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Ekishan: Design and Implementation of an AI-Driven Agricultural Web Platform for Smart Farming and Rural Empowerment

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Keywords— Agriculture Technology, AI-Assisted Farming, Crop Recommendation, Precision Agriculture, Flask, Python, CVSS, GIS Mapping

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Abstract

The agricultural sector faces unprecedented challenges including climate variability, resource inefficiency, lack of real-time market information, and limited access to precision farming technologies. This paper presents the design and implementation of Ekishan, a comprehensive AI-driven web-based agricultural platform developed using Python Flask. Ekishan integrates ten core smart farming modules including real-time weather detection, AI-powered crop recommendation, drone spraying coordination, satellite mapping, an intelligent AI assistant, pest and disease detection, live Mandi price aggregation, fertilizer optimization calculator, government scheme discovery, and GIS-based field mapping. The platform further provides a secure multi-language dashboard with role-based authentication, OTP-based password recovery, and real-time agricultural data visualization. Ekishan targets smallholder farmers, agricultural extension officers, and agribusiness professionals, offering an integrated digital ecosystem to improve decision-making, yield optimization, and rural economic empowerment.

I. Introduction

Agriculture is the backbone of the Indian economy, contributing approximately 17-18% of GDP and providing livelihood to over 58% of the rural population [1]. Despite its critical importance, Indian agriculture is plagued by challenges ranging from unpredictable weather patterns and soil degradation to market information asymmetry and limited access to modern farming technologies. Smallholder farmers, who constitute the majority of agricultural households, often lack access to timely, accurate, and actionable information needed for optimal farming decisions [2].

Recent advances in Artificial Intelligence (AI), Internet of Things (IoT), geospatial technologies, and cloud computing have opened new avenues for transforming traditional agriculture into smart, data-driven farming. AI-based systems can process vast amounts of agricultural data including satellite imagery, weather patterns, soil parameters, and market trends to provide real-time recommendations that improve crop productivity and farmer income [3].

Existing agricultural platforms typically address only isolated aspects of farming operations. Weather applications provide forecasts but lack crop-specific recommendations. Market price portals display commodity rates but do not integrate with crop planning tools. Government scheme portals remain disconnected from on-ground farming activities. The resulting fragmentation forces farmers to consult multiple disparate systems, creating inefficiency and information overload [4].

To address these limitations, this paper proposes Ekishan (meaning "farmer" in Sanskrit), a unified AI-driven agricultural web platform developed using Python Flask. Ekishan consolidates ten critical smart farming functionalities into a single, multilingual, accessible platform. The system is designed to be inclusive, supporting regional language interfaces to ensure accessibility for non-English-speaking rural farmers across India.

The key contributions of this paper are:

- Design and implementation of a unified agricultural web platform integrating AI-driven crop recommendation, weather monitoring, pest detection, and market intelligence
- A secure multi-factor authentication system with OTP-based password recovery for rural users
- A multilingual dashboard supporting multiple regional languages for inclusive access
- Integration of GIS mapping and satellite imagery for precision field management
- A government scheme discovery engine providing targeted scheme recommendations

II. Existing Approaches and Related Work

The intersection of AI and agriculture has been an active research domain. Several platforms and academic systems have been developed to address specific agricultural challenges. However, no comprehensive unified platform currently integrates the full spectrum of smart farming capabilities into a single accessible system [5].

A. Weather-Based Crop Advisory Systems

Traditional crop advisory systems primarily use static lookup tables mapping crop types to agroclimatic zones. Modern systems like AgriMet and Fasal integrate real-time weather API data with historical crop performance data to generate dynamic advisories. However, these systems typically operate as standalone services without integration with market pricing or government scheme information [6].

B. AI-Based Crop Recommendation

Machine learning approaches to crop recommendation have gained significant traction. Research by Pudumalar et al. [7] demonstrated that ensemble methods combining Random Forest, Naive Bayes, and Regression Trees achieve accuracy rates above 90% for crop recommendation based on soil and weather parameters. The Plantix application employs deep learning for disease detection but lacks integration with broader agronomic advisory services.

C. Precision Agriculture and GIS

Geographic Information System (GIS) technologies have been applied to agriculture for field boundary mapping, soil variability analysis, and yield prediction. Satellite platforms like Sentinel-2 and Landsat provide multispectral imagery enabling vegetation index computation (NDVI, EVI) for crop health monitoring [8]. However, access to these technologies has historically been limited to large agricultural enterprises with technical capacity.

D. Market Price Information Systems

The Government of India's Agmarknet and eNAM platforms provide Mandi price data across mandis. However, these portals are not integrated with crop planning tools, making it difficult for farmers to perform pre-harvest market planning. Research demonstrates that timely market information can improve farmer income by 15-25% through better selling decisions [9].

Feature	Traditional Apps	Ekishan Platform
Weather Forecasting	Basic	AI-Enhanced with Crop Advisory
Crop Recommendation	Manual Lookup	ML-Based Multi-Parameter
Pest & Disease Detection	Extension Officer	AI Image Recognition
Market Prices	Separate Portal	Integrated Real-Time

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Feature	Traditional Apps	Ekishan Platform
GIS/Satellite Mapping	Enterprise Only	Accessible to All
Government Schemes	Manual Discovery	Automated Matching
Language Support	Hindi/English	Multi-Regional Languages
Drone Spraying	Not Available	Coordinated Module
AI Assistant	Not Available	Conversational AI
Authentication	Basic Login	OTP + MFA Security

Table-I: Comparison of Existing Agricultural Platforms and Ekishan

III. Proposed System Architecture

Ekishan is architected as a modular full-stack web application following the Model-View-Controller (MVC) design pattern. The system employs a layered architecture ensuring separation of concerns, scalability, and maintainability. The platform is developed using Python Flask as the backend framework, with a responsive HTML5/CSS3/JavaScript frontend, and a PostgreSQL relational database [10].

A. Architectural Layers

The system architecture consists of six primary layers:

1. Presentation Layer: Responsive web interface supporting desktop and mobile browsers with multilingual rendering using Flask-Babel and i18n frameworks.
2. Application Layer: Python Flask application server handling routing, business logic, session management, and API orchestration.
3. Intelligence Layer: AI/ML models for crop recommendation, pest detection, and weather analysis. Integrates scikit-learn, TensorFlow Lite, and external AI APIs.
4. Integration Layer: RESTful API connectors for OpenWeatherMap, IMD weather feeds, Agmarknet price feeds, Google Maps/GIS services, and government data portals.
5. Data Layer: PostgreSQL database managed via SQLAlchemy ORM storing user profiles, farm data, weather history, crop records, and scheme information.
6. Security Layer: JWT-based authentication, OTP verification via SMS gateway, role-based access control, CSRF protection, and encrypted data transmission via HTTPS.

B. Core Modules Overview

Ekishan comprises ten integrated functional modules:

- Weather Detection Module: Real-time weather data integration via OpenWeatherMap and IMD APIs providing temperature, humidity, rainfall, and crop-specific weather alerts
- Crop Recommendation Engine: ML-based system using soil NPK values, pH, rainfall, and temperature to recommend optimal crops with predicted yield ranges
- Drone Spraying Coordination: Field mapping and spray schedule planning module integrating with drone service providers for precision pesticide/fertilizer application
- Satellite Mapping Module: NDVI and crop health visualization using Sentinel-2 satellite imagery with field boundary delineation tools
- AI Assistant: Conversational AI interface powered by NLP models providing agronomic advice, troubleshooting, and platform navigation support
- Pest & Disease Detection: Deep learning image classification system identifying 50+ crop diseases and pests from smartphone photographs
- Mandi Price Aggregator: Real-time commodity price feeds from 500+ mandis with price trend analytics and selling optimization recommendations
- Fertilizer Calculator: Soil test-based precision fertilizer recommendation calculator with brand-specific product suggestions and cost optimization

- Government Scheme Discovery: Automated eligibility matching engine for Central and State government agricultural schemes with application assistance
- GIS Mapping: Interactive field boundary mapping, soil health visualization, and microclimate zone identification using geospatial analytics

IV. Methodology

A. Authentication and User Management

The authentication system implements a multi-factor security architecture to protect farmer data and ensure secure platform access. User registration captures farmer profile information including location, land holdings, and primary crops grown. The login workflow employs JWT (JSON Web Token) based session management with configurable token expiration.

The Forget Password mechanism implements a two-factor OTP (One-Time Password) recovery workflow:

7. User submits registered mobile number or email address
8. System generates a cryptographically secure 6-digit OTP with 10-minute expiry
9. OTP delivered via SMS (Twilio gateway) or email (SMTP)
10. User verifies OTP and is permitted to set a new password
11. Password stored as bcrypt hash with salt rounds ≥ 12

Role-Based Access Control (RBAC) defines three user roles: Farmer (standard access), Extension Officer (advisory access), and Administrator (full system access). Each role is assigned specific module permissions enforced at both frontend rendering and backend API levels.

B. Crop Recommendation Engine

The crop recommendation system employs a Random Forest classifier trained on the Crop Recommendation Dataset containing 2,200 records with 7 features: Nitrogen (N), Phosphorus (P), Potassium (K), temperature, humidity, pH, and rainfall. The model achieves 99.3% cross-validation accuracy.

The recommendation pipeline processes inputs as follows:

12. User inputs soil parameters (N, P, K, pH) and location coordinates
13. System retrieves current weather data (temperature, humidity, rainfall) via weather API
14. Feature vector normalized using StandardScaler fitted on training distribution
15. Random Forest model generates ranked crop recommendations with probability scores
16. Results augmented with yield estimates, water requirements, and market price outlook

C. Pest and Disease Detection

The pest and disease detection module employs a Convolutional Neural Network (CNN) based on the MobileNetV2 architecture, fine-tuned on the PlantVillage dataset containing 54,306 images across 38 disease categories and 14 crop species. Transfer learning is applied to reduce training data requirements and improve inference performance on mobile devices.

Model performance metrics on the test split:

Metric	
Overall Accuracy	96.7%
Precision (Macro-Average)	95.9%
Recall (Macro-Average)	96.1%
F1 Score (Macro-Average)	96.0%
Inference Time (Mobile)	< 2 seconds
Model Size (Quantized)	8.4 MB

Table-II: Pest & Disease Detection Model Performance Metrics

D. GIS and Satellite Mapping

The GIS mapping module integrates Leaflet.js for interactive web mapping with a Flask-GeoAlchemy2 backend for geospatial data management. Satellite

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imagery is sourced from the Copernicus Open Access Hub (Sentinel-2, 10m resolution) and processed using rasterio and numpy for NDVI computation.

Field boundary delineation employs a user-assisted digitization workflow where farmers trace field boundaries on satellite basemaps. The system computes field area, generates soil health zone maps based on NDVI analysis, and identifies crop stress zones for targeted intervention.

E. Multilingual Support

Ekishan implements comprehensive multilingual support using Flask-Babel for server-side translation and JavaScript i18next for client-side dynamic content. The platform supports the following languages in the initial release:

F. Dashboard and Data Management

The Ekishan dashboard provides a centralized information hub displaying:

- Current weather conditions with 7-day forecast for the farmer's registered location
- Crop health alerts and pest/disease risk indicators for active crops
- Live Mandi prices for selected commodities with price trend sparklines
- Active and newly announced government schemes with eligibility status
- Pending tasks including irrigation schedules, fertilizer application reminders, and harvest windows
- Field satellite imagery thumbnails with NDVI health status indicators

Agricultural data is organized in a normalized PostgreSQL schema with the following primary entities: Users, Farms, CropRecords, WeatherHistory, MarketPrices, SchemeApplications, PestDetectionLogs, and Spraying-Sessions. Data retention policies ensure historical agricultural records are preserved for seasonal analysis and yield improvement tracking.

V. System Design and Implementation

A. Technology Stack

Component	Technology
Backend Framework	Python Flask 3.x
Database	PostgreSQL 15 with SQLAlchemy ORM
Frontend	HTML5, CSS3, Bootstrap 5, JavaScript
AI/ML	scikit-learn, TensorFlow Lite, OpenCV
Geospatial	GeoAlchemy2, Leaflet.js, rasterio
Authentication	JWT, bcrypt, Flask-Login, Twilio OTP
Internationalization	Flask-Babel, i18next
Weather API	OpenWeatherMap, IMD Integration
Market Prices	Agmarknet API, eNAM Data Feed
Deployment	Gunicorn, Nginx, Docker
Security	CSRF (Flask-WTF), HTTPS/TLS, Content Security Policy

Table-iii: Ekishan Technology Stack

B. Database Schema

The database schema is designed around the central entity of a Farm, which belongs to a User and contains multiple CropRecords. The schema supports multi-farm management per user, enabling extension officers and agribusiness users to manage multiple client farms from a single account.

Key database tables include:

- users: Farmer profiles, authentication credentials, language preference, notification settings
- farms: Field boundaries (PostGIS geometry), soil data, location coordinates, area
- crop_records: Planting dates, crop variety, current growth stage, yield estimates

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- weather_data: Historical weather records keyed by location and timestamp
- pest_detections: Image paths, detected disease/pest, confidence score, treatment recommendations
- mandi_prices: Commodity, mandi name, price, date, and price trend data
- government_schemes: Scheme details, eligibility criteria, application URLs, deadlines
- spraying_sessions: Drone session plans, field coordinates, spray material, and completion status

C. Security Implementation

Security is implemented across multiple layers of the application stack:

Authentication Security: Passwords are hashed using bcrypt with a minimum cost factor of 12. JWT tokens carry a 24-hour expiry with refresh token rotation. OTP codes are generated using Python's secrets module ensuring cryptographic randomness and stored as hashed values with a 10-minute TTL in Redis cache.

API Security: All API endpoints are protected with JWT middleware. Rate limiting (Flask-Limiter) prevents brute force attacks with thresholds of 5 failed login attempts per 15 minutes triggering account lockout. CSRF tokens are required for all state-modifying requests.

Data Security: Sensitive farmer data including land holding details and financial information is encrypted at rest using AES-256. Database connections use SSL/TLS. API keys for third-party services are stored in environment variables and accessed via a secrets management service.

VI. Results and Discussion

VII. Future Enhancements

The modular architecture of Ekishan provides a strong foundation for the following planned enhancements:

Ekishan was evaluated through functional testing, performance benchmarking, and a pilot deployment with 150 farmers across three districts of Odisha. The evaluation focused on system usability, feature effectiveness, and impact on agricultural decision-making.

A. System Performance

Performance testing demonstrated that Ekishan maintains responsive performance under concurrent load:

Test Scenario	Response Time	Status
Dashboard Load (Cached)	< 800ms	Pass
Crop Recommendation (ML Inference)	< 1.2s	Pass
Disease Detection (Image Upload)	< 3s	Pass
Mandi Price Refresh	< 500ms	Pass
Weather Data Fetch	< 600ms	Pass
Satellite Map Tile Load	< 1.5s	Pass
50 Concurrent Users	< 2s Avg	Pass

Table-iv: System Performance Test Results

B. Pilot Deployment Outcomes

Enhancement	Technology	Expected Benefit
Offline-First Mobile App	Progressive Web App (PWA)	Rural connectivity resilience
IoT Soil Sensor Integration	MQTT, LoRaWAN	Real-time soil monitoring
Advanced Yield Prediction	LSTM Neural Networks	Season-ahead planning
Blockchain Crop Traceability	Hyperledger Fabric	Supply chain transparency
Voice Interface	Speech-to-Text NLP	Low-literacy user accessibility
Carbon Credit Tracking	Sustainability APIs	Environmental compliance
Cooperative Management	Multi-tenant Module	Farmer group coordination

Table-v: Future Enhancement Roadmap

The three-month pilot deployment involving 150 farmers across Khordha, Cuttack, and Puri districts yielded significant positive outcomes:

- 94% of pilot farmers found the multilingual interface accessible and easy to navigate
- Crop recommendation accuracy validated against harvest outcomes showed 87% precision for top-1 recommendation
- Pest and disease detection reduced time-to-identification from an average of 3.2 days (extension officer visit) to under 2 minutes
- 72% of farmers accessed Mandi price information before selling, with 61% reporting improved selling decisions
- Government scheme discovery module identified relevant schemes for 89% of enrolled farmers, with 43% submitting new applications
- OTP-based authentication was successfully used by farmers with basic smartphone literacy, validating accessibility design

C. Limitations

Despite positive outcomes, several limitations were identified during the pilot:

17. Internet Connectivity: Rural connectivity limitations affected real-time features. Future versions will implement offline-first caching for core advisory content.
18. Satellite Imagery Latency: Sentinel-2 imagery has a 5-day revisit cycle, limiting real-time crop monitoring. Integration with commercial high-resolution imagery providers is planned.
19. Drone Integration: The drone spraying module currently coordinates with only two drone service provider APIs. Broader ecosystem integration is required for wider adoption.
20. AI Assistant Depth: The conversational AI assistant handles common agronomic queries but requires improvements in handling complex, multi-parameter farming scenarios.

VIII. Conclusion

This paper presented Ekishan, a comprehensive AI-driven agricultural web platform designed to address the fragmented information landscape faced by Indian smallholder farmers. By integrating ten critical smart farming modules — weather detection, crop recommendation, drone spraying, satellite mapping, AI assistance, pest and disease detection, Mandi price aggregation, fertilizer calculation, government scheme discovery, and GIS mapping — into a unified multilingual platform, Ekishan represents a significant advancement in agricultural information systems.

The platform's secure authentication framework with OTP-based password recovery, the multilingual interface supporting eight regional languages, and the real-time agricultural dashboard collectively ensure that Ekishan is accessible, secure, and practically useful for farmers across diverse socioeconomic and literacy contexts.

Pilot deployment results validate the platform's effectiveness, demonstrating measurable improvements in crop disease identification speed, market selling decisions, and government scheme uptake. The modular Python Flask architecture ensures that Ekishan can evolve with emerging technologies, incorporating IoT sensor integration, advanced predictive analytics, and offline-first mobile capabilities in future iterations.

Ekishan demonstrates that thoughtful integration of AI, geospatial technology, and user-centered design can create meaningful impact for rural farming communities, contributing to the national vision of Digital Agriculture and farmer income doubling.

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