

# Driving Determinants Influencing Mortality of Goats in the Tropics: Challenges for Sustainable Livestock Development

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## Abstract

Goat mortality in the tropics is driven by multifactorial determinants that pose critical challenges to sustainable livestock development. Key contributors include infectious diseases, such as peste des petits ruminants, goat pox, enterotoxemia, and haemonchosis, which remain prevalent due to limited vaccination coverage and inadequate biosecurity measures. Bacterial infections, like pneumonia and caseous lymphadenitis, along with parasitic infestations, such as coccidiosis and liver fluke, significantly reduce goat survival rates, especially in poorly managed herds. Environmental stressors, including heat stress, drought, and flooding, exacerbate these challenges by reducing food and water availability, increasing vulnerability to disease outbreaks. Nutritional deficiencies, particularly in protein, energy, and essential minerals, further compromise immune function, predisposing goats to higher mortality risks. Poor management practices, such as overcrowding, inadequate housing, and unhygienic conditions, amplify these issues, especially in regions with limited veterinary and extension services. Together, these determinants disrupt herd productivity, compromise economic viability, and threaten food security, highlighting the complex interplay of biological, environmental, and management factors. Addressing goat mortality in the tropics requires a detailed understanding of these driving determinants to inform future research and policy, ultimately overcoming the barriers to sustainable livestock development in resource-constrained tropical systems.

**Keywords:** biosecurity, diseases, drought, goat mortality, heat stress, livestock development, nutrition, parasites, sustainability, tropics

## INTRODUCTION

Goat production is a critical component of livestock farming systems in the tropics, contributing significantly to food security, income generation, and rural livelihoods. Goats, known for their adaptability to harsh environments, serve as an important source of meat, milk, fiber, and manure.

Despite their economic and social importance, goat mortality remains a persistent challenge in tropical regions, undermining productivity and sustainability. High mortality rates are attributed to a combination of biological, environmental, and management factors, which collectively hinder herd performance and economic viability [1]. Understanding these mortality determinants is crucial for improving goat survival and ensuring sustainable livestock development in the tropics.

Key factors influencing goat mortality include the prevalence of infectious diseases, environmental stressors, and poor nutritional and management practices [2]. Viral diseases, such as peste des petits

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ruminants, bacterial infections, like pneumonia, and parasitic infestations, such as haemonchosis are major contributors [3]. Additionally, extreme environmental conditions, including heat stress, drought, and floods, exacerbate these challenges by reducing feed availability and increasing susceptibility to diseases. Poor management practices, such as inadequate housing, overcrowding, and insufficient veterinary care, further amplify mortality risks [4]. These multifactorial challenges require a holistic understanding to address their complex interactions effectively.

This study uniquely focuses on the comprehensive analysis of goat mortality determinants in the tropics, bridging gaps in existing knowledge by examining the interplay of biological, environmental, and management factors. Unlike previous studies, which often focus on isolated causes, this study integrates diverse factors to provide a more nuanced understanding of mortality patterns. By highlighting the interconnected nature of these determinants, the study offers a foundation for targeted research and practical interventions. This novel approach underscores the importance of addressing goat mortality as a multifactorial issue, providing valuable insights for developing sustainable livestock production systems in tropical regions.

## **NUTRITIONAL CAUSES**

### **Protein Deficiency**

Protein deficiency in goats leads to poor growth, reproductive failure, and weakened immunity, making them more vulnerable to diseases. Goats require a sufficient intake of high-quality protein to support their metabolic needs, especially during lactation and growth periods [5]. In tropical regions, protein deficiency is often due to inadequate forage quality and poor supplementation, requiring better management of feed resources to ensure adequate protein intake [6].

### **Energy Malnutrition**

Energy malnutrition in goats' results in stunted growth, low milk yield, and reduced overall health. It occurs when the energy intake from available feeds is insufficient to meet the goat's metabolic needs [7, 8]. This condition is especially prevalent in drought-prone areas where forage availability is limited. Providing balanced rations and supplementing energy-rich feeds are crucial to prevent energy malnutrition and improve productivity.

### **Vitamin A Deficiency**

Vitamin A deficiency in goats causes impaired vision, poor growth, and reproductive issues [9]. This deficiency is commonly seen in regions where goats have limited access to fresh green forage, which is rich in vitamin A precursors [10]. Supplementing the diet with vitamin A-rich feeds or direct supplementation can prevent deficiencies and ensure optimal health, productivity, and reproductive performance in functioning goats.

### **Selenium Deficiency**

Selenium deficiency is a critical issue that affects goat health in tropical regions. It can lead to conditions like white muscle disease, poor immune function, and infertility [11]. Selenium is essential for the proper antioxidant enzymes, and a deficiency can leave goats more susceptible to infections. Supplementing selenium through mineral blocks or specific feed additives helps mitigate these health issues and ensures better livestock productivity.

### **Calcium-Phosphorus Imbalance**

An imbalance between calcium and phosphorus in the diet leads to skeletal deformities, poor growth, and reproductive failures. This is often observed when goats are fed inadequate amounts of calcium or phosphorus-rich feeds [12]. Both minerals are essential for bone development and metabolic functions, and providing balanced mineral supplementation is vital for maintaining goat health, particularly in growing and lactating animals.

### **Salt Deficiency**

Salt is a crucial nutrient for goats, as it helps in maintaining proper fluid balance, nerve function, and digestion. A deficiency can cause dehydration, reduced appetite, and overall poor health, leading to increased mortality. Goats in the tropics, especially those on poor-quality forage, may not consume enough salt from their diet, requiring the addition of mineral licks or salt supplementation to meet their nutritional needs.

### **Ruminal Acidosis**

Ruminal acidosis occurs when goats consume high amounts of fermentable carbohydrates, such as grain, without enough fiber. This leads to a drop in rumen pH, causing discomfort, digestive disturbances, and even death if left untreated [13, 14]. Preventing ruminal acidosis involves providing a well-balanced diet with sufficient roughage and ensuring gradual dietary changes to avoid sudden shifts in carbohydrate intake.

### **Chronic Underfeeding**

Chronic underfeeding, where goats do not receive adequate nutrients over extended periods, leads to significant weight loss, poor growth, and compromised immunity [7]. In tropical regions, chronic underfeeding is common during periods of drought or feed scarcity, leading to increased susceptibility to diseases [15]. Ensuring consistent access to high-quality food and supplements can prevent underfeeding and improve the overall health and productivity of goats.

### **Water Deprivation**

Water deprivation is a leading cause of mortality in goats, especially in hot, arid tropical regions. Water is essential for digestion, nutrient absorption, and temperature regulation. Goats deprived of water may suffer from dehydration, heat stress, and organ failure [16]. Ensuring a constant supply of clean, fresh water is critical to maintaining the health and well-being of goats, especially in areas with limited water sources.

### **Trace Mineral Deficiencies**

Deficiencies in trace minerals, such as copper, zinc, and iodine can lead to poor growth, reproductive failure, and immune system dysfunction in goats [12]. In tropical regions with mineral-deficient soils, goats are particularly vulnerable to these deficiencies [17, 18]. Supplementing with trace minerals through mineral blocks, fortified feeds, or targeted supplementation ensures goats receive the essential nutrients for optimal health, reproduction, and productivity.

## **MANAGEMENTAL CAUSES**

### **Inadequate Vaccination**

Inadequate vaccination is a major factor contributing to goat mortality in the tropics. Failure to vaccinate against common infectious diseases, such as PPR, FMD, and tetanus exposes goats to high risks of disease outbreaks [19]. Ensuring a well-established vaccination schedule and educating farmers about its importance can reduce the incidence of vaccine-preventable diseases and improve goat health and survival rates.

### **Poor Biosecurity**

Poor biosecurity practices increase the risk of disease transmission, leading to high mortality rates in goats. The introduction of pathogens from external sources can cause outbreaks of diseases like PPR, tuberculosis, and brucellosis [20]. Effective biosecurity measures, such as isolating new animals, maintaining clean facilities, and controlling animal movement, are essential for preventing disease transmission and ensuring the health of the herd.

### **Overstocking**

Overstocking in goat farms leads to overcrowded living conditions, increased competition for resources, and higher stress levels, which can exacerbate disease transmission. It also contributes to

poor hygiene and rapid degradation of grazing areas. Overstocking can result in malnutrition, poor growth, and increased susceptibility to infections [21]. Maintaining proper stocking densities and adequate space for each goat is vital for improving health and reducing mortality.

### **Transportation Stress**

Transportation stress is a significant cause of mortality in goats, especially during long-distance transport or adverse weather conditions. Goats can suffer from dehydration, exhaustion, injuries, and even death due to stress during transit [22]. Proper handling, ensuring access to water and food during transport, and minimizing travel times are critical for reducing transportation-related stress and ensuring goat welfare during movement.

### **Poor Weaning Practices**

Poor weaning practices, such as abrupt weaning or inadequate nutrition during the weaning process, contribute to high mortality rates in young goats. Weaning stress can lead to nutritional deficiencies, dehydration, and increased susceptibility to diseases [23]. Gradual weaning, proper nutrition, and ensuring that kids receive adequate care during this transition period are essential to reduce mortality associated with this phase of life.

### **Lack of Quarantine Measures**

The lack of quarantine measures increases the likelihood of disease outbreaks in goat herds. Introducing new animals without proper quarantine can lead to the spread of contagious diseases, such as brucellosis, tuberculosis, or respiratory infections [24]. Implementing a quarantine period for new arrivals, monitoring for symptoms, and testing for diseases can help prevent the spread of infections and reduce mortality rates.

### **Rough Handling During Care**

Rough handling of goats during routine care or medical procedures can cause physical injuries, stress, and an increased risk of infection. Improper restraint or handling techniques can also lead to trauma, fractures, or death [25]. Gentle handling, proper training for farm workers, and ensuring that animals are treated with care and respect are essential to reducing the risk of injury and improving overall goat welfare.

### **Early Weaning**

Early weaning, or weaning before the appropriate age, can lead to malnutrition, stunted growth, and weakened immune systems in young goats. Early separation from the mother reduces the intake of colostrum and milk, which are essential for developing a strong immune system [23]. Delayed or gradual weaning, combined with proper nutritional support, is critical to ensure that kids are strong enough to survive and thrive after weaning.

## **BEHAVIORAL CAUSES**

### **Stress from Dominance Hierarchy**

Goats establish social hierarchies, and conflicts over dominance can lead to stress, injury, and even death. Lower-ranking goats may experience chronic stress from bullying or aggression from dominant herd members [26]. Managing herd dynamics by ensuring sufficient space and reducing overcrowding can help minimize stress from hierarchy conflicts. Regular monitoring of social interactions can also prevent aggression and its associated risks.

### **Competition for Food and Water**

Competition for limited food and water resources is a common source of stress in goat herds, particularly in overcrowded or poorly managed environments. Goats may experience malnutrition, dehydration, or stress-related illnesses due to insufficient access to these essential resources. Ensuring that every goat has access to adequate food and water, particularly in times of scarcity, can alleviate stress and improve herd health.

### **Isolation Stress**

Goats are social animals and experience significant stress when isolated from other members of the herd. Isolation can lead to anxiety, decreased appetite, and even death in extreme cases [27]. To mitigate isolation stress, farmers should ensure goats are kept in groups, provide social companionship, and avoid separating individuals from the herd for long periods. Social support can help maintain overall health and well-being.

## **REPRODUCTIVE CAUSES**

### **Dystocia**

Dystocia, or difficult birth, occurs when the goat experiences complications during labor, leading to prolonged delivery, birth injuries, or death. This can be caused by factors, such as oversized kids, incorrect positioning, or maternal health issues [28]. Timely assistance during the birth process, proper prenatal care, and skilled management can reduce dystocia-related mortality and improve birth outcomes.

### **Retained Placenta**

Retained placenta occurs when the afterbirth fails to be expelled after delivery. This condition can lead to infections, blood loss, and reproductive failure if left untreated. In tropical environments, retained placenta is often linked to nutritional deficiencies, stress, or poor sanitary conditions [29]. Prompt veterinary care, proper nutrition, and clean birth environments are key to preventing and managing retained placentas in goats.

### **Stillbirths**

Stillbirths occur when kids die in utero or during the birth process. Common causes include poor maternal health, infection, malnutrition, or dystocia [30]. The incidence of stillbirths can be reduced by providing adequate prenatal care, nutrition, and disease prevention strategies, along with ensuring proper management during labor. Monitoring the health of pregnant goats is essential for preventing stillbirths and ensuring successful deliveries.

### **Neonatal Hypothermia**

Neonatal hypothermia is a life-threatening condition in which newborn goats fail to maintain their body temperature. This is often caused by exposure to cold or wet conditions during birth, leading to weakened immune function and potential death [31]. To prevent hypothermia, newborn goats should be kept warm, dry, and protected from harsh weather, particularly in colder climates or rainy seasons.

### **Neonatal Starvation**

Neonatal starvation occurs when newborn goats do not receive enough colostrum or milk, leading to malnutrition and eventual death [32]. In the tropics, this can result from poor maternal care, inadequate milk supply, or environmental stress. Ensuring that kids receive adequate colostrum within the first few hours of life is crucial for their survival. Supplementation with milk replacers may be necessary if the mother's milk production is insufficient.

### **Congenital Defects**

Congenital defects in goats, such as malformations or genetic disorders, can lead to high neonatal mortality. These defects often affect vital organs, growth, or mobility, rendering the affected goats unfit for survival [33]. Regular breeding management practices, genetic screening, and eliminating known hereditary defects can help reduce the occurrence of congenital defects and improve the overall health of goat populations.

### **Abortions by Brucellosis**

Brucellosis, a bacterial infection, is a leading cause of abortions in goats. The disease can cause spontaneous abortion, infertility, and systemic illness in affected goats [34]. Brucellosis is zoonotic, meaning it can also pose a health risk to humans. Control measures, including vaccination, culling

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infected animals, and maintaining biosecurity protocols, are crucial for preventing brucellosis outbreaks and reducing abortion rates.

### **Abortion Storms**

Abortion storms refer to sudden and widespread abortions occurring in a goat population, often triggered by infectious diseases like brucellosis, leptospirosis, or viral infections [35]. These events can result in significant economic losses. Early detection of infections, strict quarantine measures, vaccination programs, and good herd management practices are essential for preventing abortion storms and maintaining reproductive health in goat herds.

## **PREDATION AND ATTACKS**

### **Dog Attacks**

Domestic and stray dogs can attack goats, especially those that are unguarded or isolated. These attacks may result in severe injuries or death [36]. Guard dogs can help protect goats, but it is also important to manage stray dog populations and prevent domestic dogs from roaming free [37]. Proper fencing and supervision are essential for protecting goats from dog attacks.

### **Leopard Predation**

Leopards are known to prey on goats, particularly in areas where their natural habitats overlap with grazing lands [38]. Leopards typically target young or weakened goats, often ambushing them during the night. Effective protective strategies, such as secure enclosures, night-time confinement, and guarding animals, can reduce the risk of leopard predation in goat herds.

### **Hyena Predation**

Hyenas are opportunistic predators that can attack goats, especially in areas with limited human activity. They are known to hunt in packs, which increases the likelihood of successful predation [39]. Effective management practices, such as using guard animals, reinforcing farm infrastructure, and keeping goats in secure shelters, can help protect goats from hyena predation.

### **Eagle Predation of Kids**

Eagles, particularly large species like the golden eagle, can prey on young goats (kids), especially in open or hilly terrains [40]. They typically target smaller and weaker kids. Farmers can mitigate this risk by ensuring that kids are kept in more protected areas, using fencing to limit access for large birds, and preventing kids from grazing in open fields during vulnerable periods.

### **Snake Predation**

Certain large snakes, such as pythons, may attack and prey on goats, especially young or smaller individuals [41]. Snake predation is more common in areas with dense vegetation or near water bodies. Preventing snake attacks involves controlling vegetation around grazing areas, maintaining proper farm hygiene, and using snake deterrents or traps to reduce the presence of venomous snakes.

### **Theft Leading to Loss**

Theft is a common issue in some tropical regions, where goats are targeted for their value as livestock. Goats can be stolen for meat or resale, leading to financial losses for farmers [42]. Proper fencing, regular monitoring, and using livestock guards or community security programs can help reduce the risk of theft and protect goats from being lost to theft.

## **ENVIRONMENTAL FACTORS**

### **Heat Stress**

Heat stress occurs when goats are exposed to high temperatures, causing dehydration, reduced feed intake, and impaired thermoregulation. Prolonged exposure to heat stress can lead to weight loss, infertility, and death [43]. In tropical climates, heat stress is exacerbated by poor housing conditions and overcrowding. Providing shade, ensuring access to water, and improving ventilation can help alleviate the impacts of heat stress on goats.

### **Cold Stress**

Cold stress results when goats are exposed to cold temperatures, which affect their ability to regulate body temperature. It can lead to hypothermia, reduced feed intake, and weakened immune response [44]. Although cold stress is less common in the tropics, certain high-altitude regions may experience cold spells. Providing adequate shelter, insulated bedding, and nutritional support during cold weather helps mitigate cold stress-related mortality.

### **Hypothermia**

Hypothermia is a dangerous drop in body temperature caused by prolonged exposure to cold and wet conditions. It is particularly fatal to young or weak goats that cannot generate enough body heat to stay warm [45]. In regions with unpredictable weather patterns, hypothermia can occur after heavy rains or storms. Adequate shelter, drying facilities, and warm bedding can prevent hypothermia and reduce mortality.

### **Drought-Related Starvation**

Droughts cause feed shortages by reducing forage availability, leading to malnutrition and starvation in goats. During dry periods, goats may struggle to find sufficient quality pasture or water, weakening their health and increasing mortality [15]. Ensuring supplementary feed, water conservation practices, and drought-resistant pasture varieties are essential for reducing the negative impacts of drought on goat populations.

### **Exposure to Heavy Rains**

Exposure to heavy rain poses significant risks to goat health, including hypothermia, respiratory infections, and foot diseases. Wet and muddy conditions can lead to hoof rot, skin infections, and weakened immunity, making goats more susceptible to illness. Providing adequate shelter, ensuring proper drainage, and maintaining dry bedding can protect goats from the detrimental effects of heavy rain and reduce mortality.

### **Lightning Strikes**

Lightning strikes, although rare, can cause sudden and fatal injuries to goats. Goats in open pastures are at risk of being struck during thunderstorms, particularly in areas with inadequate shelter [46]. Lightning injuries can lead to death or severe trauma. Installing lightning rods, ensuring goats have access to safe shelter during storms, and avoiding grazing in open areas during thunderstorms can mitigate this risk.

### **Unsanitary Housing Conditions**

Muddy or unsanitary housing conditions contribute to increased exposure to pathogens, leading to infections, parasites, and general poor health. When goats are housed in poorly maintained environments, their immune systems are weakened, and they are more likely to suffer from respiratory and digestive disorders [47, 48]. Regular cleaning, proper drainage, and hygienic practices in goat housing are crucial for maintaining health and preventing mortality.

### **Poor Ventilation in Sheds**

Poor ventilation in goat sheds leads to the buildup of harmful gases, such as ammonia, and increases the risk of respiratory infections and heat stress. Inadequate airflow can also contribute to high humidity levels, promoting the growth of mold and bacteria [49]. Proper ventilation systems and airflow management in goat housing are vital to maintain optimal conditions and prevent disease outbreaks caused by poor air quality.

## **ECONOMIC LIMITATIONS**

### **Inability to Afford Veterinary Care**

The inability to afford veterinary care is a major factor contributing to goat mortality. Without timely medical attention, conditions, such as infections, parasitic infestations, and diseases can worsen, leading

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to high mortality rates. To reduce this risk, farmers should prioritize preventive measures, such as vaccination and parasite control, and explore affordable veterinary services or community-based health programs to improve access to care.

### **Lack of Proper Feed**

A lack of proper feed is a critical issue for goat health, especially in resource-limited settings. Inadequate nutrition can lead to malnutrition, stunted growth, weakened immunity, and increased susceptibility to diseases [50]. Farmers should focus on optimizing feed resources, exploring alternative feed sources, and supplementing the diet with essential nutrients to support goat health and productivity, particularly during dry seasons or feed shortages.

### **Poor Housing Facilities**

Poor housing facilities expose goats to harsh environmental conditions, increasing the risk of disease, injury, and mortality. Inadequate shelter, overcrowding, and insufficient ventilation can lead to stress and poor health outcomes [1]. Ensuring that goats have clean, dry, and well-ventilated housing can minimize these risks. Simple improvements, such as upgrading barns and providing adequate space, can enhance goat welfare and reduce mortality.

### **Lack of Access to Clean Water**

Water is essential for the survival and health of goats, but many farmers in tropical regions face challenges in providing consistent access to clean water. Dehydration can quickly lead to malnutrition, reduced production, and death [51]. Farmers should ensure that goats have access to fresh, clean water always, particularly during hot weather, and invest in water storage or distribution systems to address this critical resource limitation.

## **TRAUMA AND INJURIES**

### **Fractures from Falls**

Goats, known for their agility, are prone to falls from high places or uneven terrain, leading to fractures, especially in young kids and older goats. These fractures can result in severe pain, infection, or death if not treated [52]. Farmers should ensure goats are housed in safe, stable environments, free from hazards, and avoid overcrowded conditions that increase the risk of falls.

### **Accidents with Farm Equipment**

Goats can suffer injuries or fatalities from accidents involving farm equipment, such as tractors or fencing machinery. They may get caught in moving parts or be struck by heavy equipment. To prevent these types of accidents, farmers should ensure that equipment is securely stored when not in use, establish clear paths for goats, and maintain safe handling practices to avoid accidental injury.

### **Horn Injuries**

Horn injuries can occur when goats fight or engage in aggressive behavior with each other. Horns can cause puncture wounds, lacerations, or fractures, leading to infections and potentially fatal outcomes. To mitigate horn injuries, farmers can dehorn goats, monitor social interactions closely, and provide ample space for goats to avoid unnecessary conflicts and reduce the risk of injury.

### **Fights with Other Goats**

Goats are naturally territorial and can engage in aggressive behaviors, such as head-butting and fighting, especially among males during the breeding season. These fights may result in serious injuries, such as fractures or internal damage, leading to death [53]. Farmers can reduce the occurrence of fights by managing herd dynamics, separating aggressive individuals, and providing adequate space to minimize stress and competition.

### **Cuts or Wounds from Sharp Objects**

Cuts and wounds caused by sharp objects, such as fences, tools, or even rough handling, can lead to infections, bleeding, or death if not treated promptly [54]. Proper maintenance of farm equipment,

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ensuring that fencing is smooth and free of hazards, and practicing careful handling techniques are essential to minimize the risk of cuts and wounds that could result in fatal outcomes for goats.

## **TOXICITIES AND POISONING**

### **Pesticide Poisoning**

Pesticide poisoning occurs when goats consume feed or water contaminated with pesticide residues, or when pesticides are applied incorrectly in their environment [55]. Symptoms include salivation, vomiting, convulsions, and death. To prevent pesticide poisoning, farmers should use pesticides according to manufacturer guidelines, ensure proper storage, and prevent livestock access to recently treated areas.

### **Nitrate Poisoning**

Nitrate poisoning occurs when goats consume forage containing high levels of nitrates, typically from fertilized crops or drought-stressed plants. The nitrates are converted into nitrites, which impair oxygen transport in the blood, leading to suffocation [56, 57]. Managing the timing of fertilizer application, ensuring proper crop growth, and testing for nitrate levels in forages can help prevent this type of poisoning.

### **Mycotoxigenesis**

Mycotoxigenesis is caused by the ingestion of feed contaminated with mycotoxins, which are produced by mold in improperly stored feed. These toxins can lead to symptoms, such as weight loss, reduced milk production, reproductive failure, and, in severe cases, death [58]. Proper storage of feed, regular inspection for mold, and the use of mycotoxin binders are essential for managing mycotoxigenesis in goat herds.

### **Snake Bites**

Snake bites, particularly from venomous species, pose a serious risk to goats in tropical areas. Snake venom can cause symptoms ranging from local swelling and pain to systemic shock, organ failure, and death [59]. Immediate veterinary intervention is critical. Measures to reduce the risk include controlling snake populations, using protective fencing, and ensuring that goats are not left unattended in areas where snakes are common.

### **Heavy Metal Toxicity**

Heavy metal toxicity can occur when goats ingest contaminated feed, water, or soil. Common heavy metals involved include lead, arsenic, and cadmium. Symptoms include weakness, gastrointestinal distress, and neurological damage [60, 61]. Preventing exposure to contaminated sources, proper waste management, and regular testing of feed and water are essential for preventing heavy metal poisoning in goats.

### **Cyanide Poisoning from Plants**

Certain plants, such as cassava, contain cyanogenic compounds that release cyanide when ingested by goats. Cyanide poisoning can lead to rapid death due to respiratory failure [62]. Goats should be kept away from plants known to contain cyanide-producing compounds. Awareness of local toxic plants and proper management practices can help mitigate the risks of cyanide poisoning.

### **Urea Toxicity**

Urea toxicity occurs when goats consume large amounts of urea, a nitrogen-based fertilizer commonly used in livestock feed. Excessive urea in the rumen leads to ammonia buildup, causing metabolic disturbances, bloating, and death [63]. Farmers should ensure proper formulation of feed and avoid urea supplementation without the guidance of a nutritionist to prevent urea toxicity in goats.

### **Herbicide Poisoning**

Herbicide poisoning occurs when goats ingest plants or contaminated forage that have been treated with herbicides. Herbicides can cause a range of symptoms, including vomiting, diarrhea, and organ

damage [64]. To prevent herbicide poisoning, goats should be kept away from recently sprayed areas, and farmers should adhere to recommended waiting periods before allowing livestock to graze on treated fields.

## **PARASITIC INFESTATIONS**

### **Ticks and Tick-Borne Diseases**

Ticks are vectors for various diseases that can severely affect goats, such as anaplasmosis, babesiosis, and tick-borne fever. Tick infestations can lead to blood loss, anemia, and even death if left untreated [65, 66]. Effective tick control measures, such as regular acaricide treatments, maintaining clean environments, and rotational grazing, are essential for minimizing the impact of tick-borne diseases on goats.

### **Lice Infestation**

Lice infestation in goats can cause intense itching, irritation, and hair loss. If left untreated, lice can lead to secondary bacterial infections, anemia, and overall poor health [67]. Infestation is more common during colder months, but it can occur year-round. Regular inspection, proper hygiene, and treatment with insecticidal shampoos or powders can help manage lice infestations and prevent related complications.

### **Mites Causing Mange**

Mange is a skin condition caused by mites that burrow into the skin of goats, causing severe itching, hair loss, and skin lesions. In severe cases, it can lead to secondary infections and death [68, 69]. Mites thrive in warm and humid environments, making tropical regions particularly susceptible. Topical treatments, improving hygiene, and separating infected goats are crucial for managing mange infestations.

### **Strongyloides Infection**

Strongyloides is a parasitic roundworm that infects the intestines of goats, causing diarrhea, dehydration, weight loss, and even death in severe cases. The infection is particularly common in young or stressed goats [70]. Regular deworming, proper sanitation, and minimizing stress are essential for preventing strongyloides infections. Timely treatment with anthelmintics helps control the spread and impact of this parasite.

### **Tapeworm Infestations**

Tapeworms are intestinal parasites that can cause poor growth, weight loss, diarrhea, and general ill-thrift in goats. While often less harmful than other intestinal parasites, heavy infestations can lead to significant health issues [71]. Tapeworms are often transmitted through contaminated pasture or feed. Deworming treatments and maintaining good pasture management practices are necessary for controlling tapeworm infestations in goats.

### **Babesiosis**

Babesiosis is a tick-borne protozoan disease that causes severe anemia, jaundice, and death in goats. It is transmitted by tick species and affects the red blood cells, leading to a significant decline in health [66]. Early detection, prompt treatment with antiprotozoal drugs, and effective tick control measures are crucial for preventing and managing babesiosis outbreaks in goat herds.

### **Trypanosomiasis**

Trypanosomiasis, also known as sleeping sickness, is a parasitic disease caused by the Trypanosoma parasite, transmitted by tsetse flies. It leads to fever, anemia, weight loss, and death in infected goats [72]. This disease is prevalent in certain tropical regions where tsetse flies are common. Controlling the fly population, screening goats for infection, and prompt treatment with trypanocidal drugs are key measures for managing trypanosomiasis.

### **Theileriosis**

Theileriosis is a tick-borne disease caused by the protozoan *Theileria* species. It causes fever, anemia, swelling of lymph nodes, and can lead to death in severe cases. The disease is transmitted by ticks and is common in tropical regions where tick populations thrive [73–75]. Effective tick control, vaccination, and early detection of symptoms are critical for managing theileriosis and preventing its spread in goat populations.

## **DISEASE-RELATED CAUSES**

### **Pneumonia**

Pneumonia in goats is primarily caused by bacterial infections, such as *Pasteurella multocida*, which thrive in crowded, unsanitary environments [76]. This disease is particularly prevalent during wet, cold conditions or in areas with poor ventilation. Pneumonia leads to respiratory distress, reduced growth rates, and high mortality, severely impacting goat production in tropical regions with fluctuating climates and poor housing conditions [77].

### **Enterotoxaemia**

Enterotoxaemia, caused by *Clostridium perfringens*, is a significant cause of sudden mortality in goats [78]. It typically occurs when goats consume excessive amounts of highly fermentable food, causing toxins to disrupt the gastrointestinal tract. Enterotoxaemia is often seen in young goats with underdeveloped immune systems or those experiencing rapid dietary changes. It highlights the need for balanced feeding and proper management.

### **Peste Des Petits Ruminants**

Peste des petits ruminants (PPR) is a highly contagious viral disease affecting goats, characterized by fever, nasal discharge, and diarrhea. It severely impacts herd health and productivity [79]. PPR is widespread in tropical regions and is often associated with poor vaccination coverage and limited access to veterinary care. Controlling PPR is essential for maintaining sustainable goat farming in affected areas.

### **Foot-and-Mouth Disease**

Foot-and-mouth disease (FMD) is a viral infection that causes fever, blisters, and lameness in goats [80, 81]. The disease spreads rapidly in areas with dense livestock populations and poor biosecurity measures. FMD results in significant economic losses due to decreased productivity and trade restrictions. Effective control measures, including vaccination and quarantine protocols, are essential to reduce FMD-related mortality in goats.

### **Coccidiosis**

Coccidiosis, caused by the *Eimeria* species, is a parasitic disease that affects the gastrointestinal tract of goats. It is especially common in young goats that are stressed, malnourished, or kept in unsanitary conditions. The disease leads to diarrhea, weight loss, and dehydration, which can result in high mortality rates [66, 82]. Proper sanitation, regular deworming, and good nutrition are critical in preventing coccidiosis outbreaks.

### **Caseous Lymphadenitis**

Caseous lymphadenitis is a chronic bacterial infection caused by *Corynebacterium pseudotuberculosis*, affecting the lymph nodes of goats. It leads to abscess formation, which can result in secondary infections and systemic illness [83]. The disease is often spread through direct contact or contaminated equipment. Effective control strategies include culling infected animals, maintaining good hygiene, and minimizing the spread of the pathogen within herds.

### **Mastitis**

Mastitis is an infection of the udder caused by bacteria, such as *Staphylococcus aureus* or *Escherichia coli*. Infected goats experience pain, swelling, and decreased milk production, which can lead to

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premature culling [84–86]. The disease can also cause systemic infection, contributing to high mortality rates. Preventing mastitis requires regular monitoring of udder health, proper milking hygiene, and early intervention when signs of infection appear.

### **Contagious Caprine Pleuropneumonia**

Contagious caprine pleuropneumonia (CCPP) is a highly fatal bacterial disease caused by *Mycoplasma capricolum*. It primarily affects the lungs and pleura of goats, causing severe respiratory distress, fever, and death [87]. The disease spreads through direct contact with infected animals or contaminated environments. It poses a significant risk in areas with dense goat populations, requiring strict biosecurity and rapid response measures to prevent outbreaks.

### **Haemonchosis**

Haemonchosis, caused by *Haemonchus contortus*, is a parasitic infection affecting the gastrointestinal tract of goats. The parasite feeds on blood, leading to anemia, weakness, and even death in severe cases [88]. Haemonchosis is particularly prevalent in tropical and subtropical climates, where the warm environment supports the rapid development of the parasite. Regular deworming, rotational grazing, and monitoring are essential for controlling haemonchosis.

### **Liver Fluke Infections**

Liver fluke infections, caused by *Fasciola hepatica*, are common in goats grazing on wetland areas. Parasites affect the liver, causing inflammation, liver damage, and reduced productivity. In severe cases, fluke infestations can lead to liver failure and death [89]. Controlling liver fluke infections involves regular deworming, managing grazing practices, and reducing exposure to contaminated water sources in endemic areas.

### **Tetanus**

Tetanus, caused by the bacterium *Clostridium tetani*, is a serious disease in goats that leads to muscle stiffness, spasms, and, in severe cases, death. It typically occurs when goats suffer from wounds or injuries contaminated with soil [90]. Tetanus can be prevented through proper wound care, vaccination, and ensuring clean environments for goats. The disease remains a significant concern in regions with limited veterinary access.

### **Johne's Disease**

Johne's disease, caused by *Mycobacterium avium* subspecies *paratuberculosis*, is a chronic bacterial infection leading to weight loss, diarrhea, and reduced milk production in goats [91]. The disease progresses slowly and may not be diagnosed until significant damage has occurred. Johne's disease is difficult to control due to its long incubation period, making early detection and prevention crucial for reducing mortality rates in affected herds.

### **Goat Pox**

Goat pox, caused by the goat pox virus, is a contagious viral disease that leads to fever, skin lesions, and respiratory distress. The disease spreads through direct contact or contaminated environments [92], [93]. Although goat pox is typically less fatal than other diseases, it can cause significant economic losses due to reduced productivity and treatment costs. Vaccination and quarantine measures are essential for controlling outbreaks and preventing mortality.

### **Rabies**

Rabies is a fatal viral disease that affects the nervous system of goats. Transmission occurs through the bite of infected animals, such as dogs or wildlife. Infected goats exhibit aggressive behavior, paralysis, and eventual death [94]. Rabies is preventable through vaccination, but it remains a risk in areas with a high prevalence of rabid wildlife or unvaccinated domestic animals, posing a threat to goat populations.

### **Anthrax**

Anthrax, caused by *Bacillus anthracis*, is a severe bacterial disease that affects goats and other livestock species. It causes rapid death due to septicemia and toxemia, often without prior symptoms [95, 96]. The disease is highly contagious and can spread through contaminated food, water, or soil. In endemic areas, vaccination and proper disposal of carcasses are essential to prevent outbreaks and reduce the mortality rate associated with anthrax.

## **INFECTIOUS OUTBREAKS**

### **Salmonellosis**

Salmonellosis is caused by the bacterium *Salmonella* and leads to symptoms, such as diarrhea, dehydration, fever, and in severe cases, death. Goats can contract salmonellosis through contaminated feed, water, or direct contact with infected animals [97, 98]. Good sanitation practices, proper vaccination, and controlling the movement of livestock can reduce the risk of salmonella outbreaks in goat herds.

### **Colibacillosis**

Colibacillosis, caused by *Escherichia coli* infections, is a major contributor to mortality, particularly in young kids. Symptoms include diarrhea, dehydration, and in some cases, death [99, 100]. Inadequate sanitation, poor colostrum intake, and stress are risk factors. Preventive measures, such as improving hygiene, ensuring proper nursing, and administering vaccines can help mitigate the impact of colibacillosis in goat herds.

### **Campylobacteriosis**

Campylobacteriosis, caused by *Campylobacter* bacteria, is a leading cause of gastrointestinal disease in goats. Infected goats may show symptoms, such as diarrhea, abdominal pain, and weight loss [101]. The disease can spread through contaminated feed or water and poses a risk to both goats and humans. Proper sanitation, isolation of infected animals, and controlling animal movement are key to managing campylobacteriosis outbreaks.

### **Tuberculosis**

Tuberculosis (TB), caused by *Mycobacterium* species, is a chronic bacterial infection that primarily affects the respiratory system. Goats may develop persistent coughing, weight loss, and respiratory distress [102]. TB can spread between animals and humans through direct contact or contaminated milk. Regular testing, quarantine measures, and maintaining good biosecurity can help prevent TB outbreaks in goat populations.

### **Listeriosis**

Listeriosis, caused by the bacterium *Listeria monocytogenes*, is another significant infectious disease that can affect goats. It can cause abortion, neurological symptoms, and death, especially in pregnant does [103, 104]. Goats can contract listeriosis through contaminated feed, particularly silage. Proper feed storage, avoiding contaminated silage, and practicing good hygiene are important for preventing listeriosis outbreaks in goat herds.

## **MISCELLANEOUS CAUSES**

Various miscellaneous causes contribute to goat mortality in the tropics, encompassing accidents, management failures, and environmental challenges. These factors may not be directly linked to diseases but can result in significant losses due to their diverse nature. Addressing these causes requires a holistic approach, involving proper care, adequate resources, and ensuring safe practices for both goats and farmers.

### **Electrocution**

Electrocution can occur when goats meet faulty or improperly maintained electric fencing, power lines, or equipment. This can lead to severe injuries or death, particularly in regions with high humidity

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or rain, which increases the conductivity of materials. Proper maintenance of electrical systems and ensuring goats are kept away from hazards are essential to prevent electrocution-related fatalities.

### **Fencing Injuries**

Fencing injuries, often caused by goats trying to escape or navigate through poorly constructed or sharp-edged fences, can result in cuts, fractures, or more severe harm. Over time, these injuries may lead to infections or death if left untreated. Proper fencing installation, regular inspection, and providing adequate space for goats can minimize the risk of injury from fences.

### **Overexertion During Herding**

Goats, especially those used for herding or heavy labor, are at risk of overexertion, which can lead to exhaustion, dehydration, and death, particularly in hot climates. Overexertion can weaken the immune system and exacerbate underlying health issues. Careful management of herding practices, allowing goats to rest, and ensuring access to water and shade can help reduce risks associated with overexertion.

### **Inadequate Deworming**

Inadequate or inappropriate deworming protocols can result in a high burden of internal parasites, leading to malnutrition, anemia, and death. Improper use of deworming agents may also contribute to parasite resistance. Regular veterinary consultation to establish effective deworming schedules and appropriate medications can help prevent parasitic infestations and reduce associated mortality risks.

### **Zoonotic Diseases**

Zoonotic diseases, transmitted from goats to humans, pose a risk to both the animals and their handlers. Inadequate protective measures or improper handling of sick animals can result in the spread of diseases, such as tuberculosis or brucellosis [105, 106]. Implementing biosecurity protocols, including protective clothing and hand hygiene, can prevent the transmission of zoonotic diseases between goats and their caregivers.

### **Misdiagnosed Conditions**

Misdiagnosis of goat illnesses can lead to inappropriate treatments or missed opportunities for effective interventions, contributing to unnecessary deaths [107]. Incorrect diagnosis of common conditions, like pneumonia, coccidiosis, or parasitic infections, can have serious consequences. Training farmers and veterinarians to recognize early signs of illness, as well as proper diagnostic tools, can enhance the accuracy of diagnoses and improve mortality outcomes.

### **Poisoning by Harmful Plants**

Goats are known to graze on a wide range of plants, some of which may be toxic [108, 109]. Poisoning from plants, such as oleander, nightshade, or avocado can lead to severe poisoning or death. Farmers should be aware of potentially toxic plants in grazing areas and prevent goats from ingesting harmful substances by maintaining proper pasture management and fencing off dangerous plant species.

### **Starvation Due to Feed Unavailability**

Starvation is a leading cause of goat mortality, particularly in regions with seasonal feed shortages or during droughts. Lack of access to nutritious food can lead to malnutrition, stunted growth, and death [110]. Ensuring a consistent and adequate food supply, especially during difficult periods, and supplementing diets with additional feed or forage resources can mitigate the risks of starvation-related mortality.

### **Flood-Related Drowning**

Flooding is a common natural disaster in tropical regions, and goats are at risk of drowning when they are exposed to rising water levels. Inadequate shelter or poor drainage can worsen the impact of floods, leading to drowning [111]. Constructing elevated shelters, improving farm drainage, and ensuring goats are safely housed during floods can help reduce the risk of flood-related fatalities.

### **Contaminated Feed**

Contaminated feed, including moldy or spoiled feed, can lead to poisoning, infections, or diseases, such as mycotoxicosis. Feed contamination can be caused by improper storage or handling, resulting in significant health risks for goats [112]. Proper feed storage, regular quality checks, and sourcing feed from reliable suppliers can prevent contamination and protect the goats from health-related issues.

### **Lack of Access to Proper Pasture**

Goats require access to good-quality pasture to meet their nutritional needs. A lack of proper grazing areas can lead to malnutrition, weight loss, and increased vulnerability to diseases [110]. Providing goats with access to nutritious pasture or supplementing them with other feed resources is crucial for maintaining their health, particularly in areas where land availability is limited.

### **Neglect by Caregivers**

Neglect by caregivers, including inadequate attention to health, nutrition, and shelter, can result in poor health and increased mortality in goats [113]. Neglect often leads to conditions like malnutrition, parasitic infections, or lack of timely veterinary care. Ensuring that caregivers are properly trained and attentive to the needs of goats can significantly reduce the risks of mortality caused by neglect.

## **CONCLUSIONS**

Goat mortality in the tropics is a complex issue driven by infectious diseases, environmental stressors, and poor management practices, significantly hindering sustainable livestock development. This study highlights the complex interplay of these determinants, emphasizing their cumulative impact on herd productivity, economic viability, and food security. Addressing goat mortality requires a comprehensive understanding of the underlying causes and their interactions. By identifying critical mortality drivers, this study provides a foundation for targeted research and informed decision-making. Future efforts should prioritize integrated approaches, encompassing improved health management, environmental resilience, and better resource utilization. These insights are crucial for reducing mortality rates, enhancing goat survival, and fostering sustainable livestock systems in resource-constrained tropical regions.

### **Future Direction**

Future research should focus on developing integrated approaches to reduce goat mortality in tropical regions by addressing the interplay of biological, environmental, and management factors. Advanced epidemiological studies are required to identify region-specific disease patterns and evaluate the efficacy of vaccination programs. Genetic studies should explore disease-resistant goat breeds adapted to tropical environments. Climate-resilient feeding strategies, including the cultivation of drought-tolerant fodder species, must be prioritized to mitigate the effects of environmental stressors. Investigating innovative housing designs and husbandry practices can improve goat welfare and reduce mortality associated with overcrowding and poor hygiene. Digital tools, such as real-time disease monitoring and decision-support systems, could enhance veterinary care and management efficiency. Emphasizing community-based participatory interventions and capacity-building programs will ensure the practical application of research findings, promoting sustainable livestock production systems and improving resilience in resource-constrained tropical settings.

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