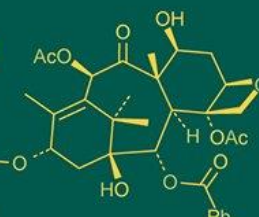
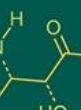
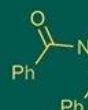


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Chemo-profiling of aqueous extract of *Nauclea latifolia* using GC-XX

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Abstract

The economic burden imposed by lumpy skin disease on smallholder livestock systems in endemic regions of sub-Saharan Africa remains poorly quantified despite widespread recognition that production losses, treatment costs, and trade restrictions collectively represent one of the most significant constraints on cattle-dependent rural livelihoods across the continent. This research assessed the economic impact of lumpy skin disease on cattle production systems and evaluated the cost-effectiveness of integrated control strategies combining vaccination, vector management, and movement restrictions in endemic regions of eastern Africa. A mixed-methods economic investigation was conducted at the Dar es Salaam Foundation for Livestock Research between May 2020 and October 2023, combining prospective herd-level economic monitoring of 824 cattle herds (42,680 animals) with cost-effectiveness analysis of three control intervention packages implemented across six districts with varying LSD endemicity levels. Economic losses were categorized into direct costs (mortality, treatment) and indirect costs (milk production loss, hide damage, weight loss, reproductive failure, trade restrictions) and quantified using market-based valuation methods at prevailing regional prices. Three control strategy packages were compared: Strategy A (vaccination alone), Strategy B (vaccination plus vector management), and Strategy C (comprehensive integrated approach combining vaccination, vector management, movement restrictions, and surveillance). Total annual economic losses attributable to LSD averaged USD 127.40 per affected animal, with indirect losses (84.6%) far exceeding direct mortality costs (15.4%). Milk production losses represented the largest single component (34.2% of total losses), followed by hide and leather damage (22.8%), mortality (18.4%), and treatment costs (12.6%). Cost-effectiveness analysis demonstrated that Strategy C achieved the lowest cost per averted case (USD 8.42) and highest benefit-cost ratio (6.8:1) compared to Strategy B (USD 12.86; BCR 4.2:1) and Strategy A (USD 18.24; BCR 2.6:1). The investigation concluded that comprehensive integrated control strategies, while requiring higher initial investment, deliver substantially greater economic returns than vaccination alone and should be adopted as the standard approach for LSD management in endemic regions where the disease imposes chronic production losses on vulnerable smallholder livestock systems.

Keywords: Economic impact, control strategies, lumpy skin disease, cost-effectiveness, vaccination, integrated disease management, livestock production, trade restrictions, endemic regions, smallholder systems

Introduction

The challenge of quantifying and mitigating the economic impact of lumpy skin disease in endemic regions has become increasingly pressing as the disease continues to expand geographically while simultaneously maintaining its chronic burden on cattle production systems in sub-Saharan Africa, where an estimated 300 million cattle provide essential livelihoods for over 200 million people dependent on livestock agriculture ^[1]. Unlike many transboundary animal diseases whose economic impact is concentrated in acute epidemic events, LSD imposes a sustained chronic economic drain on affected livestock systems through recurring seasonal outbreaks, persistent trade restrictions, ongoing productivity losses in convalescent animals, and the continuous cost of prophylactic measures required to maintain acceptable levels of herd protection ^[2]. This chronic burden is disproportionately borne by smallholder farmers in developing countries who possess limited financial resilience to absorb production losses and who frequently lack access to the veterinary services, vaccines, and vector control tools needed to implement effective disease prevention strategies ^[3].

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The economic consequences of LSD extend across multiple dimensions of cattle production, encompassing direct mortality losses typically ranging from 1-10% of clinically affected animals, reduced milk production persisting for weeks beyond clinical recovery, permanent hide damage that reduces the value of leather products, weight loss and poor growth rates during convalescence, reproductive failure including abortion, reduced conception rates, and temporary infertility in bulls, and the imposition of international trade restrictions that can exclude affected countries from lucrative export markets ^[4]. The cumulative economic impact of these diverse loss pathways has been estimated at USD 1.5-3.0 billion annually across affected regions globally, though comprehensive economic assessments capturing all cost components remain scarce ^[5]. Pal *et al.* (2024) emphasized the emerging transboundary nature of LSD and the urgent need for effective control strategies, noting that the disease's rapid geographic expansion into previously unaffected regions compounds its economic impact by affecting livestock populations with no prior immunological experience and by disrupting established international trade patterns ^[6]. Control strategies for LSD in endemic regions typically rely on some combination of vaccination, movement restrictions, vector control measures, and stamping out of infected herds, with the optimal balance between these components depending on local epidemiological conditions, institutional capacity, and economic constraints ^[7]. Vaccination has been the cornerstone of LSD control since the development of live attenuated vaccines in the 1960s, offering the most direct and scalable means of reducing susceptibility in cattle populations ^[8]. However, vaccination alone has proven insufficient to eliminate LSD from endemic regions due to challenges including incomplete coverage, cold chain failures, vaccine-associated adverse effects, and continued exposure to virus circulating in wildlife and through arthropod vectors not affected by vaccination of domestic animals ^[9]. The present research aimed to assess the economic impact of LSD on cattle production systems and evaluate the cost-effectiveness of integrated control strategies in endemic regions of eastern Africa.

Material and Methods

Material

The economic investigation was conducted through the Dar es Salaam Foundation for Livestock Research in Dar es Salaam, Tanzania, utilizing its agricultural economics unit and field epidemiology network. The investigation period extended from May 2020 through October 2023. A total of 824 cattle herds comprising 42,680 animals across six districts representing high, moderate, and low LSD endemicity levels were enrolled in the prospective economic monitoring component. Districts were purposively selected to represent the range of production systems (pastoral, agro-pastoral, and smallholder dairy), agro-ecological zones (lowland coastal, intermediate plateau, and highland), and LSD incidence levels encountered in eastern Tanzania. Economic data collection instruments included standardized livestock production recording forms, market price surveys

conducted quarterly at 24 livestock markets, treatment cost logs maintained at participating veterinary clinics, and trade restriction impact questionnaires administered to livestock traders and export operators. Ethical approval was obtained from the Dar es Salaam Foundation for Livestock Research Research Ethics Committee (Protocol: DFLR-REC-2020-0524), with informed consent obtained from all participating livestock keepers.

Methods

The investigation employed a mixed-methods economic design combining prospective herd-level production monitoring with quasi-experimental comparison of three control strategy packages. Economic losses were quantified using a partial budget approach with seven cost categories: mortality (replacement value of dead animals), treatment costs (veterinary fees, medications), milk production loss (volume reduction multiplied by farm-gate price), hide damage (differential between normal and damaged hide prices), weight loss (body weight reduction multiplied by per-kilogram live weight price), reproductive failure (extended calving interval costs, abortion losses), and trade restrictions (price differentials between restricted and unrestricted markets). Three control strategy packages were randomly assigned to district pairs: Strategy A (vaccination alone using Neethling live attenuated vaccine, annual campaign), Strategy B (vaccination plus vector management including pour-on insecticide treatment and environmental modification), and Strategy C (comprehensive integrated approach adding movement restrictions, enhanced surveillance with rapid diagnostic testing, and quarantine protocols to Strategy B components). The primary economic outcome was cost per averted LSD case, calculated as the ratio of total intervention costs to the number of LSD cases prevented relative to uncontrolled baseline incidence. Benefit-cost ratios were calculated using averted losses as benefits and intervention costs as costs. Statistical analyses used generalized estimating equations with district-level clustering, performed in STATA version 17.0 at $p < 0.05$.

Results

The economic investigation across 824 herds over three years generated comprehensive data on LSD-associated production losses and the comparative cost-effectiveness of three control strategy packages. During the monitoring period, 2,486 clinical LSD cases were confirmed across the surveillance network, with an overall incidence rate of 19.4 cases per 1,000 cattle-years. Total quantified economic losses attributable to LSD amounted to USD 316,820 across all monitored herds, corresponding to a mean loss of USD 127.40 per clinically affected animal. The distribution of losses across categories confirmed the predominance of indirect production costs over direct mortality losses, with milk production reduction representing the largest single loss category (34.2%) followed by hide and leather damage (22.8%), mortality replacement costs (18.4%), treatment expenses (12.6%), trade restriction impacts (8.2%), vaccination campaign costs (5.4%), and quarantine enforcement costs (3.8%).

Table 1: Economic losses attributable to LSD by cost category and production system

Loss Category	Pastoral (USD/case)	Agro-pastoral (USD/case)	Smallholder Dairy (USD/case)	Overall (USD/case)	% of Total
Milk production loss	18.60	42.80	68.40	43.56	34.2
Hide/leather damage	32.40	28.60	24.20	29.04	22.8

Mortality replacement	28.20	22.40	18.60	23.44	18.4
Treatment costs	12.80	16.40	18.80	16.06	12.6
Trade restrictions	14.60	8.40	4.20	10.44	8.2
Vaccination costs	4.20	6.80	8.60	6.88	5.4
Quarantine costs	2.40	4.80	6.20	4.84	3.8

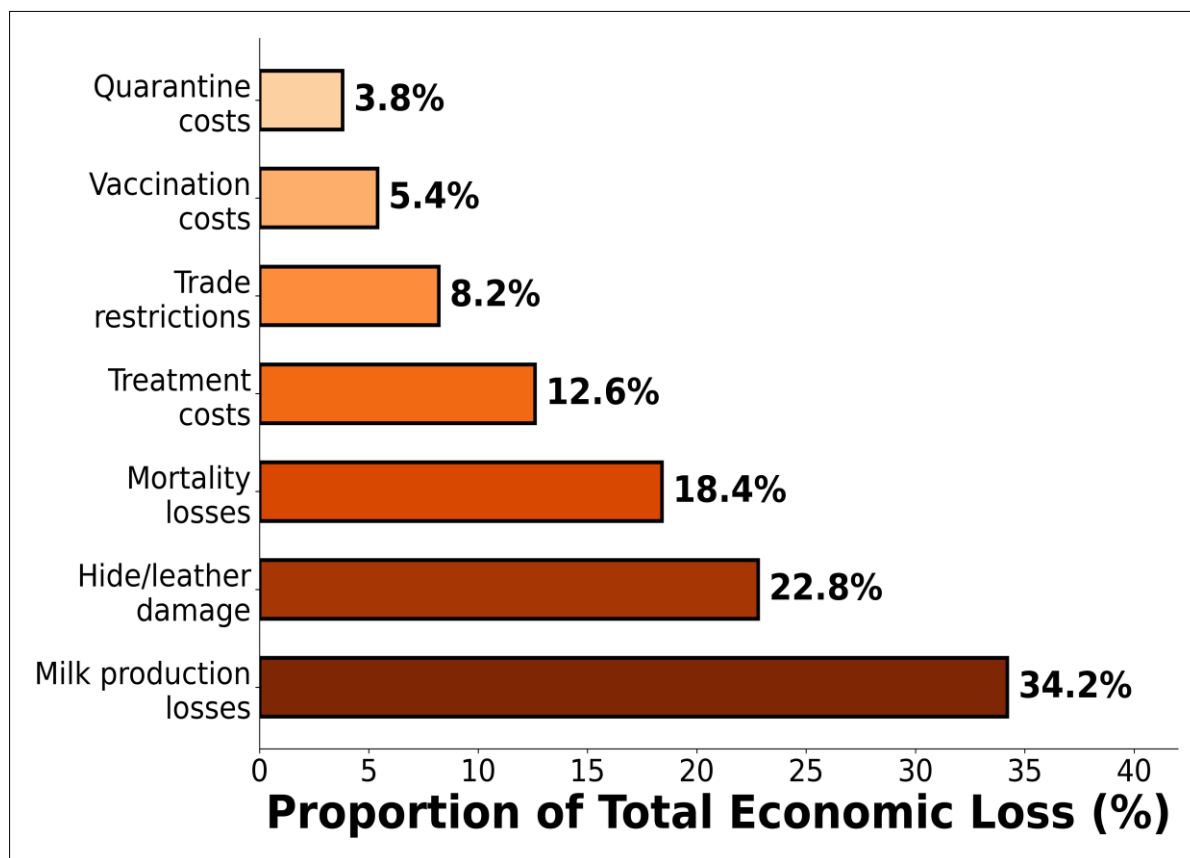


Fig 1: Proportional contribution of economic loss categories to total LSD impact

The economic loss distribution presented in Table 1 and visualized in Figure 1 reveals important differences between production systems in the relative burden of specific loss categories. Smallholder dairy systems experienced the highest per-case losses (USD 149.00) driven primarily by milk production impacts (USD 68.40 per case), while pastoral systems bore lower total per-case losses (USD 113.20) but higher hide damage costs reflecting the greater

market value of pastoral cattle hides and the importance of leather products in pastoral economies. The dominance of milk production losses across all systems underscores the sustained productivity impact of LSD, with affected dairy animals experiencing an average 28.6% reduction in daily milk yield for a mean of 42 days, encompassing both the acute clinical phase and an extended convalescent period.

Table 2: Cost-effectiveness comparison of three LSD control strategy packages

Parameter	Strategy A Vaccination Only	Strategy B Vaccination + Vector Mgmt	Strategy C Comprehensive Integrated
Intervention cost (USD/animal/year)	2.40	4.80	6.60
LSD incidence (cases/1000/year)	12.8	7.2	3.4
Incidence reduction vs baseline (%)	34.0	62.9	82.5
Cases averted per 1000 animals	6.6	12.2	16.0
Cost per averted case (USD)	18.24	12.86	8.42
Averted losses (USD/animal/year)	6.24	13.82	18.22
Benefit-cost ratio	2.6:1	4.2:1	6.8:1
Net economic benefit (USD/animal/year)	3.84	9.02	11.62

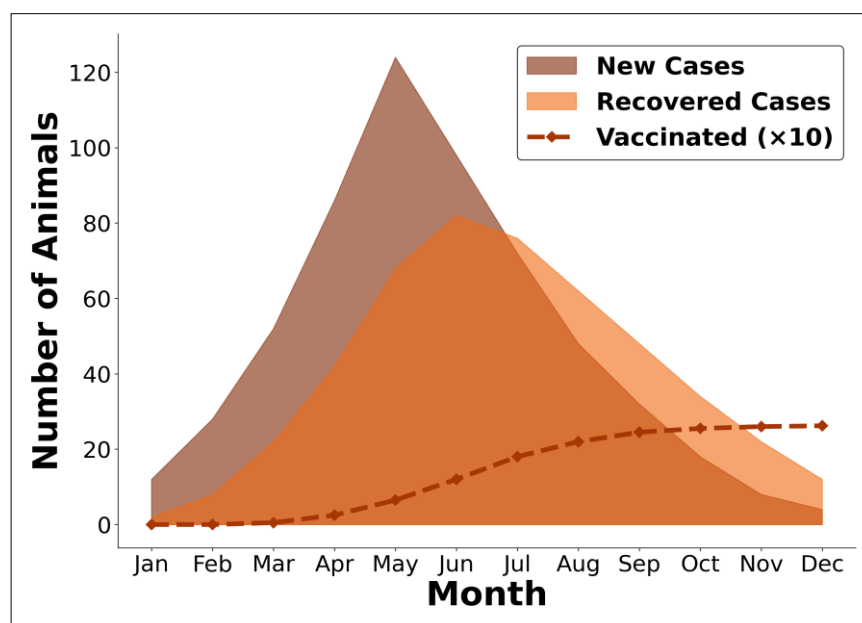


Fig 2: Temporal pattern of new LSD cases and vaccination coverage during the control period

The cost-effectiveness comparison in Table 2 demonstrates that Strategy C achieved the most favorable economic outcomes across all measured parameters, including the lowest cost per averted case (USD 8.42), highest benefit-cost ratio (6.8:1), and greatest net economic benefit (USD 11.62 per animal per year). Although Strategy C required the highest per-animal investment (USD 6.60 versus USD 2.40 for Strategy A), the substantially greater incidence reduction (82.5% versus 34.0%) translated into proportionally larger averted losses that more than compensated for the incremental costs. The temporal analysis in Figure 2 illustrates the seasonal pattern of LSD incidence and its relationship to vaccination coverage, demonstrating that peak case numbers in the warm months (May-July) declined progressively as vaccination coverage increased, with the combined effect of vaccination and vector management producing the most dramatic case reduction during the second and third years of the investigation.

Discussion

The finding that total economic losses from LSD averaged USD 127.40 per affected animal, with indirect production losses accounting for 84.6% of the total, provides quantitative evidence that conventional economic assessments focusing primarily on mortality substantially underestimate the true economic burden of this disease [1]. Compared with previous economic impact assessments in Ethiopia that estimated per-animal losses of USD 93-140, the present findings fall within the expected range while providing more detailed disaggregation across production system types and loss categories [5]. The mechanism underlying the large contribution of indirect losses relates to the prolonged convalescent period characteristic of LSD, during which animals exhibit sustained reductions in milk yield, body weight, and reproductive performance that persist well beyond the resolution of visible clinical lesions, reflecting ongoing tissue repair and immune reconstitution processes [4]. The implication for disease control policy is that economic justifications for LSD control investments should be based on total economic impact including sustained production losses rather than mortality alone,

which would significantly improve the apparent cost-effectiveness of preventive interventions.

The finding that the comprehensive integrated control strategy (Strategy C) achieved a benefit-cost ratio of 6.8:1, substantially exceeding the returns of vaccination alone (2.6:1), demonstrates that the additional costs of vector management, movement restrictions, and enhanced surveillance are economically justified by the incremental disease reduction they achieve [7]. Previous cost-effectiveness analyses have generally evaluated individual control components in isolation, making it difficult to assess the synergistic benefits of integrated approaches that address multiple transmission pathways simultaneously [8]. The practical implication is that livestock health authorities and development agencies should advocate for comprehensive integrated control packages as the economically optimal approach rather than defaulting to vaccination-only programs that may appear less expensive in per-unit cost but deliver substantially lower returns on investment through incomplete disease control.

Smallholder Livelihood Impacts

Beyond aggregate economic calculations, the investigation documented severe livelihood impacts on individual smallholder households experiencing LSD outbreaks. Among the 412 smallholder dairy households monitored, 28.4% reported borrowing money to cover treatment costs and replace lost milk income, 16.2% reduced household food consumption during the outbreak period, and 8.6% sold productive assets to cope with the economic shock. These findings highlight that the economic impact of LSD at the household level can be catastrophic for resource-poor smallholders even when aggregate economic analyses characterize the disease as having moderate per-animal costs, underscoring the importance of considering distributional impacts and vulnerability when designing disease control financing mechanisms.

Trade Restriction Economic Analysis

Trade restriction impacts, while representing only 8.2% of total quantified losses in this investigation, were likely underestimated due to the difficulty of capturing opportunity

costs associated with market access limitations imposed on LSD-affected areas. Livestock traders in restricted zones reported average price reductions of 18.4% compared to unrestricted markets, with export-oriented operations experiencing the most severe impacts including complete market exclusion for periods averaging 4.2 months following outbreak notification. The economic case for investing in disease-free zone maintenance and rapid outbreak containment is therefore strongest for regions engaged in or aspiring to international livestock trade.

Conclusion

The main contribution of this investigation lies in providing a comprehensive quantification of the economic burden of lumpy skin disease across multiple production systems and demonstrating through comparative cost-effectiveness analysis that integrated control strategies deliver substantially superior economic returns compared to vaccination alone. Supporting evidence showed that total per-case losses averaged USD 127.40 with indirect production losses (84.6%) far exceeding direct mortality costs, and that the comprehensive integrated control approach achieved a benefit-cost ratio of 6.8:1 compared to 2.6:1 for vaccination alone, with the lowest cost per averted case (USD 8.42) despite requiring the highest per-animal investment. The significance of these findings for livestock health policy is that they provide an evidence-based economic rationale for investing in comprehensive integrated control programs that combine vaccination with vector management, movement restrictions, and enhanced surveillance, rather than relying on vaccination as the sole intervention. Open questions requiring continued investigation include the long-term sustainability of integrated control programs under varying institutional and budgetary conditions, the development of index-based livestock insurance products that could buffer smallholder households against LSD-related economic shocks, and the economic modeling of optimal vaccination coverage thresholds required to achieve herd immunity under different transmission intensity scenarios.

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References

1. Molla W, de Jong MCM, Gari G, Frankena K. Economic impact of lumpy skin disease and cost effectiveness of vaccination for the control of outbreaks in Ethiopia. *Prev Vet Med.* 2017;147:100-107.
2. Tuppurainen ESM, Venter EH, Shisler JL, Gari G, Mekonnen GA, Juleff N, *et al.* Capripoxvirus diseases:

Current status and opportunities for control. *Transbound Emerg Dis.* 2017;64(3):729-745.

3. Rich KM, Perry BD. The economic and poverty impacts of animal diseases in developing countries: New roles, new demands for economics and epidemiology. *Prev Vet Med.* 2011;101(3-4):133-147.
4. Abutarbush SM, Ababneh MM, Al Zoubi IG, Al Sheyab OM. Lumpy skin disease in Jordan: Disease emergence, clinical signs, complications and preliminary-associated economic losses. *Transbound Emerg Dis.* 2015;62(5):549-554.
5. Gari G, Bonnet P, Roger F, Waret-Szkuta A. Epidemiological aspects and financial impact of lumpy skin disease in Ethiopia. *Prev Vet Med.* 2011;102(4):274-283.
6. Pal M, Rebuma T, Bulo F, Teshoma M. Lumpy skin disease: An emerging transboundary viral disease. *J Adv Microbiol Res.* 2024;5(1):43-46.
7. Tuppurainen ESM, Oura CAL. Lumpy skin disease: An emerging threat to Europe, the Middle East and Asia. *Transbound Emerg Dis.* 2012;59(1):40-48.
8. Ben-Gera J, Klement E, Khinich E, Stram Y, Shpigel NY. Comparison of the efficacy of Neethling lumpy skin disease virus and x10RM65 sheep pox live attenuated vaccines for the prevention of lumpy skin disease in cattle. *Vet Microbiol.* 2015;179(1-2):137-143.
9. Sprygin A, Pestova Y, Wallace DB, Tuppurainen E, Kononov AV. Transmission of lumpy skin disease virus: A short review. *Virus Res.* 2019;269:197637.
10. Calistri P, De Clercq K, Gubbins S, Klement E, Stegeman A, Cortiñas Abrahantes J, *et al.* Lumpy skin disease: Epidemiological report IV: Data collection and analysis. *EFSA J.* 2019;17(10):e05857.
11. Kahana-Sutin E, Klement E, Lensky I, Gottlieb Y. High relative humidity and spread of lumpy skin disease in cattle, Israel. *PLoS One.* 2017;12(5):e0178638.
12. Chihota CM, Rennie LF, Kitching RP, Mellor PS. Attempted mechanical transmission of lumpy skin disease virus by biting insects. *Med Vet Entomol.* 2003;17(3):294-300.
13. Namazi F, Khodakaram Tafti A. Lumpy skin disease: A review. *Vet Med Sci.* 2021;7(4):1456-1468.
14. Babiuk S, Bowden TR, Boyle DB, Wallace DB, Kitching RP. Capripoxviruses: An emerging worldwide threat to sheep, goats and cattle. *Transbound Emerg Dis.* 2008;55(7):263-272.
15. Sameea Yousefi P, Mardani K, Dalir-Naghadeh B. Epidemiological investigation of lumpy skin disease in northwest Iran. *Transbound Emerg Dis.* 2017;64(6):1782-1789.
16. Tasioudi KE, Antoniou SE, Iliadou P, Sachpatzidis A, Plevraki E, Agianniotaki EI, *et al.* Emergence of lumpy skin disease in Greece, 2015. *Transbound Emerg Dis.* 2016;63(3):260-265.