Impact of Lumpy Skin Disease in India: Socio-behavioural Analysis, Epidemiology and Economics

Amandeep Singh (amandeepsinghvet@gmail.com)
Guru Angad Dev Veterinary and Animal Sciences University https://orcid.org/0000-0001-9906-7659
Gurpreet Kour
Guru Angad Dev Veterinary and Animal Sciences University
Sehajpal Singh Dhillon
Guru Angad Dev Veterinary and Animal Sciences University
Parkash Singh Brar
Guru Angad Dev Veterinary and Animal Sciences University

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Abstract

The outbreak of animal diseases has both explicit and implicit economic repercussions. In the present study, a simple mathematical model has been developed to estimate the economic impact of Lumpy Skin Disease (LSD) in India along with socio-behavioral factors and epidemiological metrics. The econometrics is based on all the direct and indirect losses and expenditures incurred during the entire course of disease in a dairy farm specifically considering production losses, reproduction losses, treatment costs, preventive costs and other costs. Primary data were collected from 100 dairy farms located in Indian state of Punjab in which LSD outbreak occurred. Based on the results, the economic impact of the disease was extrapolated for the total bovines effected due to the disease in the LSD outbreak occurred in India from July, 2022 to October, 2022. Results revealed 45.25 percent morbidity in cattle, 0.19 percent in buffaloes and 27.04 in pooled sample of bovines with 12.40 percent mortality in cattle. A net economic loss of INR 1135.26 crores (USD 137.26 million) in Punjab and INR 18337.76 crores (USD 2217.26 million) in India was estimated due to LSD outbreak in bovines. The modelling approach along with socio-behavioural analysis and epidemiology provided an evidence of coherence among the prevailing factors and aided to estimate economic impact precisely.

1. Introduction

Livestock is an integral component of rural society of India. In 2020-21, the contribution of livestock was 6.17 percent and 30.87 percent to national and agricultural Gross Value Added (GVA) respectively. Dairy sector proves to be the backbone of rural economy. Among all the agricultural commodities in India, milk is the highest grossed commodity with 66.76 percent of contribution in the total value output from livestock sector. The total milk production in the country was 209.96 million tonnes with per capita availability of 427 grams per day which makes India the world leader in milk production (Basic Animal Husbandry Statistics, 2021).

Livestock disease outbreaks not only affect the microeconomics but also the macroeconomics. As far as LSD is concerned, it is a viral disease caused by Lumpy Skin Disease Virus (LSDV) belonging to family *Poxviridae*. LSD is non-zoonotic, vector-borne disease which is found in many nations primarily affecting cattle and water buffaloes. The first case of LSD was reported in Zambia in 1929 from where it traversed international borders. In India, the first outbreak of the disease was reported in the state of Odisha in 2019 (Gupta et al., 2020). In July 2022, LSD outbreak occurred in India with Gujarat as epicenter, which later spread to Rajasthan along with all the states in northern part of the country affecting cattle and buffaloes (Sharma, 2022). The onset of monsoon triggers the spread of disease because of high humidity and increased number of vectors (Mulatu and Feyisa, 2018).

LSD has huge financial impact which makes it to the list of notifiable disease by World Organization for Animal Health (OIE). It affects the economy of a nation largely due to the reduction in milk production and sometimes death of the affected animals (Abutarbush, 2015). Further, the suffering animals show severe emaciation, loss to hide, reduction in draught power, reproductive losses, infertility in males and females, etc. (Tuppurainen and Oura, 2012). These repercussions led to losses in associated industries as well like milk, meat and leather industry (Gupta et al., 2020). The cost of prevention is mainly incurred on vaccination which needs to be done before the onset of LSD outbreak (Gari et al., 2011).

The objective of the current study was to explore the practices followed by the dairy farmers during the outbreak of LSD which constituted the socio-behavioural dimesnion along with epidemiological metrics of the disease with major thrust on calculating the losses and expenses incurred by developing a simple mathematical model. To our knowledge, the study is first of its kind in India and has the potential to aid the policy makers to control the LSD disease outbreaks across the nation.

2. Research Methodology

An *ex-post facto* research design was used to investigate the economic losses due to LSD. The present investigation was done in the Indian state of Punjab because of its highest bovine productivity (Singh et al., 2021). For computing the economic impact due to LSD, a semi-structured interview schedule was developed for data collection. Data were collected purposively from 100 dairy farms which has witnessed outbreaks of LSD. The socio-behavioural variables like age, education, herd size and practices pertaining to LSD prevention viz. utilization of herbal or homeopathic treatment with type of agents, vaccination, isolation of sick animals, use of antiseptics and cleaning agents and vector control methods were studied. For understanding the dispersion of data, frequency, percentage along with mean and standard error (SE) were calculated. Epidemiological metrics like morbidity, mortality and case fatality rate were estimated. The major thrust of the study was laid on estimation of economic losses and for the said purpose econometric analysis of LSD was done based on production losses (A), reproduction losses (B), treatment costs (C), preventive costs (D) and other costs (E). The total economic impact of LSD (T) was calculated by summation of all the losses and costs in Indian National Rupee (INR) by development of a simple mathematical model which is given below:

$$T = A + B + C + D + E$$

A. Production Losses

The major production loss is due to reduction in milk production and it was estimated per dairy animal per day using the formula given below:

$$A = \frac{Lossofmilkperdayinfarm\,(liters)\,XDurationofdisease\,(days)\,XSellingpriceofmilk\,(INR)}{Totalanimalsaffectedinfarm\,(inabsolutenumber)}$$

The percentage loss in milk production was also calculated using the formula:

$$Lossinmilkproduction\,(\%) = \frac{Milkproductionbeforedisease - Milkproductionafterdisease}{Milkproductionbeforedisease} X100$$

B. Reproduction Losses

Reproduction losses were challenging to calculate as there was equivocality in the economic figures obtained during the survey. To address the issue and to bring coherence in the economic losses due to reproductive disorders, the methodologies of Kumar et al. (2013) and Deka et al. (2021) were followed with suitable extrapolations in concurrence with the data collected during the survey. Three major reproductive disorders were reported by the dairy farmers viz. anestrus, repeat breeding and abortion due to outbreak of LSD. Therefore, the equation for reproduction losses per animal per day can be written as:

$$B = Lossesduetoanestrus + Lossesduetorepeatbreeding + Lossesduetoabortion$$

Individually these losses were calculated on per day basis as:

$$Lossesduetoanestrus = \frac{(FC + TC + LC + ML)}{D} XRDAN$$

$$Lossesduetorepeatbreeding = \frac{(FC + TC + LC + CAI + ML)}{D} XRDRB$$

$$Lossesduetoabortion = \frac{(FC + TC + LC + ML)}{D} XRDAP$$

Where, FC = Feed cost, TC = Treatment cost, LC = Labour cost, ML = Milk loss, CAI = Cost of extra artificial inseminations, D = Number of days for which animal was affected with LSD, RDAN = Reproductive days lost due to anestrus, RDRB = Reproductive days lost due to repeat breeding, RDAP = Days for which animal was pregnant or days from conception to abortion. FC, TC, LC, CAI and ML corresponds to the total losses or expenditure incurred in these heads during the entire course of the disease.

The expenditure incurred on feed, treatment and labour in one month constitute the net capital loss in one month due to reproductive failures. Milk loss may be excluded on case to case basis in this expenditure because the animal can retain the milk production during reproductive failures as well. However, in certain cases milk loss can be calculated as:

1. Direct loss in milk yield because of reproductive failure
2. Loss of milk due to elongation of reproductive months i.e. delayed conception due to missed heat increases the calving interval and less number of animals will be in-milk at the certain point of time
3. Decreased milk production in next lactation cycle due to the elongation of current lactation
4. Incompetence of animal to retain peak milk yield

C. Treatment Costs

Treatment costs consisted of the expenditures made primarily on antibiotics, veterinary consultation and herbal or homeopathic drugs. The treatment costs per animal per day were estimated by the following formula:

$$C = \frac{(Costofantibiotics + Feepaidforveterinaryconsultation + Costofherbalorhomeopathicdrugs)}{(Numberofdaysforwhichanimalwasaffected X Numberofaffectedanimals)}$$

D. Preventive Costs

Under the financial head of preventive costs, the expenditures were made on vaccination, antiseptics and cleaning agents, and vector control methods. The preventive costs per animal per day were worked with the formula as under:

$$D = \frac{(Vaccinationcost + Costofantisepticsandcleaningagents + Costofvectorcontrol)}{(Numberofdaysforwhichanimalwasaffected X Numberofaffectedanimals)}$$

E. Other Costs

For precisely accounting the economic impact of any disease, there are certain hidden costs which are largely neglected. Some researchers term them as opportunity costs and consummate a lump sum amount of these costs into the total cost. However, in the present investigation, these costs are calculated as ‘other costs’ and consists of cost of family labour (FLC), cost incurred on transportation of sick animal (TPC), cost of feeding extra concentrates to sick animals (FCC), cost forfeited due to damaged hides and skins (HSC), reduction in net value or selling price or market value of the animal (SPC) and reduction in draught power of the animal (DPC). These costs were calculated per animal per day as below:

$$E = \frac{(FLC + TPC + FCC + HSC + SPC + DPC)}{(DXN)}$$

Where, D = Number of days for which animal was affected with LSD and N = Number of affected animals.

The cost of dead animal was calculated based on the primary data collected from the dairy farmers. The average cost of dead animal was calculated by total cost of the dead animals divided by the number of dead animals.

3. Results And Discussion

3.1 Socio-behavioural Analysis

3.1.1 Age

The data for 100 dairy farms in which LSD outbreak occurred were collected and analyzed for various variables under study. Upon analysis and perusal of Table 1, it was found that the age of respondents who were managing dairy farms ranged from 19 to 79 years with mean 44.15 years. Majority of the respondents (46%) were middle aged. The results of the study are in concurrence with Singh (2019) and Singh et al. (2020) wherein more than half of the respondents owning dairy farms in Punjab were middle aged.

Table 1
Distribution of respondents according to age

Age (in years)	Frequency (n = 100)	Percentage
Young (19–39)	36	36.00
Middle (39–59)	46	46.00
Old (59–79)	18	18.00
Mean ± SE	44.15 ± 1.36	

3.1.2 Education

Education is a process which brings desirable change in the behaviour of a person. In the context of present study, majority of the respondents (35%) were having education upto senior secondary level followed by 29 percent respondents which were graduate. Only one among the hundred dairy farmers was illiterate which shows that dairy farmers in Punjab had satisfactory education levels (Table 2). The results of the study accords to those reported by Singh et al. (2018), Bansal and Bansal (2018), Singh (2019) and Singh et al. (2020) wherein the dairy farmers in Punjab were found to have amenable levels of education. Sood et al. (2020) and Singh et al. (2022) in their studies had critically appraised that high education levels are leading to increasing use of information and communication technologies by dairy farmers in Punjab which in turns aids in better technology adoption.

Table 2
Distribution of respondents according to education

Education	Frequency (n = 100)	Percentage
Illiterate	1	1.00
Primary	2	2.00
Middle	5	5.00
Matriculation	23	23.00
Senior Secondary	35	35.00
Graduate	29	29.00
Post-graduate and above	5	5.00

3.1.3 Herd size

It is evident from Table 3 that majority of the farms (70%) were having one to ten dairy animals and were categorized as small dairy farms. About 86 percent and 90 percent of the respondents stated to have one to ten number of cattle and buffaloes respectively. The total animal heads in 100 dairy farms were calculated to 1272 with 758 cattle and 514 buffaloes. The results of the present study are in accordance with Kaur et al. (2017), Singh (2019) and Singh et al. (2020) wherein it was reported that the majority of dairy farmers in Punjab possess an average dairy herd of 5 to 10 dairy animals.

Table 3
Distribution of respondents according to herd size

Herd Size (in numbers)	Cattle		Buffalo		Pooled	
	Frequency (n = 100)	Percentage	Frequency (n = 100)	Percentage	Frequency (n = 100)	Percentage
Small (1–10)	86	86.00	90	90.00	70	70.00
Medium (10–20)	9	9.00	6	6.00	16	16.00
Large (20–30)	0	0.00	1	1.00	8	8.00
Very large (> 30)	5	5.00	3	3.00	4	4.00
Mean ± SE	7.58 ± 1.34		5.14 ± 0.93		12.72 ± 2.01	
Total animal heads	758		514		1272	

3.1.4 Herbal or homeopathic remedies used

Table 4 reveals that among the 100 dairy farms, 53 percent were found to be using herbal or homeopathic remedies for treating ailing animals. Some of the respondents used the herbal or homeopathic remedies along with allopathic treatment for faster recovery. Among various herbs Karru (*Picrorhiza kurroa*) was used by majority of the respondents (15%) followed by Giloy (*Tinospora cordifolia*), Tulsi (*Ocimum tenuiflorum*), Haldi (*Curcuma longa*), Neem

(*Azadirachta indica*) and Amla (*Phyllanthus emblica*). About 14 percent of the respondents were providing the combination of documented herbs for treating LSD in dairy animals. About 25 percent of the respondents provided animals with LSD homeopathic kit as treatment of LSD. Tabassum and Hamdani (2014) have reported the utility of herbal plants on skin ailments. The study highlights the usage of ethno-medicinal practices for treating various skin affections. Preethi and Devi (2020) recommended the usage of all the discussed herbs with ghee and jaggery in the form of a paste which can be provided to the affected animal twice to thrice a day for 3 to 14 days for better results. Yadav et al. (2021) has also reported successful treatment of a buffalo suffering with LSD with herbs which were provided to the animal for 15 days.

Table 4
Herbal or homeopathic remedies used

Herbal or homeopathic treatment taken	**Frequency (n = 100)**	**Percentage**
Yes	53	53.00
No	47	47.00
Type of herbal or homeopathic agent used*		
Karru (*Picrorhiza kurroa*)	15	15.00
Giloy (*Tinospora cordifolia*)	13	13.00
Tulsi (*Ocimum tenuiflorum*)	13	13.00
Haldi (*Curcuma longa*)	12	12.00
Neem (*Azadirachta indica*)	9	9.00
Amla (*Phyllanthus emblica*)	6	6.00
Combination of above	14	14.00
LSD Homeopathic Kit	25	25.00
** Multiple responses*		

3.1.5 Isolation of diseased animals, use of antiseptics and cleaning agents

With regard to the pre-emptive measures taken by the dairy farms to control the spread of disease, the results are presented in Table 5. It was found that majority of the dairy farmers (87%) isolated the diseased animals from the healthy animals. Among the antiseptics, Dettol was used by majority of the farms (50%) for cleaning the animal wounds as it is easily available in the households. Other antiseptics like betadine, potassium permanganate, neem and turmeric along with topicure spray were also used. Majority of the farms (46%) used phenol as a cleaning agent followed by phenyl (27%), potassium permanganate (14%), detergent (7%) and lime powder (6%). Akbik et al. (2014) has apprised about the potential of turmeric in wound healing and its anti-inflammatory properties. The validation of potassium permanganate solution in wound healing has been provided by Delgado-Enciso et al. (2018). Further, OIE (2017) along with Government of India advisories have recommended the usage of 2 percent phenol for 15 minutes as choice of cleaning agent for prevention of LSD.

Table 5
Isolation of diseased animals, use of antiseptics and cleaning agents

Animals with symptoms of LSD isolated from healthy animals	Frequency (n = 100)	Percentage
Yes	87	87.00
No	13	13.00
Antiseptics used to clean animal wounds		
Dettol	50	50.00
Betadine	12	12.00
Potassium permanganate	27	27.00
Neem and turmeric	4	4.00
Topicure spray	7	7.00
Cleaning agents used to clean animal farms		
Phenyl	27	27.00
Phenol	46	46.00
Lime powder	6	6.00
Potassium permanganate	14	14.00
Detergent	7	7.00

3.1.6 Vector control methods

LSD is basically a vector borne disease, hence vector control becomes imperative for prevention of LSD. Results presented in Table 6 suggest that majority of the farms (48%) were using Amitraz spray for control of vectors. About 36 percent farms did not employ any vector control method to prevent the disease. Few farms resorted to ivermectin injectable, neem smoke and mosquito repellant for vector control. Abbas et al. (2014) and Walker (2014) has reported the direct application of acaricides through dipping and spraying as most common method of vector control. Mutavi et al. (2021) has suggested the on-farm use of amitraz as acaricide in Kenya, the same of which was observed in the context of the present study. Lighting smoke around the animals using cow dung cakes is a normal practice to control mosquitoes and other vectors in India, however, the dairy farmers used dry neem leaves along with cow dung during LSD outbreak for control of vectors.

Table 6
Vector control methods used for prevention of LSD

Vector control method	Frequency (n = 100)	Percentage
None	36	36.00
Amitraz	48	48.00
Ivermectin	6	6.00
Neem smoke	7	7.00
Mosquito repellant	3	3.00

3.2 Epidemiology

The data regarding epidemiological metrics are presented in Table 7. Out of total 1272 dairy animals, a total of 344 were found to be having lesions associated with LSD which leads to 27.04 percent of morbidity. The morbidity in cattle and buffaloes was found to be 45.25 percent and 0.19 percent respectively in the study area. The mortality rate in cattle and buffaloes was 12.40 percent and zero percent respectively. However, the case fatality rate in cattle was significantly higher i.e. 27.41 percent. The results pertaining to morbidity is in concurrence to those presented by Upender et al. (2022) and Reddy et al. (2022) but mortality is on the higher side which may be due to the associated risk factors. However, Coetzer (2004) has commented that the morbidity and mortality in dairy animals due to LSD may vary from 5 to 45 percent (sometimes 100%) and 10 to 40 percent respectively. Bharti (2022) in pretext to the mortality and morbidity due to LSD in dairy cattle in Punjab reported that Government of Punjab has claimed the loss of 11,000 dairy animals with 0.12 million being found affected since its outbreak in July, 2022.

Table 7
Epidemiological metrics

Parameter	Cattle (n = 758)	Buffalo (n = 514)	Pooled (n = 1272)
Number of animals affected	343	1	344
Morbidity (%)	45.25	0.19	27.04
Mortality (%)	12.40	0.00	7.39
Case fatality rate (%)	27.41	0.00	27.33

Breed-wise results were also calculated for cattle based on the data collected and presented in Table 8. It was found that the morbidity and mortality was highest in crossbred cattle whereas the case fatality was highest in indigenous cattle. However, it was found that all breeds of cattle are susceptible for the disease. OIE (2017) and Gupta et al. (2020) stated that the clinical signs in *Bos taurus* is manifested with greater intensity as compared to *Bos indicus*. As crossbred cattle in Punjab has more exotic inheritance, therefore, more LSD affection was observed.

Table 8
Breed-wise Epidemiological Parameters of LSD in Cattle

Morbidity	**Number (n = 343)**	**Percentage**
Indigenous	35	10.20
Crossbred	212	61.81
Exotic	96	27.99
Mortality	**Number (n = 94)**	**Percentage**
Indigenous	17	18.09
Crossbred	59	62.77
Exotic	18	19.15
Breed-wise case fatality rate in cattle		**Percentage**
Indigenous (17/35)*		48.57
Crossbred (59/212)*		27.83
Exotic (18/96)*		18.75
** Figures in the parenthesis indicates mortality over morbidity*		

Various risk factors were also found to be associated with the outbreak of LSD in Punjab, few being poor hygiene of the farms, overstocking of the dairy animals, high humidity along with temperature, soaring population of vectors, poor management of the animals, menace of stray animals, transportation of animals and animal products, transboundary spread of the disease (as Punjab shares expansive border with Pakistan and neighbouring state Rajasthan which was massively struck by the outbreak of LSD), etc. The identified risk factors were also reported by Gari et al. (2010), Ince et al. (2016), Sevik and Dogan (2016), Kiplagat et al. (2020) and Reddy et al. (2022). All ages of the cattle were found to susceptible for the disease which was also reported by Tuppurainen et al. (2012).

3.3 Economic Loss

3.3.1 Loss of Milk Production

3.3.1.1 In Cattle

The dairy animals affected with LSD drastically reduce their milk production. Table 9 revealed that in cattle, per animal per day reduction in milk production due to LSD outbreak was zero to 3 liters in about 35 percent of the farms. The mean reduction in milk production per day per affected animal was calculated to be 5.45 liters. As the price of per liter of cow milk was calculated to be INR 35.61, therefore, per cow per day loss due to reduction in milk production was estimated at INR 194.07. The average number of days for which cows were affected with the disease were 15.85 and it took an average of 30 days for a cow to attain normal milk yield after recovery, thus making the entire course of disease to 45.85 days in which milk loss occurred. The economic loss due to loss of milk production per affected cow during entire course of LSD was estimated to be INR 8898.31.

Table 9
Loss of milk production per cow per day in surveyed farms

Loss of milk per day in liters	Frequency (n = 100)	Percentage
Low (0–3)	35	35.00
Medium (3–6)	27	27.00
High (6–9)	27	27.00
Very high (> 9)	11	11.00
Mean ± SE	5.45 ± 0.30	
Total number of cows affected	343	
Loss of milk production per day in affected cows (in liters)	1869.35	
Average selling price of cow milk (in INR)	35.61	
Economic loss due to loss of milk production per affected cow per day (in INR)	194.07	
Average number of days for which the cows were affected with the disease	15.85	
Average number of days which are required per cow to reach normal milk yield after recovery	30	
Total number of days for which there is loss of milk production or entire duration of disease	45.85	
Economic loss due to loss of milk production per affected cow during entire course of LSD (in INR)	8898.31	

3.3.1.2 In buffaloes

Although in the study area, only single buffalo showed the symptoms of LSD but in 12 dairy farms, reduction in milk production during the outbreak of LSD was observed. Maximum buffaloes which reduced milk production to limited extent were largely asymptomatic for LSD. Thus, the mean reduction in milk production among buffaloes was calculated to 0.22 liters (Table 10). The buffalo which was found positive for LSD reduced the milk production by 5 liters. As the average selling price of buffalo milk was calculated to be INR 60.57 in the study area, therefore, the per day loss in terms of milk production per buffalo was estimated to INR 302.85. The average number of days for which buffaloes were found affected were 10 and it took 15 more days to reach the normal milk yields, therefore, the economic impact due to loss in milk production in buffaloes were calculated to be INR 7571.25.

Table 10
Loss of milk production per buffalo per day in surveyed farms

Loss of milk per day in liters	Frequency (n = 100)	Percentage
Low (0–1)	93	93.00
Medium (1–2)	6	6.00
High (2–3)	0	0.00
Very high (> 3)	1	1.00
Mean ± SE	0.22 ± 0.07	
Total number of buffaloes affected	1	
Loss of milk production per day in affected buffalo (in liters)	5	
Average selling price of buffalo milk (in INR)	60.57	
Economic loss due to loss of milk production per affected buffalo per day (in INR)	302.85	
Average number of days for which the buffalo affected with the disease	10	
Average number of days which are required per buffalo to reach normal milk yield after recovery	15	
Total number of days for which there is loss of milk production or entire duration of disease	25	
Economic loss due to loss of milk production per affected buffalo during entire course of LSD (in INR)	7571.25	

3.3.1.3 Percentage loss of milk in dairy farms

The percentage loss of milk across dairy farms was also calculated and presented in Table 11. Results revealed that about 54 percent dairy farms witnessed 33 to 66 percent loss of milk production during the outbreak of disease. The mean percent loss of milk was calculated to 45.10 percent. Loss of milk production is a major recurring loss in any disease which impacts the microeconomics of the farm. The repercussions due to production losses negatively regresses the farm economy. Shagun and Das (2022) has reported the loss of INR 288.75 per cow per day due to LSD outbreak which is slightly higher than the loss estimated in the context of present investigation. Reddy et al. (2022) has also reported that LSD impacts milk production significantly which leads to greater economic loss. The percent reduction in milk yield is in concurrence with the studies of Alemayehu et al. (2013), Sevik and Dogan (2017), Namazi and Tafti (2021) and Pandey et al. (2021) in which reduction in milk production was estimated varying from 10 to 85 percent.

Table 11
Percentage loss of milk in dairy farms

Percentage loss of milk	Frequency (n = 100)	Percentage
0 to 33	28	28.00
33 to 66	54	54.00
66 to 100	18	18.00
Mean ± SE	45.10 ± 2.09	

3.3.2 Reproduction Losses

Reproduction is inextricably linked with the health of the animal. In case of any disease condition, reproduction is likely to get affected. The methodology used by Kumar et al. (2013) and Deka et al. (2021) was used to calculate reproduction losses. In the present study, it was found that 72 animals did not show the signs of heat i.e. suffered with anestrus, 71 were repeat breeders and 11 animals aborted their fetuses (Table 12). For anestrus, the mean of losses reported by Kumar et al. (2013) and Deka et al. (2021) for per day loss was calculated to be INR 652.05 after extrapolating the same at current prices and correlating the same with field conditions. Thus the economic losses per animal due to anestrus, repeat breeding and abortion were calculated to be INR 29896.49, INR 4707.05 and INR 7792.05 respectively for entire course of the disease i.e. 45.85 days. Kumar et al. (2013) estimated the reproduction losses due to anestrus in buffaloes to the tune of INR 372.90 per animal per day which makes INR 17097.46 for the entire course of the disease. Further, the losses due to delayed conception because of failure in detection of heat or anestrus is in accordance with the figures reported by Tariq (2019). Reproduction losses greatly affect the farm economics minutely by pressing the farmers with treatment cost but majorly by increasing the calving interval due to delayed conception (Swai et al., 2005; Tariq, 2019). All the three major reproductive problems leads to loss of reproductive months with increase cost on management of the animals. These cost compel the farmers to salvage the animals which again is a net loss to the farm economics (Mebrahtom et al., 2016).

Table 12
Losses incurred due to reproduction failures

Condition	Number of animals affected	Cost incurred per animal per day (in INR)	Cost incurred per cow during the entire course of disease
Anestrus	72	652.05	29896.49
Repeat breeding	71	102.66	4707.05
Abortion	11	169.94	7792.05

3.3.3 Treatment Costs

3.3.3.1 Cost incurred on antibiotics and veterinary consultation

Being a viral disease, LSD does not have a specific line of treatment, however, antibiotics to treat secondary bacterial infections, non-steroidal anti-inflammatory drugs (NSAIDs) to control inflammation and topical ointments to provide relief to ailing animal is given. Results presented in Table 13 depicted that majority of dairy farmers (51%) provided

treatment to the affected animals for one to ten with mean of 15.85 days. About 36 percent of the dairy farms incurred upto INR 5000 in total for treatment of LSD at their farms using antibiotics. However, the mean treatment cost using antibiotics per animal was estimated to be INR 3724.45. The mean treatment cost paid per animal per day was estimated to be INR 1294.12. The average cost incurred on antibiotics during the whole course of disease per farm was INR 8671.00 and average cost incurred on consultation from veterinarian/para-veterinarian during the whole course of disease per farm was INR 2060.00. Abutarbush et al. (2015) reported that dairy farms in Jordan spend USD 32.93 on treatment of LSD whereas Karalliu et al. (2017) estimated the same to the tune of USD 29.36 in Albania. Molla et al. (2017) while working on economics of diagnosis and medication of LSD reported that a total of USD 5 were incurred on treatment of affected animals in Ethiopia. Reddy et al. (2022) provided an insight that treatment of the affected animals is also one of the major contributors to the disease economics. More or less the results of the studies provide an insight on the financial burden of LSD treatment on the dairy farmers in various parts of the world.

Table 13
Cost incurred on antibiotics and veterinary consultation

Number of days treatment given to affected animals	**Frequency (n = 100)**	**Percentage**
1 to 10	51	51.00
10 to 20	24	24.00
20 to 30	22	22.00
More than 30	3	3.00
Mean ± SE	15.85 ± 0.71	
Total treatment cost paid for treating LSD using antibiotics (in INR)		
Low (upto 5000)	36	36.00
Medium (5000–10000)	31	31.00
High (10000–15000)	18	18.00
Very High (> 15000)	15	15.00
Mean ± SE	10731.00 ± 1309.37	
Treatment cost per animal	3724.45	
Treatment cost paid per animal per day (in INR)		
Low (upto 500)	20	20.00
Medium (500–1000)	34	34.00
High (1000–1500)	14	14.00
Very High (> 1500)	32	32.00
Mean ± SE	1294.12 ± 101.41	
Average cost incurred on antibiotics during the whole course of disease per farm (in INR)		8671.00
Average cost incurred on consultation from veterinarian during the whole course of disease per farm (in INR)		2060.00
Average cost incurred on consultation from veterinarian per animal per day (in INR)		13.09

3.3.3.2 Cost incurred on herbal or homeopathic drugs

The amount incurred on herbal/homeopathic medicine was also calculated. Results presented in Table 14 revealed that majority of the dairy farms (72%) spent less on such drugs. The average expenditure incurred on herbal/homeopathic remedies per farm was INR 329.30. However, cost incurred on herbal/homeopathic medicine per animal was INR 154.08 for the whole course of the disease which was much lower than the expenditure incurred on allopathic drugs. The total cost of treatment which includes cost on antibiotics (INR 1294.12), fee paid for veterinary consultation (INR 13.09) and cost incurred on herbal medicine (INR 2.15) per animal per day sums upto INR 1309.36.

Table 14
Cost incurred on herbal or homeopathic drugs

Cost (in INR)	Frequency (n = 100)	Percentage
Low (upto 500)	72	72.00
Medium (500–1000)	22	22.00
High (1000–1500)	3	3.00
Very High (> 1500)	3	3.00
Mean ± SE	329.30 ± 54.53	
Cost incurred on herbal medicine per animal (in INR)	154.08	
Cost incurred on herbal medicine per animal per day (in INR)	2.15	

3.3.4 Preventive Costs

3.3.4.1 Vaccination cost

The prime preventive cost comprise of the vaccination cost for LSD. During the survey, it was found that only 26 percent of the dairy farms got their dairy animals vaccinated against the disease (Table 15). The majority of the respondents cited various problems associated with LSD vaccine primarily the unavailability of disease specific vaccine, meager supply of goat pox vaccine and high cost associated with the vaccine. The average cost of vaccination per animal was estimated to be INR 58.00.

Table 15
Vaccination cost

Status	Frequency (n = 100)	Percentage
Done	26	26.00
Not done	74	74.00
Average cost of vaccination per animal (in INR)	58.00	
Average cost of vaccination per animal per day (in INR)	1.26	

3.3.4.2 Cost incurred on antiseptics and cleaning agents

Data were analyzed for estimating the cost incurred on antiseptics and cleaning agents. Results in Table 16 elucidated that majority of the farms (61%) were spending less (upto INR 500) on antiseptics and cleaning agents with mean expenditure of INR 329.23 and per animal expenditure of Rs. 280.93 during the entire course of disease.

Table 16
Cost incurred on antiseptics and cleaning agents

Cost (in INR)	Frequency (n = 100)	Percentage
Low (upto 500)	61	61.00
Medium (500–1000)	23	23.00
High (1000–1500)	8	8.00
Very High (> 1500)	8	8.00
Mean ± SE	329.23 ± 54.53	
Cost incurred on antiseptics and cleaning agents per animal (in INR)	280.93	
Cost incurred on antiseptics and cleaning agents per animal per day (in INR)	6.12	

3.3.4.3 Cost incurred on vector control methods

The cost incurred on vector control methods was calculated and presented in Table 17. It was found that majority of the dairy farms (85%) were spending less on vector control methods with mean expenditure of INR 374.00. The expenditure per animal for vector control was estimated to be INR 132.03 during the entire course of the disease.

Table 17
Cost incurred on vector control methods

Cost (in INR)	Frequency (n = 100)	Percentage
Low (upto 500)	85	85.00
Medium (500–1000)	11	11.00
High (1000–1500)	0	0.00
Very High (> 1500)	4	4.00
Mean ± SE	374.00 ± 71.27	
Cost incurred on antiseptics and cleaning agents per animal (in INR)	132.03	
Cost incurred on antiseptics and cleaning agents per animal per day (in INR)	2.87	

The preventive costs comprised of vaccination cost (INR 1.26), cost incurred on antiseptics and cleaning agents (INR 6.12), and cost incurred on vector control methods (INR 2.87) which sums upto INR 10.27.

3.3.5 Other Costs

For calculation of the net economic loss, other costs per animal viz. cost of family labour, cost of transportation of sick animal, cost of feeding extra concentrate, cost of damaged hides, reduction in net value or selling price of the animal, cost of draught power loss was also calculated. Results revealed that the cost incurred on family labour per

animal was INR 126.70, cost of transportation of sick animal was INR 192.67, cost of feeding extra concentrates was INR 622.55, reduction in net value or selling price of affected animal was estimated to be INR 13933.33 and draught power loss cannot be calculated as the animals in Punjab are not used for draught purposes anymore due to mechanization of farm operations. The sum of all these other costs per animal per day was estimated to be INR 337.17 (Table 18). Singh et al. (2014) has computed other costs as opportunity cost as they were not quantified and assumed the same at 5 percent of the total cost. However, with respect to current investigation, the other costs were quantified independently. Reddy et al. (2022) has also commented that the economic losses in LSD are also attributed to loss in body condition of the animals, feeding extra concentrates, damage to hides, etc., all of which were estimated in the present study.

The average cost of dead cow due to LSD was estimated to be INR 56400.00 in the present study whereas Molla et al. (2017) in their investigation at Ethiopia determined the same at INR 81830.00 which was greater than the evaluated loss. Truong et al. (2018) while estimating the cost of dead dairy animal in foot and mouth disease outbreak stated that the same may be taken at par with the price paid by the traders to the farmers. In present case scenario, the results are in line with Truong et al. (2018) as the cost of dead cow is calculated by deducting the average reduction in the net value or selling price of affected animal from the cost cited by farmers.

Table 18
Other costs

Type of other cost (average per animal)	For whole period (in INR)	Per day cost (in INR)
Family labour	126.70	2.76
Transportation	192.67	4.20
Feeding extra concentrates	622.55	13.58
Damage to hide/skin	583.78	12.73
Reduction in the net value/selling price	13933.33	303.89
Draught power loss	0.00	0.00

3.3.6 Total Economic Impact of LSD

The total economic impact of LSD presented in Table 19 was estimated from production losses (A), reproduction losses (B), treatment costs (C), preventive costs (D) and other costs (E). The losses incurred per animal per day due to the disease were estimated and then multiplied with a suitable multiplication factor to reach precise results. In case of cow and buffalo, multiplication factor of 45.85 and 25.00 reflects the entire course of disease in days respectively with which per day production losses, preventive costs and costs are multiplied. Whereas a multiplication factor of 21 is used for cow and buffalo for reproduction losses which signify the period of estrous cycle in dairy animals. The reproduction losses are obtained for 21 days as the animal may show the signs of estrus in the next cycle, thus missing only one estrous cycle. For treatment costs, the multiplication factor of 15.85 and 10 is used for cow and buffalo respectively because these are the mean days for which the treatment has been given to the symptomatically ill animals. The total loss per animal for the entire course of LSD in case of cow and buffalo has been estimated to be INR 59274.64 and 27081.21 respectively. The loss is less in case of buffaloes as mostly the buffaloes were found to be unharmed by LSD.

Further, percentage of individual losses were calculated among the total economic loss and it was found that 35.01 percent loss is attributed to treatment losses in cow and 27.96 percent loss is attributed to production losses in case of buffalo. This may be because of the fact that farmers spent most of the money in treating the cows as they were explicit sufferers due to LSD. In case of buffaloes, milk is a priced commodity and reduction in milk production inadvertently affects the overall farm economy. The least of the losses were observed in preventive costs as farmers tend to spend less in preventive measures.

Press Trust of India (2022) and Sharma (2022) reported the data obtained from Ministry of Fisheries, Animal Husbandry and Dairying, Government of India in which it was highlighted that LSD has spread across 251 districts in 15 states of India. It was reported that a total of 2945863 bovines were affected with LSD with 155366 cumulative deaths in the recent outbreak from July to October, 2022 in India. As far as Punjab was concerned, a total of 174464 animals were affected with LSD out of which 17932 deaths till in the outbreak of 2022. However, in context of the present investigation, the morbidity in cattle was calculated to be 45.25 percent with mortality rate of 12.40 percent, which are significantly higher than the official estimates. The reason behind high morbidity and mortality rates estimated in the current study may be the over-reporting by the respondents. Further, in the present study only those farms were taken in which LSD outbreak took place to estimate precise economic losses.

Taking into account the official data, the overall economic loss due to LSD was estimated to be INR 17461.49 crores for affected animals and INR 876.26 crores for dead animals for the outbreak of LSD occurred in 2022 at national level. Thus the total economic loss due to LSD sums upto INR 18337.76 crores (USD 2217.26 million) at national level. In case of Punjab, for the same period the losses incurred due to LSD was estimated to be INR 1034.12 crores and INR 101.13 crores for animals affected and animals died respectively, thus summing up the total economic loss to INR 1135.26 crores (USD 137.26 million). For the calculation of economic loss, per animal loss estimated for cow has been taken as the cows were affected significantly higher than the buffaloes.

Regarding the economic losses due to LSD, various researchers have reported different figures but none concerning to India. The median losses per affected lactating cow was calculated to be USD 141 (INR 11510.85), USD 1000 (INR 81637.20) for dead cow and total economic loss of LSD outbreak at herd level to be USD 1176 (INR 96005.35) in Ethiopia (Molla et al., 2017). In Turkey, total economic loss of GBP 2093.99 (INR 204475.24) per herd was reported (Sevik and Dogan, 2017). Casal et al. (2018) while calculating the economic losses due to LSD reported a net loss of EUR 8.6 million in Bulgaria, EUR 6.7 million in Former Yugoslav Republic of Macedonia and EUR 5.3 million in Albania. The same study reported the average cost per affected herd to be EUR 6994 (INR 590305.92), EUR 3071 (INR 259197.81) and EUR 869 (INR 73345.13) in Bulgaria, Former Yugoslav Republic of Macedonia and Albania respectively. Roche et al. (2020) has estimated a net loss of USD 1.45 billion due to LSD in South, East and Southeast Asian countries.

Table 19
Total economic impact of LSD

Type of loss	Cow				Buffalo			
	Per animal per day loss	Multi-plication factor	Per animal loss for entire course of disease	% of total	Per animal per day loss	Multi-plication factor	Per animal loss for entire course of disease	% of total
(A) Production losses	194.07	45.85	8898.11	15.01	302.85	25.00	7571.25	27.96
(B)Reproduction losses*	652.05	21.00	13693.05	23.10	358.63	21.00	7531.18	27.81
(C) Treatment costs	1309.36	15.85	20753.36	35.01	720.15	10.00	7201.48	26.59
(D) Preventive costs	10.27	45.85	470.8795	0.79	5.65	25.00	141.21	0.52
(E) Other costs	337.17	45.85	15459.24	26.08	185.44	25.00	4636.09	17.12
Total loss per animal for entire course of disease**			**59274.64**				**27081.21**	

**In reproduction loss, anestrus is taken into consideration as it was prevalent in majority of the animals showing symptoms of LSD.*

*** All values are in INR*

4. Conclusion

The approach followed in the current investigation led to uncovering vital trends regarding LSD outbreaks. The coherence of socio-behavioural parameters ascertained the practices followed by the dairy farmers during the outbreak. These practices affect the microeconomics of the farm to a larger extent. The methodology helped in understanding that majority of the farms were small farms having upto 10 dairy animals. The morbidity and mortality were far too high in cattle as compared to buffaloes and crossbred cattle is highly susceptible for LSD. Moreover, it was found that there is loss of about 45.10 percent milk yields of the milch animals. Among the expenses and losses, maximum expenses were made on treatment in case of cattle and maximum losses were under production head in case of buffaloes. The developed methodology can be used for calculating health economics of other diseases affecting bovines. The practices pursued at the dairy farms along with their costs can aid in devising suitable prevention plans and policies against LSD for the time to come.

Declarations

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Competing Interests

The authors declare no financial as well as non-financial competing interests.

Author Contributions

Sr. No.	Name in full and Designation	Contribution of the Author
1.	Amandeep Singh	Study design, statistical analysis and manuscript preparation.
2.	Gurpreet Kour	Statistical analysis and manuscript preparation.
3.	Sehajpal Singh Dhillon	Collection of data.
4.	Parkash Singh Brar	Study design and manuscript preparation.

Data Availability

The primary data which were collected during the study can be made available on demand.

Ethical Approval

As the study was observational based on economics, hence ethical approval was not required.

Consent to participate

The human participants from whom the data were collected, were informed and consent was taken telephonically.

Consent to publish

Not applicable in the context of present study.

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