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**RESEARCH ARTICLE**

# Economic Impact and Outbreak Preparedness Index of Lumpy Skin Disease in Dairy Cattle: Evidence from Madhya Pradesh, India

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## ABSTRACT

Lumpy skin disease (LSD) is a recently emerged transboundary viral disease that poses a serious threat to livestock farming and the livelihoods of dairy farmers. This study was undertaken to quantify the direct economic losses incurred by livestock farmers due to LSD and to evaluate the outbreak preparedness of veterinary institutions in the Jabalpur and Seoni districts of Madhya Pradesh, India. A cross-sectional, *ex post facto* research design was adopted, covering livestock farmers affected by LSD and government veterinarians serving the study area. Economic losses were estimated from production and expenditure data, whereas an LSD outbreak preparedness index (LSD-PI) was derived from nine preparedness indicators, standardized by min–max normalization and weighted using the analytical hierarchy process. Mortality, treatment, and milk-production losses emerged as the principal components of the economic burden of the disease, together contributing to an average direct loss of Rs. 6345 per respondent and Rs. 854.07 per animal-equivalent, equivalent to a 30.36% reduction in average monthly family income. Veterinary institutions in both districts showed, on average, a moderate level of outbreak preparedness (overall LSD-PI = 0.39 ± 0.16), with biosecurity being the only indicator that differed significantly between Jabalpur and Seoni ($P = 0.025$). These findings indicate that LSD continues to impose considerable socioeconomic hardship on small-scale dairy farmers and that strengthening vaccination coverage, disease surveillance, veterinary infrastructure, and biosecurity measures remains essential for effective outbreak management.

**Key words:** Biosecurity, dairy farmers, economic impact, lumpy skin disease, Madhya Pradesh, outbreak preparedness index, veterinary preparedness

## INTRODUCTION

Lumpy skin disease (LSD) is a highly contagious, poxvirus-induced infection of cattle that has emerged as one of the most economically damaging diseases affecting the global livestock sector.[1] The clinical presentation of LSD includes fever, cutaneous nodules, lymphadenopathy, a marked decline in milk yield, infertility, emaciation, and in severe cases, mortality. Although case fatality is generally low, the high morbidity associated with the disease translates into substantial productivity losses, thereby affecting the economic well-being

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of livestock-dependent households. The capacity of LSD to spread rapidly across international borders has placed it firmly among the priority transboundary animal diseases.

India has experienced widespread outbreaks of LSD in recent years, with the disease increasingly recognized as a serious threat to farmers' livelihoods across the Indian subcontinent,[2] most notably during the large-scale 2022 epidemic that affected cattle populations across several states.[3] Similar transboundary outbreaks, such as those documented in the Balkan region, have illustrated the scale of direct economic cost that LSD can impose on national livestock economies.[4] In the Indian context, the disease affects farmers through the combined burden of treatment expenditure, vaccination cost, reduced milk output, loss of productive animals, and depreciation in the market value of surviving livestock. These losses fall disproportionately on small-scale dairy farmers, for whom livestock represent both a primary income source and a store of wealth, underscoring the need to systematically quantify the economic impact of LSD. Alongside the assessment of economic losses, the level of preparedness of veterinary health institutions constitutes a second critical determinant of effective disease control. Diagnostic capacity, surveillance systems, physical and human infrastructure, availability of trained veterinarians, adherence to government guidelines, biosecurity practices, interinstitutional coordination, and community engagement jointly determine how effectively a veterinary system can respond to an outbreak. Systematic assessment of these dimensions helps identify the strengths and gaps of existing veterinary institutions.

A growing body of literature has examined the economic consequences of LSD outbreaks in different livestock production systems. In Ethiopia, LSD was shown to generate substantial economic losses driven by reduced milk yield, mortality, treatment expenditure, and lost productivity,[5] whereas a subsequent study confirmed the considerable economic burden of the disease on cattle producers and demonstrated that vaccination could meaningfully reduce these losses.[6] Among subsistence livestock keepers in Nigeria, LSD-related losses were found to be substantial and driven mainly by reduced production and mortality.[7] Comparable patterns have been reported elsewhere: Mortality and reduced milk yield were identified as the principal drivers of economic loss among Kenyan cattle farmers,[8] whereas treatment costs, mortality, and reduced milk output were shown to impose considerable economic losses on dairy farmers in Bangladesh.[9] In Thailand, LSD outbreaks were associated with a marked monthly decline in milk production,[10] and in Pakistan the disease was found to erode household income and livestock-based livelihoods.[11]

Parallel to this economic literature, several studies have emphasized the importance of institutional preparedness in disease management. The Infectious Disease Vulnerability Index was developed to benchmark countries' capacity to respond to disease outbreaks,[12] whereas the Epidemic Preparedness Index incorporated surveillance capacity, infrastructure, institutional capacity, and response mechanisms as core preparedness dimensions.[13] Robust preparedness systems have similarly been linked to improved outbreak-management outcomes,[14] with institutional capacity, trained personnel, surveillance systems, and response mechanisms identified as key determinants of preparedness.[15]

Despite this body of work, few studies have jointly examined farm-level economic losses and veterinary institutional preparedness within a single analytical framework, and such integrated evidence remains particularly scarce for India and for Madhya Pradesh in particular. Addressing this gap is important for designing coherent strategies that combine loss mitigation with improved outbreak readiness. Accordingly, the present study was conducted in the Jabalpur and Seoni districts of Madhya Pradesh, India, with the twin objectives of (i) estimating the direct economic losses incurred by livestock farmers due to LSD and (ii) developing and applying an Outbreak Preparedness Index to assess the readiness of veterinary institutions to manage LSD outbreaks. The findings are intended to inform policy responses aimed at reducing the economic burden of future LSD outbreaks.

## MATERIALS AND METHODS

### Study Area and Research Design

The study was conducted in the Jabalpur and Seoni districts of the Mahakoshal region of

Madhya Pradesh, India, using a cross-sectional, *ex post facto* research design. The two districts were purposively selected owing to their history of LSD outbreaks. Within each district, two LSD-affected blocks were selected, followed by the selection of villages that had reported confirmed LSD cases.

### Sampling Procedure

For the economic impact assessment, livestock farmers whose cattle had suffered from LSD infection were identified using snowball sampling, and case confirmation was carried out through photo elicitation using images of clinically affected animals. A total of 200 livestock farmers were sampled across the two districts. For the preparedness assessment, all government-sector veterinary officers in the selected districts who consented to participate were interviewed face-to-face.

### Development of the LSD Outbreak Preparedness Index (LSD-PI)

The LSD-PI was constructed from nine preparedness indicators: Diagnostic capability, reporting and surveillance, implementation of government guidelines, infrastructure adequacy, human resource availability, training and education, biosecurity, interinstitutional collaboration, and community awareness. Each indicator score was standardized using min–max normalization:

$$\text{Standardized score} = (Xi - Xmin)/(Xmax - Xmin) \quad (1)$$

The standardized scores were then weighted using the analytical hierarchy process (AHP), and the composite preparedness index was calculated as:

$$\text{LSD-PI} = \Sigma (Wi \times Si), \quad I = 1 \text{ to } 9 \quad (2)$$

Where Wi is the AHP-derived weight, and Si is the standardized score of the i-th indicator. Based on the resulting composite scores, veterinary institutions were classified as poorly prepared, moderately prepared, or well prepared.

### Economic Impact Assessment of LSD

Direct economic losses were estimated from production and expenditure data collected through a semi-structured interview schedule. The total direct economic cost was computed as the sum of vaccination cost, treatment cost, milk-production loss, and mortality loss:

$$TEC = VC + TC + ML + MrL \quad (3)$$

Where VC, TC, ML, and MrL denote vaccination cost, treatment cost, milk-production loss, and mortality loss, respectively. The mean economic loss per animal was obtained by dividing the total herd-level economic loss by the number of livestock units in the herd.

### Socioeconomic Variables

Sociopersonal and socioeconomic information was collected to characterize the study population and its relationship with the economic impact of LSD. Variables recorded included age, educational level, family size and type, land ownership, monthly family income, livestock ownership, dairying experience, milk production, extension agency contact, training received, and exposure to mass media.

### Statistical Analysis

Descriptive statistics (frequency, percentage, mean, standard deviation, and standard error) were used to summarize the data. Correlation, regression, and multivariate analyses were used to examine relationships among variables, and the Kruskal–Wallis test was applied to compare preparedness indicators between the two districts.

## RESULTS

### Socioeconomic Profile of the Respondents

Of the 200 livestock farmers surveyed, the majority were young (25–35 years; 57.5%), had a medium level of education (46.5%), and were male (66.0%) [Table 1]. Nearly half of the respondents had medium dairy-farming experience (48.0%), maintained small herds (40.5%), and belonged to medium-sized (41.5%) joint families (62.0%). Marginal landholding (<1 ha) characterized 84.0% of respondents, and 67.0% reported low monthly family income. More than half of the respondents reported medium exposure to mass media (57.0%)

and medium contact with extension agencies (56.0%). Collectively, these characteristics describe a study population dominated by resource-poor, smallholder dairy farmers who are particularly vulnerable to the financial consequences of livestock disease.

## Direct Economic Losses Due to LSD

Table 2 summarizes the mean cost of the four components of direct economic loss on a per-respondent basis. Mortality accounted for the largest mean loss (Rs. 2,635.00), followed by treatment (Rs. 2,284.00) and milk-production loss (Rs. 1,422.66); vaccination cost was negligible (Rs. 3.40), reflecting the low uptake of vaccination in the study area. Although mortality occurred in a relatively small proportion of animals, its economic impact was disproportionately large owing to the high market value of productive lactating cattle.

On a per-animal basis [Table 3], treatment cost (Rs. 709.80) and mortality loss (Rs. 701.86) were the largest contributors to economic loss, followed by milk-production loss (Rs. 441.80), whereas vaccination cost remained minimal (Rs. 1.06). The comparatively modest per-animal losses reflect the generally low milk yields, short infectious period, and subsistence-oriented dairy production systems that characterize the study area.

The overall direct economic cost of LSD infection, obtained by summing losses from vaccination, treatment, milk production, and mortality, is presented in Table 4. On average, LSD infection resulted in a direct economic loss of Rs. 6,345.00 per respondent and Rs. 854.07 per animal. Relative to the average monthly family income of Rs. 20,893, this represents a 30.30% reduction in income, illustrating the severity of the disease's economic impact on small-scale dairy-farming households and its potential to constrain future investment in animal health.

## Preparedness of Veterinary Institutions for LSD Outbreaks

Table 5 compares the nine preparedness indicators between Jabalpur and Seoni districts. No statistically significant difference was observed between the two districts for eight of the nine indicators. Biosecurity was the only indicator that differed significantly ($P = 0.025$), with Jabalpur recording a higher preparedness score than Seoni, plausibly reflecting comparatively better infrastructure and availability of protective equipment in Jabalpur. Because the preparedness scores were derived from a relatively small sample of 30 government veterinarians, this finding should be interpreted with caution.

The composite LSD-PI scores, summarized in Table 6, indicate an overall preparedness index of $0.39 \pm 0.16$ for the study area, with Jabalpur scoring $0.44 \pm 0.17$ and Seoni scoring $0.35 \pm 0.15$. The difference between districts was not statistically

**Table 1:** Socioeconomic profile of respondents ($n$=200)

| Variable | Dominant category | Percentage |
|---|---|---|
| Age | Young (25–35 years) | 57.5 |
| Education | Medium | 46.5 |
| Gender | Male | 66.0 |
| Dairy farming experience | Medium | 48.0 |
| Herd size | Small | 40.5 |
| Family size | Medium | 41.5 |
| Family type | Joint | 62.0 |
| Landholding | Marginal (<1 ha) | 84.0 |
| Monthly family income | Low | 67.0 |
| Mass media exposure | Yes | 57.0 |
| Extension agency contact | Medium | 56.0 |

**Table 2:** Mean cost of variables contributing to direct loss due to LSD infection (per respondent)

| S. No. | Type of loss | Amount (Rs.) |
|---|---|---|
| 1 | Loss in milk production | 1422.66 |
| 2 | Vaccination | 3.40 |
| 3 | Treatment | 2284.00 |
| 4 | Mortality | 2635.00 |

LSD: Lumpy skin disease

**Table 3:** Mean cost of variables contributing to direct loss due to LSD infection (per animal)

| S. No. | Type of loss | Amount (Rs.) |
|---|---|---|
| 1 | Loss in milk production | 441.80 |
| 2 | Vaccination | 1.06 |
| 3 | Treatment | 709.80 |
| 4 | Mortality | 701.86 |

**Table 4:** Direct economic cost incurred due to LSD infection

| S. No. | Basis | Amount (Rs.) |
|---|---|---|
| 1 | Direct cost per respondent | 6345.00 |
| 2 | Direct cost per animal | 854.07 |

LSD: Lumpy skin disease

**Table 5:** Indicator-wise comparison of LSD preparedness between districts (mean±SD)

| S. No. | Indicator | Jabalpur | Seoni | Z value | Overall |
|---|---|---|---|---|---|
| 1 | Diagnostic capabilities | 0.282±0.24 | 0.189±0.85 | 0.387 NS | 0.232±0.21 |
| 2 | Reporting and surveillance | 0.492±0.154 | 0.460±0.166 | 0.254 NS | 0.475±0.16 |
| 3 | Implementation of government guidelines | 0.610±0.169 | 0.525±0.209 | 0.294 NS | 0.565±0.19 |
| 4 | Infrastructure adequacy | 0.361±0.315 | 0.346±0.252 | 0.786 NS | 0.356±0.277 |
| 5 | Human resource availability | 0.326±0.282 | 0.258±0.204 | 0.586 NS | 0.290±0.241 |
| 6 | Training and education | 0.276±0.156 | 0.206±0.116 | 0.170 NS | 0.239±0.138 |
| 7 | Biosecurity measures | 0.628±0.180 | 0.442±0.291 | 0.025* | 0.582±0.25 |
| 8 | Collaboration and coordination | 0.439±0.210 | 0.419±0.224 | 0.555 NS | 0.430±0.214 |
| 9 | Community awareness and engagement | 0.576±0.244 | 0.373±0.278 | 0.052 NS | 0.468±0.278 |

LSD: Lumpy skin disease, SD: Standard deviation, NS: Not significant; *$P$<0.05

significant (Z = 1.53, NS), indicating broadly comparable levels of overall veterinary preparedness across the two districts.

Classification of veterinary institutions by LSD-PI category [Table 7] showed that the majority (22 of 30, 73.3%) fell into the moderately prepared category. A higher proportion of low-preparedness institutions was observed in Seoni, whereas Jabalpur had a comparatively higher share of institutions in the high-preparedness category, again likely reflecting differences in infrastructure and resource availability. Given the modest sample size, these classifications should also be viewed as indicative rather than conclusive.

**Table 6:** District-wise and overall LSD preparedness index scores

| S. No. | Variable | Value | Z value |
|---|---|---|---|
| 1 | LSD-PI score – Jabalpur | 0.44±0.17 | 1.53 NS |
| 2 | LSD-PI score – Seoni | 0.35±0.15 | |
| 3 | Overall LSD-PI score | 0.39±0.16 | |

NS: Not significant, LSD: Lumpy skin disease, LSD-PI: Lumpy skin disease outbreak preparedness index

**Table 7:** Categorization of veterinary institutions based on LSD-PI

| Category | Range | Jabalpur | Seoni | Total |
|---|---|---|---|---|
| Low | <0.232 | 1 | 3 | 4 |
| Medium | 0.232–0.563 | 11 | 11 | 22 |
| High | >0.563 | 3 | 1 | 4 |

LSD-PI: Lumpy skin disease outbreak preparedness index

## DISCUSSION

The findings of this study confirm that LSD imposes a substantial direct economic burden on small-scale dairy farmers in Madhya Pradesh, with mortality, treatment expenditure, and milk production losses emerging as the dominant cost components. This pattern is broadly consistent with reports from Ethiopia,[5] Bangladesh[9] and Kenya,[8] where mortality and reduced milk yield were similarly identified as the principal drivers of LSD-related economic loss, and with findings from Thailand[10] and Pakistan,[11] where milk-production decline and eroded household income, respectively, were highlighted as major consequences of LSD outbreaks. The negligible vaccination cost recorded in the present study reflects low vaccination coverage in the study area, a finding of particular concern given evidence from Ethiopia that vaccination can substantially reduce the economic losses associated with LSD outbreaks.[6] The scale of income loss observed here – 30.36% reduction in average monthly family income – underscores the acute vulnerability of resource-poor, smallholder dairy farmers, most of whom held marginal landholdings and reported low baseline incomes even before disease losses were incurred. This vulnerability parallels observations among subsistence farmers in Nigeria,[7] where limited buffering capacity against livestock losses similarly translated economic shocks into significant livelihood impacts.

With respect to institutional preparedness, the finding that veterinary institutions in both districts exhibited, on average, only moderate readiness echoes the broader preparedness literature, which consistently identifies surveillance capacity, infrastructure, trained personnel, and institutional coordination as key determinants of effective outbreak response.[12-13,15] The significant district-level difference in biosecurity preparedness, coupled with the absence of significant differences across the remaining eight indicators, suggests that overall

preparedness gaps in the study area are relatively uniform, with biosecurity representing a specific and addressable weak point. This is consistent with the view that targeted improvements in specific preparedness dimensions, rather than uniform investment, may yield the greatest gains in outbreak readiness.[14]

Taken together, the economic and preparedness findings point to a mutually reinforcing policy challenge: weak biosecurity and moderate overall institutional preparedness increase the likelihood and severity of future outbreaks, which in turn impose disproportionate economic hardship on smallholder farmers with limited capacity to absorb such shocks. Strengthening vaccination coverage, disease surveillance, veterinary infrastructure, and biosecurity practices therefore emerges as a coherent set of policy priorities for reducing both the incidence and the economic consequences of LSD outbreaks in the region. Matter: Certain limitations should be acknowledged. The preparedness assessment was based on responses from 30 government veterinarians, a modest sample that limits the precision of district-level comparisons and warrants cautious interpretations of the reported preparedness classifications. The economic impact estimates are based on *ex post facto*, self-reported production and expenditure data, which may be subject to recall bias. Future research incorporating longitudinal data collection and a larger, more geographically diverse sample of veterinary institutions would help to validate and extend these findings.

## CONCLUSION

This study demonstrates that LSD imposes a considerable direct economic burden on livestock farmers in Jabalpur and Seoni districts of Madhya Pradesh, with mortality, treatment expenditure, and reduced milk production accounting for the bulk of this loss, and with the resulting decline in monthly family income illustrating the disease's disproportionate impact on small-scale dairy-farming households. The assessment of veterinary institutional preparedness revealed a generally moderate level of outbreak readiness across both districts, with biosecurity standing out as the only dimension showing a significant district-level difference. These findings collectively indicate that continued investment in vaccination coverage, disease surveillance, veterinary infrastructure, and biosecurity measures is essential to strengthen outbreak preparedness and to reduce the socioeconomic burden of LSD on smallholder dairy farmers.

## AUTHORS' CONTRIBUTIONS

Saurabh Sharma and Hari R. conceived of the presented idea and applied the methodology. Saurabh Sharma developed the theory, conducted data collection, performed the computations, and wrote a draft. Ruchi Singh supervised the research, writing correction, and methodology. Rashmi Vishwakarma, Priyanka Prajapati, and Bhavana Gupta reviewed the writing up. Sunil Nayak provided guidance throughout the research process. All authors discussed the results and contributed to the final manuscript.

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## DATA AVAILABILITY STATEMENT

Data associated with this study will be made available by the corresponding author upon reasonable request.

## DECLARATION OF COMPETING INTERESTS

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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