A Deep Learning Enabled Agricultural Decision Support System for Sustainable Farming

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Abstract— Agricultural productivity is highly influenced by variations in soil characteristics, climatic conditions, and market dynamics, making crop selection a challenging task for farmers. Traditional decision-making methods often depend on personal experience, which may not always produce optimal outcomes under changing environmental conditions. This work presents an intelligent decision support framework that combines machine learning and deep learning techniques to assist farmers in selecting suitable crops while estimating expected yield and future market prices. The proposed framework processes agricultural datasets containing soil nutrients, seasonal information, weather parameters, and soil properties through data cleaning, feature preparation, and training procedures before generating predictions. A Random Forest model is employed to identify the most appropriate crops for a given set of agricultural conditions, whereas a Long Short-Term Memory (LSTM) network is utilized to estimate future crop prices based on historical trends. The platform further integrates user registration, secure authentication, dataset management, and an interactive recommendation interface that allows users to obtain crop suggestions using either complete soil parameters or limited input values. In addition, the system provides location-based seed purchase information to help farmers identify nearby markets offering the recommended crop varieties. Experimental observations indicate that the proposed framework delivers reliable recommendations by integrating crop suitability analysis, yield estimation, and price forecasting within a unified environment. The developed platform serves as a practical decision-support solution that enables informed agricultural planning, reduces resource wastage, and supports sustainable farming practices through data-driven recommendations.

Keywords— Precision agriculture, crop recommendation, crop yield prediction, crop price forecasting, Random Forest, Long Short-Term Memory (LSTM), machine learning, deep learning, predictive analytics, soil nutrient analysis, weather-based crop selection, agricultural decision support, smart farming, sustainable agriculture, seed purchase assistance.

I.INTRODUCTION

Agriculture remains one of the most significant contributors to economic growth and food security, yet crop production is continuously affected by changing weather patterns, soil conditions, nutrient availability, and market fluctuations. Farmers often rely on traditional knowledge or previous cultivation practices when selecting crops, which may not always produce favorable results under varying environmental conditions. The increasing availability of agricultural data and advancements in intelligent computing have created opportunities to support farming decisions through data-driven prediction models [7]. These technological developments are transforming conventional farming into a knowledge-driven process by enabling accurate analysis of agricultural information for improved crop management and resource utilization [8].

Recent developments in machine learning have enabled the analysis of large agricultural datasets to identify meaningful relationships between soil properties, climatic factors, and crop performance. Predictive techniques assist in recommending crops that are suitable for specific environmental conditions while also estimating expected productivity and future market trends [5]. Such information allows farmers to optimize land utilization, reduce unnecessary input costs, and improve profitability through informed decision-making. The application of intelligent learning algorithms has significantly enhanced the reliability of agricultural forecasting and precision farming practices [6].

Although several agricultural advisory systems provide crop recommendations or weather information, most existing solutions focus on individual services and do not integrate crop selection, yield estimation, price forecasting, and seed availability into a unified platform [1]. The absence of a comprehensive decision-support framework limits the practical usefulness of these applications, particularly for farmers seeking complete guidance before cultivation. Developing an integrated platform capable of combining multiple agricultural services can substantially improve farming efficiency and support sustainable agricultural management [4].

The proposed framework addresses these limitations by combining machine learning and deep learning techniques within a single intelligent platform. A Random Forest model is employed to identify suitable crops using soil nutrients, seasonal conditions, and environmental parameters, while a Long Short-Term Memory (LSTM) network predicts future crop prices from historical data [5]. The platform further incorporates secure user authentication, dataset processing, interactive crop recommendation, yield estimation, and seed purchase information to support end-to-end agricultural planning. By integrating predictive analytics with practical farming services, the developed system provides a scalable and effective solution for improving crop selection, maximizing productivity, and promoting sustainable agricultural practices [7], [8].

II.RELATED WORK

X. Yang et al. (2021) presented "A Survey on Smart Agriculture: Development Modes, Technologies, and Security and Privacy Challenges" [1]. The authors provided a comprehensive review of recent developments in smart agriculture by examining the adoption of digital technologies across different stages of crop production. Their study discussed the contribution of wireless sensor networks, artificial intelligence, cloud computing, big data analytics, and Internet of Things (IoT) devices in improving farming operations. The survey also described various smart farming architectures that enable continuous monitoring of soil conditions, environmental parameters, and crop health through automated sensing systems. Besides technological advancements, the paper highlighted concerns related to data security, privacy protection, and communication reliability that may affect large-scale agricultural deployments. The authors concluded that future farming systems should combine intelligent decision-making with secure data management to improve productivity while ensuring dependable agricultural services under rapidly changing environmental and technological conditions.

M. Javaid, A. Haleem, I. H. Khan, and R. Suman (2023) presented "Understanding the Potential Applications of Artificial Intelligence in the Agriculture Sector" [2]. The paper explored how artificial intelligence is transforming conventional agricultural practices by supporting informed decision-making throughout the farming cycle. The authors discussed several AI-based applications, including crop recommendation, disease identification, irrigation scheduling, yield estimation, and quality assessment of agricultural products. They explained that intelligent algorithms are capable of processing large volumes of agricultural data collected from sensors, satellite imagery, and historical records to generate accurate predictions. The study further emphasized that AI can reduce unnecessary resource consumption while improving production efficiency and crop quality. According to the authors, integrating predictive models into farming activities enables timely intervention and minimizes losses caused by uncertain environmental conditions. Their findings demonstrated that artificial intelligence has become an essential technology for promoting sustainable agriculture and improving overall farm management practices.

M. Javaid, A. Haleem, R. P. Singh, and R. Suman (2022) presented "Enhancing Smart Farming Through the Applications of Agriculture 4.0 Technologies" [3]. The authors examined the influence of Agriculture 4.0 technologies on modern farming by describing the integration of machine learning, cloud computing, robotics, automation, Internet of Things devices, and big data analytics into agricultural environments. The study explained that these technologies enable continuous monitoring of crops, efficient utilization of fertilizers and water resources, and real-time analysis of farming conditions. The paper also discussed the importance of digital platforms that assist farmers in making better cultivation decisions based on accurate field information. Furthermore, the authors highlighted how automation minimizes manual effort while increasing operational efficiency and production quality. The research concluded that Agriculture 4.0 provides a strong technological foundation for sustainable farming by improving productivity, reducing operational costs, and supporting intelligent agricultural decision-support systems across different cultivation scenarios.

R. Tombe (2020) presented "Computer Vision for Smart Farming and Sustainable Agriculture" [4]. The study investigated the application of computer vision techniques for automating agricultural monitoring and improving precision farming practices. The author described how digital image processing can assist in identifying crop conditions, monitoring plant growth, and detecting abnormalities within agricultural fields without requiring extensive manual observation. The research explained that computer vision systems can process visual information collected through cameras and unmanned aerial vehicles to provide accurate field assessments. Such intelligent monitoring techniques enable farmers to identify problems at an early stage and implement corrective measures before crop productivity is significantly affected. The study also emphasized that integrating computer vision with artificial intelligence can improve the efficiency of agricultural management while reducing labor requirements. The proposed approach demonstrated the potential of image-based technologies for supporting sustainable farming through continuous observation and timely agricultural decision-making.

AlZubi and K. Galyna (2023) presented "Artificial Intelligence and Internet of Things for Sustainable Farming and Smart Agriculture" [5]. The authors discussed the combined use of artificial intelligence and Internet of Things technologies for developing intelligent agricultural systems capable of monitoring field conditions in real time. Their work explained how IoT sensors continuously collect information related to soil moisture, temperature, humidity, and environmental conditions, while artificial intelligence analyzes the collected data to generate useful recommendations for farmers. The study highlighted several agricultural applications, including precision irrigation, crop health monitoring, and resource optimization. The authors also described the role of automated decision-support systems in reducing water consumption, improving fertilizer management, and increasing overall crop productivity. The research concluded that integrating AI with IoT technologies creates an efficient farming environment that supports sustainable agricultural development, minimizes resource wastage, and enhances the accuracy of farm management decisions under diverse cultivation conditions.

III.DATASET DETAILS

The proposed intelligent agricultural recommendation system is developed using a publicly available Crop Recommendation Dataset, which contains structured agricultural records representing soil characteristics, climatic conditions, and crop categories. The dataset includes important parameters such as Nitrogen (N), Phosphorus (P), Potassium (K), temperature, humidity, soil pH, and rainfall, along with the corresponding crop label. These features describe the physical and chemical conditions of agricultural land and provide the necessary information for building predictive models that recommend suitable crops under different environmental conditions. Before model development, the dataset undergoes preprocessing to improve its quality and learning capability. Duplicate and inconsistent records are removed, while numerical attributes are normalized to maintain a common scale across all features. The processed data is then divided into 80% training data and 20% testing data, enabling the models to learn from historical observations and evaluate prediction performance on unseen samples.

The prepared dataset is utilized to train two predictive models within the proposed framework. A Random Forest classifier analyzes soil nutrients and environmental attributes to identify the most suitable crop for cultivation, whereas a Long Short-Term Memory (LSTM) network estimates future crop prices by learning historical market trends. The trained models are integrated into the application to provide crop recommendations, expected yield information, and price predictions through an interactive user interface. In addition, the system includes secure user authentication and a Seed Purchase Details module that assists farmers in locating seed suppliers for the recommended crops. By combining agricultural data analytics with machine learning and deep learning techniques, the dataset enables the development of an intelligent decision-support platform that improves crop planning, resource utilization, and sustainable farming practices.

IV.PROPOSED METHODOLOGY

The proposed framework presents an intelligent agricultural decision-support system that utilizes a Long Short-Term Memory (LSTM) network to forecast future crop prices using historical agricultural data. The objective of the framework is to assist farmers in making profitable cultivation decisions by providing reliable price predictions before harvesting. Since agricultural markets exhibit seasonal and time-dependent variations, the LSTM model is selected because of its ability to learn long-term sequential patterns from historical records. The developed application integrates secure user authentication, dataset processing, crop recommendation, crop price prediction, yield estimation, and seed purchase information within a unified web-based environment, enabling users to access multiple agricultural services through a single platform.

The methodology begins with collecting and preprocessing the agricultural dataset containing soil nutrients, environmental conditions, and historical crop information. During preprocessing, duplicate and inconsistent records are eliminated, while numerical features are normalized to improve model stability and learning efficiency. The prepared dataset is divided into 80% training data and 20% testing data, ensuring that the prediction model is evaluated using previously unseen samples. This preprocessing stage enhances data quality and enables effective model training.

The processed historical price data is then supplied to the LSTM network, where sequential information is learned through interconnected memory cells. Unlike conventional neural networks, the LSTM architecture employs input, forget, and output gates to retain important historical information while filtering irrelevant patterns. This mechanism enables the model to capture seasonal price fluctuations and long-term market behavior more effectively. During training, the network continuously updates its internal parameters through backpropagation to minimize prediction error and improve forecasting accuracy. Once training is completed, the optimized model generates future crop price predictions for the selected crop based on learned temporal relationships.

The trained LSTM model is integrated into the application interface, allowing users to obtain predicted crop prices along with crop recommendations, expected yield, and seed purchase details. By combining deep learning-based forecasting with practical agricultural support services, the proposed framework enables informed decision-making, improves cultivation planning, minimizes financial uncertainty, and promotes sustainable farming through accurate price prediction and data-driven agricultural management.

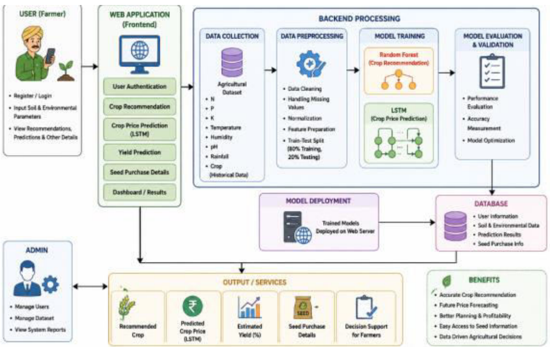


Figure 1: System Architecture of the Proposed LSTM-Based Intelligent Agricultural Prediction System

Figure 1 presents the architecture of the proposed intelligent agricultural prediction system developed for crop recommendation and crop price forecasting. The process begins with farmer registration and secure user authentication through the web application. After login, users provide soil nutrient values, environmental conditions, and cultivation parameters. The agricultural dataset is then preprocessed by performing data cleaning, normalization, feature preparation, and an 80:20 train-test split before model development. The processed data is supplied to the LSTM (Long Short-Term Memory) model, which learns historical crop price patterns and predicts future market prices. The prediction module is integrated with crop recommendation, yield estimation, and seed purchase information to assist farmers in planning cultivation activities. All user information, prediction results, and agricultural records are securely stored in the database. The administrative module manages datasets, users, and reports. By integrating data preprocessing, deep learning, and agricultural decision-support services into a unified framework, the proposed system provides accurate price forecasting, efficient crop planning, and supports sustainable farming practices.

V.RESULT AND DISCUSSION

The proposed LSTM-based intelligent agricultural prediction system was evaluated through the developed web application under different farming scenarios. The application successfully performed user registration, secure login, dataset preprocessing, crop recommendation, crop price prediction, yield estimation, and seed purchase information retrieval within a single integrated platform. During system execution, users entered soil nutrient values, seasonal information, and environmental parameters through an interactive interface. The agricultural dataset was preprocessed using data cleaning, normalization, and feature preparation techniques before training the prediction model. The Long Short-Term Memory (LSTM) network was trained using historical agricultural records, enabling it to learn temporal price variations and generate reliable future crop price forecasts. After training, the application accurately predicted crop prices while simultaneously presenting suitable crop recommendations and expected yield information based on the provided input values. The integrated seed purchase module further assisted users by displaying information about locations where recommended crop seeds could be obtained. All user information, agricultural records, prediction outputs, and application data were securely maintained within the MySQL database to ensure efficient data management and reliable system operation. Experimental observations indicate that the proposed framework effectively captures historical market trends and delivers consistent crop price predictions through the LSTM model. The integration of deep learning-based forecasting with crop recommendation, yield estimation, and seed purchase services provides a practical, scalable, and user-friendly agricultural decision-support system. The developed framework enables farmers to make informed cultivation and marketing decisions, optimize resource utilization, reduce financial uncertainty, and promote sustainable farming through accurate, data-driven agricultural planning

Figure 2: Model Training Results

The Train ML Models module displays the performance of the machine learning algorithms used in the proposed agricultural prediction system. After preprocessing the agricultural dataset and dividing it into training and testing sets, the models are trained using the prepared data. The interface presents the names of the trained algorithms along with their corresponding accuracy values. In this implementation, the Random Forest model is utilized for crop recommendation, while the Long Short-Term Memory (LSTM) model is employed for crop price prediction based on historical agricultural data. Displaying the model accuracy allows users to verify that the training process has been completed successfully before proceeding to the prediction stage. This module serves as an important validation step by confirming that the trained models are ready for deployment within the application. Once training is completed, the learned models are integrated with the crop recommendation and price prediction modules, enabling farmers to receive suitable crop suggestions and forecasted market prices through the web-based interface. The successful completion of this stage ensures reliable prediction performance and supports data-driven agricultural decision-making.

Figure 3: Crop Recommendation, Yield Estimation, and Crop Price Prediction Results

The figure illustrates the output generated by the proposed intelligent agricultural prediction system after processing the user-provided soil and environmental parameters. Based on the supplied input values, the application recommends the most suitable crops for cultivation and displays the corresponding predicted yield percentage along with the estimated future market price for each recommended crop. In the illustrated example, the system recommends Rice and Jute, indicating that Rice has a higher predicted yield than Jute under the given field conditions. Simultaneously, the application provides the forecasted market price for each crop, enabling farmers to compare both productivity and expected economic returns before making cultivation decisions. These predictions are generated using the trained machine learning models integrated into the application, where crop suitability is determined from agricultural parameters and future prices are estimated using the Long Short-Term Memory (LSTM) model. Presenting crop recommendation, yield estimation, and price forecasting within a single interface enables farmers to evaluate multiple cultivation alternatives efficiently. This integrated decision-support mechanism helps improve crop selection, optimize resource utilization, minimize financial risk, and support profitable and sustainable agricultural planning through data-driven recommendations.

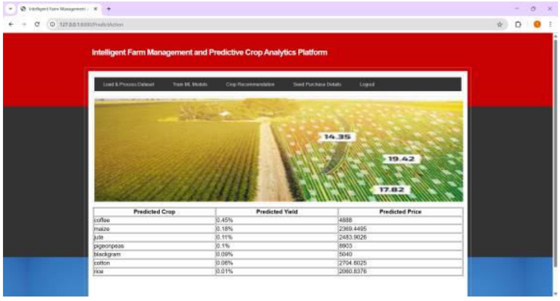
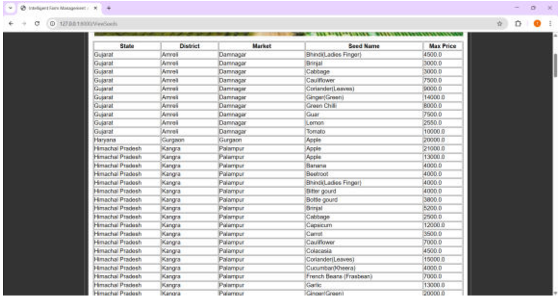


Figure 4: Multiple Crop Recommendation, Yield Estimation, and Price Prediction Results

The figure presents the prediction results generated by the proposed intelligent agricultural prediction system for the selected soil and environmental conditions. After processing the user-provided input parameters, the application recommends multiple crops that are suitable for cultivation and displays the corresponding predicted yield percentage and estimated future market price for each crop. In the illustrated example, the system suggests several crops, including Coffee, Pomegranate, Jute, Maize, Muskmelon, Cotton, and Rice, allowing farmers to compare different cultivation alternatives. Each recommended crop is accompanied by its expected yield and forecasted market price, enabling users to evaluate both agricultural productivity and potential economic returns before selecting a crop for cultivation. The future price estimates are generated using the trained Long Short-Term Memory (LSTM) model, which learns historical price trends to produce reliable market forecasts. Presenting multiple crop options within a single interface provides greater flexibility in decision-making, particularly when farmers consider factors such as soil suitability, expected income, and market demand. This integrated prediction module supports informed agricultural planning, efficient resource allocation, reduced cultivation risk, and improved farm profitability by combining crop recommendation, yield estimation, and price forecasting into a unified decision-support system.



State	District	Market	Seed Name	Max Price
Gujarat	Amreli	Damnagar	Bhindi(Ladies Finger)	4500.0
Gujarat	Amreli	Damnagar	Brinjal	3000.0
Gujarat	Amreli	Damnagar	Cabbage	3000.0
Gujarat	Amreli	Damnagar	Cauliflower	7500.0
Gujarat	Amreli	Damnagar	Coriander(Leaves)	9000.0
Gujarat	Amreli	Damnagar	Ginger(Green)	14000.0
Gujarat	Amreli	Damnagar	Green Chilli	8000.0
Gujarat	Amreli	Damnagar	Guar	7500.0
Gujarat	Amreli	Damnagar	Lemon	2550.0
Gujarat	Amreli	Damnagar	Tomato	10000.0
Haryana	Gurgaon	Gurgaon	Apple	20000.0
Himachal Pradesh	Kangra	Palampur	Apple	21000.0
Himachal Pradesh	Kangra	Palampur	Apple	13000.0
Himachal Pradesh	Kangra	Palampur	Banana	4000.0
Himachal Pradesh	Kangra	Palampur	Beetroot	4000.0
Himachal Pradesh	Kangra	Palampur	Bhindi(Ladies Finger)	4000.0
Himachal Pradesh	Kangra	Palampur	Bitter gourd	4000.0
Himachal Pradesh	Kangra	Palampur	Bottle gourd	3800.0
Himachal Pradesh	Kangra	Palampur	Brinjal	5200.0
Himachal Pradesh	Kangra	Palampur	Cabbage	2500.0
Himachal Pradesh	Kangra	Palampur	Capsicum	12000.0
Himachal Pradesh	Kangra	Palampur	Carrot	3500.0
Himachal Pradesh	Kangra	Palampur	Cauliflower	7000.0
Himachal Pradesh	Kangra	Palampur	Colacasia	4500.0
Himachal Pradesh	Kangra	Palampur	Coriander(Leaves)	15000.0
Himachal Pradesh	Kangra	Palampur	Cucumbar(Kheera)	4000.0
Himachal Pradesh	Kangra	Palampur	French Beans (Frasbean)	7000.0
Himachal Pradesh	Kangra	Palampur	Garlic	13000.0
Himachal Pradesh	Kangra	Palampur	Ginger(Green)	20000.0

Figure 5: Seed Purchase Information Module

The figure illustrates the Seed Purchase Information module of the proposed intelligent agricultural prediction system. After generating crop recommendations and price predictions, the application provides farmers with detailed information about locations where the recommended crop seeds can be purchased. The interface displays a structured table containing State, District, Market, Seed Name, and Maximum Price, allowing users to identify suitable seed suppliers based on their geographical location. This information enables farmers to compare the availability and pricing of different seeds before making purchasing decisions. By presenting organized market details within the application, the module reduces the effort required to search for reliable seed sources and supports efficient procurement planning. The integration of seed purchase information with crop recommendation, yield estimation, and crop price prediction creates a comprehensive agricultural decision-support platform. This feature assists farmers in selecting appropriate seeds, estimating cultivation costs, and planning agricultural activities more effectively. Consequently, the proposed system not only provides intelligent predictions but also supports practical farming operations by connecting predictive analytics with real-world agricultural resources, thereby improving cultivation efficiency, reducing planning time, and promoting informed and sustainable farming practices.

DISCUSSION

The proposed intelligent agricultural prediction framework combines Long Short-Term Memory (LSTM)-based crop price forecasting with crop recommendation and agricultural support services to assist farmers in making informed cultivation decisions. The system utilizes a preprocessed agricultural dataset containing soil nutrients, environmental conditions, and historical crop information to train the LSTM model for learning temporal price patterns. A web-based application integrates secure user registration, login authentication, dataset processing, crop recommendation, crop price prediction, yield estimation, and seed purchase information into a unified platform. Farmers can provide soil and environmental parameters through the application interface, after which the trained LSTM model predicts future crop prices while the recommendation module suggests suitable crops based on the given inputs. The platform further provides estimated yield information and seed purchase details, enabling users to plan cultivation and marketing activities more efficiently.

Experimental evaluation indicates that the proposed framework successfully captures historical market trends and generates consistent crop price forecasts using the LSTM network. The integration of deep learning-based prediction with crop recommendation and yield estimation provides comprehensive decision support rather than isolated forecasting results. Furthermore, user information, agricultural records, prediction outputs, and application data are securely maintained in the MySQL database, ensuring reliable data storage and efficient system management. By combining intelligent price forecasting with practical agricultural services through a single web-based environment, the proposed framework offers a scalable and user-friendly solution for improving crop planning, optimizing resource utilization, reducing financial uncertainty, and promoting sustainable farming through data-driven agricultural decision-making.

VI.CONCLUSION

This work presents an intelligent agricultural prediction framework that employs a Long Short-Term Memory (LSTM) network to forecast future crop prices and support data-driven farming decisions. The proposed system utilizes a preprocessed agricultural dataset containing soil nutrients, environmental conditions, and historical crop information to train the LSTM model for learning temporal market trends. The developed web application integrates secure user registration, authentication, dataset processing, crop recommendation, crop price prediction, yield estimation, and seed purchase information within a single platform, enabling farmers to access essential agricultural services through an interactive interface. Experimental results demonstrate that the LSTM model effectively captures historical price variations and generates reliable crop price forecasts, while the integrated recommendation module assists users in selecting suitable crops based on soil and environmental parameters. All user information, agricultural records, prediction outputs, and application data are securely maintained in the MySQL database, ensuring reliable data management and efficient system operation. By combining deep learning-based forecasting with practical agricultural support services, the proposed framework provides a scalable, accurate, and user-friendly solution for improving cultivation planning, optimizing resource utilization, reducing financial uncertainty, and promoting sustainable farming practices. Future enhancements may include the integration of real-time weather information, satellite and IoT sensor data, advanced hybrid deep learning models for improved forecasting accuracy, multilingual advisory support, mobile-based accessibility, and cloud-enabled deployment to provide intelligent agricultural recommendations across diverse farming environments.

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