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Assessing the Spatial Clustering and Temporal Trends of Dengue Outbreaks in Jhapa District, Nepal

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Abstract

This study investigates the spatio-temporal distribution of dengue fever in Jhapa District, Nepal, an area increasingly affected by vector-borne diseases due to urbanization, climate variability, and environmental conditions. Using Geographic Information System (GIS) tools, secondary health data from 2019 to 2024, and field observations, the study identifies key hotspots of dengue incidence and mosquito breeding sites across 15 local levels. The findings reveal that urban municipalities such as Birtamod and Damak have the highest concentration of confirmed dengue cases, correlating strongly with the presence of outdoor breeding containers like ponds, garages, and pump stations. Statistical analysis shows a significant positive correlation ($r = 0.861$, $p < 0.01$) between the number of breeding containers and reported cases. The study concludes that dengue has transitioned from a seasonal to an endemic threat in the district, calling for urgent, targeted vector control strategies, improved environmental management, and sustained community engagement to mitigate future outbreaks.

Keywords: *Dengue fever, Aedes mosquitoes, vector-borne disease, spatial distribution, breeding sites, urbanization.*

Introduction

Dengue is a mosquito-borne viral infection caused by the dengue virus (DENV), which includes four distinct but closely related serotypes: DENV-1, DENV-2, DENV-3, and DENV-4. This disease is primarily transmitted by the female Aedes aegypti mosquito, though Aedes albopictus may also act as a secondary vector (World Health Organization [WHO], 2023). Infection results in dengue fever, characterized by high fever, severe headaches, retro-orbital pain, joint and muscle pain (commonly referred to as "breakbone fever"), skin rash, and mild bleeding manifestations. In severe cases, it can progress to dengue hemorrhagic fever or dengue shock syndrome, which may lead to plasma leakage, severe bleeding, multi-organ failure, and death (Halstead, 2007).

The historical origins of dengue can be traced back to Chinese medical texts from 265 to 420 AD, which described a dengue-like illness known as “water poison,” likely spread by flying insects (Gubler, 1998). The first recorded global outbreaks occurred simultaneously in Asia, Africa, and North America during the 1780s, indicating the worldwide presence of the disease even then (Mackenzie, Gubler, & Petersen, 2004). The role of mosquitoes in the transmission of dengue was confirmed experimentally in 1906, and the virus itself was first isolated in 1943 from United State military personnel stationed in the South Pacific during World War II (Gubler, 1998). In the 1950s, severe forms of the disease dengue hemorrhagic fever and dengue shock syndrome were first identified during outbreaks in the Philippines and Thailand, coinciding with the discovery of all four virus serotypes (Halstead, 2007).

Dengue has since become a major global public health concern, especially in tropical and subtropical regions. It is now endemic in over 100 countries across Asia, the Pacific, the Americas, Africa, and the Caribbean (WHO, 2023). WHO estimates that around 390 million dengue infections occur annually, of which approximately 96 million are clinically apparent (WHO, 2023). Factors such as rapid urbanization, international travel, population growth, and climate change have all contributed to the rapid spread and increasing frequency of dengue outbreaks (Mackenzie et al., 2004). Despite intensive research, no specific antiviral treatment exists for dengue, and prevention continues to rely on mosquito control and public health interventions. Vector-Borne Disease is a disease that results from an infection transmitted to humans and other animals by blood-feeding arthropods, such as mosquitoes, ticks, and fleas. Other viral diseases transmitted by vectors include chikungunya fever, Zika virus fever, yellow fever, West Nile fever, Japanese encephalitis (all transmitted by mosquitoes), and tick-borne encephalitis (transmitted by ticks) (WHO, 2020). Despite its largely mountainous terrain, Nepal is afflicted with five VBDs, namely malaria, lymphatic filariasis (LF), Japanese encephalitis (JE), visceral leishmaniasis (VL) (also known as kala-azar) and dengue fever (DF). The World Health Organization (WHO) has declared dengue fever an endemic in over 100 countries, most of which are in tropical and subtropical regions of the world, including Southeast Asia, South America, and parts of Africa. The dengue threat is highest in Asia and the Americas, with Southeast Asia and the Western Pacific region accounting for over 70% of the global dengue statistics.

Dengue is an arthropod-borne viral disease caused by the flavivirus DENV, which is spread by the mosquito vectors Aedes aegypti and Aedes albopictus. The dengue virus has four serotypes: DENV1-4. According to the most recent reports from the World Health Organization (WHO), dengue fever is endemic in 128 countries worldwide and poses a risk and threat to 3.6 billion people. The flavivirus is estimated to infect more than 350 million people each year. Dengue is primarily a tropical disease that thrives in warmer climates, but it is also endemic in subtropical and colder climates. Nepal is one of the countries where Dengue fever is endemic, and there has been an increase in cases since September 28th.

Approximately 80% of the world's population is at risk of one or more vector-borne diseases (VBDs) that are only spread by mosquitoes. Natural disasters can vary in frequency and magnitude, and they are defined as the abnormal intensity of severe weather, including flooding, hurricanes, tropical cyclones, tsunamis, monsoons, earthquakes, and more. Rapid-onset disasters, in particular, pose a number of risks to public health, including emerging and reemerging infectious diseases (Emch et al., 2017). Dengue virus (DENV) is the most significant mosquito-borne viral infection in humans, causing subclinical (inapparent) or clinically apparent cases ranging from mild fever to severe dengue hemorrhagic fever or shock syndrome. The factors determining disease severity remain unclear, though antibody responses are thought to play a role. A pediatric cohort study in Colombo, Sri Lanka, involving 799 children over a year, aimed to examine these responses. Results showed high dengue transmission with a sero-prevalence of 53.07% and infection incidence of 8.39 per 100 children annually. Findings revealed differences in antibody responses between primary and repeat infections and linked cross-neutralizing responses to reduced disease severity, aiding vaccine development efforts (Corbett, K. S., 2014).

Dengue was first reported in Nepal in 2004, with the earliest confirmed outbreak occurring in Chitwan district in the lowland Terai region (Pun, 2011). The disease gradually spread across the Terai and into the hill regions, with periodic outbreaks increasing in both frequency and intensity. Initially, the disease was considered a seasonal and localized issue, particularly in the warmer, lower-altitude regions. However, in subsequent years, cases were detected in Kathmandu Valley and other hilly regions, indicating a significant geographic expansion likely driven by climate change, urbanization, population movement, and the adaptation of Aedes mosquitoes to cooler climates and higher elevations (Dewan et al., 2016). By 2010, dengue had become endemic in many parts of Nepal, and outbreaks began occurring almost every year, with major surges in 2010, 2013, 2016, 2019, and 2022. The 2019 outbreak was particularly severe, with over 17,000 confirmed cases reported from 68 out of 77 districts, including thousands from Kathmandu Valley, a region previously considered less prone to mosquito-borne diseases (MoHP, 2020). In 2022, Nepal faced its largest-ever outbreak, with over 54,000 confirmed cases and dozens of fatalities reported nationwide, severely affecting both urban and semi-urban areas (WHO, 2022). This marked a turning point in national awareness of dengue as a year-round public health concern rather than a seasonal or localized epidemic.

The increasing trend of dengue outbreaks in Nepal is closely linked to changing environmental conditions, unplanned urban growth, ineffective vector control, and increased travel and trade. Public health authorities have since initiated vector surveillance, awareness campaigns, and diagnostic improvements, although challenges in prevention and control remain significant due to limited resources and a lack of sustained community engagement.

Objectives

This study aims to assess the spatial distribution and current condition of dengue disease in Jhapa District, Nepal, considering the rising global concern over vector-borne disease. It seeks to identify the key locations that act as bridging points for dengue vectors and to compare reported dengue cases between the years 2020 and 2024 B.S. and to analyze temporal changes in the prevalence and spread of the disease in the district.

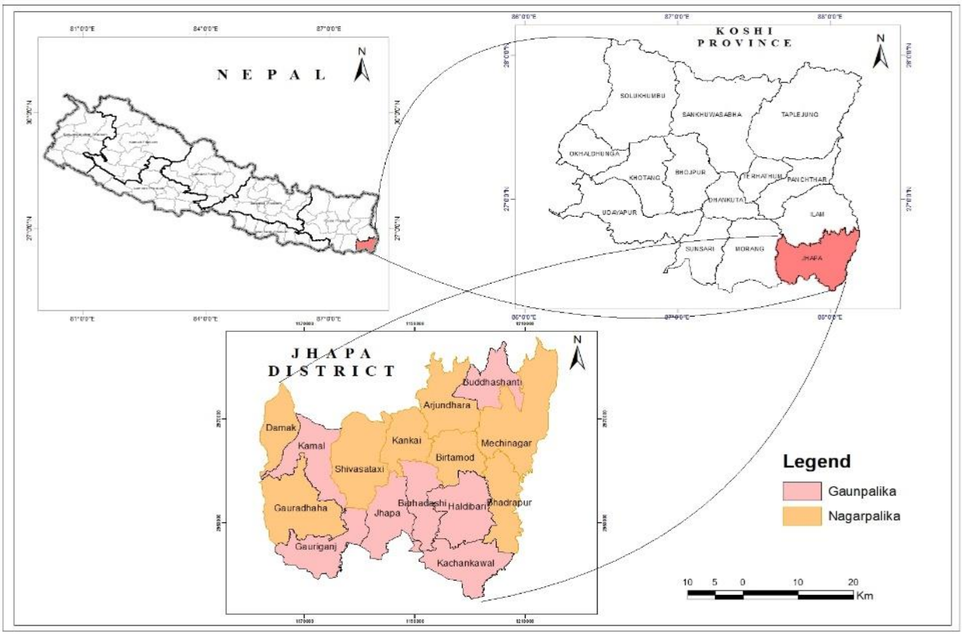
Methods and materials

Jhapa, a densely populated district in the eastern Tarai region of Nepal, lies between 26° 21' 40” N to 26° 48' 21” N latitude and 87° 38' 8” E to 88° 11' 16” E longitude. The district encompasses 15 administrative divisions, including eight municipalities and seven rural municipalities (fig 1).

Characterized by a subtropical monsoon climate and predominantly plain topography, Jhapa is strategically connected via the east-west highway and the north-south corridor linking it to hill and mountain districts. This study investigates the spatio-temporal distribution of dengue in Jhapa District using a mixed-method approach comprising spatial analysis, secondary data review, and field verification. Quantitative data on dengue incidence for the years 2020 to 2024 A.D. were obtained from the Epidemiology and Disease Control Division (EDCD) and local health offices. Spatial analysis was conducted using Geographic Information System (GIS) tools to map the distribution of cases and identify hotspots. Dengue case locations were geocoded, and clustering patterns analyzed. Field visits and consultations with local health workers helped to identify vector breeding sites, particularly in high-incidence areas. Year-on-year differences were assessed through descriptive statistics and comparative analysis. Environmental correlations were explored using satellite imagery and land use maps, focusing on factors such as urban density, water bodies, and vegetation cover. Ethical standards were upheld by utilizing only publicly available and anonymized health data.

Figure 1

Study area



Results and discussion

Results

City-level man-made water bodies such as ponds, tanks, and treatment plants are commonly used for firefighting, groundwater recharge, rainwater harvesting, drinking water storage, irrigation, fisheries, and recreation. These artificial water sources often serve as breeding grounds for Aedes aegypti, which prefers containers like plastic drums, buckets, and discarded tires. In contrast, Aedes albopictus is generally a rural species breeding in natural habitats such as bamboo stumps and tree holes, but it can adapt to artificial containers when available (Barbazan et al., 2008; Oli et al., 2024). Dengue vectors have been recorded at elevations up to 2,438 meters, showing high adaptability (Barbazan et al., 2008). Common breeding environments include pump stations, garages, swamps near paddy fields, and institutional areas where stagnant water collects. Vegetation zones such as deciduous forests and horticultural areas further support mosquito breeding by maintaining moisture and providing shelter. Warm and humid climates especially temperatures between 26-30°C and humidity above 60% are ideal for vector development. Additionally, monsoonal rainfall, particularly between May and September, with contributions from the northeast monsoon in winter, significantly increases breeding habitats and the risk of dengue transmission (WHO, 2023; Emch et al., 2017). Laboratory-confirmed daily dengue cases based on immunoglobulin M tests were obtained and summarized at the ward level from the District Public Health Office, Jhapa, Nepal. GIS layers (administrative boundaries, land use, water bodies) were obtained from NGIIP (http://www.ngiip.gov.np/) and processed using the Modified UTM projection; 2021 population data came from Nepal's Central Bureau of Statistics. Jhapa's climatic classification, as per Thornthwaite's method, ranges from humid to per-humid based on the moisture index and is considered mega-thermal based on thermal efficiency. The region's climate data, collected from five stations, revealed that Jhapa experiences relatively warmer temperatures compared to other parts of Nepal, with a temperature gradient from west to east. The average annual temperature ranges from 16.4°C in winter to 41°C in summer, peaking just before the monsoon season. Jhapa receives 250-300 cm of rainfall annually, primarily during the monsoon, with more precipitation in the hilly north than in the southern plains. The district exhibits five distinct seasons, with the monsoon being the warmest. Jhapa's elevation ranges from 58 m the lowest point in Nepal to 500 m, although mosquito breeding can occur up to elevations of 2400 m MSL. These environmental and climatic factors provide a foundational context for understanding the spatial and temporal distribution of dengue within the district.

Spatial distribution of dengue disease in Jhapa District

Dengue fever in Jhapa District, Nepal is spatially clustered and heterogeneous. This means that dengue cases are identify in the clinical test are the not randomly distributed, but are concentrated in certain areas.

The spatial distribution of dengue cases in Jhapa District reveals significant heterogeneity, with dengue incidence highly concentrated in certain local levels. Among all, Birtamod Municipality exhibits the highest dengue burden, with 5,880 tests resulting in 1,976 confirmed cases, and the largest number of breeding containers (71).

Table 1

Spatial variation in dengue testing, confirmed cases, and vector breeding sites across local levels in Jhapa district, Nepal

S. N.	Local Level	No. Household	Total Population	Number of Tests	Total Dengue	No of Breading Container
1.	Arjundhara Municipality	20935	84018	344	102	11
2.	Barhadashi Gaunpalika	9035	37946	16	23	29
3.	Bhadrapur Municipality	17329	70913	1026	293	38
4.	Birtamod Municipality	29852	116192	5880	1976	71
5.	Buddhashanti Gaunpalika	13285	53010	470	39	10
6.	Damak Municipality	27569	107227	8432	1909	37
7.	Gauradaha Municipality	14846	60451	74	18	131
8.	Gauriganj Gaunpalika	8547	35506	107	13	40
9.	Haldibari Gaunpalika	7878	32722	507	158	87
10.	Jhapa Gaunpalika	8515	39302	239	35	23
11.	Kachanakawal Gaunpalika	9946	41317	75	1	1
12.	Kamal Gaunpalika	13165	53894	254	27	77
13.	Kankai Municipality	13169	53148	957	125	23
14.	Mechinagar Municipality	32695	133073	290	163	49
15.	Shivasatakshi Municipality	18253	74077	213	36	101
	Total	245019	992796	18884	4918	728

Source: *District Health Office vital Record, 2022.*

Damak Municipality follows closely, recording 8,432 tests and 1,909 dengue cases, indicating both municipalities as critical hotspots. Other municipalities such as Bhadrapur and Mechinagar also report elevated numbers, with 293 and 163 cases respectively. In contrast, rural areas like Kachanakawal Gaunpalika show minimal impact, with only 1 dengue case and 1 breeding container despite a population of over 41,000. Interestingly, Gauradaha Municipality, while recording only 18 dengue cases from 74 tests, reports a disproportionately high number of breeding containers (131), suggesting potential future risk if not addressed. Haldibari and Kamal Gaunpalika also show a high density of breeding containers (87 and 77, respectively) with moderate case counts, warranting vector control interventions. Overall, out of 18,884 tests conducted district-wide, 4,918 dengue cases were confirmed, and 728 mosquito breeding containers were identified. These figures highlight the urgent need for targeted vector control, especially in urbanized and densely populated municipalities where dengue clusters are most prevalent.

Dengue vector bridging's center

Container materials that support dengue vector breeding were classified into eight categories: concrete, plastic, natural, clay, ceramic, rubber, glass, and miscellaneous (e.g., tin, paper-based materials). Containers were also categorized by placement as either indoor or outdoor. Among the surveyed breeding sources, four major types of outdoor breeding sites were identified: garages (40), pump stations (16), ponds (655), and swamp areas (17), totaling 728 containers (table 2). The data indicate that Birtamod Municipality had the highest number of containers (71), including 21 garages, 8 pump stations, 41 ponds, and 1 swamp area. This corresponds with the highest number of confirmed dengue cases (1,976) in the district, suggesting a strong correlation between breeding sites and disease incidence. Damak Municipality, which reported the second-highest dengue cases (1,909), had 37 breeding containers, mainly from garages (11), pump stations (4), and ponds (22). Gauradaha, Kamal, and Haldibari Gaunpalikas also exhibited significant breeding sites, mostly from ponds, with 130, 76, and 87 containers respectively, though their dengue case numbers were comparatively lower possibly indicating under-testing or emerging risk zones. Mechinagar Municipality, despite having 49 breeding sites, had 163 confirmed cases, while Shivasatakshi had 101 breeding containers but only 36 cases, suggesting variable transmission risk based on other environmental or behavioral factors.

Table 2

Distribution of key outdoor dengue vector breeding containers by local level in Jhapa district, Nepal

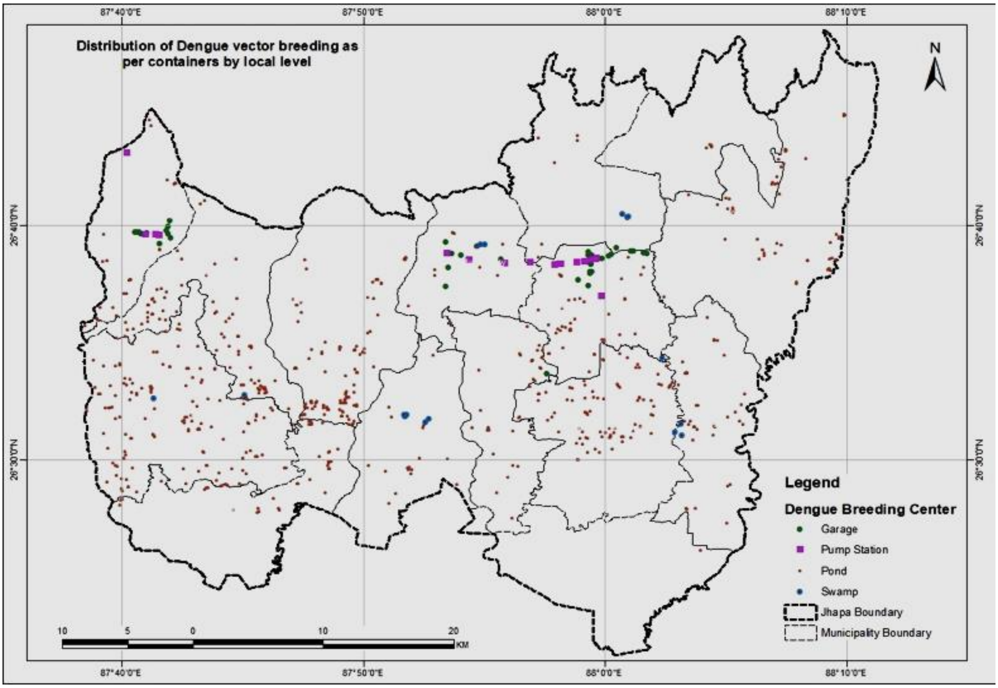
SN	Local Level/ Container type	Garage	Pump Station	Pond	Swamp	Total
1.	Arjundhara Municipality	1	1	6	3	11
2.	Barhadashi Gaunpalika	1	0	28	0	29
3.	Bhadrapur Municipality	0	0	35	3	38
4.	Birtamod Municipality	21	8	41	1	71
5.	Buddhashanti Gaunpalika	0	0	10	0	10
6.	Damak Municipality	11	4	22	0	37
7.	Gauradaha Municipality	0	0	130	1	131
8.	Gauriganj Gaunpalika	0	0	40	0	40
9.	Haldibari Gaunpalika	0	0	87	0	87
10.	Jhapa Gaunpalika	0	0	18	5	23
11.	Kachanakawal Gaunpalika	0	0	1	0	1
12.	Kamal Gaunpalika	0	0	76	1	77
13.	Kankai Municipality	6	3	11	3	23
14.	Mechinagar Municipality	0	0	49	0	49
15.	Shivasatakshi Municipality	0	0	101	0	101
	Total	40	16	655	17	728

Sources: *District Health Office vital Record,2022*

The study indicates that Aedes aegypti mosquitoes typically have a flight range of 100-500 meters (McDonald, 1977; Trpis & Hausermann, 1986; Muir & Kay, 1998), significantly less than some other species like Aedes taeniorhynchus, which can disperse up to 10 km (Provost, 1957). Therefore, a 500-meter buffer around these breeding containers -especially ponds can be considered the suspected risk zone, with households located within this buffer being potentially at risk of dengue transmission (figure 2).

Figure 2

Distribution of key outdoor dengue vector breeding containers by local level



Temporal and spatial patterns of Dengue

The distribution of dengue cases across Jhapa District between 2019 and 2024 reveals marked spatial clustering and temporal fluctuations (fig 3). A total of 7,023 dengue cases were reported over the six-year period, with significant concentration in a few urban municipalities (Table 3).

Table 3

Temporal and spatial patterns of dengue (2019 and 2024)

S N	Local Level	Years						
		2019	2020	2021	2022	2023	2024	Total
1.	Arjundhara Municipality	51	49	3	5	186	19	313
2.	Barhadashi Gaunpalika	0	0	0	7	35	8	50
3.	Bhadrapur Municipality	2	0	0	1	38	1	42

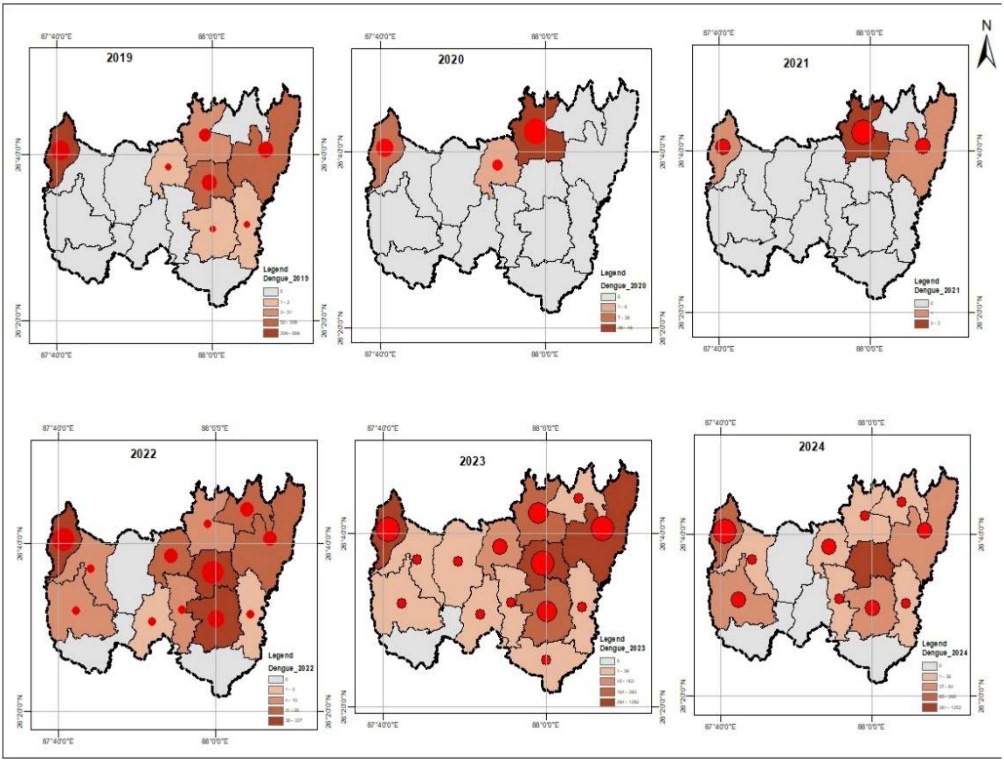
4.	Birtamod Municipality	131	0	0	227	1080	1252	2690
5.	Buddhashanti Gaunpalika	0	0	0	35	33	15	83
6.	Damak Municipality	688	38	1	337	1292	260	2616
7.	Gauradaha Municipality	0	0	0	10	23	64	97
8.	Gauriganj Gaunpalika	0	0	0	0	0	0	0
9.	Haldibari Gaunpalika	200	0	0	80	177	47	306
10.	Jhapa Gaunpalika	0	0	0	2	15	0	17
11.	Kachanakawal Gaunpalika	0	0	0	0	1	0	1
12.	Kamal Gaunpalika	0	0	0	6	20	3	29
13.	Kankai Municipality	2	6	0	34	56	36	134
14.	Mechinagar Municipality	208	0	1	34	320	64	627
15.	Shivasatakshi Municipality	0	0	0	0	18	0	18
Total		1084	93	5	778	3294	1769	7023

Source: *District Health Office vital Record, 2025*

Birtamod Municipality recorded the highest cumulative cases (2,690), followed closely by Damak Municipality with 2,616 cases. These two urban centers accounted for more than 75% of all dengue cases in the district. The spike in Birtamod began in 2022 (227 cases) and escalated rapidly in 2023 (1,080 cases) and 2024 (1,252 cases). Damak similarly experienced a sharp rise, peaking at 1,292 cases in 2023. These trends suggest a strong correlation between urban density, stagnant water sources, and rapid vector proliferation in these areas. Urban infrastructure such as unmanaged construction sites, improper waste disposal, and household water storage likely contributed to the increased mosquito breeding environments. Conversely, rural municipalities like Gauriganj and Kachanakawal reported negligible cases zero and one respectively, throughout the six years period. This may indicate either low transmission rates due to environmental or socio-economic factors, or underreporting due to limited access to diagnostic and health services.

Figure 3

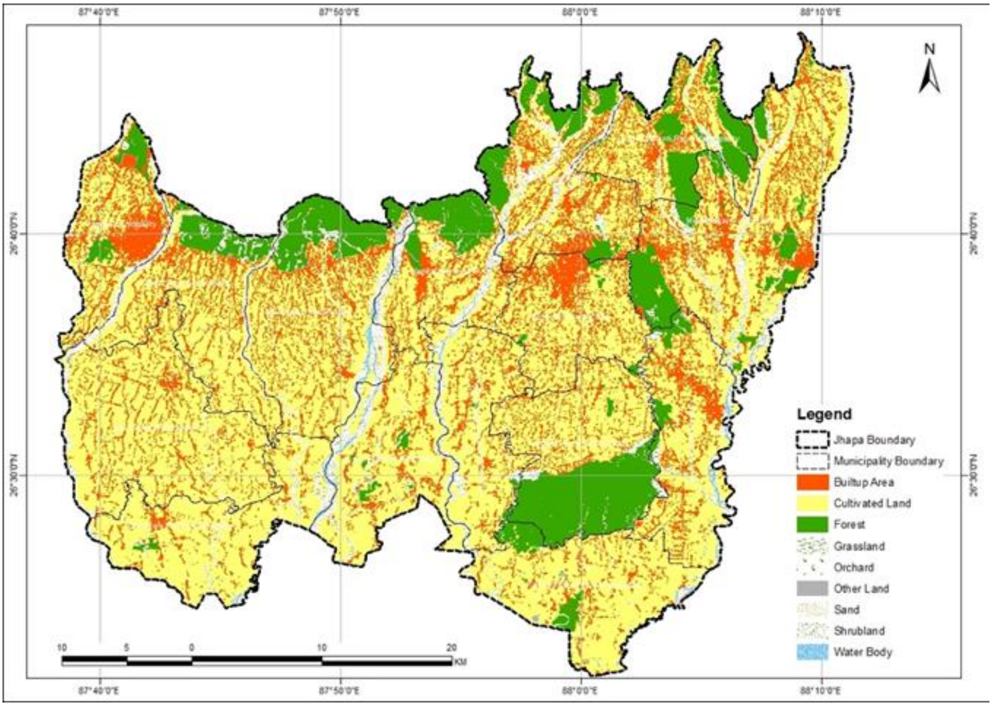
Temporal and spatial patterns of dengue (2019 and 2024)



A notable observation is the district-wide outbreak in 2023, when Jhapa recorded 3,294 dengue cases, representing the highest annual burden during the period of six years. Though the total number declined to 1,769 cases in 2024, it remained significantly higher than pre-2022 levels, indicating the continued endemicity of the disease. Other municipalities such as Mechinagar (627 cases), Haldibari (306 cases), and Arjundhara (313 cases) also reported consistent outbreaks, reinforcing the need for broader intervention. The data indicate a clear urban-rural divide, with urban and semi-urban areas being disproportionately affected. The sharp rise in cases post-2021 aligns with changing climatic patterns, increased rainfall, and expanding urbanization in Jhapa District (fig 4). This reinforces the urgent need for targeted vector control, community awareness, and infrastructure improvements, particularly in the urban municipalities where the burden is highest.

Figure 4

Temporal and spatial patterns of dengue (2019 and 2024)



Discussion

The spatial and temporal patterns of dengue in Jhapa District reflect an alarming concentration of cases in specific urban municipalities, especially Birtamod and Damak. These municipalities together accounted for over 75% of all dengue cases between 2019 and 2024, highlighting them as epicenters of transmission. This clustering is closely tied to urban infrastructure challenges such as poor waste management, inadequate drainage, and unchecked water storage practices, which create ideal breeding habitats for Aedes mosquitoes. The findings suggest that increased urbanization without corresponding public health and sanitation measures can exacerbate vector proliferation and disease transmission. Moreover, rural areas such as Kachanakawal and Gauriganj Gaunpalikas recorded minimal or no cases, possibly due to lower population densities or underreporting resulting from limited healthcare access. Environmental and climatic conditions in Jhapa further amplify the dengue risk. With annual rainfall ranging from 250 to 300 cm and summer temperatures peaking up to 41°C, the region offers optimal conditions for mosquito breeding. The spatial analysis revealed a strong association between artificial water containers especially those found near garages, pump stations, and ponds and the density of dengue cases. A Pearson correlation coefficient of 0.861 ($p < 0.01$) between the number of breeding containers and dengue incidence underscores this relationship. This not only validates the role of environmental factors in dengue transmission but also emphasizes the critical need for proactive environmental sanitation and vector control. Targeted interventions such as container management, larvicide application, and community awareness campaigns should be prioritized in high-risk zones.

Another concerning trend is the increasing year-round persistence of dengue in Jhapa, shifting the disease from a seasonal outbreak to an endemic public health threat. The peak outbreak in 2023, followed by sustained high case numbers in 2024, suggests that the district is now facing continuous transmission cycles. This could be driven by climate change, with warmer winters allowing mosquitoes to survive longer, and human factors such as increased mobility and construction. The presence of Aedes vectors at elevations up to 2,400 meters above sea level also implies a geographic expansion of risk areas, including previously unaffected hill regions. Therefore, a district-wide integrated vector management strategy is essential, involving not just local government and health institutions but also active community participation to achieve long-term dengue control.

Conclusions

The spatio-temporal analysis of dengue in Jhapa District highlights a clear and concerning trend of rising disease incidence, especially in densely populated urban municipalities like Birtamod and Damak. These areas have consistently reported the highest number of confirmed dengue cases and also host the largest number of identified mosquitoes breeding containers, underscoring a strong correlation between human activity, urban development, and disease transmission. This indicates the urgent need for targeted vector surveillance and control measures in urban hotspots to mitigate future outbreaks. Climatic and environmental conditions in Jhapa, including high temperatures, substantial rainfall, and favorable breeding habitats, significantly contribute to the proliferation of Aedes mosquitoes. The presence of breeding containers such as ponds, garages, and pump stations, coupled with poor water management practices, has created an ideal environment for mosquito reproduction. The strong positive correlation between breeding site density and dengue cases statistically confirms the direct influence of environmental factors on disease spread.

Finally, the observed shift from seasonal to year-round dengue outbreaks suggests that dengue has become endemic in Jhapa District. This shift is likely fueled by climate change, rapid urbanization, and insufficient public health infrastructure. To effectively address the growing threat, integrated vector management strategies, improved waste and water management, community engagement, and continuous health education are essential. Without proactive intervention, the frequency and severity of dengue outbreaks in Jhapa are likely to increase, posing greater public health risks in the coming years.

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