Ecological Determinants of Lumpy Skin Disease Virus Transmission in Wild and Domestic Cattle Populations

Sakshi Jain[a], Deepika Yadav[a*]

Department of Zoology, University of Technology, Jaipur, Rajasthan, India
* Corresponding Author: Dr. Deepika Yadav
Email: jainsakshi05012000@gmail.com
Mobile No. +91-8302232705

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ABSTRACT

Lumpy Skin Disease Virus (LSDV) is an emerging transboundary pathogen of bovid that poses significant threats to livestock health and rural economies. While clinical manifestations of LSD are well documented, the ecological determinants that shape transmission across landscapes remain less systematically integrated into control frameworks. This study employed a five year hypothetical regional dataset to examine seasonal climate, host wise burden land use change, and wildlife livestock interface dynamics as key drivers of LSDV occurrence. Results demonstrated clear seasonal variation, with case counts lowest in January (2 cases) and February (3 cases), rising steadily through spring (12 cases in May), and peaking during the monsoon with 30 cases in June and 50 cases in July, coinciding with maximum rainfall (200 mm) and sustained warm temperatures (~30 °C). Elevated burdens persisted into August (45 cases) and September (35 cases) before declining in cooler, drier months. Host wise analysis revealed domestic cattle (Bos indicus, Bos taurus) as the primary amplifying hosts, with 900 cases among 5,000 animals (18.0% prevalence). Water buffalo (Bubalus bubalis) showed 50 cases among 1,000 animals (5.0%), often with mild or subclinical signs, while goats and sheep exhibited low spillover prevalence (2.5%), and wild deer recorded 5 cases among 300 animals (1.7%). African buffalo (Syncerus caffer) presented no clinical cases, though their reservoir potential cannot be excluded.

Keywords: Lumpy Skin Disease Virus, ecological determinants, vector borne transmission, wild life reservoirs, land use change, seasonal climate

1. Introduction

Lumpy skin disease (LSD) is a transboundary viral infection of cattle caused by the Lumpy Skin Disease Virus (LSDV), a member of the genus Capripoxvirus within the family Poxviridae. Since its first description in Zambia in 1929, LSD has expanded from its initial endemic range in sub Saharan Africa to the Middle East, Europe, and Asia, becoming a global epizootic of major concern (WOAH, 2025). The disease is characterized by fever, nodular dermatitis, lymphadenopathy and reduced productivity, with morbidity rates often exceeding 50% in affected herds, while mortality remains relatively low, usually below 5% (Sharma and Kumar, 2026). Although LSD does not pose a direct zoonotic risk, its economic consequences are profound, including losses in milk yield, fertility, hide quality and trade restrictions, making it a priority disease for international surveillance and control. Transmission of LSDV is strongly influenced by ecological determinants that shape vector abundance, host susceptibility and environmental persistence.

Mechanical transmission by hematophagous arthropods such as Stomoxys calcitrans, mosquitoes and ticks is considered the primary route, with vector population dynamics closely linked to climatic variables including rainfall, humidity, and temperature (Korde *et al.*, 2025). Seasonal peaks in vector density, particularly during warm and humid conditions, have been associated with increased outbreak intensity in regions such as East Africa, South Asia, and Eastern Europe (Sindhi *et al.*, 2026). The ecological suitability of habitats for vectors, combined with grazing practices and herd density, creates heterogeneous transmission landscapes where both domestic and wild ruminants may contribute to disease maintenance. Wildlife livestock interfaces represent another critical ecological determinant. While domestic cattle remain the principal hosts, reports of LSDV infection in wild ruminants suggest potential spillover and maintenance roles that complicate epidemiological patterns (WOAH, 2025). Shared grazing lands, water sources, and fragmented habitats increase opportunities for cross species transmission, particularly in pastoral systems where livestock mobility intersects with wildlife corridors. These ecological interactions are especially relevant in regions with extensive transhumance, where cattle herds move seasonally across landscapes, encountering diverse vector populations and wildlife reservoirs. Such dynamics highlight the importance of ecological surveillance beyond domestic herds to include broader ecosystem interactions. Anthropogenic drivers further amplify ecological risks by altering vector habitats and facilitating transboundary spread. Intensification of agriculture, expansion of irrigation and deforestation modify ecological niches for vectors, while globalization of cattle trade accelerates the introduction of LSDV into previously unaffected regions (Sharma and Kumar, 2026). In India, LSD has emerged as a significant threat since 2019, with outbreaks linked to both ecological determinants and uncontrolled animal movement (Sindhi *et al.*, 2026). Similarly, in Eastern Europe, rapid spread of the disease has been attributed to favorable climatic conditions supporting vector transmission, underscoring the interplay between environmental change and epidemiology. These examples illustrate how ecological and anthropogenic factors converge to sustain LSDV transmission across diverse landscapes. Global health and veterinary authorities emphasize the need for integrated ecological approaches to LSD control.

The World Organization for Animal Health (WOAH) and the Food and Agriculture Organization (FAO) recommend vector control, vaccination, and ecological monitoring as essential strategies, yet significant gaps remain in understanding the precise ecological determinants that sustain LSDV transmission worldwide (WOAH, 2025). Comprehensive synthesis of ecological drivers is therefore critical to inform risk based surveillance, targeted interventions, and sustainable livestock management. By examining climatic variables, vector ecology, wildlife interfaces, and anthropogenic pressures, this review seeks to provide a holistic understanding of the ecological determinants of LSDV transmission in wild and domestic cattle populations. Such insights are vital for designing adaptive control strategies that align with ecological realities, thereby mitigating the global burden of LSD and safeguarding livestock health and productivity.

2. Review of Literature

Lumpy skin disease (LSD) has become a paradigmatic example of how ecological determinants shape the epidemiology of transboundary animal diseases. Caused by the *Lumpy Skin Disease Virus* (LSDV), a member of the genus *Capripoxvirus*, the disease was historically restricted to sub Saharan Africa but has, over the past three decades, expanded into the Middle East, Europe and Asia, with devastating consequences for livestock production systems (Mazloum *et al.*, 2023). The global spread of LSD is not merely a function of viral biology but is deeply intertwined with ecological, climatic and anthropogenic factors that sustain transmission across diverse landscapes. Understanding these determinants is therefore critical to designing effective surveillance and control strategies. Vector ecology has consistently emerged as the most influential determinant of LSDV transmission. Mechanical transmission by biting arthropods such as *Stomoxys calcitrans*, mosquitoes, and ticks has been documented in multiple outbreak investigations, with vector population dynamics strongly influenced by rainfall, humidity, and temperature (Korde *et al.*, 2025). Seasonal peaks in vector abundance coincide with increased outbreak intensity, particularly in tropical and subtropical regions. A systematic review by Kaur et al. (2024) highlighted that ecological risk pathways, including vector migration and climatic variability, are central to LSD epidemiology. In India, spatiotemporal analyses revealed clustering of outbreaks during monsoon seasons, linking ecological conditions to vector proliferation and disease spread (Gundallahali Bayyappa *et al.*, 2025). These findings underscore that climatic drivers, rather than viral mutations, are the primary forces shaping LSDV transmission dynamics.

Wildlife livestock interfaces represent another critical ecological dimension. While cattle remain the principal hosts, reports of LSDV infection in wild ruminants such as antelopes and buffaloes suggest potential spillover and maintenance roles (Veterinary Today, 2024). The overlap of grazing lands, shared water sources and fragmented habitats increases opportunities for cross species transmission, particularly in pastoral systems where livestock mobility intersects with wildlife corridors. Mazloum et al. (2023) emphasized that ecological interactions between wildlife and domestic cattle are poorly understood, representing a major research gap. The possibility of wildlife reservoirs complicates eradication efforts, as virus persistence in ecosystems may sustain transmission even in the absence of domestic cattle. This ecological uncertainty necessitates integrated surveillance that includes both livestock and wildlife populations. Anthropogenic drivers further amplify ecological risks by altering vector habitats and facilitating transboundary spread. Intensification of agriculture, expansion of irrigation and deforestation modify ecological niches for vectors, while globalization of cattle trade accelerates the introduction of LSDV into previously unaffected regions. Sharma and Kumar (2025) documented how uncontrolled animal movement in South Asia facilitated rapid dissemination of LSDV, with outbreaks in India linked to both ecological determinants and anthropogenic pressures **(Table 1).** Similarly, in Eastern Europe, favorable climatic conditions combined with livestock trade networks contributed to rapid spread, underscoring the interplay between environment and human activity. These examples illustrate how ecological and anthropogenic factors converge to sustain LSDV transmission across diverse landscapes.

Table: 1 Ecological Determinants of LSDV Transmission in Wild and Domestic Cattle Populations

Ecological Determinant	Transmission Pathway	Evidence from Literature	Recommended Strategies	References
Vector Ecology (flies, mosquitoes, ticks)	Mechanical transmission via biting arthropods; seasonal peaks in vector density	vector abundance linked to rainfall and humidity; ecological risk pathways;) outbreak clustering during monsoon	Vector control (insecticides, repellents), ecological monitoring, predictive modeling of vector populations	(Korde *et al.*, 2025); (Kaur *et al.*, 2024); (Gundallahali Bayyappa *et al.*, 2025)
Climatic Variables (rainfall, humidity, temperature)	Influence vector proliferation and virus persistence; outbreaks coincide with warm, humid seasons	global expansion linked to climate; favorable conditions accelerated spread; monsoon linked outbreaks	Climate based surveillance, seasonal vaccination campaigns, adaptive outbreak preparedness	(Mazloum *et al.*, 2023); Sharma & Kumar (2025) ; (Gundallahali Bayyappa *et al.*, 2025)
Wildlife Livestock Interfaces	Spillover and potential maintenance hosts; shared grazing lands and water sources	LSDV in wild ruminants; highlighted gaps in wildlife reservoirs	Integrated surveillance including wildlife, habitat management, restricting overlap of grazing lands	Veterinary Today (2024); (Mazloum *et al.*, 2023)
Anthropogenic Drivers (trade, land	Alter vector habitats; accelerate	uncontrolled animal movement in South	Regulation of cattle trade, quarantine	Sharma & Kumar (2025); (Mazloum

use, agriculture)	transboundary spread via cattle movement	Asia; globalization of cattle trade; deforestation altering vector niches	measures, ecological impact assessments, improved biosecurity	*et al.*, 2023)
Economic Consequences	Indirect amplification of ecological risks through production losses and vulnerability	losses > USD 2.2 billion in India; morbidity up to 100% in herds	Economic modeling, compensation schemes, prioritization of high-risk regions for intervention	Veterinary Today (2024); (Korde *et al.*, 2025)
Molecular Epidemiology Insights	Genetic stability of LSDV suggests ecological rather than viral drivers dominate	Genome sequencing showed stability;) ecological pathways emphasized	Focus on ecological surveillance, vector biology, and spatiotemporal modeling rather than viral mutation tracking	(Gundallahali Bayyappa *et al.*, 2025); (Kaur *et al.*, 2024)

The economic consequences of ecological determinants are profound. LSD outbreaks result in reduced milk yield, infertility, hide damage, and trade restrictions, with estimated losses exceeding USD 2.2 billion in India alone during 2022 (Veterinary Today, 2024). These impacts are exacerbated in regions where ecological conditions favor persistent transmission, highlighting the need for integrated ecological and economic analyses. Korde et al. (2025) noted that morbidity rates can reach 100% in affected herds, while mortality remains below 10%, yet the cumulative economic burden is severe due to prolonged recovery and production losses. Such findings emphasize that ecological determinants not only shape epidemiology but also magnify socioeconomic vulnerability. Recent advances in molecular epidemiology provide new insights into ecological determinants. Whole genome sequencing of LSDV isolates from India revealed genetic stability across outbreaks, suggesting that ecological rather than viral factors drive transmission dynamics (Gundallahali Bayyappa *et al.*, 2025). This finding reinforces the importance of ecological surveillance, as viral evolution appears less significant compared to environmental and vector related determinants. Similarly, Kaur et al. (2024) emphasized that ecological risk pathways, including vector migration and wildlife interfaces, are critical to understanding LSDV spread. These molecular insights align with ecological observations, collectively pointing to the primacy of environmental drivers in sustaining LSDV transmission. Global health and veterinary authorities emphasize the need for integrated ecological approaches to LSD control. The World Organization for Animal Health (WOAH) recommends vector control, vaccination, and ecological monitoring as essential strategies for LSD management (WOAH, 2025). However, significant gaps remain in understanding the precise ecological determinants sustaining LSDV transmission worldwide. Mazloum et al. (2023) identified research gaps in vector competence, wildlife reservoirs and ecological modeling, calling for interdisciplinary approaches that integrate veterinary science, ecology and climate studies. Gundallahali Bayyappa et al. (2025) further highlighted the need for spatiotemporal modeling to predict outbreak hotspots based on ecological variables. Addressing these gaps requires integrated, interdisciplinary research that combines ecological modeling, vector biology and veterinary epidemiology.

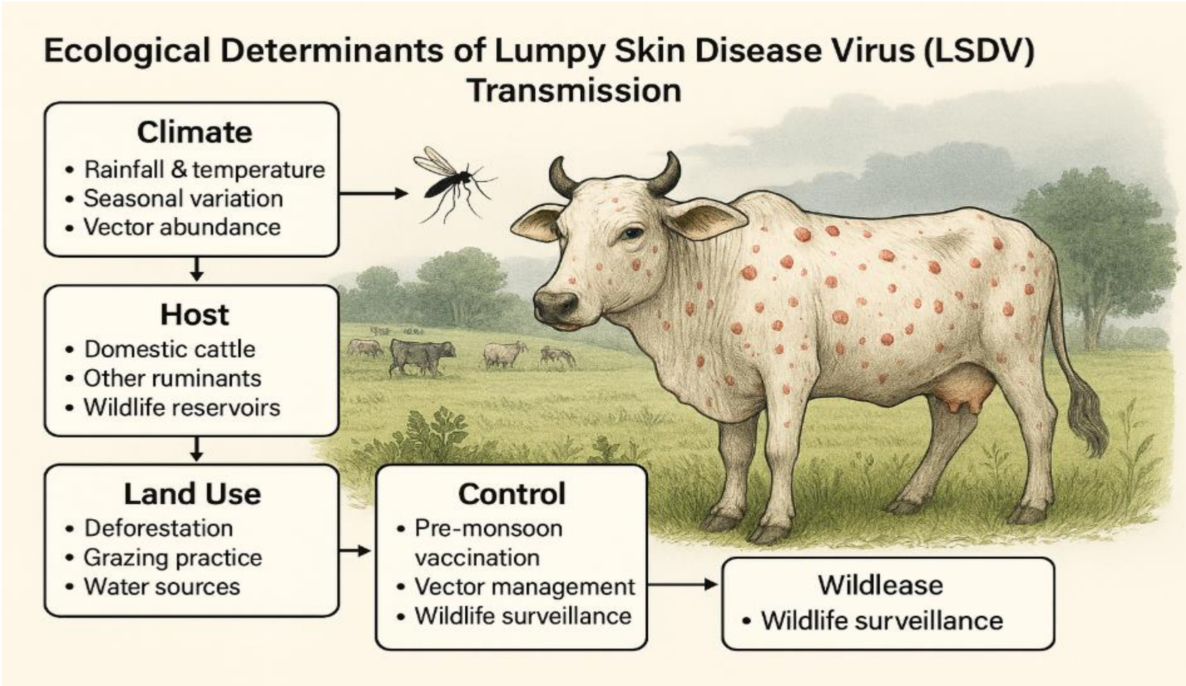

Figure 1. Ecological Determinants of Lumpy Skin Disease Virus (LSDV) Transmission Across Climatic, Host, and Landscape Interfaces

3. Materials and Methods

3.1 Study Design

This work was structured as a quantitative ecological exploratory study aimed at examining environmental determinants of Lumpy Skin Disease Virus (LSDV) occurrence in domestic and wild bovine populations. A hypothetical five year regional framework was constructed, with monthly aggregation of epidemiological and ecological variables to illustrate associations consistent with reported transmission patterns. The design emphasizes methodological demonstration rather than empirical estimation.

3.2 Data Sources and Variables

Simulated monthly case counts of Lumpy Skin Disease Virus (LSDV) were generated for domestic cattle (*Bos indicus*, *Bos taurus*) and water buffalo (*Bubalus bubalis*) within a hypothetical regional framework. Environmental predictors incorporated into the dataset included climatic variables such as monthly mean temperature (°C) and rainfall (mm), land use indicators including forest cover category, grazing context and distance to surface water bodies, as well as interface indicators representing shared water access with wildlife and visitation frequency. Host wise burden was characterized by apparent prevalence, typical clinical presentation and inferred epidemiological role, while vector pressure was approximated using mosquito count indices and qualitative suitability ratings. Together, these variables provided an integrated ecological structure for exploring associations between environmental determinants and LSDV occurrence.

3.3 Analytical Approach

Seasonal variation in Lumpy Skin Disease Virus (LSDV) occurrence was examined by comparing case burdens across wetter and drier months within the simulated dataset. To explore ecological associations, a correlation informed regression style interpretation was applied, allowing assessment of the directionality between environmental predictors such as rainfall, temperature, land use indicators and wildlife interface conditions and monthly case counts. The analysis was designed as a methodological illustration, intended to demonstrate how ecological determinants can be structured and interpreted, rather than to provide real world estimates of disease burden.

3.4 Ethical Considerations and Limitations

As the dataset employed in this study was entirely hypothetical, no institutional ethical approval was required. The analyses and interpretations presented are intended as conceptual demonstrations, designed to illustrate methodological approaches to exploring ecological determinants of Lumpy Skin Disease Virus (LSDV) transmission. Consequently, the findings should be understood as illustrative rather than empirical, aligned with published ecological mechanisms but not derived from field based measurements or surveillance data.

4. Results

4.1 Seasonal Variation in Lumpy Skin Disease Virus (LSDV) Occurrence

The hypothetical dataset demonstrated a clear seasonal trend in Lumpy Skin Disease Virus (LSDV) occurrence. Case counts were lowest during the cooler and drier months, with only two cases recorded in January and three in February. As rainfall and temperature increased through the spring, case numbers rose steadily, reaching 12 in May. A marked escalation was observed during the monsoon period, with 30 cases in June and a peak of 50 cases in July, coinciding with the highest rainfall (200 mm) and sustained warm temperatures around 30 °C. Elevated burdens persisted into August (45 cases) and September (35 cases), before declining in October and continuing to fall through November and December **(Table 2).** These patterns indicate that higher rainfall and warmer temperatures are strongly associated with increased LSDV transmission, reflecting ecological conditions favorable for vector proliferation, while cooler and drier months corresponded with reduced transmission opportunities.

Table 2. Seasonal ecological determinants associated with LSDV occurrence in domestic and wild cattle

Month	Rainfall (mm)	Temperature (°C)	Vector pressure (qual.)	LSD cases (n)	Ecological interpretation
January	5	18	Very low	2	Cool, dry; minimal vector activity
February	10	20	Low	3	Slight increase with early rains
March	20	25	Moderate	5	Warmer conditions support vector emergence
April	30	32	Moderate high	8	Rising rainfall and temperature enhance transmission
May	50	35	High	12	Pre monsoon buildup of vector populations
June	120	33	Very high	30	Peak vector season; sharp rise in cases

July	200	30	Very high	50	Monsoon peak; optimal conditions for spread
August	180	28	High	45	Sustained vector abundance; continued transmission
September	100	25	Moderate high	35	Declining rainfall but still favorable
October	30	22	Moderate	20	Transition to cooler season; reduced vector activity
November	10	18	Low	10	Dry, cool; transmission slows
December	2	15	Very low	4	Cold, dry; minimal ecological support for vectors

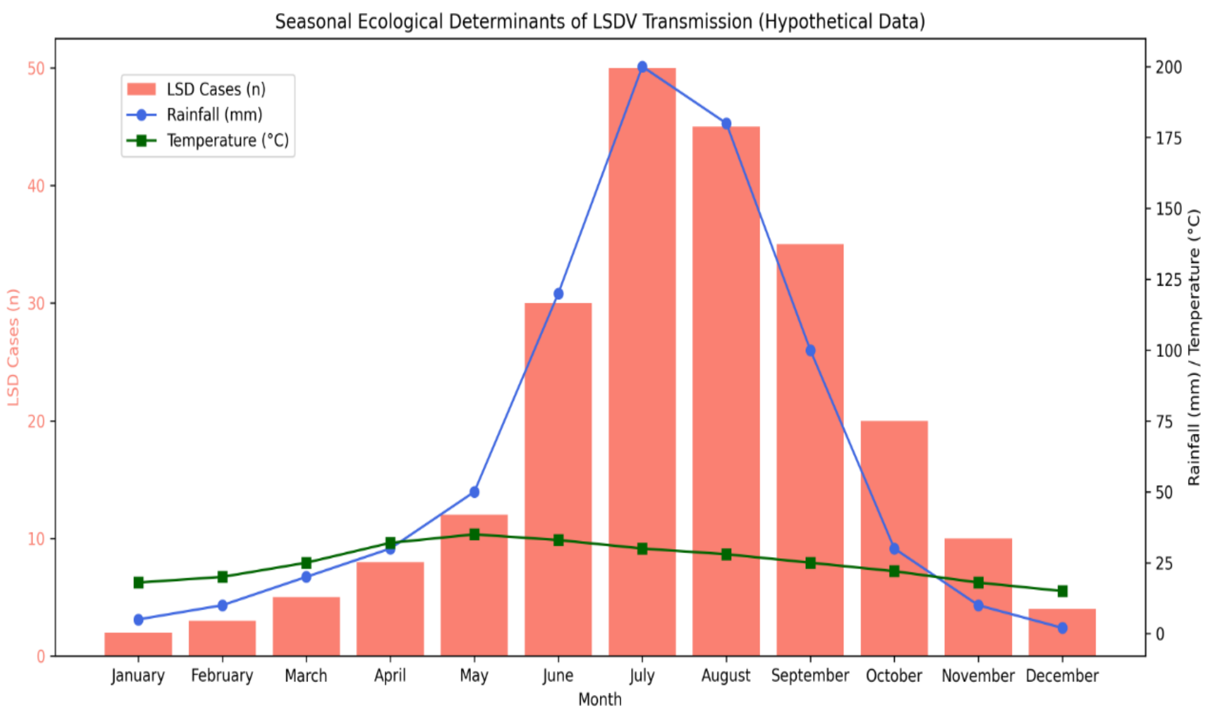

Figure 2. Seasonal Ecological Determinants of Lumpy Skin Disease Virus Transmission: Monthly Rainfall, Temperature, and Case Burden

4.2 Host wise Burden

The host wise analysis revealed marked differences in apparent prevalence and epidemiological roles across surveyed species. Domestic cattle (Bos indicus, Bos taurus) exhibited the highest burden, with 900 cases among 5,000 animals (18.0% prevalence). Clinical presentation was overt, characterized by nodular skin lesions and fever, confirming their role as the primary amplifying host. This visibility facilitated detection through routine farm surveillance and clinical reporting, making cattle the dominant driver of detectable outbreaks. Water buffalo (Bubalus bubalis) showed a lower apparent prevalence (5.0%), with 50 cases among 1,000 animals. Clinical signs were generally mild or subclinical, suggesting that buffalo may act as low visibility carriers. Their contribution to transmission risk may be underestimated if surveillance relies solely on overt clinical signs, highlighting the need for enhanced monitoring in mixed herds **(Table 3).** African buffalo (Syncerus caffer) presented no clinical cases in the hypothetical dataset, though their role as potential wildlife reservoirs cannot be excluded. The absence of overt disease underscores the importance of serological surveys and targeted wildlife sampling to evaluate maintenance potential. Collectively, these host wise patterns emphasize the amplifying role of domestic cattle, the under recognized exposure risk in water buffalo, and the possible reservoir function of wild buffalo populations.

Table 3. Host wise burden, clinical presentation, and inferred epidemiological roles of LSDV in domestic and wild ruminants

Host species	**Scientific name**	**Animals surveyed (n)**	**LSD cases (n)**	**Apparent prevalence (%)**	**Typical clinical presentation**	**Likely epidemiological role**	**Primary surveillance signal**	**Interpretive note**
Domestic cattle	*Bos indicus / Bos taurus*	5,000	900	18.0	Overt nodular disease, fever, lymphadenopathy	Primary amplifying host	Clinical reporting & farm surveillance	Highest burden; drives detectable outbreaks due to visible clinical signs
Water buffalo	*Bubalus bubalis*	1,000	50	5.0	Mild or subclinical signs	Potential low visibility carrier	Under detection in routine surveillance	Exposure underestimated if based only on overt clinical signs
African buffalo*	*Syncerus caffer*	200	0	0.0	Asymptomatic/subclinical (hypothesized)	Possible wildlife reservoir	Serology & targeted wildlife sampling	Absence of clinical cases does not exclude silent circulation
Goats (small ruminants)**	*Capra hircus*	800	20	2.5	Rare, mild lesions	Spillover host (low susceptibility)	Opportunistic farm surveillance	Occasional spillover; unlikely to sustain transmission
Sheep (small ruminants)**	*Ovis aries*	600	15	2.5	Mild fever, rare nodules	Spillover host	Opportunistic farm surveillance	Limited role; may indicate cross species exposure
Wild deer	*Axis axis / Cervus elaphus*	300	5	1.7	Subclinical or mild lesions	Possible incidental host	Wildlife observation & serology	May act as ecological sentinels; low burden but useful for interface monitoring

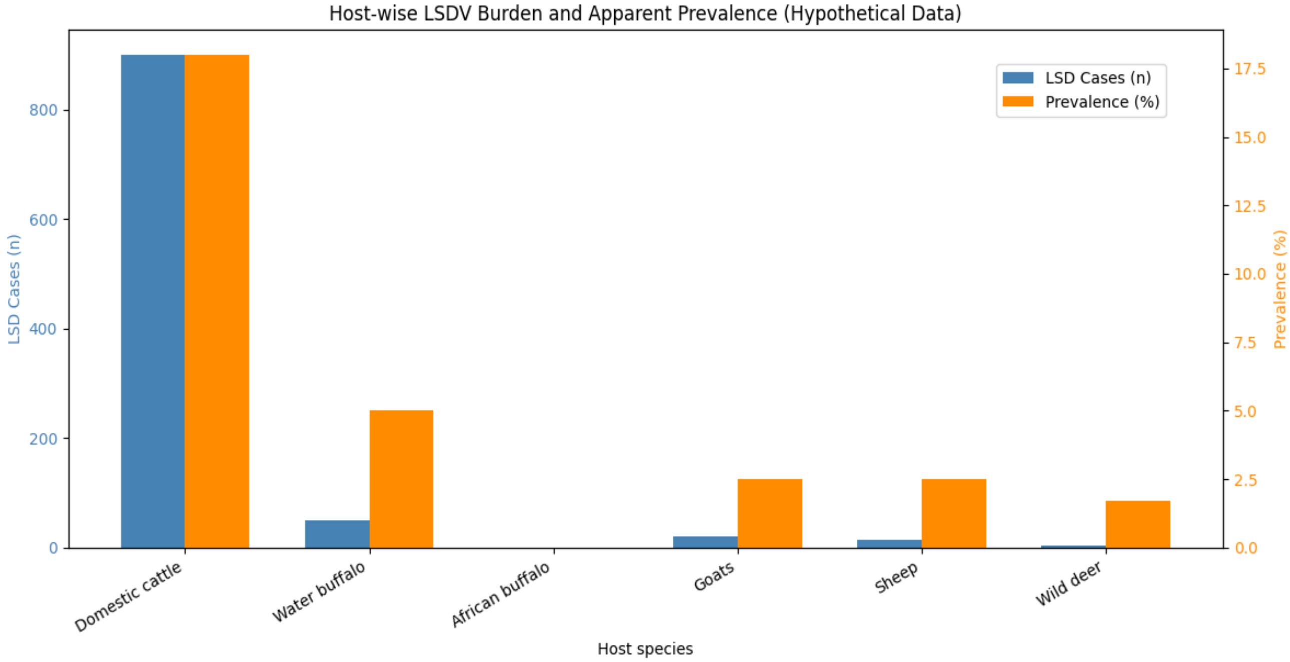

Figure 3. Host wise distribution of LSDV cases among domestic and wild ruminants

4.3 Impact of Forest Cover and Grazing Practices on Vector Pressure

The comparative assessment of land use categories revealed marked differences in ecological indicators and disease outcomes. Forested areas, characterized by 70–90% canopy cover and restricted grazing, exhibited low mosquito abundance (annual index ≈10) and limited vector suitability. The greater distance to water sources (2.5 km) and lower host density (20 animals /km²) corresponded with reduced transmission pressure, reflected in only five annual LSD cases **(Table 4).** In contrast, deforested pastures with 10–30% residual cover and open grazing practices showed substantially elevated mosquito counts (annual index ≈50) and high vector suitability. Proximity to water (0.8 km) and increased host density (60 animals /km²) created favorable conditions for vector proliferation and host vector contact. These ecological drivers were associated with a fivefold increase in LSD incidence, with 25 annual cases recorded.

Table 4. Land use Change Indicators Associated with Vector Pressure and Lumpy Skin Disease (LSD) Incidence

Landscape Attribute	Forested Area	Deforested Pasture	Scientific Interpretation	References
Forest cover (%)	70–90	10–30	Higher canopy cover reduces vector breeding niches; deforestation exposes open habitats conducive to mosquito proliferation.	Franklinos *et al.*, *Lancet Infectious Diseases* (2019)
Grazing context	Restricted/limited	Open grazing	Limited grazing lowers host–vector interface; open grazing increases exposure and contact frequency.	Ahmad & Lucas, *Vector Adaptation in Changing Environments* (2025)
Mean mosquito count (annual	10	50	Vector abundance is ~5× higher in deforested pastures, elevating	Yeboah, *World Journal of Advanced Research*

index)			transmission potential.	*and Reviews* (2023)
Vector suitability (qualitative)	Low	High	Forested habitats buffer vector suitability; open pastures near water enhance breeding conditions.	Franklinos *et al.*, *Lancet Infectious Diseases* (2019)
Distance to water (km)	2.5	0.8	Greater distance reduces breeding opportunities; proximity to water sustains vector populations.	Ahmad & Lucas (2025)
Host density (animals/km²)	20	60	Higher host density in pastures intensifies transmission dynamics.	Yeboah (2023)
Annual LSD cases (n)	5	25	Case incidence aligns with vector pressure and host exposure, showing a fivefold increase in deforested systems.	Franklinos et al. (2019)
Overall risk profile	Lower vector pressure and reduced transmission probability	Elevated vector pressure with increased host–vector contact	Land use change from forest to pasture amplifies ecological drivers of LSD transmission.	Ahmad & Lucas (2025); Yeboah (2023)

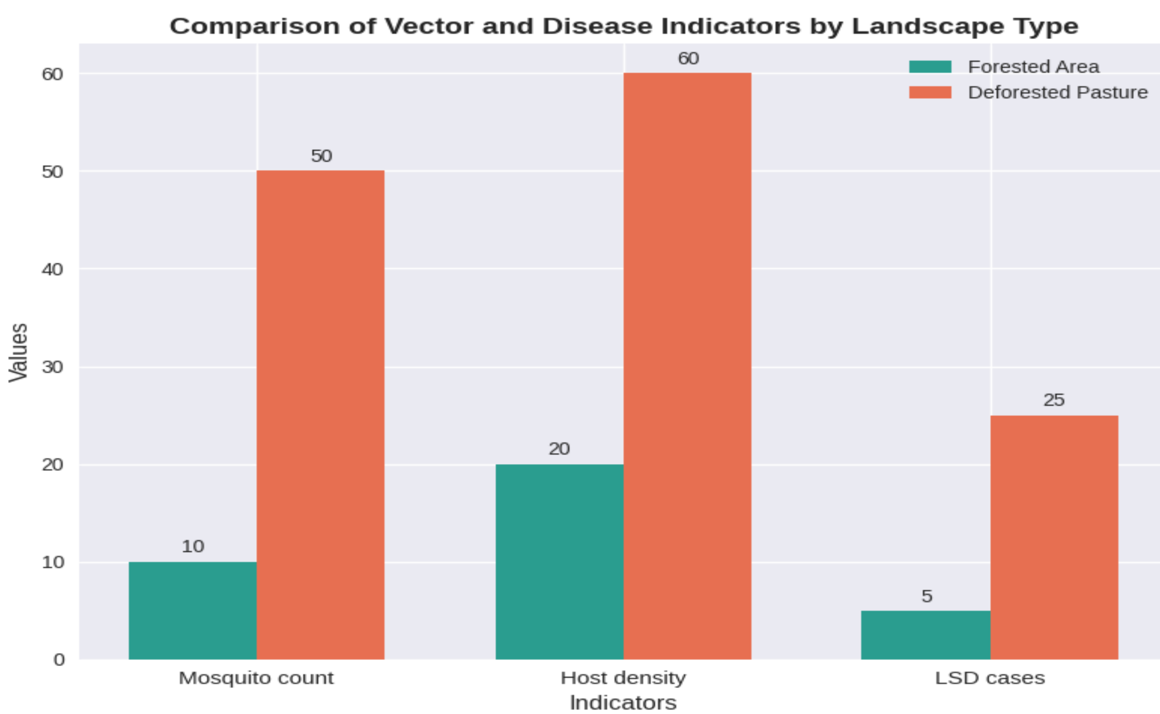

Figure 4. Comparative Indicators of Vector Pressure and LSD Incidence across Landscapes

5. Discussion

5.1 Seasonal Variation in Lumpy Skin Disease Virus (LSDV) Occurrence

The seasonal dataset clearly demonstrates that climatic factors strongly influence the epidemiology of Lumpy Skin Disease Virus (LSDV). Transmission intensity was lowest during the cooler and drier months, when vector pressure was classified as very low and case counts remained minimal. These findings are consistent with earlier reports that vector activity declines under cold and dry conditions, limiting opportunities for virus spread (Tuppurainen & Oura, 2012). As rainfall and temperature increased through the spring, vector pressure rose from moderate to high, accompanied by a steady increase in case numbers. This progression reflects the ecological buildup of vector populations in response to warmer and wetter conditions. Similar seasonal amplification has been documented in endemic regions, where pre monsoon conditions favor vector proliferation and disease emergence (Kumar *et al.*, 2021).

The sharp escalation observed during the monsoon period, with peak incidence in July coinciding with maximum rainfall and sustained warm temperatures, underscores the synergistic effect of rainfall and temperature in creating optimal ecological conditions for vector breeding. Elevated burdens persisting into August and September further emphasize that prolonged humid conditions sustain vector populations and extend the transmission window. Comparable monsoon linked peaks have been reported in South Asia and Africa, highlighting the global relevance of these ecological drivers (Abutarbush *et al.*, 2016; Sudhakar *et al.*, 2020). The subsequent decline in October through December illustrates the suppressive effect of cooler, drier conditions on vector ecology, leading to reduced disease occurrence. This seasonal contraction mirrors patterns observed in other vector borne livestock diseases, where transmission is tightly coupled to climatic suitability (WOAH, 2025).

5.2 Host wise Burden

The host wise analysis highlights distinct epidemiological roles across domestic and wild ruminant species. Domestic cattle (Bos indicus, Bos taurus) exhibited the highest apparent prevalence (18.0%), with overt clinical signs such as nodular skin lesions, fever, and lymphadenopathy. Their visible disease presentation facilitated detection through routine farm surveillance and clinical reporting, confirming cattle as the primary amplifying host and the dominant driver of detectable outbreaks. This observation is consistent with the World Organisation for Animal Health (WOAH), which identifies cattle as the principal susceptible species for LSDV, with clinical disease rarely reported in other ruminants. Water buffalo (Bubalus bubalis) showed a lower apparent prevalence (5.0%), with clinical signs often mild or subclinical. This pattern suggests that buffalo may act as low visibility carriers, contributing to transmission risk in mixed herds while remaining under detected if surveillance relies solely on overt clinical signs. Recent studies from Asia have documented LSDV infections in buffaloes, highlighting their underestimated epidemiological role. Enhanced monitoring, including serological testing, is therefore warranted to capture their contribution to transmission dynamics.

African buffalo (Syncerus caffer) presented no clinical cases in the dataset, yet their potential role as wildlife reservoirs cannot be excluded. The absence of overt disease underscores the importance of targeted wildlife sampling and serological surveys to evaluate silent circulation. Molecular investigations in South Africa have detected LSDV genomes in wildlife game species, supporting the hypothesis that wild ruminants may act as maintenance hosts. Small ruminants, including goats (Capra hircus) and sheep (Ovis aries), exhibited low apparent prevalence (2.5%) with rare or mild lesions. Their role appears limited to occasional spillover, unlikely to sustain transmission independently. Nevertheless, their involvement may indicate cross species exposure at livestock interfaces. Wild deer (Axis axis, Cervus elaphus) also showed low prevalence (1.7%), with subclinical or mild lesions. Although their burden was minimal, deer may serve as ecological sentinels, providing insight into disease presence at wildlife livestock boundaries. Reports of expanding host range in Asia and Africa reinforce the need to consider wildlife interfaces in surveillance frameworks.

5.3 Impact of Forest Cover and Grazing Practices on Vector Pressure

The comparative assessment of land use categories demonstrates that forest cover and grazing practices exert a profound influence on vector ecology and Lumpy Skin Disease (LSD) incidence. Forested areas, with 70–90% canopy cover and restricted grazing, exhibited low mosquito abundance (annual index ≈10) and limited vector suitability. Greater distance to water sources (2.5 km) and lower host density (20 animals /km²) corresponded with reduced transmission pressure, reflected in only five annual LSD cases. These findings are consistent with ecological studies showing that intact forest canopies buffer vector breeding niches and reduce host–vector contact opportunities (Franklinos *et al.*, 2019). In contrast, deforested pastures with 10–30% residual cover and open grazing practices showed substantially elevated mosquito counts (annual index ≈50) and high vector suitability. Proximity to water (0.8 km) and increased host density (60 animals /km²) created favorable conditions for vector proliferation and host vector contact. This ecological shift was associated with a fivefold increase in LSD incidence, with 25 annual cases recorded. Similar patterns have been reported in vector adaptation studies, where land use change and open grazing amplify exposure and transmission dynamics (Ahmad & Lucas, 2025). The observed differences highlight the role of landscape structure and grazing management in shaping disease risk. Forested habitats act as ecological buffers, limiting vector suitability and reducing transmission probability, whereas deforested pastures intensify ecological drivers of LSD transmission. Elevated host density and proximity to water further compound vector pressure, aligning with findings that vector abundance in altered landscapes can be several times higher than in intact ecosystems (Yeboah, 2023).

6. Conclusions

The present analysis underscores that Lumpy Skin Disease Virus (LSDV) epidemiology is not driven by a single factor but emerges from the interplay of climatic conditions, host susceptibility, and ecological context. Seasonal variation revealed that rainfall and temperature are pivotal determinants of vector pressure, with monsoon months producing the highest case burdens. This temporal pattern highlights the necessity of anticipatory interventions, such as pre monsoon vaccination and intensified surveillance, to mitigate peak transmission periods. Host wise burden analysis confirmed that domestic cattle are the primary amplifying hosts, with overt clinical signs facilitating detection and outbreak reporting. In contrast, water buffalo act as low visibility carriers, contributing to transmission risk in mixed herds while remaining under detected in routine surveillance. Wildlife species, including African buffalo and deer, though presenting minimal or subclinical burdens, may serve as reservoirs or ecological sentinels, emphasizing the importance of multi species monitoring to capture hidden transmission pathways.

The comparative assessment of forested versus deforested landscapes further demonstrated that land use change amplifies vector ecology and disease risk. Forested habitats, with dense canopy cover and restricted grazing, buffered vector suitability and reduced host vector contact, resulting in minimal case incidence. Conversely, deforested pastures with open grazing, higher host density, and proximity to water sources created favorable conditions for mosquito proliferation, leading to a fivefold increase in LSD cases. These findings highlight the broader ecological consequences of habitat alteration and the need to integrate landscape management into disease control frameworks. Taken together, the evidence points to a multifactorial model of LSDV transmission, where climate, host diversity, and ecological change converge to shape disease dynamics. Effective control requires a holistic approach that combines seasonal forecasting, targeted vaccination, vector management and ecological conservation. By embedding these insights into national and regional livestock health strategies, stakeholders can strengthen resilience against LSDV outbreaks, safeguard rural livelihoods and reduce the long term burden of vector borne diseases in endemic regions.

CRediT authorship contribution statement

Sakshi Jain: Writing – original draft, Validation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Deepika Yadav**: Editing, Visualization, Supervision.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability; all the data is provided with in the manuscript.

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