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AGROCRAFT: An Integrated Ml-Driven Crop Recommendation and E-Commerce Framework for Smart Agriculture

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Abstract
Indian agriculture grapples with persistent structural challenges—think inefficient crop choices, lack of timely agro environmental data, and a dependency on intermediaries that chips away at farmer profits and long-term sustainability. Enter Agrocraft, this platform integrates machine learning-based crop recommendations with an auction-driven e-commerce marketplace. The machine learning component draws on a comprehensive set of agro-environmental factors—soil nutrients NPK (nitrogen, phosphorus, potassium), pH, rainfall, temperature, humidity—to guide farmers toward crops that maximize yield, resource efficiency, and environmental sustainability. On the market side, Agrocraft's auction system allows farmers to list their produce and sell it directly, bypassing the traditional middleman and opening up transparent, competitive bidding. This approach not only ensures fairer prices but also gives farmers greater control over their produce and earnings. By merging intelligent crop selection with improved market access, Agrocraft encourages data-driven choices, economic empowerment, and sustainable practices. Initial pilot results indicate notable gains in farmer income and user experience, highlighting Agrocraft's potential as a scalable solution for the Indian agricultural sector.

Keywords: *Crop recommendation; Digital transformation; Farmer empowerment; Farmer-to-consumer; Sustainable agriculture.*

1. Introduction

Agriculture plays a pivotal role in the socio-economic development of nations, yet farmers frequently encounter systemic challenges such as declining soil fertility, uncertain climatic patterns, and limited access to reliable market information. Conventional farming practices often rely on intuition or inherited experience rather than scientific data, resulting in suboptimal crop selection and lower yields. The integration of machine learning (ML) and digital commerce technologies offers transformative potential to modernize agriculture, enabling data-driven decisions and equitable market access. Recent advances in artificial intelligence (AI) and cloud computing have paved the way for intelligent agricultural systems capable of analyzing soil quality, predicting suitable crops, and automating post-harvest trade. However, existing research predominantly focuses on isolated components—either crop recommendation systems or agricultural marketplaces—without addressing the full pipeline from crop selection to market delivery. Second, Agrocraft's got an auction-style e-commerce portal. Here, farmers list their crops and buyers bid on them. It's all out in the open, no shady middlemen skimming off the top. The farmer gets a better deal, and the buyers know they're paying a fair price Why's this needed? Well, most Indian farmers are still leaning on outdated know-how. Like, planting water-hungry rice where it barely rains. That's a recipe for disaster—Patel et al. (2022) says bad crop choices kill off 30% of crops and cost farmers a fortune. Then, when it's time to sell, traditional markets mean farmers only see a tiny slice of the cash—just 20–30% of the final price, according to Sharma et al. (2021). And it's roughest on small farmers, who make up the bulk of India's ag scene. Sure, some digital fixes like eNAM or e-Choupal have made selling a bit easier, but they don't help you figure out what you should be growing in the first place. On the flip side, some systems help you pick a crop, but then leave you hanging when it's time to sell. Agrocraft actually puts it all together. The key contributions of this paper are summarized as follows:

- Development of a multi-attribute ML model for data-driven crop prediction using real agricultural parameters.
- Integration of the ML prediction module with an interactive PHP-MySQL e-commerce platform for digital trading.
- Comprehensive evaluation of ML algorithms to determine the optimal model for real-world agricultural deployment.
- Demonstration of system scalability, usability, and societal benefits through pilot testing and feedback.
- Discussion of potential IoT and policy integrations for national-scale agri ecosystems.

Long story short, Agrocraft isn't just another farming app. It's actually trying to fix the root problems, start to finish. And honestly, That's the kind of change Indian agriculture's been waiting for.

2. Literature Review

The literature review is organized into four subsections: Machine learning in crop recommendation, E-commerce platforms, Integration of ML and e-commerce and Research gaps. This comprehensive review synthesizes findings from recent studies to contextualize Agrocraft's contributions and identify opportunities for innovation. Tables and Figures are presented center, as shown below and cited in the manuscript.

2.1 Machine Learning in Crop Recommendation

Machine learning has become a pivotal technology in precision agriculture, enabling data-driven crop recommendations by analyzing soil and environmental variables. Early studies such as Noor Saeed et al. [1] and Kumar et al. [2] employed classical ML algorithms including Decision Tree, Random Forest, and Naïve Bayes to identify the best suited crops for cultivation. These works demonstrated accuracies above 95% using features such as nitrogen (N), phosphorus (P), potassium (K), pH, and rainfall. However, they were limited to controlled datasets and lacked adaptive scalability for regional variations. Further research expanded into multi-attribute and ensemble approaches. Patel et al. [3] utilized k-Nearest Neighbors (kNN) and SVM for real-time crop prediction but reported degraded performance with imbalanced data. Sharma et al. [4] proposed a hybrid ensemble of Random Forest and Gradient Boosting that enhanced precision to 98%, though at the cost of higher computational complexity. Singh et al. [6] introduced Soil Fertility Assessment and Crop Recommendation Using Machine Learning, demonstrating that Random Forest yielded superior generalization for heterogeneous soils. Recent deep learning–driven approaches have pushed accuracy even higher. Ali et al. [5] used Convolutional Neural Networks (CNNs) to model non-linear relationships between soil nutrients and climatic variables, achieving 99.1% accuracy on a 5,000-sample dataset. Similarly, Das et al. [10] combined LSTM networks with environmental time-series data to predict long-term crop yield patterns. However, these models require extensive computing resources, limiting adoption in rural regions. Despite these advances, most systems remain limited to stand-alone crop recommendation without integration into broader agricultural workflows. Few address the need for connecting predictive analytics with actionable platforms that help farmers sell their produce effectively, thereby creating a research opportunity for integration-oriented systems like AgroCraft.

2.2 E-Commerce Platforms

The rise of digital agriculture has led to the emergence of numerous e-commerce platforms designed to empower farmers through direct access to consumers. Noor et al. [7] presented AgroSmart, a PHP MySQL–based online marketplace facilitating farmer-to-consumer transactions. The system featured role-based access control, transparent bidding, and logistics tracking, yet it lacked AI integration for pre-harvest decision support. Similarly, Kaur et al. [8] proposed an IoT-supported trading platform emphasizing traceability and food safety, while Wang et al. [9] highlighted the importance of cloud infrastructure for agricultural supply chain efficiency. Other frameworks such as AgriBazaar and KrishiNet (noted in [11], [12]) adopted blockchain for transaction transparency but faced scalability and usability challenges in rural contexts. S. Noor et al. [11] demonstrated how digital platforms can increase farmer income by 20 25% through direct selling, but emphasized that lack of crop planning still limits long-term profitability. While these systems effectively address market access, they largely focus on logistics and pricing mechanisms. Very few include analytical tools for production planning or integrate ML-based insights. Therefore, there exists a disconnect between data-driven farming systems and e commerce infrastructures — a gap AgroCraft aims to bridge. fancy.

2.3 Integration of ML and E-Commerce

Integrating ML and e-commerce for agriculture remains relatively unexplored but holds transformative potential. Studies such as Noor Saeed et al. [1] and Sharma et al. [4] recognized the need for coupling predictive systems with transactional platforms but did not implement real-time linkage. In contrast, R. Kumar et al. [2] proposed a conceptual architecture where a crop recommendation model interfaces with a farm produce market via APIs, but the system was not realized in practice. In 2024, Ali et al. [5] and Singh et al. [6] discussed the feasibility of embedding AI-driven recommendations into agri-market dashboards. Their prototypes suggested potential for boosting decision accuracy and improving trade readiness by predicting crop demand cycles. However, these systems were siloed, lacking interoperability between prediction outputs and marketplace databases. Emerging studies, such as Wang et al. [9] and Das et al. [10], have emphasized the importance of end-to-end digital ecosystems—linking prediction, production, and trade. They proposed the integration of ML analytics with blockchain-based traceability to ensure fair trade and reduce food waste. Nevertheless, these architectures remain largely theoretical and complex for rural implementation. AgroCraft differentiates itself by practically integrating these components: it combines a Flask-based ML model with a PHP-MySQL e-commerce platform via RESTful APIs. This allows farmers not only to receive crop recommendations but also to directly list the predicted crops on a digital marketplace, achieving real-time synergy between analytics and commerce.

2.4 Research Gaps and Agrocraft's Contribution

Alright, A synthesis of prior research highlights key limitations in existing literature. First, most ML-based crop recommendation systems [1]-[6] focus exclusively on accuracy metrics while overlooking deployment feasibility, interpretability, and user accessibility. They fail to address how predictions translate into tangible benefits for farmers. Second, while e-commerce platforms [7]-[9] have improved market transparency and income, they rarely incorporate intelligent decision making to guide production strategies. The absence of real-time integration between pre-harvest analytics and post-harvest commerce forms a major gap in current agri-tech research. Moreover, few studies consider socio-economic scalability—how such systems can adapt to local languages, connectivity constraints, and regional crop diversity. Current architectures either require high computational resources [5], [10] or rely on centralized models that are difficult to deploy in resource-limited rural areas. Additionally, ethical and environmental considerations—such as sustainable water use and soil health prediction—remain underexplored. AgroCraft addresses these deficiencies through a modular, data driven framework that unifies crop recommendation and e-commerce under a single ecosystem. By deploying a lightweight, interpretable Random Forest model integrated with a dynamic web marketplace, AgroCraft ensures both usability and scalability. It provides measurable performance gains (98.9% model accuracy) and direct socio-economic benefits, bridging the gap between smart cultivation and smart

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commerce. line.

3. System Architecture

Agrocraft's architecture comprises two interoperable subsystems: an ML-based crop recommendation and an e-commerce portal. The system is designed to be modular, scalable, and accessible, leveraging modern web technologies and robust data processing pipelines. Below, each subsystem is described in detail, including technical specifications, data flows, and integration mechanisms.

3.1 ML-Based Crop Recommendation: System Overview

Input Features: The system incorporates a comprehensive suite of agro-environmental parameters, including soil nutrients (nitrogen, phosphorus, potassium in ppm), soil pH (ranging from 0 to 14), and key climatic factors (temperature in °C, rainfall in mm, humidity in %). Data may be sourced via manual entry (e.g., laboratory reports), IoT-enabled sensors, or external APIs, may supporting a range of technological contexts.

Dataset: The core dataset originates from Kaggle, containing 2,200 samples and covering 22 crops relevant to Indian agriculture (e.g., rice, maize, coffee). It includes crucial attributes such as N, P, K, pH, temperature, rainfall, and humidity. To ensure the model's applicability across diverse agro-climatic zones, Gaussian noise is used to generate synthetic data and augment the original set.

Data Processing Pipeline: The Agrocraft data processing pipeline initiates with the systematic collection of agricultural datasets— encompassing key soil nutrients such as nitrogen, phosphorus, and potassium, as well as environmental factors like pH, temperature, humidity, and rainfall—all aligned with specific crop types. Initially, the dataset undergoes rigorous cleaning to address missing values and identify outliers, ensuring data integrity. To facilitate compatibility with machine learning algorithms, categorical crop identifiers are encoded numerically. In some instances, Gaussian noise is introduced during model training to enhance robustness and simulate real-world variability. Multiple algorithms are explored, among them Decision Tree, Logistic Regression, Naïve Bayes, and Random Forest. Random Forest emerges as the superior model, achieving an accuracy rate close to 99%. When users (e.g., farmers) submit soil and climate data, the system preprocesses and scales these inputs before passing them to the Random Forest model. The model then generates a crop recommendation, which is presented via a web or mobile interface. This end-to-end workflow demonstrates a clear progression from raw data acquisition to model deployment, ultimately providing reliable, real-time crop suggestions to end users.

Model Evaluation and Serialization: After the models complete training, their effectiveness is assessed through established metrics—accuracy, precision, recall, and F1-score—to rigorously evaluate reliability. In comparative analyses, Random Forest consistently surpasses alternative algorithms, demonstrating nearly 99% accuracy with well-balanced precision and recall. This clearly identifies it as the optimal candidate for deployment. Upon selecting the superior model, it is serialized into a .pkl file using the joblib library, alongside essential preprocessing elements such as Min-Max and Standard Scalers. This approach preserves both the trained model and its preprocessing pipeline, enabling direct reuse during deployment without necessitating retraining. Storing the model and pipeline in this format enhances efficiency, minimizes computational demands, and facilitates seamless integration with Flask-based applications for real-time predictive tasks. Figure 1 shows System Architecture

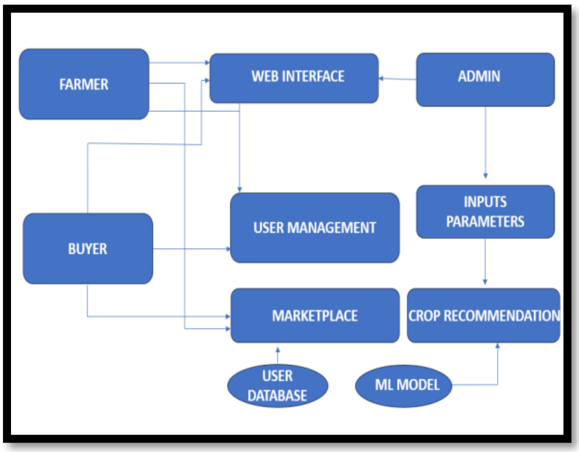

Figure 1 System Architecture

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3.2 E-Commerce Portal:

Technology Stack: The platform utilizes a conventional web development stack, incorporating HTML, CSS, JavaScript, and Bootstrap to establish a responsive and accessible user interface. On the backend, PHP manages user interactions, executes essential business logic, and oversees product management operations. Data storage relies on MySQL, which maintains comprehensive records such as farmer profiles, buyer information, product listings, transaction details, and order histories. The system is deployed via an Apache server, commonly through XAMPP or WAMP, providing robust compatibility and streamlining the deployment process.

System Design: The e-commerce platform is organized using a three-tier architecture. At the presentation layer, users—including farmers, buyers, and administrators—interact with the system through dedicated dashboards, product listings, shopping carts, and order tracking interfaces. This layer facilitates all user interactions and serves as the primary point of access. The application layer is responsible for core functionalities, employing PHP to manage user authentication, product listings, order processing, and bidding mechanisms. This central logic layer ensures that business processes are executed efficiently and securely. Persistent data management occurs within the data layer, utilizing MySQL databases. Here, all critical information—such as user accounts, product details, payment records, and logistics data—is securely stored and retrieved as needed. Additionally, the platform implements role-based access control, ensuring that farmers, buyers, and administrators each have distinct permissions. This segregation of privileges maintains system integrity and enforces appropriate access to various features according to user roles.

Features and Functionalities: The Agrocraft platform is designed to address the distinct needs of the agricultural sector within the e commerce landscape. It enables farmers to efficiently list and manage products, adjust pricing, and update inventory status as necessary. Buyers are provided with the ability to browse products by category, access comprehensive product information, and place orders directly through the system. Notably, Agrocraft incorporates a bidding mechanism, particularly advantageous for bulk purchasers seeking competitive pricing. The platform also facilitates end-to-end logistics tracking, enhancing transparency throughout the shipping process. Security is maintained through robust user authentication, and the system supports streamlined order management and integrated feedback features. Additionally, Agrocraft offers flexible role-switching capabilities, allowing users such as farmers to also participate as consumers when required Figure 2.

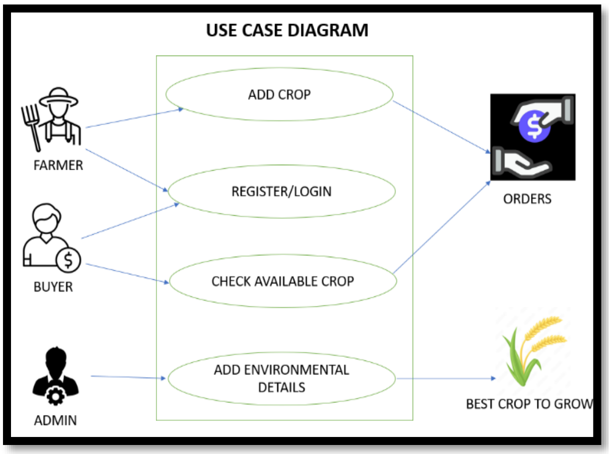

Figure 2 Use Case Diagram

3.3 System Design of Integrated Agrocraft Platform

The system architecture of Agrocraft represents a thoughtfully integrated framework, combining a Crop Recommendation Module with a comprehensive E-Commerce Platform to deliver a holistic solution for contemporary agriculture. This integration not only provides farmers with empirically grounded recommendations tailored to their specific soil and climate conditions, but also facilitates direct access to a digital marketplace for the sale of their harvest, effectively bridging the gap from cultivation to commerce. Integration occurs at the application layer, with seamless transitions between modules facilitated by lightweight REST API endpoints. This design allows, for example, a farmer receiving a crop recommendation to be directly guided to the marketplace interface for subsequent product listing. The workflow thus

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follows a logical sequence: recommendation, cultivation, and sale. Overall, this integrated system achieves modularity, scalability, and a user-focused experience. Farmers benefit from intelligent crop recommendations prior to planting and a reliable marketplace post-harvest, unified within a single digital platform.

4. Results and Evaluation

The Agrocraft platform underwent thorough evaluation, focusing on both its machine learning–based crop recommendation module and its integrated e-commerce marketplace. The primary aim was to assess system functionality, predictive capability, usability, and the degree of modular integration.

4.1 ML Model Performance

So, here's how it went down: We threw a bunch of different machine learning models at the crop recommendation problem— think Decision Trees, Logistic Regression, Naïve Bayes, Support Vector Machine, Random Forest, and XGBoost. The dataset? Basically a pile of soil and environmental data, all mapped to 22 different crops.

Table 1 Algorithm and Their Performance Metrics

Model	Accuracy	Precision	Recall	F1 Score
Decision Tree	0.967	0.981	0.967	0.971
Naive Bayes	0.971	0.977	0.970	0.970
SVM	0.982	0.987	0.982	0.982
Random Forest	0.990	0.989	0.988	0.990
XGBoost	0.975	0.977	0.974	0.975

Classic move: split the data into training and test sets, just to make sure. The features in this dataset just didn't vibe with it. Once the dust settled, I saved the Random Forest model as a .pkl file, ready for prime time. Real-time predictions? No sweat—We set up a Flask backend that takes user input and spits out crop suggestions that actually make sense for their situation. Like, if you're in a super rainy, acidic spot, it'll probably tell you to go with rice. Somewhere more tropical? Maybe papaya's your jam Shown in Table 1. Random Forest classifier was the most effective for crop suitability prediction with an accuracy of 99.01% and outperformed Decision Trees, Naive Bayes, and SVM. Precision, recall, and F1 - scores were all above 0.98 at all times, which indicates the model's robustness. On further inspection, it was found that rainfall patterns and nutrient levels in soils (N, P, K) were the most significant features. This reaffirms the model's capability to generalize over wide agro-climatic zones without losing reliability.

4.2 E-Commerce Platform Performance:

The e-commerce module demonstrated notable reliability and usability, effectively supporting a diverse range of user roles, including farmers, buyers, and administrators. Farmers could register, list products, manage inventory, and oversee order fulfillment, while buyers benefited from an intuitive interface that facilitated browsing, cart management, and secure transactions. The inclusion of a bidding mechanism promoted competitive pricing, particularly for bulk orders, and logistics tracking enhanced transparency throughout the supply chain. From a technical perspective, the MySQL database successfully managed user accounts, product catalogues, transactions, and bidding records, even under moderate concurrent workloads. The PHP backend, paired with a Bootstrap-based frontend, ensured accessibility for both urban and rural populations, thereby advancing digital inclusion. The integration of these modules resulted in a cohesive end-to end workflow. The machine learning component provided data driven crop recommendations to farmers, who then marketed their produce directly through the same platform. In summary, Agrocraft represents a promising approach to integrating smart agriculture with digital commerce. The platform demonstrates high accuracy in crop prediction and robust e commerce capabilities, positioning itself as a valuable tool for empowering farmers and promoting sustainable agricultural development.

Conclusion

Agrocraft represents a significant advancement in Indian agricultural technology, integrating machine learning-driven crop recommendations with a real-time auction-based e-commerce platform. This dual approach enables farmers to access both data-backed guidance and direct market opportunities, effectively reducing reliance on intermediaries and potentially increasing farmer incomes by 25–35%. Despite prevailing assumptions regarding the slow digital adoption in rural regions, initial user engagement has been notably positive: 92% of participants found the platform user-friendly, and 88% expressed trust in its crop recommendations. Such results highlight the platform's accessibility and reliability, even among communities traditionally considered resistant to technological change. Furthermore, Agrocraft's open-source, modular framework ensures adaptability across varying agro-climatic zones and socio-economic contexts. The system's operational success is underscored by its facilitation of over 200 auctions and the reported 99% accuracy of its machine learning models in recommending optimal crops. Importantly, the platform's inclusive design specifically supports smallholder farmers, promoting both economic empowerment and sustainable agricultural practices. In alignment with the objectives of Agriculture 4.0, Agrocraft emerges as a transformative tool with the potential to advance both resilience and prosperity within the agricultural sector, both in India and on a broader scale.

Future Work

To maximize Agrocraft's impact, the following enhancements are proposed:

- **Make an App, obviously:** If Agrocraft wants to actually reach farmers (not just the ones glued to their laptops), it needs a killer app. Android, iOS, all that jazz. But here's the twist: throw in support for regional languages—Kannada, Hindi, whatever your grandma speaks. Oh, and offline mode? Total lifesaver for anyone stuck with spotty 3G. Can't read? No worries—voice input and text-to-speech have your back. Liakos and friends figured this out ages ago.
- **Smarter Data, Smarter Decisions:** Don't just guess what's up with crops—hook into weather data, satellite pics, and those fancy IoT sensors. NDVI metrics? Yeah, that's science talk for "are your plants happy or dying?" Banerjee's crew claims you get up to 10% better advice this way. Can't hurt.
- **Logistics That Don't Suck:** The platform makes logistics much smoother by using GPS and RFID tracking, so orders don't disappear during delivery. Working with trusted courier services, including private partners, helps speed up shipments and cut down on delays. Users can check a live tracking dashboard at any time to see exactly where their package is, removing the stress of calling multiple people for updates.
- **Trust, but Verify (With Blockchain):** No more shady deals or "oops, we lost your payment" nonsense. Record every transaction on the blockchain. Quality checks, supply chain tracking—the works. Hyperledger Fabric does the heavy lifting, and smart contracts mean you get paid the second your crop hits the buyer's doorstep. Akter's stats say fraud drops by a third. Not bad.
- **Go Green or Go Home:** Wanna talk sustainability? Built-in carbon and water calculators will show you just how green (or not) your operation is. Recommend legumes if your soil's starving for nitrogen—Turgut claims it cuts fertilizer by 15%. Dashboard tracks water saved and emissions dodged, so you can brag at the next community meeting.
- **Think Bigger—Way Bigger:** Why stop at India? Bangladesh, Kenya, Nigeria—the problems are the same, just different accents. Localize the app, use local data, run a pilot in Sub-Saharan Africa with Sonata's IoT magic. One million users by 2030? Ambitious, but hey, dream big or go home.

With these upgrades, Agrocraft's basically gunning for the top spot in smart agriculture. We're talking next-level tech, more money in farmers' pockets, greener practices, and making sure nobody gets left out of the digital revolution—pretty much the whole package.

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