



# Milletmate-Millets Value Chain Platform

N Nalini Krupa<sup>1</sup>, A Venkata Sravanthi<sup>2</sup>, V Ujwala Siva Geetha Sri<sup>3</sup>, Ch Keshava Gopalu<sup>4</sup>,  
V Adishesu<sup>5</sup>

Assistant Professor, Department of Artificial Intelligence and Machine Learning, Vasireddy Venkatadri Institute of  
Technology, Guntur, Andhra Pradesh, India<sup>1</sup>

Student, Department of Artificial Intelligence and Machine Learning, Vasireddy Venkatadri Institute of Technology,  
Guntur, Andhra Pradesh, India<sup>2,3,4,5</sup>

**ABSTRACT:** Millet farming in India, particularly in Andhra Pradesh and Telangana, is characterized by significant price volatility and dependence on intermediaries that reduce the net income of smallholder farmers. MilletMate is a web-based platform developed to address these systemic challenges by establishing a direct digital value chain between millet farmers and buyers. The platform integrates three core capabilities: a real-time direct marketplace enabling buyers to browse and contact verified farmers, a machine learning-based crop price prediction module that forecasts optimal selling prices for over ten millet varieties including Ragi, Jowar, and Bajra, and a six-month demand forecasting system powered by time-series analysis. The application is built using a Django-based backend, a responsive web frontend, and is deployed on Amazon CloudFront for scalability. The system supports multilingual access in English, Telugu and Hindi, ensuring inclusivity for local farming communities. The price prediction module achieves 89.5% accuracy in estimating market prices, enabling data-informed selling decisions. This paper presents the architecture, methodology, implementation, and evaluation of MilletMate, demonstrating its potential to digitize and democratize the millet agricultural ecosystem.

**KEYWORDS:** *Millet agriculture, Crop price prediction, Machine learning, Agricultural marketplace, Demand forecasting, Farmer-buyer platform, Django, Time-series analysis, Digital value chain*

## I. INTRODUCTION

Millets are a group of highly nutritious, drought-resistant cereal crops that have been cultivated in the Indian subcontinent for thousands of years. India is one of the world's largest producers of millets, contributing approximately 41% of global millet production. Despite their agronomic resilience and increasing global demand as health foods, millet farmers in India continue to face structural challenges that limit their economic well-being. Chief among these are the absence of transparent pricing mechanisms, heavy reliance on middlemen, and limited access to organized buyer networks.

The traditional agricultural supply chain for millets involves multiple layers of intermediaries — commission agents, aggregators, and wholesale traders — each extracting a margin from the crop value before it reaches the end consumer or processor. Farmers, often lacking market intelligence, are compelled to sell at rates significantly below prevailing market prices. This information asymmetry perpetuates a cycle of underpricing and financial vulnerability for farming households.

With increasing internet penetration in rural India, fueled by affordable mobile data and government digital literacy initiatives, technology-driven agricultural platforms have emerged as powerful tools to reconfigure market dynamics. Platforms that leverage artificial intelligence and machine learning for agricultural decision support have demonstrated measurable improvements in farmer income and market efficiency. However, most existing solutions either focus on large-scale commodity crops or provide only partial functionality such as crop advisory without addressing commerce or pricing.

MilletMate is designed as an integrated solution that specifically targets the millet value chain. It enables farmers to list their produce and connect directly with buyers through a verified marketplace, provides ML-based price predictions to inform selling decisions, and forecasts future demand trends using time-series models. This paper describes the design,

development, and evaluation of MilletMate, organized as follows: Section II reviews related literature; Section III presents the system architecture; Section IV details the methodology; Section V describes the implementation; Section VI presents results and discussion; Section VII concludes the paper.

## II. LITERATURE REVIEW

A growing body of research has explored the intersection of digital technology and agricultural market systems. This section reviews key works relevant to the three core capabilities of MilletMate.

### A. Agricultural E-Commerce and Market Linkage Platforms

Studies on India's electronic National Agriculture Market (eNAM) platform have demonstrated that digital market integration can improve farmer price realization by 15–25% through transparent auction mechanisms. However, eNAM primarily targets major commodities such as wheat and rice, with limited support for minor cereals like millets. Research by Kumar et al. (2021) on mobile-based agricultural marketplaces found that direct farmer-to-buyer platforms reduce transaction costs and increase farmer bargaining power. Despite these findings, no dedicated platform for the millet value chain existed prior to MilletMate.

### B. Crop Price Prediction Using Machine Learning

Machine learning approaches to crop price forecasting have been extensively studied. Ensemble methods such as Random Forest and Gradient Boosting have demonstrated strong performance in predicting agricultural commodity prices, with studies reporting  $R^2$  scores above 0.85 on historical market datasets. Recurrent neural networks (RNNs) and Long Short-Term Memory (LSTM) architectures have been applied to time-series price data, capturing seasonal and cyclical price patterns. Research by Sharma et al. (2022) applied XGBoost to APMC millet price data from multiple Indian states and reported a mean absolute percentage error (MAPE) of less than 8%. These findings inform the price prediction methodology adopted in MilletMate.

### C. Demand Forecasting in Agriculture

Time-series forecasting models, including ARIMA, SARIMA, and deep learning alternatives, have been applied to agricultural demand prediction with varying degrees of accuracy. Seasonal decomposition approaches have proven effective for crops with pronounced harvest cycles, such as millets. A study by Reddy and Prasad (2023) on demand forecasting for Jowar in the Deccan Plateau found that SARIMA models outperformed simple regression methods for six-month ahead forecasts. MilletMate incorporates similar time-series techniques to provide buyers and farmers with forward-looking demand intelligence.

### D. Research Gap

While individual components of agricultural technology platforms have been studied in isolation, no prior work presents an integrated system that combines direct farmer-buyer communication, ML-based price prediction, and demand forecasting specifically for the millet crop ecosystem. MilletMate addresses this gap by unifying these capabilities in a single, accessible web platform.

## III. SYSTEM ARCHITECTURE

MilletMate follows a multi-tier web application architecture consisting of a presentation layer, an application layer, a machine learning inference layer, and a data layer. The system is deployed on Amazon CloudFront, providing low-latency content delivery across geographies.

### A. High-Level Architecture

The platform is structured around three distinct user roles: Farmers, who register, list produce, and access price predictions; Buyers, who browse listings, place orders, and contact farmers directly; and Administrators, who monitor platform activity, verify users, and maintain data integrity. Role-based access control ensures that each stakeholder interacts only with features relevant to their function in the value chain.

## B. Technology Stack

Layer	Technology	Purpose
Frontend	HTML5, CSS3, JavaScript	Responsive user interface
Backend Framework	Django (Python)	Business logic and API routing
Database	PostgreSQL / SQLite	User, listing, and transaction data
ML Framework	scikit-learn / Python	Price prediction and demand forecasting
Deployment	Amazon CloudFront (AWS)	CDN and scalable hosting
Authentication	Django Auth (Session-based)	Role-based secure access
Multilingual Support	i18n (Django)	English, Telugu and Hindi language support
Notifications	Django Signals	Real-time order and price alerts

## C. Module Architecture

The platform comprises five primary functional modules:

- **User Management Module:** Handles farmer and buyer registration, profile management, authentication, and role assignment.
- **Marketplace Module:** Enables farmers to create produce listings with details such as crop variety, quantity, location, and asking price. Buyers can browse, filter by location or variety, and place direct orders.
- **Direct Communication Module:** Provides a messaging interface allowing buyers to contact farmers directly, eliminating the need for intermediaries and enabling real-time price negotiation.
- **Price Prediction Module:** Accepts inputs of crop variety, district, and season, and returns a predicted market price based on a trained ML regression model.
- **Demand Forecasting Module:** Visualizes projected demand trends for selected millet varieties over a six-month horizon using time-series analysis, supporting harvest and sales planning.

## IV. METHODOLOGY

### A. Price Prediction Model

The price prediction module employs a supervised machine learning approach trained on historical millet market price data sourced from the market portal maintained by the Government of India. The dataset encompasses daily arrival and modal price data across multiple mandis in Andhra Pradesh and Telangana over a period of five years.

Feature engineering involved extracting the following predictive variables: crop variety (categorical), district/mandi location (categorical, label-encoded), month of transaction (integer, capturing seasonality), year (integer), historical average price (continuous), and minimum support price (MSP) for the corresponding year (continuous). The target variable is the modal market price in Indian Rupees per quintal.

A Random Forest Regression model was selected as the primary algorithm based on its robustness to outliers, ability to handle mixed data types, and strong performance in prior agricultural price prediction studies. Hyperparameter tuning was performed using grid search with five-fold cross-validation, optimizing for minimum root mean square error (RMSE). The final model achieved a price prediction accuracy of 89.5%, with an  $R^2$  score of 0.93 and a MAPE of 5.2% on the held-out test set comprising 20% of the dataset.

### B. Demand Forecasting Model

For six-month demand forecasting, a Seasonal ARIMA (SARIMA) model was applied to monthly millet arrival volume data. The seasonal component captures the harvest-driven periodicity in millet supply, while the autoregressive and

moving average components model trend and noise. Forecasts are presented as visual charts within the platform dashboard, enabling users to anticipate supply-demand dynamics before making listing or procurement decisions.

### C. Data Flow

When a farmer or buyer requests a price prediction, the frontend sends a POST request to the Django REST API endpoint with the input parameters. The backend preprocesses the inputs, applies the label encoders fitted during training, and passes the feature vector to the serialized scikit-learn model. The predicted price is returned as a JSON response and rendered in the UI within the same page interaction, providing a seamless user experience.

## V. IMPLEMENTATION

### A. User Registration and Role Management

New users register through the platform's signup portal, selecting their role as either Farmer or Buyer. Django's built-in authentication framework manages session tokens and password hashing. An admin panel provides oversight of all user accounts, enabling verification and deactivation capabilities to maintain a spam-free environment.

### B. Marketplace and Direct Messaging

Farmers create produce listings specifying the millet variety (from over ten supported types including Ragi, Jowar, Bajra, Foxtail Millet, and Pearl Millet), available quantity in quintals, location, and expected price. Buyers can filter listings by variety, location, and price range. The direct messaging feature allows buyers to initiate contact with listed farmers, fostering transparent price negotiation without intermediary involvement. Real-time alerts notify farmers of new buyer inquiries and order placements.

### C. Multilingual Accessibility

Recognizing the linguistic diversity of the target user base, MilletMate implements Django's internationalization (i18n) framework to support English, Telugu and Hindi interfaces. Users can toggle their preferred language from the navigation bar. This feature is critical for adoption in rural Andhra Pradesh and Telangana, where Telugu is the primary language of agricultural communities.

### D. Deployment Infrastructure

The application is hosted on Amazon Web Services (AWS) and distributed via Amazon CloudFront, a content delivery network (CDN) that ensures low-latency access for users across different geographic regions. This deployment architecture supports horizontal scalability, allowing the platform to accommodate growing user loads during peak harvest and market seasons without performance degradation.

## VI. RESULTS AND DISCUSSION

### A. Price Prediction Performance

Metric	Value	Interpretation
Accuracy	89.5%	High confidence in price estimates
R <sup>2</sup> Score	0.93	Model explains 93% of price variance
MAPE	5.2%	Average error within ₹26 on ₹500 price
RMSE	₹31.4 / quintal	Low absolute prediction error
Training Split	80% / 20%	Standard train-test partition
Algorithm	Random Forest Regressor	Ensemble method, robust to outliers

**B. Comparative Analysis with Existing Platforms**

Feature	eNAM	AgroStar	Fasal	MilletMate
Millet-Specific	Partial	No	No	Yes
Direct Farmer-Buyer Messaging	No	No	No	Yes
ML Price Prediction	No	Partial	Yes	Yes (89.5% accuracy)
6-Month Demand Forecasting	No	No	Partial	Yes
Multilingual (Telugu)	Yes	No	No	Yes
Free to Use	No	No	No	Yes
Role-Based Access Control	Yes	No	No	Yes
Admin Monitoring	Yes	No	No	Yes

**C. Discussion**

The evaluation demonstrates that MilletMate achieves competitive prediction performance while offering a combination of features not available in any single existing platform. The 89.5% price accuracy represents a meaningful improvement over manual price estimation practices currently employed by farmers, who typically rely on word-of-mouth or delayed market reports. The direct messaging capability addresses the most critical gap in the existing digital agriculture landscape for millets — the absence of a reliable channel for direct farmer-buyer interaction without intermediary involvement.

The multilingual support in Telugu is a particularly significant design decision, as literacy in English among farming communities in Andhra Pradesh and Telangana is limited. By making the platform accessible in the user's native language, MilletMate lowers the adoption barrier substantially. The deployment on AWS CloudFront ensures that the platform remains responsive even during high-traffic periods such as post-harvest seasons.

Limitations of the current system include the dependence on historical price data quality from market, which may have gaps for certain millet varieties or remote mandis. The demand forecasting model assumes historical patterns will persist, which may not hold during supply shocks or policy changes such as MSP revisions. These limitations point toward opportunities for model enhancement in future work.

**VII. CONCLUSION AND FUTURE WORK**

This paper presented MilletMate, a web-based agricultural value chain platform that integrates a direct farmer-buyer marketplace, machine learning-based crop price prediction, and six-month demand forecasting for millet crops in India. The platform addresses key structural challenges in millet agriculture — price opacity, middleman dependency, and lack of market intelligence — through a unified, multilingual digital solution. The price prediction module demonstrated 89.5% accuracy using a Random Forest Regression model trained on historical APMC market data. Deployed on Amazon CloudFront, the platform is scalable and accessible for rural farming communities in Andhra Pradesh and Telangana.

Future work will focus on several enhancements. First, integration of real-time weather and satellite data as additional features for the price prediction model is expected to improve accuracy further during climatic anomalies. Second, the development of a mobile application for Android and iOS will extend accessibility to farmers who primarily use smartphones rather than desktop browsers. Third, the messaging module will be enhanced with real-time WebSocket-based chat to improve the buyer-farmer communication experience. Fourth, the platform will be expanded to support additional minor cereals beyond millets, including sorghum and finger millet variants currently underrepresented in digital agricultural platforms. Finally, integration with government MSP announcement APIs will allow the pricing module to automatically update its reference benchmarks, maintaining prediction relevance across policy cycles.

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