

Rainfall and human activities drive *Aedes aegypti* breeding sites infestation and larval density in urban and rural settings of Bobo-Dioulasso in western Burkina Faso

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Abstract

Aedes aegypti, the primary vector of dengue, chikungunya and Zika, breeds mainly in artificial containers around households, and its larval abundance reflects a complex interplay between climate and human practices. In our cross-sectional survey conducted in urban and rural sectors of Bobo-Dioulasso across dry and rainy seasons, entomological indices exceeded WHO epidemic thresholds, with the House Index reaching 66.7% and the Breteau Index ranging from 107 to 147, indicating sustained transmission risk.

Infestation varied markedly by container type. Domestic materials (41.9%), basins (29.4%) and flower pots (28.6%) showed the highest positivity rates, whereas kettles and animal skins were rarely colonized. Notably, although less frequent, terracotta jars, barrels, tires and miscellaneous containers produced more than 70% of all larvae, identifying them as principal production sites. This confirms that structural characteristics of containers, rather than their abundance alone, decisively shape larval habitat suitability.

Seasonality also structured larval dynamics. More containers were positive during the dry season, but mean density was three-fold higher in the rainy season, with rainfall exhibiting a non-linear relationship, intermediate precipitation promoting proliferation. After accounting for climatic variables, urban households consistently harbored higher larval densities, reflecting intensive water storage and inadequate waste management.

Collectively, proliferation is driven by the combined effects of rainfall dynamics and human practices. Container-related structural and ecological factors, type, exposure and organic matter, therefore exert a more pronounced influence on larval productivity than mere container availability. Interventions should prioritize highly productive containers, particularly jars, barrels and tires, by integrating rainfall-based surveillance with community-led source reduction in areas at greatest transmission risk.

Introduction

Arthropod-borne viruses (arboviruses), particularly those transmitted by *Aedes* mosquitoes, constitute an increasing public health concern in sub-Saharan Africa. Among these diseases, dengue is the most prevalent and poses the greatest public health burden, with more than half of the global population at risk and an estimated 100–400 million infections occurring annually [1]. In Burkina Faso, the epidemiology of dengue has changed markedly over the past decade, with successive outbreaks reported in 2016, 2017, and, most notably, in 2023, when the country experienced its largest documented epidemic [2–4]. Recent entomological investigations have identified *Aedes aegypti* as the principal vector responsible for dengue transmission in the country [5, 6].

Aedes aegypti is a highly anthropophilic mosquito that has successfully adapted to human-modified environments, enabling its persistence and expansion in rapidly urbanizing areas[7]. The abundance and distribution of this mosquito are governed by the interaction between climatic conditions and anthropogenic environmental changes.

Rainfall directly influences the availability of breeding habitats by creating both natural and artificial water-holding containers, thereby promoting immature mosquito development [8, 9]. However, anthropogenic activities substantially amplify these effects by increasing the number and diversity of artificial larval habitats. Discarded tires, water storage jars and barrels, plastic containers, metal cans, construction debris and abandoned vehicles provide highly productive breeding sites that can sustain *Ae. aegypti* populations even during prolonged dry periods, when natural aquatic habitats become scarce [7, 10, 11]. In addition, household practices such as domestic water storage, inadequate solid waste management and poor environmental sanitation further enhance larval habitat availability and contribute to persistent vector proliferation.

Bobo-Dioulasso, the second largest city in Burkina Faso provides an ideal setting for investigating the interactions between climatic and anthropogenic drivers of *Ae. aegypti* abundance. Located within the Sudanian climatic zone, the city comprises densely populated urban neighborhoods surrounded by peri-urban and rural communities, creating a pronounced gradient of environmental conditions human activities, and infrastructure [12, 13]. Urban neighborhoods are characterized by high human population density, irregular water supply, widespread domestic water storage and inadequate solid waste management, all of which generate abundant and persistent breeding habitats for *Ae. Aegypti* [6, 12, 14, 15]. Conversely, rural areas are more strongly influenced by seasonal rainfall which creates transient breeding sites such as tree holes and temporary pools while household water storage practices allow vector populations to persist throughout the dry season [16].

Although rainfall and anthropogenic factors are widely recognized as key determinants of *Ae. aegypti* ecology, their combined influence on mosquito abundance has received limited attention in Burkina Faso, particularly across urban-rural gradients. Most previous studies have focused either on seasonal variation of vector populations or upon characterization of breeding habitats without explicitly quantifying the interactive effects of climatic and human-related factors on larval density. Addressing this knowledge gap is essential for developing integrated and context-specific vector control strategies that incorporate both environmental variability and human behavioral determinants [17]. In this study, we investigated the combined effects of rainfall and anthropogenic activities on *Aedes aegypti* density across urban and rural settings in Bobo-Dioulasso, Burkina Faso. Specifically, we quantified larval density and standard entomological indices during the dry and rainy seasons and assessed the influence of climatic variables and container characteristics on larval abundance. Our findings provide evidence to support targeted, context-specific vector control interventions in areas at high risk of arboviral transmission.

Materials and Methods

Study area

The study was conducted in Bobo-Dioulasso (11°11'N, 4°17'W), the second largest city in Burkina Faso, located at Guiriko Region in the southwestern part of the country (Figure 1). The city lies within the Sudanian climatic zone, which is characterized by two distinct seasons: a rainy season extending from May to October and a dry season from November to April. Annual rainfall ranges between 900 and 1,200 mm, while mean annual temperatures vary from 25°C to 32°C. This climatic regime provides favorable conditions for the seasonal development of *Aedes aegypti* populations. Two study sites with contrasting ecological and socio-environmental characteristics were selected to represent urban and rural settings within the city: Sector 6 (urban) and Sector 33 (rural) (Figure 1).

Selection and description of study sites

Urban site (Sector 6)

Sector 6 was selected to represent the urban setting because of its position, planned residential layout, and relatively well-developed urban infrastructure. According to the RGPH 2019, sector 6 has a population of 12,266 and comprises 2,926 households. The area is characterized by paved roads, a formal drainage network for wastewater and stormwater, and access to piped water, electricity, health facilities, schools and municipal waste collection services. Housing is predominantly constructed with cement blocks and arranged in planned residential plots. Despite these urban amenities, numerous artificial water-holding containers capable of supporting *Ae. aegypti* breeding were observed around households including discarded tires, plastic containers, flower pots, blocked drains and domestic water-storage containers. These breeding habitats are largely associated with human activities and urban waste accumulation.

Rural site (Sector 33)

Although administratively part of the city of Bobo-Dioulasso, sector 33 displays ecological and socio-economic characteristics typical of rural settings (limited infrastructure, reliance on water storage, and proximity to vegetated areas). For this reason, we refer to it as a rural site in the present study. According to the RGPH 2019, sector 33 has a population of 27,251 and comprises 5,956 households. Most houses are constructed from traditional materials (banco or adobe) and

potential mosquito breeding habitats consisted of both natural and artificial water-holding sites, including three holes, leaf axils temporary rain-filled puddles, watering troughs, buckets and domestic water-storage containers. Compared with the urban site, aquatic habitats were generally more dispersed and frequently associated with agricultural and household activities.

Rationale for site selection

The two study sites were selected to capture the environmental and anthropogenic heterogeneity that characterizes Bobo-Dioulasso. Sector 6 represents a highly urbanized environment where vector breeding is primarily associated with artificial containers generated by human activities, intensive urbanization, and high population density. Conversely, Sector 33 represents a predominantly rural environment, where mosquito breeding habitats arise from a combination of natural water collections and domestic water-storage practices under conditions of limited infrastructure. Comparing these contrasting settings provides an opportunity to evaluate how rainfall, sanitation infrastructure, waste management, housing characteristics and water-storage practices influence *Aedes aegypti* larval abundance under different ecological and socio-economic conditions within the same metropolitan area (Figure 2). This urban-rural comparison also enables the identification of context-specific determinants of vector proliferation that may inform targeted surveillance and control strategies.

Study design and data collection

Prior to conducting the larval surveys, verbal informed consent was obtained from the head of each household. This study was conducted in two contrasting sites within Bobo-Dioulasso, Burkina Faso: Sector 6 (urban) and Sector 33 (rural). Entomological surveys were carried out during the dry season (February, April, and December 2025) and the rainy season (June, September, and October 2025). Thirty (30) households per site were visited during each survey campaign.

During each survey, every water-holding container found within each visited concession was systematically inspected. All inspected containers were recorded using a tablet equipped with a standardized data collection form specifically designed for this study. For each container, the following data were recorded: sector, concession identifier, container type, presence or absence of water, presence or absence of larvae (including larval stage) or pupae, water source (rainwater, borehole water, or National Office for Water and Sanitation (ONEA) tap water), water clarity (clear, turbid, or purulent), and presence of vegetation around and inside the container. When larvae or pupae were present, they were collected using a pipette or dipper, transferred into a labelled container and transported to the laboratory. Upon arrival at the laboratory, each container was opened by number, emptied and treated to remove impurities. Larval identification was performed using standard morphological keys based on the respiratory siphon: *Anopheles* larvae lack a siphon, *Aedes* larvae possess a short siphon and *Culex* larvae possess a long siphon [18]. After identification, larvae were counted and the count was recorded directly into the tablet.

These data were subsequently used to calculate larval density, entomological indices (Breteau Index, House Index, Container Index) [19] and the density of positive breeding sites per concession.

Data management and statistical analysis

All field data were collected using standardized entomological survey forms and entered into a secure database (Microsoft Excel 2016). Three classical entomological indices were calculated to assess the level of *Aedes aegypti* infestation across sites and seasons:

- Breteau Index (BI): number of positive containers per 100 inspected premises.
- House Index (HI): percentage of premises positive for at least one container with *Aedes* larvae.
- Container Index (CI): percentage of water-holding containers positive for *Aedes* larvae.

All statistical analyses were performed using R software (version 4.3.2) [20], with the significance threshold set at $\alpha = 0.05$. To evaluate the impact of rainfall and anthropogenic activities on larval density, a generalized linear mixed model (GLMM) with a negative binomial distribution was fitted. Larval count was used as the response variable, while site (urban vs. rural), season, rainfall, temperature and humidity were included as fixed effects. Concession ID and collection date were treated as random effects to account for repeated measures. Pearson correlation analysis was conducted to explore relationships among environmental parameters and their association with larval abundance. Differences in mean larval densities across sites and seasons were tested using ANOVA, followed by Tukey’s post hoc comparisons when significant differences were detected.

Results

General description of sampling

A total of 816 water-holding containers were inspected across the study area. The most frequently encountered container types were kettles (19.1%, 95% CI: 16.4-21.8), terracotta jars (18.4%, 95% CI: 15.8-21.1) and barrels (16.1%, 95% CI: 13.6-18.6). Tires (12.0%, 95% CI: 9.8-14.3) and cans (10.7%, 95% CI: 8.6-12.9) also represented a substantial proportion of inspected containers, while watering holes (8.6%), buckets (4.3%), domestic materials (3.8%), flower pots (2.6%), basins (2.1%) and animal skins (0.2%) were less common. Positivity rates varied across container types: terracotta jars (18.0%), barrels (13.0%), tires (21.4%), cans (27.6%), watering holes (21.4%), buckets (22.9%), domestic materials (41.9%), flower pots (28.6%) and basins (29.4%) showed notable proportions of positive containers whereas kettles (5.8%) and animal skins (0%) had the lowest positivity. These findings highlight the heterogeneity of container types and their relative contribution to larval productivity, as illustrated in Table 1.

Table 1: Distribution of inspected water-holding containers by type and positivity status

Container types	Containers				Positive containers			
	Effectif	Proportion (%)	Lower	Upper	Effectif	Proportion (%)	Lower	Upper
kettle	156	19.1	16.4	21.8	9	5.8	16.4	21.8
Teraccotta jar	150	18.4	15.8	21.1	27	18	15.8	21.1
Barrel	131	16.1	13.6	18.6	17	13	13.6	18.6
Tire	98	12	9.8	14.3	21	21.4	9.8	14.3
Can	87	10.7	8.6	12.9	24	27.6	8.6	12.9
watering hole	70	8.6	6.7	10.5	15	21.4	6.7	10.5
bucket	35	4.3	2.9	5.8	8	22.9	2.9	5.8
Domestic materiel	31	3.8	2.6	5.1	13	41.9	2.6	5.1
Flower pot	21	2.6	1.6	3.7	6	28.6	1.6	3.7
Autres	18	2.2	1.2	3.3	5	27.8	1.2	3.3
Bassin	17	2.1	1.1	3.1	5	29.4	1.1	3.1
Animal_skin	2	0.2	0	0.6	0	0	0	0.6

However, positivity rate alone does not reflect true larval productivity. When considering the absolute number of *Ae. aegypti* larvae collected (Table 2), a different pattern emerges. Despite their high positivity rate (41.9%), domestic materials contributed only 84 larvae in total (mean: 2.71 larvae per container), representing a marginal fraction of the overall larval burden. In contrast, terracotta jars yielded the highest total larval count with 604 larvae (mean: 4.03 per container), followed by the "others" category (512 larvae; mean: 28.4 per container, driven by a few heavily infested items), barrels (402 larvae; mean: 3.07 per container) and tires (337 larvae; mean: 3.44 per container). Cans (298 larvae; mean: 3.47) and watering holes (255 larvae; mean: 3.64) also contributed substantially. Together, terracotta jars, others, barrels, and tires accounted for over two-thirds (69.9%) of all larvae collected, despite representing only 46.5% of inspected containers. Conversely, kettles, the most abundant container type (19.1%), had the lowest larval yield (49 larvae; mean: 0.31 per container) confirming their limited role in *Ae. aegypti* production. These findings underscore that targeting interventions based solely on container frequency or positivity may be insufficient; rather, a focus on containers combining high positivity with high larval loads, particularly terracotta jars, barrels, tires and cans should be prioritized for maximum impact on vector reduction.

Table 2: Larval productivity of *Ae. aegypti* by container type

Container type	Inspected	Positive	Total larvae	Mean larvae (SD)	Max larvae	% of total larvae
Terracotta jar	150	27	604	4.03 (13.9)	32	22.9
Others	18	5	512	28.4 (66.7)	87	19.4
Barrel	131	17	402	3.07 (18.4)	25	15.2
Tire	98	21	337	3.44 (10.3)	45	12.8
Can	87	24	298	3.47 (7.64)	38	11.3
Watering hole	70	15	255	3.64 (10.1)	52	9.7
Basin	17	5	107	6.29 (11.8)	38	4.1
Flower pot	21	6	100	4.76 (11.3)	49	3.8
Domestic material	31	13	84	2.71 (4.88)	21	3.2
Bucket	35	8	82	2.34 (5.07)	22	3.1
Kettle	156	9	49	0.31 (1.73)	16	1.9
Animal skin	2	0	0	0 (0)	0	0
Total	816	150	2,83	3.47 (16.1)	87	

The sampling was balanced between the two collection sites, with **396** containers (**48.5%**) from the urban sector (Sector 6_Urban) and **420** (**51.5%**) from the rural sector (Sector 33_Rural). Regarding seasonal distribution, **230** containers (**28.2%**) were examined during the dry season and **586** (**71.8%**) during the rainy season. Of all containers inspected, **150** (**18.4%**) were found positive for *Aedes aegypti* larvae, while **666** (**81.6%**) were negative.

Differences in container use and positivity between study sites

The comparative analysis of container types between rural and urban sites revealed significant differences for certain categories. Flower pots were more frequent in urban areas ($p = 0.01$) and showed higher positivity ($p = 0.03$). Domestic materials were strongly associated with positivity in rural sites ($p < 0.001$). Cans exhibited similar overall distribution ($p = 0.91$) but significantly higher positivity in urban areas ($p = 0.04$). Watering holes were more common in rural sites ($p = 0.03$), though positivity did not differ significantly ($p = 0.79$). Other container types, including barrels, buckets, kettles, terracotta jars, tires and basins, showed no significant differences between sites (Table 3)

Table 3: Distribution of all and positive containers perbsite (Sector 33 Rural vs. Sector 6 Urban) with Fisher’s exact test p -values.

Containers	All containers			Positive containers		
	Sect_33 (Rural)	Sect_6 (Urban)	<i>P_value</i>	Sect_33 (Rural)	Sect_6 (Urban)	<i>P_value</i>
Animal_skin	2	0	0.50	0	0	1.00
Others	11	7	0.48	4	1	0.21
Barrel	76	55	0.11	10	7	0.45
Bassin	6	11	0.22	2	3	1.00
bucket	21	14	0.39	6	2	0.16
Can	44	43	0.91	7	17	0.04
Domestic materiel	18	13	0.47	12	1	0.00
Flower pot	5	16	0.01	0	6	0.03
kettle	79	77	0.86	2	7	0.17
Terracotta jar	71	79	0.28	16	11	0.29
Tire	42	56	0.08	7	14	0.16
watering hole	45	25	0.03	8	7	0.79

Entomological indices

House Index (HI)

The House Index, which expresses the percentage of inspected houses with at least one positive container, showed notable variations between sites and seasons (**Figure 2**). In the rural sector (Sect33_Rural), the HI reached 63.3% during the dry season, before decreasing to 46.7% during the rainy season. In the urban sector (Sect6_Urban), the index remained high and stable, with a rate of 66.7% in both seasons.

Container Index (CI)

The Container Index, which corresponds to the percentage of positive water-holding containers among all containers inspected, revealed a strong seasonality (**Figure 2**). In the rural sector, the CI decreased from 30.4% in the dry season to 11.3% in the rainy season, representing a reduction of approximately 63%. In the urban sector, a similar but more pronounced trend was observed, with a CI of 47.8% in the dry season dropping to 10.5% in the rainy season, a decrease of nearly 78%.

Breteau Index (BI)

The Breteau Index, which represents the number of positive containers per 100 inspected houses, showed very high values across all sites (**Figure 2**). In the rural sector, the BI reached 140 positive containers per 100 houses during the dry season, compared to 107 during the rainy season. In the urban sector, similar values were observed, with 147 during the dry season and 107 during the rainy season.

Larval density, distribution and variability

Analysis of the distribution of *Aedes aegypti* larvae in positive containers revealed marked seasonal differences. In the rural sector, the mean larval density was 8.6 larvae per positive container ($\sigma=10.7$) during the dry season compared to 28.2 larvae ($\sigma=49.1$) during the rainy season, representing a threefold increase.

In the urban sector, a similar trend was observed, with a mean of 12.8 larvae ($\sigma=12.3$) during the dry season versus 31.4 larvae ($\sigma=38.9$) during the rainy season. In both sites, the number of positive containers was higher during the dry season (42 in the rural sector and 44 in the urban sector) than during the rainy season (32 in each site). Notably, the standard deviations were particularly high during the rainy season, reflecting a highly heterogeneous distribution where certain containers harbored a very large number of larvae.

Relationship between rainfall and larval density

A generalized linear model with a Poisson distribution was fitted to assess the effect of rainfall accumulation on the number of *Ae. aegypti* larvae. Rainfall accumulation was treated as a categorical variable, with the 191.5 mm class serving as the reference category against which all other levels were compared. The analysis revealed a complex and non-linear relationship between these two variables. Model coefficients indicated that low rainfall accumulations (1012 mm) were associated with a significant negative effect ($-0.81, p<0.001$), while intermediate accumulations (2485 mm) showed a significant positive effect ($+0.16, p=0.001$). In contrast, very high accumulations (3995 mm) again exhibited a significant negative effect ($-0.44, p=0.001$), whereas the intermediate reference accumulation (191.5 mm) had no significant effect ($-0.0005, p=0.995$). Furthermore, the urban site (Sect6_Urban) was associated with a significantly higher larval density than the rural site ($+0.34, p=0.001$), under equal rainfall conditions. These results suggest that moderate precipitation levels favour larval proliferation.

Discussion

Our findings reveal a high level of *Aedes aegypti* abundance in both urban and rural settings of Bobo-Dioulasso, with all entomological indices (House Index, Container Index, and Breteau Index) substantially exceeding the epidemic risk thresholds recommended by the World Health Organization (WHO). These results indicate widespread vector proliferation and underscore the importance of both environmental and anthropogenic factors in shaping *Ae. aegypti* populations.

Container heterogeneity and larval productivity

The diversity of water-holding containers identified in this study is consistent with previous investigations conducted in Africa [11, 15, 21]. Domestic materials, basins and flower pots exhibited the highest individuals of mosquitoes whereas kettles and animal skins were rarely or never colonized. The low infestation observed in kettles is likely attributable to their frequent use and regular water replacement, which interrupts larval development.

However, container infestation rates alone did not accurately reflect their contribution to *Ae. aegypti* production. When larval abundance was considered, a markedly different pattern emerged. Terracotta jars, despite exhibiting only moderate infestation rates, produced the largest proportion of larvae, accounting for nearly one-quarter of all immature mosquitoes collected. Likewise, barrels, discarded tires and a heterogeneous group of miscellaneous containers contributed disproportionately to total larval production. Overall, these container types accounted for more than 70% of all larvae while representing less than half of the inspected containers. This finding highlights the existence of highly productive breeding habitats, commonly referred to as "super-producer" containers, which disproportionately sustain vector populations [1, 22].

In contrast, several container types with relatively high infestation rates contributed only marginally to overall larval production. Domestic materials, although the most frequently infested containers, yielded comparatively few larvae. Similarly, flower pots and basins supported relatively low larval productivity despite moderate infestation rates. Kettles, although representing nearly one-fifth of all inspected containers, produced very few larvae, confirming their limited epidemiological importance [23, 24].

These findings demonstrate that container abundance or infestation frequency alone is insufficient for identifying the principal sources of vector production. Instead, vector control programmes should prioritize container types that combine high larval productivity with persistent infestation, particularly terracotta jars, barrels, discarded tires, and other large water-storage containers. Such targeted source reduction strategies are increasingly recognized as more effective than non-selective container removal in reducing *Ae. aegypti* populations [21, 25–28].

Building on these observations of larval productivity, it is also important to consider how container type and site context influence the likelihood of positivity.

These findings emphasize the role of specific container types in shaping mosquito breeding risk across different environments. The higher positivity of flower pots and cans in urban areas aligns with studies showing that artificial containers in residential settings are major breeding sites for *Aedes* mosquitoes [29, 30]. Similarly, the strong association of domestic materials with positivity in rural areas reflects the importance of local practices and household waste management in rural vector ecology, consistent with evidence from Sri Lanka where discarded non-degradable items were key breeding sites in rural and semiurban zones [31, 15, 13].

The observed differences highlight the need for context-specific vector control strategies: targeting ornamental and domestic-use containers in urban areas, while focusing on utilitarian and discarded materials in rural settings. This approach is supported by broader research showing that mosquito breeding habitat preferences vary significantly between urban, peri-urban and rural ecosystems influenced by container type, organic enrichment, and human practices [21, 28]. Overall, these results reinforce the importance of tailoring surveillance and control interventions to the ecological and socio-cultural context of each site, ensuring that the most productive container types are prioritized in vector management programs.

Seasonal variation and the influence of rainfall

One of the most important findings of this study is the nonlinear relationship between rainfall and larval density. This relationship was assessed using cumulative monthly rainfall data, which, despite its limitations, revealed clear ecological patterns consistent with the dynamics of container-breeding mosquitoes. Moderate rainfall was associated with increased larval abundance, whereas both limited and excessive rainfall reduced larval densities. This pattern is consistent with the ecological response of container-breeding mosquitoes to precipitation. Moderate rainfall replenishes breeding habitats while maintaining favorable temperature and humidity conditions for egg hatching and larval development. Conversely, prolonged drought reduces the availability of aquatic habitats while intense rainfall may flush immature stages from containers or overflow breeding sites, thereby reducing larval survival [8].

Similar nonlinear relationships between rainfall and *Ae. aegypti* abundance have been reported in several tropical regions and have recently been incorporated into predictive models of dengue transmission [32]. These findings emphasize that rainfall should not be considered solely in terms of total precipitation but also in terms of its temporal distribution and intensity, both of which strongly influence vector population dynamics.

Urban-rural differences in larval abundance

After accounting for climatic variables, urban households consistently exhibited significantly higher larval densities than rural households, despite the similar number of positive containers observed at both sites. This difference reflects the higher mean number of larvae per container in the urban sector compared to the rural sector. This observation suggests that anthropogenic factors substantially amplify the effects of climate on *Ae. aegypti* proliferation.

In our study, both sites are located within the city of Bobo-Dioulasso. Sector 6, characterized by higher population density, more intensive domestic water storage, and greater accumulation of discarded containers, illustrates typical urban conditions that favour persistent breeding habitats. In contrast, sector 33, although administratively part of the city,

displays ecological and socio-economic features more consistent with rural settings. Similar patterns have been documented in Cameroon and elsewhere in sub-Saharan Africa where rapid urbanization has promoted the proliferation of artificial larval habitats and increased the risk of arboviral transmission [33, 11, 34, 15, 35, 13]. In contrast, breeding habitats in sector 33, although administratively part of the city, remain more dependent on seasonal rainfall and are more dispersed. However, the influence of urbanization in this peripheral area also shapes larval dynamics, distinguishing it from typical rural settings.

These results reinforce growing evidence that unplanned urbanization, inadequate sanitation infrastructure, poor solid waste management and household water-storage practices are major determinants of *Ae. aegypti* abundance in African cities.

Entomological indicators and epidemic risk

The entomological indices recorded during this study indicate a persistently high risk of arbovirus transmission in both study sites. The House Index reached 66.7% in the urban sector, while the Breteau Index ranged from 107 to 147 corresponding to two-fold the WHO epidemic alert threshold of 50 [36]. Such exceptionally high values reflect intense household infestation and widespread availability of breeding habitats.

Comparable associations between elevated Breteau Index values and dengue outbreaks have been reported in South America and other endemic regions, where BI values exceeding 100 have frequently preceded epidemic transmission [37–39]. Although entomological indices alone cannot reliably predict dengue outbreaks, the consistently elevated values observed in this study indicate substantial epidemic potential, particularly in densely populated urban neighborhoods where vector–human contact is greatest.

Seasonal aggregation of larval production

An apparently paradoxical finding was that a greater number of containers were positive during the dry season, whereas the mean larval density per positive container was approximately three times higher during the rainy season. This result suggests that the rainy season favors the emergence of a relatively small number of exceptionally productive breeding sites rather than a uniform increase in larval production across all containers.

The large standard deviations observed during the rainy season indicate a highly aggregated distribution of larvae, with a limited number of containers harboring disproportionately large immature populations. Such aggregation is a well-recognized characteristic of *Ae. aegypti* ecology. Focks (2004) estimated that fewer than 20% of available containers may produce more than 80% of the adult mosquito population, a pattern subsequently confirmed in several endemic regions [22, 40].

This aggregation has important operational implications. Rather than attempting to eliminate all water-holding containers, vector control programmes may achieve greater efficiency by identifying and targeting the relatively small number of highly productive breeding sites responsible for sustaining most of the mosquito population. Combining this targeted source reduction approach with rainfall-based surveillance and community engagement could substantially improve the effectiveness and cost-efficiency of dengue vector control programmes in Burkina Faso.

Conclusion

This study demonstrates that *Aedes aegypti* larval abundance in Bobo-Dioulasso is shaped by the combined effects of climatic variability and anthropogenic environmental conditions. Rainfall, container characteristics, and contextual human practices related to water storage and waste management interact to determine the availability and productivity of larval habitats, thereby influencing the spatial and seasonal dynamics of this important arbovirus vector. In our study, human practices were not assessed through direct interviews but inferred from the type, use, and management status of

containers observed during field surveys. Regarding entomological indices House, Container, and Breteau indices observed in both urban and rural settings exceeded the World Health Organization thresholds for epidemic risk, indicating a substantial and persistent potential for the transmission of dengue and other *Aedes*-borne arboviruses. These findings have important implications for integrated vector management in Burkina Faso. Control strategies should be adapted to both seasonal conditions and local environmental contexts. During the dry season, interventions should prioritize the identification and elimination of positive breeding sites, whereas during the rainy season, efforts should focus on highly productive "super-producer" containers that sustain most of the immature mosquito population. Integrating rainfall-based surveillance with community-led source reduction, improved household water storage practices and strengthened solid waste management could further enhance the effectiveness and long-term sustainability of *Ae. aegypti* control programmes. Such targeted, evidence-based interventions will be essential for reducing the risk of arboviral transmission in Bobo-Dioulasso and other rapidly urbanizing cities in West Africa.

Declarations

Ethics approval and consent to participate: This study did not involve live human participants. It consisted exclusively of entomological surveys of *Aedes aegypti* breeding sites in Bobo-Dioulasso. Ethical approval and consent to participate are therefore not applicable. **Consent for publication:** Not applicable

Availability of data and material: The datasets generated during and/or analysed during the current study are available in the Zenodo repository, <https://doi.org/10.5281/zenodo.22099910>

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Figures

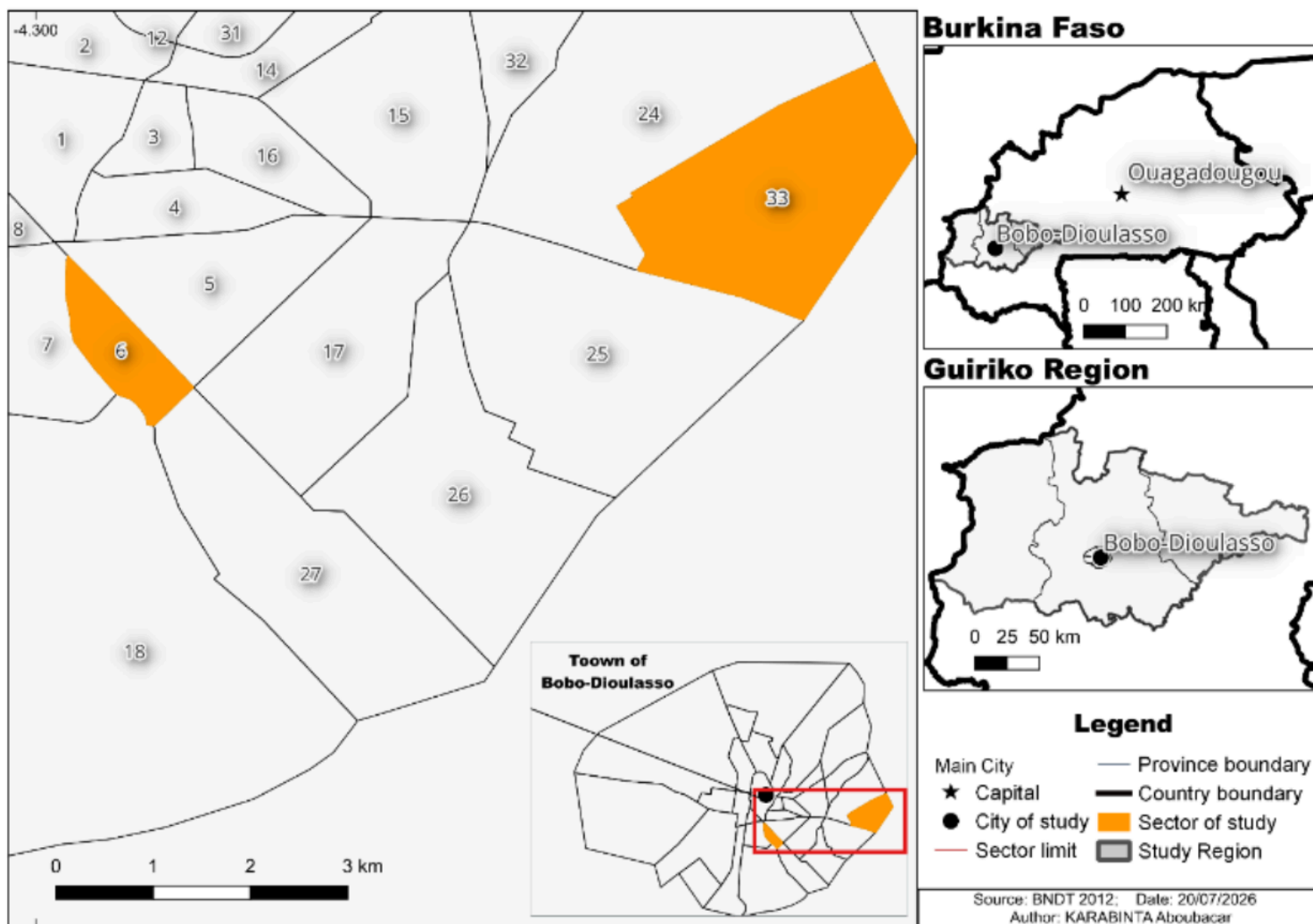


Figure 1

Geographic map of Bobo Dioulasso in the Guiriko Region, Burkina Faso, indicating the two study sites in yellow (A. KARABINTA, 2026)



Figure 2

Photographs showing the configuration of the two study sites (Laouali Zouera)

- A: Urban site: Non-functional breeding sites: waste, worn tires, and small containers (tins)
- B: Rural site: functional breeding sites (human and animal)

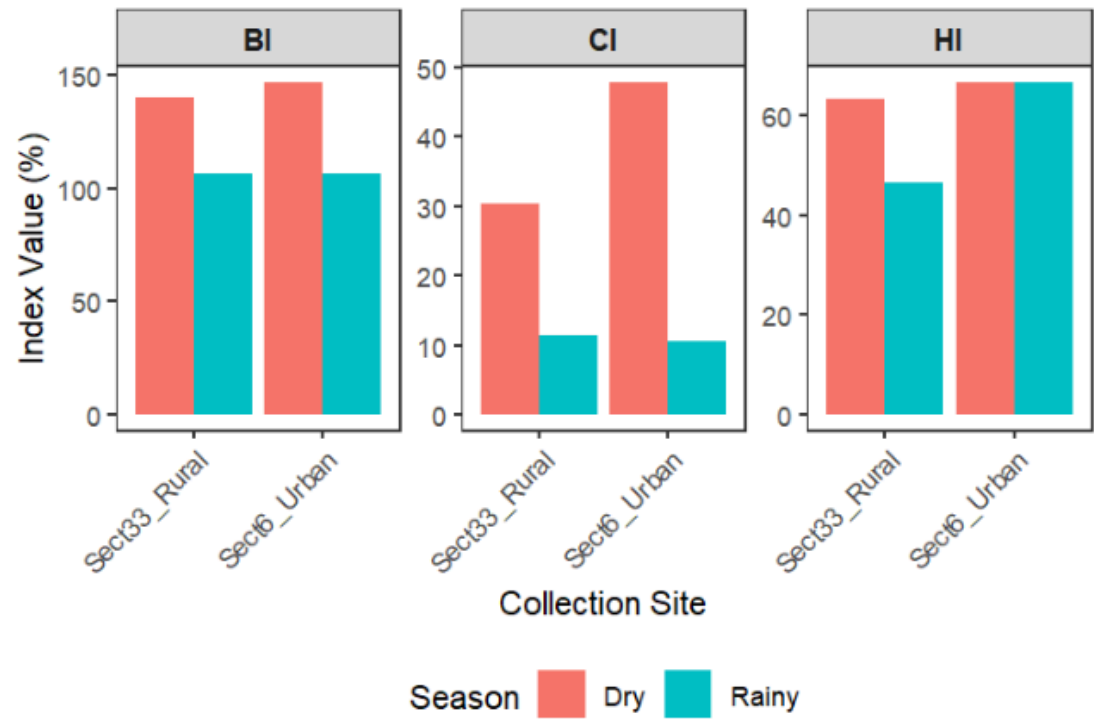


Figure 3

Entomological indices by study site and season

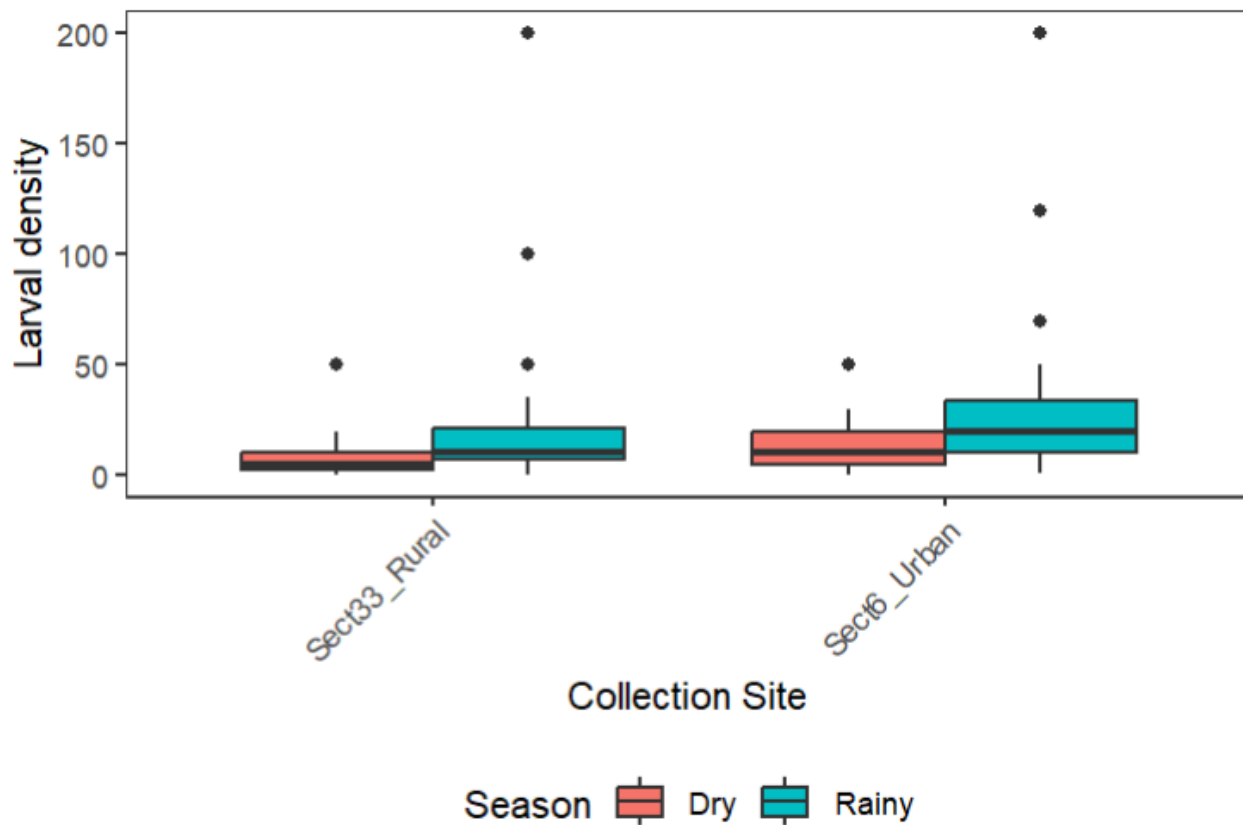


Figure 4

Larval density by study site and season

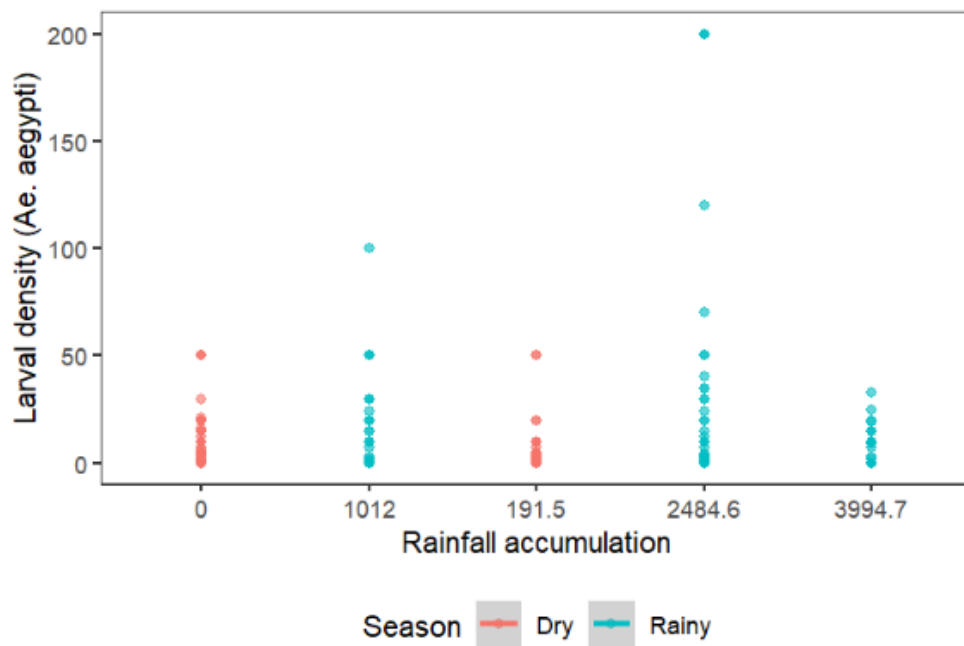


Figure 5

Relationship between rainfall and larval density