e-ISSN:2706-6800
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Automatic livestock monitoring to identify abnormal behavior on the Balcashi ranch, Chimborazo Province

Monitoreo automático de ganado para identificar comportamientos anormales en la hacienda balcashi Provincia del Chimborazo

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Published
Edwards Deming Higher Technological Institute. Quito - Ecuador

Periodicity
October - December
Vol. 1, No. 27, 2025
pp. 1-9
http://centrosuragraria.com/index.php/revista

Dates of receipt
Received: April 12, 2025
Approved: June 30, 2025

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Abstract: Livestock farming, an essential economic pillar in rural areas, faces growing challenges in the early detection of abnormal behavior in cattle, such as lameness or isolation, which affect their welfare and productivity. This study presents an automated monitoring system implemented at Hacienda Balcashi (Chimborazo, Ecuador), which integrates environmental sensors for temperature, humidity, precipitation, and movement with machine learning algorithms. Based on the analysis of historical data from 2019–2024, a significant correlation was found between temperature ($r = 0.45$, $p < 0.01$), humidity ($r = 0.32$, $p < 0.05$), and the occurrence of abnormal behaviors. Notable differences were identified between breeds, with Holstein being the most vulnerable (1.2 events/day), followed by Jersey (0.8) and Criollo (0.5), highlighting the influence of climate adaptability. The logistic regression model achieved an accuracy of 82% and an AUC-ROC of 0.84. This work contributes to precision livestock farming in high Andean contexts, proposing a replicable approach that optimizes animal welfare and operational efficiency and can be scaled up through regional adjustments.

Keywords: Precision livestock farming, machine learning, animal welfare, heat stress.

Resumen: La ganadería, pilar económico esencial en zonas rurales, enfrenta retos crecientes para detectar de forma temprana comportamientos anómalos en el ganado, como cojera o aislamiento, que afectan su bienestar y productividad. Este estudio presenta un sistema automatizado de monitoreo implementado en la Hacienda Balcashi (Chimborazo, Ecuador), que integra sensores ambientales de temperatura, humedad, precipitación y de movimiento con algoritmos de aprendizaje automático. A partir del análisis de datos históricos 2019–2024, se evidenció una correlación significativa entre temperatura ($r = 0.45$, $p < 0.01$), humedad ($r = 0.32$, $p < 0.05$) y la ocurrencia de conductas anormales. Se identificaron diferencias notables entre razas, siendo la Holstein la más vulnerable (1.2 eventos/día), seguida de Jersey (0.8) y Criollo (0.5), lo cual resalta la influencia de la adaptabilidad climática. El modelo de regresión logística alcanzó una precisión del 82% y un AUC-ROC de 0.84. Este trabajo contribuye a la ganadería de precisión en contextos altoandinos, proponiendo un enfoque replicable que optimiza el bienestar animal y la eficiencia operativa, y que puede escalarse mediante ajustes regionales.

Palabras clave: Ganadería de precisión, aprendizaje automático, bienestar animal, estrés térmico.

Introduction

Livestock farming is one of the main economic activities globally, playing an essential role in food security, job creation, and the development of rural economies (Santana et al., 2025). In particular, cattle farming faces various challenges, including the early detection of abnormal behaviors that could indicate health, welfare, or productivity problems. Behaviors such as lameness, social isolation, or irregular feeding patterns can be signs of disease, pain, or stress conditions, and their timely identification is key to mitigating risks, reducing economic losses, and improving animal welfare (Senanayake et al., 2024; Kaur & Virk, 2025).

Traditionally, livestock monitoring has been based on direct observation by field workers or veterinarians, which introduces factors of subjectivity, human fatigue, and lack of continuity, especially in geographically complex environments such as the Ecuadorian Sierra. The Balcashi Ranch, located in the province of Chimborazo (Ecuador), represents a typical scenario of these limitations, where the Andean

e-ISSN:2706-6800

climate, extensive grazing conditions, and the racial diversity of livestock make it difficult to implement traditional health and production control systems.

Faced with this problem, the incorporation of emerging technologies has opened up new possibilities for transforming traditional livestock farming into more intelligent and sustainable systems. Among these technologies are environmental and motion sensors, the Internet of Things (IoT), and, in particular, artificial intelligence (AI) techniques, which allow large volumes of data to be analyzed in real time to detect patterns and anomalies (Wang et al., 2023; Farooq et al., 2022; Khan et al., 2024).

Several recent studies have demonstrated the effectiveness of machine learning in classifying normal and abnormal behavior in cattle based on data collected by inertial sensors, accelerometers, and smart collars (Russel & Selvaraj, 2024; Guarda-Vera & Muñoz-Poblete, 2025). For example, Hollevoet et al. (2024) were able to identify stress and disease behaviors in goats by analyzing accelerometer data, and Tian et al. (2024) developed a predictive system for mastitis in dairy cows by integrating data on rumination, milk production, and electrical conductivity. These applications highlight the potential of AI to reduce dependence on human monitoring and optimize decision-making.

This research proposes the design and implementation of an automated monitoring system adapted to the conditions of Hacienda Balcashi, integrating climate sensors for temperature, humidity, precipitation, and behavior sensors such as accelerometers with machine learning algorithms. It starts with the analysis of historical data collected between 2019 and 2024, and applies a quantitative, h y methodology to evaluate the relationship between climate variables, animal breed, and the frequency of abnormal behaviors.

This work is distinguished by its contextualized approach to high-altitude livestock farming and its potential scalability to other farms with similar characteristics. In addition, it provides a methodological basis that can be expanded in future studies to include elements such as audio sensors (Gavojdian et al., 2024), blockchain for traceability (Mansour, 2022), or advanced IoT systems (Kaur & Virk, 2025). This contributes to closing the technological gap in rural regions and promotes more efficient, ethical, and climate-resilient livestock farming.

Methodology

This research adopts a quantitative, observational, and analytical approach designed to understand the relationship between climate variables, individual livestock characteristics, and the manifestation of abnormal behaviors. The study was conducted at Hacienda Balcashi, located in the province of Chimborazo (Ecuador), based on a set of historical data collected between 2019 and 2024.

The main database was an Excel file ("Balcashi_Livestock_2019-2024.xlsx"), containing daily records of climatic variables such as temperature °C, relative humidity %, precipitation mm, and livestock behavior, where behaviors are coded as "normal" if they are grazing or resting and "abnormal" if they are lame or isolated. Each record includes individual animal identification, breed (Criollo, Jersey, Holstein), date, and location.

The independent variables were temperature, humidity, precipitation, and breed. The main dependent variable was the type of behavior (normal or abnormal), and secondarily, the specific type of abnormality detected.

Procedure and data preprocessing

A retrospective longitudinal analysis methodology was applied, considering repeated measurements per animal over time. Preprocessing included data cleaning by removing duplicates and re ting missing values, detecting outliers using the interquartile range (IQR), coding categorical variables, and normalizing numerical variables.

Statistical modeling and validation

Statistical analysis began with an Exploratory Data Analysis (EDA) to identify preliminary patterns and relationships between variables. Subsequently, Pearson and Spearman correlation tests were used to evaluate the association between climate variables and the frequency of abnormal behaviors.

Logistic regression was applied for predictive modeling, training the model with 70% of the data and validating it with the remaining 30%. Evaluation metrics included accuracy, precision, recall, and area under the ROC curve (AUC). Additionally, mixed models (random effects)

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were used to control for individual variability per animal, and ANOVA was used to evaluate differences by breed.

Infrastructure and tools

Data analysis was performed in Python (v3.9), using libraries such as Pandas, NumPy, Scikit-learn, and Statsmodels. Data were visualized with Matplotlib and Seaborn. Jupyter Notebook was used as the development environment.

Ethical considerations

Although this is a retrospective study based on existing data, the confidentiality of the information and the welfare of the animals were guaranteed. Field observations were made without altering the animals' routines or inducing stressful situations.

Results

Relationship between climatic variables and abnormal behavior

Correlation between climatic variables and abnormal behaviors

To assess the relationship between climatic conditions and abnormal livestock behavior, data on climatic and behavioral variables recorded between 2019 and 2024 were extracted and normalized. Pearson's correlation coefficient was used to quantify the associations between the variables.

Table 1: *Correlation between climate variables and abnormal behavior*

Variable	Coefficient (r)	p-value
Temperature	0.45	<0.01
Humidity	0.32	<0.05
Precipitation	0.12	>0.1

The results indicated a moderate positive correlation between temperature and the frequency of abnormal behaviors ($r = 0.45$, $p < 0.01$), and a smaller but significant association with humidity ($r = 0.32$, $p < 0.05$). Precipitation was not significantly correlated ($r = 0.12$, $p > 0.1$), suggesting that heat stress plays a more important role than rainfall in this context. This implies that rising temperatures, possibly associated with climate change, could become a key trigger of animal distress at high altitudes.

Frequency of abnormal behavior by breed

To determine whether there are differences in susceptibility to abnormal behavior between breeds, the data were grouped by breed and a one-factor ANOVA was applied. In addition, mixed models were used to control for individual variability of each animal in repeated measurements.

Table 2: *Frequency of abnormal behaviors by breed*

Breed	Mean (events/day)	Standard deviation
Holstein	1.2	0.3
Jersey	0.8	0.2
Creole	0.5	0.1

The analysis revealed statistically significant differences ($F(2,147) = 5.67$, $p < 0.01$). The Holstein breed had the highest incidence of abnormalities (1.2 events/day), followed by Jersey (0.8) and Criollo (0.5). This difference can be interpreted from the perspective of environmental adaptability: foreign breeds such as Holstein, developed in temperate climates, tend to show greater physiological sensitivity to heat stress and altitude hypoxia. The lower level of events in Criollo reinforces their adaptive genetic value, opening the discussion on their inclusion in resilient genetic improvement programs.

Logistic regression model performance

A logistic regression model was trained with 70% of the dataset to predict the occurrence of abnormal behaviors based on climatic variables and breed. Validation was performed with the remaining 30%.

Table 3: *Classification model metrics*

Metric	Value (%)	Confidence interval (95%)
Accuracy	82	79-85
Precision	78	74-81
Recall	75	71-79
AUC-ROC	0.84	0.81-0.87

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The model achieved an accuracy of 82%, a precision of 78%, a recall of 75%, and an AUC-ROC of 0.84. This performance validates its applicability in real-world scenarios with a low margin of error, allowing corrective decisions to be made before severe clinical or economic consequences occur.

In terms of robustness, it is in line with studies such as that by Russel & Selvaraj (2024). However, effectiveness will also depend on the operating threshold and the frequency of retraining in changing environments, which should be considered for large-scale implementation.

The findings show that climate variables and breed are significant predictors of abnormal behavior in Balcashi cattle. The proposed model offers a viable tool for early detection, although its scalability requires adjustments for other regions, as suggested by Farooq et al. (2022).

Conclusions

The authors showed that it was possible to implement an automatic monitoring system for abnormal behavior in cattle at the Balcashi Ranch, including climate variables and characteristics of the cattle themselves. The findings indicated that temperature and humidity had a significant relationship with the emergence of anomalies (r = 0.45 and r = 0.32), which corroborates the literature on heat stress and its effect on animal welfare (Senanayake et al., 2024; Kaur & Virk, 2025). They also found notable differences between breeds, with Holstein showing greater susceptibility to abnormal behavior (1.2 events/day), followed by Jersey (0.8) and Criollo (0.5), which highlights the adaptive importance of climate (Gavojdian et al., 2024; Qiao et al., 2021).

The performance of the logistic regression model was robust, with an accuracy of 82% and an AUC-ROC of 0.84, confirming its effectiveness for early detection of injuries or functional anatomical problems. Its performance, although lower than that reported by Wang et al. (2023), could be explained by the wide variety of conditions present in the Ecuadorian highlands. The incorporation of environmental sensors and accelerometers together with automatic learning methods is in line with the latest global advances in precision livestock farming (Santana et al., 2025; Russel & Selvaraj, 2024).

This work provides a scalable methodological framework for high Andean farms, promoting animal welfare and sustainability, although its implementation requires local adaptations, as noted by Farooq et al. (2022). The automation of livestock monitoring represents a key step toward more efficient and ethical production.

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