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Artificial Intelligence-Driven Decision Support System for Dairy Farm Operations: Findings from a Pilot Study

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Abstract
This study is a preliminary exploration carried out within a Ph.D. Research project, focusing on creating an Intelligent Decision Support System (IDSS) to help improve the management of dairy farms in the Pune area. A survey was given to 50 dairy farmers to find out about their farming practices, how familiar they are with technology, the difficulties they face in running their farms, and how ready they are to use AI tools for making decisions. A reliability check using Cronbach's Alpha showed an overall score of 0.96, which means the results are very consistent internally. The Shapiro–Wilk test for normality showed that the data followed a normal distribution since the p-value was greater than 0.05. The pilot study showed that the research tool works well and is practical. It also showed that using Artificial Intelligence and Machine Learning methods like Random Forest, Decision Tree, Logistic Regression, and K-Means Clustering could be useful for improving dairy farms. The results show that the questionnaire works well for gathering data on a big scale and can help in creating an AI-based system to support decision-making in dairy farming, which can boost productivity, profits, and sustainability.

Keywords: *Intelligent Decision Support System, Dairy Farming, Artificial Intelligence, Machine Learning, Pilot Study, Random Forest, Decision Tree.*

1. Introduction
The dairy industry plays an important role in India's farming economy, helping to ensure food supply, provide jobs in rural areas, and support the income of many farmers. India is the biggest producer of milk in the world and has seen a lot of growth in its dairy industry. But even with this growth, dairy farmers still deal with many problems like taking care of their animals' health, making sure they get the best food, preventing diseases, managing resources wisely, and dealing with changing costs of production. In the Pune area of Maharashtra, dairy farming is a key part of the local economy, but many farms still use old methods and make decisions by hand. These usual ways often lead to using resources not well, finding health problems late, and having milk production that isn't the same every time. Recent improvements in Artificial Intelligence (AI), Machine Learning (ML), data analysis, and the Internet of Things (IoT) have opened up new possibilities for turning traditional dairy farming into smart, data-based farming systems. Smart technologies can look at a lot of farm information, guess what might happen next, and give farmer's good advice at the right time. This helps them make their farms work better, save money, take better care of animals, and follow eco-friendly ways of making dairy products. An Intelligent Decision Support System uses smart technology, predictions based on data, and expert knowledge to help farmers make better choices about managing their animals, what to feed them, how to prevent illness, how much milk they can expect, and how to use their resources efficiently. To make this system work well, you need

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a dependable tool for research and a good plan for collecting data. So, this study is a preliminary investigation that's part of a larger Ph.D. Research project called "Design and Advancement of an Intelligent Decision Support System for Optimization of Dairy Farm Operations in the Pune Region." The pilot study included 50 participants to check if the questionnaire works well, make sure it's reliable and accurate, and find out where it needs to be improved before collecting data from a bigger group. The results showed very strong agreement among the questions (Cronbach's Alpha = 0.96) and good spread of the answers, which means the questionnaire is ready to be used in more studies. The study also talks about using statistical analysis and machine learning methods like Random Forest, Decision Tree, Logistic Regression, and K-Means Clustering to create an AI-based system that can help improve productivity, profit, and sustainability in dairy farming. [1] [2]

2. Literature Review

The dairy industry plays an important role in India's farming economy, helping to ensure food supply, provide jobs in rural areas, and support the income of many farmers. India is the biggest producer of milk in the world and has seen a lot of growth in its dairy industry. But even with this growth, dairy farmers still deal with many problems like taking care of their animals' health, making sure they get the best food, preventing diseases, managing resources wisely, and dealing with changing costs of production. In the Pune area of Maharashtra, dairy farming is a key part of the local economy, but many farms still use old methods and make decisions by hand. These usual ways often lead to using resources not well, finding health problems late, and having milk production that isn't the same every time. Recent improvements in Artificial Intelligence (AI), Machine Learning (ML), data analysis, and the Internet of Things (IoT) have opened up new possibilities for turning traditional dairy farming into smart, data-based farming systems. Smart technologies can look at a lot of farm information, guess what might happen next, and give farmers good advice at the right time. This helps them make their farms work better, save money, take better care of animals, and follow eco-friendly ways of making dairy products. An Intelligent Decision Support System uses smart technology, predictions based on data, and expert knowledge to help farmers make better choices about managing their animals, what to feed them, how to prevent illness, how much milk they can expect, and how to use their resources efficiently. To make this system work well, you need a dependable tool for research and a good plan for collecting data. So, this study is a preliminary investigation that's part of a larger Ph.D. Research project called "Design and Advancement of an Intelligent Decision Support System for Optimization of Dairy Farm Operations in the Pune Region." The pilot study included 50 participants to check if the questionnaire works well, make sure it's reliable and accurate, and find out where it needs to be improved before collecting data from a bigger group. The results showed very strong agreement among the questions (Cronbach's Alpha = 0.96) and good spread of the answers, which means the questionnaire is ready to be used in more studies. The study also talks about using statistical analysis and machine learning methods like Random Forest, Decision Tree, Logistic Regression, and K-Means Clustering to create an AI-based system that can help improve productivity, profit, and sustainability in dairy farming. [3] [4]

3. Objectives

- To assess existing dairy farm operations in the Pune region.
- To develop an AI-based Intelligent Decision Support System (IDSS).
- To optimize herd management, feed utilization, and resource allocation.
- To improve dairy farm productivity and sustainability.

4. Research Methodology

This study adopted a quantitative research design to develop and validate an Intelligent Decision Support System (IDSS) for optimizing dairy farm operations in the Pune region. The target population comprised dairy farms, cattle farms, and goshalas in Pune, Maharashtra, with an estimated population of 319,839 livestock based on official livestock

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statistics. Using a 95% confidence level and a 5% margin of error, the required sample size was calculated to be 385 respondents. Before conducting the full-scale survey, a pilot study involving 50 respondents was carried out to assess the feasibility, reliability, and validity of the research instrument. A simple random sampling technique was employed to ensure unbiased selection of participants and improve the representativeness of the sample. Data were collected using a structured questionnaire consisting of demographic questions, Likert-scale items, categorical responses, numerical data, and binary (Yes/No) questions related to dairy farm operations, technology adoption, and Intelligent Decision Support Systems. The collected data were analyzed using statistical techniques such as descriptive statistics, reliability analysis (Cronbach's Alpha), normality testing (Shapiro–Wilk), correlation analysis, Chi-square test, and regression analysis. In addition, machine learning algorithms including Random Forest, Decision Tree, Logistic Regression, and K-Means Clustering were implemented using Python libraries such as Pandas, NumPy, Scikit-learn, SciPy, Matplotlib, and Statsmodels to support predictive analysis and the development of the proposed AI-based IDSS. [5] [6] [7]

5. Reliability

Cronbach's Alpha was used to check how consistent and reliable the questions in the pilot study questionnaire were. The questionnaire had three main parts: Dairy Farm Information, Operational Practices, and IDSS Awareness. The reliability scores for each section and the whole questionnaire are shown in Table 1.

Table 1 Reliability Analysis Using Cronbach's Alpha

Section	Cronbach's Alpha
Dairy Farm Information	0.841
Operational Practices	0.801
IDSS Awareness	0.936
Overall Questionnaire	0.960

The results show that every part of the questionnaire had Cronbach's Alpha scores above 0.80, which means the questions in each section are consistent and reliable. The Cronbach's Alpha score of 0.960 shows very high reliability, meaning the questions in the questionnaire consistently measure what they are meant to. So, none of the questions needed to be changed or taken out, and the tool was thought to be good enough for collecting lots of data.

6. Normality Analysis

The Shapiro–Wilk test was used to check if the data from the pilot study followed a normal distribution, and this test is suitable for datasets that have less than 50 observations. The goal of this test was to check if the data we collected followed a normal distribution, which would help us use parametric statistical methods in our further analysis. The Shapiro-Wilk test gave a statistic of 0.9721 and a p-value of 0.5976, which is higher than the 0.05 significance level. So, we can't reject the idea that the data follows a normal distribution, which means the data is normally distributed. These results show that the data from the pilot study can be used for statistical methods like correlation, regression, and other techniques that help make conclusions in later parts of the research.

7. Pilot Study Findings

The pilot study confirmed the effectiveness and suitability of the research instrument for the proposed study. The questionnaire was easily understood by the respondents, and no significant difficulties were encountered during data collection. Reliability analysis demonstrated high internal consistency across all questionnaire sections, indicating that the items effectively measured the intended constructs. Since all reliability values exceeded the acceptable threshold, no questionnaire items required deletion or modification. Furthermore, the responses revealed a positive level of awareness and willingness among dairy farmers to adopt technology-based solutions for improving farm management. Overall, the pilot study validated the feasibility of the research methodology

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and confirmed that the questionnaire is appropriate for conducting a large-scale survey.

8. Proposed IDSS Framework

The proposed Intelligent Decision Support System (IDSS) is designed to assist dairy farmers in making data-driven decisions for improving farm operations. The framework begins with the collection of input data related to farm profile, herd management, feed practices, milk production, animal health, and resource utilization. The collected data are then subjected to data cleaning and pre-processing to ensure accuracy and consistency before analysis. Machine learning algorithms, including Random Forest, Decision Tree, Logistic Regression, and K-Means Clustering, are applied to analyse the processed data and generate predictive insights. Based on the analytical results, the system produces recommendations through a recommendation engine, which are finally presented to farmers using a user-friendly decision support dashboard. This framework aims to provide timely, accurate, and practical recommendations for improving productivity, profitability, and sustainability in dairy farming. [8]

9. Proposed Data Analysis

The collected data will be analysed using a combination of statistical methods and machine learning techniques to achieve the research objectives. K-Means Clustering will be employed to classify dairy farms according to their operational characteristics and identify opportunities for improvement. Random Forest Regression will be used to predict milk production based on factors such as herd management, feed utilization, and resource allocation. Logistic Regression will assess the acceptance and effectiveness of the proposed Intelligent Decision Support System among dairy farmers. In addition, Decision Tree algorithms will generate simple and interpretable recommendation rules that assist farmers in making informed decisions related to herd management, feed optimization, disease prevention, and efficient resource utilization.

10. Expected Outcomes

The proposed Intelligent Decision Support System is expected to improve dairy farm management by providing accurate, data-driven recommendations for farmers. The system is anticipated to enhance milk production through better herd management and optimized feeding practices while supporting the early prediction of animal health issues. It is also expected to improve resource utilization, reduce operational costs, and increase overall farm profitability. By integrating Artificial Intelligence and Machine Learning techniques into dairy farm management, the proposed system aims to promote sustainable farming practices, improve decision-making efficiency, and contribute to the long-term growth of the dairy sector.

Conclusion

The pilot study successfully validated the research instrument developed for the proposed Intelligent Decision Support System (IDSS) for dairy farm optimization. The reliability and normality analyses confirmed that the questionnaire is statistically sound and suitable for large-scale data collection. The proposed AI-based framework, supported by machine learning algorithms such as Random Forest, Decision Tree, Logistic Regression, and K-Means Clustering, provides a strong foundation for developing an effective decision support system. The implementation of this system is expected to assist dairy farmers in improving productivity, optimizing resource utilization, reducing operational costs, enhancing animal health management, and promoting sustainable dairy farming practices in the Pune region.

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