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Effect of Climatic Conditions and Lunar Luminosity on the Mortality of Hair Sheep

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Abstract

Climate change, primarily driven by human activities, has a growing negative impact on animal health and welfare by modifying environmental variables such as temperature, rainfall, and the frequency of extreme weather events. These factors directly and indirectly affect livestock productivity, promote the emergence of diseases, increase mortality, and compromise food security. The objective of this study was to identify and analyze the relationship between climatic conditions and sheep mortality in the state of Yucatán, as a basis for the design of preventive technologies. Information obtained over four years from necropsies performed on the flock at the Mocochá Experimental Center was used. Data were classified by cause of death, age group, year of evaluation, and quarter (season). The analyses showed no statistically significant differences ($P > 0.05$) between grouped causes of death and climatic variables such as average maximum-minimum ambient temperature differential (DTAMMP), rainfall (PP), and lunar luminosity level (NLL). However, when considering age groups, lambs were more susceptible to death under high precipitation ($P < 0.05$) and low lunar luminosity conditions ($P < 0.05$). Statistical differences were also identified between years evaluated for DTAMMP and NLL ($P < 0.05$), and between seasons, particularly between the cold season and the other seasons. It is concluded that mortality from respiratory and digestive diseases increases under conditions of extreme temperature combined with high precipitation. Furthermore, predator attacks intensify in scenarios with extreme temperatures, rainfall, and low lunar luminosity. These findings allow a better understanding of the impact of climate on sheep mortality and contribute to the development of adaptive strategies in the face of climate change.

Subject Areas

Agricultural Engineering

Keywords

Climate Change, Sheep Mortality, Climatic Factors

1. Introduction

Climate change is an unquestionable reality that profoundly affects biodiversity and the balance of ecosystems, with negative repercussions on the production, health and welfare of both wild and domestic animals. Variations in temperature, precipitation and extreme events alter available resources and favor the appearance of diseases, which compromises the sustainability of natural and productive systems [1] [2]. In this context, climate change and the increase in environmental temperatures impact ruminant livestock in multiple ways: directly, on the animal, by affecting its productivity, reproduction, health and welfare; and indirectly, by modifying the availability, quality and seasonality of feed resources [3].

In the particular case of sheep, their condition as homeothermic animals allows them to maintain a constant body temperature, which favors their adaptation to thermally variable environments. To dissipate excess heat when environmental temperature approaches body temperature, sheep employ physiological mechanisms such as evaporation, through sweating and panting [1]. The pile layer also plays a crucial role in protecting against solar radiation and in thermal regulation, facilitating heat loss by evaporation and convection [4].

However, despite the ability of sheep to regulate their body temperature and adapt to different thermal conditions, climate can have a significant effect on lamb mortality. This effect is closely related to a variety of environmental factors that together can predispose animals to disease. The climatic conditions prevailing at certain times of the year influence both the manifestation of various pathologies and mortality rates [5] [6]. To understand more precisely the effects of climate on animals, it is essential to analyze the fluctuations of climatic indicators throughout the year. Although environmental temperature has been the most commonly used variable to evaluate the impact of heat stress on productive efficiency, its explanatory value can be increased when considered in conjunction with other climatic factors, such as rainfall and the level of lunar luminosity [7].

Another important consequence of climate change is its ability to modify the intensity and distribution of ecological interactions between prey and predators [8]. Evidence suggests that higher temperatures and more stable climates, with less seasonality, may favor an increase in predation pressure. However, increasing climatic instability associated with climate change, especially in tropical regions, tends to reduce predation pressure in these ecosystems. In contrast, some temperate climate zones may experience an increase in the intensity of prey-predator interactions as a result of changes in weather patterns and resource availability [9]. These alterations could have important implications on the dynamics of animal populations, indirectly affecting the structure of productive systems and associated ecosystem services. For this reason, the objective of this study was to identify and analyze the climatic factors that influence sheep mortality in the state of Yucatan, in order to generate useful information for the development of preventive technologies and management strategies that contribute to mitigating their effects and improving the sustainability of the sheep production system in the region.

2. Materials

2.1. Location

The study was carried out during the months of January 2012 to December 2015, at the Mocochá Experimental Field located in the state of Yucatan, Mexico (21˚13'15" N 89˚45'15" W), with a tropical sub-humid climate (Awo) and a mean annual temperature of 26.5˚C, with a total precipitation of 900 mm and 9 meters above sea level (meaning m.a.s.l.).

2.2. Characteristics of the Animal Population and General Management

The study was conducted in a sheep flock composed of approximately 300 females and 20 sires, including animals of the Pelibuey, Blackbelly, Dorper, Katahdin and Ille de France breeds. The breeding system was semi-controlled, with only one lambing period per year, strategically programmed so that lambing would coincide with the months of greatest forage availability, thus optimizing lamb survival and the use of food resources. The sheep were managed under an extensive daily grazing system, using established pastures with grasses adapted to dry tropical conditions, such as African star (*Cynodon plectostachyus*), Guinea (*Megathyrsus maximus*) and Buffel (*Cenchrus ciliaris*). Herd health management included the regular application of preventive vaccines against pneumonia and downy mildew, as well as systematic deworming programs to control gastrointestinal parasites (nematodes and cestodes) and nasal cavity parasites. For the present investigation, information was collected from necropsies performed during a period of four consecutive years (year 1 to year 4). These were carried out by the technical personnel responsible for the animal health area of the experimental center, with the objective of identifying the cause of death of each animal and associating it with environmental and climatic variables of the corresponding period.

3. Methods

3.1. Sheep Age Categorization

To facilitate the analysis of the information related to mortality, the sheep were grouped into age categories according to their age at the time of death. The classification was made as follows: Breeding: animals from birth to 11 months of age. Young sheep: animals from 12 to 23 months of age. Adult: animals from 24 to 71 months of age (equivalent to 2 to 5.9 years). Old: animals from 72 months of age and older (6 years or more). This categorization made it possible to identify patterns of susceptibility to climatic factors and causes of mortality associated with each stage of physiological development, contributing to the differential analysis of the environmental impact on the different age groups of the herd.

3.2. Classification of the Seasons of the Year

Based on local climatic conditions in the state of Yucatan, the year was divided into four seasons to facilitate the temporal analysis of sheep mortality in relation to the environment. The classification was established as follows: January to March: period of cold weather and transition to drought. April to June: period of intense drought, characterized by high temperatures and low precipitation. July to September: period of intense rainfall, associated with higher humidity and abundant forage. October to December: rainy season with lower temperatures, commonly known as the northerly season, influenced by cold fronts. This classification made it possible to link the mortality records with the prevailing climatic conditions in each quarter, contributing to the analysis of the seasonal effects on sheep health and survival.

3.3. Information Collected from Necropsies

During the study period, detailed information was collected for each deceased sheep through necropsies performed by animal health personnel. The following data were recorded for each case: Date of death, identification number of the sheep, date of birth, breed, sex, age at death, place where the animal was found, and clinical diagnosis of the necropsy, corresponding to the cause of death.

Necropsies were performed following a standardized protocol that included an external examination and a complete internal examination of each deceased animal. In the external examination the following aspects were evaluated: General condition and body condition, Condition of meats and muscle coverage, Condition of skin and presence of visible lesions, Evaluation of mucous membranes (coloration and appearance), Presence of wounds, tumors or other external abnormalities. The internal examination covered inspection of: Subcutaneous tissue and muscle tissue, Peripheral and deep lymph nodes, Digestive system (from oral cavity to large intestine), Respiratory system (nose, larynx, trachea, lungs), Circulatory system (heart, major vessels), Urogenital system (kidneys, Bone system (presence of fractures, bone lesions), Central and peripheral nervous system (when required), Complementary laboratory analysis in specific cases, such as bacterial culture or histopathological analysis. Based on macroscopic and laboratory findings, a clinical diagnosis of the cause of death was established for each case, which allowed classifying deaths by affected systems or by specific conditions (infectious, parasitic, traumatic, predation, etc.). When the cause of death corresponded to predation, it was due to attacks by dogs, considered the main predators of sheep, responsible for a high number of casualties in the flocks, as has been reported in several studies [10].

3.4. Weather Information

The climatological information used in this study was obtained from the historical databases of the National Water Commission (CONAGUA) and the National Meteorological Service (SMN) [11], available on their official platform https://smn.conagua.gob.mx/es/. Monthly data corresponding to the four years of the study period (2012-2015) were collected, including the following parameters: minimum temperature, average temperature, maximum temperature, and average rainfall. The data were extracted at the national level and by state, specifically for the state of Yucatan, according to the months and years corresponding to the mortality information collected. This information allowed us to analyze the annual and seasonal climatic fluctuations and their possible relationship with the mortality observed in the sheep flock.

3.5. Lunar Luminosity Information

To integrate the variable of lunar luminosity in the analysis, information from the lunar calendar was collected through the Tutiempo.net website, obtaining data corresponding to the lunar phases by year and month during the study period (2012-2015). This information was linked to the date of death of each sheep, allowing the identification of the lunar phase present at the time of death: full moon, crescent, new moon and waning quarter. Based on the theoretical reference on illumination intensity provided by each phase, the following relative brightness values were assigned: Full moon: 100% brightness, waxing and waning quarter: 50% brightness, new moon: 0% brightness [12].

3.6. Statistical Analysis

Once the information was collected, the data were captured and processed using SAS statistical software, version 2019. For the analysis, a general linear model (GLM) was used, which allows us to analyze unbalanced data through the least squares method, which adjusts the linear model and to understand the dispersion of data we used analysis of variance, standard deviation and the coefficient of variation. They were considered as dependent variables: Rainfall precipitation (PP), Difference between average maximum and average minimum ambient temperature (DTAMMP), Lunar luminosity level (NLL), determined based on lunar phases. As fixed variables, the following were included: main causes of death grouped together, age group of the deceased sheep (offspring, young, adult and old), time of year (January-March: cold and beginning of dry season; April-June: intense dry season; July-September: intense rainfall; October-December: rainfall and cold or northerlies), year of evaluation (years 1 to 4 of the study-2012-2015). For comparison between means, Duncan's multiple range test was applied with a significance level of $P < 0.05$. This approach allowed us to identify significant statistical differences between categories and to evaluate the effect of climatic factors on sheep mortality patterns in different environmental and temporal contexts.

4. Results

4.1. Leading Causes of Death in Sheep

During the study period, 224 necropsies were performed on deceased sheep, identifying various causes of death. The most frequent causes were attacks by predators (38.83%) and respiratory diseases (27.23%), followed by less frequent causes such as metabolic disorders and ruminal acidosis (4.46%), internal parasites (4.01%), physical trauma (3.57%), tympanism (2.67%), as well as various digestive disorders (peritonitis, intestinal intussusception, diarrhea-hypoproteinemia and enteritis), which together represented a lower percentage. Isolated cases of tetanus, locomotor problems, complications during parturition and plant intoxication were also documented, each with a frequency of 0.44%. In 9.91% of the cases, it was not possible to perform a necropsy, so the cause of death was classified as unknown.

For the purposes of analysis in the following table, the main causes were grouped into three categories: attacks by predators, respiratory diseases and digestive diseases, which concentrated a total of 179 necropsies, representing 80.70% of all deaths recorded over four years (2012-2015). The corresponding data are presented in **Table 1**, which shows the relationship between the grouped causes of death and three environmental variables: maximum-minimum ambient temperature difference (DTAMMP), rainfall (PP) and lunar luminosity level (NLL). As for the DTAMMP, no significant statistical differences ($P > 0.05$) were found among the causes of death, although the average value recorded was higher than 11˚C, indicating a tendency towards extreme thermal conditions.

Table 1. Effect of climatic and light variables on causes of mortality in sheep.

Causes of death grouped	Variable			
	N	DTAMMP ˚C	PP mm	NLL %
Predators	87	12.83 a	45.20 d	39.25 a
Respiratories	61	11.66 ab	91.83 bcd	43.0 a
Digestives	31	12.16 ab	100.02 bcd	41.0 a

Different letters mean statistically significant differences ($p < 0.05$, Tukey). For this analysis, the lunar luminosity level covered new moon to crescent. Difference of Maximum Ambient Temperature-Average Minimum Temperature (DTAMMP), Pluvial Precipitation (PP) and Lunar Luminosity Level (NLL).

Regarding rainfall, no significant statistical differences were observed ($P > 0.05$); however, predator attacks coincided numerically with periods of lower rainfall, unlike the other causes of death. In relation to the level of lunar luminosity, although no significant statistical differences were detected ($P > 0.05$), predator attacks occurred more frequently in conditions of very low lunar luminosity, particularly during the new to crescent moon phases. These findings suggest a clear but not statistically significant trend, in which predator attacks are intensified in darker and drier environments, conditions that could favor their activity and make detection by livestock and herders more difficult. This pattern, although it requires further statistical confirmation, may be relevant for the design of prevention strategies focused on the environmental conditions of greatest risk.

4.2. Age of Deceased Sheep

The analysis of the 224 necropsies also made it possible to evaluate the relationship between the age of the deceased sheep and the environmental variables: maximum-minimum ambient temperature difference (MTDAMD), rainfall (PP) and lunar luminosity level (LLL), the results of which are presented in Table 2. In general terms, the highest proportion of mortality corresponded to young sheep (37.94%), followed by adults (28.12%), old (24.10%) and young (9.82%). This pattern indicates that, although growing and productive sheep are more resistant than offspring, they are also more vulnerable to accumulated environmental stress.

With respect to DTAMMP, no significant statistical differences were found between age groups ($P > 0.05$); however, numerically, a clear trend was identified: the greater the thermal amplitude, the higher the mortality, especially in young sheep, followed by adults and old sheep. In all groups, the average thermal difference exceeded 12˚C, suggesting that extreme thermal conditions affect sheep regardless of their age, although with greater impact on growing animals. Regarding rainfall, a statistically significant difference ($P < 0.05$) was detected between age categories.

The offspring were more susceptible to death during periods of high rainfall compared to the other groups. This vulnerability may be attributed to their lower thermoregulatory capacity and greater susceptibility to opportunistic infections associated with humid environments. In contrast, juveniles, adults, and older individuals showed lower mortality under these conditions, although they continued to be affected by other environmental factors.

Table 2. Relationship between climatic variables and lunar luminosity with age at mortality in sheep.

Age	Variable			
	Sheep deceased	DTAMMP ˚C	PP mm	NLL %
Offspring	22	12.03 a	116.92 a	52.27 a
Young	85	12.13 a	76.73 b	45.88 ab
Adult	63	12.25 a	78.77 b	33.33 b
Old	54	12.40 a	68.30 b	45.37 ab

Different letters mean statistically significant differences ($p < 0.05$, Tukey). For this analysis, the lunar luminosity level covered new moon to crescent. Difference of Maximum Ambient Temperature-Average Minimum Temperature (DTAMMP), Pluvial Precipitation (PP) and Lunar Luminosity Level (NLL).

Regarding lunar luminosity, a significant difference ($P < 0.05$) was also found when comparing mortality between pups and adults. During periods of low lunar luminosity (between the new moon and the first quarter), illumination decreased by up to 36.2%, and mortality rates among pups practically tripled compared to adults. This association suggests that darkness could increase the vulnerability of pups, possibly by favoring the action of predators or by hindering vigilance by mothers or other personnel in charge of handling. No statistically significant differences (P > 0.05) were found for young, adult, and old sheep in terms of lunar luminosity. Together, these findings reinforce the hypothesis that environmental factors interact differentially with animal age, increasing the risk of mortality under certain conditions. In particular, young animals are at greater risk under high rainfall and low light conditions, while juveniles show greater sensitivity to wide temperature differences, which represents key information for designing management and prevention strategies tailored to each age group.

4.3. Sheep Mortality in the Years Assessed

Table 3 shows the distribution of sheep deaths during the four years of evaluation (2012-2015), both in absolute terms and in relation to the total population of animals in the production unit by year. Of the total necropsies analyzed, 6.25% corresponded to **year 1**, 28.12% to **year 2**, the same percentage to **year 3**, and 37.5% to **year 4**. However, when mortality is adjusted for the population size of each year, it is observed that the actual mortality was 9. 33% in **year 1**, 21% in **year 2**, 12.6% in **year 3**, and 10.5% in **year 4**. This reveals that the peak relative mortality occurred in year 2, even though the highest absolute number of cases occurred in **year 4**.

In relation to the difference between maximum and minimum average ambient temperature (DTAMMP), a progressive increase was observed during the first three years of the study, remaining at high levels (>12˚C) during years 3 and 4. This increase was statistically significant (P < 0.05) when comparing year 1 with year 3 and year 4, which suggests a tendency towards more extreme climatic conditions over time. This behavior was associated with an increase in the number of sheep deaths, which reinforces the relationship between thermal amplitude and mortality risk in the flock. Rainfall did not show significant statistical differences between years (P > 0.05); however, it remained an important variable in the analysis of specific causes of death, as discussed in other sections of the study.

Table 3. Annual distribution of mortality in sheep as a function of climatic factors and lunar luminosity.

Years evaluated	Variable			
	N	DTAMMP (˚C)	PP (mm)	NLL (%)
1	14	11.70 b	77.63 a	62.5 ab
2	63	12.08 ab	85.48 a	51.75 bc
3	63	12.40 a	79.73 a	65.0 a
4	84	12.28 a	74.41 a	48.0 c

Different letters mean statistically significant differences (p < 0.05, Tukey). For this analysis, the lunar luminosity level covered new moon to crescent. Difference of Maximum Ambient Temperature-Average Minimum Temperature (DTAMMP), Pluvial Precipitation (PP) and Lunar Luminosity Level (NLL).

Regarding the level of lunar luminosity (NLL), significant statistical differences ($P < 0.05$) were detected between the first year and the last year evaluated, while the intermediate years showed no differences between them ($P > 0.05$). This finding is relevant considering that years with lower lunar luminosity coincided with higher frequency of predator attacks, as documented in the previous tables. Taken together, these results suggest that the trend of increasing thermal amplitude-together with changes in lunar luminosity - could be contributing to the interannual variability in sheep mortality, being key factors to consider in the design of adaptive management strategies in the face of a changing climatic environment.

4.4. Quarterly and Seasonal Sheep Mortality

Sheep mortality was also analyzed by quarter of the year, considering both climatic conditions and the level of lunar luminosity. This information is presented in Table 4, which shows a significant variation in sheep mortality accumulated throughout the year, mainly associated with changes in temperature, precipitation and lunar luminosity. As for the difference in average maximum-minimum ambient temperature (DTAMMP), a statistically significant difference ($P < 0.05$) was found when comparing the first quarter (January-March) with the remaining quarters. During this period, the thermal difference averaged 13.35˚C, reflecting highly extreme conditions with cold nights and warm days. This quarter coincides with the beginning of the dry season and forage shortage, which generates significant physiological stress in the animals, especially due to the low availability of feed and the drop in temperatures. This scenario resulted in the highest accumulation of sheep deaths during the year.

With respect to rainfall, statistically significant differences ($P < 0.05$) were also identified between quarters. The first quarter (January-March) not only presented the lowest rainfall of the year, but also registered the highest accumulated sheep mortality, which evidences the influence of early drought combined with cold on the vulnerability of the animals. The July-September quarter, corresponding to the heavy rainy season, presented the lowest sheep mortality and showed significant differences ($P < 0.05$) with respect to the other quarters, suggesting that the increased availability of water and forage during this time favors animal welfare. The quarters April - June (intense dryness) and October-December (rains and thermal decrease) presented moderate mortality, with no statistical difference between them ($P > 0.05$).

In relation to the level of lunar luminosity, a significant statistical difference ($P < 0.05$) was found in the October-December quarter, which registered the lowest lunar illumination of the year (31.37%). This period coincided with a mid-level cumulative sheep mortality, which reinforces the hypothesis that low lunar luminosity may favor events such as predator attacks, especially in combination with adverse climatic conditions such as rainfall and low temperatures. Overall, these results reflect a clear seasonality in sheep mortality, with the first quarter of the year being the period of greatest risk, due to the combination of high thermal amplitude, drought and decrease in available forage. These findings are fundamental to design seasonal management strategies that contemplate feed supplementation, thermal refuge and preventive surveillance, especially at critical times of the year.

Table 4. Effect of environmental variables and lunar luminosity on quarterly and seasonal sheep mortality.

QUARTER	Variable			
	N	DTAMMP (˚C)	PP (mm)	NLL (%)
January – March	81	13.35 a	37.81 c	45.67 a
(Cold-start Dry)	54	12.26 b	85.70 b	47.22 a
April – June	38	11.98 b	140.03 a	46.05 a
(Intense dry)	51	10.54 c	92.81 b	31.37 b

Different letters mean statistically significant differences ($p < 0.05$, Tukey). For this analysis, the lunar luminosity level covered new moon to the crescent. Difference of Maximum Ambient Temperature-Average Minimum Temperature (DTAMMP), Pluvial Precipitation (PP) and Lunar Luminosity Level (NLL).

5. Discussion

The results of this study show that sheep mortality is influenced by a complex combination of environmental, physiological and ethological factors, which coincides with the findings of other authors and provides novel elements for the analysis of health risks in extensive production systems. Sánchez Mendoza *et al.* (2020) [13] point out that climate change alters, directly or indirectly, the distribution and incidence of a wide range of diseases. However, the complexity of the host-pathogen relationship, added to its interaction with environmental factors, makes it difficult to accurately predict the appearance or modification of these diseases. Cheng *et al.* (2022) [14] note that climate change directly affects the thermoregulation, metabolism, immune function and productivity of livestock, and indirectly impacts the availability of food and water, as well as the dynamics of pest and pathogen populations. Along the same lines, Sharma *et al.* (2024) [15] warn that climate change constitutes one of the main threats to the sustainability of livestock systems. The direct effects are related to alterations in environmental conditions -such as temperature, relative humidity, precipitation, droughts and floods-, which translate into thermal stress and reproductive problems. Indirect effects, on the other hand, are manifested in the increase of infectious, vector and parasitic diseases.

One of the most relevant causes identified in this work was attacks by predators, which represented 38.83% of the recorded deaths. This finding coincides with what was reported by Murguía and Rojas (2019) [10], who pointed out that domestic or feral dogs act out of hunting instinct rather than food need, generating significant losses by attacking in groups and causing multiple deaths in a single event. This pattern coincides with what was observed in the present study, especially in phases of low lunar luminosity (new moon to crescent), when visibility decreases and attacks become more frequent. Contrary to the belief that attacks are concentrated only at night, Perez (2002) [16] documents and this study indirectly supports that they can occur at any time of the day, being characteristic for producing multiple wounds and high mortality, without consumption of the carcass.

As for respiratory and digestive diseases, it was found that these causes intensified during conditions of high rainfall and extreme temperatures, particularly in young animals and calves. This behavior coincides with that reported by Nava *et al.* (2006) [7], who also documented an increase in sheep mortality during the rainy season, especially in suckling calves. However, unlike their report, in the present study the highest total mortality occurred in the first quarter of the year (January-March), a period characterized by low temperatures, onset of drought and scarcity of forage, suggesting that not only humidity, but also cold stress and food limitation, have a decisive influence on mortality.

The impact of thermal stress was also evident when analyzing the difference between maximum and minimum ambient temperature (DTAMMP). Throughout the years evaluated, a sustained increase in this variable was observed, exceeding 12˚C in recent years, suggesting a trend towards more extreme climatic conditions. In this sense, González (2020) [17] emphasizes that heat stress affects metabolic, digestive, reproductive and production functions in ruminants, reducing productive efficiency and increasing the risk of disease. This effect is accentuated in conditions of nutritional imbalance, as occurs during intense dry.

The effects of climate change are also reflected in the findings of this study. As pointed out by Blanco *et al.* (2020) [2], the increase in global temperature and altered precipitation patterns are directly and indirectly impacting livestock production systems. In this case, they are manifested in the decrease of available forage, greater exposure to pathogens and more challenging environmental conditions, especially for young animals and calves, the most susceptible to adverse conditions. The low lunar luminosity recorded in some quarters is also associated with an increase in the frequency of attacks by predators, which reinforces the idea that climatic and astronomical variables interact in a relevant way in the dynamics of herd mortality.

On the other hand, although Molina (2010) [18] maintains that ruminants have a wide thermal tolerance and that moderate thermal changes do not significantly affect production, the data from the present study indicate that, under extreme temperature changes combined with forage deficit and high humidity, mortality levels do increase. This suggests that this is not just an isolated factor, but the cumulative and interactive effect of several environmental factors, which exceed the physiological thresholds of sheep adaptation.

In summary, the results of this study provide evidence that sheep mortality does not respond to a single cause, but is conditioned by interrelated multi-causal factors, including climate, light, nutrition, heat stress and predator pressure. This knowledge is key to establishing more precise management strategies and preventing losses, especially under climate change scenarios that tend to exacerbate these conditions.

6. Conclusions

1) The results obtained show that sheep mortality is closely related to the interaction between climatic and light factors. A greater activity of predators was identified under conditions of extreme environmental temperature, low rainfall and low level of lunar luminosity. Likewise, respiratory and digestive diseases increased their incidence when extreme temperatures were combined with increased precipitation.

2) In the case of offspring, mortality was higher when very extreme temperatures coexisted with intense rainfall, while in other age categories, mortality was associated with extreme temperatures and moderate rainfall. Throughout the years evaluated, a progressive increase in the number of dead sheep was observed as the difference between the average maximum and minimum environmental temperature widened and precipitation decreased.

3) Finally, the first quarter of the year proved to be the most critical, with high mortality rates associated with very extreme temperatures, low precipitation and high lunar luminosity. Similarly, the last quarter showed high mortality under conditions of low temperature extremes, high precipitation and very low levels of lunar luminosity. These findings allow a more comprehensive understanding of the environmental factors that influence sheep mortality, which is essential to establish preventive and management strategies adapted to different climatic scenarios.

Conflicts of Interest

The authors declare no conflicts of interest.

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