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Review Article

Lumpy Skin Disease in Dairy Cattle: A Review

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LSD, Cattle health, Dairy production, Economic impact, Disease management

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Abstract | Lumpy Skin Disease Virus (LSDV), the causative agent of LSD in cattle, has emerged as a transboundary pathogen of growing global concern due to its rapid spread, significant economic losses, and impact on livestock health. LSD has affected millions of cattle across Africa, Asia, and parts of Europe, with reported mortality rates typically ranging between 1% and 5%. LSD causes significant economic losses by reducing milk yield, impairing reproduction, restricting meat exports, and causing long-term damage to skin, meat quality, and internal organs. While LSD poses a significant threat worldwide, its emergence in Pakistan presents unique challenges due to the country's reliance on livestock for economic stability and rural livelihoods. An LSD outbreak poses a significant threat to the agricultural economy of Pakistan. According to the Economic Survey of Pakistan, 2023-2024, Pakistan is the third-largest milk producer with over 57.5 million cattle and 46.3 million buffaloes. LSD was first detected in Pakistan in 2022, in a cattle farm located in Karachi, Sindh. In Pakistan, LSD outbreaks caused over 190,000 cases and 7,500 deaths. A sharp post-flood surge of LSD was observed in Punjab, Pakistan, with 362 outbreaks reported by late September 2025. Environmental factors such as high humidity, heat, poor hygiene, and increased vector activity significantly contributed to the rapid disease spread. In endemic regions lacking structured disease management, vaccination remains a key preventive strategy. Effective surveillance and vaccination are essential to minimizing the spread and impact of this economically devastating disease. The export restrictions are legally imposed trade measures based on disease control regulations, not on the quality or safety of animal products. Although no specific antiviral exists for LSD, supportive treatment includes antibiotics to prevent secondary infections, anti-inflammatory drugs, and strict vector control measures. Key research gaps are identified, including the lack of long-term surveillance data, limited understanding of molecular transmission pathways, poor documentation of farm-level economic losses in Pakistan, and the absence of a unified One Health response. The review underscores the urgency of developing thermostable vaccines suitable for low-resource settings, investing in longitudinal studies, and integrating climate and vector dynamics into LSD control strategies. These insights aim to inform policy, guide research priorities, and improve disease preparedness across South Asia. Future priorities should focus on developing and implementing LSD-specific vaccination programs (inactivated and live attenuated), strengthening cold-chain logistics, enhancing disease surveillance, and integrating a One Health approach to mitigate future epidemic risks under changing climatic conditions.

Novelty Statement | This review article offers an attentive analysis of how climate stressors, vector activity, and post-flood circumstances exclusively drove recent LSD outbreaks in Pakistan. It outlines major gaps in molecular transmission understanding, long-term surveillance, and true economic impact on dairy farms. The paper also introduces a framework for sustainable disease control.

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Introduction

Lumpy Skin Disease Virus (LSDV) is classified within the *Poxviridae* family and belongs to the *Capripoxvirus* genus, which also includes Goat Pox and Sheep Pox viruses (Issimov *et al*., 2020). Members of the *Poxviridae* family are characterized by double-stranded DNA genomes (Tuppurainen and Oura, 2012). LSDV particles are pleomorphic but generally appear brick-shaped and are susceptible to agents such as ether and trypsin. The viral genome is approximately 154 kilobase pairs in length. Notably, LSDV exhibits considerable heat resistance, surviving at 55 °C for up to two hours and at 65 °C for around 30 min. The virus can also persist for extended periods in shaded farm environments lacking adequate sunlight. Purebred and exotic cattle breeds are generally more susceptible to LSD due to their lower adaptive immunity to local pathogens and environmental stressors, as reported in multiple studies (Tuppurainen *et al*., 2021). In some cases, the disease may be complicated by secondary bacterial infections. Although more prevalent during humid summer months, LSD outbreaks can also occur during winter. Humid and warm climates facilitate LSD outbreaks by increasing the population of blood-feeding insects such as mosquitoes and biting flies, which act as mechanical vectors for the virus. The disease is often linked to areas with high moisture levels, such as wetlands or low-lying lands. The disease is primarily transmitted through arthropod vectors (flies, mosquito and ticks) (Tuppurainen *et al*., 2021). LSD was first reported in Africa in the 1920s, later spreading to the Middle East, then Southeast Europe, and more recently into South and Southeast Asia, including countries like India, Bangladesh, and Pakistan. Historically, LSD was confined to Eastern and Southern Africa during the 1970's (Elsheikh *et al*., 2024). Gradually expanded northwest across the continent, including parts of Sub-Saharan West Africa (Lee *et al*., 2024). Although initially regarded as an African disease, its geographic reach began to widen significantly after 2000, with outbreaks reported in Middle Eastern countries. By 2013, new cases emerged in Turkey, Georgia, Russia, Bangladesh, and China, marking the disease's introduction into Asia and raising global health concerns. More recently, in 2021, LSD was detected in Vietnam, Malaysia, and Thailand (Arjkumpa *et al*., 2022). In March 2022, Indonesia officially confirmed its first case on Sumatra Island.

The first outbreak of LSD in Pakistan was reported at a cattle farm in Karachi (Sindh) in 2022 (Rida *et al*., 2024). While Pakistan was previously free of LSD (Jamil *et al*., 2022; Khan *et al*., 2025), the disease was already endemic in neighboring countries such as India and Bangladesh. The entry of LSD into Pakistan is believed to have occurred through uncontrolled cross-border livestock movement, informal animal trade, and vector migration from neighboring endemic regions like India. This regional proximity facilitated the spread of LSD into Pakistan, where it has now become an emerging endemic threat, prompting its removal from the list of LSD-free countries (Lu *et al*., 2021).

LSD impacts dairy cattle by reducing milk production (Vinitchaikul *et al*., 2023) and diminishing their economic value. Affected animals may develop painful skin nodules, scabs, general weakness, and swelling in the brisket, limbs, and genital areas (Gupta *et al*., 2020), leading to reduced mobility and hide damage (Datten *et al*., 2023). Additional signs include lymph node enlargement, emaciation, mastitis, early embryonic loss, and in some cases, erosion of mucous membranes and respiratory tract involvement (Sprygin *et al*., 2018), all contributing to significant economic losses for livestock farmers.

Proper screening, preventive measures (Kayesh *et al*., 2020), and adequate treatment should be practiced to minimize economic losses and prevent outbreaks of LSD. For prevention, the vaccination schedule should be followed, and insect repellents should be used regularly to prevent LSD outbreaks through insects (Tuppurainen *et al*., 2021).

Transmission of LSD

The transmission of LSD is possible through both direct and indirect routes (Aleksandr *et al*., 2020), direct contact with infected animals can spread LSD among cattle (Kumar *et al*., 2021). Moreover, it can also be transmitted through insects such as mosquitoes, flies, and ticks (Bianchini *et al*., 2023). Furthermore, fomites also play a role in the transmission of disease, such as contaminated food, water, and instruments, such as the use of infected needles or other surgical instruments (Punyapornwithaya *et al*., 2023).

While the classical transmission routes of LSDV primarily via hematophagous arthropods such as stable flies (*Stomoxys calcitrans*), mosquitoes (*Aedes, Culex* spp.), and ticks (*Rhipicephalus, Amblyomma* spp.) are well-documented, emerging research indicates that broader ecological and molecular factors significantly influence disease dynamics. Climate change, particularly rising temperatures and increased humidity, has expanded the geographical range and seasonal activity of these vectors, contributing to year-round transmission in tropical regions like South Asia. Changes in rainfall patterns and monsoon variability further intensify vector breeding, elevating the risk of outbreaks. Additionally, while cattle and buffalo are primary hosts, recent serological and PCR-based evidence suggests that wildlife species such as antelope and deer may serve as potential reservoirs, complicating eradication efforts. The role of vector ecology is especially critical in South Asia, where communal grazing and

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proximity to wetlands create ideal vector habitats. On a molecular level, specific genetic determinants such as mutations in the LSDV GPCR, RPO30, and EEV genes have been associated with enhanced viral replication, vector adaptation, and immune evasion. These genomic variations not only affect transmission efficiency but may also influence virulence and host range. The host range of LSDV is limited, and it cannot complete its cycle in living organisms other than large ruminants. For example, small ruminants like sheep and goats, when kept near infected animals, did not catch LSD. However, LSD was observed in water buffaloes in Egypt in 1988, but morbidity and mortality were low compared to cattle. Cattle of all ages and both sexes are equally susceptible to LSDV (Di Felice *et al*., 2024).

Pathogenesis, clinoco-pathological and histo-pathological observations

The pathogenesis of LSD involves complex interactions between viral replication, host immune response, and tissue-specific pathology. Following transmission, LSDV exhibits strong tropism for endothelial cells, fibroblasts, and macrophages, leading to widespread vascular damage, lymphangitis, and dermal necrosis that underlie the formation of characteristic nodules. Recent immunopathological studies have revealed that LSDV infection induces a dysregulated immune response marked by elevated proinflammatory cytokines (e.g., IL-1β, TNF-α) and recruitment of mononuclear cells to infected tissues. Histologically, skin lesions show severe vasculitis, thrombosis, necrosis, and a pronounced infiltration of macrophages and lymphocytes. Moreover, the virus appears to modulate host immunity by downregulating MHC expression and interfering with interferon signaling, aiding in immune evasion and prolonged persistence in host tissues. Notably, recent field studies in South Asia have highlighted breed-specific differences in disease severity, with indigenous cattle breeds such as Sahiwal and Red Sindhi demonstrating lower lesion burden and faster recovery compared to exotic breeds. This observation aligns with genetic studies identifying polymorphisms in innate immune genes such as TLR4, TLR9, and interferon-gamma pathways in Bos indicus cattle, which may contribute to enhanced antiviral responses. Understanding these immunogenetic mechanisms is critical not only for refining treatment strategies but also for guiding selective breeding programs aimed at enhancing herd resilience in endemic regions. Following infection, the incubation period has been experimentally observed to last between 4 and 7 days. However, in naturally occurring cases, this period can extend to about 28 days or even up to 35 days. The LSD virus replicates intradermal within fibroblasts, macrophages, pericytes, and endothelial cells, leading to viremia. This results in the development of vacuities and lymphangitis in the affected areas. After recovery from an LSD infection, cattle generally develop antibodies that last for approximately six months. The economic impact of LSD outbreaks is significant, particularly during lactation periods, as the severity of the disease reduces milk production due to high fever and associated bacterial mastitis (Ratyotha *et al*., 2022).

Subsequent lumpy virus infection, LSDV virus replicates, and there is onset of viremia, which leads to high onset of fever. Just after the start of fever, there is the appearance of ulcerative and necrotic nodules throughout the body. Practically, while using intradermal injection of the virus, there was a localized inflammation at the site of injection, followed by viremia and clearance of the virus by means of oral and nasal release, finally generalized skin nodules and occurrence of virus in semen at day 42 of the start of fever. Vasculitis and lymphangitis may occur due to viral intracellular replication in macrophages, fibroblasts, endothelial cells, and pericytes. Deficiency in humoral immunity in young calves, emaciated animals, and lactating cows was one of the causes of LSD in ruminants. Calves remain immunized up to six months after attaining acquired immunity from maternal antibodies, got their infected dams were resistant to clinical disease. Yet, no carrier state has been known by affected animals after clearing the infection against LSDV. LSDV also affects muscles of the muzzle, exclusive of the oral and nasal cavity, respiratory system, digestive system, and reproductive system, leads to pneumonia, keratitis, dysentery, myiasis and mastitis (Tuppurainen *et al*., 2021).

LSDV infection typically manifests as an acute illness with symptoms including fever, general weakness, and the development of skin nodules and lesions. The disease is characterized by the formation of blisters on the skin, which can range from 2 to 5 cm in diameter. These blisters usually appear on areas such as the head, neck, legs, udder, and genital regions. The nodules often become necrotic, leading to ulceration and the formation of deep, crusty scabs. Larger blisters may remain necrotic and scarred for several months, while smaller blisters usually heal more rapidly (Sevik and Dogan, 2017).

Edema of the legs leads to lameness evident in certain illnesses caused by LSDV (Tuppurainen and Oura, 2012). Mastitis, orchitis and abortion were also evident in cattle suffering with LSD but absence of nodules in the aborted fetus (Sevik and Dogan, 2017). During necropsy, findings presence of ulcerative and necrotic nodules was commonly evident in the GIT as well as in the respiratory tract (Zeynalova *et al*., 2016).

Histopathological examination of skin nodules affected by LSD typically reveals distinctive eosinophilic intracytoplasmic inclusion bodies located within keratinocytes, macrophages, endothelial cells, and pericytes. These inclusion bodies are often linked with ballooning

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degeneration in the spinous layer of the epidermis, a key feature of the disease. Additionally, the affected skin areas usually exhibit infiltration by inflammatory cells, including macrophages, lymphocytes, and eosinophils, into the superficial dermal tissues. In more severe cases, extensive vasculitis and coagulative necrosis in the subcutaneous muscle tissues may be observed (Namazi and Khodakaram, 2021). Histopathological studies of skin biopsies from affected areas typically show changes such as swelling, increased blood flow, thickening of the skin, fluid accumulation, and excessive keratin production in the epidermis (Ratyotha *et al.*, 2022).

Diagnosis and treatment protocoal

Although multiple diagnostic methods for LSD are available including clinical examination, virus isolation, polymerase chain reaction (PCR), real-time PCR, and serological assays such as ELISA and virus neutralization tests each varies significantly in terms of field applicability, sensitivity, specificity, and cost-effectiveness, particularly in low-resource settings. PCR and real-time PCR are considered the gold standard for confirming LSDV due to their high sensitivity and specificity (>95%), but they require well-equipped laboratories, trained personnel, and a cold chain for sample transport, which limits their feasibility in rural or remote areas of South Asia. Serological tests like ELISA, while less specific due to cross-reactivity with other *Capripoxviruses*, are more practical for large-scale surveillance and post-vaccination monitoring, especially when rapid, portable kits are available. Virus isolation, though definitive, is time-consuming, labor-intensive, and impractical for outbreak response. In contrast, clinical diagnosis though rapid and inexpensive has limited accuracy in early or subclinical cases and can be confounded by other dermatographia diseases. For low income, high-burden regions like Pakistan, the adoption of validated, low-cost point-of-care diagnostics such as lateral flow assays or isothermal amplification-based tests (e.g., LAMP) may offer a practical balance between accuracy and accessibility. A tiered diagnostic approach using rapid field tests for screening and PCR for confirmation can improve both disease detection and resource allocation in endemic areas.

The primary diagnosis of lumpy skin disease is based on the formation of nodular lesions of 2-5 cm diameter, especially on the face, limbs, head, neck, udder, and genitalia, within 48 hours of the onset of febrile. These nodules are circumscribed, firm, round and raised, and involve the skin, subcutaneous tissue and sometimes even the underlying muscle (Sevik and Dogan, 2017).

Lumpy Skin Disease (LSD) may be clinically confused with several conditions that cause similar cutaneous lesions in cattle. These include pseudo-lumpy skin disease, a mild herpesvirus infection; cutaneous leucosis, which also produces nodular skin lesions; and bovine herpes mammalitis, affecting teats and udders. Para pox virus infections, like bovine papular stomatitis, can lead to proliferative lesions, while photosensitization from toxic plants or chemicals results in severe dermatitis. Fungal conditions such as ringworm and dermatophytosis, along with bacterial infections like Dermatophilosis, may present similarly. Insect bites, urticaria, sheep pox, skin trauma (e.g., burns), actinobacillosis caused by *Actinobacillus lignieresii*, and demodectic mange are also considered in the differential diagnosis. Definitive identification requires clinical evaluation, epidemiological context, and laboratory testing, including PCR, ELISA, histopathology, lesion biopsy, necropsy, and postmortem analysis (Huang *et al.*, 2022).

Currently, there is no antiviral treatment specifically targeting LSDV; therefore, management relies on comprehensive supportive care to reduce clinical symptoms, prevent complications, and improve animal recovery. Infected cattle should be promptly isolated to prevent further transmission. Broad-spectrum antibiotics such as long-acting oxytetracycline or penicillin-streptomycin combinations are routinely used to control secondary bacterial infections that often develop through open skin lesions. Non-steroidal anti-inflammatory drugs (NSAIDs), including flunixin meglumine or meloxicam, are administered to reduce fever, inflammation, and pain, improving animal comfort. Skin nodules and ulcerative lesions should be cleaned regularly with antiseptic solutions to prevent fly infestation and maggot formation. In some cases, wound-healing ointments or fly-repellent creams may be applied. Supportive therapy also includes adequate fluid supplementation, vitamin injections (especially vitamins A and E), and high-energy nutrition to enhance immune response and minimize production losses.

Epidemiological data of recent outbreaks of LSD

LSD was first observed in 1929 in Zambia. it has spread in cattle populations across African countries, the Middle East, Europe, and Asia.

LSD once restricted to Africa, has expanded rapidly into the Middle East, Central Asia, and the Indian subcontinent over the past decade, revealing critical regional differences in its epidemiology. In African countries, LSD typically follows a seasonal pattern linked to specific vector populations and is often controlled through well-established veterinary infrastructure and targeted vaccination programs. In contrast, the epidemiological landscape in South Asia particularly in countries like Pakistan is shaped by a complex interplay of ecological, socio-economic, and infrastructural factors. The region's dense cattle populations, year-round presence of mechanical and biological vectors due to tropical and subtropical climates, and widespread informal livestock trade across porous borders contribute to continuous transmission cycles. Moreover, mixed farming systems, communal grazing practices, and limited access to veterinary care create additional challenges for containment.

Economic importance

In affected countries, lumpy skin disease has caused severe financial damages. The losses caused by LSD included the extensive milk reduction almost from 10 to 85% due to secondary mastitis and high rise in temperature, decrease in growth rate leads towards severe emaciation, damaged to hide, abortion, infertility may be temporary or permanent, cost on treatment as well as on vaccination and mortality of infected animals with LSD. The entire price of the LSD endemics was 822 940.7 GBP in Turkey while surveyed 393 herds (Sevik and Dogan, 2017).

In Ethiopia, the entire price of the LSD endemics was 58 USD and 6.43 USD for each animal for Holstein Friesian and local zebu, respectively. In industrial cattle farming, almost 45 to 65% subsequent losses were estimated from the LSD (Tuppurainen and Oura, 2012). Recent LSD outbreak in Pakistan provides more contextually relevant insights into the disease's financial toll at the farm level. A 2023 field survey conducted across Khyber Pakhtunkhwa revealed that affected households experienced direct losses averaging PKR 6,869 per animal for treatment and PKR 175 per animal for vaccination, with additional indirect losses of approximately PKR 17,280 per animal

Table 1: Geographic distribution of LSD in Asia: 2021-2022.

Country	1st time reported	Time period	Total out-breaks	Susceptible	Cases	Killed and disposed of	Slaughtered	Death	Vacci-nated
Pakistan	04-03-2022	Jul-Dec 2021	1	74	5	0	0	0	0
			1	46	12	0	0	1	0
			1	75	43	0	0	4	0
		Jan-Jun 2022	1	-	13,285	-	-	291	451,986
Indonesia	02-03-2022	Jan-Jun 2022	31	8,406	174	0	6	2	0
Singapore	12-03-2022	Jan-Jun 2022	1	58	13	0	0	0	0
Bangladesh	15-09-2019	Jul-Dec 2019	4	750	175	0	0	0	-
China (People's Rep. of)	26-08-2019	July-Dec 2019	1	65	65	65	0	0	-
		Jan-June 2020	5	163	52	40	0	5	-
		July-Dec 2020	1	26	3	2	0	1	-
India	18-11-2019	July-Dec 2019	3	932	79	0	0	0	-
Nepal	29-07-2020	Jan-Jun 2020	1	3,000	500	0	0	12	-
		Jul-Dec 2020	7	11292	914	0	0	0	-
		Jul-Dec 2021	13	26342	1838	0	0	0	-
Sri Lanka	19-01-2021	Jul-Dec 2020	6	543	83	0	0	0	-
Bhutan	30-10-2020	Jul-Dec 2020	-	22307	160	0	0	3	0
Vietnam	01-11-2020	Jul-Dec 2020	259	2091	12525	1092	0	2	-
		Jul-Dec 2021	6	500	134	0	0	60	-
Myanmar	23-11-2020	Jul-Dec 2020	1	63	6	0	0	0	-
Thailand	09-04-2021	Jan-Jun 2021	473	1702538	84935	20	0	6700	0
		Jul-Dec 2021	103	133063	5365	0	0	143	0
		Jan-Jun 2022	6	420	75	0	0	9	-
Malaysia	21-06-2021	Jan-Jun 2021	113	6038	228	0	13	0	-
		Jul-Dec 2021	196	8046	473	0	83	2	-
Laos	02-07-2021	Jan-Jun 2021	9	2996	369	0	0	0	0
Cambodia	16-06-2021	Jan-Jun 2021	4	1228	219	0	0	0	-
		Jul-Dec 2021	47	9411	1419	0	0	27	-
		Jan-Jun 2022	3	761	43	0	0	5	
Mongolia	07-09-2021	Jul-Dec 2021	10	4574	60	60	0	0	4514
Chinese Taipei (Taiwan)	10-07-2020	Jan-Jun 2021	1	130	18	31	0	0	122

due to reduced milk yield and PKR 2,222 in lost workdays. Similar trends have been observed in Sindh and Punjab, where exotic breeds more severely impacted than indigenous cattle experienced up to 22% reduction in milk production over a 60-day period. In Punjab alone, over 84,000 cases were reported during the 2022 outbreak, with projected losses estimated at PKR 80.4 billion if uncontrolled. The economic impact is particularly devastating for smallholder farmers, who often depend on a single or few animals for income, traction, and food security. Costs associated with animal deaths, reduced fertility, delayed calving, and poor market value of recovered animals further intensify the long-term losses. These findings underscore the urgency for cost-effective vaccination strategies, early detection systems, and government-led compensation schemes, especially in rural and peri-urban areas where livestock remains a primary economic asset.

The causative agent, Lumpy Skin Disease Virus (LSDV), is closely related to sheep pox and goat pox viruses and shares similar economic importance due to its impact on animal health and trade. Like these viruses, LSDV poses a significant barrier to international livestock trade and has the potential to be misused as an agent of economic bioterrorism (Namazi and Khodakaram, 2021).

Lumpy Skin Disease (LSD) has rapidly expanded beyond India, with outbreaks now reported in China, Pakistan, and Eastern Europe, while Southern Africa remains a high-incidence region. Effective control is vital to reduce its impact on livestock productivity and ensure food security. In India, early detection and prompt intervention are key to minimizing economic losses. The 2019 outbreaks in East and South Asia significantly contributed to the cross-border spread of the disease, resulting in major financial setbacks (Das *et al.*, 2021).

Disease in Pakistan

In Pakistan, an outbreak of LSD would have profound effects due to the country's reliance on agriculture and its position as the second-largest livestock producer in the world. Pakistan's livestock sector includes around 49.6 million cattle and 41.2 million buffaloes, with annual increases of 3.1 million and 1.2 million, respectively. This sector contributes approximately Rs. 1466 billion to the national economy, representing 60.6% of the agricultural sector's value addition and 11.7% of the GDP. Additionally, it accounts for 3.1% of the country's total exports, making it a key source of foreign exchange. With around 8 million families dependent on livestock for 35-40% of their income, the introduction of LSD could be catastrophic. The potential for trade embargoes and the anticipated decline in rural economic activity could severely impact both the livestock industry and the livelihoods of millions of rural households. According to DAWN News Pakistan, over 20,000 cattle have been affected by Lumpy Skin Disease (LSD) in Sindh, with 15,100 cases reported in Karachi alone and 54 animal deaths. The outbreak has not only impacted livestock health but also disrupted the meat supply chain, leading to a surge in chicken prices, which reportedly exceeded Rs. 570 per kilogram (Khan *et al.*, 2021).

Severe cases of Lumpy Skin Disease (LSD) often result in damage to the udder and teats, causing a persistent decline in milk production even after recovery. Lesions in these areas create a suitable environment for secondary infections, leading to mastitis, which significantly reduces both the quality and quantity of milk (Akhter *et al.*, 2023).

Lumpy Skin Disease (LSD) causes major economic setbacks, especially in developing nations (Tadesse-Degu and Fesseha, 2020). Infected animals suffer from reduced appetite and weight loss, leading to a decline in milk yield. The disease also affects meat quality, and in countries where LSD is endemic, the export of meat is restricted. Firm skin nodules (2-5 cm) reduce hide quality, limiting its use in the leather industry (Chouhan *et al.*, 2022). In Pakistan, LSD threatens both the dairy and beef sectors and disrupts international trade (Saqib *et al.*, 2023). Although reported case numbers over 84,000 nationwide during the 2022 outbreak provide an overview of LSD's scale in Pakistan, the absence of robust disease surveillance systems and longitudinal monitoring severely limits the ability to track transmission trends or evaluate control measures over time. Most available data are event-driven and collected during outbreaks, with minimal integration into national animal health databases, resulting in underreporting and delayed response. Furthermore, socio-economic impacts at the farm level are often overlooked. Field studies from Khyber Pakhtunkhwa and Sindh have shown that affected farmers suffer not only from direct financial losses such as treatment costs, reduced milk yield, and animal mortality but also from long-term effects including decreased fertility, reduced market value of recovered animals, and food insecurity. Livelihood disruption is particularly severe for smallholder farmers who rely heavily on livestock for daily income and draught power. In response, some farmers have shifted toward keeping indigenous breeds, adopted traditional isolation practices, or delayed livestock sales to recover market value. Livestock movement is also affected due to necessary culling and quarantine measures. According to FAO, meat from LSD-suspected animals without fever may be consumed after proper cooking, but febrile animals must be excluded from the food chain and safely disposed of (Bianchini *et al.*, 2023).

Following the severe floods in Punjab, Pakistan, during September 2025, a significant rise in LSD cases has been documented by the Livestock and Dairy Development Department. The first confirmed outbreak was reported on 13 August 2025 in the Rahim Yar Khan District of

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Punjab. Since then, approximately 362 outbreaks have been recorded across the province up to 29 September 2025. The post-flood environment appears to have created highly favorable conditions for disease transmission. Factors such as persistently high temperatures, elevated humidity, uncontrolled animal movement during flooding, poor hygiene, and a surge in mosquito and biting-fly populations have collectively contributed to the sharp increase in LSD cases observed after 23 September 2025. This pattern highlights the close link between climatic disturbances and the epidemiological dynamics of vector-borne livestock diseases in the region. In Punjab, vaccination coverage against LSD remains below 10%, with most animals receiving goatpox vaccines that provide only partial (50–80%) protection. Limited availability of LSD-specific vaccines and poor cold-chain infrastructure hinder effective immunization. Delays in procurement and restricted access further reduce vaccination impact, especially among smallholder farmers.

Disrupting the dairy cycle

Lumpy Skin Disease (LSD) poses a serious threat to the global dairy and meat sectors, especially in regions where the disease is endemic (Khan *et al*., 2022). It adversely affects essential biological functions such as feeding, reproduction, and milk production in dairy and fattening animals. Infected cattle often suffer from high fever, lethargy, appetite loss, restlessness, weight reduction, and depression, all of which contribute to decreased feed intake and poor feed efficiency. These symptoms, coupled with extensive skin lesions, compromise nutrient absorption and create conditions favorable for secondary infections (Tadesse-Degu and Fesseha, 2020). Reproductive performance is also impaired, as fever and systemic illness disrupt hormonal balance, leading to temporary infertility in both males and females. Pregnant animals face a higher risk of miscarriage due to illness-related stress and immune suppression. Moreover, udder lesions increase susceptibility to bacterial infections, often resulting in mastitis, which further diminishes milk yield and quality. Even after recovery, animals may take several weeks to regain their previous milk production levels (Pal *et al*., 2024).

Prevention and control of LSD

Effective prevention and control of Lumpy Skin Disease (LSD) remain difficult due to limited understanding of its transmission among wildlife species and challenges in managing domestic livestock (Ratyotha *et al*., 2022). Veterinary vaccines are critical for ensuring animal health, improving productivity, and supporting global food security (Shahzad *et al*., 2024). The spread of *Capripoxviruses* is exacerbated by legal and illegal animal trade, environmental changes, limited vaccine availability, and poor access to veterinary resources in endemic regions (Sevik and Dogan, 2017). Core strategies such as vaccination, movement control, and removal of infected animals, coupled with symptomatic and supportive treatment, are essential for effective disease management (Salib and Osman, 2011). Vaccination and Vector Control Vaccination remains the most effective strategy against LSD. Movement from affected areas should only be allowed for animals vaccinated at least 28 days prior. Vector control, targeting mosquitoes, flies, and ticks, is vital in reducing disease transmission. Farm sanitation, including spraying with 1% formalin (1 L per 100 L water) and disinfectants, supports virus elimination (Khan *et al*., 2024). Slaughter campaigns and strict biosecurity protocols should be implemented, including control over the movement of people, equipment, milk, feed, and hides from infected premises. Vaccination Programs and Local Response Polyvalent and live attenuated vaccines such as Lumpy vax and OBP formulations based on the Neethling strain are widely used, offering immunity for up to three years (Khan *et al*., 2021). Cross-immunization trials using Romanian and Kenyan sheep pox strains have also shown potential, although limited to avoid cross-species disease risk. Ring vaccination (25-50 km radius), combined with movement restrictions, has shown success in regions like Israel and southeastern Europe. High vaccination coverage (80–100%) is essential. Record-keeping for animal ID, vaccine status, and movement history aids in tracking and control. In Pakistan, LSD outbreaks caused over 190,000 cases and 7,500 deaths. In response, the Ministry of National Food Security and Research launched a public awareness campaign targeting veterinarians, farmers, and transport personnel (Khatri *et al*., 2023). Biosecurity, Surveillance, and Global Strategy. Strict biosecurity; cleaning of equipment, vehicles, and premises is crucial (Gari *et al*., 2011). Quarantine of new or symptomatic animals is necessary, given the disease's 21-day incubation period. Vector management with insecticides reduces transmission risk (Khan *et al*., 2021). Trade bans on animals, hides, semen, and carcasses during outbreaks are essential (Sevik and Dogan, 2017). Consistent vaccination, movement control, and prompt culling have proven effective but remain challenged by vector persistence and delays in removing infected animals (Tuppurainen *et al*., 2021). Long-term control also depends on farmer and veterinarian education to improve early detection and reduce morbidity (Beard, 2016). Although live vaccines can cause mild local lesions (Bedekovic *et al*., 2018), they provide effective protection. Inactivated vaccines offer a safer alternative but require multiple doses (Hamdi *et al*., 2020). DIVA-compatible vaccines are recommended for distinguishing infected from vaccinated animals in endemic areas (Tuppurainen *et al*., 2021). The global spread of LSD is linked to animal trade and vector migration, emphasizing the need for international surveillance, biosecurity, and trade control (Das *et al*., 2021).

Effective LSD control requires early detection, movement restrictions, and strategic establishment of temporary control zones, based on veterinary guidance and factors like geography, livestock density, and vector activity. Affected and contact premises may face disinfection protocols and animal isolation to contain the spread (Namazi and Khodakaram, 2021). Farmer awareness is vital; customized posters, leaflets, and training improve understanding of symptoms, reporting, and preventive measures. Enhancing laboratory capacity and training diagnostic staff are key to early detection (Datten *et al*., 2023).

Preventing dairy losses from LSD depends on strict biosecurity and quarantine enforcement. Livestock imports and returning shipments are regulated, with biosecurity officers monitoring entry points. Goat pox vaccines are used temporarily until LSD vaccines are approved by DRAP (Jamil *et al*., 2022). Together, movement control, emergency vaccination, farmer education, and diagnostic preparedness form the backbone of an effective national LSD response (Mulatu and Feyisa, 2018).

Recent studies in Punjab indicate that less than 10% of the livestock population have been vaccinated against LSD, primarily using goat-pox vaccines, which afford only 50–80% protection against LSD. The Punjab government has not yet procured sufficient imported LSD-specific vaccine doses, and vaccination is largely limited to registered or large-scale farms. Cold-chain challenges are also reported, vaccine distribution is hindered by poor refrigeration, delays in procurement.

Conclusions

Lumpy Skin Disease (LSD) poses a serious threat to cattle health and the livestock economy, especially in developing countries. It reduces milk yield and quality, compromises meat and hide value, and leads to trade restrictions. The disease's spread is intensified by vectors, poor biosecurity, and limited access to effective vaccines. Effective control of LSD relies on a multifaceted approach, including timely vaccination, strict quarantine, vector control, early diagnosis, and farmer awareness. Strengthening veterinary infrastructure and encouraging research into improved vaccines and diagnostics are essential steps. A coordinated national and global response, backed by sound policy and community engagement, is key to reducing the disease burden and protecting food security. Post-flood conditions in Punjab, Pakistan, during 2025 led to a marked escalation of LSD outbreaks, totaling 362 by late September. The surge was strongly associated with hot, humid weather, poor hygiene, increased vector activity, and lack of adequate vaccination coverage following the floods. These findings highlight the critical influence of climatic, environmental, and preventive factors on the transmission dynamics of LSD among livestock. Moreover, cross-border collaboration is critical, as LSD does not recognize political boundaries and often spreads through informal livestock movement. Surveillance systems must be modernized using digital tools to enable rapid detection and response. Incentivizing farmers to report outbreaks without fear of economic loss can improve transparency and early containment. Public and private partnerships can further enhance vaccine delivery, field diagnostics, and capacity building at the grassroots level. In the long term, integrating LSD control into broader animal health programs will help build resilience against future transboundary animal diseases.

The findings emphasize that post-flood conditions significantly intensified LSD outbreaks in Punjab due to environmental stressors, inadequate vaccination coverage, and weak vector control. Future priorities should focus on developing and implementing LSD-specific vaccination programs (inactivated and live attenuated), strengthening cold-chain logistics, enhancing disease surveillance, and integrating a One Health approach to mitigate future epidemic risks under changing climatic conditions.

Declarations

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