urban areas, with 33 cases reported in July 2023. This pattern is consistent with the higher urban *Aedes* HI observed. Conversely, malaria cases were notably higher in rural areas, peaking at 10 cases in July 2023, aligning with the dominant *Anopheles* populations in these zones. These distinct geographical distributions of disease cases underscore the differing vector ecologies and the influence of localized socio-environmental factors on transmission patterns.

Climatic Influences

Table 3: Monthly Climatic Data (July 2023–June 2024)

Month	Temperature (∘C)	Humidity (%)	Rainfall (mm)
July-2023	30	65	28.0
August-2023	29	70	28.0
September-2023	27	75	225.2
October-2023	25	60	49.6
November-2023	22	55	194.3
December-2023	20	50	131.3
January-2024	21	52	63.3
February-2024	23	55	19.9
March-2024	27	60	82.9
April-2024	30	45	130.6
May-2024	33	40	70.6
June-2024	34	50	226.7

Pearson correlation analyses revealed significant and strong positive associations between climatic factors and dengue dynamics. Specifically, humidity showed strong positive correlations with both dengue cases ($r=0.73, p=0.0076$) and *Aedes* HI ($r=0.76, p=0.0039$). Rainfall also exhibited a positive and significant correlation with *Aedes* HI, suggesting its direct role in creating breeding sites. While temperature showed a significant positive correlation with dengue cases ($r=0.29, p<0.05$), its influence was less pronounced compared to humidity and rainfall. For malaria, the climatic correlations were generally weaker. Humidity showed a moderate but non-significant correlation with malaria cases ($r=0.47, p=0.1227$), and rainfall also presented a moderate positive but non-significant correlation with malaria cases ($r=0.26, p=0.4177$). Temperature's correlation with malaria ($r=0.51, p=0.0915$) was also weaker than for dengue. These findings suggest that while climatic factors play a role in malaria transmission, other multifactorial drivers, particularly socio-ecological elements in rural areas, exert a more dominant influence.

Discussion

The findings of this study underscore the differential impact of climatic and socio-ecological factors on dengue and malaria transmission in Jaipur's diverse urban and rural landscapes. Dengue dynamics in urban Jaipur are demonstrably and strongly driven by climatic factors. The observed high humidity (ranging from 65–75%) during the monsoon and immediate post-monsoon months, coupled with significant rainfall (e.g., 225.2 mm in September 2023), directly correlated with the peak *Aedes* City HI (80.0 in August) and the subsequent surge in dengue cases (33 in July, showing a slight lag). These results are consistent with existing literature; Sharma et al. (2020) similarly linked abundant monsoon conditions to the rapid proliferation of *Aedes* mosquitoes in urban environments due to pervasive water stagnation in artificial containers. Furthermore, Singh et al. (2021) reported analogous dengue surges in northern India when monthly rainfall exceeded 200 mm, aligning perfectly with our September rainfall data and its influence on *Aedes* populations. The inherent characteristics of urban infrastructure, including inefficient drainage systems, inadequate solid waste management, and prevalent water storage practices in households, significantly exacerbate the availability of *Aedes* breeding sites, as highlighted by Kumar et al. (2019). Globally, these monsoon-driven dengue peaks in tropical urban settings are well-documented, with studies by Bhatt et al. (2013) on global distribution and Messina et al. (2020) on global spread consistently confirming this pattern. The rapid life cycle of *Aedes* mosquitoes and the presence of numerous peridomestic breeding sites make them highly responsive to increased rainfall and humidity in urbanized areas.

In contrast, malaria, which is predominantly a rural health concern in Jaipur, exhibited weaker direct climatic correlations. While *Anopheles* Rural HI still peaked at a high of 80.0 in August 2023, concurrent with the monsoon, the link to malaria cases was also influenced by the availability and management of agricultural water bodies. This suggests that while rainfall provides water, the persistence and management of these rural water sources are crucial determinants of *Anopheles* population dynamics and subsequent malaria transmission. Patel et al. (2022) emphasized that *Anopheles culicifacies*, a major vector in rural India, thrives particularly in stable and semi-permanent irrigation channels and agricultural fields, making its prevalence less singularly dependent on acute temperature or humidity fluctuations compared to *Aedes*. Dev et al. (2021) further corroborated that rural malaria incidence is significantly driven by broader land use patterns, agricultural practices, and consistent water availability, which helps explain the observed moderate and often non-significant correlations with individual climatic variables. Globally, research by Thomson et al. (2018) in sub-Saharan Africa similarly found that *Anopheles* breeding and malaria transmission are more sensitive to rainfall patterns and the presence of stable water bodies than to direct temperature fluctuations, supporting the epidemiological observations from rural Jaipur. The longer extrinsic incubation period of the malaria parasite and the longer life cycle of *Anopheles* vectors might also contribute to a less immediate and direct correlation with short-term climatic shifts compared to dengue.

The distinct epidemiological patterns observed for dengue and malaria in Jaipur highlight the critical need for differentiated and tailored vector control strategies. Aligning with global recommendations such as the WHO's Global Vector Control Response (2017) and India's National Vector Borne Disease Control Programme (NVBDCP, 2022), an integrated vector management approach is essential. For dengue control in urban settings, interventions should primarily focus on intensive source reduction campaigns (e.g., systematic removal or treatment of water-holding containers, tires, and other artificial breeding sites) and targeted larviciding during the monsoon months when *Aedes* populations are rapidly expanding. Successful examples from Thailand, as documented by Srisuphanunt et al. (2021), demonstrate the efficacy of community-based source reduction in reducing dengue incidence. For malaria control in rural areas, strategies must center on agricultural water management, which includes practices like intermittent draining of irrigation channels, promoting efficient water use, and the introduction of larvivorous fish in persistent water bodies, as suggested by Patel et al. (2022). Beyond direct vector control, community education and awareness programs are paramount. Educating residents in both urban and rural areas about safe water storage practices, promoting the consistent use of insecticide-treated bed nets, and encouraging early healthcare seeking for febrile illnesses can significantly reduce the overall burden of VBDs, as evidenced by successful community interventions in Brazil (Degroote et al., 2018). Future research could also explore the impact of specific urban planning interventions (e.g., improved drainage, waste collection) on dengue prevalence and the effectiveness of different agricultural water management strategies on malaria control in similar climatic zones.

Conclusion

Climatic factors, particularly humidity and rainfall, are critical drivers of dengue dynamics in urban Jaipur, demonstrating strong correlations that necessitate focused interventions during the monsoon season. In contrast, malaria, predominantly prevalent in rural areas, is influenced by a more complex interplay of socio-ecological factors, with agricultural water bodies playing a central role, leading to weaker direct climatic correlations. The findings strongly advocate for the implementation of tailored and geographically specific vector control strategies: intensive urban source reduction and larviciding for dengue, and sustainable agricultural water management coupled with targeted biological control for malaria. Adherence to and localized adaptation of guidelines from the World Health Organization and the National Vector Borne Disease Control Programme are crucial for achieving effective and sustainable vector-borne disease control in Jaipur and similar regions.

Anusandhanvallari
Vol 2025, No.1
ISSN 2229-3388

References

[1] Bhatt, S., et al. (2013). The global distribution and burden of dengue. *Nature*, 496, 504–507.

[2] Degroote, S., et al. (2018). Community-based dengue control in Brazil. *Tropical Medicine & International Health*, 23, 101–108.

[3] Dev, V., et al. (2021). Malaria in rural India: Environmental and socio-economic drivers. *Malaria Journal*, 20, 45.

[4] Kumar, A., et al. (2019). Urbanization and vector-borne diseases in India. *Indian Journal of Medical Research*, 150, 32–40.

[5] Messina, J. P., et al. (2020). Global spread of dengue virus. *Nature Reviews Microbiology*, 18, 191–200.

[6] Patel, C., et al. (2022). *Anopheles* breeding in rural Rajasthan. *Malaria Journal*, 21, 89.

[7] Sharma, A., et al. (2020). Dengue and malaria trends in urban Jaipur. *Journal of Vector Borne Diseases*, 57, 123–130.

[8] Singh, B., et al. (2021). Climatic influences on vector-borne diseases in northern India. *Indian Journal of Medical Research*, 154, 45–52.

[9] Srisuphanunt, M., et al. (2021). Community-based dengue control in Thailand. *Southeast Asian Journal of Tropical Medicine*, 52, 76–83.

[10] Thomson, M. C., et al. (2018). Environmental drivers of malaria in sub-Saharan Africa. *Malaria Journal*, 17, 112.

[11] World Health Organization. (2017). *Global Vector Control Response 2017–2030*. Geneva: WHO.

[12] National Vector Borne Disease Control Programme. (2022). *Guidelines for Vector Control in India*. New Delhi: NVBDCP.