CropTap: A Crop Recommender System Using Data-Driven Algorithm

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Abstract: This study developed and fully implemented CropTAP, a comprehensive and data-driven crop recommender system created to support more informed and practical agricultural decision-making in the municipalities of Tagoloan and Misamis Oriental. The system integrates soil characteristics, climate information, and historical crop performance, and it combines these datasets with machine learning algorithms to produce accurate and science-based crop recommendations, fertilizer suggestions, and planting insights that are easier for users to understand. Following the Agile SDLC approach, CropTAP was built using Python Flask for the recommendation engine, Laravel MySQL for backend operations and data management, and React for the user interface, which allows centralized data handling along with improved accessibility for agricultural officers. The results of the implementation show that the system effectively addressed long-standing issues involving fragmented records, inconsistent evaluation methods, and inefficient crop selection. It achieved this by providing tailored recommendations, clear dashboards, and practical guides that support better productivity and more efficient use of resources. Usability evaluations indicated generally positive acceptance from users, emphasizing the platform's helpful functionality and strong alignment with real-world agricultural workflows. Overall, CropTAP modernizes traditional farming practices by delivering a reliable decision support tool that strengthens sustainable and evidence-based crop planning at the municipal level.

Keywords: *Crop Recommender System, Data-Driven Algorithm, Machine Learning, Precision Agriculture, Soil Analysis, Climate Data, Sustainable Farming, Agricultural Decision Support System, Tagoloan Agriculture.*

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I. INTRODUCTION

In the era of digital transformation, technologies were revolutionizing various industries, including agriculture. Farmers often struggled with determining the most suitable crops for cultivation due to uncertainties in soil and climate conditions. Traditional farming methods lacked real-time, evidence-based recommendations, leading to inefficient land use and reduced productivity. [1] The integration of advanced ensemble learning methods and data-driven algorithms offered a solution by analyzing diverse datasets to enhance decision-making in agriculture (Akkem et al., 2023). This project sought to address these challenges by developing a Crop Recommender System that provided accurate and science-based recommendations for farmers.

[2] Agriculture played a crucial role in ensuring food security and economic stability, yet many farmers struggled with poor yields and financial losses due to the absence of accurate, data-driven insights (Jadhav et al., 2022). By utilizing machine learning techniques, this project aimed to improve crop selection by analyzing soil composition, climate data, and historical crop performance data. [3] Implementing a Crop Recommender System using a data-driven algorithm enabled farmers to make informed decisions, reducing financial risks and promoting sustainable farming practices (Anguraj et al., 2021).

The Department of Agriculture in Tagoloan was initially identified as the primary beneficiary of this research. Some sectors of the municipality relied on agriculture, with many small and medium-scale farmers depending on traditional crop selection methods. However, challenges such as climate variability, soil degradation, and inefficient resource allocation hinder optimal agricultural productivity. The existing manual and fragmented crop recommendation processes lacked integration with IT systems, preventing effective data utilization. Due to limited availability and

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completeness of local agricultural datasets in Tagoloan, the study was expanded to include the province of Misamis Oriental, where more comprehensive data could be accessed. This broader data coverage allowed for improved training and validation of the Crop Recommender System while still focusing on Tagoloan as the primary testing and deployment site.

The office previously relied on outdated recommendation methods, often based on tradition rather than scientific evidence. [4] While these approaches reflected local experience, they were not always effective in addressing modern agricultural challenges such as changing climate conditions and soil variability (Tandog & Condes-Tandog, 2023). As a result, farmers often chose crops poorly suited to their environment, leading to lower yields, reduced profitability, and inefficient resource use. By developing a Crop Recommender System, the study aimed to bridge the gap between traditional practices and modern agricultural advancements. Although initial data and observations came from Tagoloan, the system was designed for broader application across Misamis Oriental. [5] It analyzed soil type, climate patterns, and historical crop performance data to generate precise recommendations and improve overall agricultural outcomes in the region (Garg & Alam, 2023).

To ensure technical feasibility and robust performance, the system integrates database management, a machine learning algorithm, and web development. A relational database system, such as MySQL, was used to efficiently store and manage large datasets on soil characteristics, climate data, and historical crop performance data. Machine learning models implemented using Python libraries processed these datasets to generate predictive crop recommendations. Additionally, a web-based interface allowed agriculturists and administrators to input data and access personalized recommendations seamlessly. This technology-driven approach modernized agricultural decision-making, leading to improved productivity and sustainability.

The study aimed to develop and implement CropTAP, a crop recommender system utilizing a hybrid approach that combines machine learning algorithms with rule-based agronomic logic. By integrating historical data-driven insights with established agricultural standards, the system provides accurate and scientific crop recommendations to optimize crop selection, enhance productivity, and promote sustainable farming practices.

- ➢ To gather and analyze the functional and non-functional requirements for the system, ensuring it effectively processes soil characteristics, climate patterns, and farmer profiles.
- ➢ To train, test, and validate a hybrid recommendation engine using Random Forest for predictive modeling and rule-based logic for agronomic feasibility.
- ➢ To design and develop a web-based application with a centralized database architecture for secure data management and farm analytics visualization.
- ➢ To deploy the system in a live production environment to demonstrate its operational readiness and accessibility.
- ➢ To evaluate the system's functionality and usability through functional testing and the System Usability Scale (SUS) to ensure it meets end-user needs.

II. RELATED WORK

This chapter presented an in-depth review of existing literature and technological developments relevant to crop recommender systems. The review included a structured examination of both foreign and local studies, analyzing the integration of machine learning (ML), Internet of Things (IoT), data mining, and software frameworks within the agricultural domain. The discussion was organized into two primary thematic groups: (1) Soil and Data-Centric Approaches and (2) IoT and User-Centric Platforms. Each category was evaluated based on its methodology, tools used, performance results, limitations, and relevance to small-scale farmers in the local Philippine context. The chapter concluded with a synthesis that highlighted the study's contribution to addressing gaps in existing systems, justifying the development of CropTAP.

Modern crop recommendation systems were increasingly built on multi-disciplinary technologies that supported intelligent agricultural practices. Among these were machine learning models such as Random Forest, Decision Trees, K-means clustering, Long Short-Term Memory (LSTM), Genetic Algorithms, and Gaussian Process Regression (GPR), which helped generate predictive models using structured datasets, including soil and climate data. These algorithms were commonly implemented in Python due to its extensive ecosystem for data science and machine learning.

On the hardware side, IoT sensors (e.g., for measuring pH, temperature, soil moisture, and NPK levels) enabled real-time environmental data collection. These sensors were typically interfaced through microcontroller boards like Arduino and Raspberry Pi, with data streamed into back-end systems for further processing. Software frameworks like Flask, Django, and Laravel were employed to manage data and provide user access via web or mobile interfaces. Despite their advancements, many of these systems were limited in either their accessibility to non-expert users or their adaptability in regions with poor internet infrastructure. The challenge, therefore, lay in designing systems that in;

- [6], [7], [8], [9], [10] Soil and data-centric studies, including Soberano et al. (2023), Ahmed et al. (2021), Thongnim et al. (2025), Rani et al. (2023), and Lagrazon and Tan (2023), utilize advanced machine learning techniques such as Random Forest, Genetic Algorithms, and LSTM networks to achieve high crop recommendation accuracies (94.6%–97.2%) and yield improvements. These approaches excel in analytical precision but are limited by scalability, computational demands, and lack of real-time, farmer-accessible interfaces.

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- [11], [12], [13], [14], [15] IoT and user-centric systems by Abdullahi et al. (2024), Konaté et al. (2020), Sowmya et al. (2025), Dela Cruz et al. (2025), and Agustin et al. (2022) prioritize real-time monitoring and user-friendly platforms, achieving up to 99.5% accuracy with IoT sensors and mobile/web interfaces. However, their dependence on stable internet connectivity restricts their utility in rural, low-connectivity areas. A hybrid approach integrating robust predictive models with accessible, offline-capable systems is essential to address these gaps and enhance agricultural outcomes.

The literature reveals a distinct contrast between systems designed for analytical accuracy and those optimized for real-time, user-friendly deployment. Soil and data-centric models demonstrate high predictive precision but lack practical interfaces for field deployment. Conversely, IoT and user-centric models are more accessible but often underutilize advanced predictive algorithms.

This gap highlights the necessity for a hybrid system like CropTAP. CropTAP is designed to combine the analytical power of machine learning with a lightweight and user-friendly web interface. Developed using Python for algorithm implementation, Flask for lightweight API development, Laravel for backend management, react for front-end design, and MySQL for database handling, the system will offer localized recommendations tailored to Tagoloan's soil and crop data.

The significance of CropTAP lies in its context-sensitive design. It will address local farmers' needs who may have limited internet access or digital literacy while providing scientifically grounded crop recommendations. This dual capability positions CropTAP not merely as a technical innovation but as a socially relevant tool for sustainable agriculture in the region.

III. METHODOLOGY

[16] This study employed the Agile methodology, utilizing an iterative life cycle to allow for continuous refinement and stakeholder input (Zayat & Senvar, 2020). This approach was critical for facilitating direct engagement with agricultural officers and local farmers to define system requirements, a practice justified by similar studies engaging local experts (Dela Cruz et al., 2025). The design phase translated these requirements into visual and technical specifications. High-fidelity prototypes were created using Figma to ensure the platform was intuitive and accessible. Simultaneously, the system's data structure was modeled using an Entity-Relationship Diagram (ERD). This approach allows for the efficient modeling of data concepts and relationships, comparable to methods used in other agricultural decision support systems (Konaté et al., 2020).

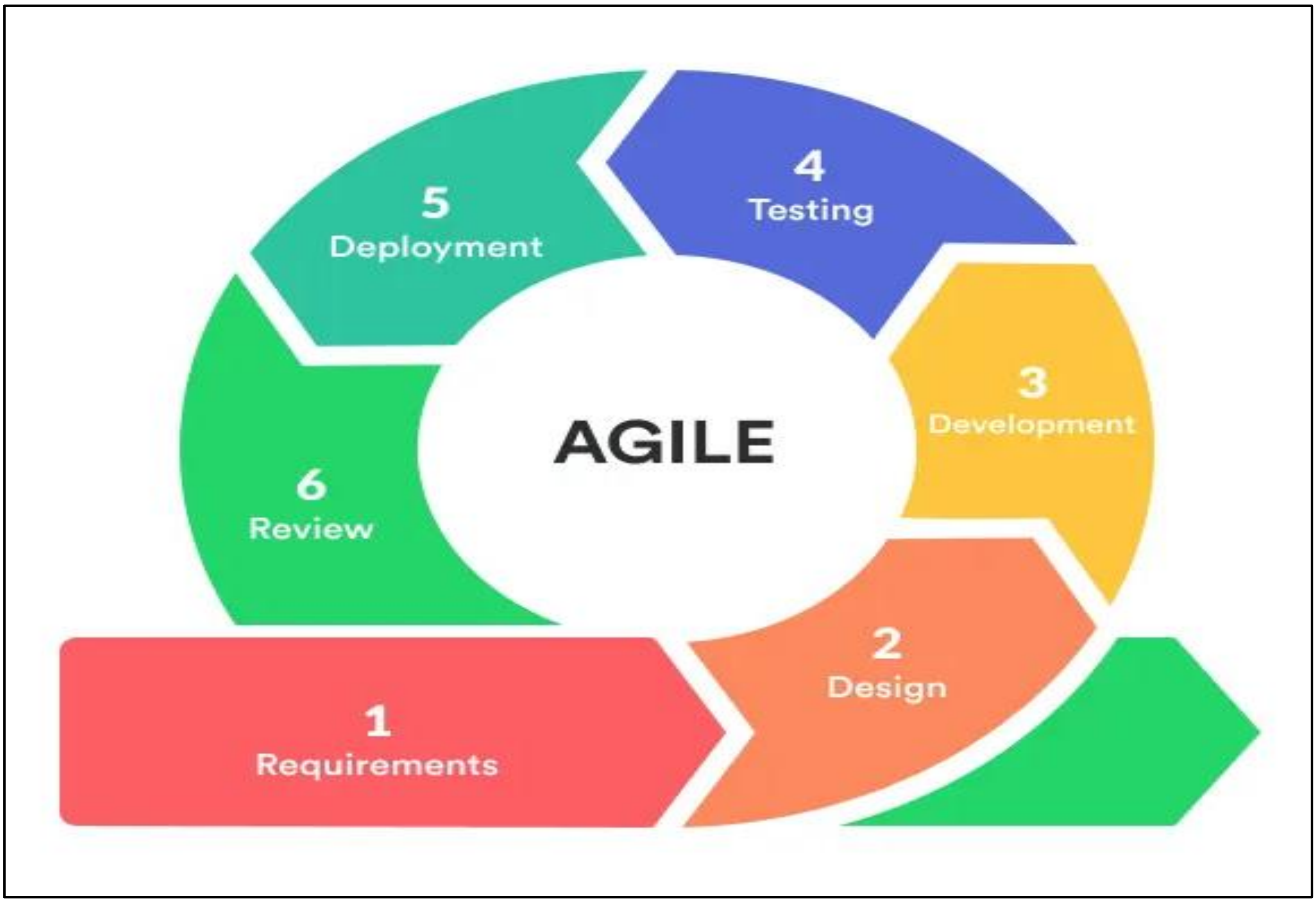

Fig 1 Agile Model Diagram, adopted from Dela Cruz et. al. (2025).

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A suite of modern development tools was selected to construct the system's layered architecture. [17] The presentation layer was built using React, a widely adopted library for building dynamic user interfaces (Lakshmanan et al., 2024), and styled with Tailwind CSS. [18] The application logic was implemented using Laravel, chosen for its robust authentication and data handling capabilities (Cimino et al., 2023). MySQL was employed as the relational database management system to manage structured datasets. The machine learning component was developed using Python and deployed as a microservice using Flask. Throughout the process, Visual Studio Code (VS Code) served as the primary development environment (Dela Cruz et al., 2025), while GitHub was employed to manage the repository and coordinate development tasks (Khosravi et al., 2024).

[19] The system was implemented using a modular Layered Architecture (see Figure 2), reflecting the global shift toward digitalized farming practices and cloud-based solutions (Shamshiri et al., 2024). The implementation separates the application into distinct presentation, application, machine learning, and data layers. The Presentation Layer manages user interaction via React, communicating with the Application Layer (Laravel) via Inertia.js. The Machine Learning Layer operates as a standalone Python/Flask API that processes soil and climate inputs to return real-time crop suitability scores. Finally, the system was deployed on a virtual private server to ensure consistent data access for agricultural officers in the field, a critical accessibility feature for agricultural decision-support systems (Konaté et al., 2020).

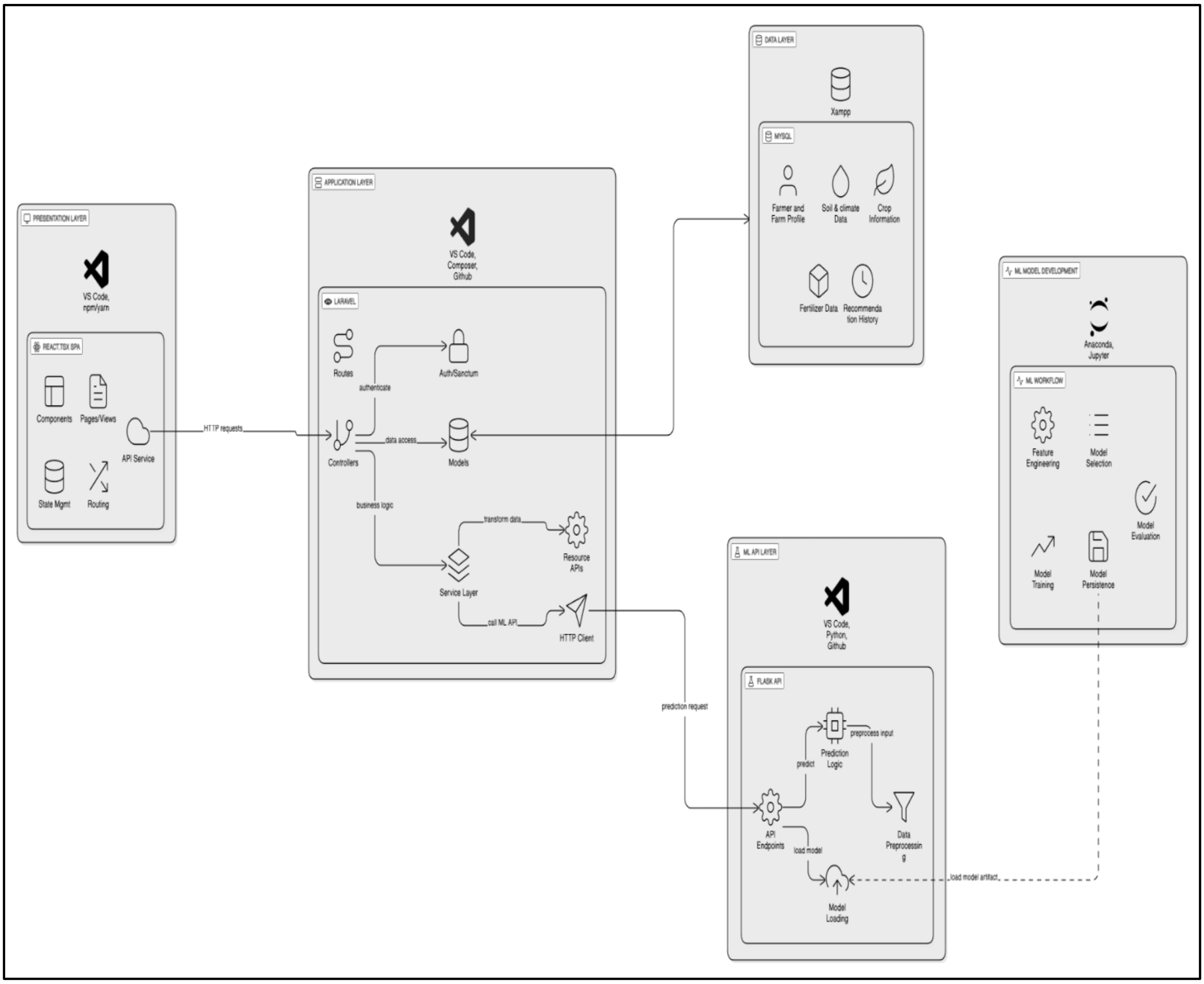

Fig 2 Implemented Layered Architecture

IV. RESULT & DISCUSSION

The following figures display the high-fidelity graphical user interface (GUI) of the CropTAP system. Each interface was developed as a single-page application using React and styled with Tailwind CSS, with Inertia.js managing communication with the Laravel backend. The resulting modules directly correspond to the use cases established in the requirements phase.

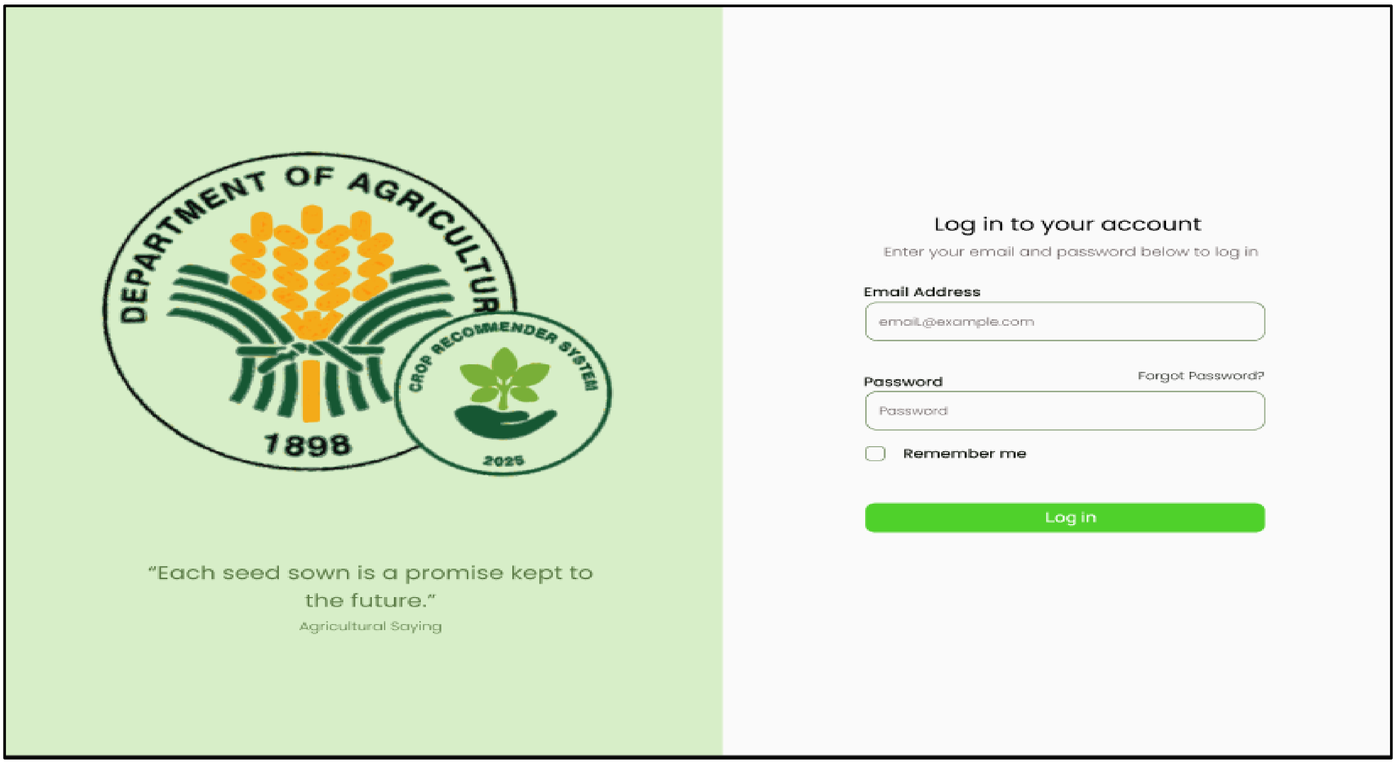

Fig 3 Login Interface

To access the system, a user first logs in using their credentials. The interface provided fields for user credentials, a button to initiate login, and a link for new user registration ('Sign up'). Upon successful authentication, the user was directed to the system Dashboard.

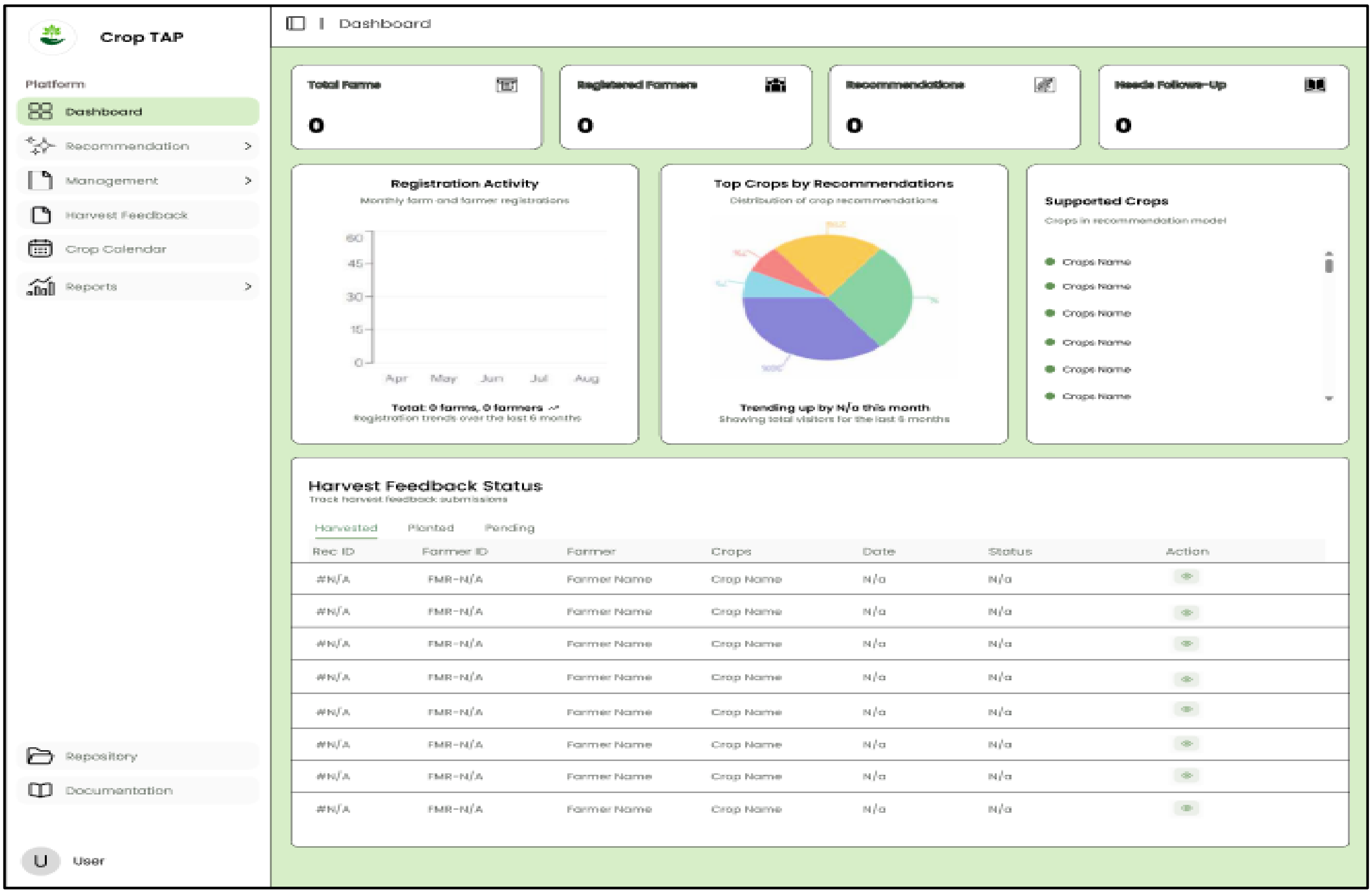

Fig 4 Dashboard

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The Dashboard provides a high-level overview of system data, including summary statistics (e.g., total farms and farmers), recent activity, and shortcuts to key functions. This design includes cards, stats, results, and quick-action buttons. Next, you will be directed to the Recommendation.

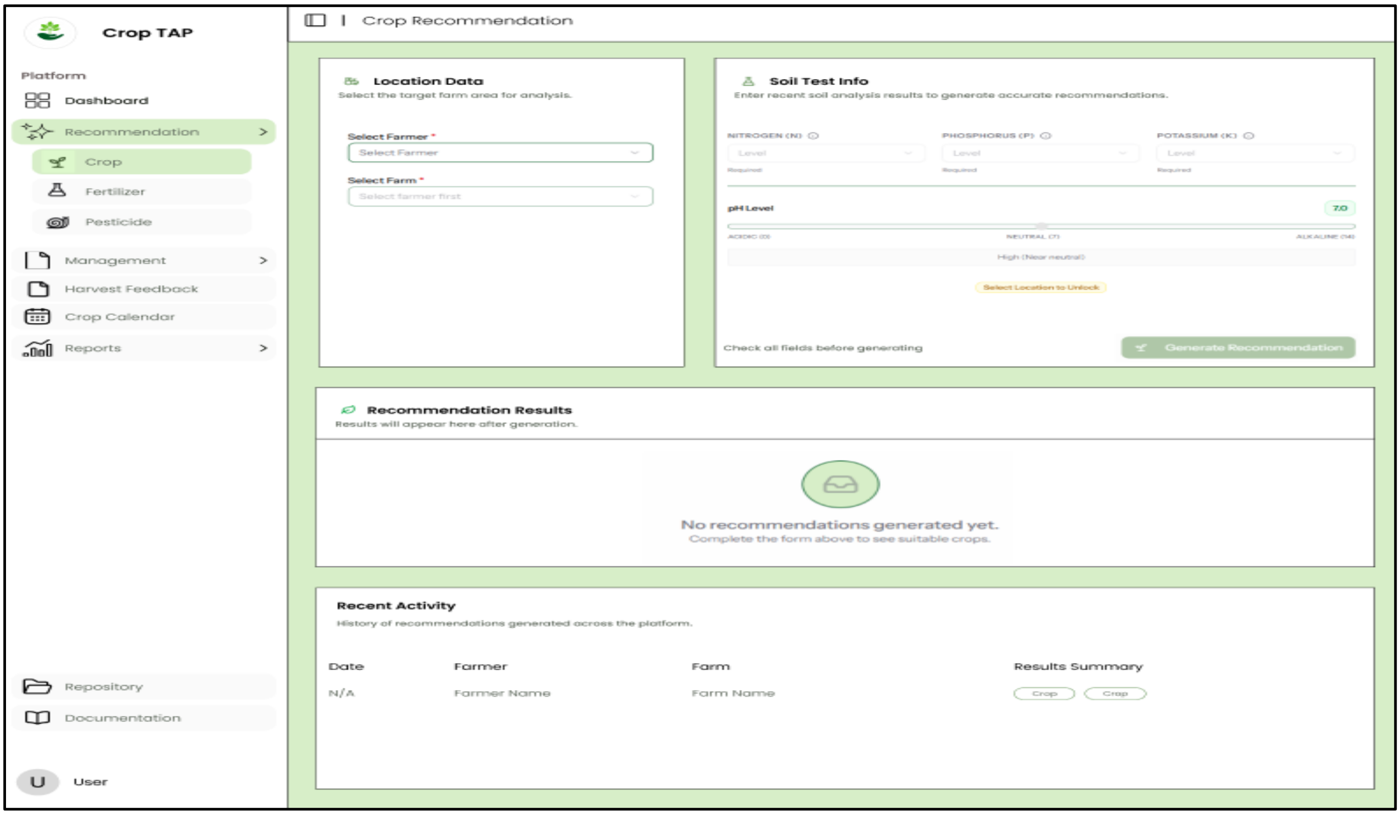

Fig 5 Crop Recommender

The Recommendation: Crop featured the ability to select certain farmers and farms, displaying information such as soil test results, climate data, temperature, rainfall, humidity, and more. This design contained drop-down fields, input fields, a fetch data button, and results. Next was the Fertilizer section.

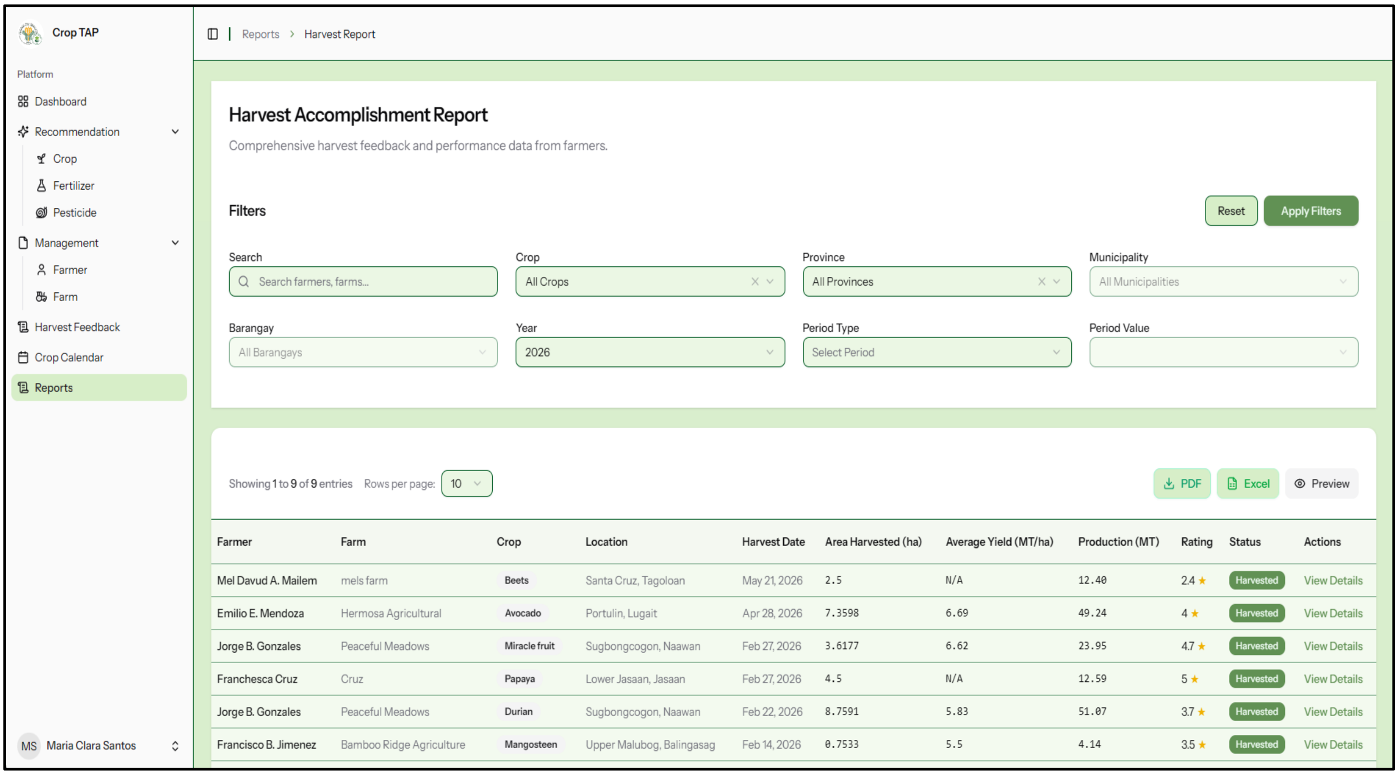

Fig 6 Reports

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The Crops Calendar featured categorized crops, each with a calendar that displayed information above. This design contained dropdowns, calendars, and informational displays. Next was the Harvest Feedback section.

To determine the most effective predictive engine for the CropTAP system, three regression algorithms, Random Forest, XGBoost, and Gradient Boosting, were trained and evaluated using 3-fold cross-validation. As summarized in Table 1, the Random Forest model demonstrated superior performance across all key metrics, achieving the lowest Root Mean Square Error (RMSE) of 11.55 and the highest coefficient of determination (R^2) of 0.7481. This indicates that the model explains approximately 75% of the variance in crop suitability scores, proving it to be a reliable tool for agricultural decision-support. These findings align with local studies in Negros Occidental, where Random Forest also outperformed Naive Bayes and Decision Trees with 94.6% accuracy (Soberano et al., 2023). Furthermore, the model's robustness validates international research identifying Random Forest as highly effective for complex agricultural datasets (Rani et al., 2023).

Table 1 Model Performance Comparison

Model	**Validation RMSE (Lower is Better)**	**MAE (Lower is Better)**	**R-squared (R^2) (Higher is Better)**
RandomForest	11.55	6.14	0.7481
XGBoost	11.57	6.23	0.7470
Gradient Boosting	11.56	6.25	0.7476

An analysis of the trained model's feature importance (Figure 3) revealed the logic driving the system's recommendations. The model identified historical yield as the most critical predictor, followed closely by pH proximity and climate suitability (temperature and humidity). This hierarchy confirms that the algorithm does not merely memorize data but actively weighs biological constraints against historical trends. The prioritization of soil pH aligns with recent findings that emphasize real-time monitoring of soil nutrient levels as essential for effective soil management in the Philippines (Dela Cruz et al., 2025). By heavily weighting environmental factors, the system effectively mimics agronomic expertise, ensuring that recommendations are biologically feasible rather than just statistically probable.

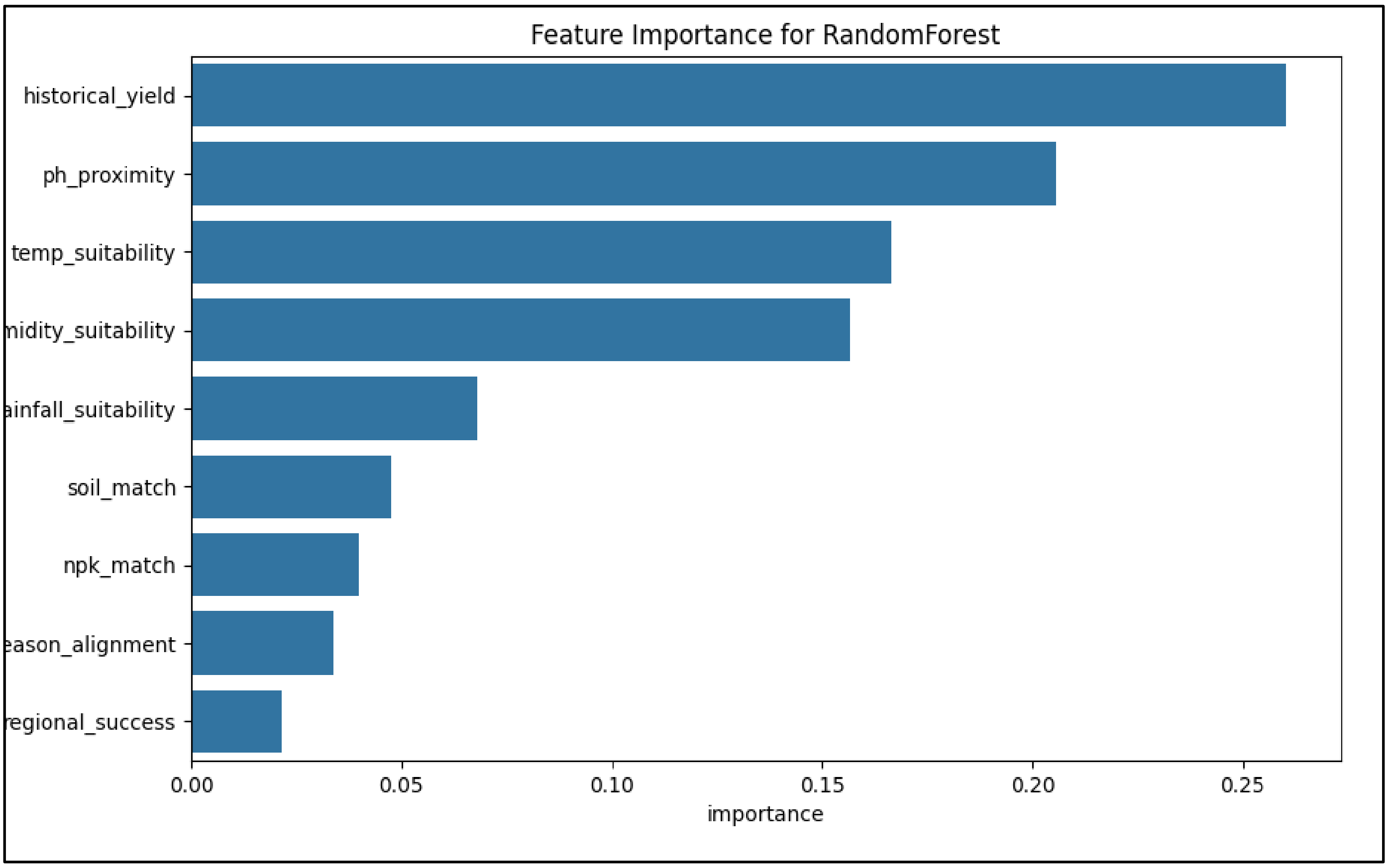

Fig 7 Feature Importance for Random Forest Model

Following the successful deployment of the system on a virtual private server, functional testing across 22 test cases resulted in a 100% pass rate after initial refinements to the recommendation selection features. To evaluate user acceptance, the System Usability Scale (SUS) was administered to agricultural officers and farmers. The system achieved an average SUS score of 54, categorizing it as "Marginal" or "OK." While users praised the integration of functions and the clarity of the dashboard, the score reflects a learning curve common in initial prototypes of technical

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systems. Qualitative feedback highlighted minor difficulties in navigation, which were subsequently addressed. Despite this, the successful adoption of the system in a live environment demonstrates its potential to modernize local agricultural workflows, addressing the need for accessible tools in regions with limited digital infrastructure (Konaté et al., 2020).

Table 2 Final System Usability Scale (SUS) Computation

Participant	Sum of the Adjusted SUS Score	SUS Score (Sum × 2.5)
P1	19	47.5
P2	25	62.5
P3	21	52.5
P4	22	62.5
P5	21	52.5
Average SUS score:	-	54

V. CONCLUSION & FUTURE WORKS

The project successfully met all major objectives set at the beginning of the study, particularly the development of a functional, data-driven crop recommender system capable of integrating soil characteristics, climate patterns, and historical crop performance data to generate reliable crop suitability recommendations. The objectives related to system design, database development, machine learning model training, and the creation of a user-friendly interface were fully achieved through the Agile SDLC and systematic implementation of Python–Flask, Laravel–MySQL and React. While minor refinements in interface labeling and localized content were identified as areas for improvement, these did not hinder the system's overall effectiveness. The findings suggest that CropTAP not only operates as intended but also introduces a structured, evidence-based process that enhances decision-making for agricultural officers and farmers in Tagoloan and Misamis Oriental.

The project's results carry significant implications for agricultural decision-making and broader IT operations within the Municipal Agriculture Office, demonstrating how a data-driven system can transform traditional workflows into structured, evidence-based processes. By centralizing farmer, soil, climate, and crop data and automating the generation of science-based recommendations, CropTAP directly addresses the long-standing problems of fragmented information management, reliance on manual judgment, and inconsistent crop selection practices. Its contributions extend beyond operational efficiency by aligning with key Sustainable Development Goals (SDGs): SDG 2 (Zero Hunger) through improved agricultural productivity and informed crop planning; SDG 9 (Industry, Innovation, and Infrastructure) through the integration of machine learning, database systems, and modern software architectures into local governance; and SDG 12 (Responsible Consumption and Production) by promoting efficient resource use and reducing risks associated with improper crop–soil matching. Together, these advancements confirm that CropTAP offers a meaningful and technically grounded solution to the agricultural challenges faced by Tagoloan and Misamis Oriental, strengthening the municipality's capacity to implement sustainable, data-driven agricultural strategies.

Despite the project's successes, several limitations influenced its implementation and outcomes. The availability and completeness of local soil and climate datasets remained a constraint, requiring expanded data sourcing from the broader Misamis Oriental region to support model training and validation. Nevertheless, this constraint provided valuable insights into the realities of deploying IT solutions in rural and semi-rural environments. Users, developers, and stakeholders can learn from the importance of iterative design, continuous data validation, and stakeholder-centered development. The outcomes of CropTAP emphasize that adopting data-driven systems requires not only technological readiness but also capacity-building and consistent data management practices, key lessons that will guide future enhancements, wider deployment, and sustainable integration into agricultural governance.

Based on the study's findings and conclusions, several recommendations are proposed to support the successful deployment, long-term sustainability, and continuous improvement of the CropTAP system. These recommendations address the practical needs of users, administrative actions for stakeholders, and technical considerations for future developers and researchers.

RECOMMENDATION

➢ *Optimize UI/UX for Navigation and User Accessibility*

Prioritize an intuitive, responsive dashboard to reduce technical barriers for users with varying digital literacy. Refining menus and incorporating visual cues will ensure efficient interaction with data modules, strengthening the system's practical utility in the field.

➢ *Integrate Geotagging of Farmlands and High-Yield Crop Zones for Location-Specific Contextualization.*

Incorporating GIS-based geotagging will allow the system to map farms, visualize crop suitability patterns, and identify locally successful crops based on historical yield. This feature will give future users clear insights into what crops perform best in their specific locality, strengthening the accuracy and interpretability of recommendations.

➢ *Contextualize Planting Guides by Including Local Fertilizer and Pesticide Brand Equivalents.*

To enhance practical utility for agricultural officers and farmers, CropTAP should incorporate locally available fertilizer and pesticide brands that match their generic nutrient or active ingredient requirements within the tips and guides module. This will ensure recommendations are

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actionable and aligned with real market availability in Misamis Oriental and adjacent municipalities.

- *Expand Data Sourcing and Improve Dataset Completeness for More Robust Model Performance.*

Future developers should address current data limitations by collecting more granular soil profiles, localized climate patterns, and crop-specific performance records. Partnerships with DA–BSWM, PAGASA, LGUs, and research institutions are encouraged to enrich datasets and improve predictive accuracy.

- *Introduce Additional Decision-Support Modules Such as Pest/Disease Alerts, Yield Forecasting, and Economic Analysis.*

New features may include predictive pest infestation models, market price forecasting, or cost–benefit calculators to support comprehensive farm planning further. These additions will expand the system's usefulness beyond suitability recommendations to full-cycle farm management.

REFERENCES

[1]. Y. Akkem, S. K. Biswas, and A. Varanasi, "Streamlit application for advanced ensemble learning methods in crop recommendation systems – A review and implementation," Indian J. Sci. Technol., vol. 16, no. 48, pp. 4688–4702, 2023, doi: 10.17485/IJST/v16i48.2850.

[2]. J. Jadhav, S. B. Raut, and A. Nagdive, "Crop recommendation system using machine learning," Int. J. Eng. Res. Technol. (IJERT), vol. 11, no. 5, pp. 245–250, 2022.

[3]. K. Anguraj et al., "Crop recommendation on analyzing soil using machine learning," Turk. J. Comput. Math. Educ., vol. 12, no. 6, pp. 1784–1791, 2021.

[4]. T. K. C. Tandog and L. Condes-Tandog, "Farming amidst climate change: The contextual vulnerability of farmers in Cotabato, Philippines," J. Agric. Res. Dev. Ext. Technol., vol. 5, no. 1, pp. 23–46, 2023, doi: 10.5281/zenodo.10984000.

[5]. D. Garg and M. Alam, "An effective crop recommendation method using machine learning techniques," Int. J. Adv. Technol. Eng. Explor., vol. 10, no. 102, pp. 498–514, 2023, doi: 10.19101/IJATEE.2022.10100456.

[6]. K. T. Soberano et al., "Predictive soil-crop suitability pattern extraction using machine learning algorithms," Int. J. Adv. Appl. Sci., vol. 10, no. 6, pp. 8–16, 2023, doi: 10.21833/ijaas.2023.06.002.

[7]. U. Ahmed, J. C-W. Lin, G. Srivastava, and Y. Djenouri, "A nutrient recommendation system for soil fertilization based on evolutionary computation," Comput. Electron. Agric., vol. 189, Art. no. 106407, 2021, doi: 10.1016/j.compag.2021.106407.

[8]. P. Thongnim, P. Srinil, and T. Phukseng, "Data-driven clustering of smart farming to optimize agricultural practices through machine learning," Bull. Electr. Eng. Inform., vol. 14, no. 2, pp. 1343–1354, 2025, doi: 10.11591/eei.v14i2.9343.

[9]. S. Rani et al., "Machine learning-based optimal crop selection system in smart agriculture," Sci. Rep., vol. 13, no. 1, Art. no. 15997, 2023, doi: 10.1038/s41598-023-42356-y.

[10]. P. G. Lagrazon and J. B. Tan, Jr., "Predicting crop yield in Quezon Province, Philippines using Gaussian Process Regression," in ICMERALDA, 1st ed. IEEE, 2023, pp. 1–10.

[11]. M. O. Abdullahi, A. D. Jimale, Y. A. Ahmed, and A. Y. Nageye, "Revolutionizing Somali agriculture: Harnessing machine learning and IoT for optimal crop recommendations," Discover Appl. Sci., vol. 6, no. 77, 2024, doi: 10.1007/s42452-024-05739-y.

[12]. J. Konaté, A. G. Diarra, S. O. Diarra, and A. Diallo, "SyrAgri: A recommender system for agriculture in Mali," Information, vol. 11, no. 12, Art. no. 561, 2020, doi: 10.3390/info11120561.

[13]. B. J. Sowmya et al., "Leveraging machine learning for intelligent agriculture," Discov. Internet Things, vol. 5, Art. no. 33, 2025, doi: 10.1007/s43926-025-00132-6.

[14]. R. Dela Cruz et al., "Digging deeper: Soil quality monitoring system for Alaminos City farmers," Int. J. Res. Innov. Soc. Sci., vol. 9, no. 2, pp. 36–45, 2025, doi: 10.47772/IJRISS.2025.9020126.

[15]. E. J. B. Agustin, H. A. Alcaraz, and D. M. N. Bristol, "The emergence of disruptive smart farming technologies in Philippine agriculture under the new normal," Int. J. Prog. Res. Sci. Eng., vol. 3, no. 3, pp. 23–26, 2022.

[16]. W. Zayat and O. Senvar, "Framework study for agile software development via Scrum and Kanban," Int. J. Innov. Technol. Manag., vol. 17, no. 4, Art. no. 2030002, 2020, doi: 10.1142/S0219877020300025.

[17]. V. Lakshmanan, R. Ramachandiran, B. Ragul, and S. Pradeep. (2024). Agriculture Enhancement Using Machine Learning With React. Research Square. [Online]. Available: https://doi.org/10.21203/rs.3.rs-4289286/v1

[18]. A. Cimino, F. Longo, V. Solina, and S. Verteramo, "A multi-actor ICT platform for increasing sustainability and resilience of small-scale farmers after pandemic crisis," Br. Food J., 2023, doi: 10.1108/BFJ-01-2023-0049.

[19]. R. R. Shamshiri et al., "Digitalization of agriculture for sustainable crop production: A use-case review," Front. Environ. Sci., vol. 12, Art. no. 1375193, 2024, doi: 10.3389/fenvs.2024.1375193.