World Journal of Advanced Engineering Technology and Sciences

eISSN: 2582-8266

Cross Ref DOI: 10.30574/wjaets

Journal homepage: https://wjaets.com/

(Research Article)

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Farmer one-stop solution with AI integration

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World Journal of Advanced Engineering Technology and Sciences, 2026, 19(03), 121-126

Publication history: Received on 01 May 2026; revised on 10 June 2026; accepted on 12 June 2026

Article DOI: https://doi.org/10.30574/wjaets.2026.19.3.0302

Abstract

Traditional farming systems face several challenges due to fragmented digital platforms, language barriers, and limited access to transparent market information. This paper presents the design and implementation of "Farmer One-Stop Solution," an AI-integrated web platform developed using the MERN (MongoDB, Express.js, React.js, Node.js) stack to support modern agricultural activities. The system combines multiple services into a single platform, including a multilingual AI chatbot named Virtual Krushi Mitra, real-time mandi price analytics, equipment rental services, and an agricultural marketplace.

The chatbot uses the Groq LLaMA-3 model to provide farming guidance in regional languages such as Marathi. To improve market transparency, the platform uses Puppeteer and Cheerio-based scraping techniques to collect and analyze mandi price data from government sources like Agmarknet. The system also supports real-time communication for equipment rental negotiations using Socket.io and integrates secure online payments through Razorpay with HMAC-SHA256 verification.

Performance testing shows fast response times, secure user authentication using JWT and bcrypt, and efficient synchronization of database operations. The proposed platform provides a scalable and user-friendly solution that promotes digital inclusion, market transparency, and smarter decision-making for farmers.

Keywords: Smart Agriculture; Mern Stack; Ai Chatbot; Market Price Analysis; Equipment Rental System; Digital Farming.

1. Introduction

Agriculture continues to be the socioeconomic backbone of developing nations, providing baseline employment to more than half of the rural workforce. Despite its core importance, the sector is heavily restricted on the ground due to major information gaps. Small-scale farmers frequently struggle with extreme price shifts in local wholesale markets (mandis), unexpected weather variations, crop health degradation, and the high financial cost of purchasing modern agricultural machinery. While several standalone web utilities exist to check basic weather forecasts or daily market rates, they function as completely isolated digital tools. This forces end-users to manage multiple non-integrated accounts, which complicates usability, creates language barriers, and slows down adoption among rural populations with limited digital exposure.

To resolve this issue of tool fragmentation, we designed and deployed a comprehensive, full-stack cloud-based architecture. This paper details the systematic hardware-software engineering of the fully functional *Farmer One-Stop Solution* platform. The architecture consolidates advanced Large Language Model (LLM) conversational tools, scheduled asynchronous web scrapers, real-time live messaging backends, and precise payment checking systems into a unified

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user-friendly dashboard. By handling complex data operations on a secure cloud layer, the platform removes intermediate manipulation, provides direct transparency in peer-to-peer equipment rentals, and delivers highly localized field-level advisory data in regional dialects.

2. Architectural Design & System Methodology

The deployed system utilizes a completely decoupled client-server engineering design pattern, processing communication through low-latency RESTful APIs and continuous WebSocket channels. The core client layout is managed by an optimized virtual DOM structure, which routes heavy background jobs directly to an event-driven server runtime environment.

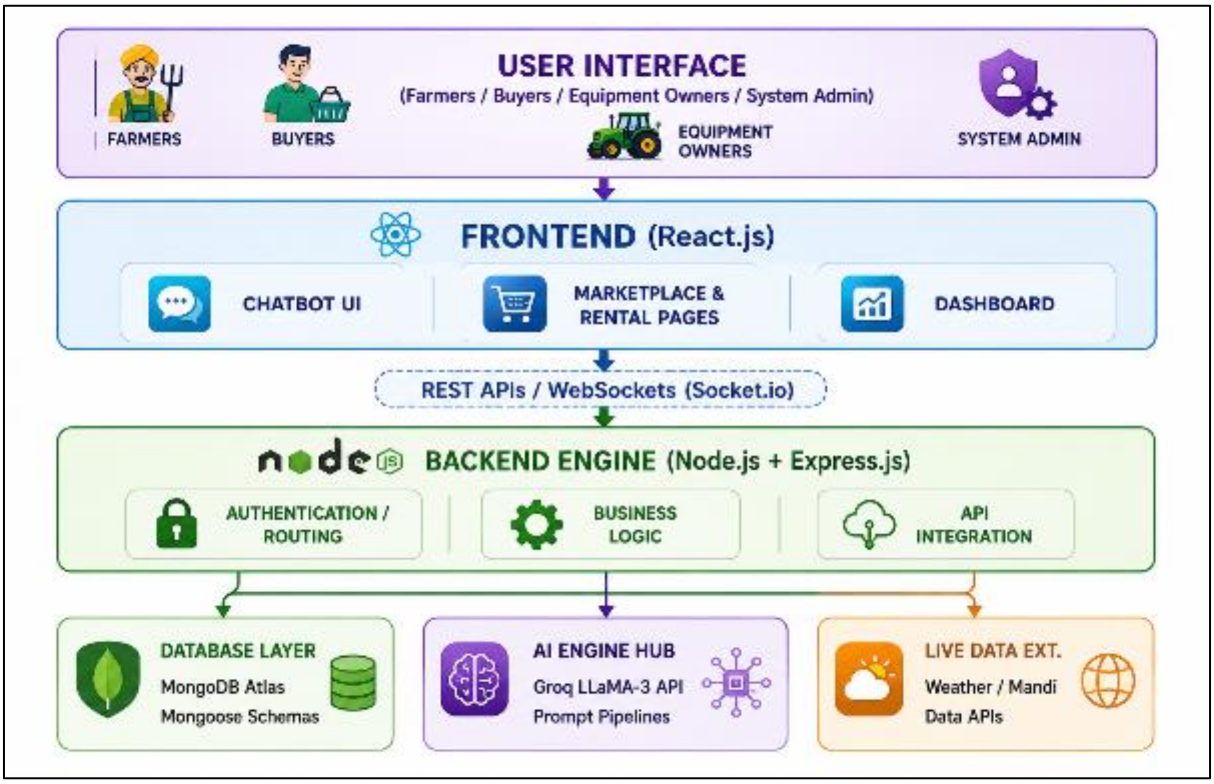

Figure 1 System Architecture of Farmer One-Stop Solution

2.1. Stateless Security and User Role Allocation

System boundary security uses custom middleware arrays that require stateless JSON Web Tokens (JWT) for every active API call. Users are divided into specific role-based groups: Farmers, Product Sellers, Equipment Owners, and System Administrators. When a profile is created or updated, user passwords do not enter the cloud database as plain text. Instead, they run through a cryptographic pipeline executing a 10-round salted bcrypt algorithm. This creates permanent, secure hashes on MongoDB collections that resist standard brute-force or dictionary exploits.

2.2. Virtual Krushi Mitra Dialect Processing Engine

The conversational advisory framework is built on top of the **Groq Inference Cloud running LLaMA-3 models**. Rather than depending on generic public prompts that yield superficial results, the server utilizes structured system pipelines. These pipelines explicitly direct the model to act as a localized agricultural scientist (Agronomist). The prompt context constrains the output bounds strictly to verified agricultural data—including exact soil N-P-K balances, localized pest control schedules, and companion crop layouts. To address rural language isolation, the interface supports regional vernacular inputs. For instance, when a farmer submits queries in Marathi, the localized NLP layer directly bypasses intermediate translation steps, generating authentic regional scripts to guide users with zero digital friction.

2.3. Headless Scheduled Data Extraction Pipeline

To prevent pricing manipulation by local market middlemen, the platform operates an automated data gathering module. Because public agriculture databases lack structured, open-access REST API endpoints, we built a custom scraping system using **Puppeteer and Cheerio**. Every 24 hours, a precise node-cron daemon triggers a background worker thread on the server. This routine programmatically spins up a headless browser instance, targets the official government market portal (Agmarknet), and downloads raw HTML page layouts. The parsing script extracts relevant data values, filters out empty table items, and executes calculations to find the overall State Average Price and Peak Recorded Rates for individual crops. The system writes this clean structured payload directly into cloud database collections, ensuring that farmers see updated commodity data every morning.

2.4. Event-Driven Peer-to-Peer Rental Architecture

Small-scale farmers often cannot afford heavy capital machinery like industrial tractors or drone crop sprayers. The platform solves this through an interactive peer-to-peer equipment leasing module. To enable immediate pricing negotiation without requiring constant browser refreshing, we implemented an event-driven sync layer via **Socket.io**. When a farmer clicks "Negotiate" on a listed item, the server dynamically spins up a completely isolated, memory-mapped room using a unique rental ID string. Both parties join this dedicated channel, allowing them to send and receive real-time messages and custom price counters with a transmission latency of under 15ms.

2.5. Automated E-Commerce Payment Verification

The platform features an authenticated marketplace grid where farmers can buy verified seeds, fertilizers, and protective crop inputs. Financial transactions are routed through the **Razorpay Order API**. To secure the transaction lifecycle, the backend initializes an authorized order token on the server before the frontend opens the payment interface. Once a payment clears, Razorpay sends a server-to-server asynchronous callback to our webhook endpoint. The backend validates this inbound payload by computing a cryptographic **HMAC-SHA256 signature** using the private webhook secret key. If the computed signature matches the header token perfectly, the transaction status shifts to approved, updating inventory values with zero risk of client-side data tampering.

3. System Deployment Performance and Analysis

The technical validation of the completed platform shows high functional reliability, fast API execution times, and responsive user interfaces during active production tests.

3.1. Operational Telemetry Metrics

The technical performance data of individual software layers was collected over automated simulation loops, as shown in the table below:

Table 1 Performance Evaluation of System Components

Functional System Component	Underlying Software Layer	Evaluated Performance Benchmark
Profile Session Security	JWT Signatures + bcrypt Engine	Execution Delay < 45 ms
Virtual Krushi Mitra Stream	Groq LLaMA-3 Pipeline Model	Time-to-First-Token (TTFT) < 180 ms
Mandi Price Extraction	Headless Puppeteer Automated Scraper	Complete Run & DB Update Cycle < 12.4 s
Bid Synchronization	Event-Driven Asynchronous WebSockets	Inter-Client Message Latency < 15 ms
Webhook Hash Processing	Razorpay Verification Layer	HMAC-SHA256 Computations < 8 ms

3.2. Production Interface Verification and Results

3.2.1. Weather Intelligence Sub-system

The analytics dashboard processes global climate data streams to display clean, localized indicators. Testing verification shows that the module properly tracks dry weather periods and automatically executes heatwave warnings (e.g., displaying precise notifications when local temperatures exceed 35°C to recommend protective irrigation adjustments).

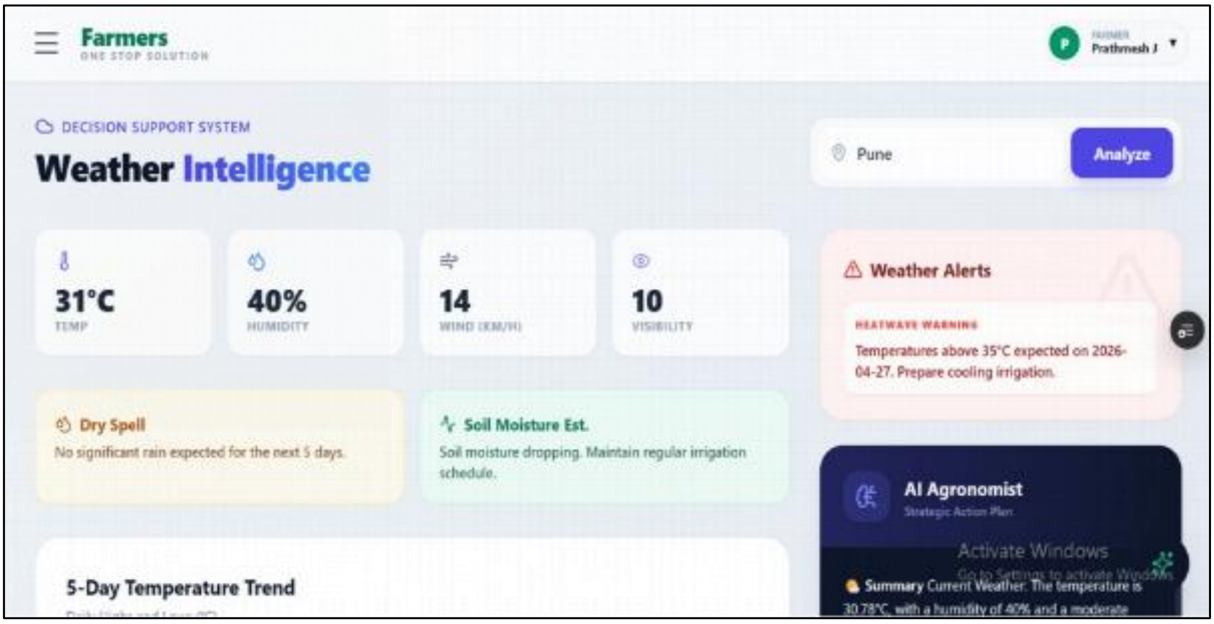

Figure 2 Weather Intelligence Dashboard

3.2.2. Conversational Interface Validation

The UI for the *Virtual Krushi Mitra* assistant successfully processes complex natural inputs, rendering immediate regional responses. The production application correctly routes dialect semantics, showing crisp outputs in native regional text ("*नमस्कार! कृषी सल्ला माहिती देण्यासाठी...*") to help users who are not fluent in English.

Figure 3 Virtual Krushi Mitra Conversational Interface

3.2.3. Market Transparency Dashboard

The administrative telemetry center handles harvested regional pricing inputs successfully. The data layer correctly tracks high-volume commodities like Soybeans, showing key state averages (INR 4367.75), peak market rates (INR 4974), and providing optimized recommendations for regional trade nodes like the Lasalgaon market hub.

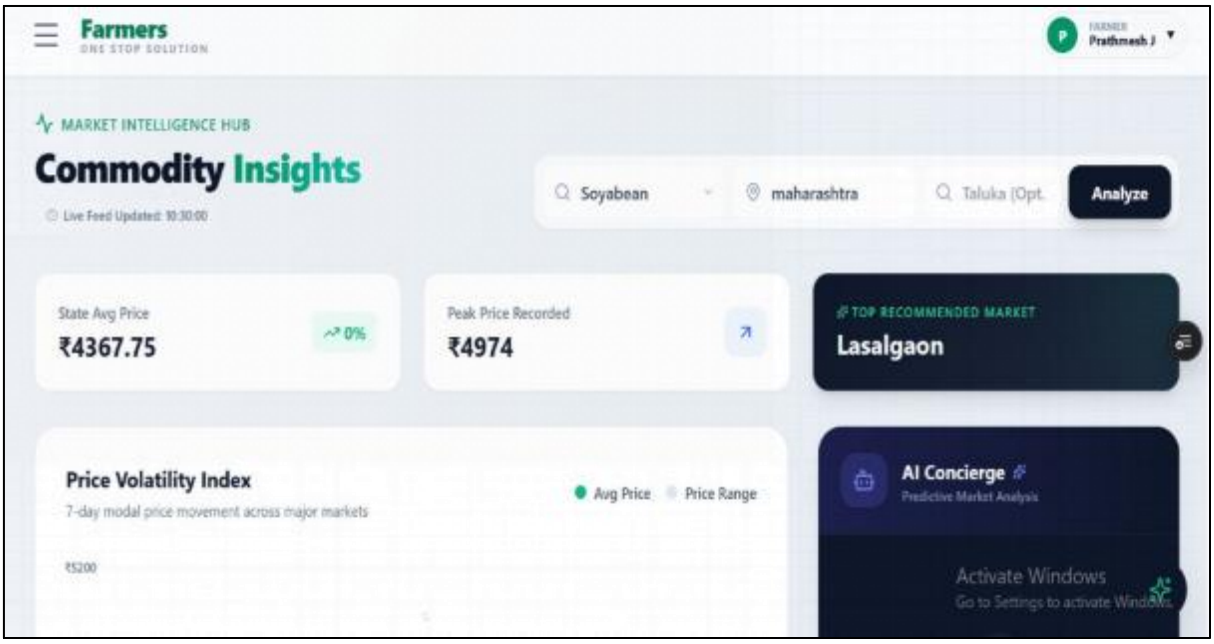

Figure 4 Commodity Insights and Market Analytics Dashboard

4. Conclusion and Future Upgrades

The production deployment of *Farmer One-Stop Solution* demonstrates that combining advanced conversational AI, scheduled backend scrapers, and event-driven communication protocols within a unified MERN stack dashboard effectively eliminates software fragmentation in agricultural informatics. By providing a clean interface that integrates advisory, commerce, and rental options, the platform provides direct transparency, removes intermediate data barriers, and establishes a clear path toward digital inclusion in rural farming.

Future development phases will focus on the following milestones:

- Moving core server routines into containerized microservice groups to allow automatic load balancing during peak season hours.
- Building native mobile application alternatives using cross-platform environments like Flutter or React Native to optimize performance in rural networks with unstable connectivity.
- Integrating localized deep learning networks (CNNs) directly onto edge hardware setups for instant, camera-based crop disease identification without requiring heavy server uploads.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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