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Characterization and Classification of Bovine Lameness in Extensive Livestock Farming: A Study Conducted in the Upper Lomami Pastoral Area (DRC)

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Abstract

This study aimed to inventory, to classify, and to analyze the different types of bovine lameness observed in the extensive livestock farming system at the Pastoral du Haut Lomami (PHL) in the Democratic Republic of Congo. A descriptive and analytical approach was conducted on cattle of different zootechnical categories, based on clinical observations, analyses of health records, and locomotor assessments using a standardized score. The data were processed using descriptive statistics, multivariate analyses (PCA, hierarchical clustering), and logistic regression models. The results show that lameness is the main cause of hospitalization in all studied sections, with a particularly high prevalence during the dry season. The classification of lameness reveals a clear predominance of non-infectious forms, dominated by hoof deformities, representing more than half of the cases in both seasons. Fractures, mainly observed in young animals, constitute the second major cause, while joint disorders remain secondary. Spatial analysis of the lesions highlights a strong predominance of hind limb involvement, suggesting the influence of biomechanical and environmental stresses. Multivariate analyses confirm that lameness is strongly associated with indicators of declining general condition, such as weight loss and wounds. Furthermore, certain factors, notably the dry season and deficiencies in trace elements such as zinc, appear to be significant determinants of lesion location. Overall, this study highlights the multifactorial nature of bovine lameness in extensive systems, dominated by mechanical, environmental, and nutritional stresses, with a marked influence of seasonality.

Keywords

Characterization, Classification, Bovine Lameness, Extensive Livestock Farming, Pastorale du Haut-Lomami

1. Introduction

Lameness results from damage to the integrity of the supporting apparatus, comprised of the skeleton, muscles, and associated structures. This damage can be the consequence of acute trauma, but most often results from a complex interaction of predisposing factors of mechanical, nutritional, environmental, or metabolic origin. Clinical examination generally allows identification of the triggering factor responsible for the expression of lameness; however, this apparent factor may hide pre-existing underlying causes that influence the animal's susceptibility to developing the locomotor disorder [1]-[3].

Several authors propose a classification of lameness based on the symptom that prompted the consultation, useful for guiding the localization of the lesion and assessing its severity [2] [4] [5]. [6] [7] distinguish four main types:

- Weight-bearing lameness: involvement of an organ essential for supporting the limb (bones, joints, or feet);
- Supportive lameness: a voluntary adaptation of the gait aimed at limiting pain
- Mechanical or involuntary lameness: often linked to muscular, ligamentous, or nerve damage;
- Mixed lameness: a combination of several mechanisms, common in clinical practice.

The detection of lameness in a moving bovine relies on the observation of several locomotor parameters. [8]-[11] identified six main indicators:

- Speed of movement (generally decreased);
- Gait rhythm (irregular or asynchronous);
- Stride length and foot placement (shortened or asymmetrical);
- Weight distribution across the four limbs (weight shifting);
- Back line (frequently arched in lame animals);
- Head position (often lowered or oscillating, depending on the weight-bearing). The intensity and combination of these signs allow lameness to be classified according to different levels (absence, slight, moderate, severe) and the course of action to be adapted [12]-[14].

The most frequently reported lesions in extensive farming are white line disease, sole abscesses, trauma, and interdigital diseases; digital dermatitis, more common in intensive farming, can nevertheless occur if moisture persists [15]-[17]. Uneven ground, long distances traveled, parasite pressure, and exposure to stony terrain are aggravating factors.

Early detection is a major weakness in extensive farming: animal observation is less frequent and restraint is often limited, which delays diagnosis and complicates management [18]-[20]. Treatment relies primarily on curative hoof trimming, anti-inflammatories, and, if necessary, antibiotics, but operational constraints often limit the possibility of rapid intervention [21].

2. Environment, Animals, Materials, and Methods

2.1. Study Area

This study was conducted on a herd of cattle raised at the Company PHL, in the Haut-Lomami Province. It covers the town of Kamina and the territory of Kaniama Kasese, encompassing the chiefdoms of Kasongo Nyembo and Mutombo Mukulu. Covering an area of approximately 220,000 hectares, it is located between 7˚ and 9˚ South latitude and 24˚ and 25˚ East longitude, at an altitude ranging from 1000 to 1200 meters.

Since the 2015 territorial reorganization, the Haut-Lomami Province has been one of the 26 provinces of the Democratic Republic of Congo, formerly the Katanga Province. It comprises five territories: Bukama, Malemba-Nkulu, Kamina, Kabongo, and Kaniama, as well as the city of Kamina, the provincial capital. The province covers an area of 108,204 km^2 and has an estimated population of 2,957,000. Its landscape is dominated by high plateaus (Kamina) and the large Kamalondo depression in the southeast. The vegetation consists of grassy savannas and areas of open woodland.

2.2. Animals

The cattle breed raised within the Compagnie Pastorale du Haut-Lomami (PHL) is largely crossbred and characterized by a significant diversity of coat colors and morphological conformations. This heterogeneity results from multiple crossbreedings involving, in particular, the Friesland, Hereford, Aberdeen Angus, Shorthorn, Afrikander, Devon, Brahman, Santa Gertrudis, Simmental, and Bonsmara breeds were studied.

The study focused on sick cattle of all ages and both sexes, monitored at hospital kraals in the Kelambwe and Kankundwe sections of the Lovoy sector, as well as Kindele and Makanza in the Kileka sector. (**Table 1**)

These study areas were chosen based on the similarity of their soil characteristics, dominated by sandy soils, which are likely to play a role in the pathogenesis of certain diseases observed in livestock. Furthermore, their geographical proximity to the urban center of Kamina facilitated the logistical organization of the collection, transport, and storage of biological samples to the analytical laboratories, thus helping to ensure the quality and reliability of the data collected.

Kiabukwa constitutes the administrative section of the Pastoral Farm of Haut-Lomami and hosts the General Directorate of the enterprise. Therefore, this section was not included among the sampling sites used for the comparative analyses of bovine lameness. Consequently, field investigations and statistical analyses were conducted only in the operational livestock sections of Kelambwe, Kankundwe, Kindele, and Makanza.

Table 1. GPS coordinates of study sections.

Sections	Latitude	Longitude
Kiabukwa	8˚45'39.1"S	24˚50'26.7"E
Kelambwe	8˚35'11.9112"S	24˚41'24.3186"E
Kankundwe	8˚45'25.4"S	24˚49'22.4"E
Makanza	8˚47'51.3"S	24˚16'07.8"E
Kindele	8˚38'55.5"S	24˚10'42.3"E

2.3. Equipment

2.3.1. Clinical Equipment

The examination of cattle required additional equipment to assess animals' general condition and to identify any clinical signs associated with lameness. It included:

- A thermometer for measuring body temperature;
- A stethoscope for cardiorespiratory auscultation;
- A brush for cleaning the anatomical areas to be examined;
- A curette for exploring and cleaning foot lesions.

2.3.2. Supplementary Equipment

The following additional equipment were used to collect data on the ground:

- A structured survey questionnaire;
- A notepad;
- Pens;
- A mobile phone (iPhone 16 Pro Max), used for collecting, entering, and documenting field data, including recording information gathered and geolocating study sites by acquiring GPS coordinates;
- The phone's built-in camera (iPhone 16 Pro Max), used for taking photos and documenting field observations.

2.4. Methods

2.4.1. Studied Animals

The total number of cattle included in this study was 378 animals. During the rainy season, the distribution was as follows: in Kelambwe, 17 lame and 35 non-lame cattle; in Kankundwe, 18 lame and 35 non-lame cattle; in Kindele, 16 lame and 40 non-lame cattle; and finally, in Makanza, 23 lame and 44 non-lame cattle.

During the dry season, the recorded numbers were: in Kelambwe, 22 lame and 24 non-lame cattle; in Kankundwe, 11 lame and 20 non-lame cattle; in Kindele, 11 lame and 11 non-lame cattle; and in Makanza, 25 lame and 26 non-lame cattle.

The animals included in the lame cattle group consisted of all cattle admitted to the kraal hospital and presenting lameness during the study period. In contrast, the non-lame cattle group included cattle admitted to the kraal hospitals for conditions other than lameness.

The study was conducted in strict accordance with animal welfare principles. The measures implemented included:

- Gentle and appropriate handling of the animals;
- Restraint limited to what was strictly necessary during interventions;
- Obtaining informed consent from the livestock managers.

2.4.2. General Herd Characterization: Farm Documentation

The general characterization of the herd was an essential step in determining the number of animals raised in the four study sections. Livestock records were provided by the farm manager for analysis as recommended by [21]-[23].

2.4.3. Determining the Prevalence of Diseases at the Hospital Kraal: Identifying Available Clinical Cases

The prevalence frequencies were calculated in relation to the total number of animals admitted to the kraal hospital for each season.

The objectives of this step were:

- To assess the frequency of the main diseases diagnosed at the hospital kraal during the study period;

- To identify health priorities for the farm.

Clinical cases were identified based on a review of the hospital kraal's health records including the date, animal details and reason for admission [24]-[26].

2.4.4. Characterization of Lameness: Remote and Close-Up Examination, Locomotion Score

After a general observation of the herds in the hospital kraals of the different sections, lame animals were identified. They were primarily animals from breeding herds reported by herders as sick.

1) Remote Observation

Remote observation facilitated the evaluation of several parameters related to locomotion [27]:

- Speed and gait rhythm;

- Stride length and foot placement;

- Weight distribution across the four limbs;

- Spinal alignment and head position.

Generally lame animals displayed an unsteady gait, a curved back, and, in some cases, did not place their feet on the ground.

2) Close Clinical Examination

Diagnostic confirmation relied on a close clinical examination of the identified animals. This step included:

- Measurement of body temperature;

- Detailed examination of the affected limb to verify and classify the conditions [28].

The clinical examination was done as suggested by [29], including the search for primary lesions and the assessment of changes in limb volume.

3) Classification of Lameness

The severity of lameness was classified by a gait score on a five-point visual scale (score 1 to 5), proposed by [30]. This score was given to each animal while walking on a hard, flat surface. The valuation of leg placement and the animal's back position were then made possible.

Locomotion scoring was performed in each section by a veterinary technician previously trained for this assessment.

An illustration of this categorization is shown in **Figure 1**.

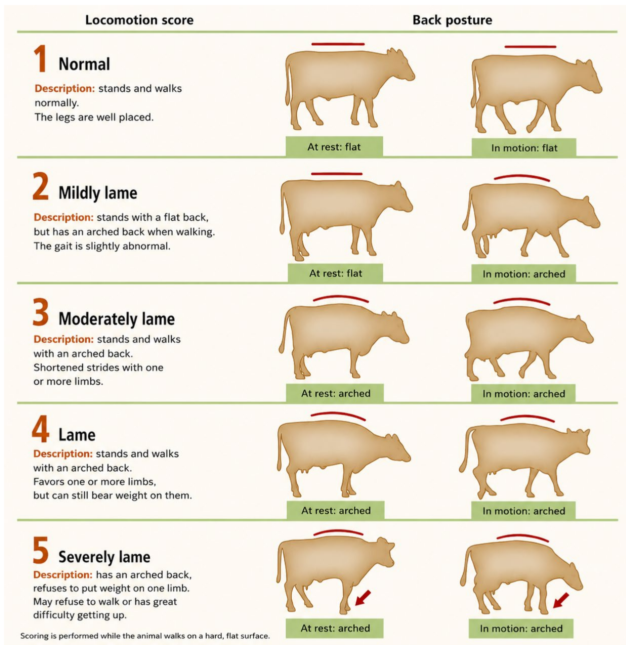

Figure 1. Motility score in dairy cow [31].

Animals were restrained before close examination. Adult animals were immobilized in the restraint chute, while young animals were restrained by the "lying down" technique which uses a rope made of bovine hide, equipped with an easy-to-release slipknot, which immobilizes the hind limbs and safely lowered the animal to the ground through the coordinated action of the handlers [23].

2.4.5. Determining the Origins of Lameness

Close foot examination was an essential step to evaluate the lameness. Foot lesions were easily recognized, assessment of horn integrity, detection of weight-bearing abnormalities, and thus, the precise origin of the lameness was determined [32].

Proper physical restraint of adult animals was done in a holding pen, and the affected limb by lifted and secured to the crossbar with a cowhide rope. Young animals were restrained was the lying-down technique, also using a cowhide rope, as described by [33].

Before any examination, the hoof was thoroughly cleaned with water, removing manure and mud, and the inter-digital area was gently brushed to improve visibility and avoid diagnostic errors [34].

A combined visual inspection and palpation led to the effective clinical examination:

- General shape of the hoof: assessment of the symmetry of both hooves (medial and lateral), analysis of the hoof wall angle;

- Size and length: checking for excess horn, deformities, or irregular growth;

- Condition and quality of the hoof: hardness, texture, color, possible detection of hemorrhages or localized alterations;

- Foot support: observation of abnormal wear areas, detection of overloading of one of the hooves, a frequent sign of pain or compensatory locomotor behavior [30] [35].

2.4.6. Mineral Variables

After disinfection of the jugular area, 20 ml of blood were collected by jugular venipuncture. Following coagulation, the obtained serum was kept refrigerated and transported under appropriate conditions to the laboratory for analysis. Sampling was carried out twice: during the rainy season in December 2023 and during the dry season in July 2024. Trace element analyses were performed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The minerals analyzed included calcium (Ca), copper (Cu), selenium (Se), manganese (Mn), and zinc (Zn), and the results were expressed in mg/L.

2.5. Statistical Analysis

The data were analyzed by descriptive statistics, Analysis of variance (ANOVA), Chi-square test, Principal Component Analysis (PCA) and Hierarchical Ascending Classification (HAC), Multivariate Logistic Regression, and the confusion matrix of the model predicting the location of foot lesions: comparison between actual observations and predicted classifications (overall accuracy: 71.3%).

3. Results

3.1. Observed Bovine Pathologies

Table 2 and **Table 3** present the main reasons for hospitalization of cattle recorded in the different study sections during the rainy and dry seasons. These reasons reflect the diversity of health conditions affecting the animals and highlight variations according to the sections considered. Comparative analysis of these causes of hospitalization leads to the identification of the most frequent pathologies as well as those specific to each section, thus providing a key element for guiding prevention and healthcare strategies adapted to local conditions.

Table 2 displays the distribution of reasons for cattle hospitalization across the studied sections, with significant variations between sections. Lameness is the leading cause in all sections, accounting for 28.6% to 34.0% of cases. Weight loss is the second most frequent reason for hospitalization, ranging from 13.4% to 23.1%. Abortion appears as a significant reason in some sections, notably Kelambwe (17.3%) and Kindele (16.1%), but is completely absent in Kankundwe and Makanza. Wounds are also a notable reason for hospitalization (between 11.9% and 19.2%). Some pathologies are less prevalent but show a localized distribution. Skin diseases, for example, are observed mainly in Kankundwe (13.2%), Kindele (8.9%), and Makanza (10.4%). Otitis is rare but present in Makanza (11.9%), while conjunctivitis is reported only in Kelambwe (7.7%).

Table 2. Causes for cattle hospitalization in the study sections in the rainy season.

Motifs d'hospitalisation	Kelambwe n (%)	Kankundwe n (%)	Kindele n (%)	Makanza n (%)
Abscess	0 (0.0)	11 (20.8)	10 (17.9)	12 (17.9)
Weight loss	12 (23.1)	9 (17.0)	9 (16.1)	9 (13.4)
Abortion	9 (17.3)	0 (0.0)	9 (16.1)	0 (0.0)
Lameness	17 (32.7)	18 (34.0)	16 (28.6)	23 (34.3)
Dermatosis	0 (0.0)	7 (13.2)	5 (8.9)	7 (10.4)
Otitis	0 (0.0)	0 (0.0)	0 (0.0)	8 (11.9)
Conjonctivitis	4 (7.7)	0 (0.0)	0 (0.0)	0 (0.0)
Wounds	10 (19.2)	8 (15.1)	7 (12.5)	8 (11.9)

Table 3. Reasons for cattle hospitalization in the study areas during the dry season.

Reasons for hospitalisation	Kelambwe n (%)	Kankundwe n (%)	Kindele n (%)	Makanza n (%)
Abscess	5 (10.9)	6 (19.4)	3 (13.6)	0 (0.0)
Weight loss	9 (19.6)	5 (16.1)	4 (18.2)	8 (15.7)
Abortion	4 (8.7)	0 (0.0)	0 (0.0)	0 (0.0)
Lameness	22 (47.8)	11 (35.5)	11 (50.0)	25 (49.0)
Dermatosis	0 (0.0)	2 (6.5)	0 (0.0)	6 (11.8)
Otitis	0 (0.0)	1 (3.2)	0 (0.0)	0 (0.0)
Conjonctivitis	0 (0.0)	0 (0.0)	0 (0.0)	3 (5.9)
Wounds	6 (13.0)	6 (19.4)	4 (18.2)	9 (17.6)

The above table highlights a wide variation in the reasons for hospitalization across the study areas. Limping remains by far the leading cause of hospitalization in all areas, with particularly high rates in Kelambwe (47.8%), Kankundwe (35.5%), Kindele (50.0%), and in Makanza (49.0%). Weight loss is the second most frequently reported cause, ranging from 15.7% to 19.6%. Abscesses remain relatively common in some areas, notably in Kelambwe (10.9%), Kankundwe (19.4%), and Kindele (13.6%). Wounds also represent a significant reason for hospitalization, with rates varying from 13.0% to 19.7%. Skin diseases, found only in Kankundwe (6.5%) and Makanza (11.8%), are more commonly observed in the dry season. Otitis, conjunctivitis, and miscarriages are rarely reported. Miscarriages are reported only in Kelambwe (8.7%).

The results of the Pearson chi-square test with Monte Carlo correction revealed a significant association between disease prevalence and the total number of patients at the Kraal Hospital in the study sections. The observed variations in the number of hospitalization reasons are not due to random sampling but contribute significantly to the total number of cases received at the Kraal Hospital in both the rainy (p value < 0.0001) and the dry seasons (p value < 0.011). Lameness takes a big share among other diseases. It illustrates the marked heterogenic distribution of clinical cases between different sections in both seasons.

The overall analysis of these figures shows that frequencies vary from one reason for hospitalization to another. Some conditions appear across all sections, while others are concentrated in specific areas. In all cases, lameness, weight loss, and wounds are the most recurrent conditions across all sections.

During the rainy season, the hierarchical classification (**Figure 2(a)**) groups the conditions into four sets: 1) otitis, conjunctivitis, and miscarriage, which have very similar distributions; 2) wounds and weight loss, associated by their statistical proximity; 3) abscesses and dermatosis, forming a coherent cluster; and 4) lameness, which appears as an isolated pattern due to its distinctly different profile. These groupings highlight distinct epidemiological patterns among the reasons for hospitalization. Lameness stands out clearly from the other conditions. It is associated with the other groups at a very high level of dissimilarity, indicating that it follows a particular distribution profile.

The PCA biplot (**Figure 2(b)**) shows that certain pathologies tend to frequently appear together. The vectors "wounds," "weight loss," and "lameness" point in the same direction, indicating a strong correlation and a common context, probably linked to weakened animals or those exposed to trauma. A second group includes "abscesses," "dermatosis," and "otitis," reflecting skin and infectious diseases favored by hygiene and environmental factors. Conversely, "conjunctivitis" and "abortion" are at the opposite end of these groups: they are weakly correlated with other diseases and reflect specific factors. Locomotor pathologies thus contrast with ocular and reproductive diseases, indicating that these problems do not occur in the same locations or under the same husbandry conditions.

In dry season, the dendrogram derived from hierarchical cluster analysis (**Figure 3(a)**) highlights three main groups of reasons for hospitalization based on their similarity. The first group comprises four conditions (dermatosis, abortion, otitis, and conjunctivitis) that present very similar profiles and dissimilarities. A second group includes abscesses and wounds, suggesting similar conditions of traumatic or infectious origin. Finally, lameness and weight loss form a cluster distinct from the other reasons, with very high dissimilarities, an indication of appearance of these two conditions in clinical contexts different from other pathologies.

The results of principal component analysis (**Figure 3(b)**) demonstrate significant correlations between certain variables and facilitate the identification of the most important conditions in the data structure. To the left of axis F1 are variables associated with infectious or localized conditions, such as conjunctivitis, dermatosis, otitis, abscesses, and abortion. These conditions are strongly correlated with each other, suggesting community of characteristics, likely related to localized infections or inflammations. Their proximity indicates their tendency to occur together in the same observations. To the right of axis F1, variables such as weight loss and sores are associated with signs of general deterioration in health. These conditions are also correlated with each other, suggesting that sections showing these symptoms share a common clinical profile. Lameness is a particular observation, located in the right-hand side of the graph, close to the variables of weight loss and sores. This suggests it is correlated with signs of general weakness rather than with localized conditions like infections. It thus appears as an important indicator of overall health status in the farms.

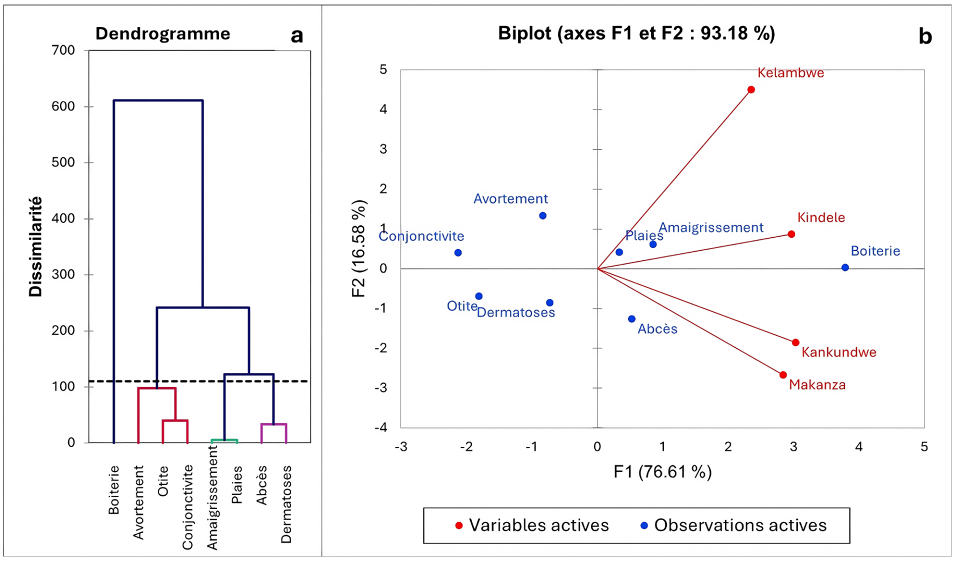

Figure 2. Classification and distribution of bovine pathologies in the rainy season.

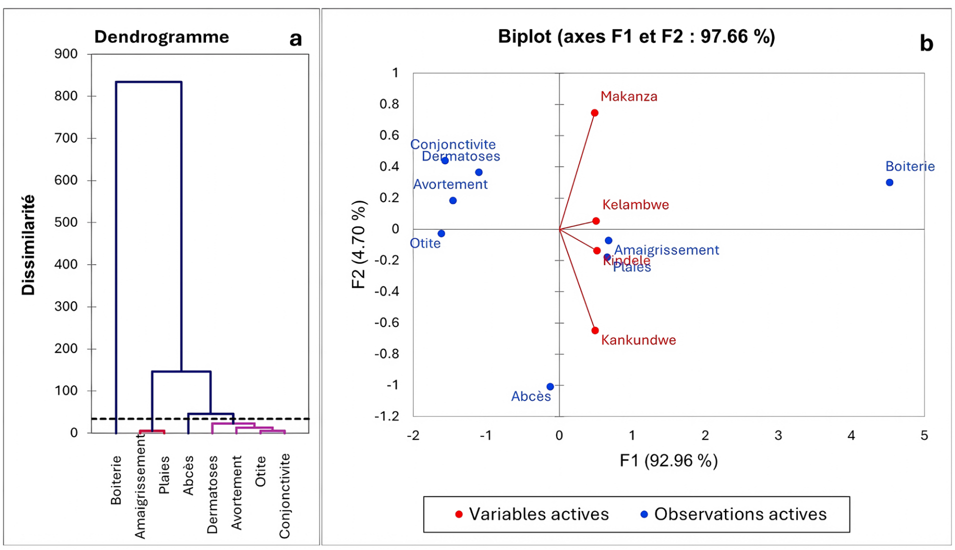

Figure 3. Classification and distribution of bovine pathologies during the dry season.

3.2. Classification of Lameness

Table 4 and Table 5 present a detailed analysis of lameness observed in the different livestock categories in the rainy and dry seasons. For each study section, the data include the average age of the animals, the lameness score, and the type of lameness identified.

Table 4. Classification of lameness observed in the study sections during the rainy season.

Section	Category	Age (mois)	Score
Kelambwe	Calf	6.1 ± 0.6	3.1 ± 0.8
	Cow	92.3 ± 31.1	3.2 ± 0.8
Kankundwe	Calf	7.5 ± 0.7	3.0 ± 1.4
	Heifer	17.6 ± 3.2	3.3 ± 0.8
	Steer	27.3 ± 7.3	3.0 ± 0.9
Kindele	Bull	116.8 ± 25.6	3.0 ± 1.2
	Cow	99.8 ± 29.5	3.4 ± 0.8
Makanza	Steer	29.1 ± 3.3	3.1 ± 0.8
	Heifer	27.3 ± 7.9	3.4 ± 0.8
	Young Bull	42.7 ± 0.6	3.1 ± 1.0

The results in Table 3 display significant heterogeneity in cattle ages across sections and zoo-technical categories, contrasting with the relative homogeneity of lameness scores observed across all study groups. This consistency in scores, generally between 3.0 and 3.4, suggests that lameness is a cross-cutting problem affecting the entire herd, regardless of the animals' age or physiological status.

Table 5. Classification of lameness observed in the study sections during the dry season.

Sections	Catégorie	Age	Score
Kelambwe	Young Bull	69.8 ± 10.7	3.0 ± 0.8
	Cow	95.6 ± 0.9	3.2 ± 0.9
	Calf	3.7 ± 1.9	3.5 ± 0.8
Kankundwe	Steer	40.0 ± 16.1	2.75 ± 0.5
	Heifer	25.3 ± 7.5	3.7 ± 0.6
	Reformed	143.0 ± 2.8	2.5 ± 0.7
	Calf	6.5 ± 0.7	2.5 ± 0.7
Kindele	Heifer	24.7 ± 19.3	2.3 ± 0.6
	Young Bull	84.5 ± 4.1	2.8 ± 0.5
	Cow	76.0 ± 32.9	3.0 ± 1.1
	Calf	7.3 ± 1.3	2.9 ± 0.7
Makanza	Steer	26.6 ± 8.4	3.2 ± 0.4
	Heifer	34.0 ± 1.4	3.1 ± 1.4
	Reformed	144.5 ± 23.3	3.5 ± 0.7

The results show a wide variability in age across sections and livestock categories, contrasting with overall lameness scores ranging from 2.3 to 3.7. This distribution indicates that lameness affects the entire herd, regardless of age, and confirms its multifactorial nature in extensive livestock systems. The presence of high scores in certain young categories, particularly calves and heifers, suggests an early onset of locomotor disorders, while culled animals do not systematically exhibit the highest scores. The differences observed between sections reflect the influence of local grazing conditions and herd management practices, highlighting the need for prevention strategies tailored to the specific characteristics of each pastoral unit. The analysis of variance (ANOVA) test revealed no statistically significant difference (P = 0.05) between the locomotion scores recorded in the different categories of lame animals present in the hospital kraals of the study sections. In other words, the different levels of lameness were distributed evenly across all categories.

3.3. Origins, Etiologies and Location of Lameness in Study Animals

Table 6. Etiologies of lameness identified upon close examination of animals during the rainy season.

Causes lameness	Catégory of animals	Number	Frequency (%)
Fetlock arthritis	Steer	1	1.4
Elbow Arthritis	Bull	1	1.4
	Steer	1	1.4
Knee Arthris	Cow	2	2.7
	Heifer	1	1.4
Hoof deformity	Steer	11	14.9
	Heifer	18	24.3
	Bull	2	2.7
	Young bull	2	2.7
	Cow	17	23.0
	Calf	1	1.4
Shoulder fracture	Calf	1	1.4
Femur fracture	Calf	3	4.1
	Heifer	1	1.4
Tibia fracture	Calf	2	2.7
	Cow	1	1.4
	Young bull	1	1.4
Elbow dislocation	Calf	1	1.4
Limb Paralysis	Calf	1	1.4
Hoof paralysis	Calf	1	1.4
Tendon rupture	Cow	1	1.4
	Heifer	2	2.7
	Steer	1	1.4
	Bull	1	1.4

Analysis of the pattern of lameness observed during the rainy season reveals that hoof deformities are by far the leading cause, accounting for nearly 70% of all cases. These deformities affect all categories of animals, but especially heifers and cows. Joint disorders (arthritis of the fetlock, elbow, and knee) represent approximately 10% of cases, and fractures (shoulder, femur, and tibia) account for about 12 to 15% of lameness, primarily affecting calves. Less common causes, such as dislocations, paralysis, and tendon ruptures, mainly affect young animals. (Table 6)

Table 7. Etiologies of lameness identified upon close examination of animals during the dry season.

Causes of lameness	Category of animals	Number	Frequency (%)
Fetlock arthritis	Bull	1	1.6
	Reformed	1	1.6
	Cow	1	1.6
	Calf	1	1.6
Knee arthritis	Cow	1	1.6
	Heifer	1	1.6
	Calf	1	1.6
	Bull	1	1.6
	Young Bull	1	1.6
	Heifer	6	9.7
	Reformed	2	3.2
	Bull	7	11.3
	Young bull	1	1.6
	Cow	18	29.0
	Calf	2	3.2
Femur fracture	Calf	4	6.5
Tibia fracture	Calf	4	6.5
	Cow	1	1.6
	Reformed	1	1.6
Hoof paralysis	Calf	1	1.6
Woof wound	Calf	1	1.6
	Heifer	1	1.6
Tendon rupture	Cow	1	1.6
	Calf	2	3.2
	Reformed	1	1.6

Analysis of the Table 7 above shows that hoof deformities are the leading cause of lameness during the dry season, accounting for nearly 53% of cases. They primarily affect cows (29%), bulls (11.3%), and heifers (9.7%).

Arthritis (fetlock, knee) represents a small but significant proportion, approximately 10%. It affects various categories of animals (cow, heifer, bull, calf).

Fractures (femur, tibia) account for approximately 16% of cases, mainly affecting calves.

Other causes, such as paralysis, hoof problems (wounds), and tendon ruptures, are rare (approximately 5% each).

Table 8 presents the location of lameness in the cattle, comparing its distribution between the rainy and dry seasons. The data indicate the number of animals affected in each anatomical area (right foreleg, left foreleg, right hind leg, left hind leg, etc) as well as the relative frequency (%) of each location of lameness.

Table 8. Location of lameness in the animals examined.

Localisation atteinte	Rainy season n (%)	Dry season n (%)
Right anterior	10 (13.5)	13 (18.6)
Left anterior	10 (13.5)	9 (12.9)
Left anterior and right posterior	0 (0.0)	2 (2.9)
Right posterieur	28 (37.8)	18 (25.7)
Left posterior	25 (33.8)	28 (40.0)
Left and right posterior	1 (1.4)	0 (0.0)

This table shows that the location of lameness in the rainy and dry seasons reveals a strong predominance of hind limb involvement in both seasons.

During the rainy season, 72.9% of lameness cases affect the hind limbs (right hind 37.8%, left hind 33.8%), compared to 65.7% during the dry season (left hind 40%, right hind 25.7%).

The forelimbs account for 27% of cases during the rainy season and 31.5% of cases during the dry season.

Bilateral lameness is rare: 1.4% during the rainy season (right and left hind) and 2.9% during the dry season (left forelimb and right hind).

Multivariate Logistic Regression

This procedure was chosen because our dependent variable (Location) has more than two unordered categories (right forelimb (RF), left forelimb (LF), right hindlimb (RL), left hindlimb (LH)).

- Adjusted Variables: The model simultaneously incorporated age, season, animal category, the four limb sections, and the five minerals.

- Reference Category Selection: Calculations were performed using LF (Left Forelimb) or RF (Right Forelimb) as the reference categories to quantify the relative risk of hindlimb involvement. (Table 9)

Table 9. Factors associated with the location of lameness.

Parameters	Modalities	Localisation AD (ORa [IC 95 %]; p)	Localisation PD (ORa [IC 95 %]; p)	Localisation PG (ORa [IC 95 %]; p)
Age	Per moth	1.01 [0.98 - 1.04]; 0.55	0.99 [0.96 - 1.02]; 0.48	0.98 [0.95 - 1.01]; 0.18
Season	Dry vs Rain	1.14 [0.65 - 2.02]; 0.65	1.98 [0.98 - 3.95]; 0.06	2.35 [1.12 - 4.90]; 0.02
Category	Cow vs Calf	0.88 [0.45 - 1.72]; 0.71	2.15 [1.02 - 4.52]; 0.04	2.75 [1.32 - 5.75]; 0.006
Section	Makanza vs Kelambwe	1.05 [0.58 - 1.92]; 0.85	1.08 [0.62 - 1.85]; 0.78	1.15 [0.68 - 1.95]; 0.62
	Kankundwe vs Kelambwe	0.98 [0.52 - 1.85]; 0.95	0.92 [0.48 - 1.75]; 0.81	1.05 [0.55 - 2.02]; 0.88
	Kindele vs Kelambwe	1.10 [0.55 - 2.20]; 0.78	0.85 [0.42 - 1.72]; 0.65	1.18 [0.62 - 2.25]; 0.61
Zinc (Zn)	Per mg/L	0.98 [0.88 - 1.08]; 0.65	0.84 [0.74 - 0.96]; 0.009	0.76 [0.67 - 0.87]; <0.001
Sélénium (Se)	Per mg/L	1.02 [0.88 - 1.18]; 0.81	1.08 [0.94 - 1.25]; 0.25	1.16 [1.01 - 1.34]; 0.04
Calcium (Ca)	Per mg/L	1.00 [0.98 - 1.02]; 0.98	1.00 [0.98 - 1.02]; 0.99	1.01 [0.99 - 1.03]; 0.35
Copper (Cu)	Per mg/L	0.99 [0.89 - 1.10]; 0.85	0.93 [0.84 - 1.03]; 0.15	0.91 [0.80 - 1.04]; 0.16

The significance threshold is $p < 0.05$).

1) Sex: Using the left forelimb (LF) as the reference, cows have a 2.75 times higher risk of lameness in the left hindlimb (LF).

2) Trace elements: Each one-unit increase in zinc reduces the risk of lameness in the LF by 24% compared to the LF. Widespread deficiency during the dry season is therefore a spatial risk factor.

3) Sites: No section differs significantly from Kelambwe (Reference) regarding the location of lameness.

4) Seasonality: The risk in the LF more than doubles during the dry season (ORa = 2.35), which can be correlated with both mineral depletion and soil modification.

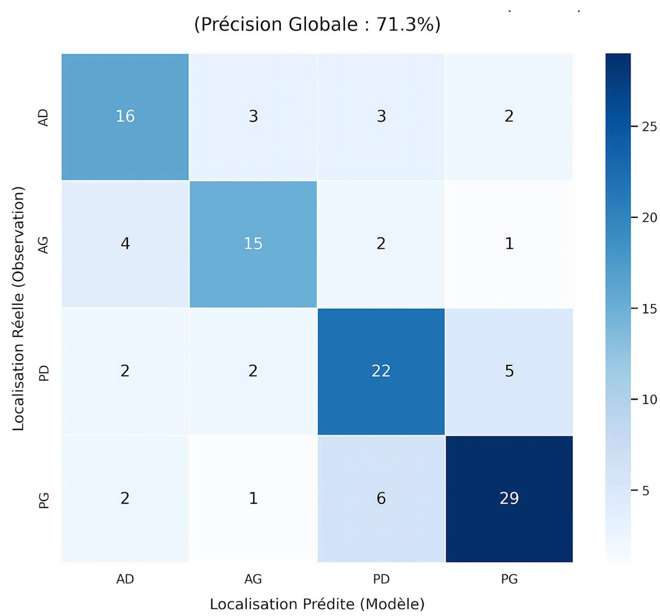

Figure 4. Confusion matrix of the model for predicting the location of foot lesions: comparison between actual observations and predicted classifications (overall accuracy: 71.3%).

- The PG (Left Posterior) axis: Note that this is the limb with the best prediction (29/38), which validates the importance of our findings on Zinc and Selenium as specific markers for this limb.

- The PG (Left Posterior) axis: Note that this is the limb with the best prediction (29/38), which validates the importance of our findings on Zinc and Selenium as specific markers for this limb.

- Errors: Errors are small and often occur between the limbs of the same pair (example: predicting right anterior instead of left anterior), which is common in veterinary practice. **Figure 4**: Confusion matrix of the model for predicting the location of foot lesions: comparison between actual observations and predicted classifications (overall accuracy: 71.3%).

- The LP (Left Posterior) axis: Note that this is the limb with the best prediction (29/38), which validates the importance of our findings on Zinc and Selenium as specific markers for this limb.

- Errors: The errors are small and often occur between the limbs of the same pair (example: predicting right anterior instead of left anterior), which is common in veterinary practice.

4. Discussion

4.1. Prevalence of Encountered Bovine Diseases

The results of the present study revealed marked heterogeneity in bovine diseases among the different study sections, reflected by significant variations according to season and geographical location. This variability confirms that cattle health status is closely influenced by environmental, climatic, and zootechnical factors shaping livestock production systems. These observations are consistent with findings widely reported in extensive livestock systems in sub-Saharan Africa, as highlighted by [36] [37].

4.1.1. Dominance of Lameness: A Major Health Constraint

Lameness was by far the main cause of cattle hospitalization in all study sections and during both seasons. This finding agrees with the work of [38] who reported that locomotor disorders represent one of the major health problems in extensive and semi-intensive cattle production systems due to movement conditions, soil characteristics, and insufficient hoof care.

According to [38], lameness is often multifactorial, involving traumatic, infectious, and nutritional causes. In the context of the present study, the high prevalence observed during both rainy and dry seasons suggests that this condition is not solely linked to climatic conditions but is also associated with structural husbandry practices, particularly prolonged transhumance, pasture degradation, and the absence of preventive measures such as hoof trimming.

The isolation of lameness in multivariate analyses, particularly in hierarchical clustering and principal component analysis (PCA), confirms its central role in structuring herd health status. [39] emphasized that, in PCA, an isolated variable often indicates a strong contribution to total variance, which is consistent with the epidemiological weight of lameness observed in this study.

4.1.2. Methodological Contribution of Multivariate Analyses

The combined use of hierarchical clustering and principal component analysis proved relevant for identifying distinct epidemiological profiles. According to [39], these methods make it possible to synthesize complex information and highlight latent relationships between variables, which was clearly demonstrated in the present study.

The results showed that locomotor disorders and signs of general health deterioration contrasted with localized and reproductive disorders, reflecting different health contexts and requiring differentiated prevention strategies.

4.2. Origins, Etiologies, and Location of Bovine Lameness According to the Season

Analysis of **Tables 6-8** clearly showed that the lameness observed in the cattle studied was predominantly of non-infectious origin during both the rainy and dry seasons. This predominance reflects the influence of mechanical, environmental, and management-related factors in the development of locomotor disorders in tropical extensive systems.

4.2.1. Predominance of Non-Infectious Lameness

In both seasons, non-infectious causes accounted for more than 90% of lameness cases (94.6% during the rainy season and 91.9% during the dry season). This distribution is comparable to that reported in several studies conducted in extensive and semi-extensive systems, where biomechanical constraints related to prolonged walking, soil characteristics, and the absence of regular hoof trimming constitute the main risk factors [32] [38].

Unlike intensive systems, where infectious lameness conditions such as digital dermatitis and foot rot are frequently predominant, tropical extensive systems are characterized by a greater expression of traumatic and conformational disorders [40]. The results of the present study fully align with this epidemiological pattern.

4.2.2. Hoof Deformities: Dominant and Transversal Cause

Hoof deformation was the leading cause of lameness during both seasons, with a higher prevalence during the rainy season (68.9%) than during the dry season (61.3%). This constant predominance confirms the central role of bovine foot biomechanical imbalance in the development of locomotor disorders [41].

During the rainy season, persistent soil moisture promotes horn maceration, softening, and progressive deformation under body weight and prolonged walking. This situation leads to alteration of the foot axis, overloading of weight-bearing areas, and eventually the establishment of chronic lameness. During the dry season, although humidity decreases, hard and abrasive soils lead to excessive and irregular hoof wear, aggravating pre-existing conformational defects [42]. These opposite yet complementary mechanisms explain the persistence of this dominant cause throughout the year.

4.2.3. Locomotor Injuries and Seasonal Influence

Fractures ranked second among non-infectious causes, with a higher frequency during the dry season (16.1%) than during the rainy season (12.2%). This difference may be explained by the compactness and hardness of dry soils, which increase impact intensity during movement and favor bone trauma, particularly in animals traveling long distances [36].

Conversely, conditions such as luxations and limb paralysis were observed exclusively during the rainy season. Slippery muddy soils and unstable terrain constitute predisposing factors for falls and acute joint injuries [32]. Hoof wounds, on the other hand, appeared only during the dry season, reflecting the abrasive effect of rocky and dry soils on the sole and hoof wall, as also reported by [37] [43].

4.2.4. Lameness of Infectious Origin

Infectious lameness remained minor during both seasons and was exclusively dominated by arthritis. However, a slight increase in its proportion was observed during the dry season (8.1% versus 5.4% during the rainy season). This trend suggests chronic progression of infections acquired during the wet season that persist or become clinically apparent under drier conditions [36].

The absence of other major infectious diseases such as digital dermatitis confirms that the lameness observed was not primarily due to infectious health problems but rather to interactions between mechanical, nutritional, and environmental factors.

4.2.5. Statistical Analysis and Epidemiological Significance

Statistical analysis (Chi-square test) showed that the overall distribution of infectious and non-infectious lameness did not differ significantly between seasons, indicating qualitative stability of the major etiological categories. However, variations observed for specific causes such as fractures and hoof wounds indicate a real influence of seasonality on lesion type.

These findings confirm that lameness in extensive systems is a multifactorial disease whose clinical expression is modulated by climatic conditions without radically changing the overall etiological structure [42] [43].

In conclusion, bovine lameness observed in this study was predominantly of non-infectious origin and mainly characterized by hoof deformities regardless of season. Seasonality influenced the relative frequency of certain traumatic causes more than the overall etiological structure. These findings highlight the importance of preventive approaches centered on functional hoof trimming, pasture adaptation, and soil management rather than exclusively sanitary strategies.

4.3. Specific Etiologies of Lameness According to Animal Category and Season

Table 6 and **Table 7** highlight the diversity of lameness causes observed in the studied cattle, as well as their differential distribution according to animal categories and season. This category-based approach provides a better understanding of the pathophysiological mechanisms and specific risk factors associated with each animal group within the studied farming system.

4.3.1. Hoof Deformities: Dominant Etiology across All Seasons

Regardless of the season, hoof deformities constituted the primary cause of lameness. They accounted for nearly 70% of cases during the rainy season and approximately 53% during the dry season. This predominance confirms the central role of hoof imbalance in the etiology of bovine lameness, as widely documented in the literature [41] [43].

During the rainy season, the high proportion of deformities observed in heifers and cows may be explained by prolonged soil moisture, which promotes horn maceration, loss of rigidity, and progressive alteration of foot biomechanics [42]. Adult females, due to their body weight and, for cows, the physiological demands associated with reproduction and lactation, are particularly vulnerable to these imbalances [44].

During the dry season, although the overall frequency of deformities decreased, they remained predominant, mainly affecting cows (29%), bulls (11.3%), and heifers (9.7%). The hardness and abrasiveness of the soil lead to excessive and irregular horn wear, aggravating conformational defects and promoting chronic lameness [45].

4.3.2. Joint Disorders: Arthritis and Category Distribution

Arthritis affecting the fetlock, elbow, and knee accounted for approximately 10% of lameness cases during both seasons. Its occurrence across different animal categories (cows, heifers, bulls, and calves) reflects a multifactorial origin involving trauma, secondary infections, and joint overloading [36].

The slight persistence, or even relative increase, of arthritis during the dry season may indicate chronic progression of joint lesions that developed during the rainy season and became more clinically apparent under changing environmental conditions [43]. In adult animals, repeated microtrauma associated with prolonged walking constitutes a major aggravating factor.

4.3.3. Marked Vulnerability of Young Animals

Fractures involving the shoulder, femur, and tibia represented a substantial proportion of lameness cases, ranging from 12% to 16% depending on the season, and mainly affected calves. This predominance among young animals may be explained by skeletal immaturity, relative fragility of bone structures, and difficulty adapting to uneven or unstable terrain [36].

During the rainy season, muddy and slippery soils favor falls, whereas during the dry season, soil compactness increases trauma severity upon impact. These findings are consistent with Blowey (2005), who emphasized that bone trauma in young cattle is strongly influenced by soil characteristics and pasture supervision.

4.3.4. Paralysis, Dislocations, and Tendon Ruptures

Rare causes such as luxations, limb or hoof paralysis, and tendon ruptures mainly affected calves and, to a lesser extent, adult females. Their low frequency (<5%) suggests isolated accidental events, often related to severe trauma or secondary neurological lesions [36].

The tendon ruptures observed in cows and heifers may be associated with chronic mechanical overload, particularly during advanced gestation or lactation, aggravated by prolonged walking on unfavorable terrain [40].

4.3.5. Integrated Reading by Animal Category

Category-based analysis revealed that:

- Cows and heifers were mainly affected by hoof deformities, reflecting the cumulative effects of body weight, reproductive physiology, and environmental constraints;
- Calves were particularly exposed to fractures, paralysis, and luxations, highlighting their structural vulnerability;
- Bulls and young bulls, although less represented, mainly exhibited hoof deformities, probably related to body mass and asymmetric hoof wear.

These findings confirm that lameness in extensive livestock systems is a multifactorial condition whose clinical expression is modulated by several determinants, including age, sex, physiological status, and seasonal variations. This observation is consistent with the conclusions reported by [44], who demonstrated the combined influence of these factors on the occurrence and severity of bovine lameness.

5. Conclusions

This study demonstrates that bovine lameness in extensive livestock farming in the Haut-Lomami region constitutes a major health problem, characterized by a high prevalence and an etiology dominated by non-infectious factors. The predominance of hoof deformities, observed regardless of season or animal category, underscores the central role of biomechanical constraints and inadequate hoof health management in this type of farming system.

Seasonality acts primarily as a modulating factor, influencing the relative frequency of the different etiologies without altering their overall hierarchy. The dry season appears to be a critical period, associated with an increase in cases and aggravating factors such as soil degradation and mineral deficiencies. The predominance of lesions in the hind limbs confirms the impact of locomotor constraints related to prolonged movement and unfavorable environmental conditions.

Furthermore, the high incidence of injuries in young animals and foot deformities in adult females highlights the need for a differentiated approach based on livestock categories. Multivariate analyses have provided a better understanding of the interactions between diseases and confirmed the central role of lameness in shaping the health status of herds.

These results support the implementation of integrated prevention strategies based on:

- Improved grazing management and movement conditions,
- Implementation of functional hoof trimming programs,
- Appropriate mineral supplementation,
- And enhanced clinical monitoring, particularly in young animals.

Looking ahead, further studies are needed to quantify the economic impact of lameness and evaluate the effectiveness of preventive interventions under the real-world conditions of tropical pastoral systems.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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