Predicting Methane Emissions from Dairy Cows Using Machine Learning

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Abstract

Methane emissions from dairy cows are a major contributor to agricultural greenhouse gas emissions. Developing accurate and efficient methods to predict methane emissions from dairy cows is essential to develop mitigation strategies. Machine learning (ML) models offer a promising approach to this challenge, as they can learn complex relationships between methane emissions and a variety of indicators, such as milk production, feed intake, and environmental conditions. In this study, we propose to use ML models to predict methane emissions from dairy cows at Gladbacherhof, an organically managed research farm of Justus Liebig University Giessen, located in Villmar, Germany. The primary focus is not only on accurate predictions but also on identifying key indicators that influence methane production. This aims to inform cost-effective measurement strategies and facilitate the development of targeted mitigation approaches, aligning with the financial interests of farmers.

Introduction

Livestock production stands as the foremost contributor to greenhouse gas emissions within the global agricultural sector. Methane emissions from the livestock sector alone account for a significant 18% of global greenhouse gas levels. Hence, the projections of methane emissions is key to provide insights into regulating the mechanism of greenhouse gas emissions. Various indicators about production performance, animal physiology, and environmental conditions, affect methane emissions of dairy cows. To develop effective mitigation strategies, it is essential to identify precise indicators that are more informative for an accurate and efficient predictive model. ML models offer a promising approach to predict methane emissions from dairy cows. Such models can learn complex relationships between methane emissions and a variety of indicators.

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Within this context, we propose to employ ML models to predict methane emissions from dairy cows at Gladbacherhof, an organically managed research farm of Justus Liebig University Giessen, located in Villmar, Germany. The primary focus is not only on accurate predictions but also on the practical benefits for farmers and the contribution to organic farming sustainability by identifying crucial indicators influencing methane production.

Methods

Data on a comprehensive set of indicators such as milk yield, fat and protein content, lactation stage, cow age, weight, feed intake, feeding time, energy intake, air temperature, relative humidity, and air pressure, are initially collected from multiple sources, including methane detector, automated milking systems, and a climate station. The collected data is then preprocessed to ensure it is clean and in a format suitable for ML modeling. Following preprocessing, sensitivity analysis and feature selection are employed to identify the indicators that exert the most influence on methane emissions. Random forest algorithm is utilized for this purpose. Once the most important factors are identified, ML models are developed to predict methane emissions. Various ML algorithms, including Long Short Term Memory (LSTM), Convolutional Neural Network (CNN), and hybrid network of CNN-LSTM, are deployed due to their capability to learn complex relationships. The hyperparameters of the ML models are optimized using Bayesian optimization, an effective global optimization algorithm well-suited for ML model optimization.

Results and Discussion

Analyzing over 6 million data points, preliminary results show promise in simulating methane emissions through ML approaches. A major workload is the development of algorithms for data preprocessing and for data gap filling. Our meticulous data preparation and rigorous feature selection process set the stage for robust machine learning model development. Preliminary results indicate that feed intake, cow weight, cow age, and lactation days are promising indicators for the prediction of methane emissions. However, final results are pending due to the need of further model refinement.

Conclusion

This study addresses a critical environmental concern by focusing on methane emissions from organic dairy farming. By employing advanced ML techniques and leveraging state-of-the-art data collection methods, we aim to develop predictive models that will not only enhance measurement accuracy but also inform cost-effective mitigation strategies. As our research progresses, we anticipate valuable insights that can significantly contribute to the global effort in reducing greenhouse gas emissions from livestock production.

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