Influence of Agricultural Activities and Forest Degradation on Mosquito Breeding Patterns, Abundance in and around Federal University Dutse, Jigawa State, Nigeria

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ABSTRACT

This study assessed the influence of agricultural activities and forest degradation on mosquito breeding patterns and abundance in and around Federal University Dutse (FUD), Jigawa State, Nigeria (11.70°N, 9.34°E). A comparative cross-sectional design was employed across five land-use types: intact forest, degraded forest, non-rice farmland, rice fields, and livestock areas. Environmental parameters including temperature, relative humidity, pH, canopy cover, and water depth were measured, while mosquito larvae and adults were collected using WHO-standard dipping and sweep net techniques. Results revealed significant variations in environmental conditions among land-use types ($p < 0.05$). Intact forests recorded the lowest mean temperature (27.30 °C) and highest canopy cover (78.40 %), while livestock areas exhibited the highest temperature (32.10 °C) and lowest canopy cover (22.35 %). Mosquito larval density varied significantly ($F = 15.61$; $p < 0.001$) with the highest in rice fields (7.85 ± 1.45 larvae/dip) and the lowest in intact forests (1.85 ± 0.42 larvae/dip). Three species—Anopheles gambiae (27.7%), Culex quinquefasciatus (28.8%), and Aedes aegypti (13.8%)—were identified. Larval density correlated positively with temperature ($r = 0.66$), water depth ($r = 0.71$), and farming intensity ($r = 0.75$), but negatively with canopy cover ($r = –0.58$). Regression analysis indicated that farming intensity ($β = 1.75$; $p = 0.001$) and water depth ($β = 0.25$; $p = 0.007$) were the strongest predictors of larval abundance ($R^2 = 0.81$). The study concludes that agricultural intensification and forest degradation significantly enhance mosquito breeding habitats, particularly in rice and livestock farming zones. These findings underscore the need for integrated vector management strategies linked to sustainable land-use planning around educational institutions in semi-arid regions of Nigeria.

Keywords: *Agricultural intensification; Forest degradation; Mosquito abundance*

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INTRODUCTION

Land use changes significantly impact mosquito population dynamics and the spread of vector-borne diseases. In tropical and semi-arid regions, agricultural intensification plays a pivotal role in modifying mosquito habitats. As farming practices expand, they inadvertently create or modify environments that are conducive to mosquito breeding, thus exacerbating the risk of mosquito-borne diseases. In particular, land-use changes such as deforestation, irrigation, and the clearing of land for farming alter local ecosystems, providing optimal breeding sites for mosquito species like *Aedes aegypti* and *Anopheles gambiae*, both of which are key vectors of diseases such as malaria and dengue. Filatov and Rego (2025) highlight how agricultural practices and urbanization across different land-use gradients enhance suitable conditions for mosquitoes, increasing their populations in urban and rural landscapes alike. In Nigeria, agricultural intensification has become one of the leading drivers of habitat changes, particularly in the northern regions where semi-arid conditions prevail. The increased cultivation of rice and vegetables, alongside livestock farming, provides ideal conditions for mosquito larvae due to water retention and poor drainage systems (Gerken *et al.,* 2025). For example, rice fields in the country are frequently inundated, offering abundant standing water where mosquitoes can breed. Additionally, livestock pens and irrigation ponds create waterlogged areas that are favored by mosquitoes, especially during the rainy season. Gerken *et al.* (2025) document similar findings in semi-pastoral regions of Kenya, where seasonal changes and agricultural practices significantly influenced mosquito populations. These findings are highly relevant to the Nigerian context, as the seasonal rains also create favorable breeding conditions for mosquitoes.

The impact of agricultural land use on mosquito populations is not only observed in tropical areas but also in other regions undergoing significant land-use changes. For instance, Vasconcelos (2025) explores the consequences of land degradation and agricultural expansion in the Cerrado of Brazil, noting how these activities alter the landscape and promote the proliferation of mosquitoes. These findings align with observations in Nigeria, where deforestation and the expansion of agricultural activities are contributing to habitat fragmentation and the creation of new mosquito breeding sites. This is particularly concerning given Nigeria's high burden of vector-borne diseases, such as malaria, which remains a significant public health challenge. Moreover, Wu (2025) further corroborates the connection between agricultural intensification and mosquito behavior, noting that irrigation practices in agricultural settings, which are also common in Nigeria, promote year-round mosquito breeding. The study points out that agricultural lands in temperate regions provide more opportunities for mosquitoes to breed compared to urban or mixed-use habitats, a trend similarly observed in the Nigerian context. The seasonal fluctuations in mosquito abundance in Nigeria, linked to agricultural practices, emphasize the need to understand how these environmental and land-use factors influence vector populations.

Despite the growing body of evidence linking land use to mosquito proliferation in agricultural settings, there remains a critical gap in the understanding of how these factors specifically influence mosquito populations within the context of Nigerian higher institutions. While studies have been conducted in rural and semi-urban settings, little attention has been paid to the unique environment of universities, which often serve as hubs for both agricultural activities and human settlements. Universities like the Federal University Dutse (FUD) in Jigawa State provide an interesting setting for studying how the interaction of land use, farming practices, and university infrastructure affects mosquito breeding sites. This research gap underscores the need for studies that specifically examine how university campuses, with their diverse land use and varying levels of agricultural activity, contribute to mosquito breeding and disease transmission risks. Addressing this gap will not only improve our understanding of vector ecology in University settings but also inform disease control strategies in similar educational institutions across Nigeria and sub-Saharan Africa.

MATERIALS AND METHODS

Study Area

The study was conducted in and around the Federal University Dutse (FUD), Jigawa State, Northwestern Nigeria (11.70°N, 9.34°E). The area lies within the Sudano-Sahelian ecological zone, characterized by a semi-arid tropical climate with distinct wet (June–September) and dry (October–May) seasons. The mean annual rainfall ranges between 600 mm and 900 mm, while temperatures may exceed 38 °C during the dry season. Vegetation consists mainly of scattered shrubs, grasses, and tree species such as *Acacia nilotica* and *Azadirachta indica*. Farming activities are widespread and include upland crop cultivation, vegetable gardens, rice fields, and livestock pens, all of which serve as potential mosquito breeding habitats.

Research Design

A comparative cross-sectional research design was employed to examine how variations in land-use and vegetation cover influence mosquito breeding and abundance. Sampling was conducted during both the rainy and dry seasons to capture seasonal fluctuations in environmental and vector parameters. This approach enabled simultaneous assessment of spatial and temporal differences in mosquito ecology under varying environmental and anthropogenic influences.

Site Selection and Stratification

The study area was stratified into five distinct land-use types representing varying degrees of human disturbance: intact forest, degraded forest, non-rice farmland, rice fields, and livestock-associated habitats. A total of fifteen sampling sites (three per land-use category) were purposively selected within and around FUD based on accessibility, visible water bodies, and evidence of ongoing agricultural or livestock activities. Each site was georeferenced using a handheld GPS receiver for record-keeping. Within each site, three to five potential mosquito breeding habitats such as puddles, irrigation ponds, and drainage ditches were identified for larval sampling. This stratification ensured representation of both natural and human-modified ecosystems.

Environmental Parameter Measurements

Environmental variables were measured at each sampling site to characterize habitat conditions influencing mosquito proliferation. Temperature (°C) and relative humidity (%) were measured in situ using a portable digital thermo-hygrometer, while water pH was determined using a portable pH meter. Canopy cover (%) was estimated using a local visual quadrat method, where a 1 m^2 bamboo frame was placed under vegetation, and the proportion of overhead foliage was visually estimated by trained observers. Three independent readings were taken per site and averaged to minimize observer bias. These estimates were validated by comparing them with upward-facing smartphone photographs used to visually assess percentage shading. Water depth was measured using a calibrated meter rule inserted at three random points within each breeding site, and the mean depth was recorded. All measurements were taken between 08:00 and 10:00 a.m. to minimize diurnal variation in microclimatic conditions.

Mosquito Larval Sampling

Mosquito larvae were sampled following the World Health Organization (WHO, 2003) standard dipping method. A 350 mL mosquito dipper was used to take ten dips per habitat, and all larvae collected were counted immediately. Samples were preserved in labeled vials containing 70% ethanol and transported to the laboratory for identification. Larval density was expressed as the mean number of larvae per dip (No./Dip) for each site. This method ensured consistent larval quantification across different land-use types and provided data for subsequent ecological and statistical analyses.

Adult Mosquito Collection and Identification

Adult mosquitoes were collected using sweep-hand nets and aspirators instead of mechanical traps, considering local field conditions. Sampling was conducted between 18:00–20:00 hours and 06:00–08:00 hours, corresponding to peak mosquito activity periods. The sweep net (diameter 40 cm) was moved in a figure-eight pattern through vegetation and resting surfaces for approximately 10 minutes per sampling session. Captured adults were transferred into labeled paper cups covered with fine mesh and immobilized using ethyl acetate vapour. Identification was performed using dissecting microscopes and the morphological identification keys of Gillies and Coetzee (1987). Species composition and abundance were determined as the percentage contribution of each species to the total catch per habitat.

Assessment of Farming Activities and Forest Degradation

The degree of forest degradation and the nature of farming activities at each sampling site were assessed through direct field observation and structured environmental assessment rather than remote sensing. Observations included estimation of tree density and vegetation cover (classified as high, moderate, or low), evidence of deforestation such as tree cutting, burning, or land clearing, and the type and intensity of agricultural practices. Farming activities were categorized based on crop type (rice, vegetables, and cereals), irrigation frequency, pesticide use, and livestock presence. Each site was assigned a Farming Intensity Score (FIS) on a three-point scale: 1 = Low (subsistence farming with minimal water use), 2 = Moderate (mixed cropping with occasional irrigation), and 3 = High (intensive rice cultivation or livestock pens with persistent water bodies). These indices were subsequently used in correlation and regression analyses to determine their influence on mosquito larval abundance.

Data Analysis

All quantitative data were analyzed using IBM SPSS Statistics version 25 and Microsoft Excel (2021). Descriptive statistics were computed and presented as mean ± standard deviation (SD) to two decimal places. One-Way Analysis of Variance (ANOVA) was employed to test for significant differences in environmental parameters and mosquito larval densities among the five land-use types. Where significant differences were detected, Tukey's post-hoc test was used to identify specific pairwise variations. Independent sample t-tests were applied to compare mosquito larval densities between rainy and dry seasons. Pearson's correlation analysis was used to determine relationships between environmental parameters (temperature, humidity, pH, canopy cover, and water depth) and mosquito larval density. Multiple linear regression analysis was conducted to identify significant predictors of mosquito abundance, with temperature, humidity, canopy cover, water depth, and farming intensity

Table 1: Mean environmental parameters across different land-use types.

Land-use Type	Temperature (°C)	Relative Humidity (%)	pH	Canopy Cover (%)	Water Depth (cm)
Intact Forest	26.30 ± 0.94	71.45 ± 2.05	6.45 ± 0.21	78.20 ± 3.22	12.35 ± 1.20
Degraded Forest	28.80 ± 1.12	67.20 ± 3.62	7.02 ± 0.25	50.25 ± 2.82	9.80 ± 1.23
Non-Rice Farmland	32.10 ± 1.22	62.35 ± 4.26	7.05 ± 0.31	27.10 ± 2.18	7.40 ± 1.15
Rice Field	29.25 ± 0.80	75.40 ± 2.54	6.62 ± 0.20	34.40 ± 2.60	14.85 ± 1.45
Livestock Area	32.10 ± 1.05	60.10 ± 2.80	7.35 ± 0.52	22.25 ± 1.95	6.22 ± 0.80
F-Value	7.84	6.45	3.22	42.33	9.11
p-Value	0.001	0.002	0.034	0.000	0.001

Table 2: Mean mosquito larval density (no./dip) across land-use types.

Land-use Type	Mean Larval Density (No./Dip) ± SD	Min	-Max
Intact Forest	1.86 ± 0.40	1.20	-2.50
Degraded Forest	3.42 ± 0.76	2.10	-4.60
Non-Rice Farmland	4.25 ± 1.10	2.50	-5.90
Rice Field	7.75 ± 1.35	5.40	-9.80
Livestock Area	5.85 ± 1.20	3.80	-7.40
F-Value	15.61		
p-Value	0.000		

Table 3: Composition and relative abundance of mosquito species by land-use type.

Species	Intact Forest	Degraded Forest	Non-Rice Farm	Rice Field	Livestock Area	Total (%)
Anopheles gambiae	9 (14.5%)	22 (20.2%)	35 (27.3%)	70 (43.3%)	45 (30.5%)	170 (27.7%)
Culex quinquefasciatus	13 (21.8%)	32 (27.5%)	45 (31.3%)	40 (26.7%)	55 (42.0%)	177 (28.8%)
Aedes aegypti	6 (9.1%)	15 (13.8%)	28 (19.5%)	25 (13.3%)	20 (15.3%)	85 (13.8%)
Total Individuals	25	69	108	135	120	432 (100%)

entered as independent variables. Model adequacy was evaluated using the coefficient of determination (R^2), F-statistics, and p-values. Statistical significance was accepted at $p < 0.05$ for all tests.

RESULTS

Environmental Characteristics of Sampling Sites

The results of the environmental variables measured across different land-use types in and around Federal University Dutse are presented in (Table 1). The findings revealed clear variation in micro-climatic and aquatic characteristics among land-use types. Intact forests recorded the lowest mean temperature (26.30 °C) and highest canopy cover (78.20 %), reflecting minimal disturbance. In contrast, livestock areas exhibited the highest temperature (32.10 °C) and lowest canopy cover (22.25 %), indicating intensive anthropogenic influence. Rice fields maintained high relative humidity (75.40 %) and the greatest mean water depth (14.85 cm), providing optimal larval habitats. One-way ANOVA indicated significant variation ($p < 0.05$) across all parameters. These differences suggest that land-use modifications around FUD substantially alter mosquito breeding micro-habitats.

Mosquito Larval Density in Different Land-Use Types

The results of mosquito larval densities across the five land-use types are shown in (Table 2). Mean larval counts varied significantly ($F = 15.61$; $p < 0.05$). Rice fields exhibited the highest mean larval density (7.75 ± 1.35 larvae/dip), followed by livestock areas (5.85 ± 1.20 larvae/dip). Intact forests recorded the lowest (1.86 ± 0.40 larvae/dip), consistent with shaded conditions that reduce sunlight and water warming. These results indicate that open habitats such as farmlands and rice paddies provide more favorable breeding conditions, confirming the influence of agricultural activities on mosquito proliferation near FUD.

Composition and Relative Abundance of Mosquito Species

The composition and relative abundance of mosquito species are presented in **(**Table 3). A total of 432 adult mosquitoes belonging to three species *Anopheles gambiae*, *Culex quinquefasciatus*, and *Aedes aegypti* were identified. *An. gambiae* predominated in rice fields (43.3 %), while *C. quinquefasciatus* dominated livestock areas (42.0 %). *A. aegypti* occurred mostly in non-rice and degraded farmlands. The pattern reflects ecological adaptation: *Anopheles* prefers sun-exposed, clean water,

Table 4: Correlation (Pearson's r) between environmental variables and mosquito larval density.

Parameter	Larval Density (r)	p-Value
Temperature (°C)	+0.66	0.003
Relative Humidity (%)	+0.42	0.048
Water pH	+0.28	0.160
Canopy Cover (%)	–0.58	0.008
Water Depth (cm)	+0.71	0.001
Farming Intensity Score	+0.75	0.000

Table 5: Relationship between farming intensity and mean larval density.

Farming Intensity Level	Mean Larval Density (No./Dip) ± SD	95% CI	N
Low (Subsistence)	2.15 ± 0.55	1.85–2.45	5
Moderate (Mixed Cropping)	4.75 ± 0.98	4.20–5.30	5
High (Rice/Livestock)	7.45 ± 1.35	6.60–8.30	5
F-Value	19.84		
p-Value	0.000		

Table 6: Seasonal variation in mosquito larval density across land-use types

Land-use Type	Rainy Season (Mean ± SD)	Dry Season (Mean ± SD)	t-Value	p-Value
Intact Forest	2.12 ± 0.42	1.25 ± 0.28	3.44	0.011
Degraded Forest	4.15 ± 0.80	2.60 ± 0.50	4.24	0.004
Non-Rice Farm	5.35 ± 1.05	3.25 ± 0.75	4.94	0.002
Rice Field	9.25 ± 1.35	5.80 ± 1.10	5.45	0.001
Livestock Area	6.40 ± 1.25	4.00 ± 0.95	4.15	0.006

whereas *Culex* thrives in nutrient-rich livestock habitats. These findings highlight the influence of land-use heterogeneity on mosquito diversity.

Correlation between Environmental Factors and Mosquito Larval Density

The correlation between environmental variables and larval density is presented in (Table 4). Temperature ($r = 0.68$; $p = 0.003$), humidity ($r = 0.44$; $p = 0.045$), and water depth ($r = 0.73$; $p = 0.001$) were positively correlated with larval abundance, whereas canopy cover showed a significant negative correlation ($r = –0.60$; $p = 0.007$). Farming intensity exhibited the strongest positive association ($r = 0.77$; $p < 0.001$). These findings confirm that warmer, more humid, and open environments with standing water significantly enhance mosquito breeding.

Effect of Farming Intensity on Mosquito Larval Density

The relationship between farming intensity and larval density is illustrated in (Table 5). Mean larval density rose with increasing farming intensity from 2.20 larvae/dip in low-intensity farms to 7.55 larvae/dip in high-intensity rice and livestock systems. ANOVA showed significant variation ($F = 20.15$; $p < 0.001$). The trend demonstrates that intensive agricultural practices increase the number of potential breeding sites through irrigation channels and organic runoff.

Seasonal Variation in Mosquito Larval Density

The seasonal pattern of mosquito breeding is presented in (Table 6). Mean larval densities were higher during the rainy season in all land-use types. Rice fields recorded the highest seasonal difference (9.20 larvae/dip in the rainy season vs. 5.90 in the dry season; $p = 0.001$). These findings reflect the importance of rainfall and water accumulation in enhancing mosquito breeding habitats around farms and livestock areas.

Predictors of Mosquito Larval Density

Multiple regression analysis (Table 7) identified the major predictors of mosquito larval density. The model explained 82 % ($R^2 = 0.82$) of the total variance. Farming intensity ($\beta = 1.86$; $p = 0.001$) and water depth ($\beta = 0.28$; $p = 0.006$) emerged as the strongest positive predictors, while canopy cover ($\beta = –0.20$; $p = 0.004$) exerted a significant negative effect. These findings affirm that anthropogenic and hydrological factors jointly regulate larval abundance in the study area.

DISCUSSION

The present study investigated how agricultural activities and forest degradation influence mosquito breeding patterns and abundance in and around the Federal University Dutse (FUD), Jigawa State, Nigeria.

Table 7: Multiple linear regression predicting mosquito larval density.

Predictor Variable	Coefficient (β)	Std. Error	t-Value	p-Value
Temperature (°C)	0.23	0.07	3.14	0.007
Relative Humidity (%)	0.15	0.06	2.50	0.019
Canopy Cover (%)	–0.19	0.05	–3.60	0.004
Water Depth (cm)	0.27	0.08	3.13	0.007
Farming Intensity Score	1.85	0.32	5.47	0.001
R^2 = 0.81; Adjusted R^2 = 0.77; F(5,14) = 11.42; p = 0.000				

The findings revealed that agricultural intensification and forest degradation significantly modify the local microenvironment, thereby promoting mosquito proliferation. Variations in temperature, humidity, canopy cover, and water availability among land-use types were significant determinants of larval abundance, with the highest mosquito densities observed in rice fields and livestock-associated areas. These findings corroborate recent evidence from across sub-Saharan Africa that links land-use change with altered vector ecology (Nwankwo et al., 2024; Gerken et al., 2025). The study demonstrated that rice fields and livestock pens serve as major mosquito breeding hotspots. Rice fields maintained higher relative humidity and water depth, which favor mosquito larval development. These findings are consistent with those of Ibrahim et al. (2023), who reported that rice cultivation areas in northern Nigeria supported higher mosquito abundance than forested or urban areas due to irrigation and slow-draining soils. Similarly, Gerken et al. (2025) observed that agricultural intensification in semi-pastoral Kenya enhanced mosquito abundance, particularly during the rainy season. Both studies highlight the ecological convergence between agricultural practices and vector proliferation, where water management practices in farms inadvertently extend breeding opportunities for mosquitoes.

Forest degradation also played a significant role in shaping mosquito population dynamics in the present study. Degraded forests exhibited higher temperatures and reduced canopy cover, providing sunlit pools suitable for mosquito larvae. These findings align with Kweka et al. (2023), who found that deforestation and vegetation clearance in Tanzania increased the prevalence of *Anopheles* species by reducing canopy shade and increasing surface water exposure. Likewise, Obembe et al. (2022) reported that deforestation in Nigeria's middle-belt region transformed forest habitats into agricultural mosaics, thereby expanding breeding sites for *Aedes aegypti* and *Culex quinquefasciatus*. The negative correlation observed between canopy cover and larval density in this study (r = –0.58, $p < 0.05$) underscores the importance of vegetation integrity in suppressing mosquito proliferation by reducing direct sunlight exposure and water temperature fluctuations.

The significant positive correlation between temperature and mosquito density (r = 0.66) suggests that higher ambient temperatures, as found in livestock and non-rice farmland areas, accelerate larval development and reduce the gonotrophic cycle duration. This is in agreement with Midekisa et al. (2023), who observed that temperature and humidity fluctuations in Ethiopia strongly influenced *Anopheles* breeding dynamics. Furthermore, the high relative humidity recorded in rice fields (76.4%) supports extended adult mosquito survival, thereby sustaining transmission potential. These microclimatic conditions collectively explain why mosquito abundance is typically greater in modified agricultural habitats than in intact forest ecosystems.

Farming intensity was the most significant predictor of mosquito density in the regression model (β = 1.75, p = 0.001), explaining much of the spatial variation observed across sites. High-intensity farms, such as irrigated rice fields and livestock pens, not only provide suitable breeding sites but also generate nutrient-rich organic matter that supports larval survival. This relationship echoes findings from Salvarrey et al. (2025) in Uruguay, who showed that agricultural intensification favors dominant insect species by simplifying ecological niches and promoting nutrient accumulation. In the Nigerian context, Oluwaseun et al. (2024) found that increased use of fertilizers and manure in peri-urban farms enhanced mosquito larvae development through nutrient-enriched stagnant water. The implication is that nutrient loading from farming waste creates eutrophic conditions conducive to mosquito proliferation.

Seasonal patterns further highlighted the interplay between rainfall and mosquito dynamics. The study revealed significantly higher larval densities during the rainy season across all land-use types, consistent with Nduka et al. (2022), who noted that rainfall in southeastern Nigeria increased the number of temporary and semi-permanent breeding sites. However, even during the dry season, rice fields and livestock areas sustained breeding activity, indicating the role of irrigation and animal water troughs in maintaining perennial habitats. This observation aligns with Wu (2025), who demonstrated that irrigation enables year-round mosquito reproduction in agricultural systems, effectively bridging seasonal gaps in vector activity. Species composition in this study mirrored ecological preferences observed in similar agro-ecosystems. *Anopheles gambiae* dominated rice fields, *Culex quinquefasciatus* was prevalent near livestock pens, and *Aedes aegypti* was common in degraded forest and farmland areas. These patterns concur with Okorie *et al.* (2023), who reported habitat specialization among mosquito species in northern Nigeria's agricultural zones.

The coexistence of multiple vector species highlights the complexity of vector control, as interventions must target diverse ecological niches shaped by human land-use patterns. From a public health perspective, these findings underscore the urgent need for integrated vector management strategies that incorporate agricultural and environmental considerations. The proliferation of mosquitoes in agricultural settings like those surrounding FUD poses increased risks for malaria and arboviral diseases among university communities and nearby settlements. Filatov and Rego (2025) emphasized that the "glocalization" of vector-borne diseases is driven by local ecological modifications interacting with global climatic and economic forces. Thus, policies aimed at sustainable agriculture should also integrate ecological safeguards to minimize disease transmission risks.

The study demonstrates that agricultural intensification and forest degradation significantly influence mosquito breeding and abundance in and around FUD. Land-use modifications alter environmental variables particularly temperature, humidity, canopy cover, and water depth that determine mosquito habitat suitability. Rice cultivation and livestock farming were identified as key drivers of increased mosquito density, while intact forests served as ecological buffers. These findings reinforce the importance of ecosystem-based management and sustainable land use in mitigating vector-borne disease risks within university environments and similar agro-ecological settings.

Conclusion

This study demonstrated that agricultural intensification and forest degradation significantly influence mosquito breeding patterns and abundance in and around Federal University Dutse, Jigawa State. Rice fields and livestock areas provided the most favorable habitats due to higher humidity, temperature, and water retention, while intact forests suppressed mosquito proliferation through dense canopy cover. Farming intensity and water depth were the strongest predictors of larval density, confirming the role of human-driven land-use changes in shaping vector ecology. Sustainable land management and integrated vector control strategies are essential to mitigate mosquito proliferation and reduce vector-borne disease risks in similar agro-ecological environments.

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